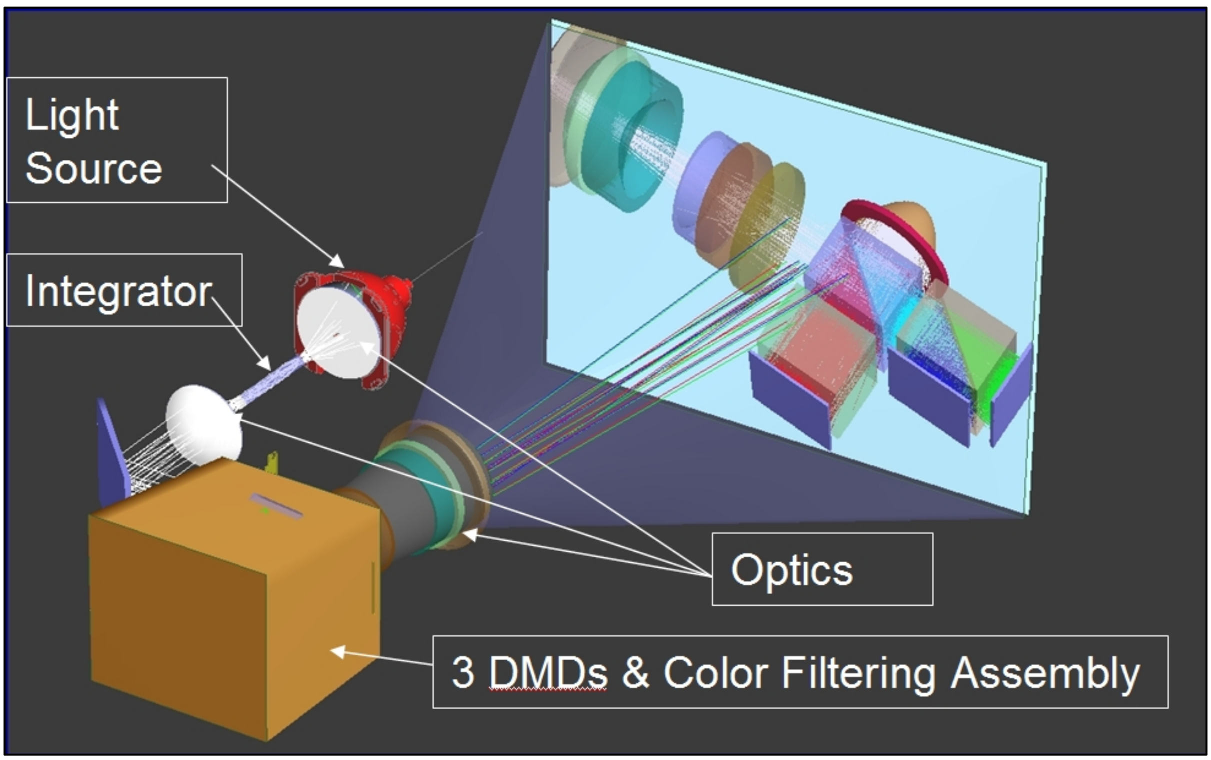
FRED

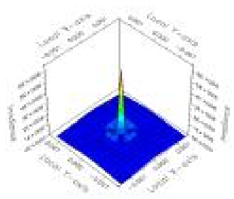
User Manual

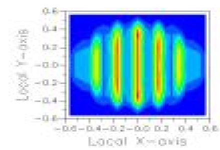


Revision 6.100
September 14, 2007

Chapter 1 – Introduction

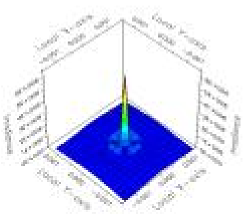
Introduction to the FRED Reference Manual





If you are like many computer users, you have opened this reference manual as a last resort and under duress. You don't have the time or the inclination to read an entire manual before you see results. We have made an effort to organize this manual to provide immediate gratification while being both complete and informative.

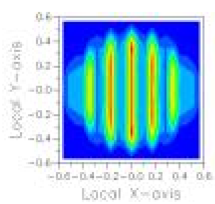
What is FRED?



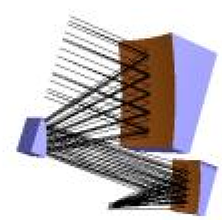
FRED is an optical engineering software package designed to analyze optical systems including mechanical structures using non-sequential, sequential, and coherent raytracing. FRED has a point and click graphical user interface for building geometry and performing analysis that is both powerful and intuitive. FRED can analyze a wide range of optical phenomena including straylight, scatter, illumination, imaging quality, coherent propagation, irradiance, intensity, polarization, and much more. FRED also has excellent graphics that facilitates visualizing the optical system.

How do you get started?

One of the best ways to learn how to use FRED is to go through the tutorials There are several tutorials offered on different topics. We recommend that new users start with the Test Flight document and then work through the 7 step by step tutorial in the hyper-text help in FRED under the Help Menu.



This help file is still under construction. In addition, not all of the commands have been documented. If you are not able to find what you need in the help files, please **call or email** us regarding any questions or problems you have.



Additional Information

Though optical technology is discussed in general terms, this manual is not a primer in optical technology. A list of **excellent books and papers on various optical topics is provided** in the reference section in this manual.

Help Manual Overview

This help file has been organized into 31 chapters.

The quality of this help manual will be enhanced with feedback from users. We would like to hear or read any suggestions you have for content, organization, or style. Please email support@photonengr.com with suggestions.

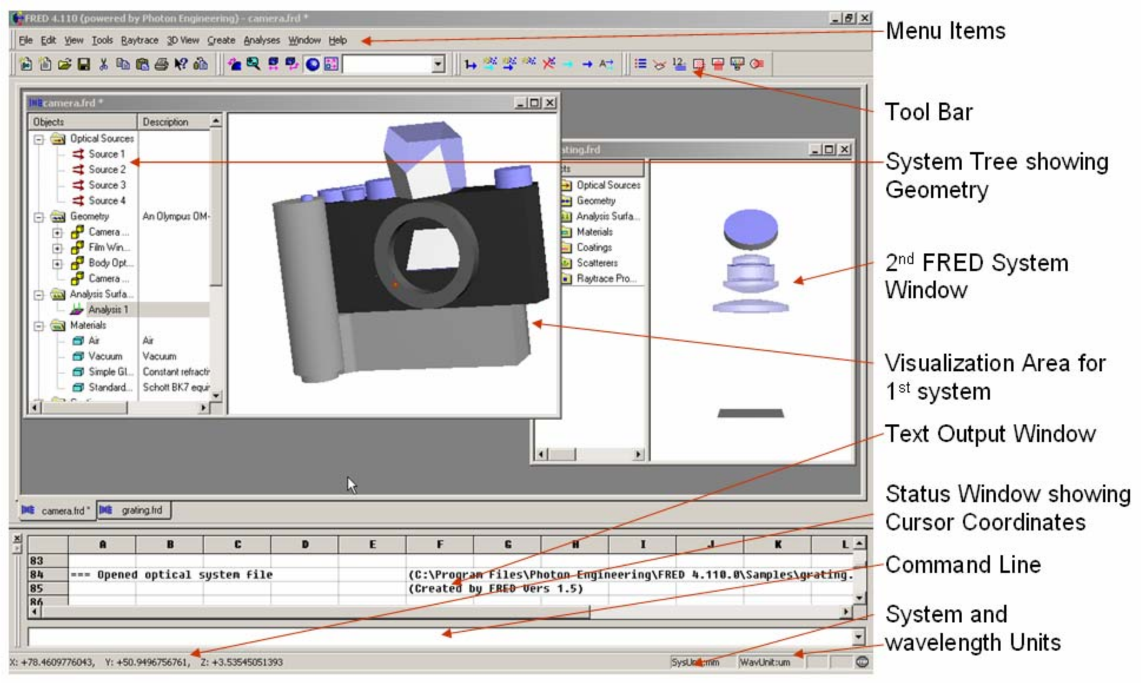
Document View Architecture

The FRED graphical user interface (GUI) is very similar to most Windows programs, but it has been tailored to the needs of optical design and analysis. A FRED document can be considered as a stand-alone optical system consisting of at least one or more of the following seven major object types:

- **Optical sources** – Objects that describe the wavelengths, positions, angles, wavelength apodization (weighting), position apodization, angle apodization, coherence, and flux of rays to be created. Note that sources are NOT rays, they are only the definitions of the ray starting points and directions.
- **Geometry** – Objects that describe elements that are made of surfaces and curves. This includes optical as well as mechanical geometry.
- **Analysis surfaces** – Objects that allow the analysis of ray positions, directions, irradiance, and intensity. These can be placed on any surface in the optical system.
- **Materials** – Objects that are assigned to surfaces to describe the complex refractive index (n-ik) properties of the surfaces using the geometry and coatings.
- **Coatings** – Objects that are assigned to surfaces to describe the reflection, transmission, and absorption characteristics of the surfaces. These can be entered as coefficients or as thin film coating layers. The coatings allow FRED to maintain correct radiometry through a raytrace.
- **Scatterers** – Objects that are assigned to surfaces to describe the scatter properties of a surface.
- **Raytrace Properties** – Objects that are assigned to surfaces to describe whether reflected and/or transmitted rays are traced from the surface. These objects also control how many ray splits are allowed (children) for a given parent ray.

The FRED user interface comes complete with menus, toolbars, system tree, visualization view, text output window, status line, and command line. The user interface has standard Windows Menu items at the top of the FRED document interface that features drop down lists when selected. This Menu list includes all of FRED's functionality with the Tools, Raytrace, 3D View, Create, and Analyses menus.

The Toolbar features many standard Windows icon buttons to open documents, cut-and-paste folder operations, undo/redo functions, and more. The toolbar is customizable and, besides including many standard FRED functions for raytrace, analyses and viewing, can be customized to add or delete icons for almost every FRED menu item.

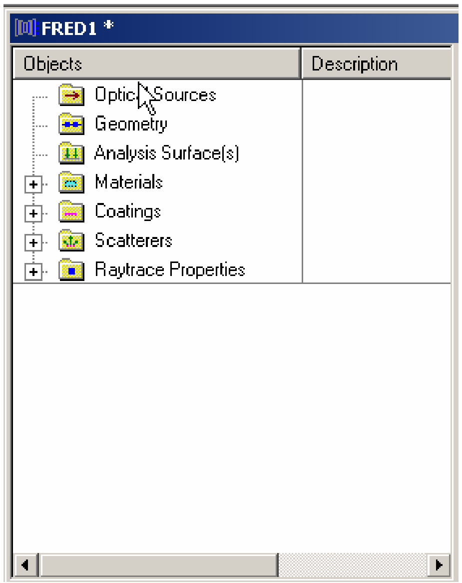


The visualization area is the main viewing area to verify geometry generation. This area can be set to view two-axis profiles, X-Y, X-Z, Y-Z or any combination of these two axes, or arbitrary views from any 3D direction. It is also possible to use the trackball to manipulate any view or directly input viewing coordinates into the Tools → Preference → Visualization menu dialog.

The text output area can be selected to be either spreadsheet-like with cells containing output information, or similar in functionality to a notepad where output results are simply shown in text format. The preference for spreadsheet or notepad-like is set in the View → Output Window → Cells menu.

The status window is menu-specific and can show everything from cursor coordinates detailing where the cursor is on the visualization window when active to showing the function selected when using menu or tool bar items. The status window also shows the system and wavelength units in the bottom right hand corner. Finally the command line can be used to directly enter enhanced FRED basic script commands.

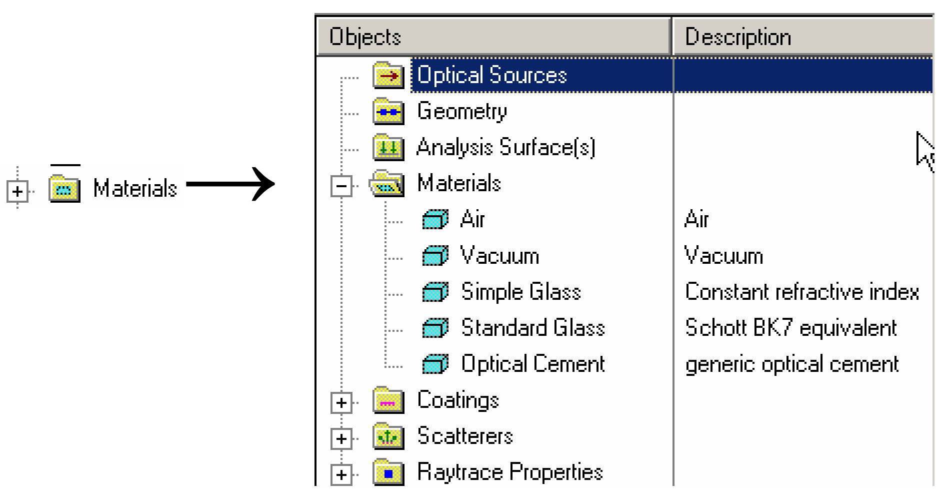
Each FRED document has a system tree which provides a hierarchal organization of the FRED document and contains the 7 folders of information specific to each document: Geometry, Analysis surfaces, Materials, Coatings, Scatterers, and Raytrace Properties. A node in the system tree view refers to one of these folders and consists of an icon, title, and a description as shown below.



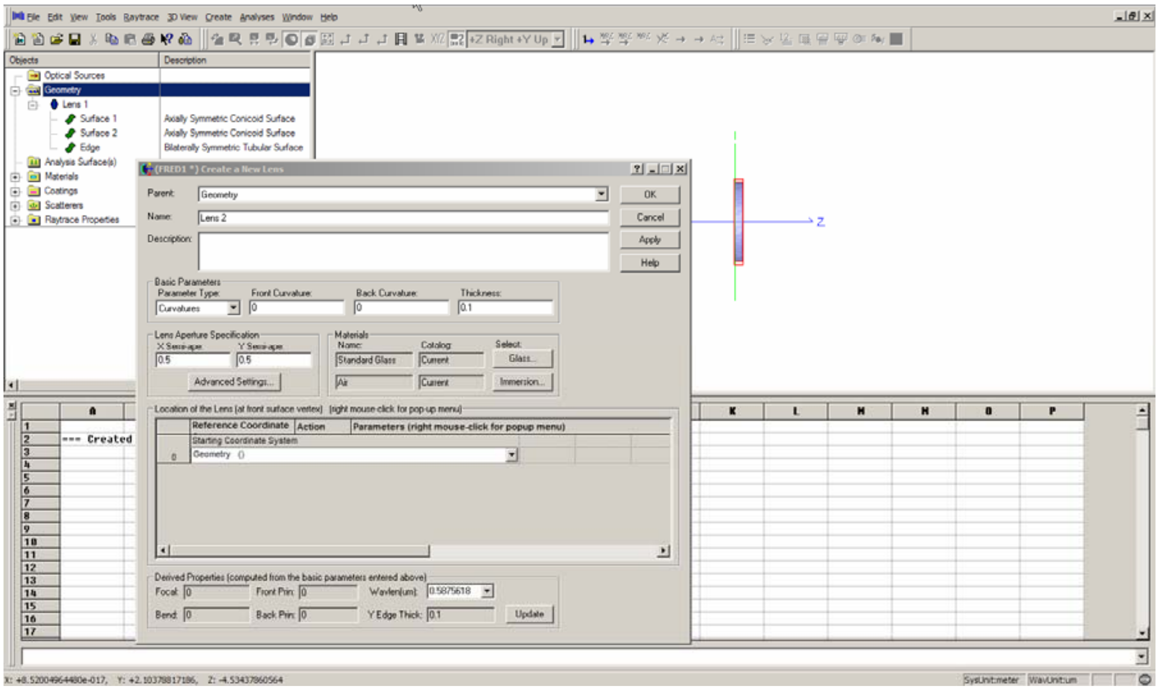
Defining Objects

To define or enter objects, such as a lens or mirror, in ***FRED***, you ***right*** click on the appropriate node in the system tree. This will bring up a menu of actions; choosing to enter a new object will then bring up a dialog box in which you enter the parameters for the object to be entered. As you enter the parameters, you can click Apply to see how the object is being created before you enter other parameters. You click on OK to finalize the entering of the object.

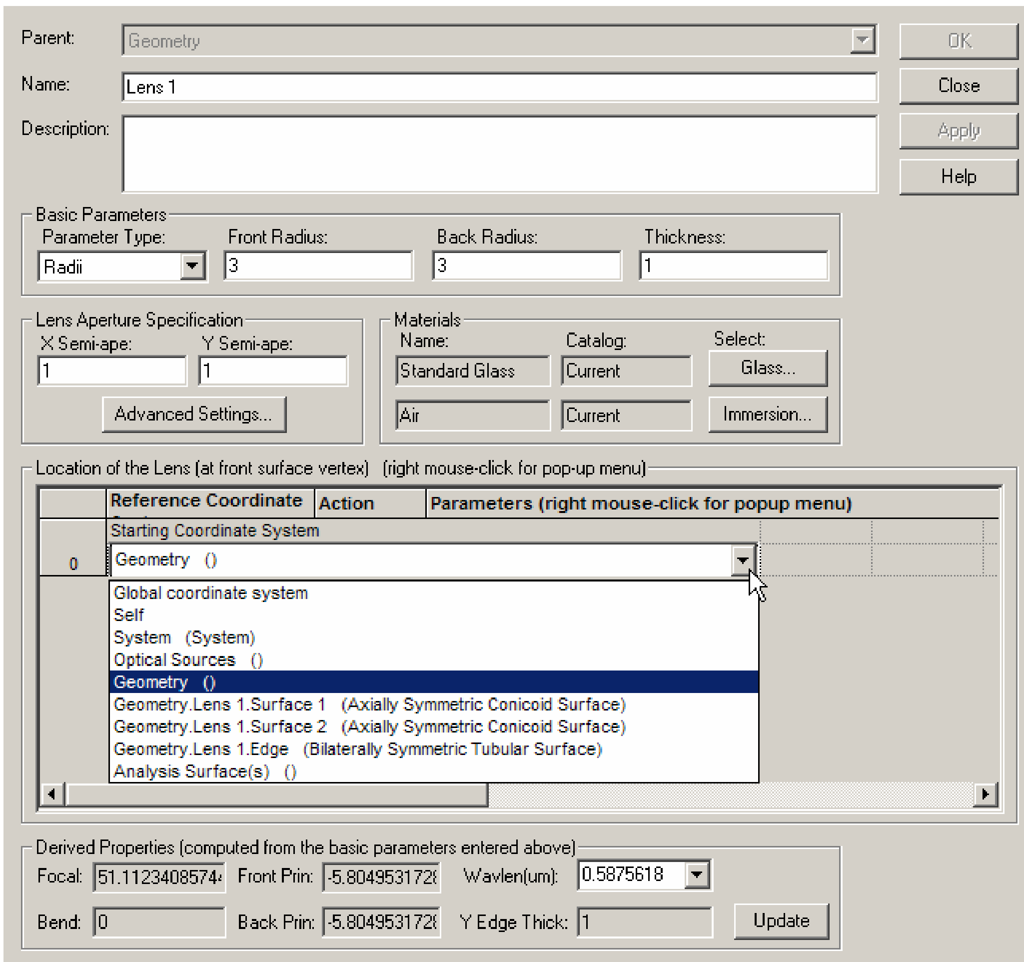
When an object is entered into a ***FRED*** document, it is listed under the appropriate node. A node with objects can be expanded to show the objects or collapsed to hide the objects, similar to the Windows Explorer. A collapsed node has a ⊞ symbol in front of the node and an expanded node has a ⊟ symbol in front of the node. To expand or collapse a node, ***left*** mouse click on the ⊞ or ⊟ symbols respectively. For example, expanding the Materials node will show all the materials currently in the document. The materials shown below are in all ***FRED*** documents by default.



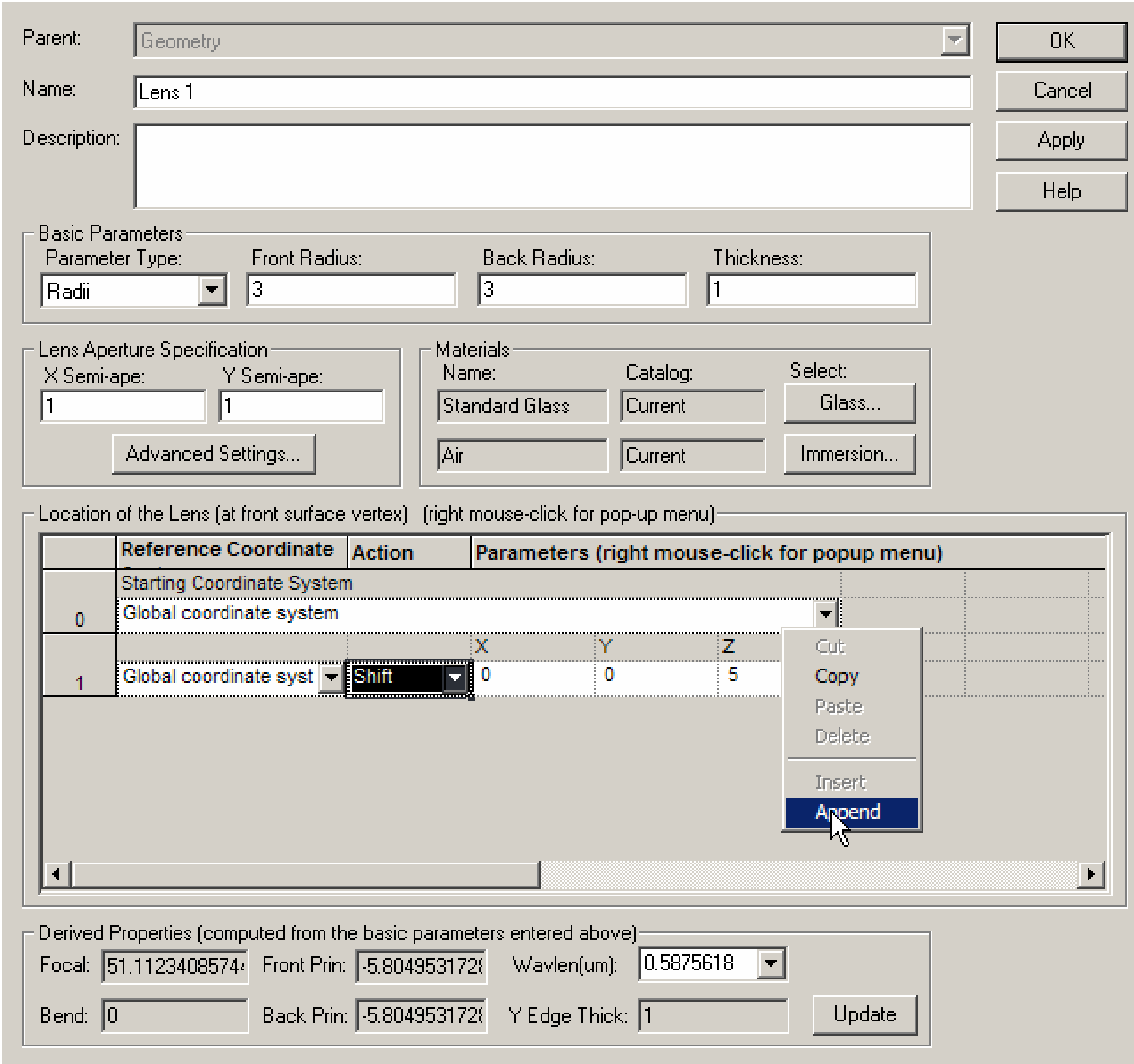
To create a lens element is a simple process. First, right mouse click on the Geometry Folder in the system tree to have the geometry creation menu appear. Then select the “Create News Lens” menu option to have the “Create a New Lens Dialogue” appear. Accept the default lens information by Left mouse clicking on the OK button to create the lens as shown in Y-Z profile below. Notice that if you click on the + sign in front of the lens node, the system shows that the lens is comprised of three surfaces, the front, back and edge of the lens. So a lens primitive in FRED creates a solid with all three surfaces automatically created to define a complete solid bounded object.



Objects (curves, surfaces, lens, prisms, mirrors, custom elements, and subassemblies) in FRED are located by default at the global origin in the Y-Z plane. After making a surface, custom element, lens, mirror, prism or subassembly you can move this object by right mouse clicking on the object in the geometry folder, and then selecting the option to position the object. Objects can be positioned in global space, or in reference to any other positioned object. This is particularly useful if you only know the distance of this object in reference to another object which is often the case in optical designs. Most objects often have a specific tab on the Edit dialogue which allows them to be defined directly or can be modified directly in their creation dialogue. Please note that it is best to group curves and surfaces together into custom elements and subassemblies and position all of these objects at one time by defining the correct position on the custom element or subassembly. Shown below is the lens creation dialogue showing the many reference coordinates available to position a lens.



After selecting the reference coordinate system you can then right mouse click on the 0 reference coordinate and append a change to the position by selecting the append modification, selecting the reference coordinated action and the shift, rotation or change to the position of the object as shown below.



The hierarchy of the geometry building in *FRED* works as follows:

The Geometry Folder can contain:

- Subassemblies
- Elements
  - Lens – Dynamic, know how to create and maintain themselves
  - Mirror – Dynamic, know how to create and maintain themselves
  - Prism – Dynamic, know how to create and maintain themselves
  - Custom Element – static they defined by the user, contain user defined surfaces and curves

A Subassembly can also contain:

- Other Subassemblies
- Elements (Mirrors, Lenses, Prisms or Custom types)

An Element can contain:

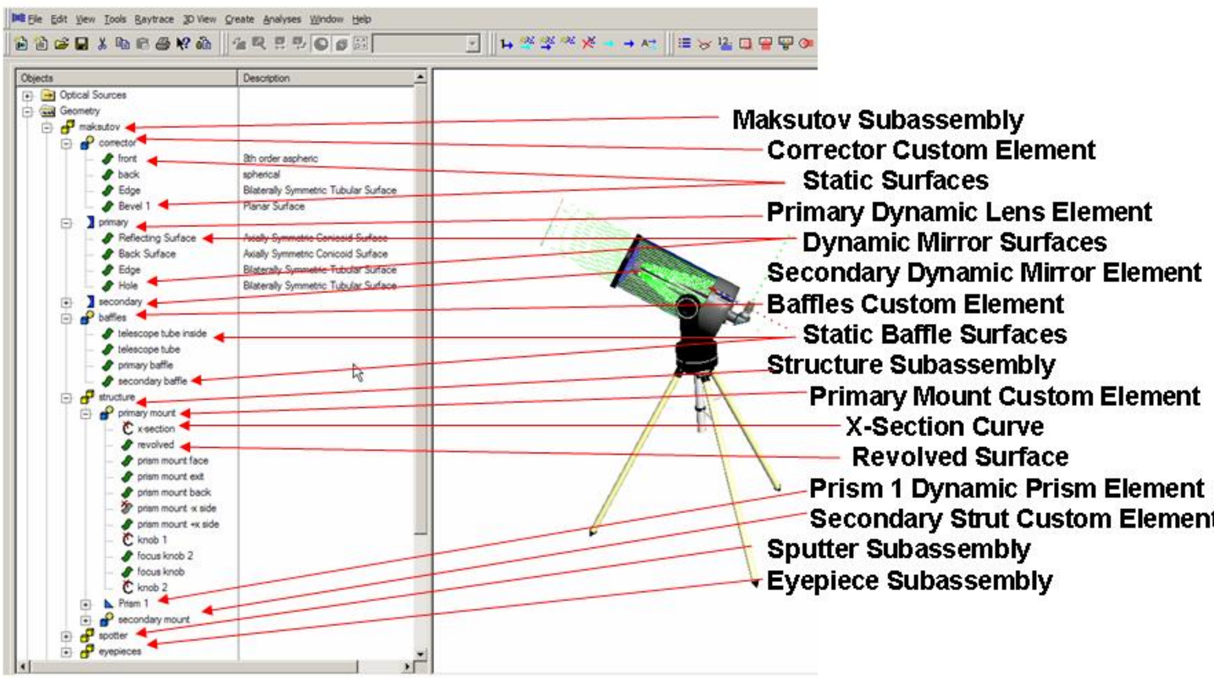
Surfaces – created directly or used as trimming surfaces (implicit surfaces)

Curves – used to create explicit surfaces by extrusion, revolution or ruling, or to be used as a trimming curve

A Surface can contain:

Curves – used to create explicit surfaces by extrusion, revolution or ruling, or to be used as a trimming curve

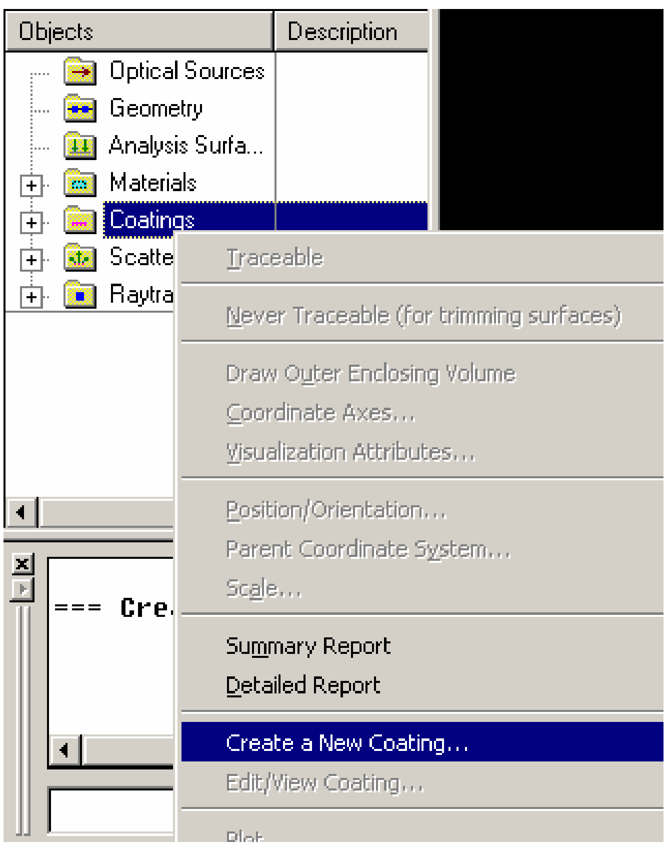
The figure below is an excellent example of the geometry hierarchy with subassemblies, elements, surfaces and curves called out under the geometry folder.



All of the commands in *FRED* are available through a ***left*** mouse button click on the appropriate menu item,

a ***left*** mouse click on the appropriate toolbar item,

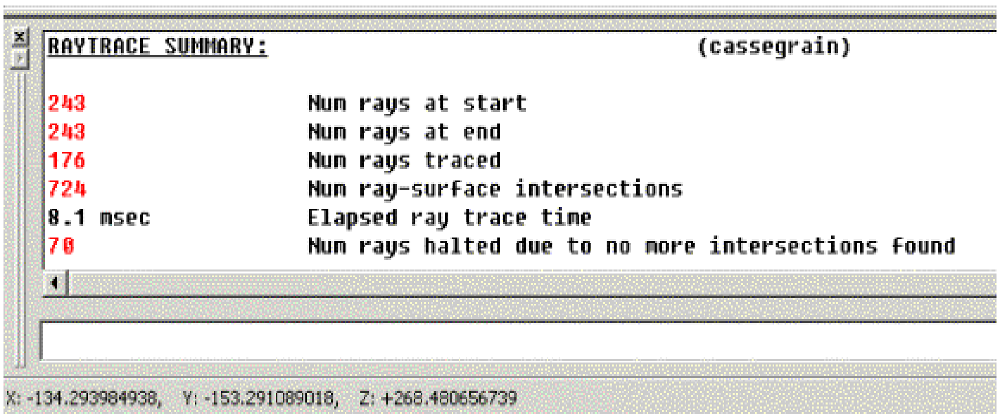
or a ***right*** mouse click on the appropriate node in the system tree view.



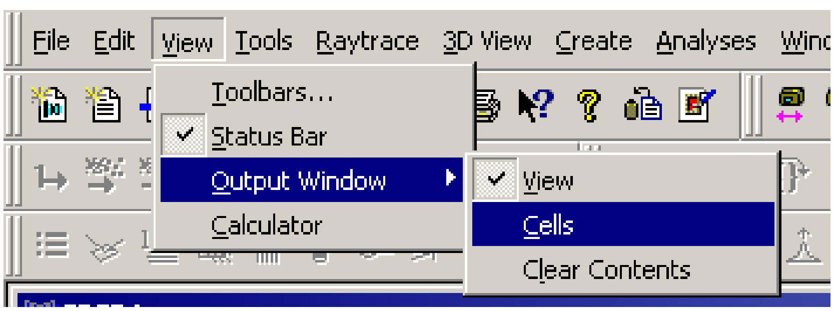
Generally, if you want to perform an action with the information in a *FRED* document, you do so with either a menu item or toolbar item. If you want to add or change an object in the *FRED* document, then ***right*** click on the appropriate node of the system tree and make a selection in the pop-up menu.

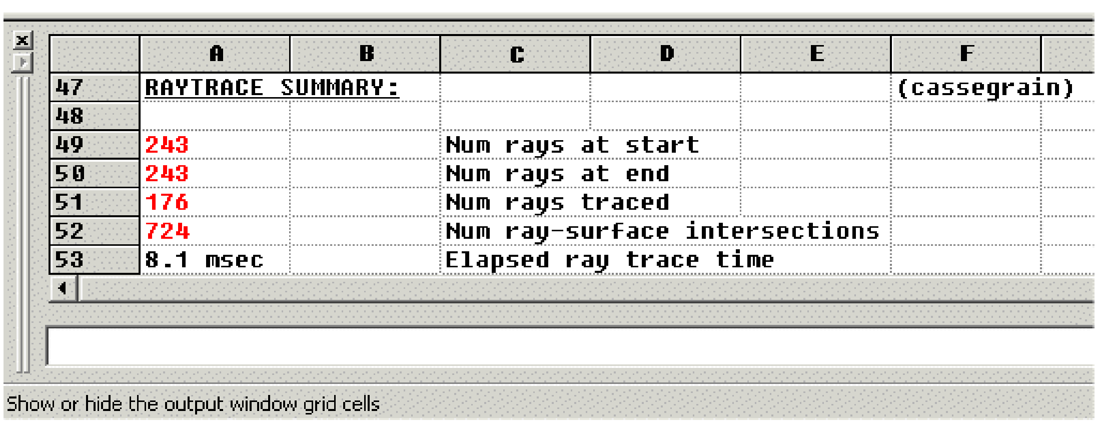
The Output Window and the Command Line

The results of actions taken with the information in a ***FRED*** document are listed in the output window. For example, if a raytrace is performed then the results of the raytrace are listed in the output window (as shown below). In addition, the coordinates of the cursor in the visualization window are shown below the output window and command line.



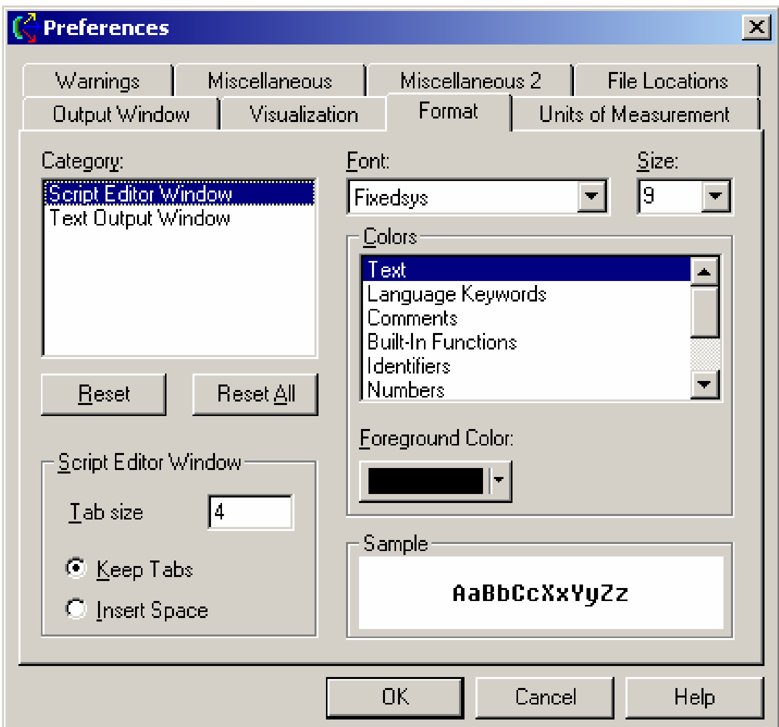
The output window is actually a spreadsheet. The view of the output window can be toggled between a plain text format (Notepad-like) or a spreadsheet format with cells similar to Excel in the View menu (View → Output Window → Cells).



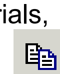
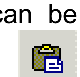
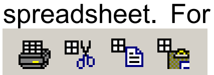


Commands can be typed in manually on the command line. Presently, any of the enhanced BASIC scripting commands can be entered into the command line; multiple commands on the same line are separated by colons.

You can change the color of text, numbers, and formulae in the output window in the format page of the preferences dialog (Tools → Preferences → Format). This format page handles both the output window and the script editor so you need to select the output window as the category before you can change the output window colors.

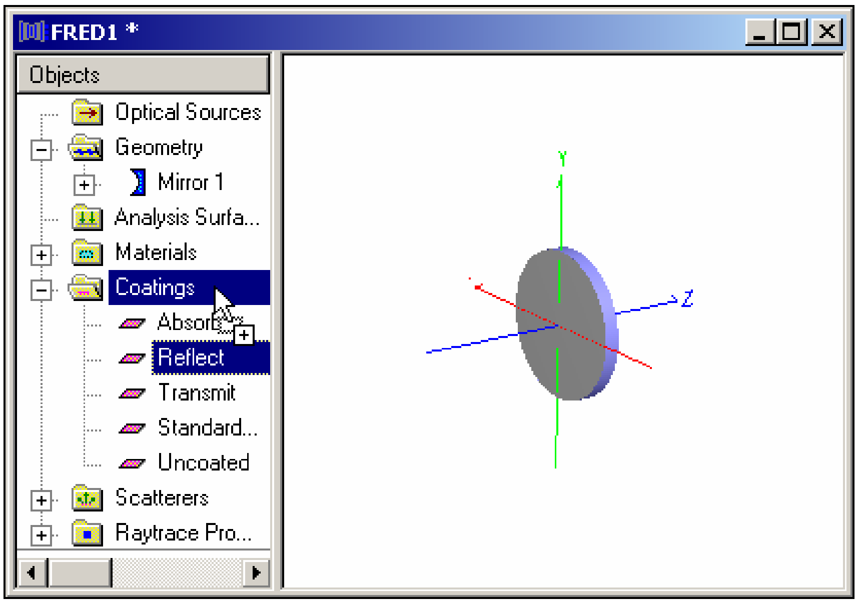


Copy-and-Paste

Most objects in *FRED* including geometry objects, materials, coatings, and optical sources can be copied and pasted using the copy command, , (Ctrl+C) and paste command, , (Ctrl+V). The exception to this is the output window, which is actually a spreadsheet. For operations inside the output window, use the output window commands,  which are print, cut (Shift+Ctrl+X), copy (Shift+Ctrl+C), and paste (Shift+Ctrl+V) respectively. If you want to copy a raytrace result from the output window into a dialog box text window, then you use , (Shift+Ctrl+C), to copy out of the output window spreadsheet and , (Ctrl+V), to paste into the dialog box text window.

Drag-and-Drop

A quicker alternative to copy-and-paste is drag-and-drop. All *FRED* geometry objects, materials, coatings, and sources can be dragged and dropped to make copies. To make copies with drag-and-drop, simply ***left*** mouse click on the object to be copied and while pressing the Ctrl key and holding the left mouse button down, drag the object to another node in the same section of the system tree and release the mouse key and then the Ctrl key. When you press the Ctrl key, you will get a "+" next to the cursor, indicating a copy is being made.

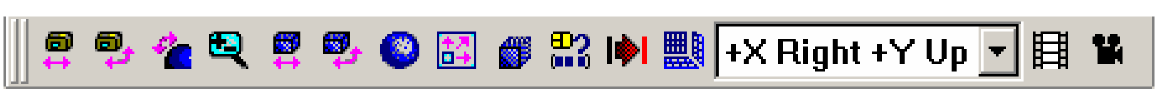


To move an object with drag-and-drop, ***left*** mouse click on the object to be moved and drag the object to another location in the same section of the system tree.

In the case of materials and coatings, they can be dragged and dropped onto geometry objects to apply them to geometry objects. You do not need to hold down keys to apply a material or coating using the drag-and-drop method.

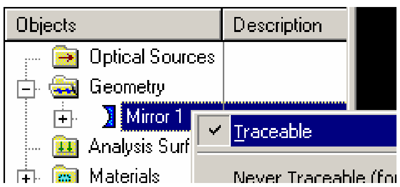
Visualization

The visualization window can be zoomed, translated, rotated, etc., using the visualization window toolbar controls.



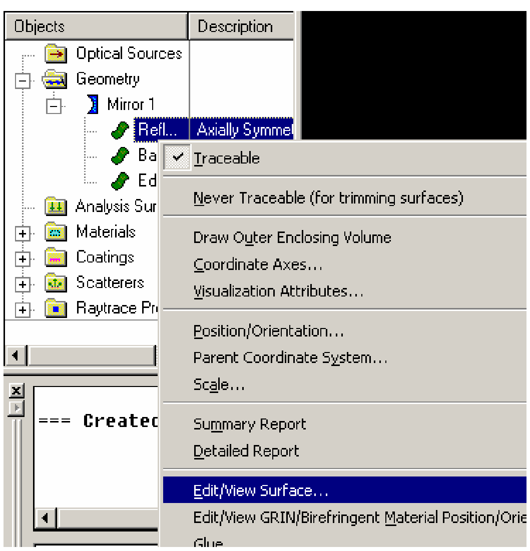
The trackball option, , allows the user to spin the objects about a fixed point. The default fixed point is the global origin. The fixed point can be changed to any surface in the *FRED* document by placing the cursor over the object, pressing the Ctrl key, and left mouse clicking on the object. You may have to turn off other objects to get a clear view of the object you wish to make the center of the rotation.

If you want something to be visible in the visualization window (and raytraced), then the object must have the Traceable toggle switch turned on. This option is available in the right mouse click pop-up menu. When entering a new item in the geometry, the default is to be traceable.

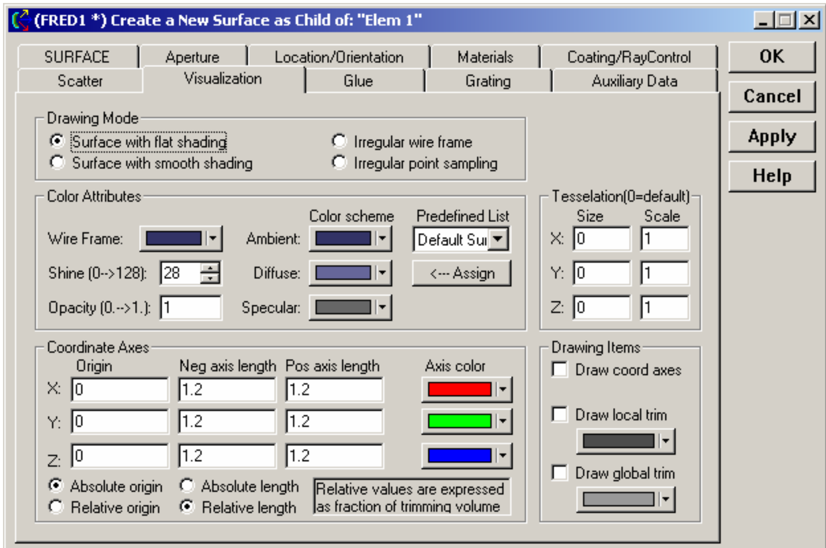


When you left mouse click on a geometry or source object in the *FRED* tree view, then a bounding box around that object is traced out in RED in the visualization view. This helps you verify the proper item is selected.

The color, transparency, and surface drawing mode of an individual surface can be changed in the visualization page of the surface edit dialog. To display this dialog page, ***right*** mouse click on the surface you would like to edit, and choose "Edit/View Surface...".

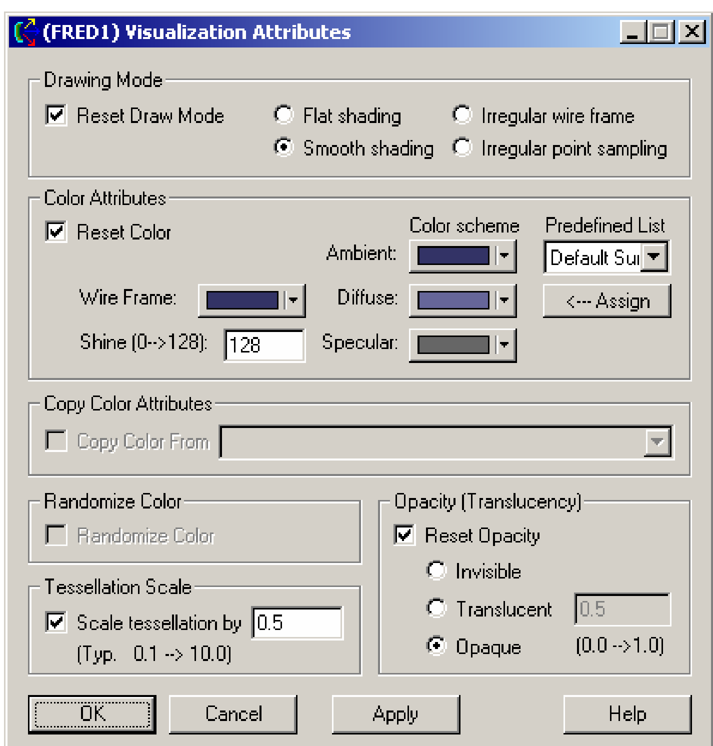


From there, click on the Visualization tab, shown on the next page.



There are times when the rendering of an object is poor or non-existent because the object is fairly small compared to the Outer Trimming Volume. If an object is not rendering properly in the visualization window (and it is set as Traceable) then reducing the tessellation in the visualization page of the surface edit dialog will likely fix the problem (see the right hand side of the Visualization page).

The color, transparency, and surface drawing mode can be changed for all the objects highlighted in the tree with the Color Attributes dialog available in the pop-up menu from a ***right*** mouse click on any geometry node. When selecting a color for an object, be sure to click the Assign box before clicking OK.



FRED will allow multiple independent documents to be open at the same time. This makes it easy to compare and contrast systems and to copy-and-paste from one document to another. It should be noted that the objects and system raytrace information in any given open FRED document is independent of any other open FRED documents.

Both the drag-and-drop option and the copy-and-paste option can be done inside of one document or between multiple documents. If you apply a material or coating from one document to another document via a drag-and-drop, the material or coating is automatically added to the materials or coating node respectively and will be available inside the destination document for future use.

The GUI interface is discussed in more detail in the user interface section of the help files.

Chapter 2 - FRED Document Views

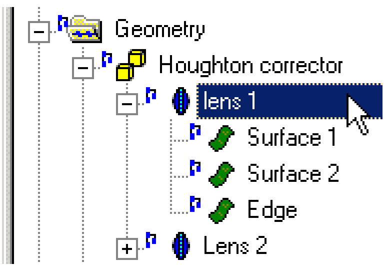
Topics and Examples

This section has examples and topics that explain the FRED document views including the **Tree View** and the **Visualization Window**.

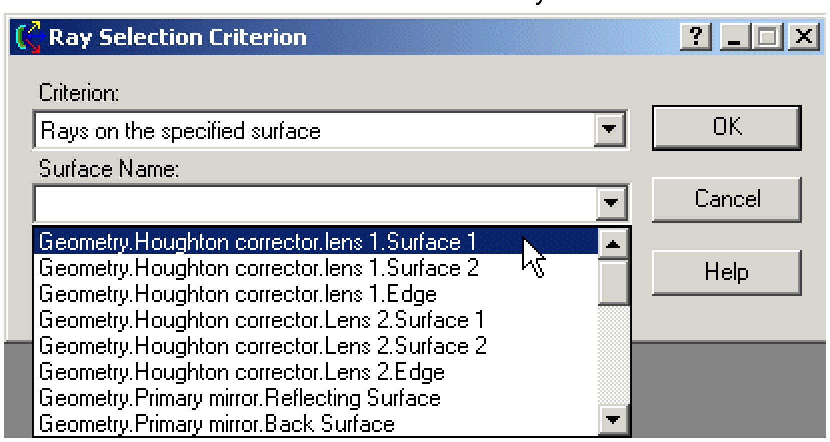
- Hierarchy Naming Convention

Hierarchy Naming Convention

The graphical representation of FRED document data hierarchy is shown in the Tree View. The graphical nature of the Tree View makes the organization of the data clear. In the example below, Surface 1, Surface 2, and the Edge are child nodes of element Lens 1. The subassembly called Houghton Corrector is the parent node of elements Lens 1 and Lens 2. And the Geometry node is the parent node of the Houghton Corrector.



The textual representation of the data hierarchy is also easy to understand but not quite as transparent. Parent child node relationships are denoted with a ".", for example see how Surface 1 of element Lens 1 is denoted in the Ray Selection Criterion dialog example below.



Chapter 3 – Creating and Editing Simple Sources

Create Simplified Source…

Description - Create Simplified Source…

There are two options for creating new sources from scratch in FRED: the Create Detailed Source… dialog and the Create Simplified Source… dialog. The Create Detailed Source… dialog provides all the available source options and the Create Simplified Source… dialog provides simpler user interface for generating commonly used sources. A source created with the Create Simplified Source… dialog can edited with either the Edit / View Simplified Source… dialog or the Edit / View Detailed Source… dialog. If a source created with the Create Simplified Source… dialog is edited with the Edit / View Detailed Source… dialog, it may no longer be possible to edit it with the Edit / View Simplified Source… dialog depending on what source attributes that were changed in the Edit / View Detailed Source… dialog.

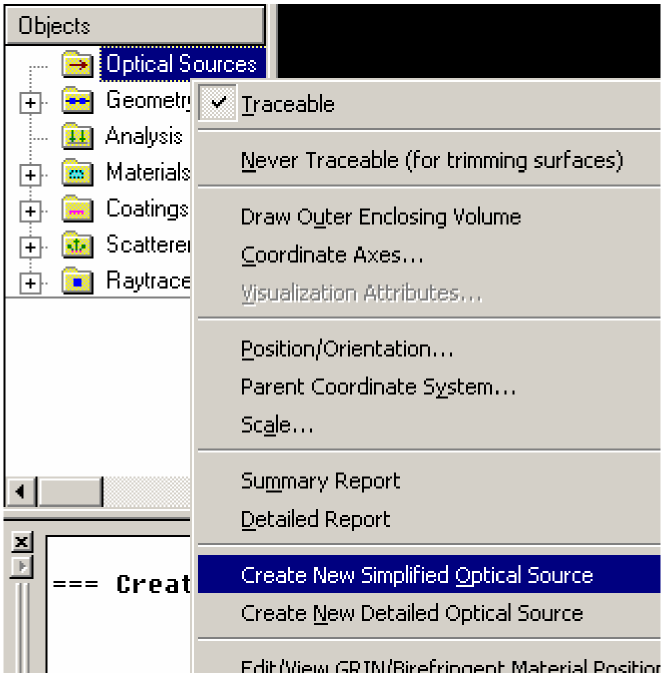
As stated above, the Create Simplified Source… dialog allows the user to quickly create common source types with a relatively small number of user inputs. The following sources can be created with the Create Simplified Source… dialog:

- Detailed Optical Source (arbitrary user defined source) – *Note that Detailed Optical Source ray locations and directions cannot be edited with the Simplified Optical Source dialog.*
- Collimated Source (Plane wave)
- Point Source (Spherical wave)
- Laser Beam (Gaussian 00 mode)
- Diode Laser Beam (Astigmatic Gaussian)

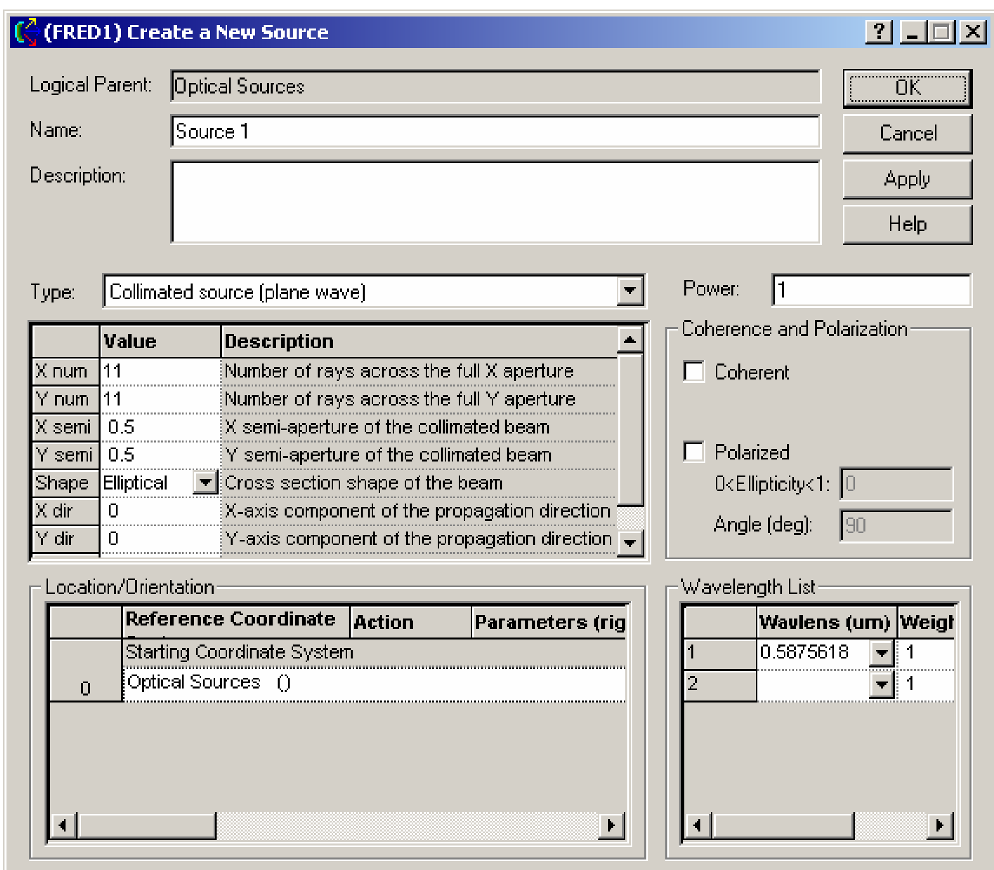
The Create Simplified Source… command will then set all the detailed source attributes to generate the selected source type.

How Do I Get There? - Create Simplified Source…

Right click on the Optical Sources and select Create New Simplified Optical Source… in the right click pop-up menu,



Dialog Box and Controls -Create Simplified Source...



See Also - Create Simplified Source...

There are four source types available in the pull down menu in the Create Simplified Source… dialog. The four options are discussed separately.

Detailed Optical Source (arbitrary user defined source)

Collimated Source (Plane wave)

Point Source (Spherical wave)

Laser Beam (Gaussian 00 mode)

Diode Laser Beam (Astigmatic Gaussian)

Edit / View Simplified Source...

Description - Edit / View Simplified Source...

The Edit / View Simplified Source… dialog allows the user to quickly edit Simple Source types with a relatively small number of user inputs. Simple Sources are sources setup to model commonly used sources.

The following sources are options in the Edit / View Simplified Source… dialog:

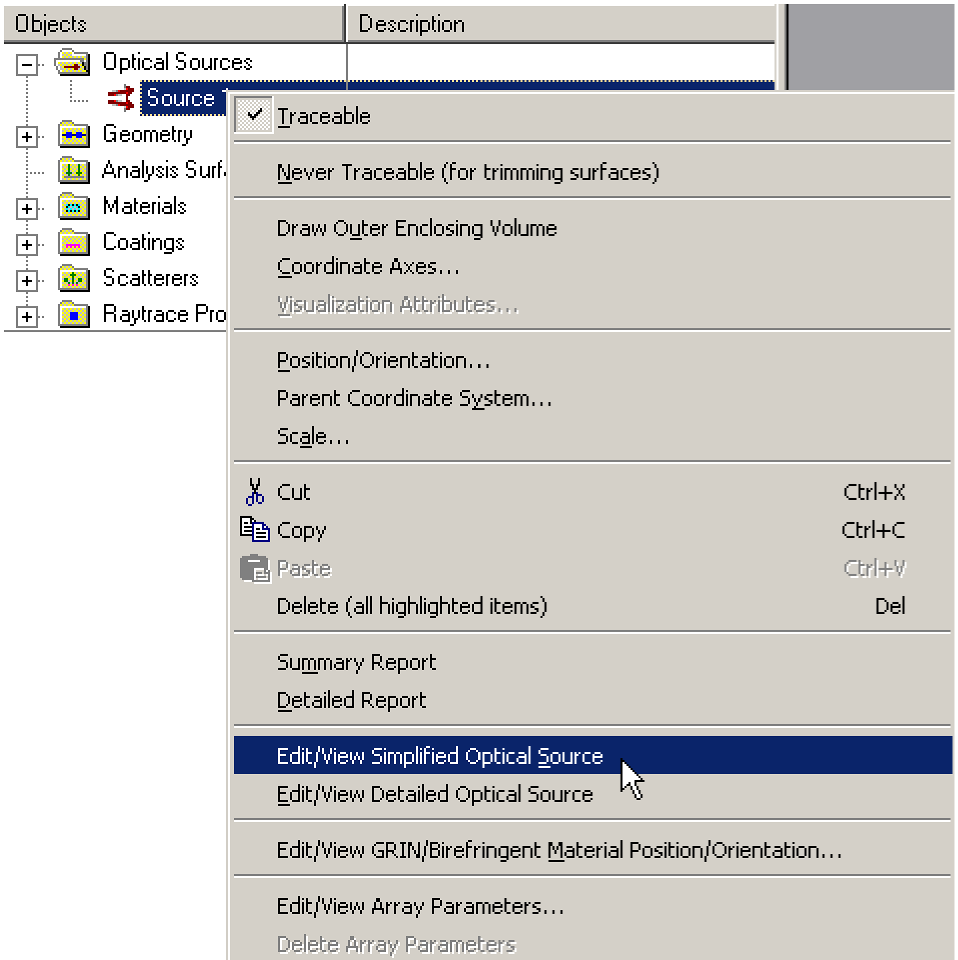
- Detailed Optical Source (arbitrary user defined source)
- Collimated Source (Plane wave)
- Point Source (Spherical wave)
- Laser Beam (Gaussian 00 mode)
- Diode Laser Beam (Astigmatic Gaussian)

The Edit / View Simplified Source… command will then set all the detailed source attributes to generate the selected source type.

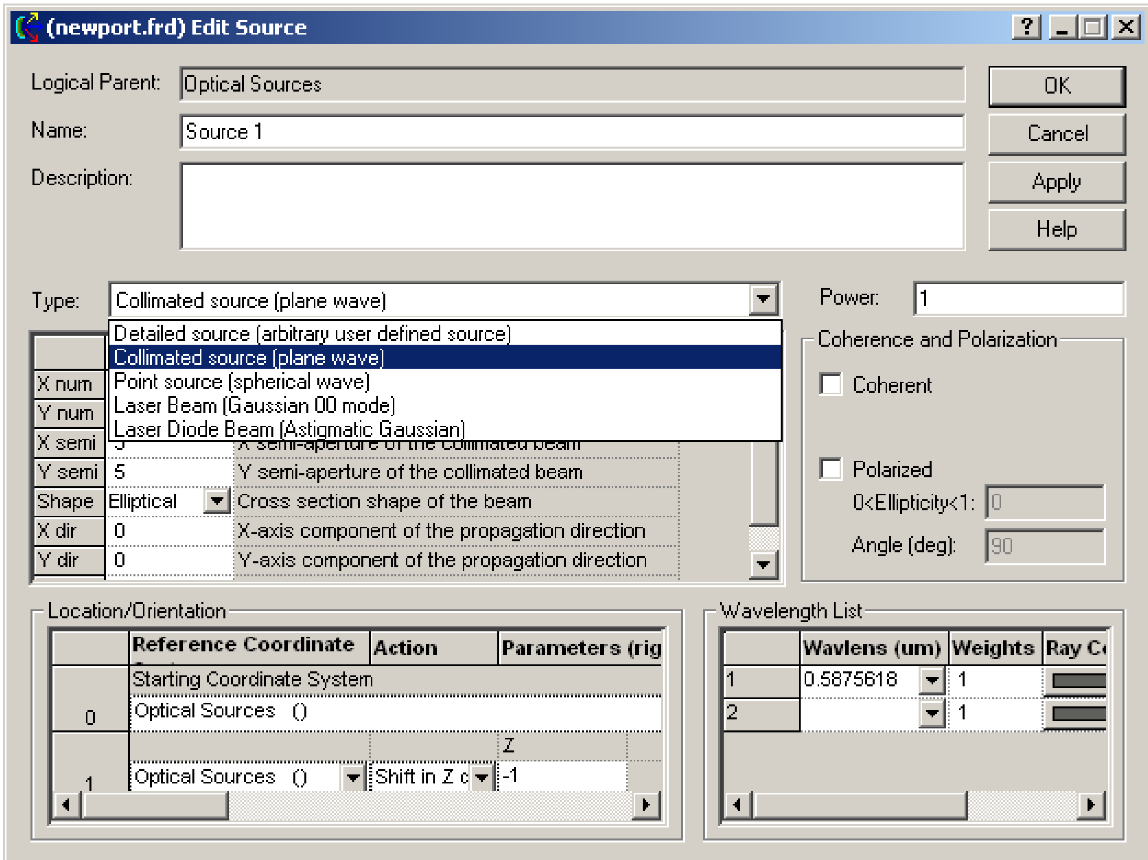
A Simple Source created with the Create Simplified Source… dialog can edited with either the Edit / View Simplified Source… dialog or the Edit / View Detailed Source… dialog. If a source created with the Create Simplified Source… dialog is edited with the Edit / View Detailed Source… dialog, it may no longer be possible to edit it with the Edit / View Simplified Source… dialog depending on what source attributes that were changed in the Edit / View Detailed Source… dialog.

How Do I Get There? - Edit / View Simplified Source...

Right click on the Optical Sources and select Edit / View New Simplified Optical Source… in the right click pop-up menu.



Dialog Box and Controls - Edit / View Simplified Source...



There are four source types available in the pull down menu in the **Edit / View Simplified Source…** dialog. The four options are discussed separately.

- Detailed Optical Source (arbitrary user defined source)
- Collimated Source (Plane wave)
- Point Source (Spherical wave)
- Laser Beam (Gaussian 00 mode)
- Diode Laser Beam (Astigmatic Gaussian)

See Also… Edit / View Simplified Source…

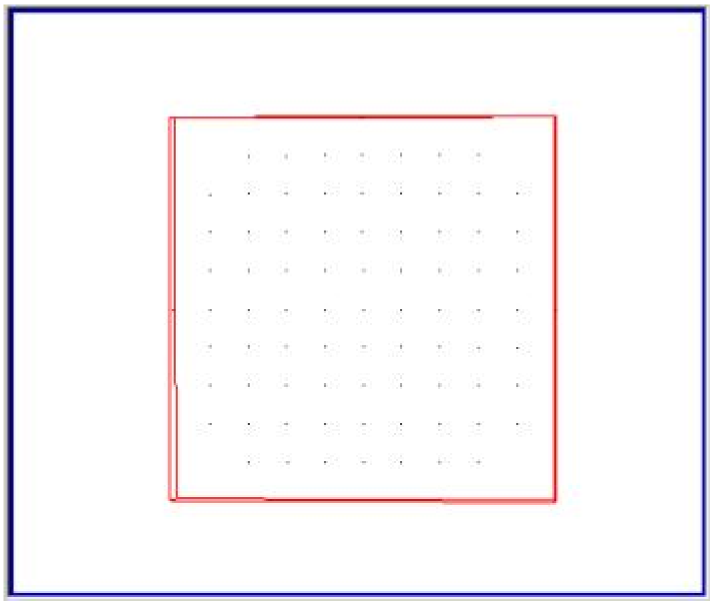
- Detailed Optical Source (arbitrary user defined source)
- Collimated Source (Plane wave)
- Point Source (Spherical wave)
- Laser Beam (Gaussian 00 mode)
- Diode Laser Beam (Astigmatic Gaussian)

Collimated Source (Plane Wave)

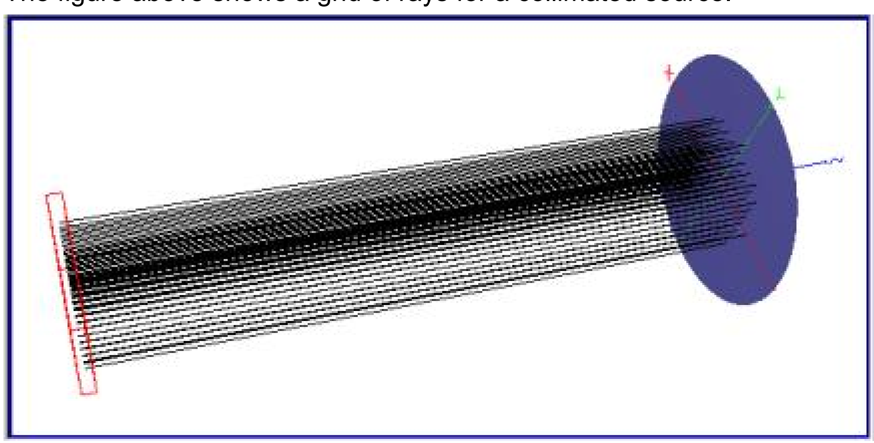
Description

Collimated Source (Plane Wave)

The **Create Simplified Source…** dialog provides simple user interface for generating commonly used sources types. The **Collimated Source (Plane Wave)** option generates a grid of collimated rays.



The figure above shows a grid of rays for a collimated source.



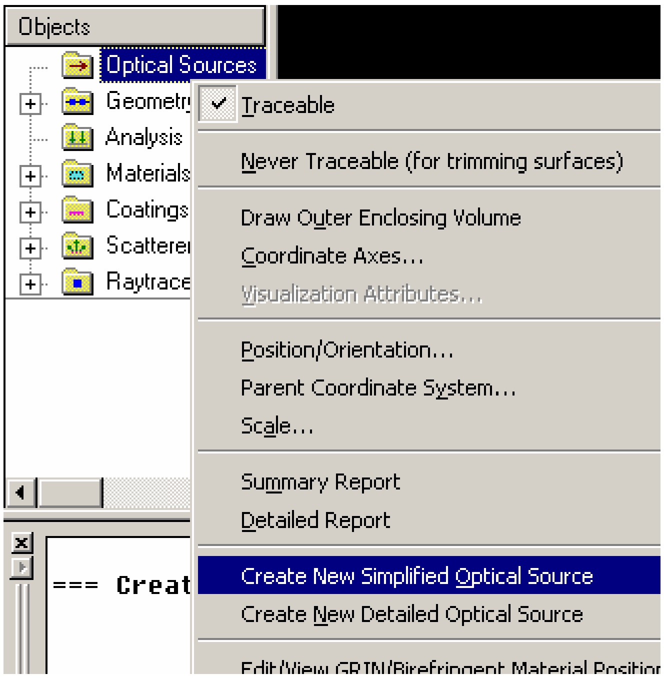
The grid of rays above traced to a plane.

[How Do I Get There?](#)

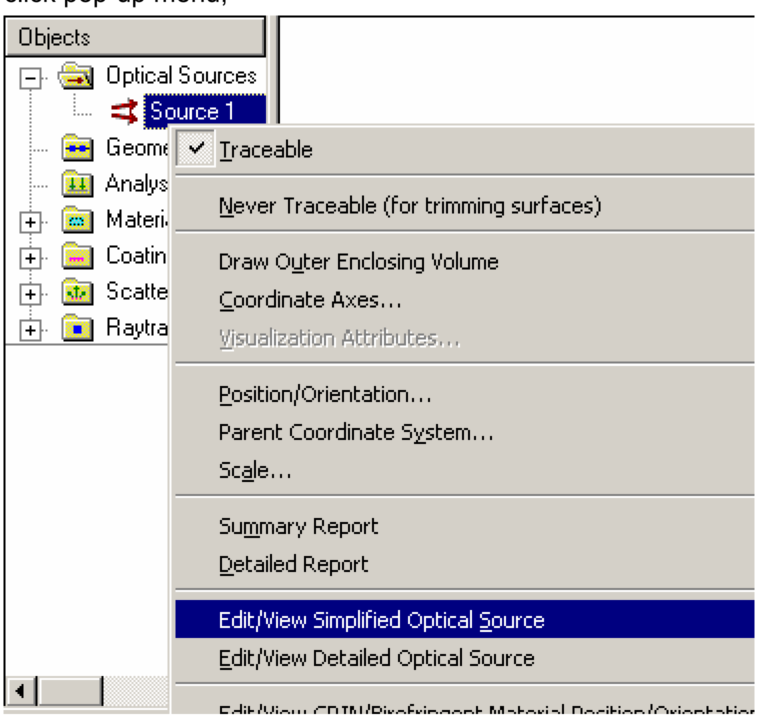
Collimated Source (Plane Wave)

There are two different ways to execute this command:

1. Right click on the **Optical Sources** and select **Create New Simplified Optical Source…** in the right click pop-up menu,



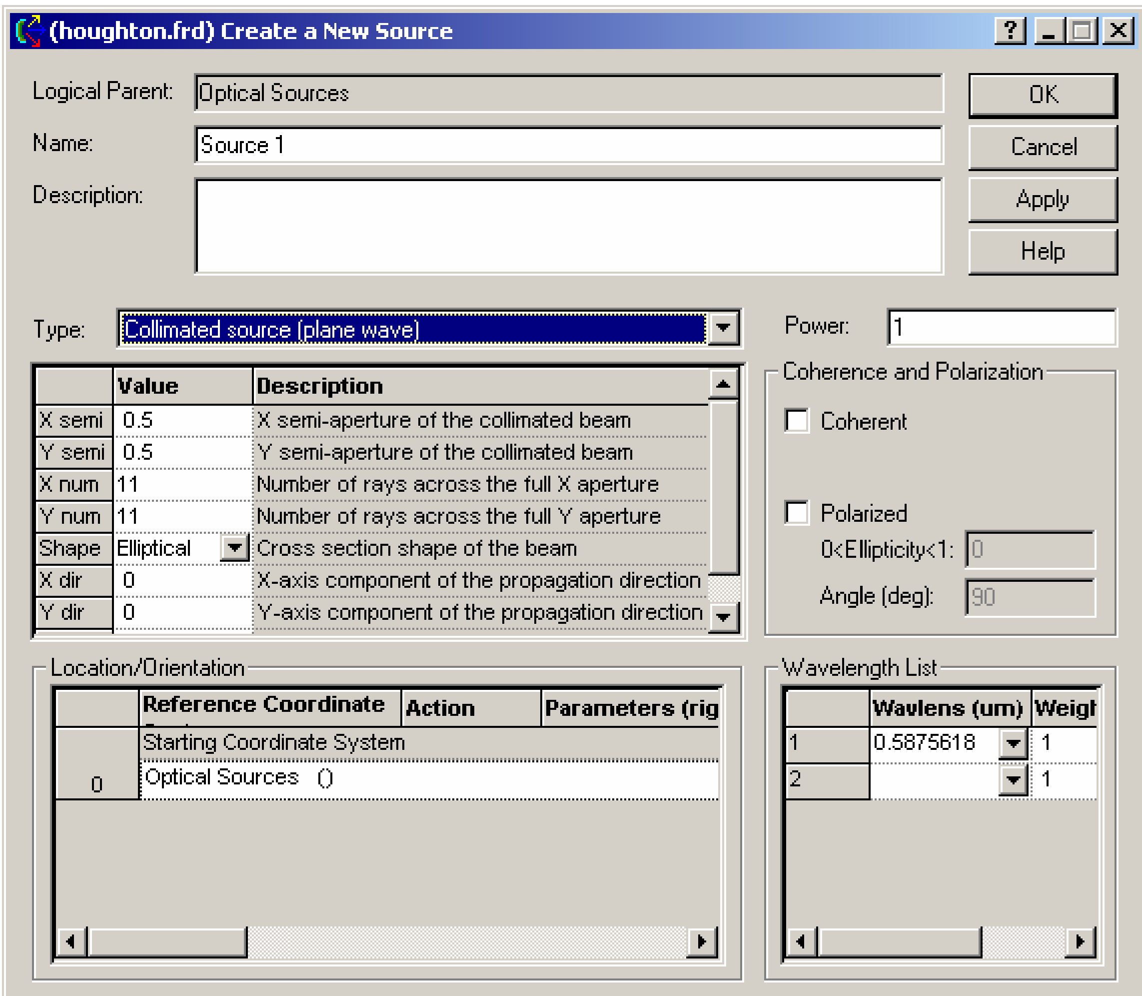
2. Right click on a **Sources** and select **Edit/View Simplified Optical Source…** in the right click pop-up menu,



In the **Create New Simplified Optical Source…** dialog, select the **Collimated Source (Plane Wave)** option.

Dialog Box and Controls

Collimated Source (Plane Wave)



Control	***Inputs***	***Defaults***
Parent:	Logical Parent for the Source listed here.	Optical Sources
Name:	Name of the Source is listed here. The name can be of any alphanumeric text length.	Source #
Description:	A user description of the Source can be entered here.	blank
Type:	Type of the Simplified Source can be selected from this pull down menu.	Collimated Source
X semi	X axis semi-aperture of the grid of rays in the collimated beam.	0.5
Y semi	Y axis semi-aperture of the grid of rays in the collimated beam.	0.5
X num	Number of rays across the full aperture of the collimated beam in the X direction.	11
Y num	Number of rays across the full aperture of the collimated beam in the Y direction.	11
Shape	Cross section of the beam.	Elliptical
X dir	X direction cosine α.	0
Y dir	Y direction cosine β.	0
Z dir	Z direction cosine γ.	1
Location/Orientation	Location/Orientation Parent and any required translations and rotations to correctly position the Source.	Optical Sources
Power	Total power of the Source.	1
Coherence and Polarization		
Coherent	If checked, rays are treated as Gaussian Beamlets and coherently propagated.	Unchecked
Polarization	If checked, polarization data for the rays is maintained and stored.	Unchecked
Ellipticity	Sets the ellipticity of the polarization state, 0 represents linear polarization and 1 represents circular.	0
Angle	Sets the angle of the polarization relative to the X axis.	90
Wavelength List		

Table	The wavelengths, weights, and rendered ray colors are set in this section.	0.5875618
OK	Create a new Optical Source and close dialog box.	
Cancel	Discard new Optical Source and close dialog box.	
Apply	Accept new Optical Source changes and keep dialog box open.	
Help	Access this Help page.	

See Also...

Collimated Source (Plane Wave)

Detailed Optical Source (arbitrary user defined source)
Point Source (Spherical wave)
Laser Beam (Gaussian 00 mode)
Diode Laser Beam (Astigmatic Gaussian)
Coherent Source Introduction

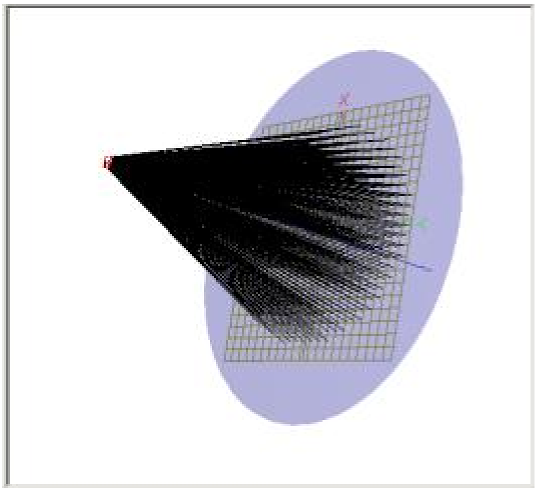
Diode Laser Beam (Astigmatic Gaussian)

Description
How Do I Get There?
Dialog box and Controls
Application Notes
See Also...

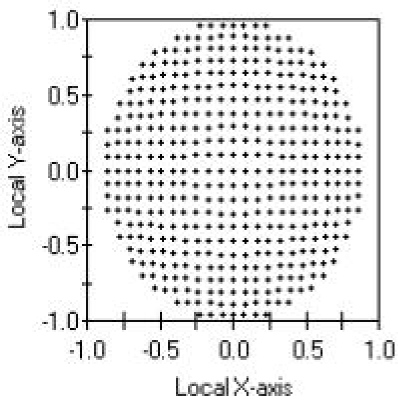
Description

Diode Laser Beam (Astigmatic Gaussian)

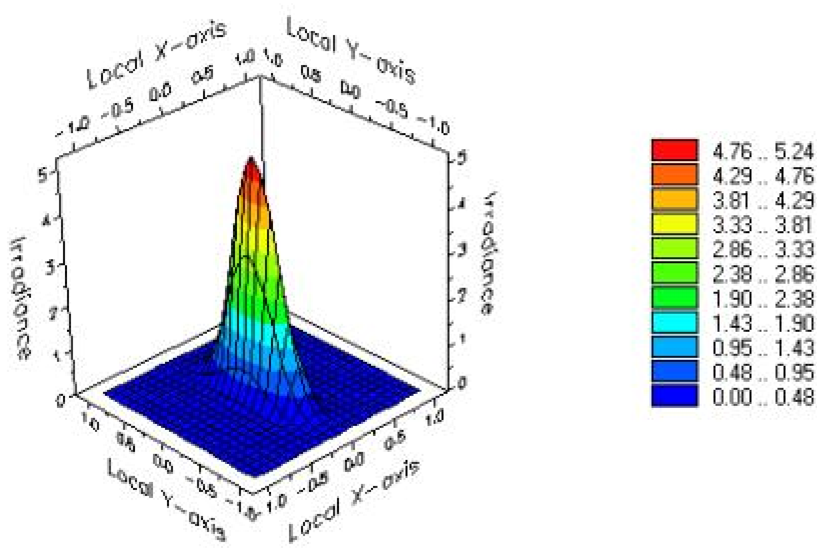
The Create Simplified Source dialog provides simple user interface for generating commonly used sources types. The Diode Laser Beam (Astigmatic Gaussian) option generates a diverging set of rays that emanate from separate X & Y focii along the z-axis. The diverging set of rays is apodized so that the irradiance profile of the beam is gaussian.



The Position Spot Diagram for this grid of rays looks much like a regular grid of diverging rays.



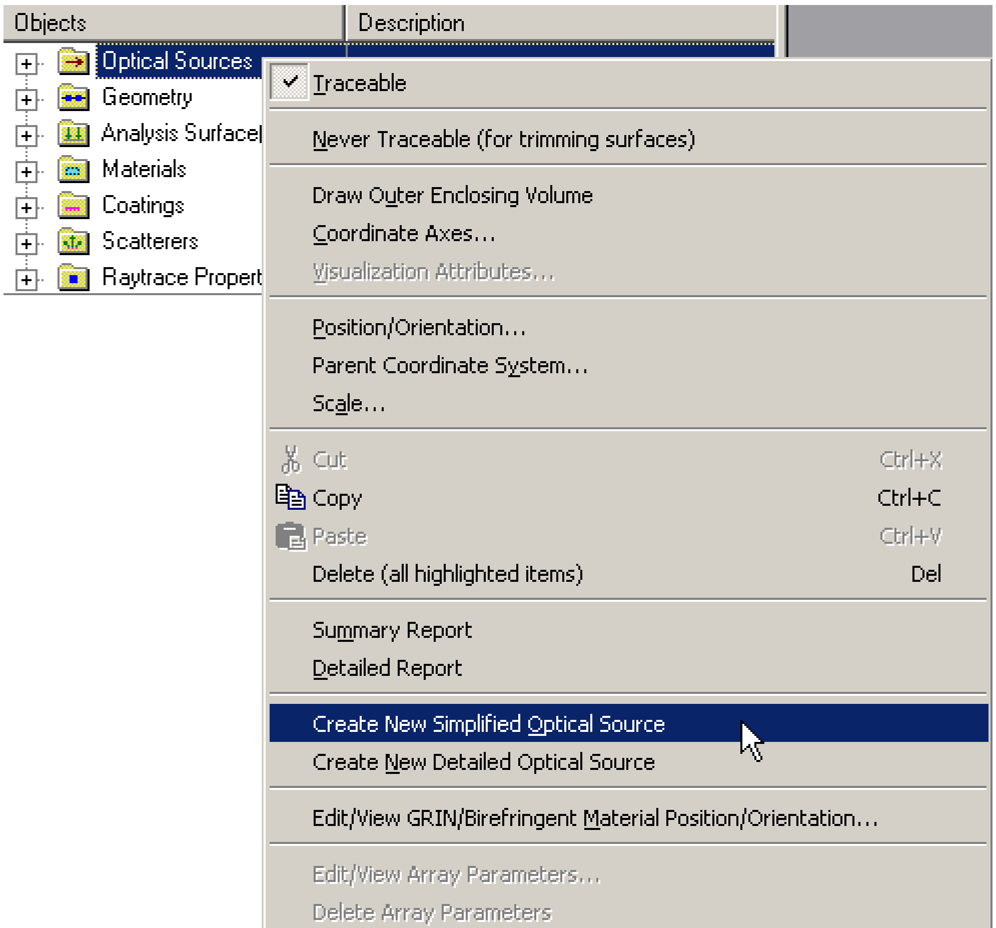
The Irradiance Spread Function however has a Gaussian profile with a different divergence angle in the X and Y directions. The Position Spot Diagram above and the Irradiance Spread Function below have the same extent in the X and Y.



How Do I Get There?
Diode Laser Beam (Astigmatic Gaussian)

Create a new Simplified Source by:

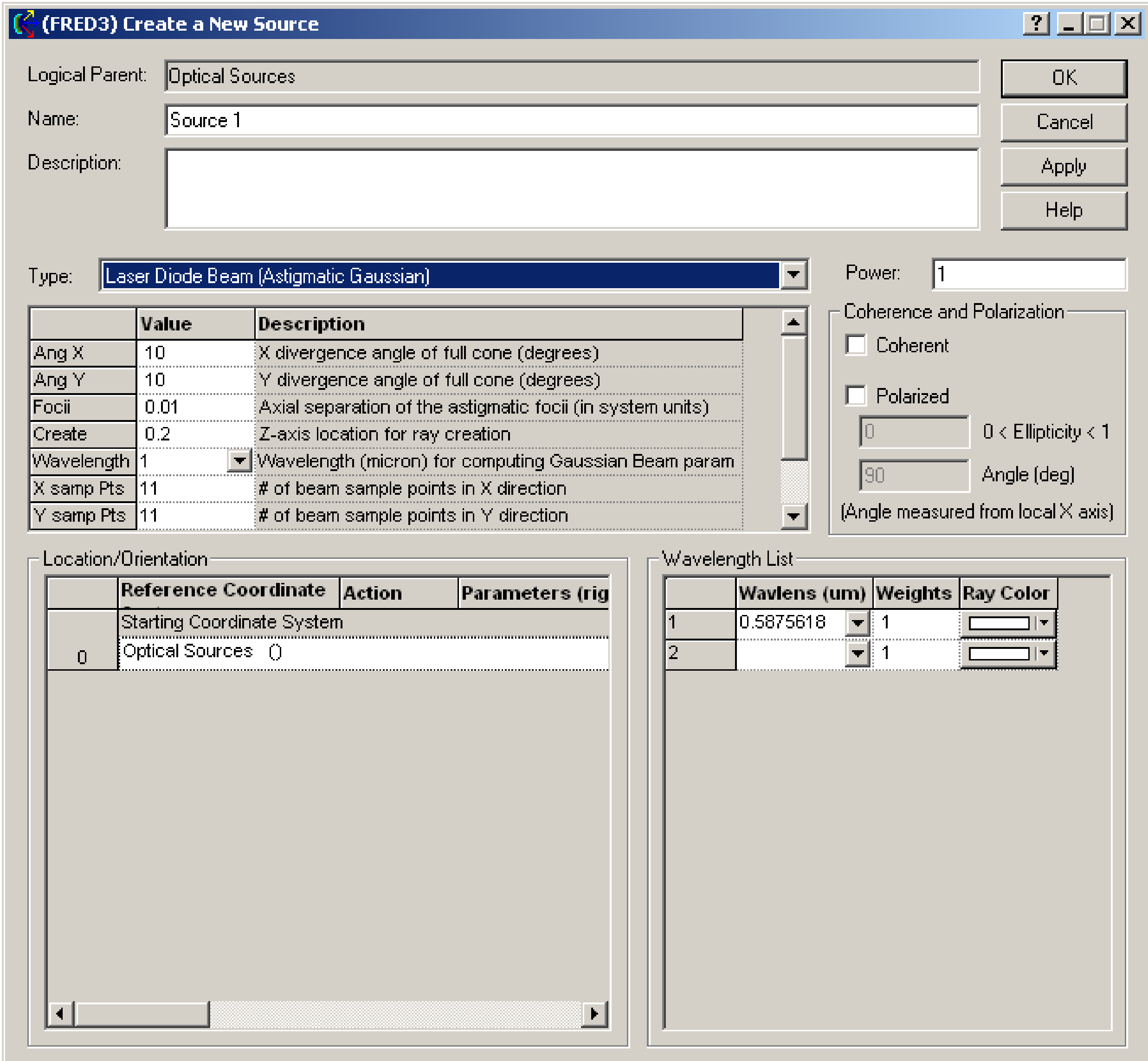
1. Right clicking on the Optical Sources and select Create New Simplified Optical Source.............



2.

3. Use the Accelerator Key - Ctrl+Alt+I

Dialog Box and Controls
Diode Laser Beam (Astigmatic Gaussian)



Control	*Inputs*	*Defaults*
Logical Parent:	Logical Parent for the Source is listed here.	Optical Sources
Name:	Name of the Source is listed here. The name can be of any alphanumeric text length.	Source *n*
Description:	User description of the Source can be typed here.	blank
Type:	Type of the Simplified Source can be selected from this pull down menu. Choose **Laser Diode**.	Collimated Source
Ang X Ang Y	Divergence full cone angle in the X and Y direction in degrees.	10

Focii	Axial separation between focii in the X- and the Y- directions.	10
Create	Plane in which the beam is synthesized from the grid of rays (see App Notes below for more detail).	0.2
X Sample Pts Y Sample Pts	Number of sample points in the X and Y directions across the beam.	11
Location/Orientation:	Location/Orientation Parent and any required translations and rotations to correctly position the Source.	Optical Source
Power:	Total power of the Source.	1
Coherence and Polarization		
Coherent	If checked, rays are treated as Gaussian Beamlets and coherently propagated.	Unchecked
Polarization	If checked, then polarization data for the rays is maintained and stored.	Unchecked
Ellipticity	Sets the ellipticity of the polarization state; 0 represents linear polarization and 1 represents circular.	0
Angle	Sets the angle of the polarization relative to the local source X axis.	90
Wavelength List		
Table	Wavelengths, weights, and rendered ray colors are set in this section.	0.5875618, 1, black
OK	Create a new Optical Source and close dialog box.	
Cancel	Discard new Optical Source and close dialog box.	
Apply	Accept new Optical Source changes and keep dialog box open.	
Help	Access this Help page.	

Application Note

Diode Laser Beam (Astigmatic Gaussian)

- For coherent sources, FRED synthesizes the LD wavefront on a plane located at the 'Create' z-location using the number of rays specified in

"X/Y samp Pts". These "X & Y samp Pts" can be thought of as defining the angular sampling of the source. Tracing <u>does not</u> begin at the 'Create' plane. The beamlets associated with each ray are propagated back to the current origin of the source before tracing begins.

- For incoherent sources, FRED sets the pathlengths and powers of this Astigmatic Laser Diode beam on a plane located at the 'Create' z-location using the rays selected in X/Y Samp Pts. Tracing does not begin at the 'Create' plane. Each ray is propagated back to the current origin of the source before tracing begins.

- For both coherent and incoherent versions of the Laser Diode source, the 'Create' plane should be in the far-field, i.e., z_{create} >> $Z_{Rayleigh}$= (□□□□□. In general, choose the Create plane to correspond to the position at which the beam first encounters optical elements.

- A Simplified Source can be viewed or edited as a Detailed Source. The complete set of parameters used to construct the Diode Laser Beam Simplified Source are shown when editing/viewing the source in a Detailed Source dialog. Such parameters include the location of the X & Y focii and the beamwaist sizes computed from the divergence angle.

See Also….
Diode Laser Beam (Astigmatic Gaussian)

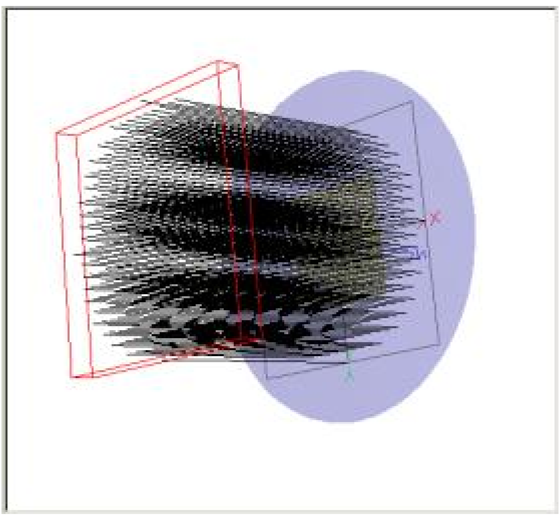
Detailed Optical Source (arbitrary user defined source)
Collimated Source (Plane wave)
Point Source (Spherical wave)
Laser Beam (Gaussian 00 mode)
Coherent Source Introduction

Laser Beam (Gaussian 00 mode)

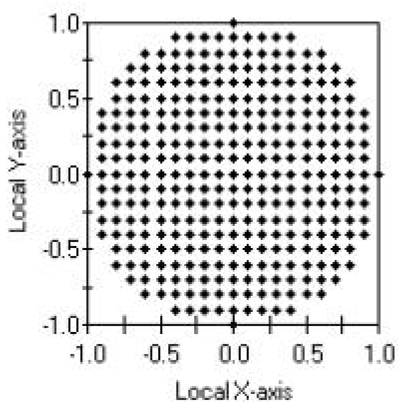
Description

Laser Beam (Gaussian 00 mode)

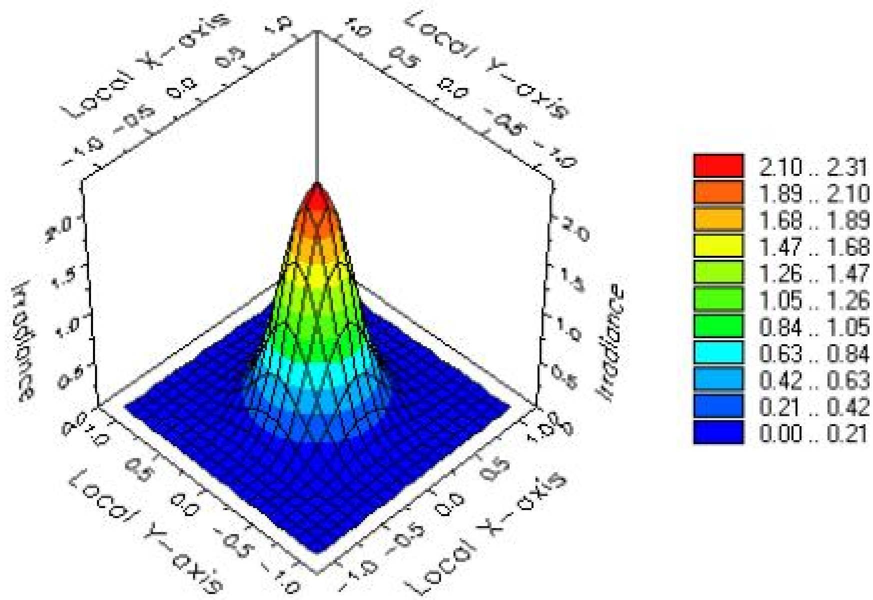
The **Create Simplified Source…** dialog provides simple user interface for generating commonly used sources types. The **Laser Beam (Gaussian 00 mode)** option generates collimated grid of rays that has been apodized in position so that the irradiance profile of the beam has a Gaussian profile.



The **Position Spot Diagram** for this grid of rays looks like a regular grid of rays.



The **Irradiance Spread Function** however has a Gaussian profile. The **Position Spot Diagram** above and the **Irradiance Spread Function** below have the same extent in the X and Y.

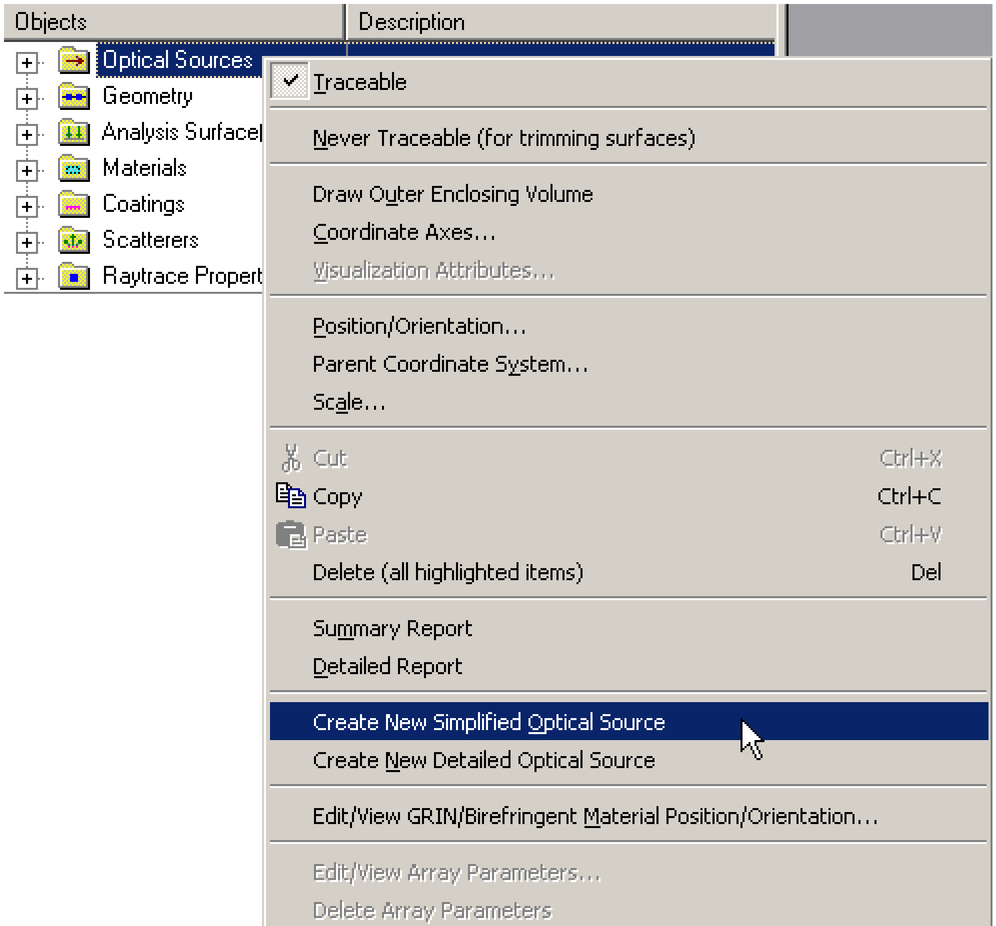


How Do I Get There?

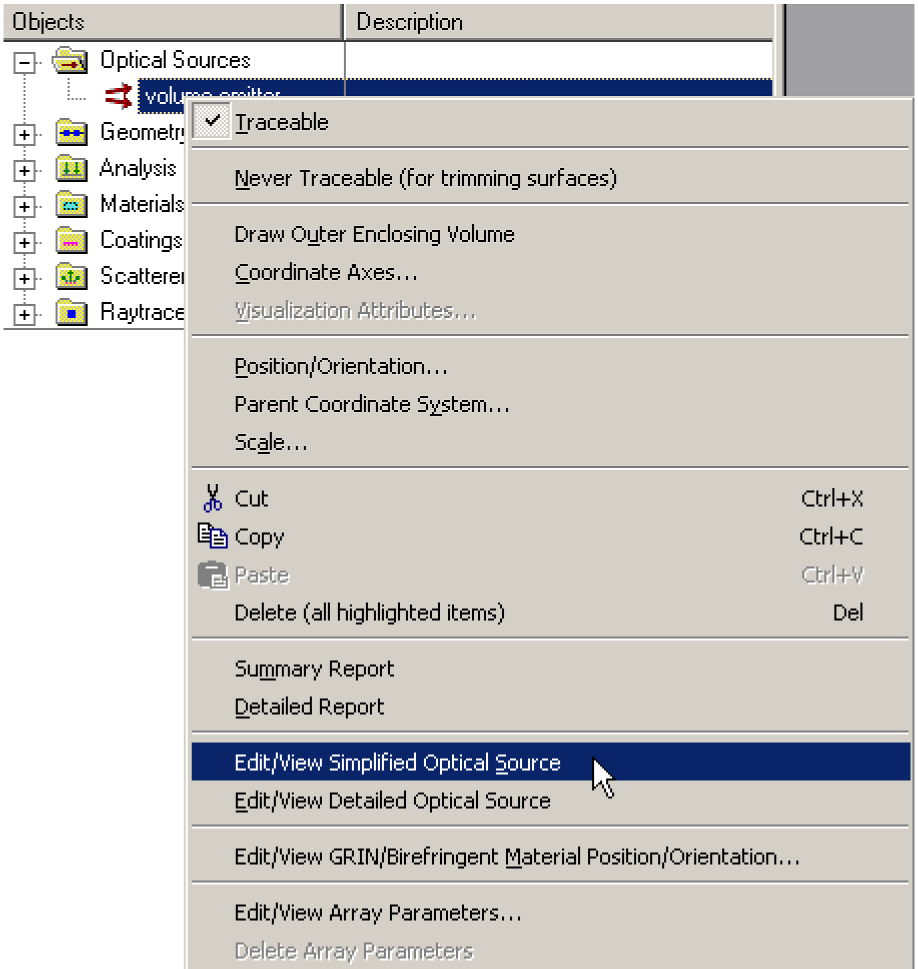
Laser Beam (Gaussian 00 mode)

There are two different ways to execute this command:

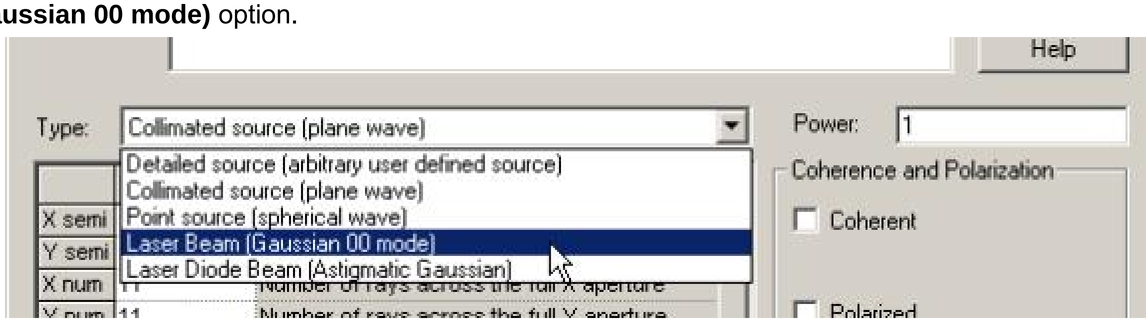
1. Right click on the **Optical Sources** and select **Create New Simplified Optical Source…** in the right click pop-up menu,



2. Right click on a **Source** and select **Edit/View Simplified Optical Source…** in the right click pop-up menu,

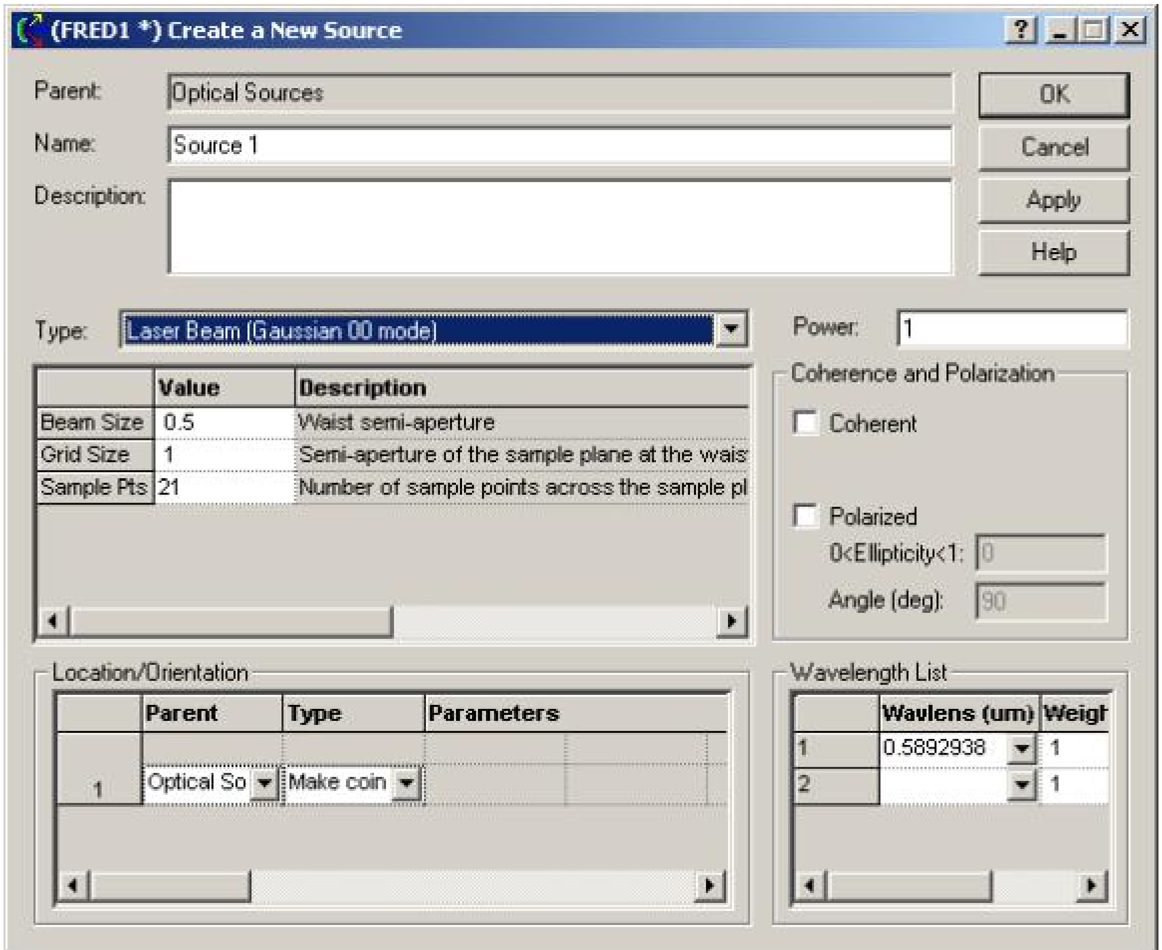


In the **Create New Simplified Optical Source…** dialog, select the **Laser Beam (Gaussian 00 mode)** option.



Dialog Box and Controls

Laser Beam (Gaussian 00 mode)



Control	Inputs	Defaults
Parent:	Logical Parent for the Source is listed here.	Optical Sources
Name:	Name of the Source is listed here. The name can be of any alphanumeric text length.	Source *n*
Description:	User description of the Source can be typed here.	blank
Type:	Type of the Simplified Source can be selected from this pull down menu. Choose **Laser Beam**.	Collimated Source
Beam Size	Gaussian beam waist semi-aperture measured at the $1/e^2$ points. The Gaussian beam waist is set with the position apodization in the Create and Edit/View Detailed Source… dialogs.	0.5
Grid Size	Semi-aperture of the grid of rays in the Gaussian beam.	1

Sample Pts	Number of sample points (in X and Y) across the Gaussian beam profile.	21
Location/Orientation:	Location/Orientation Parent and any required translations and rotations to correctly position the Source.	Optical Source
Power:	Total power of the Source.	1
Coherence and Polarization		
Coherent	If checked, rays are treated as Gaussian Beamlets and coherently propagated.	Unchecked
Polarization	If checked, then polarization data for the rays is maintained and stored.	Unchecked
Ellipticity	Sets the ellipticity of the polarization state, 0 represents linear polarization and 1 represents circular.	0
Angle	Sets the angle of the polarization relative to the X axis.	90
Wavelength List		
Table	Wavelengths, weights, and rendered ray colors are set in this section.	0.5892938
OK	Create a new Optical Source and close dialog box.	
Cancel	Discard new Optical Source and close dialog box.	
Apply	Accept new Optical Source changes and keep dialog box open.	
Help	Access this Help page.	

See Also…
Laser Beam (Gaussian 00 mode)

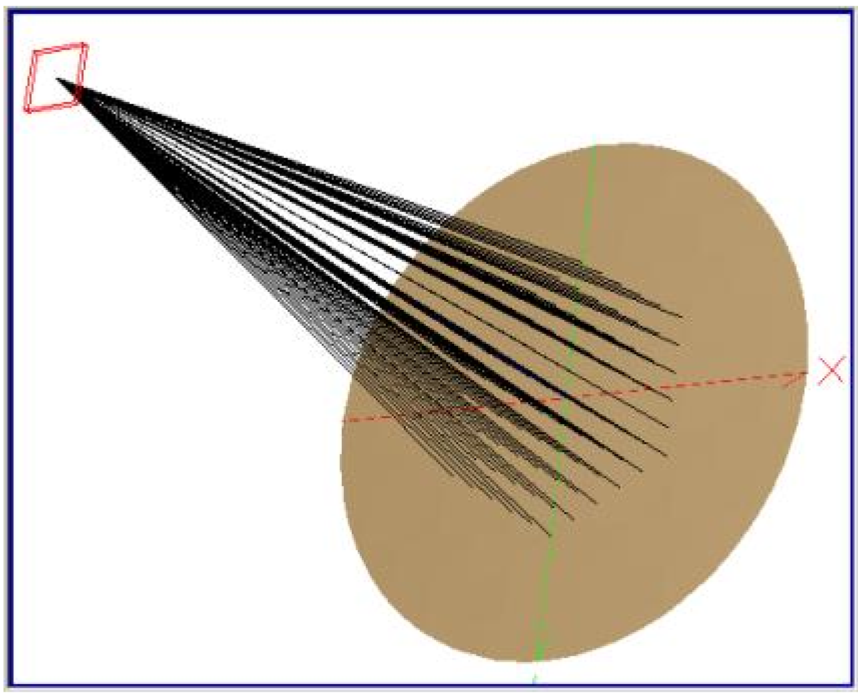
Detailed Optical Source (arbitrary user defined source)
Collimated Source (Plane wave)
Point Source (Spherical wave)
Diode Laser Beam (Astigmatic Gaussian)
Coherent Source Introduction

Point Source

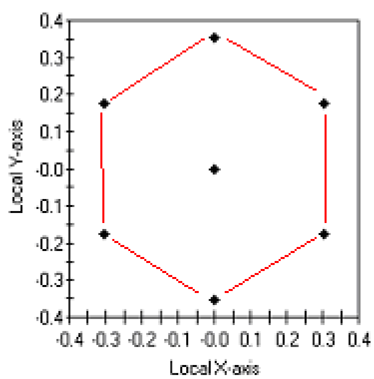
Description

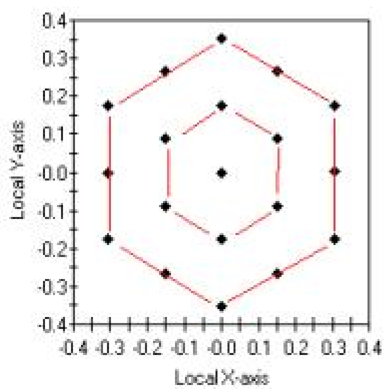
Point Source

The Create Simplified Source… dialog provides simple user interface for generating commonly used sources types. The Point Source option generates a point source of rays. The rays go from a single point towards a grid of hexagonal points in a plane.



The user defines the angular spread and the number of hexagonal grid zones to use to cover that angular range. One zone, or the first zone, is simply a hexagon with the array at the center. A second zone adds a ring to the outside of the single zone hexagon. A third zone adds an another ring to the outside of the two zones, and so on.



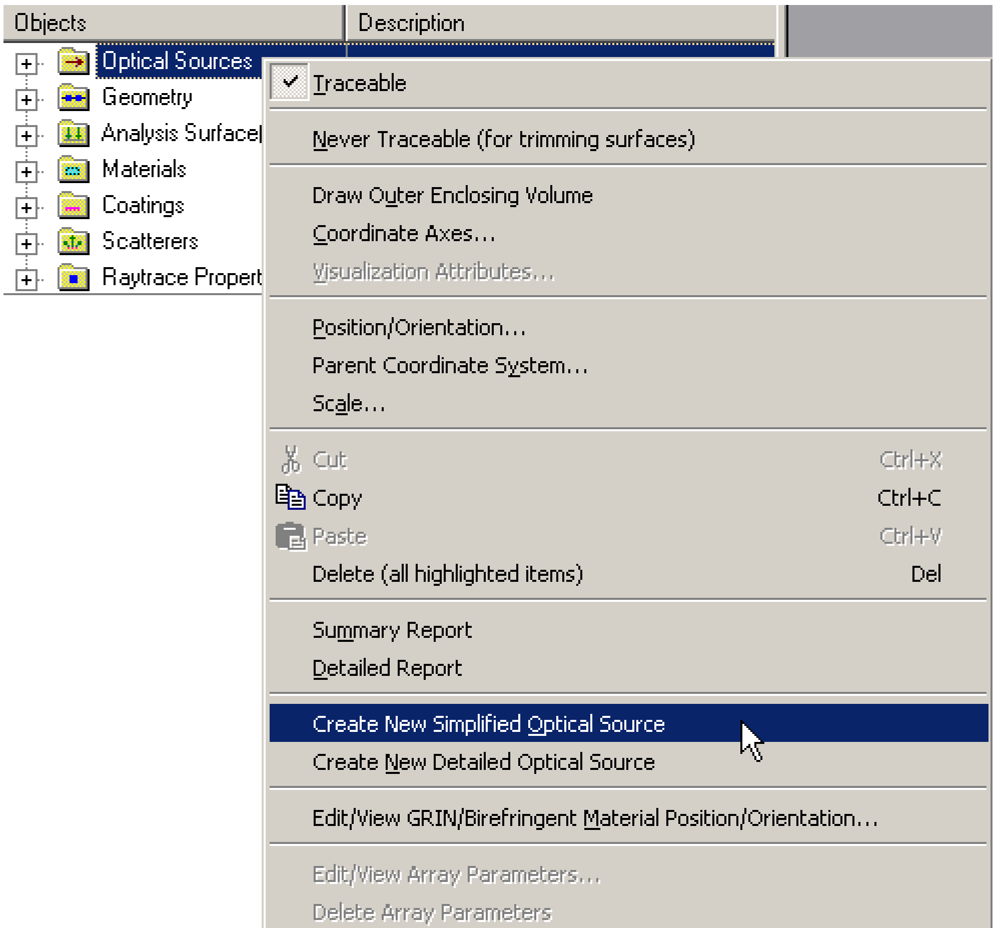


[How Do I Get There?](#)

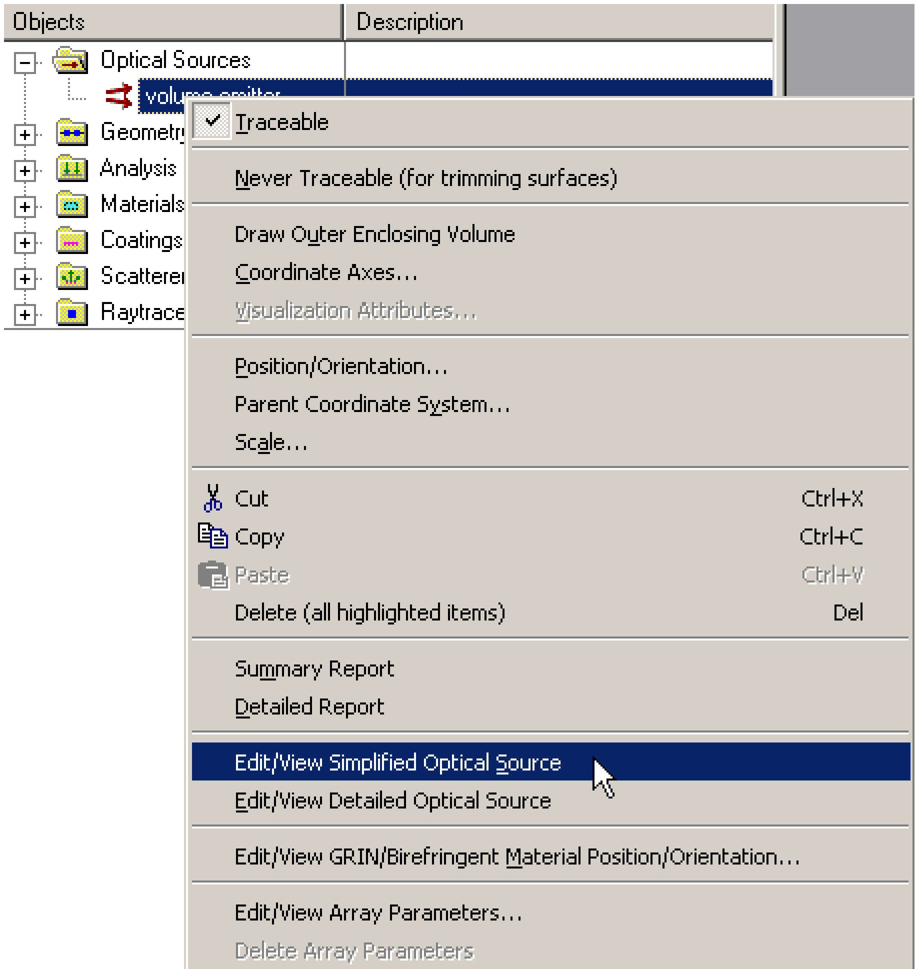
Point Source

There are two different ways to execute this command:

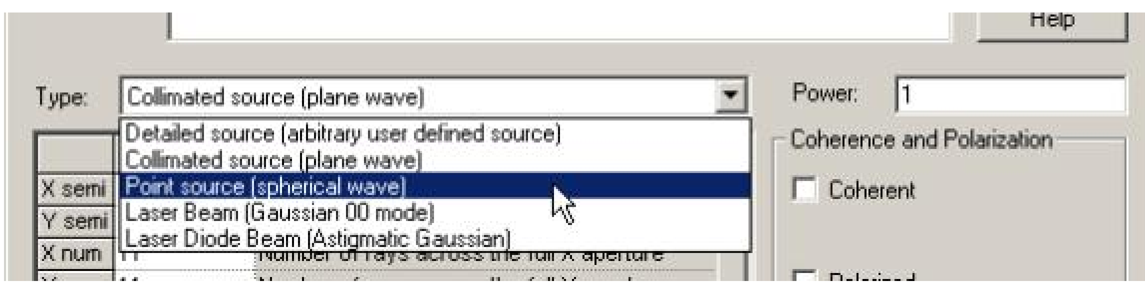
1. Right click on the Optical Sources and select Create New Simplified Optical Source… in the right click pop-up menu,



2. Right click on a Sources and select Edit/View Simplified Optical Source… in the right click pop-up menu,

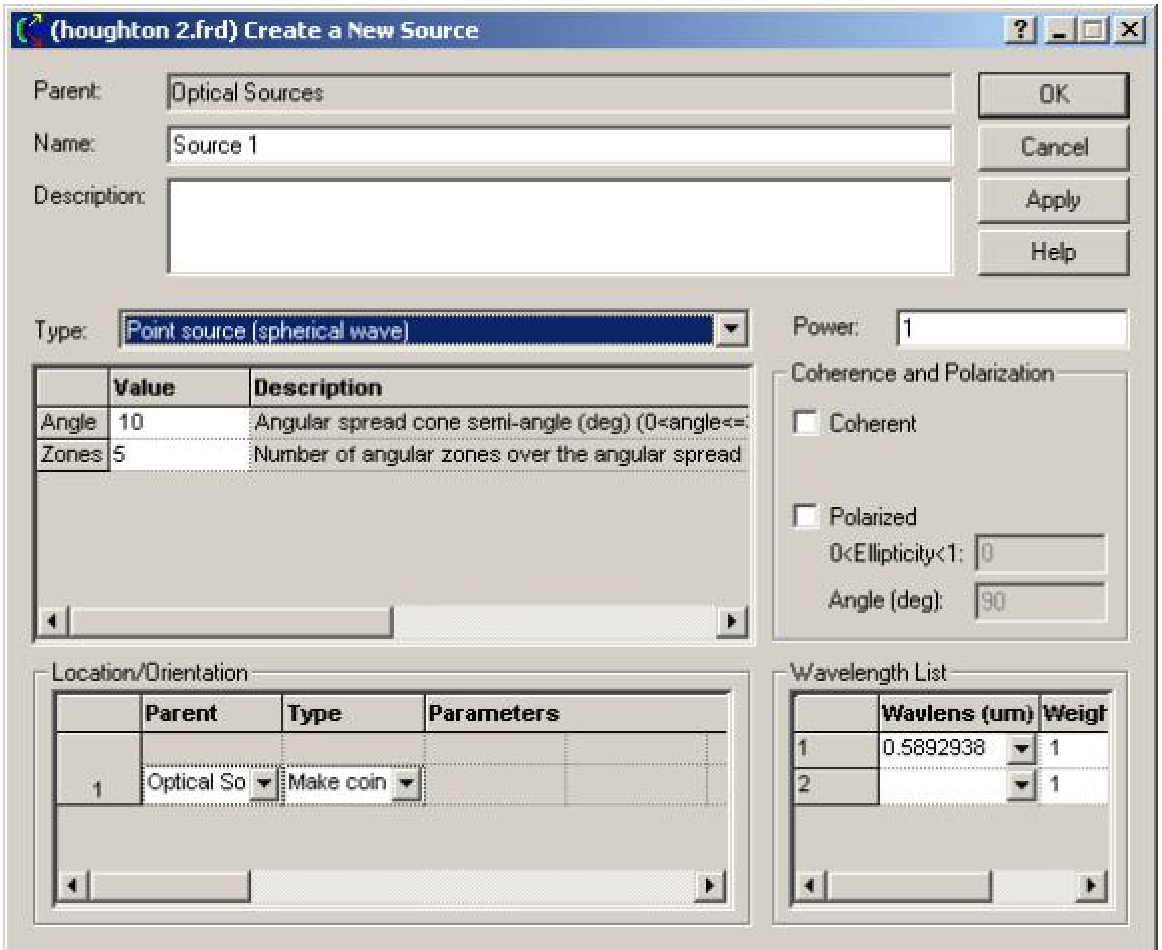


Once the Create New Simplified Optical Source… dialog appears, select the Point Source option.



Dialog Box and Controls

Point Source



Control	*Inputs*	*Defaults*
Parent	Logical Parent for the Source is listed here.	Optical Sources
Name	Name of the Source is listed here. The name can be of any alphanumeric text length.	Source #
Description	User description of the Source can be typed here.	
Type	Type of the Simplified Source can be selected from this pull down menu. Choose **Point Source**.	Collimated Source
Angle	Half angle of the ray bundle from the source.	10

Zones	Number of hexagonal zones used to fill the angular spread of the ray bundle. One zone is simply a hexagon with one ray in the center generating 7 rays total. Two zones adds a ring around the hexagon generating 19 rays. A third rings adds another ring which generates 35 rays. And so on.	5
Location/Orientation	Location/Orientation Parent and any required translations and rotations to correctly position the Source	Optical Source
Power	Total power of the Source.	1
Coherence and Polarization		
Coherent	If checked, rays are treated as Gaussian Beamlets and coherently propagated.	Unchecked
Polarization	If checked, then polarization data for the rays is maintained and stored.	Unchecked
Ellipticity	Sets the ellipticity of the polarization state, 0 represents linear polarization and 1 represents circular.	0
Angle	Sets the angle of the polarization relative to the X axis.	90
Wavelength List		
Table	Wavelengths, weights, and rendered ray colors are set in this section.	0.5892938
OK	Create a new Optical Source and close dialog box.	
Cancel	Discard new Optical Source and close dialog box.	
Apply	Accept new Optical Source changes and keep dialog box open.	
Help	Access this Help page.	

See Also….
Point Source

Detailed Optical Source (arbitrary user defined source)
Collimated Source (Plane wave)
Laser Beam (Gaussian 00 mode)
Diode Laser Beam (Astigmatic Gaussian)

Chapter 4 – How to Create and Edit Detailed Sources

Create and Edit Detailed Source

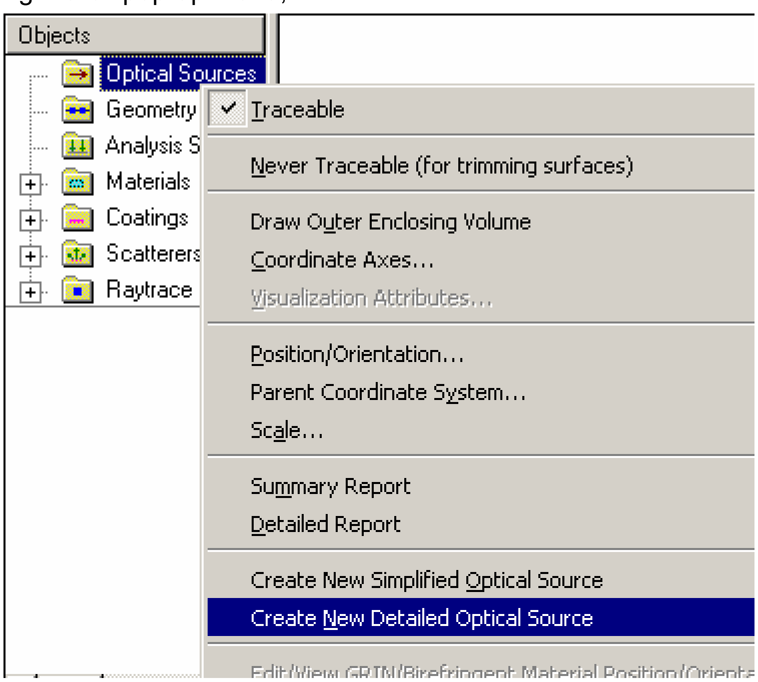
Description - Source (Create New and Edit/View Detailed Source…)

The Source page of the Create New and Edit/View Detailed Source… dialogs is the opening page of the dialog where the user can name the Source, describe the Source, and establish the initial starting conditions of the Source rays.

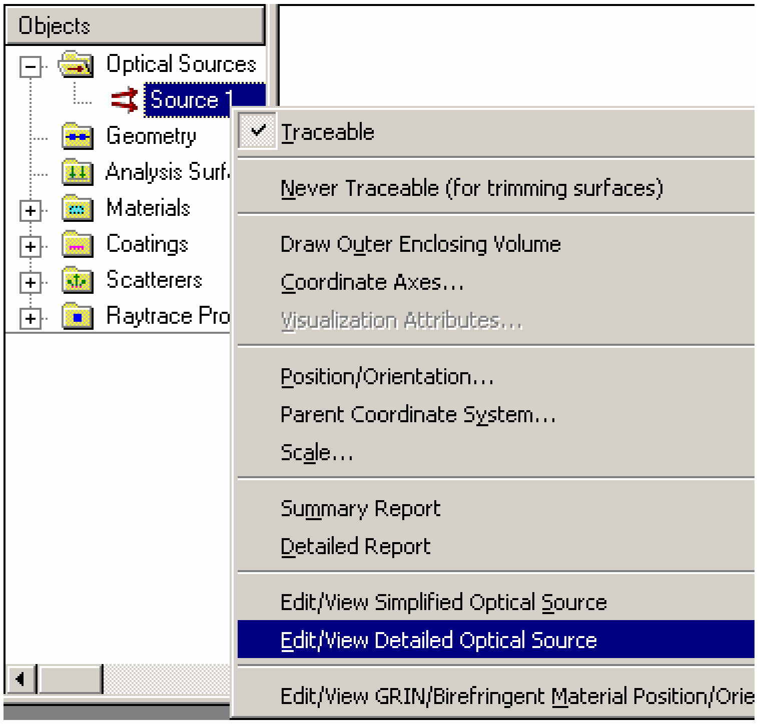
How Do I Get There? - Source (Create New and Edit/View Detailed Source…)

There are two different ways to execute this command:

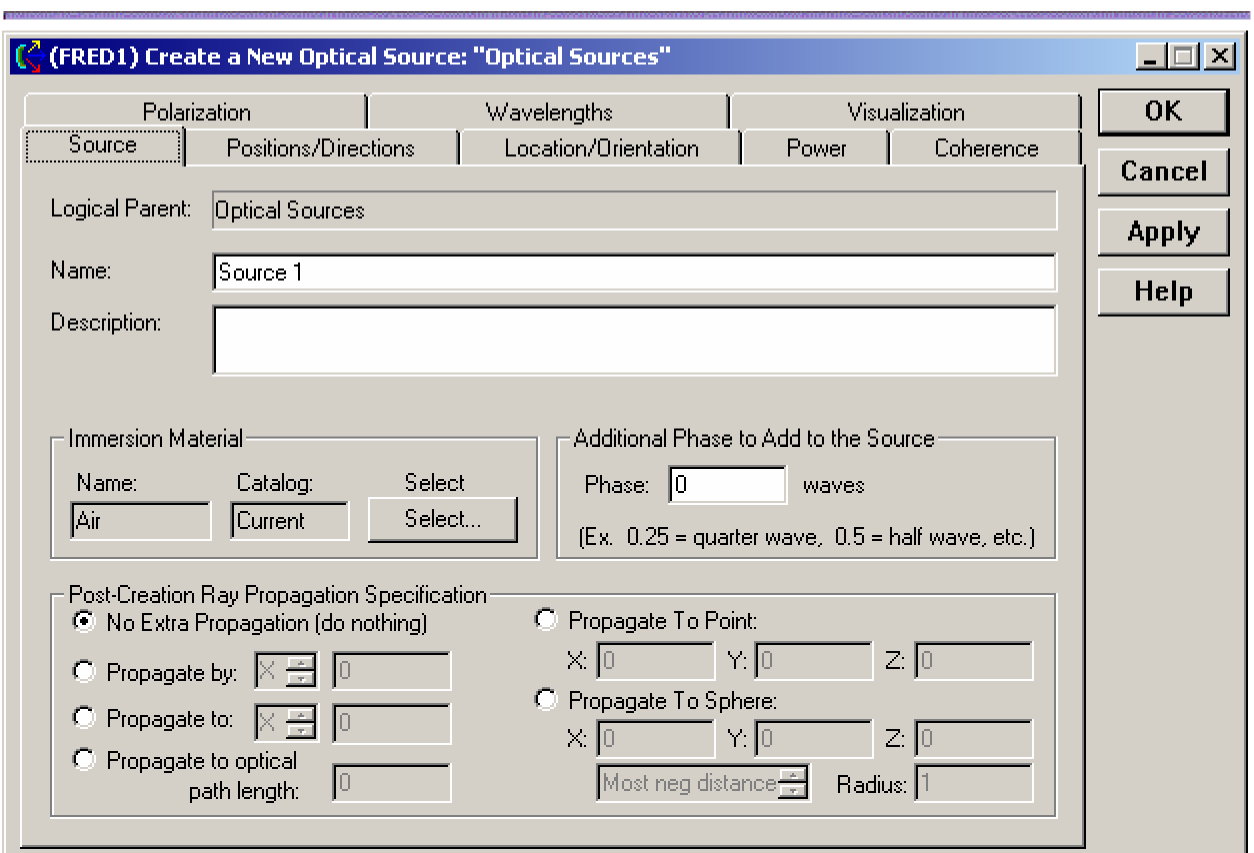
1. Right click on the Optical Sources and select Create New Detailed Optical Source… in the right click pop-up menu,



2. Right click on an Source and select Edit/View Detailed Optical Source… in the right click pop-up menu,



Dialog Box and Controls - Source (Create New and Edit/View Detailed Source…)



Control	Description	Defaults
Logical Parent	Logical parent of this source in the **Tree View**. Note that Logical parent is different than the *location* parent.	Optical Sources
Name	Alphanumeric name of any length maybe typed here.	Source *n*
Description	Alphanumeric description of any length maybe typed here.	Blank
Immersion Material		
Name	Name of material in which rays are immersed.	Air
Catalog	Specifies the catalog containing the immersion material currently in use.	Current
Select	Opens a dialog for changing the immersion material.	
Additional Phase to Add to the Source		
Phase	Add phase (in waves) to the rays prior to tracing .	0
Post-Creation Ray Propagation Specification		
No Extra Propagation (do nothing)	This selection is made if no propagation is required. Default.	Selected
Propagate by:	Rays are propagated along their trajectory by the given distance in the specified direction. If the Ray trajectory is perpendicular to the propagation direction selected then the ray is not propagated.	Not Selected
Propagate to:	Rays are propagated along their trajectory to their closest approach to the specified location. If the Ray trajectory is perpendicular to the propagation direction selected then the ray is not propagated.	Not Selected
Propagate to optical path length:	Rays are propagated along their trajectory by the specified optical path length. Optical path length is equal to the physical distance divided by the index of refraction, *OPL=length/index*.	Not Selected
Propagate to Point:	Rays are propagated along their trajectory to their closest approach to the specified point.	Not Selected

Propagate to sphere:	Rays are propagated along their trajectory to their closest approach to the surface of the specified sphere. Select negative or positive direction.	Not Selected
OK	Create a new Source and close the dialog box.	
Cancel	Discard Source changes and close the dialog box.	
Apply	Apply Source changes and keep dialog box open.	
Help	Access this Help page.	

See Also…. - Source (Create New and Edit/View Detailed Source…)

- Source
- Positions / Directions
- Location / Orientation
- Power
- Coherence
- Polarization
- Wavelength
- Visualization

Create Detailed Source - Coherence

Description - Coherence (Create New and Edit/View Detailed Source...)

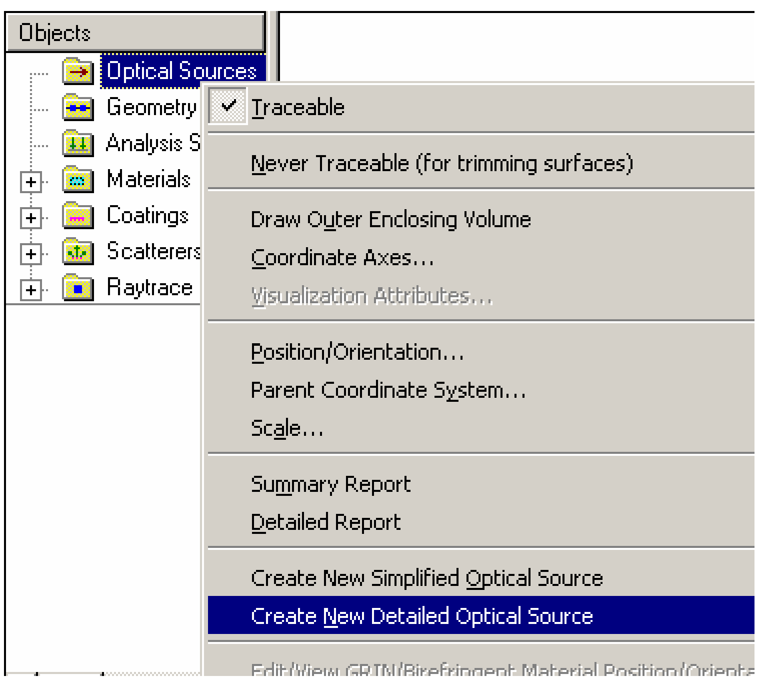
FRED performs diffraction and interference calculations using a technique called coherent beam superposition. The coherent beam superposition technique works by modeling arbitrary optical fields with the coherent summation of smaller fundamental beams. In FRED, these smaller fundamental beams are generally astigmatic Gaussian beamlets. It was been demonstrated by J. Arnaud that Gaussian beams could be represented and propagated with real rays. Those real rays can be traced through an optical system while maintaining the Gaussian beam representation. The near and far field diffraction patterns can be calculated coherently summing the Gaussian beams, which are represented by real rays traced through the system.

If the Source is set as coherent on the Coherence page, then each of the ray positions defined in the source becomes a Gaussian beamlet that is represented by two, four, or eight secondary real rays. In addition to choosing the number of secondary rays, the overlap of the adjacent beam overlap factor, and the secondary beam scaling can be set on the Coherence page.

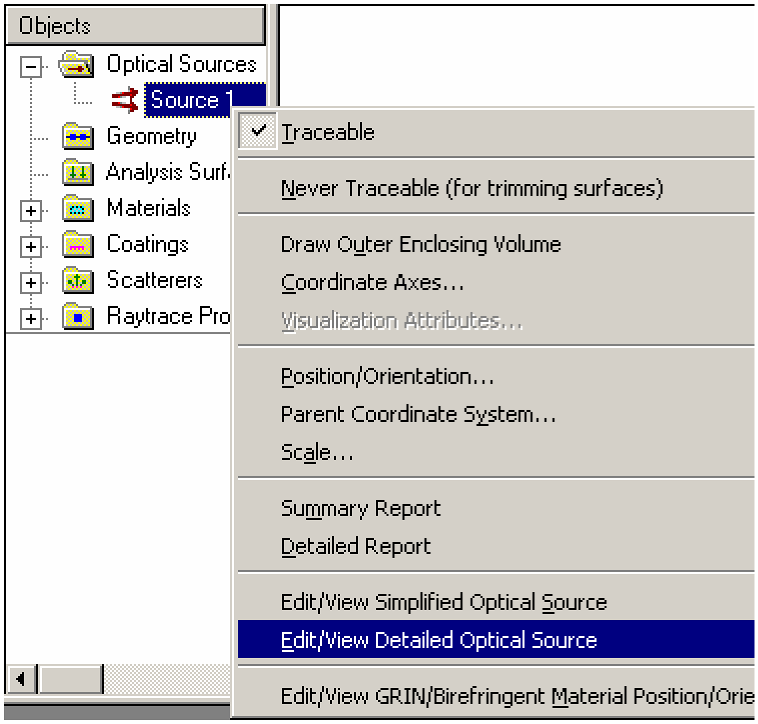
How Do I Get There? - Coherence (Create New and Edit/View Detailed Source...)

There are two different ways to execute this command:

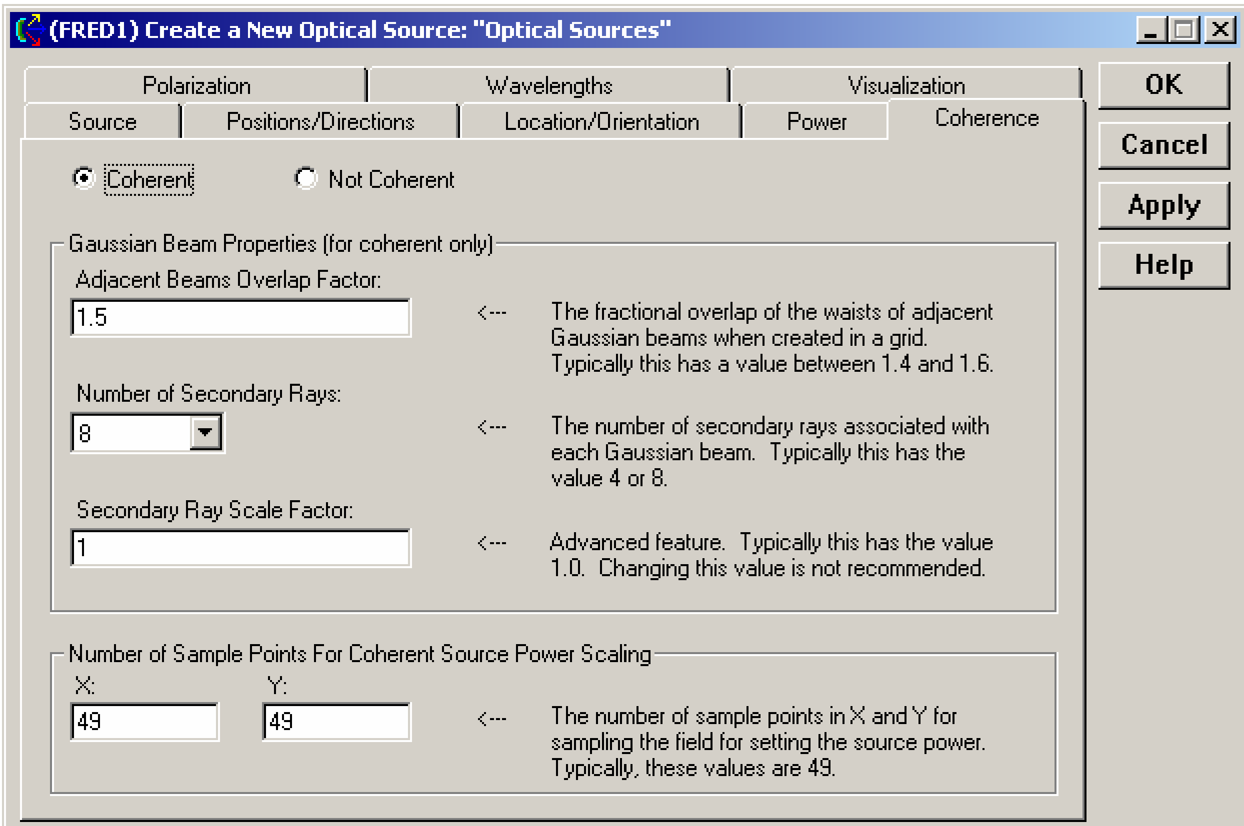
1. Right click on the Optical Sources and select Create New Detailed Optical Source… in the right click pop-up menu,



2. Right click on an Source and select Edit/View Detailed Optical Source… in the right click pop-up menu,


Objects
Optical Sources
Source 1
Geometry
Analysis Surf
Materials
Coatings
Scatterers
Raytrace Pro
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes…
Visualization Attributes…
Position/Orientation…
Parent Coordinate System…
Scale…
Summary Report
Detailed Report
Edit/View Simplified Optical Source
Edit/View Detailed Optical Source
Edit/View GRIN/Birefringent Material Position/Orie

Dialog Box and Controls - Coherence (Create New and Edit/View Detailed Source...)



Control	Inputs	Defaults
Coherent/Not Coherent	If the coherent option is selected, then the ray positions defined in the source become Gaussian beamlets represented with 2, 4, or 8 secondary real rays.	Not Coherent
Gaussian Beam Properties		
Adjacent Beams Overlap Factor	The fractional overlap of adjacent Gaussian beamlets. This factor changes the waist diameter of the Gaussian beamlets. Typical value between 1.4 and 1.6.	1.5
Number of Secondary Rays	Pull down menu of available options for the number of secondary real rays representing the Gaussian beamlets.	8
Secondary Ray Scale Factor	This is an advanced feature that scales the secondary rays representing the Gaussian beamlets.	1

Number of Sample Points for Coherent Source Power Scaling		
X,Y	Sampling resolution used only for setting source power.	49, 49
OK	Create a new Optical Source and close dialog box.	
Cancel	Discard new Optical Source and close dialog box.	
Apply	Accept new Optical Source changes and keep dialog box open.	
Help	Access this Help page.	

See Also... - Coherence (Create New and Edit/View Detailed Source...)

- Source
- Positions / Directions
- Location / Orientation
- Power
- Coherence
- Polarization
- Wavelength
- Visualization

Create Detailed Source - Location / Orientation

Description - Location / Orientation (Create New and Edit/View Detailed Source…)

The Location / Orientation page of the Create New and Edit/View Detailed Source… dialogs two functions.

- Establish the Location Parent Coordinate System for the source or object. The source or object is placed at the origin of the Location Parent Coordinate System.
- Locate and orient the source or object relative to the Location Parent Coordinate System or any other coordinate system.

The Location Parent Coordinate System should not be confused with the Logical Parent Node in the Tree View though they are cab be and are often chosen to be the same. The Location Parent Coordinate System should also not be confused with the Reference Coordinate System for a particular location or orientation transformation. The Location Parent Coordinate System will default to the Logical Parent Node but it can be changed to any other coordinate system in the FRED document. All of the nodes listed in the Geometry and Source sections of the Tree View represent available coordinate systems in the FRED document.

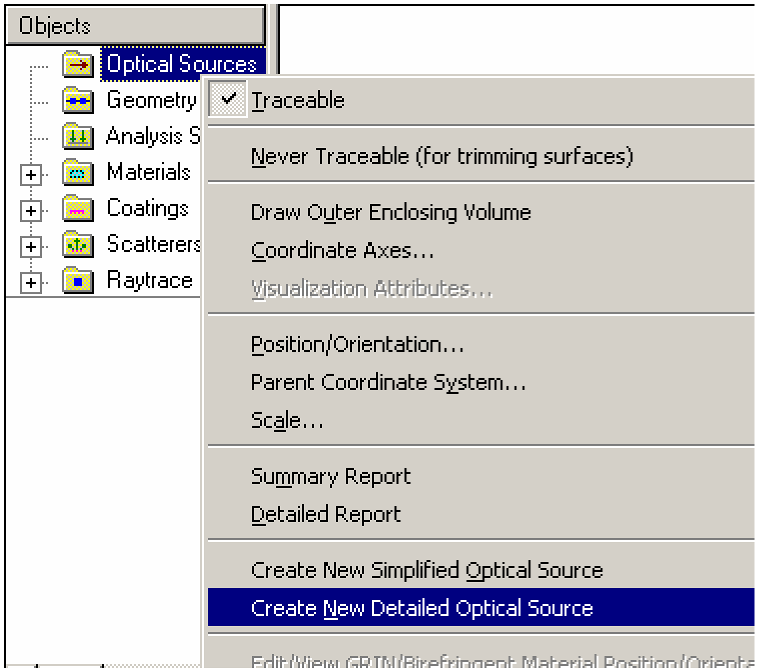
The Reference Coordinate System for the first location and orientation action will default to the Location Parent Coordinate System. For subsequent location and orientation actions, Reference Coordinate System will revert to the Reference Coordinate System on the previous action, i.e. the line above.

Note: The source or object is placed at the origin of the Location Parent Coordinate System. From there, the source or object can be moved using the Location/Orientation dialog or this tab of the Detailed Source Dialog.

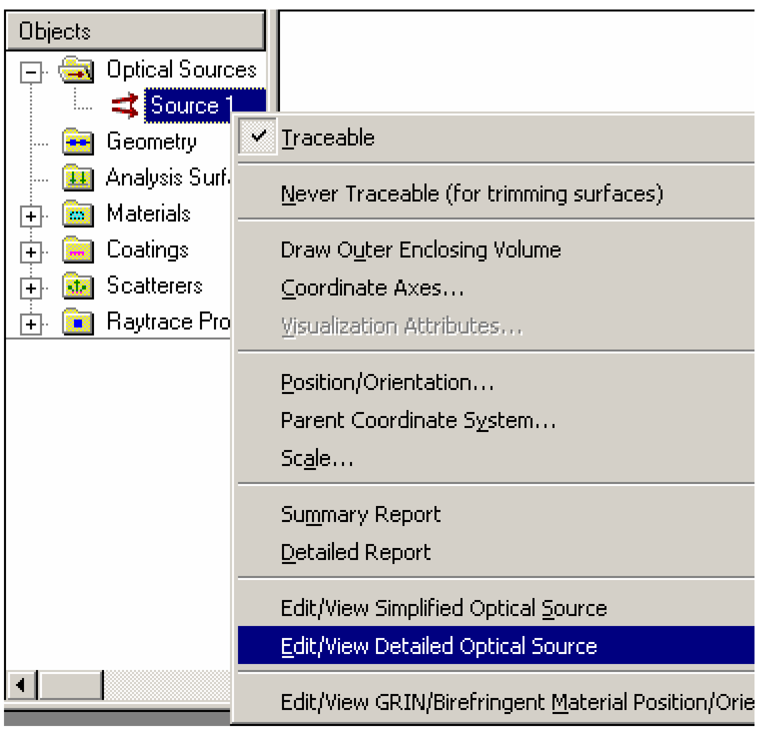
How Do I Get There? - Location / Orientation (Create New and Edit/View Detailed Source…)

There are two different ways to execute this command:

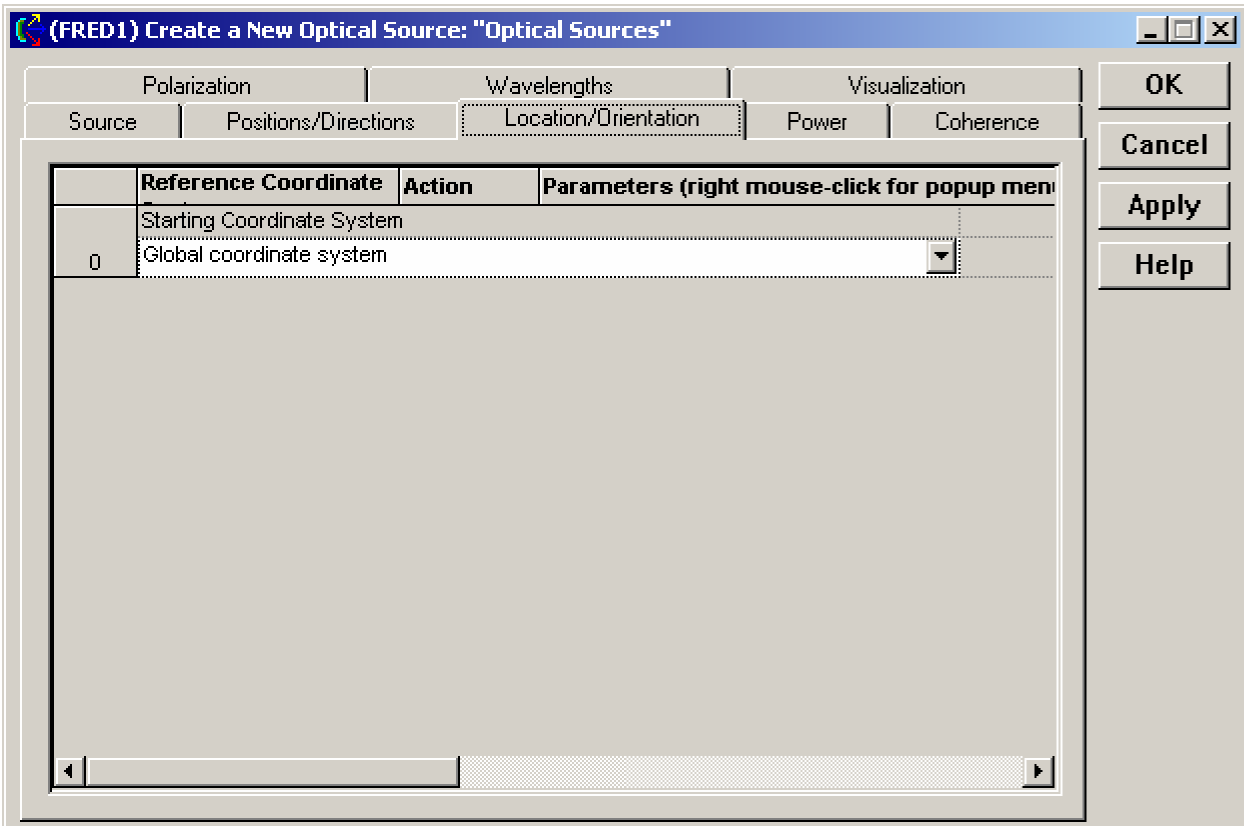
1. Right click on the Optical Sources and select Create New Detailed Optical Source… in the right click pop-up menu,



2. Right click on an Source and select Edit/View Detailed Optical Source… in the right click pop-up menu,



Dialog Box and Controls - Location/Orientation (Create New and Edit/View Detailed Source...)



Control	Inputs	Defaults
Reference Coordinate System	Pull down menu of all the coordinates systems in FRED. The nodes listed in the **Geometry** and **Source** sections of the **Tree View** represent all of the available coordinate systems in the FRED document.	Coordinate system of Parent
Action	Pull down menu listing of all possible location and orientation actions relative to the reference coordinate system.	Shift
Parameters	Spatial coordinates, angles or direction cosines.	0
OK	Accept Location/Orientation changes and close dialog box.	
Cancel	Discard Location/Orientation changes and close dialog box.	
Apply	Apply Location/Orientation changes and keep dialog box open.	

Help	Access this Help page.	

See Also… - Location / Orientation (Create New and Edit/View Detailed Source…)

- Source
- Positions / Directions
- Location / Orientation
- Power
- Coherence
- Polarization
- Wavelength
- Visualization

Create Detailed Source - Polarization

Description - Polarization (Create New and Edit/View Detailed Source…)

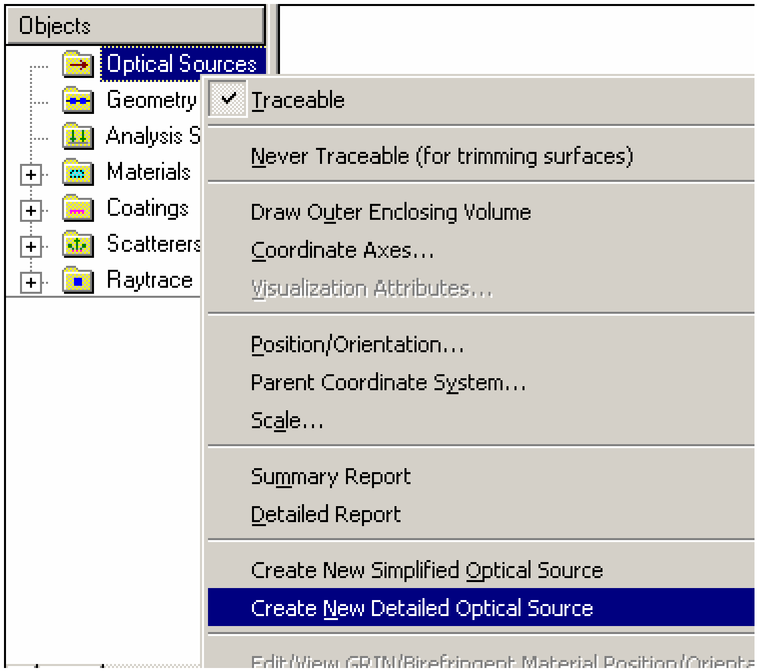
The polarization state of the rays is by default not tracked or stored for the rays. The rays can be polarized by selecting the Polarized option on the Polarization page of the Create New and Edit Detailed Optical Source… dialogs. In addition, if unpolarized rays hit a polarizer coating then they are changed from unpolarized rays to polarized rays.

The Polarization page has three sections for defining the polarization state Ellipticity, handedness, and the angle of the polarization ellipse relative to the local X axis.

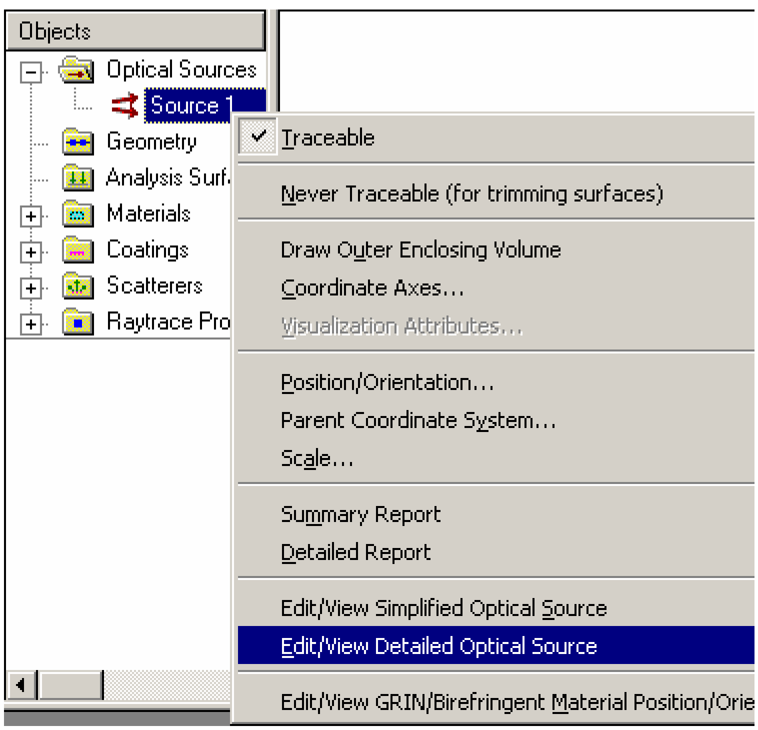
How Do I Get There? - Polarization (Create New and Edit/View Detailed Source…)

There are two ways to execute this command:

1. Right click on the Optical Sources and select Create New Detailed Optical Source… in the right click pop-up menu,

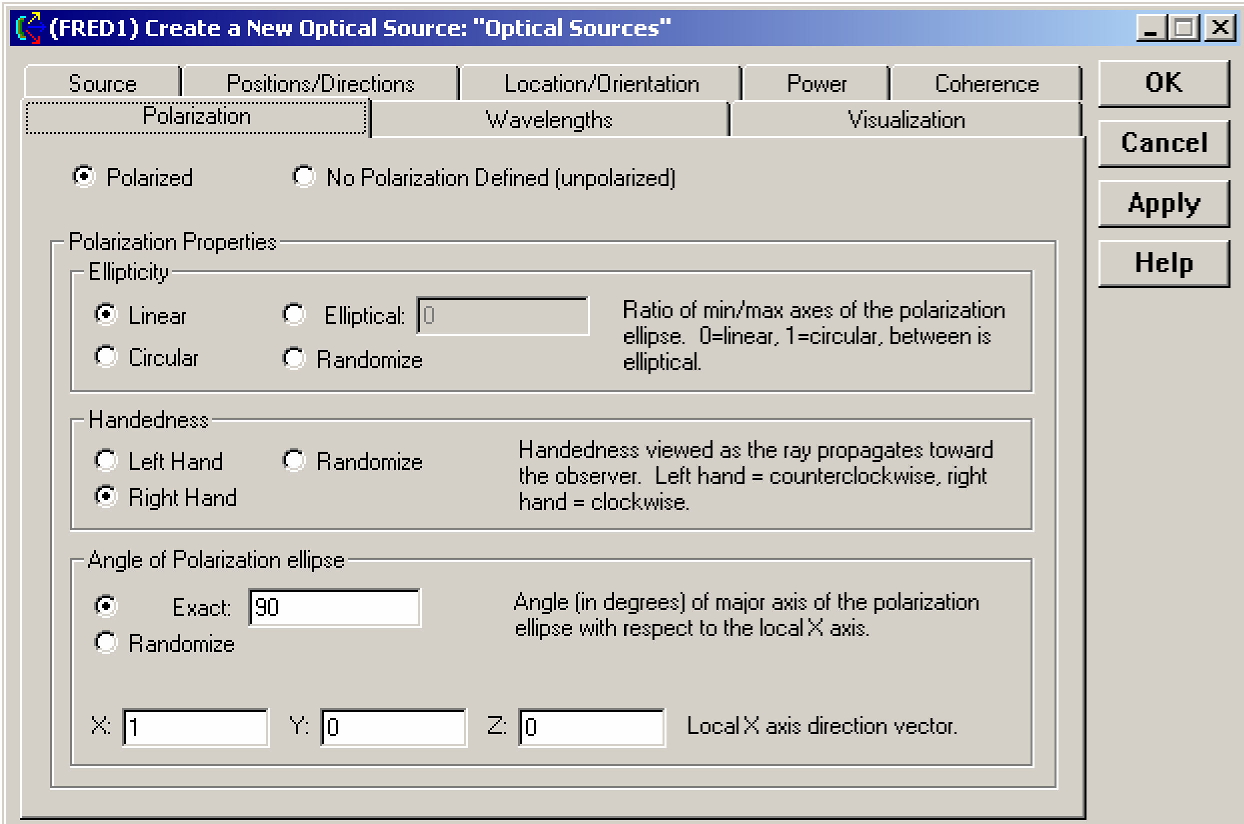


2. Right click on an Source and select Edit/View Detailed Optical Source… in the right click pop-up menu



Once the dialog appears, click on the Polarization tab.

Dialog Box and Controls - Polarization (Create New and Edit/View Detailed Source...)



Control	*Inputs*	*Defaults*
Polarized / No Polarization Defined	If the Polarized option is selected, then polarization state information of the rays is maintained and stored for each ray.	No Polarization Defined
	Polarization Properties	
Ellipticity	Sets Ellipticity of the polarization state. Linear and circular can be selected directly or an arbitrary ellipticity (0<*e*<1) may be entered. There is also the option to randomize the ellipticity.	Linear
Handedness	Sets the handedness of the polarization state. Options are right handed, left handed, or randomly chosen handedness.	Right Hand
	Angle of Polarization Ellipse	
Angle of major axis	The angle of the polarization ellipse relative to the local X axis.	Exact 90

X, Y, Z	The direction cosine vector of the local X axis used for the angle of the polarization ellipse. Note that this does NOT change the local X axis of the source itself.	1, 0, 0
OK	Create a new Optical Source and close dialog box.	
Cancel	Discard Polarization changes and close dialog box.	
Apply	Apply Polarization changes and keep dialog box open.	
Help	Access this Help page.	

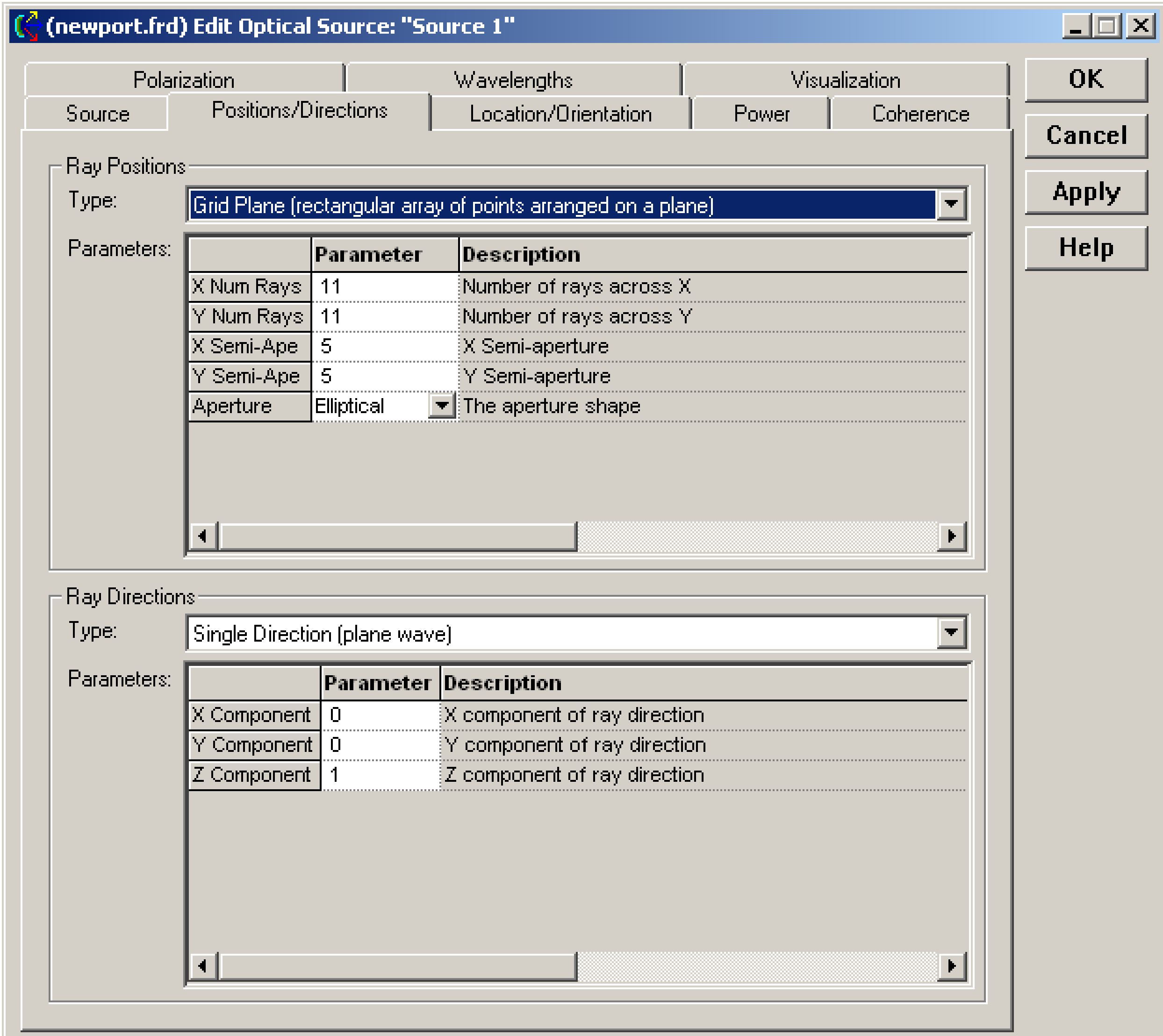
Create Detailed Source - Positions/Directions

Description - Positions/Directions (Create New and Edit/View Detailed Source...)

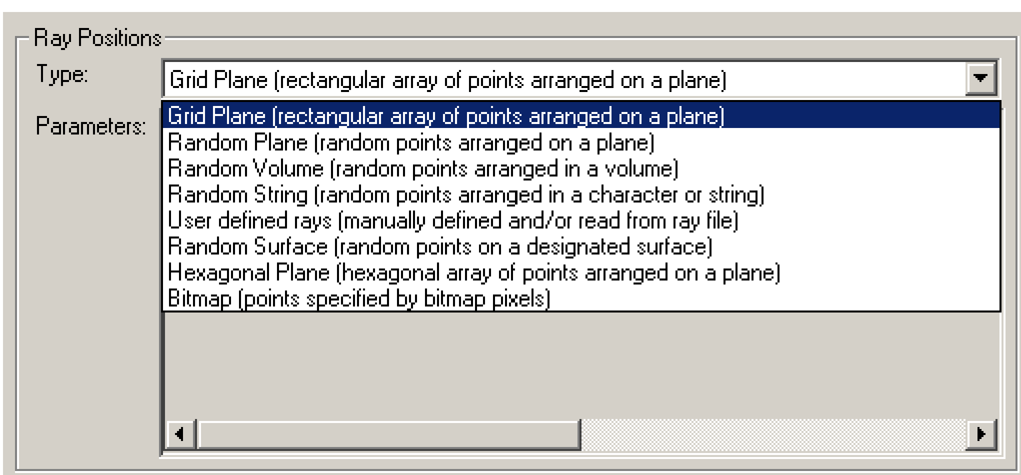
The first step to defining rays is to establish the starting positions and directions of the rays. Not surprisingly, this task is done on the Positions / Directions page of the Create New and Edit/View Detailed Source… dialogs. The Positions / Directions page has been split into these two related but separate operations:

- Positions of the rays in the Source
- Directions of the rays in the Source

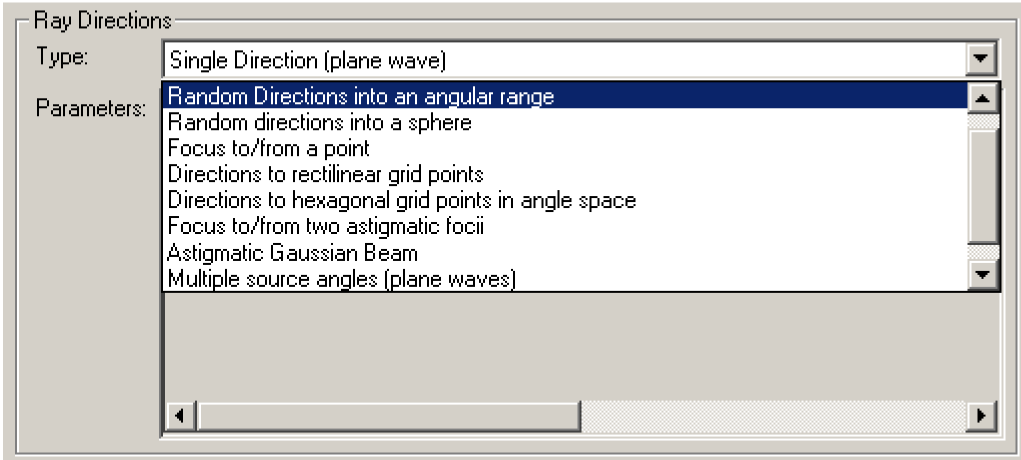
There are different options available in pull down menus for how to define the rays starting positions and directions.



There are different options available in a pull down menu for how the ray Positions are defined.



And there are different options available in a pull down menu for how the ray **Directions** are defined.

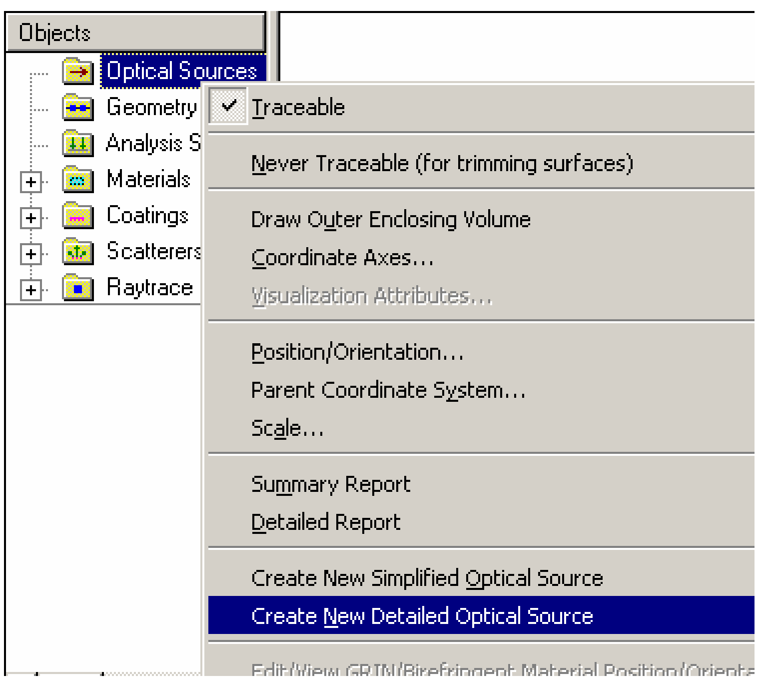


For the most part, the ray positions are independent of the ray directions. But there are some cases where ray directions are set by actions in the ray positions section alone. For example, in the case of user defined rays, the ray positions and directions are defined at the same time in the ray positions section.

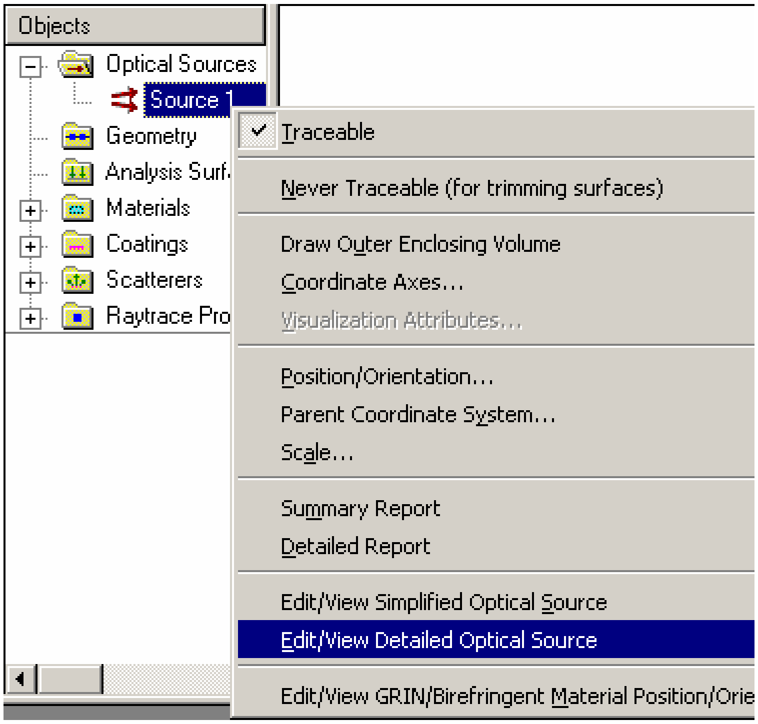
How Do I Get There? - Positions/Directions (Create New and Edit/View Detailed Source…)

There are two different ways to execute this command:

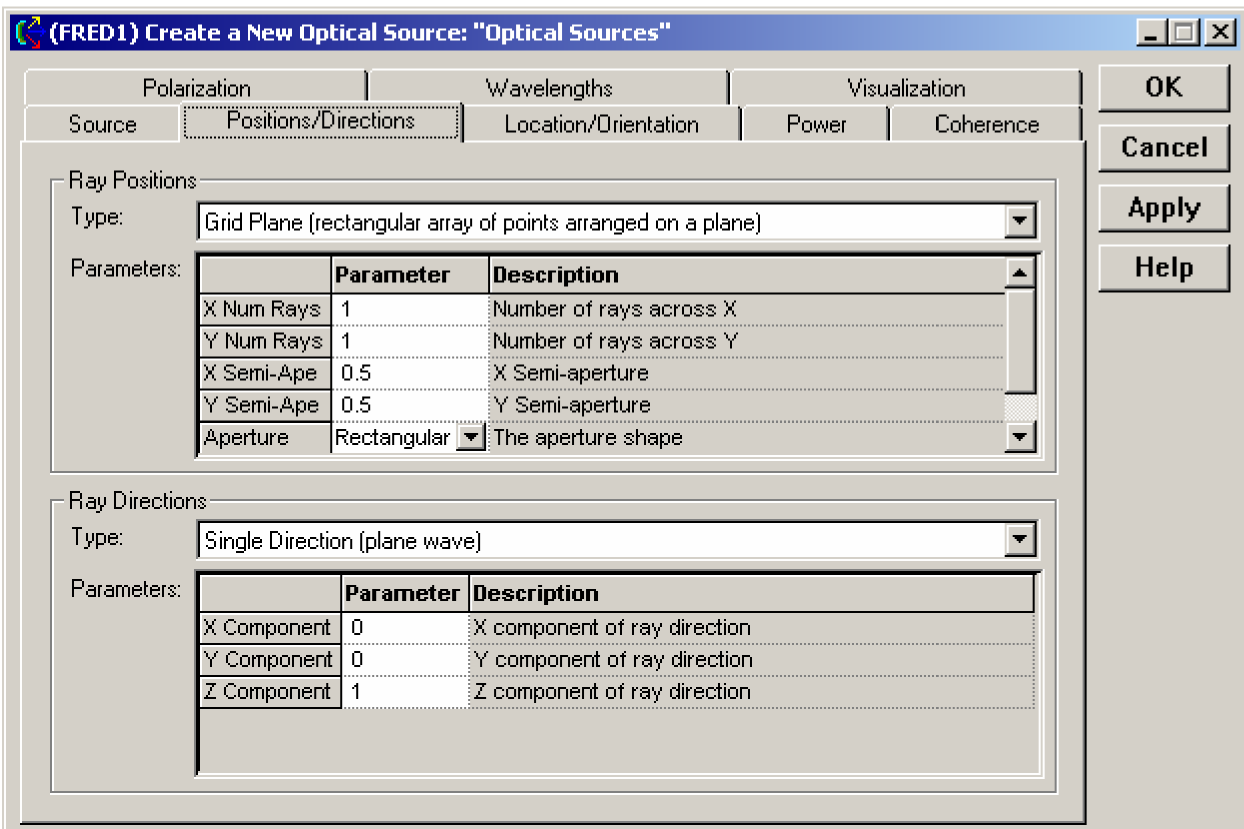
1. Right click on the Optical Sources and select Create New Detailed Optical Source… in the right click pop-up menu,



2. Right click on an Source and select Edit/View Detailed Optical Source… in the right click pop-up menu,


Objects
Optical Sources
Source 1
Geometry
Analysis Surf
Materials
Coatings
Scatterers
Raytrace Pro
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes…
Visualization Attributes…
Position/Orientation…
Parent Coordinate System…
Scale…
Summary Report
Detailed Report
Edit/View Simplified Optical Source
Edit/View Detailed Optical Source
Edit/View GRIN/Birefringent Material Position/Orie

Dialog Box and Controls - Positions/Directions (Create New and Edit/View Detailed Source…)



There are six different ways to define the positions of the rays:

- Grid Plane (rectangular array of points arranged on a plane)
- Random Plane (random points arranged in a plane)
- Random Volume (random points arranged in a volume)
- Random String (random points arranged in a character or string)
- User defined rays
- Random Surface (random points on the designated surface)

There are seven different ways to define the directions of the rays:

- Single Direction (plane wave)
- Random directions into an angular range
- Random directions into a sphere
- Focus to/from a point
- Directions to rectilinear grid points
- Directions to hexagonal gird points in angle space
- Focus to/from two astigmatic foci

The different ray position and direction options are discussed separately. Click on the option for help on that option.

See Also… - Positions/Directions (Create New and Edit/View Detailed Source…)

- Source
- Positions / Directions
- Location / Orientation
- Power
- Coherence
- Polarization
- Wavelength
- Visualization

Create Detailed Source – Position/Directions - Bitmap

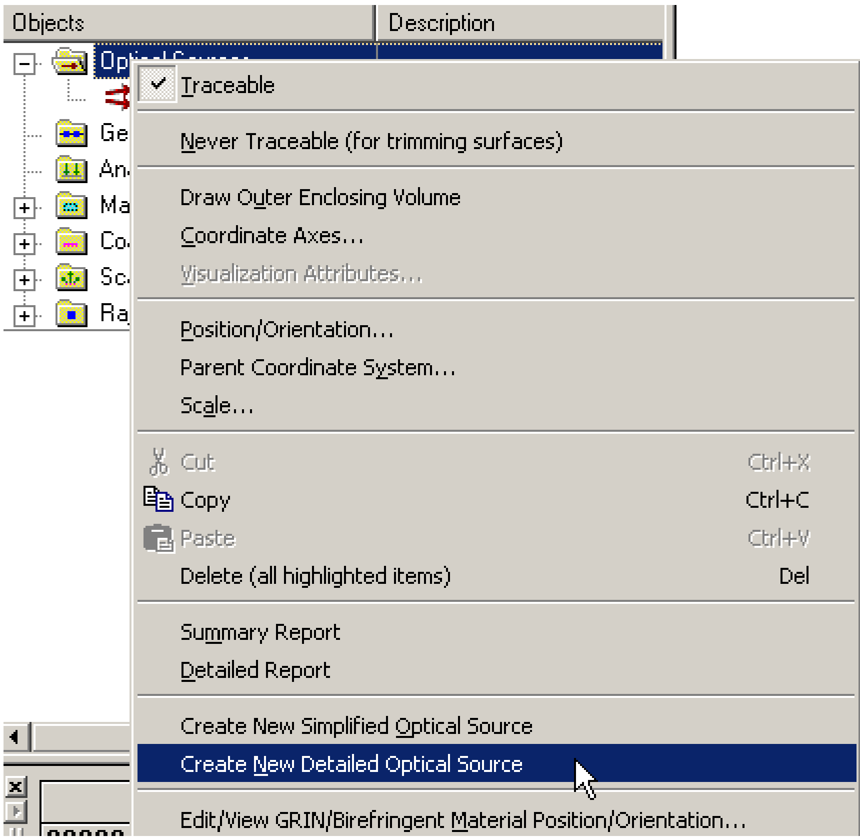
Description
Bitmap

Create a source from a color bitmap graphic. The spectral content of this source is synthesized from pixel RGB values using discrete wavelengths selected by the user. The Ray Direction type determines the angular distribution. The source shown below was synthesized with 10 wavelengths spanning the visible.

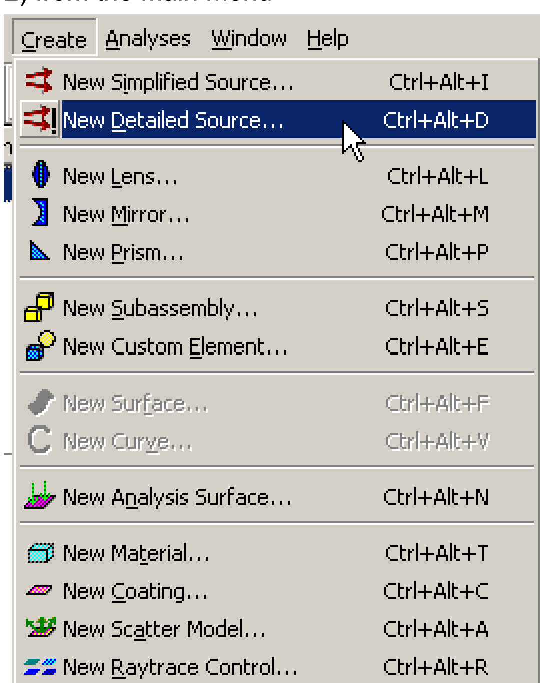
How Do I Get There?
Bitmap

There are three ways to create a Detailed Bitmap source:

1. from the Sources Tree folder drop-down:



2) from the Main menu



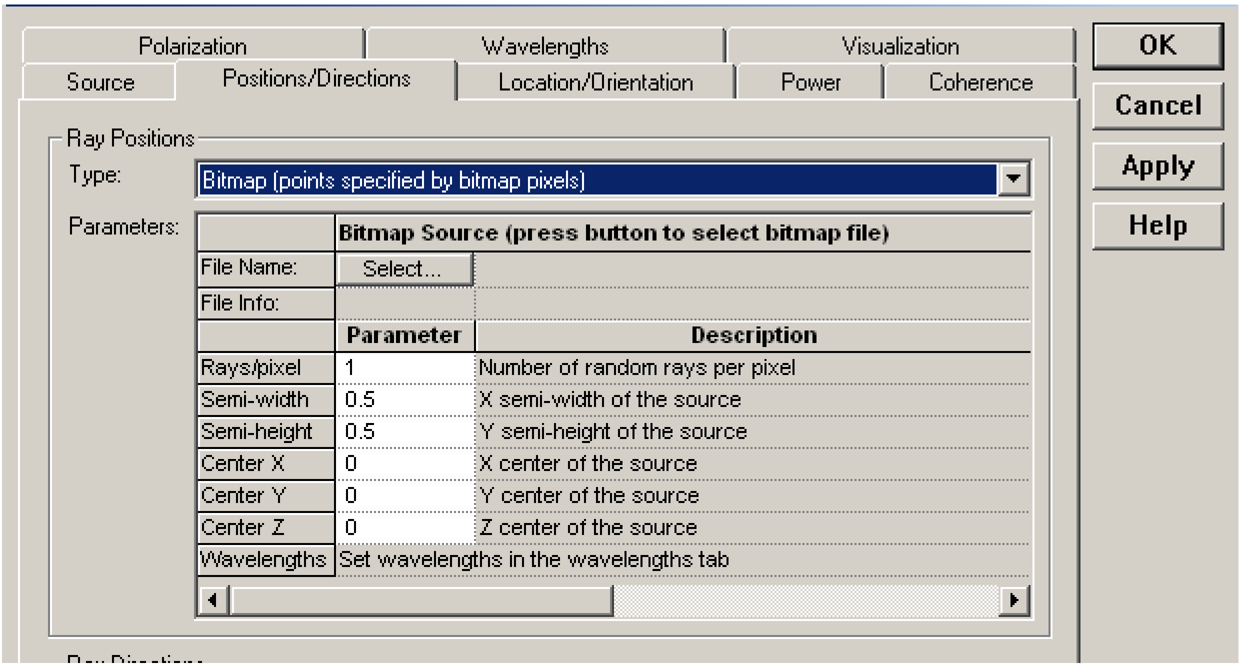
or

3) Key Accelerator Key combination Ctrl+Alt+D.

Dialog Box and Controls

Bitmap

Select Bitmap from the Ray Position dialog on the Position/Direction Tab:



Control	*Inputs / Description*	*Defaults*
	Type - Bitmap	
File Name	Name of bitmap file: (*.bmp or *.jpg)	blank
	Parameters	
Rays/pixel	Number of rays per pixel (per wavelength)	1
Semi-width/height	Set the source size here.	0.5, 0.5
Center X Y Z	Set where the center of the source is positioned.	0,0,0
OK	Accept changes and close dialog box.	
Cancel	Discard changes and close dialog box.	
Apply	Apply changes and keep dialog box open.	
Help	Access this Help page.	

- The Ray Direction dialog determines the angular distribution of this source.

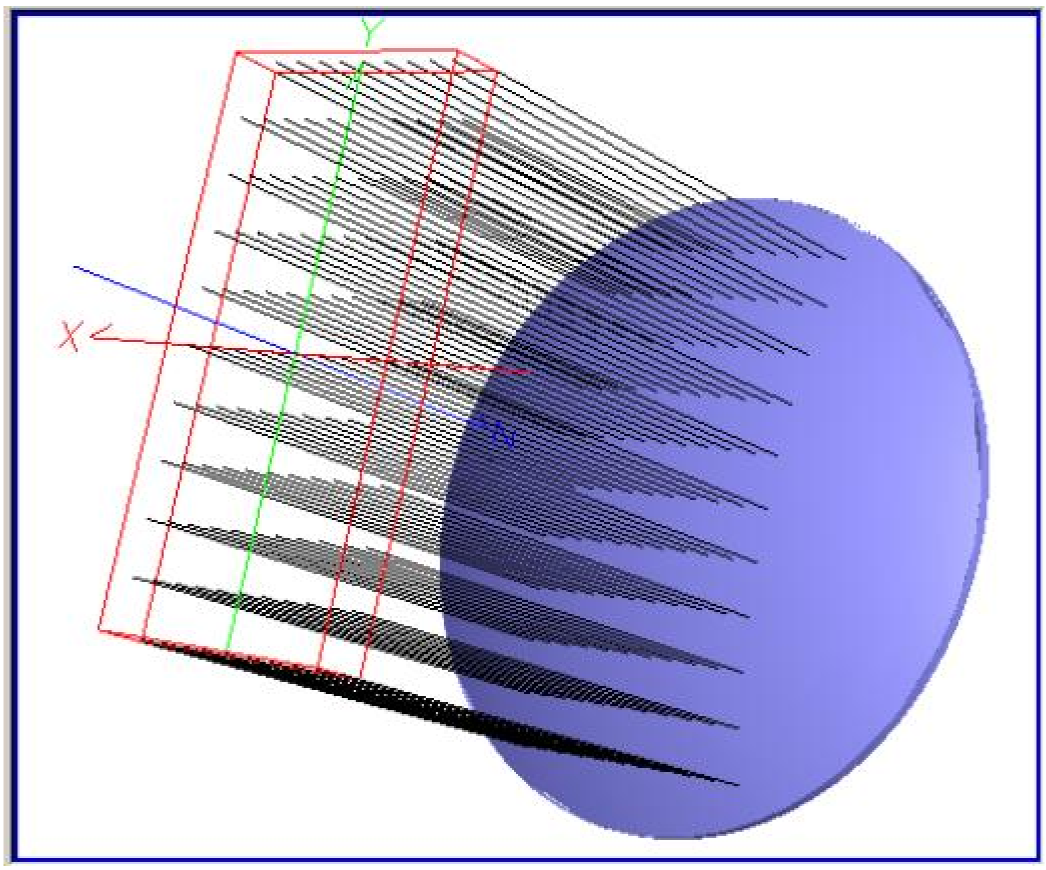
- The RGB value of each pixel is synthesized from entries on the Wavelength Tab. A ray is created for each wavelength entry.

Create Detailed Source – Position/Directions - Grid Plane

Description

Grid Plane (Create New and Edit/View Detailed Source…)

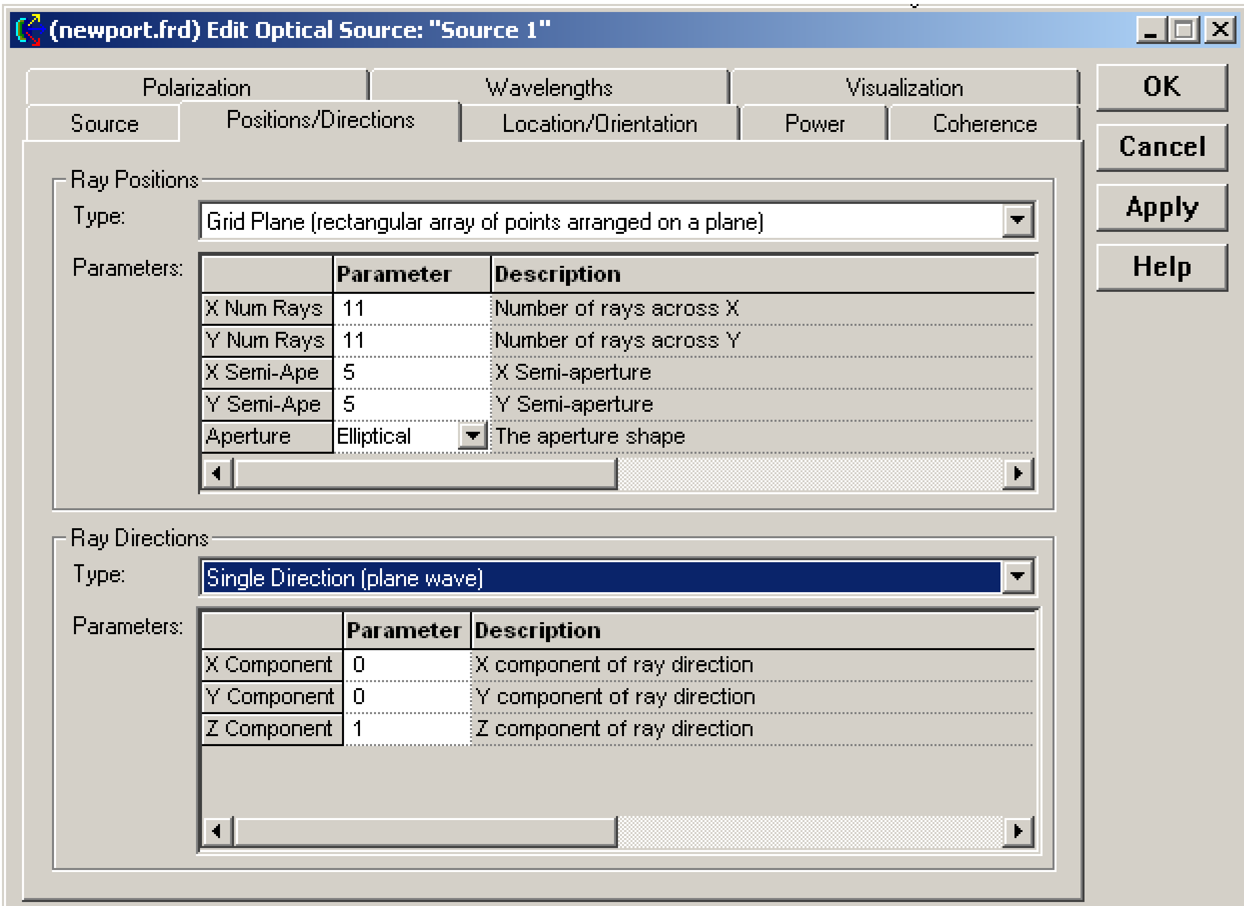
The Grid Plane option defines a rectilinear grid of ray positions.



How Do I Get There?

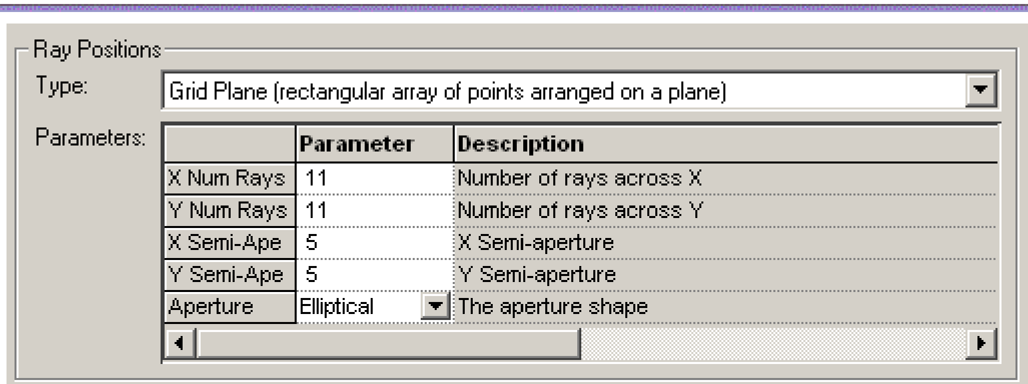
Grid Plane (Create New and Edit/View Detailed Source…)

This is an option in the Positions / Directions page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Grid Plane (Create New and Edit/View Detailed Source…)

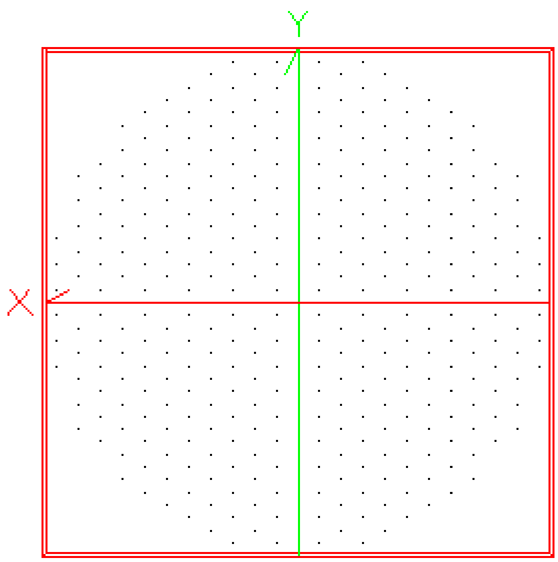


Control	Description	Defaults
Ray Positions		
Type	Pull down menu for selecting the method for defining the ray positions. Choose **Grid Plane**.	Grid plane
Parameters		
X Num Rays	Number of rays across ray bundle in the X direction.	1
Y Num Rays	Number of rays across ray bundle in the Y direction.	1
X Semi-Ape	Ray bundle semi-diameter in the X direction.	0.5
Y Semi-Ape	Ray bundle semi-diameter in the Y direction.	0.5
Aperture	Pull down menu with the available ray bundle parameter shapes.	Rectangular
OK	Create new source and close dialog box.	
Cancel	Discard new source and close dialog box.	
Apply	Apply source changes and close dialog box.	
Help	Access this Help page.	

Create Detailed Source – Position/Directions - Hexagonal Plane

Description
Hexagonal Plane

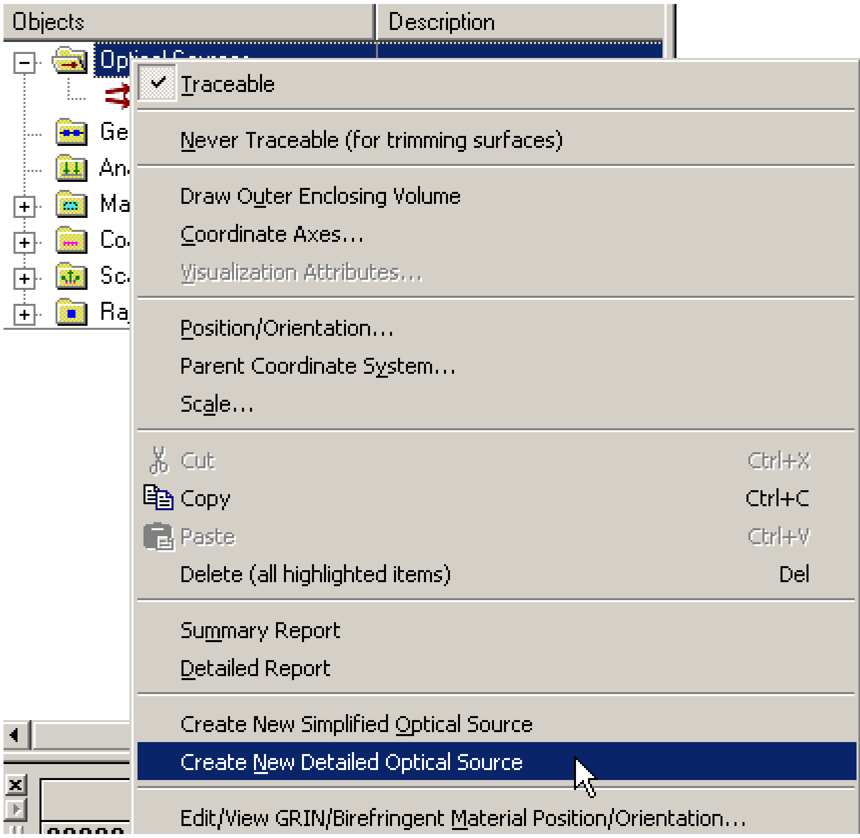
Creates a grid of rays set in a hexagonal pattern. The user sets the ray unit cell size.



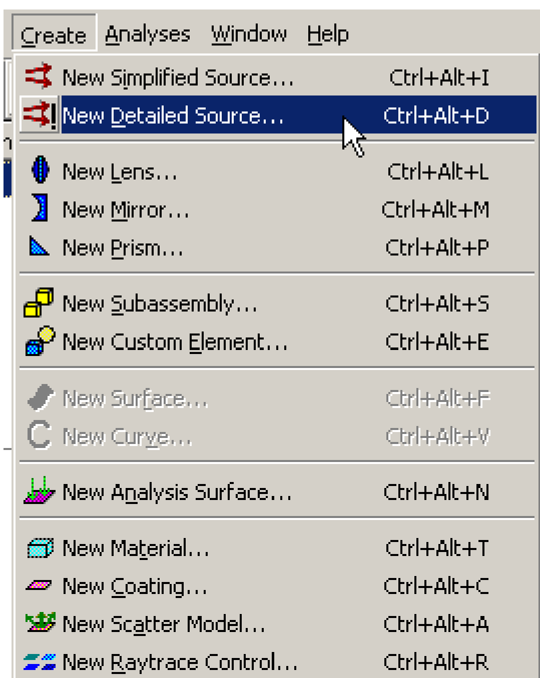
How Do I Get There?
Hexagonal Plane

There are three different ways to execute this command:

1. from the Main Menu:



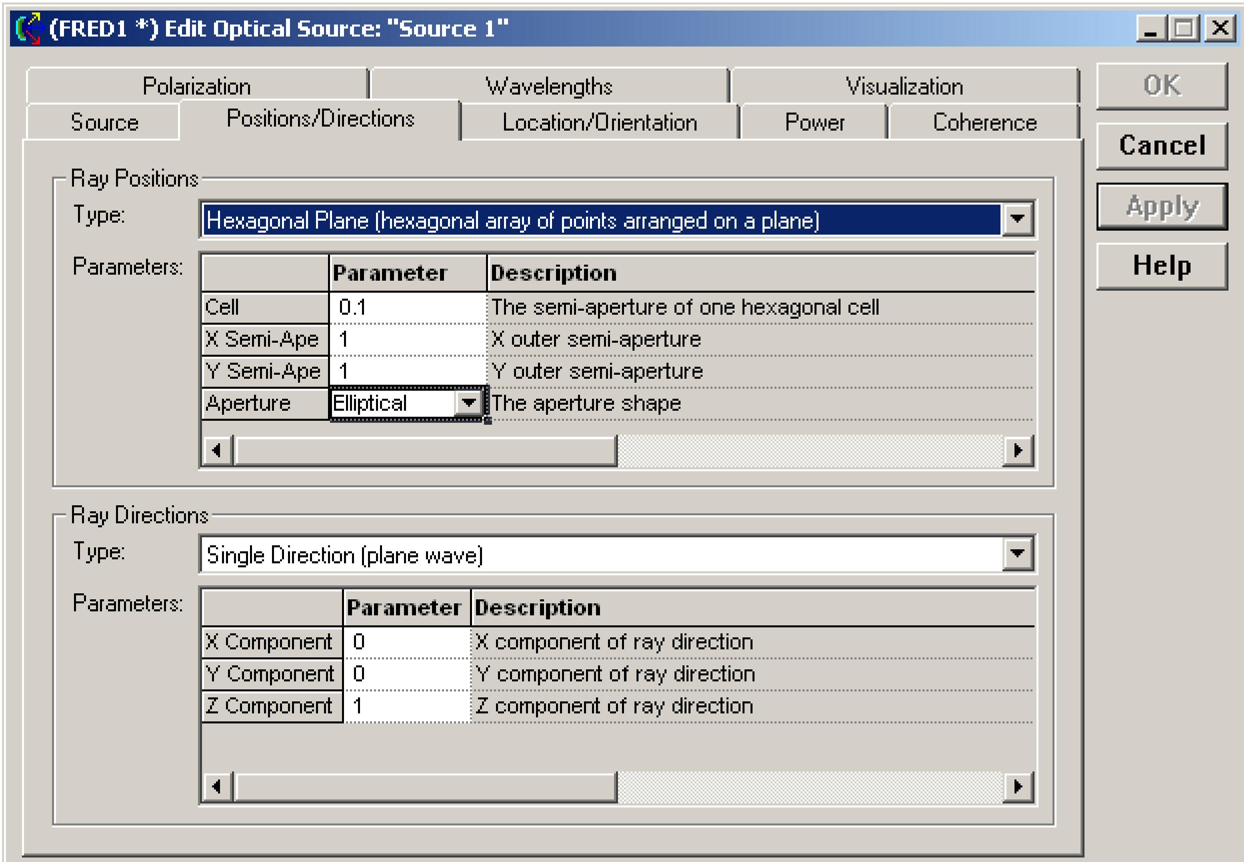
2. from the Source folder



3. from the Accelerator key Ctrl+Alt+d

Dialog Box and Controls

Hexagonal Plane



Control	***Inputs / Description***	***Defaults***
Type	Hexagonal Plane	Grid Plane
Cell	Hexagonal cell size. One ray per cell.	0.1
XY Semi-Ape	Semi-aperture of grid.	1,1
Aperture	Aperture shape (Elliptical/Rectangular)	Elliptical
OK	Accept changes and close dialog box.	
Cancel	Discard changes and close dialog box.	
Apply	Apply changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes

Hexagonal Plane

- Number of rays is determined by the cell size and aperture.

See Also….

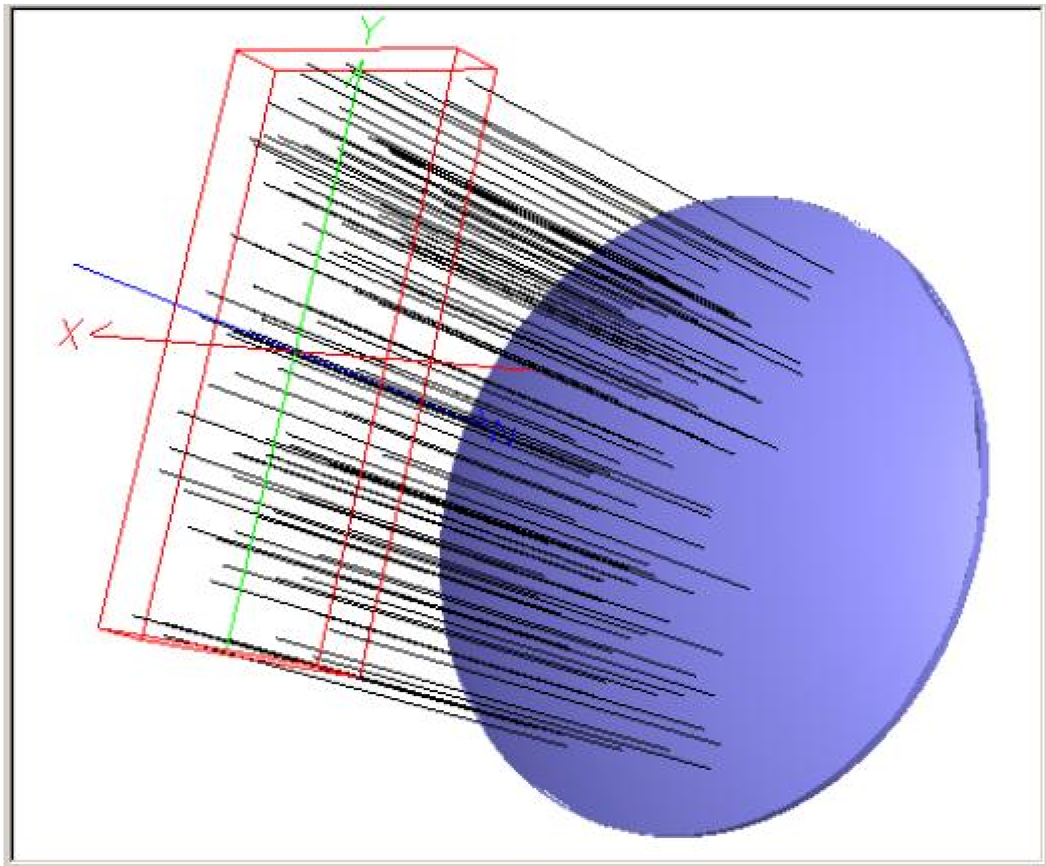
Hexagonal Plane

Create Detailed Source – Position/Directions - Random Plane

Description

Random Plane (Create New and Edit/View Detailed Source…)

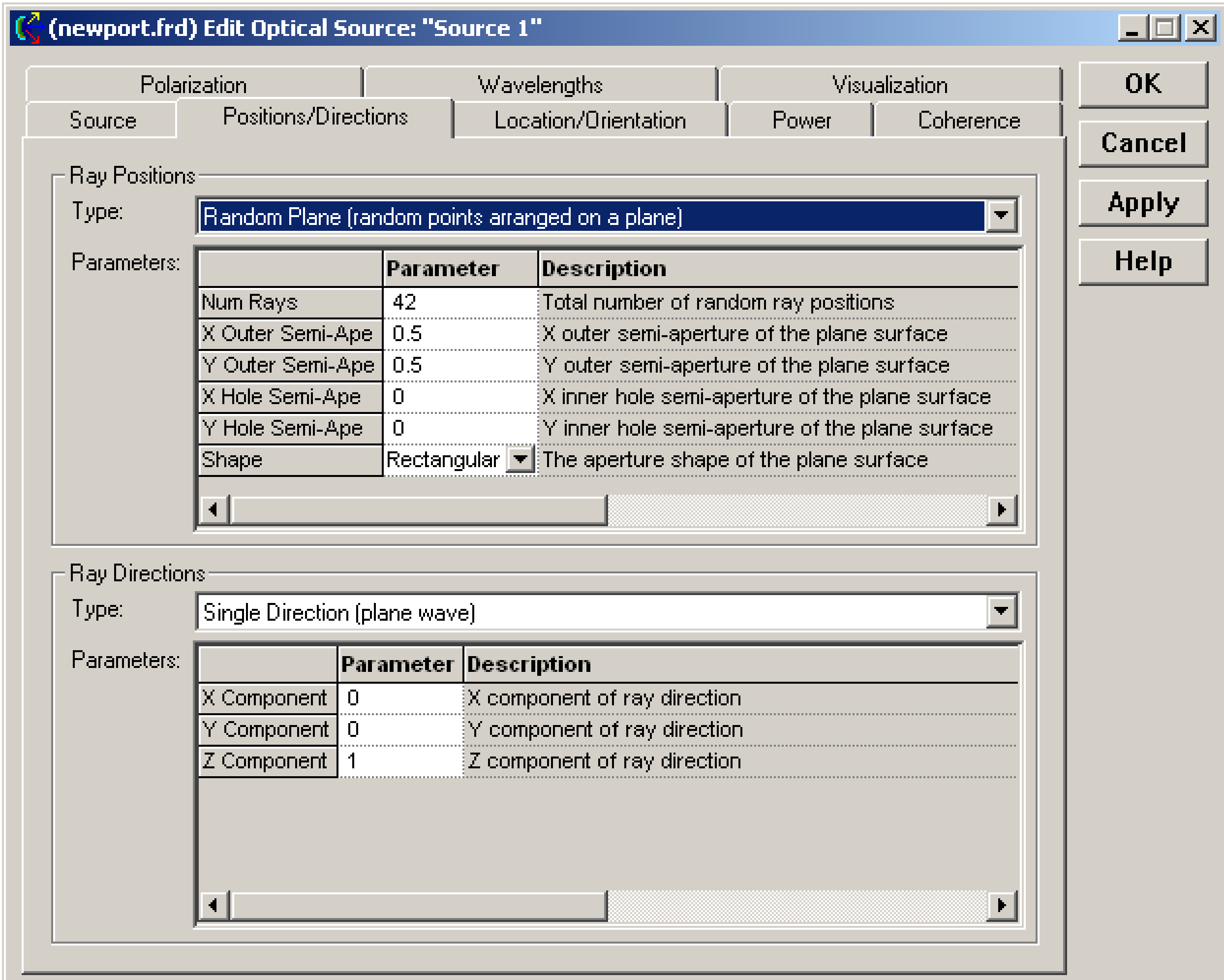
The Random Plane option defines random grid of ray positions in a plane.



How Do I Get There?

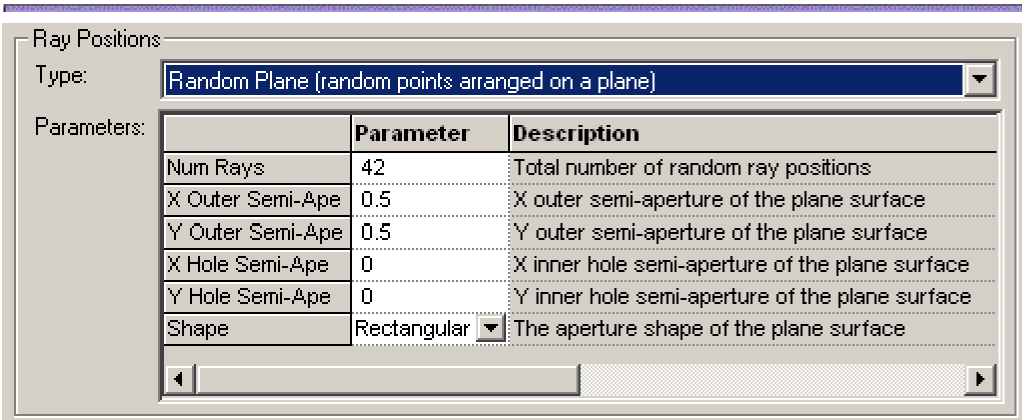
Random Plane (Create New and Edit/View Detailed Source…)

This is an option in the Positions / Directions page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Random Plane (Create New and Edit/View Detailed Source…)



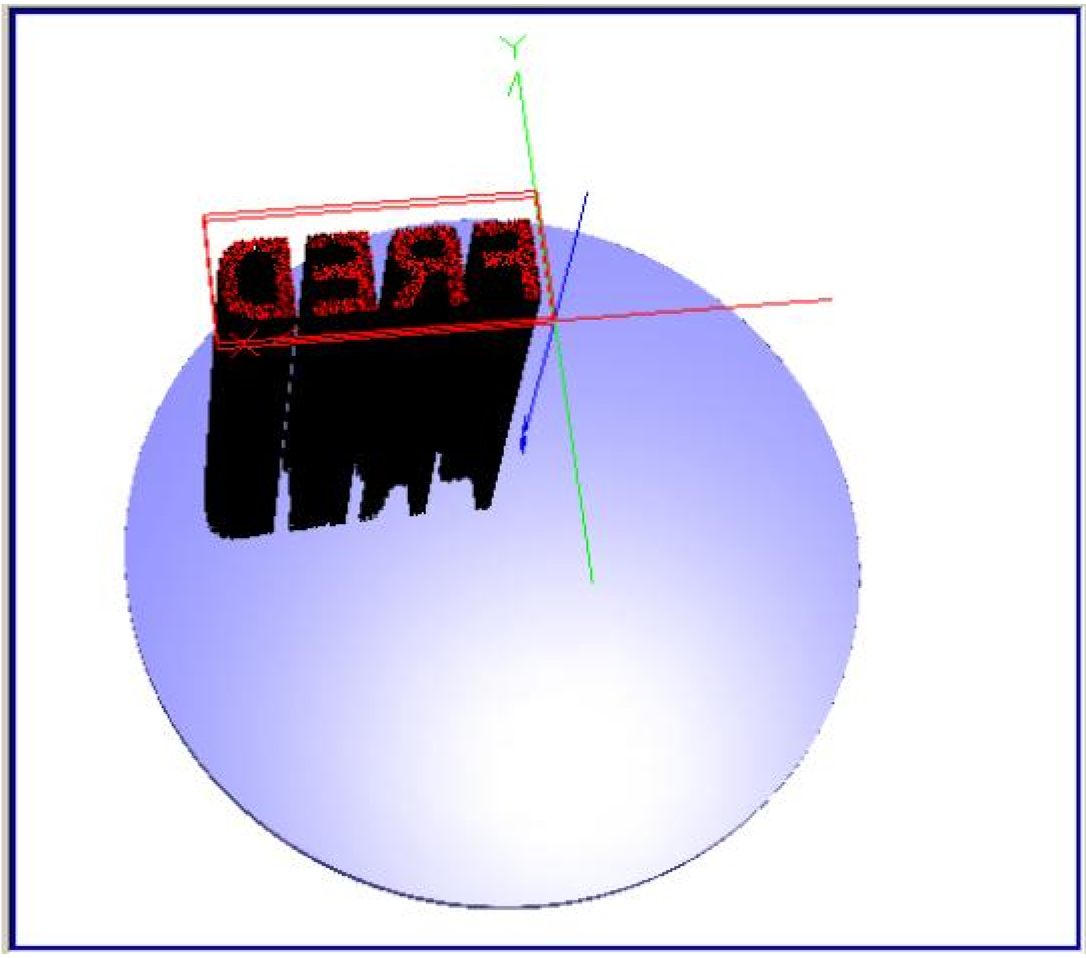
Control	Description	Defaults
Ray Positions		
Type	Pull down menu for selecting the method for defining the ray positions.	Grid plane
Parameters		
Num Rays	The number of rays randomly distributed across the ray bundle in the X and Y directions.	42
X Outer Semi-Ape	Ray bundle semi-diameter in the X direction.	0.5
Y Outer Semi-Ape	Ray bundle semi-diameter in the Y direction.	0.5
X Hole Semi-Ape	Ray bundle hole semi-diameter in the X direction.	0
Y Hole Semi-Ape	Ray bundle hole semi-diameter in the Y direction.	0
Aperture	This is a pull down menu with the available ray bundle parameter shapes.	Rectangular
OK	Create new source and close dialog box.	
Cancel	Discard new source and close dialog box.	
Apply	Apply source changes and close dialog box.	
Help	Access this Help page.	

Create Detailed Source – Position/Directions - Random String

Description

Random String (Create New and Edit/View Detailed Source…)

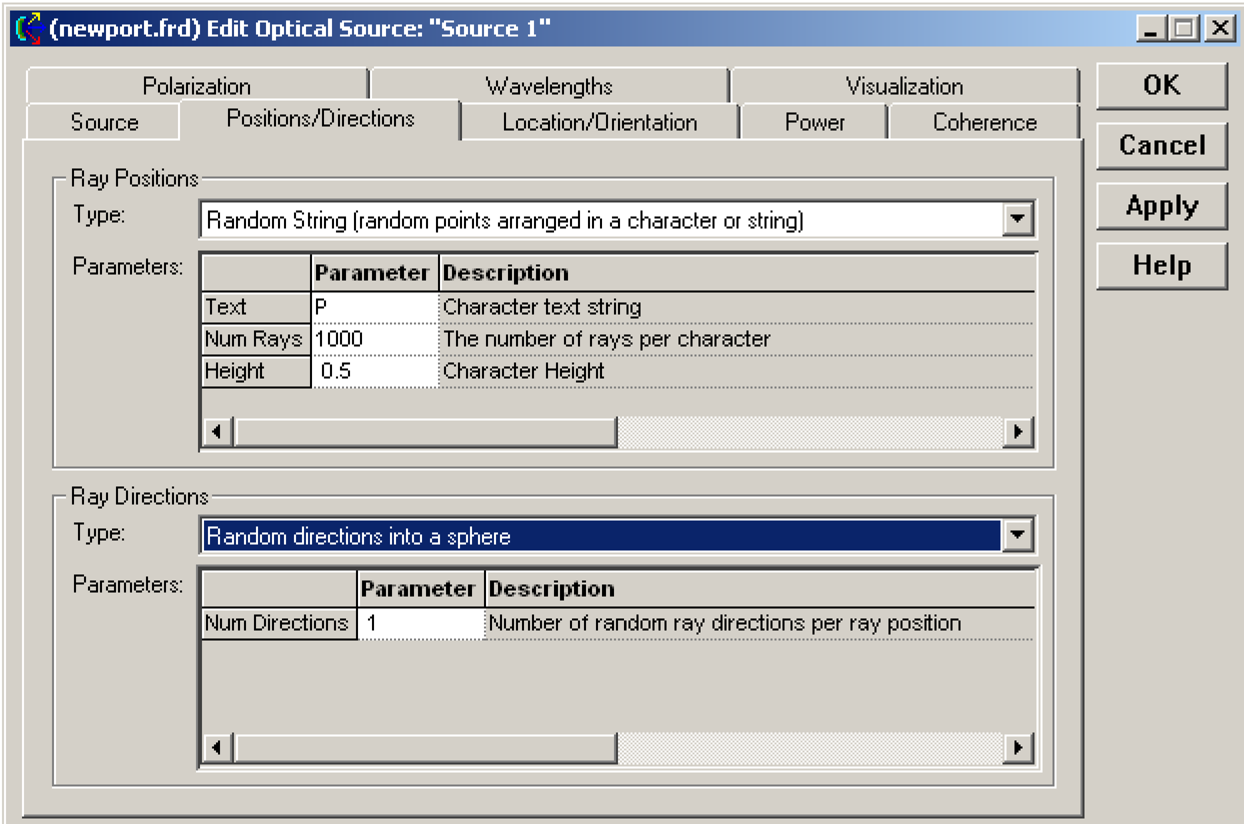
The Random String option defines random Ray Positions in a plane in the shape of the user input character string. In the example below, the Single Direction option was selected for the Ray Directions.



How Do I Get There?

Random String (Create New and Edit/View Detailed Source…)

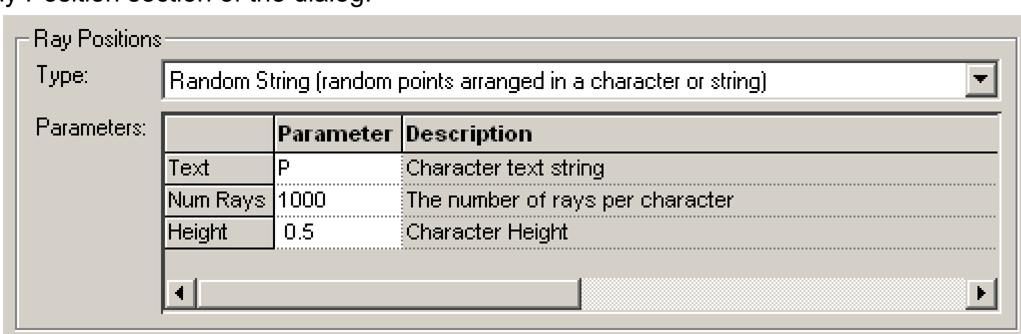
This is an option in the Positions / Directions page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Random String (Create New and Edit/View Detailed Source…)

The Ray Position section of the dialog:



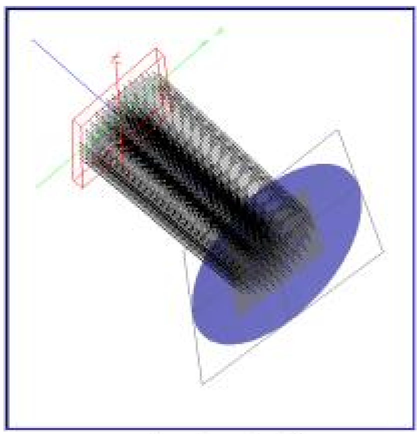
Control	Description	Defaults
Ray Positions		
Type	Pull down menu for selecting the method for defining the ray positions. Choose **Random String**.	Grid plane
Parameters		
Text	Text string used to define the position of the rays.	P
Num Rays	Number of rays randomly distributed per character.	1000
Height	Height of the characters in the string.	0.5
OK	Create new source and close dialog box.	
Cancel	Discard new source and close dialog box.	
Apply	Apply source changes and close dialog box.	
Help	Access this Help page.	

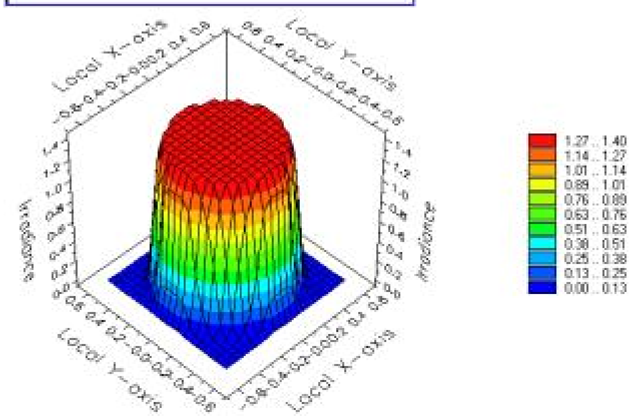
Create Detailed Source – Position/Directions - Uniform Position Apodization

Description

Uniform Position Apodization (Create New and Edit/View Detailed Source…)

The Uniform Position Apodization option scales all the rays in the source to have a uniform, equal power as a function of ray positions. This is equivalent to having no position apodization.

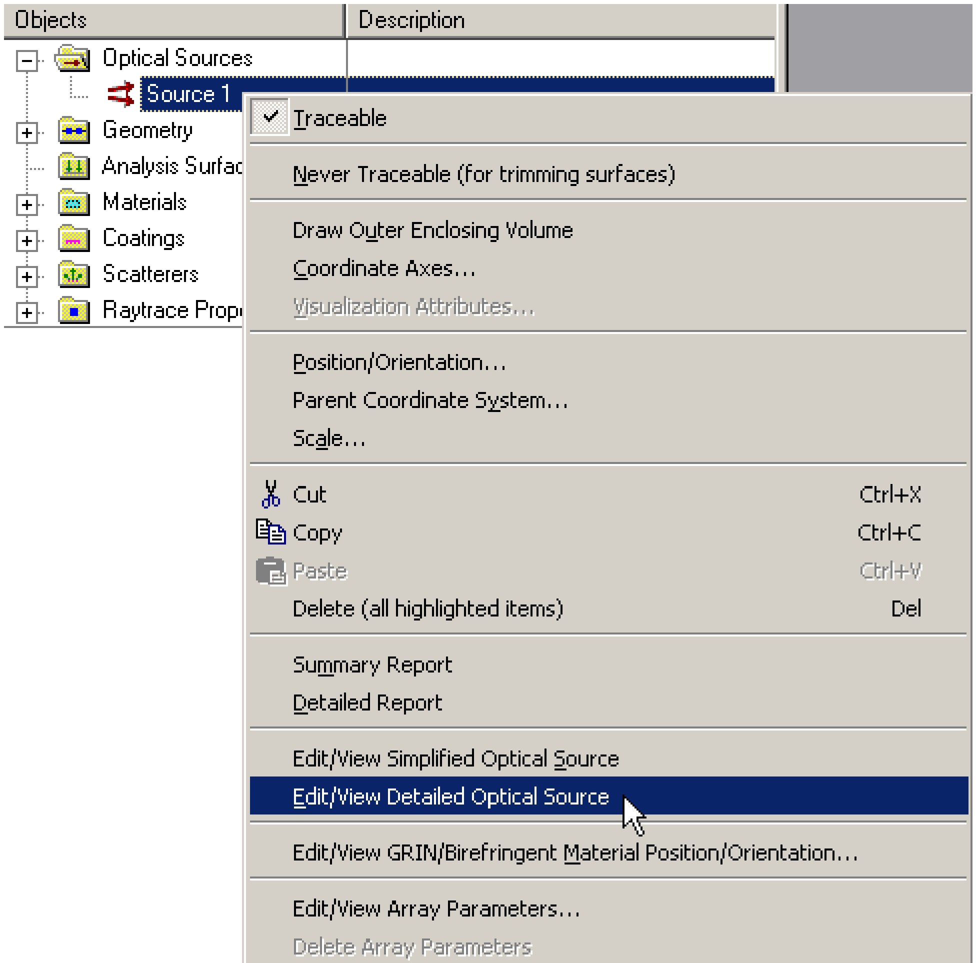




How Do I Get There?

Uniform Position Apodization (Create New and Edit/View Detailed Source…)

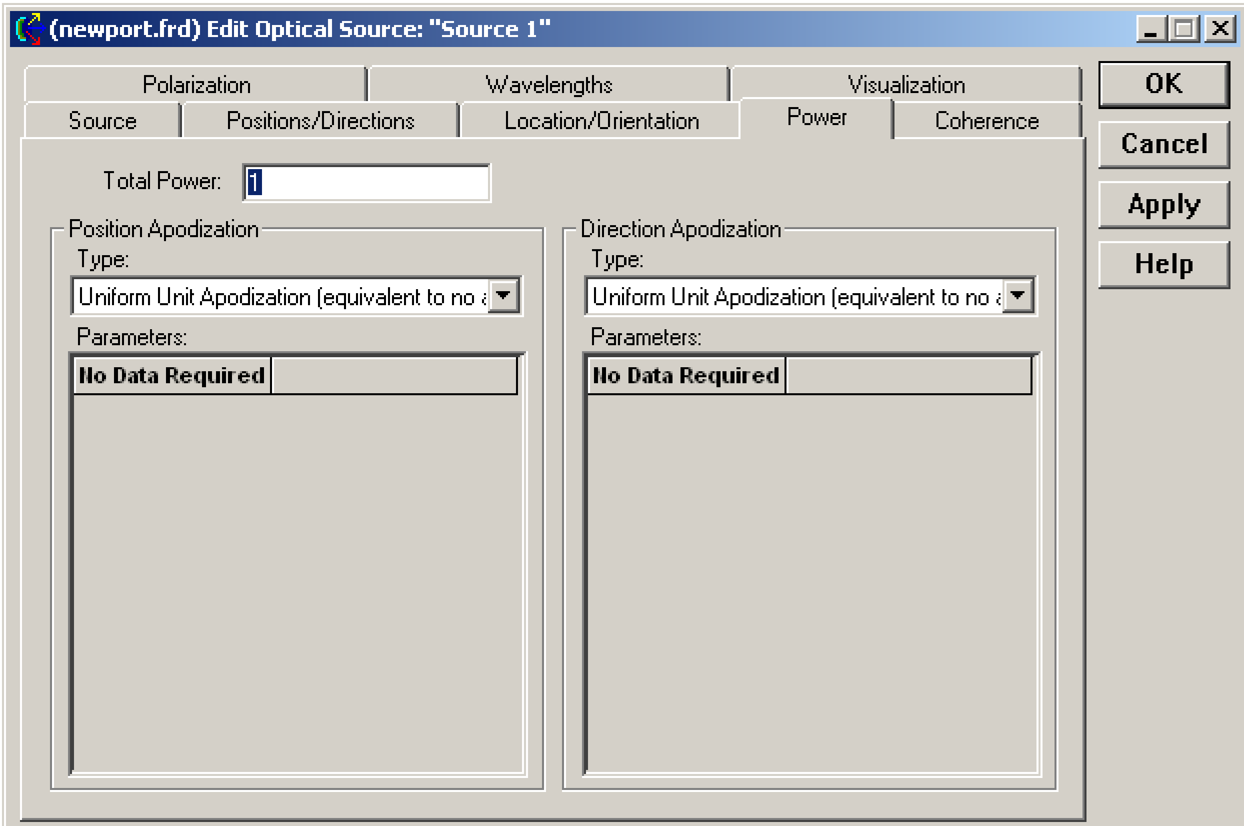
This is an option in the Power page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Uniform Position Apodization (Create New and Edit/View Detailed Source…)

The Position Apodization section of the dialog:



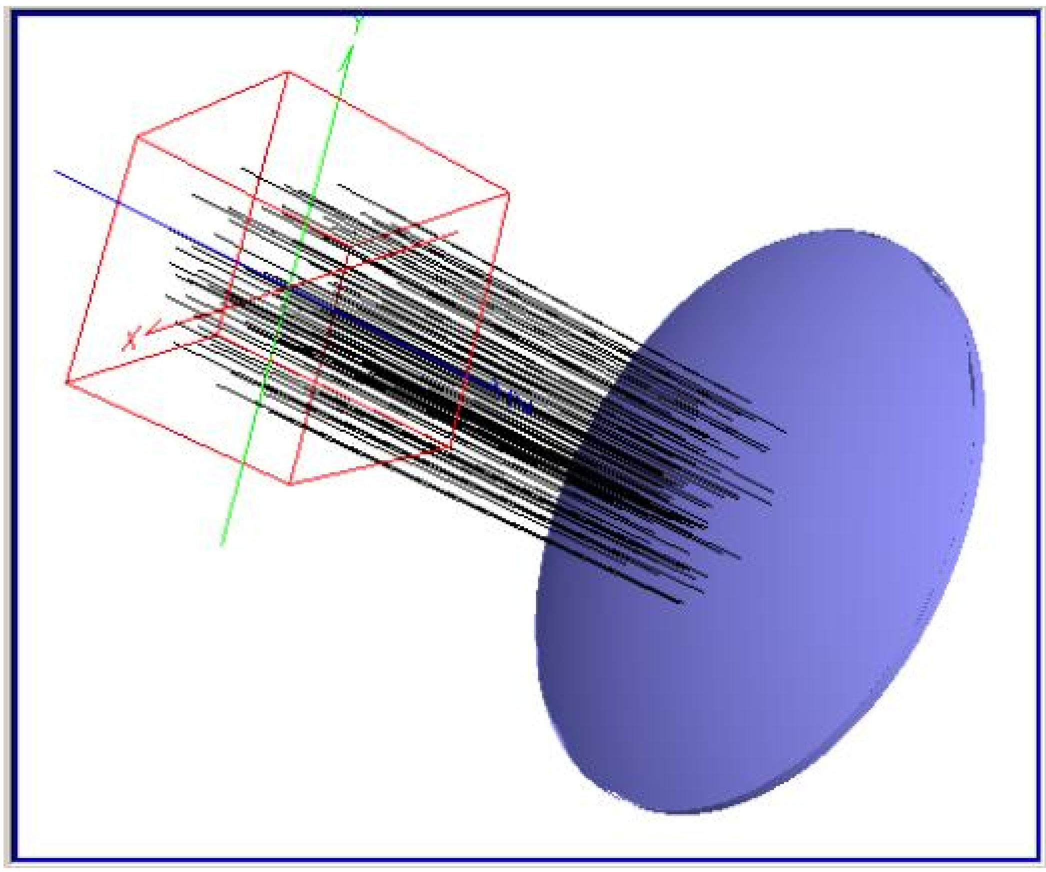
Control	*Inputs*	*Defaults*
Total Power:	Total power of the source ***after*** both the position and direction apodization functions have been applied to the rays.	1
Position Apodization		
Type:	Pull down menu of available position apodization options.	Uniform
Parameters:	There are no parameters for this option.	
Direction Apodization		
Type:	Pull down menu of available direction apodization options.	Uniform
Parameters:	There are no parameters for this option.	
OK	Create new source and close dialog box.	
Cancel	Discard new source and close dialog box.	
Apply	Apply source changes and close dialog box.	
Help	Access this Help page.	

Create Detailed Source – Position/Directions - Random Volume

[Description](#description)
[How Do I Get There?](#how-do-i-get-there)
[Dialog box and Controls](#dialog-box-and-controls)

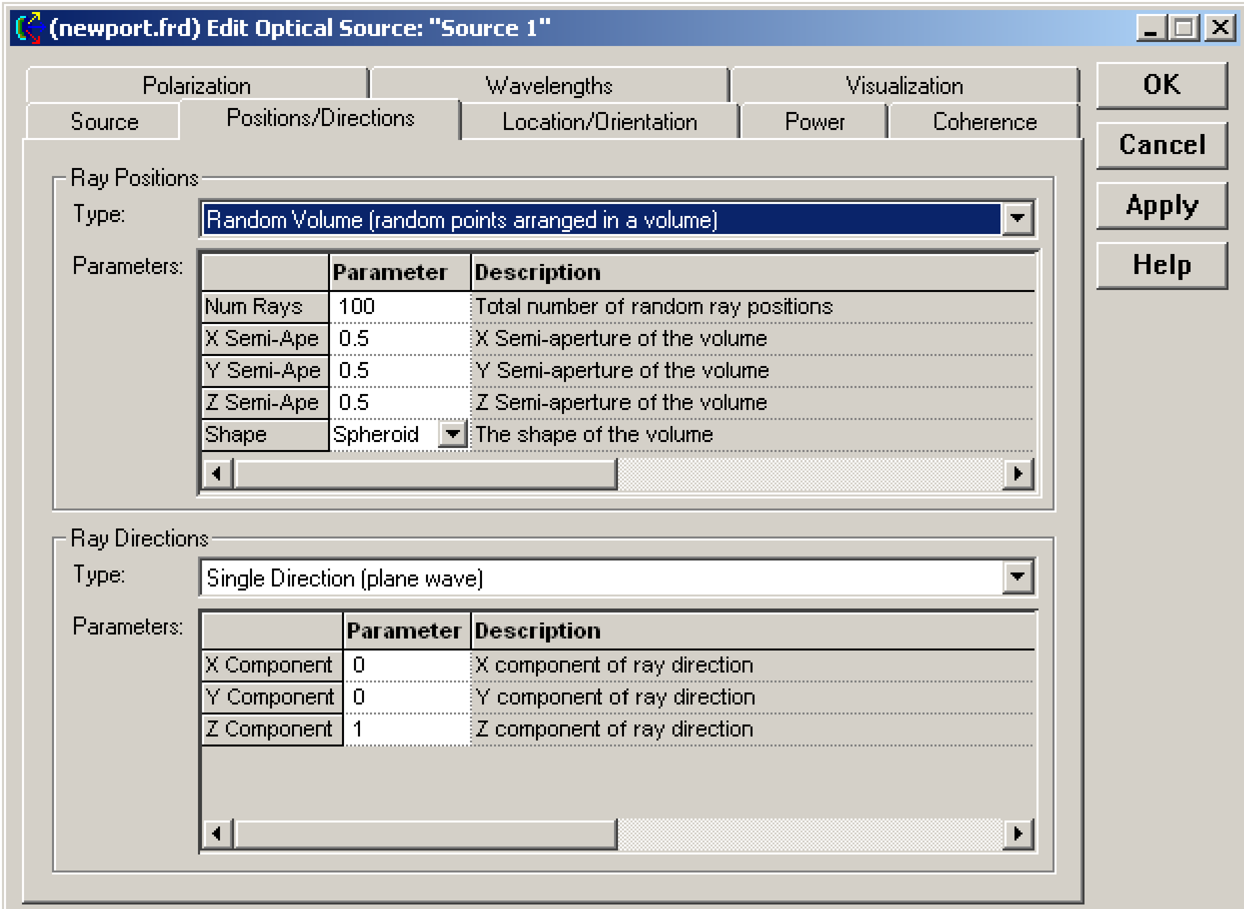
Description
Random Volume (Create New and Edit/View Detailed Source…)

The Random Volume option defines random Ray Positions in a volume. In the example below, the default settings for the Random Volume were used and the Single Direction was selected for the Ray Directions.



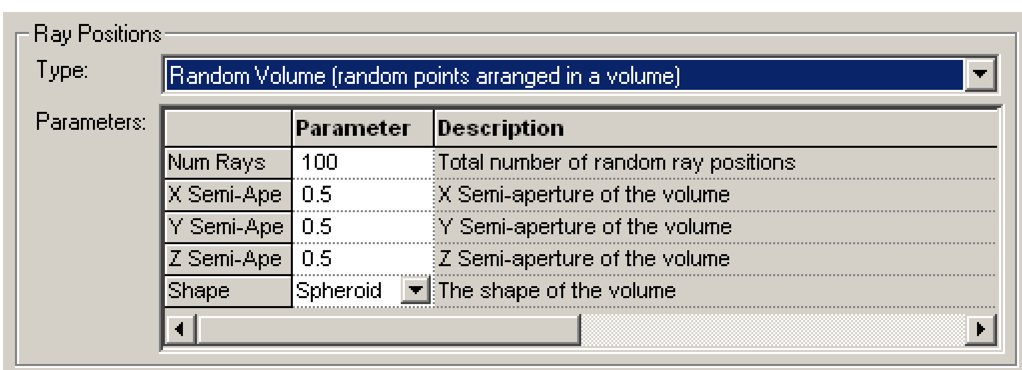
How Do I Get There?
Random Volume (Create New and Edit/View Detailed Source…)

This is an option in the Positions / Directions page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Random Volume (Create New and Edit/View Detailed Source…)



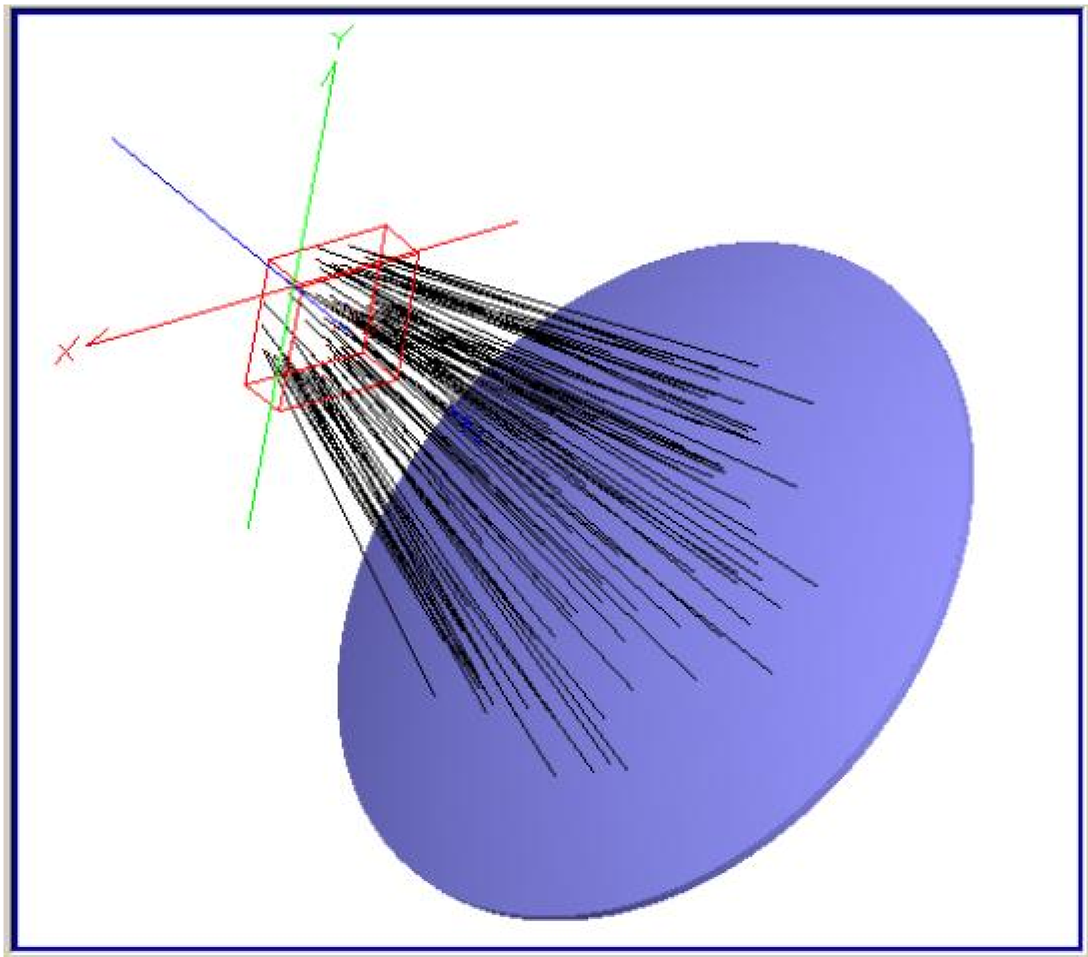
Control	Description	Defaults
Ray Positions		
Type	Pull down menu for selecting the method of defining ray positions. Choose **Random Volume**.	Grid plane
Parameters		
Num Rays	Number of rays randomly distributed in the volume.	100
X Semi-Ape	Ray volume semi-diameter in the X direction.	0.5
Y Semi-Ape	Ray volume semi-diameter in the Y direction.	0.5
Z Semi-Ape	Ray volume semi-diameter in the Z direction.	0.5
Shape	Pull down menu with the available ray bundle parameter shapes.	Spheroid
OK	Create new source and close dialog box.	
Cancel	Discard new source and close dialog box.	
Apply	Apply source changes and close dialog box.	
Help	Access this Help page.	

Create Detailed Source – Position/Directions - User Defined Rays

Description

User Defined Rays (Create New and Edit/View Detailed Source…)

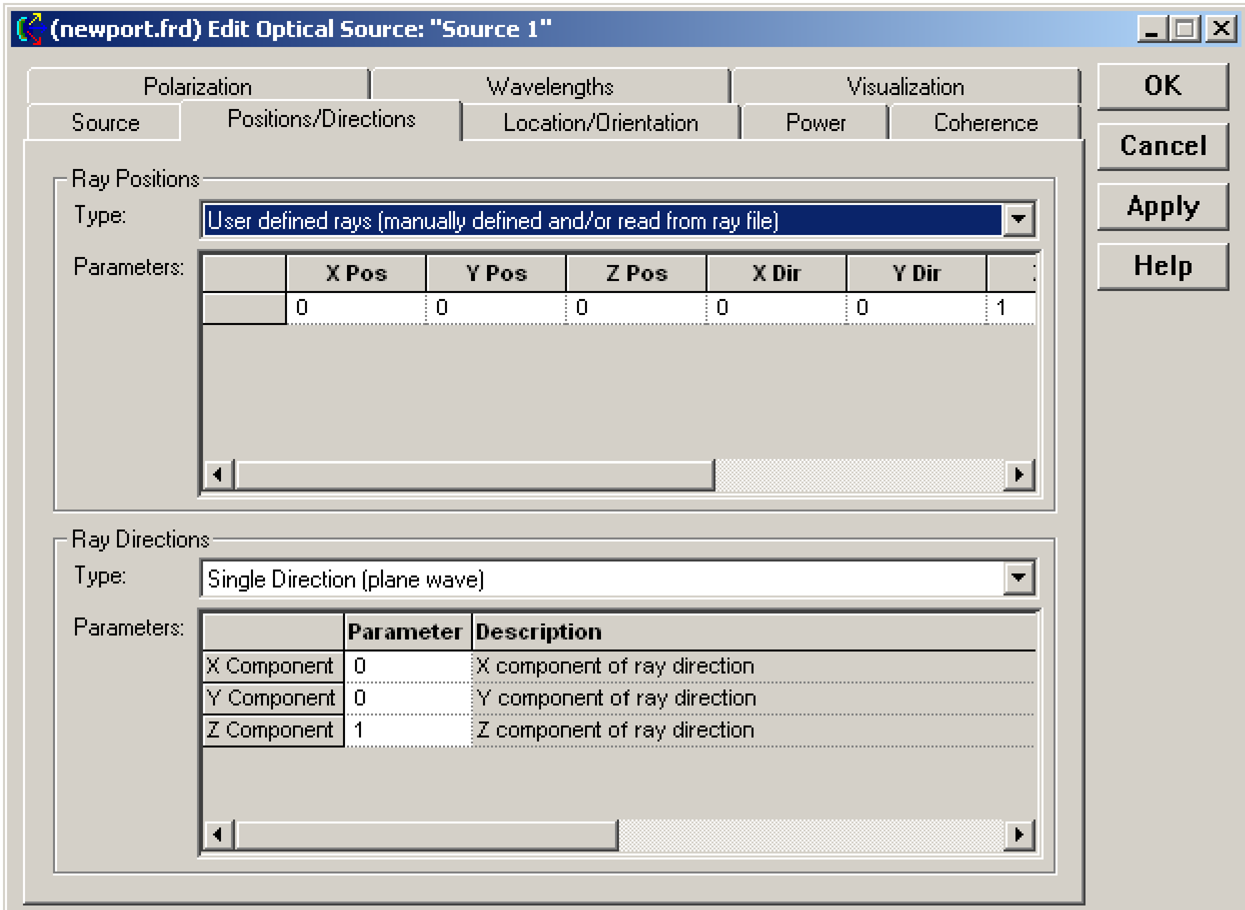
The User Defined Rays option defines Ray Position, Direction, Power, and Path Length for each ray in a tabular form.



How Do I Get There?

User Defined Rays (Create New and Edit/View Detailed Source…)

This is an option in the Positions / Directions page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



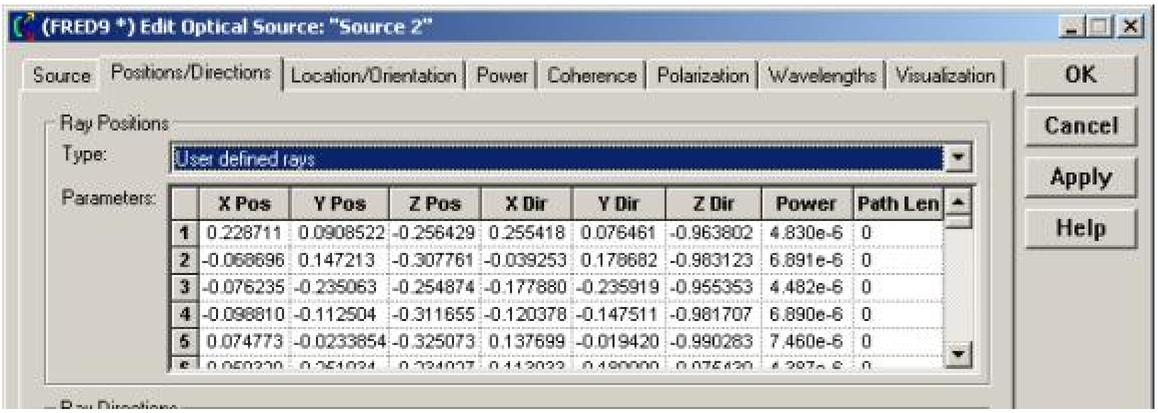
Usage

User Defined Rays (Create New and Edit/View Detailed Source…)

Rays can be inserted by hand if you know the data for the rays. To do this, enter the x, y, and z components of the position, the x, y, and z components of the direction the ray travels, the power, and the path length for one ray in one row. When you enter values, FRED automatically adds another row for more rays.

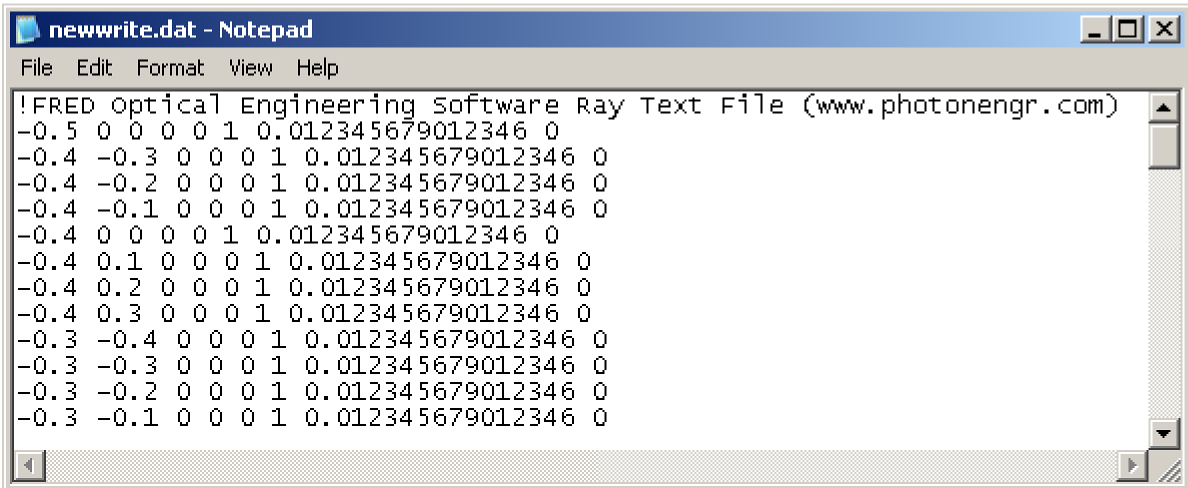
You can also import user-defined ray data from a file in any of several formats. Right mouse click on the input spreadsheet for the context menu. Select either the “Append Rays From a File…” or “Replace With Rays From a File…” menu item. This will produce a File Open dialog that will allow you to select the ray data type and the file to import. This is a handy way to import ray data files created by the ProSource software of Radiant Imaging. Note that it is important to specify the correct ray file data type in the “File Open” dialog before you attempt to import rays from the file. The wrong data type will result in invalid rays being imported from the file.

The Ray Position section of the dialog:



Control	***Description***	***Defaults***
Ray Positions		
Type	Pull down menu for selecting the method for defining the ray positions.	Grid plane
Parameters		
X Pos	X coordinate of the ray position.	0
Y Pos	Y coordinate of the ray position.	0
Z Pos	Z coordinate of the ray position.	0
X Dir	X component of the ray direction cosines α.	0
Y Pos	Y component of the ray direction cosines β.	0
Z Pos	Z component of the ray direction cosines γ.	1
Power	Power of the ray	1
Path Len	Path length of the ray at this (X, Y, Z) location.	0
OK	Create new source and close dialog box.	
Cancel	Discard new source and close dialog box.	
Apply	Apply source changes and close dialog box.	
Help	Access this Help page.	

- Text file format for entry of user-defined rays is one ray per row with eight columns of data (Xpos, Ypos, Zpos, Xdir, Ydir, Zdir, Power & Pathlength):




```
!FRED Optical Engineering Software Ray Text File (www.photonengr.com)
-0.5 0 0 0 0 1 0.012345679012346 0
-0.4 -0.3 0 0 0 1 0.012345679012346 0
-0.4 -0.2 0 0 0 1 0.012345679012346 0
-0.4 -0.1 0 0 0 1 0.012345679012346 0
-0.4 0 0 0 0 1 0.012345679012346 0
-0.4 0.1 0 0 0 1 0.012345679012346 0
-0.4 0.2 0 0 0 1 0.012345679012346 0
-0.4 0.3 0 0 0 1 0.012345679012346 0
-0.3 -0.4 0 0 0 1 0.012345679012346 0
-0.3 -0.3 0 0 0 1 0.012345679012346 0
-0.3 -0.2 0 0 0 1 0.012345679012346 0
-0.3 -0.1 0 0 0 1 0.012345679012346 0
```

Create Detailed Source – Position/Directions - Read Ray File Dialog

Description

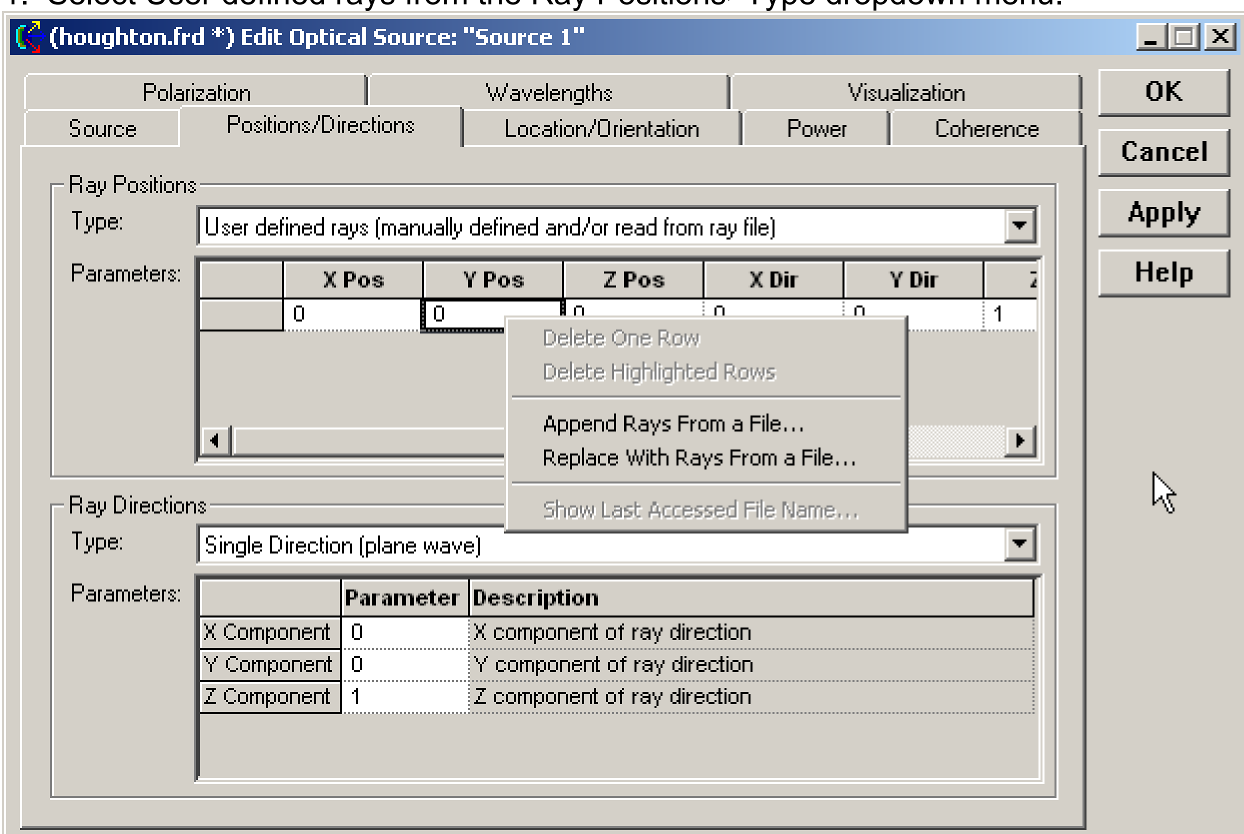
Dialog name/function

Specify a ray file and select a subsection of the content.

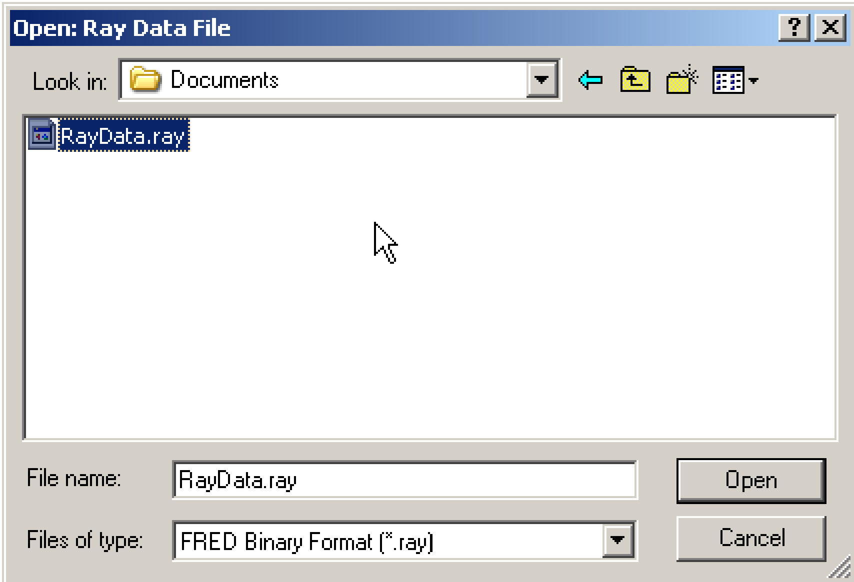
How Do I Get There?

Dialog name/function

1. Select User defined rays from the Ray Positions>Type dropdown menu.

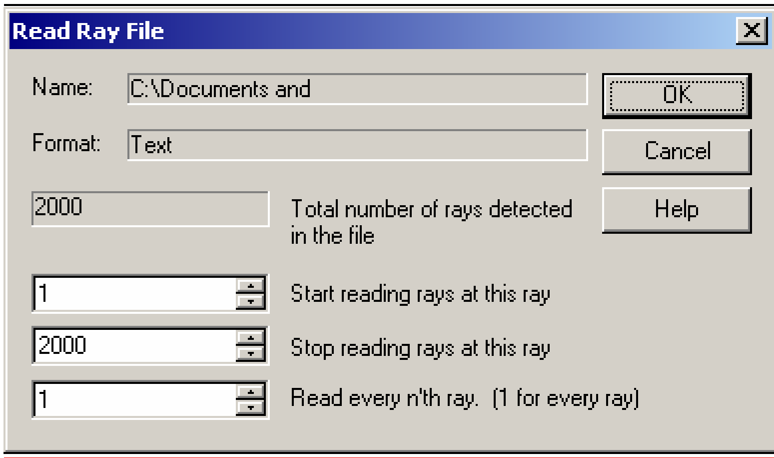


2. Select an existing ray file.



Dialog Box and Controls

Dialog name/function



Control	*Inputs / Description*	*Defaults*
Name	Ray file name	N/A
Format	Ray file format [binary = *.ray *or* text = *.txt]	N/A
Total number of rays in file	Total number of rays	N/A
Start/Stop	Beginning/ending ray number	1, max #
Read every n'th ray	Reduces number of rays read by a factor of *n*	1
OK	Read Ray File and close dialog box.	
Cancel	Discard Read and close dialog box.	
Help	Access this Help page.	

Application Notes

Dialog name/function

See Also....

Dialog name/function

Create Detailed Source - Wavelength Dialog

Description- Detailed Source Wavelength Dialog

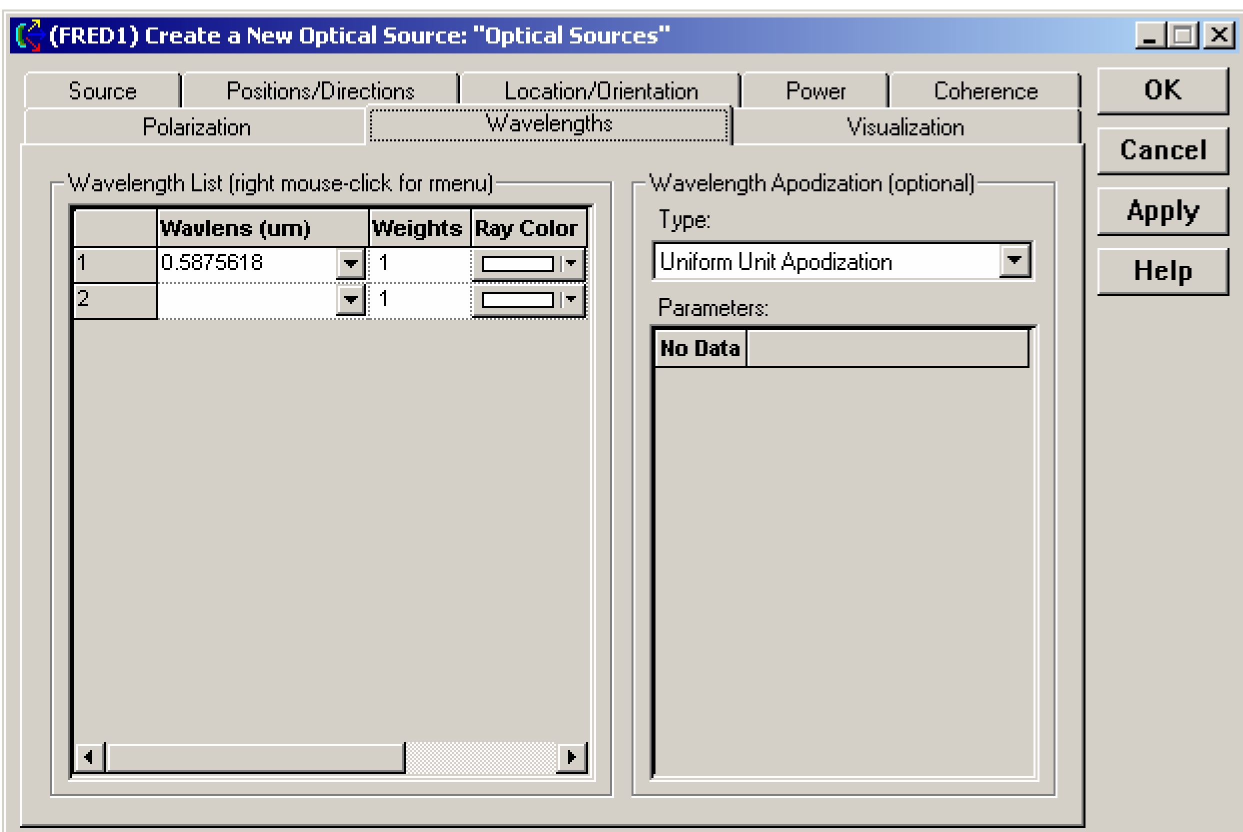
This tab of the Source editing dialog allows you to specify the wavelengths along with their associated weights and colors, and wavelength apodization for a given source.

The wavelengths are specified in units of microns. Each wavelength has an associated relative weight in arbitrary units. It also has an associated color that sets the color of the ray trajectory as it is being drawn on the computer screen. The default color is opposite of the background color of the 3D rendering window. A right mouse click context menu item can be used to automatically set ray colors to match the visual color at the associated wavelength.

How Do I Get There? - Detailed Source Wavelength Dialog

Right click on the Optical Sources folder in the tree and choose "Create New Detailed Optical Source". Alternately, right click on an existing source and choose "Edit/View Detailed Optical Source". When the dialog appears, click the Wavelengths tab.

Dialog Box and Controls - Detailed Source Wavelength Dialog



Control	Inputs / Description	Defaults
Wavelength List	Specifies the wavelengths for the source	One wavelength, 0.5875618 um, weight 1
Wavelength Apodization Type	Specifies any apodization applied to the source	Uniform Unit Apodization
Wavelength Apodization Parameters	Specifies the parameters of the apodization	
OK	Dismisses the dialog and applies the changes	
Cancel	Dismisses the dialog and discards the changes	
Apply	Keeps the dialog open and applies the changes	
Help	Displays this help article	

Application Notes - Detailed Source Wavelength Dialog

This tab is part of a modeless, resizable dialog.

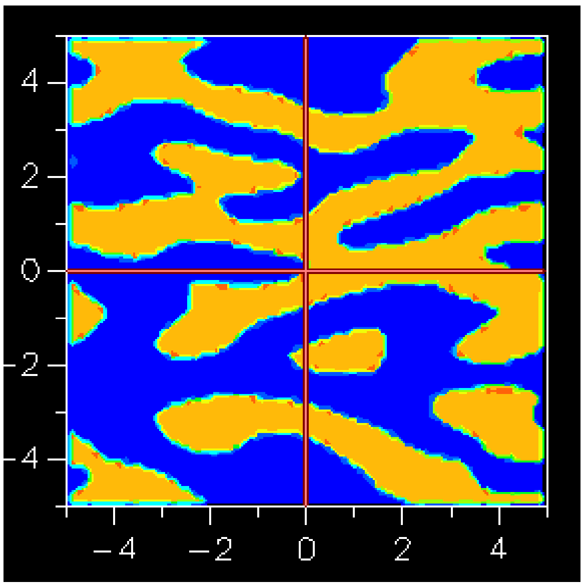
See Also…. - Detailed Source Wavelength Dialog

Create Detailed Source - Amplitude/Phase Mask from Rectilinear Grid

Description

Power Apodization - Amplitude/Phase Mask

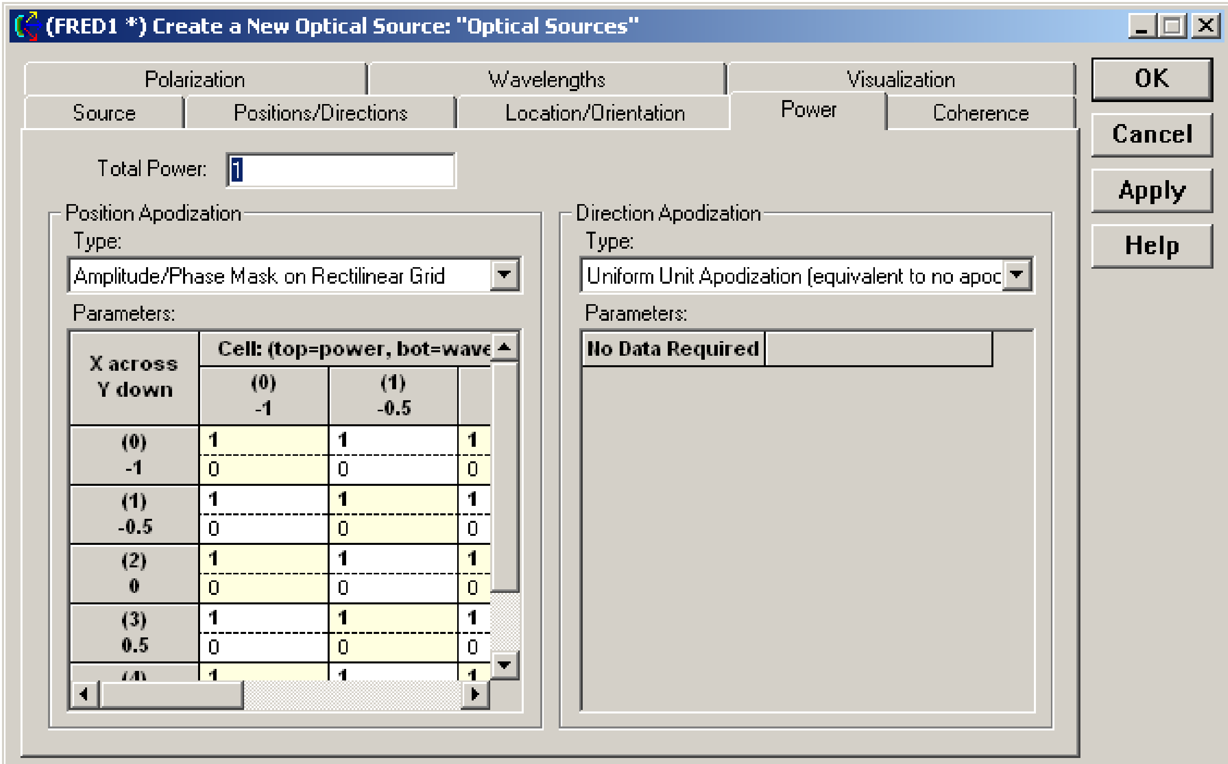
Source power can be apodized from a rectilinear grid of amplitude/phase data.



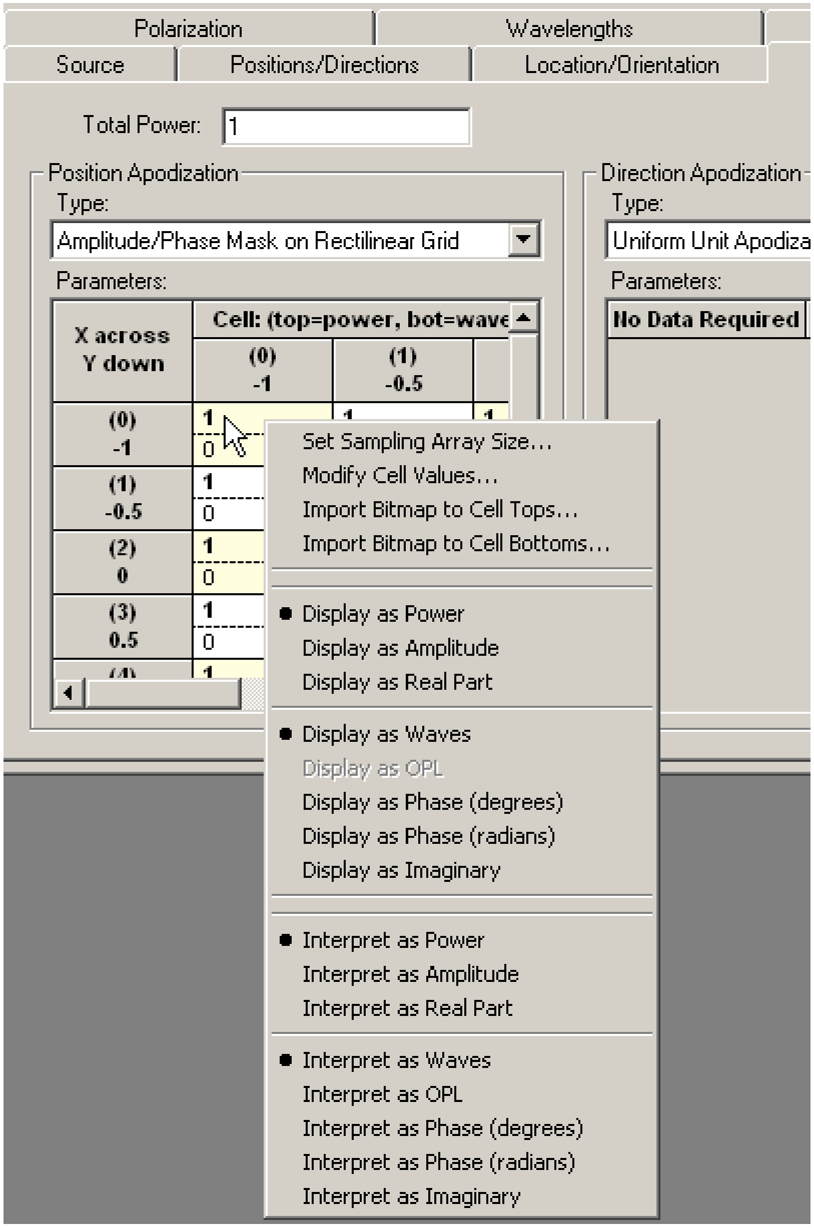
How Do I Get There?

Power Apodization - Amplitude/Phase Mask

Amplitude/Phams mask apodization can be accessed from the Position Apodization option on the Power Tab of a Detailed Source:



A right-click in the Table area offers the following options:



Importing amplitude data - Import Bitmap to Cell Tops...

Interpret as Power
Amplitude
Real Part

Importing Phase data - Import Bitmap to Cell Bottoms..

Interpret as Waves
OPL
Phase (deg)
Phase (radians)
Imaginary

Application Notes

Power Apodization - Amplitude/Phase Mask

- The Sampling Array Size should match the X- and Y-Semi-Ape as set on the Source Position/Direction Tab. Take into account the dimensions of the bitmap as well.

- The spatial sampling of a Grid should be consistent with sampling required to accurately reproduce the amplitude/phase mask. In the case of coherent sources, be aware that spatial sampling is limited to about 10λ due to the paraxial condition imposed on the individual gaussian beamlets ($\theta < 0.01$).

See Also….

Power Apodization - Amplitude/Phase Mask

R^n distance apodization
Gaussian apodization
Amplitude/Phase Mask Modify
Sizing the Amplitude/Phase Mask

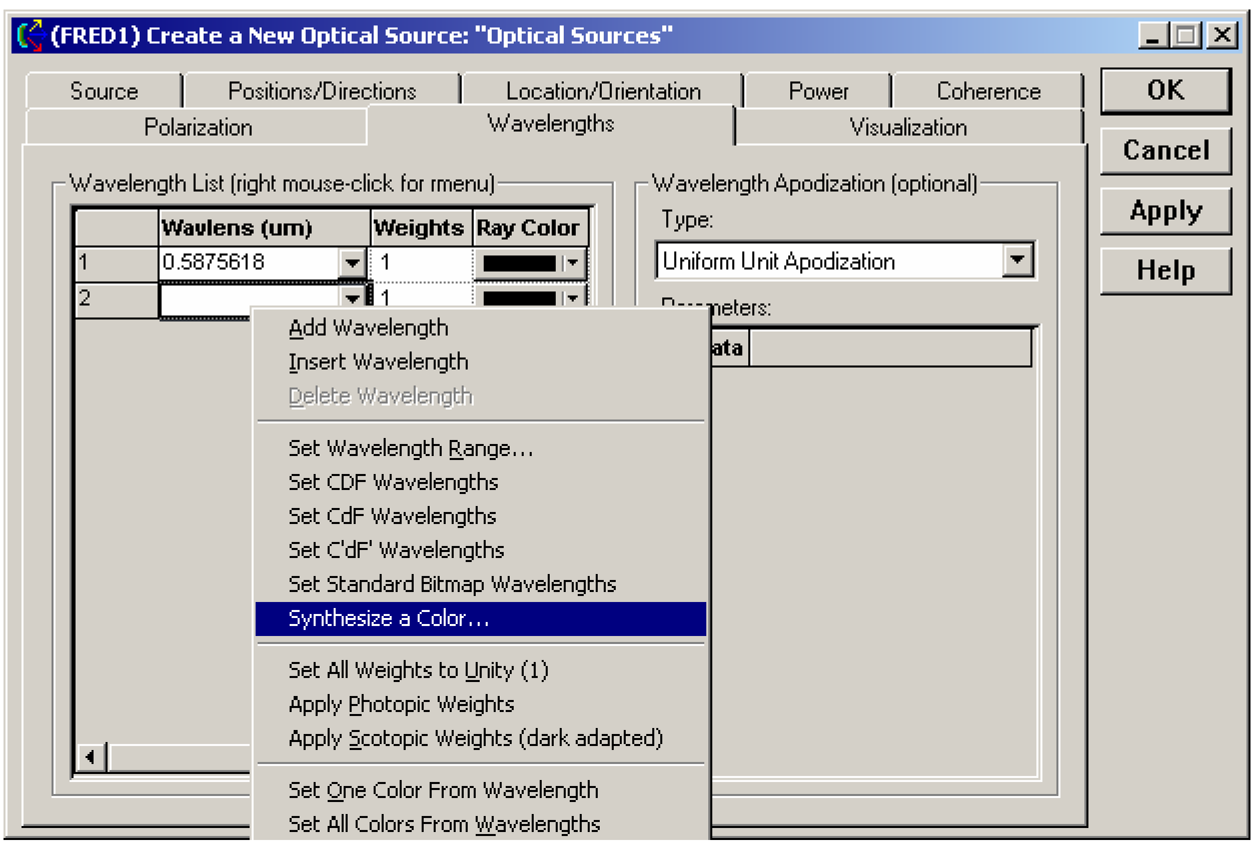
Create Detailed Source – Wavelength - Synthesize A Color Dialog

Description
Synthesize A Color Dialog

Synthesizes a source color over a given wavelength range based upon user-specified Chromaticity coordinates, Tristimulus values, or visual RGB color.

How Do I Get There?
Synthesize A Color Dialog

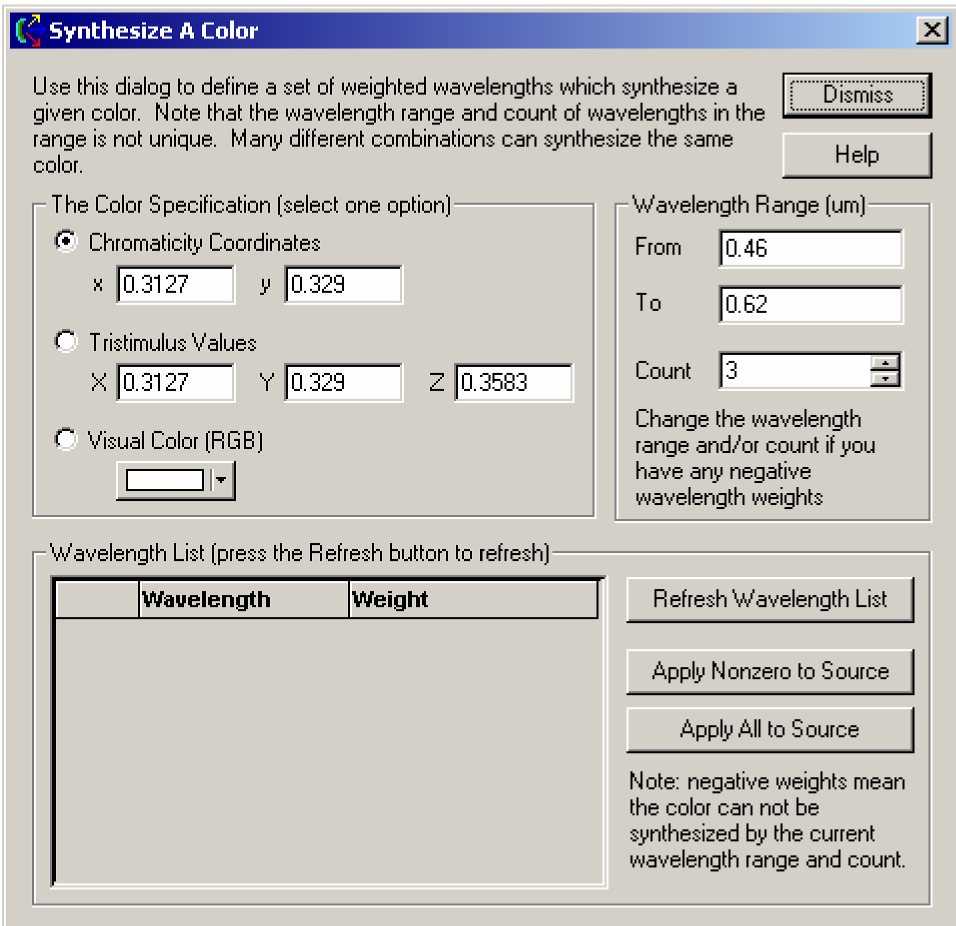
Open a dialog with a wavelength list, then right-click in the list and choose "Synthesize a Color..."



The Synthesize a Color option as shown on the Create/Edit Detailed Optical Source Dialog

Dialog Box and Controls

Synthesize A Color Dialog



Control	Inputs / Description	Defaults
The Color Specification		
Chromaticity Coordinates: x, y	Specify color using Chromaticity Coordinates.	Selected (0.3127, 0.329)
Tristimulus Values: X,Y,Z	Specify color using Tristimulus values.	Not selected (0.3127, 0.329, 0.3583)
Visual Color (RGB)	Specify color using RGB.	Not selected

Visual Color Selector	Select color from Windows RGB color palette.	White
Wavelength Range		
From - To	Range of wavelengths used to synthesize color.	0.46, 0.62
Count	Number of wavelengths in the From-To range.	3
Wavelength List		
Refresh Wavelength List	List wavelengths and weights.	
Apply Nonzero to Source	Use only nonzero weighted wavelengths in range to construct source.	
Apply All to Source	Use all wavelengths in range to construct source.	
Dismiss	Closes dialog box.	
Help	Access this Help page.	

Application Notes

Synthesize A Color Dialog

This dialog is resizable and retains its position when dismissed. It is modal and must be dismissed before other work can be done.

See Also….

Synthesize A Color Dialog

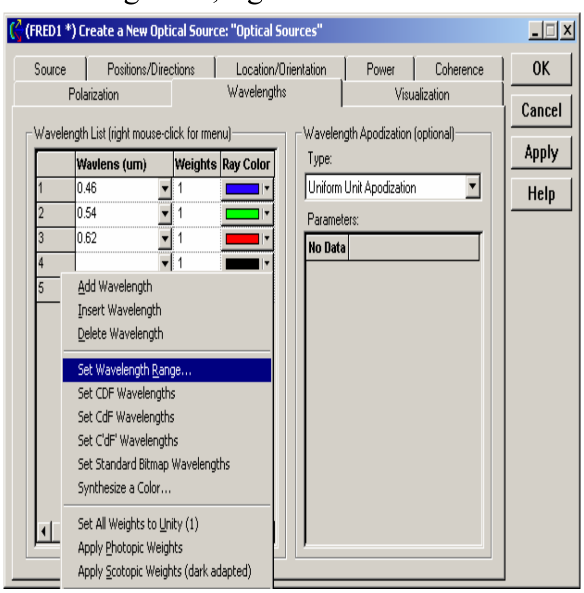
Create Detailed Source - Wavelength - Range Dialog

Description
Wavelength Range Dialog

This dialog adds a range of wavelengths to a Wavelength List.

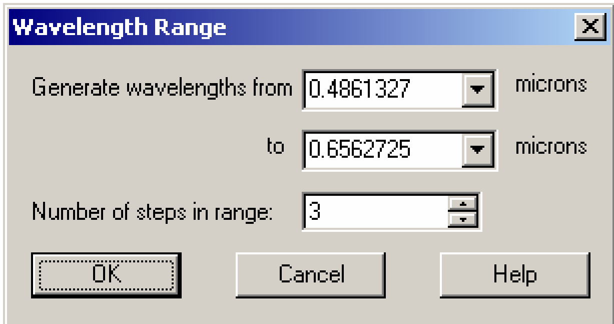
How Do I Get There?
Wavelength Range Dialog

From a wavelength list, right click and choose "Set Wavelength Range...".



The menu option for the Wavelength Range dialog, as seen from the Wavelengths page of the New Detailed Optical Source dialog

Dialog Box and Controls
Wavelength Range Dialog



Control	Inputs / Description	Defaults
Generate wavelengths from	The starting wavelength of the range, measured in micrometers.	0.4861327
to	The ending wavelength of the range, measured in micrometers.	0.6562725
Number of steps in range	The number of wavelengths between the start and the end.	3
OK	Accept Wavelength Range changes and close dialog box.	
Cancel	Discard Wavelength Range changes and close dialog box.	
Help	Access this Help page.	

Application Notes
Wavelength Range Dialog

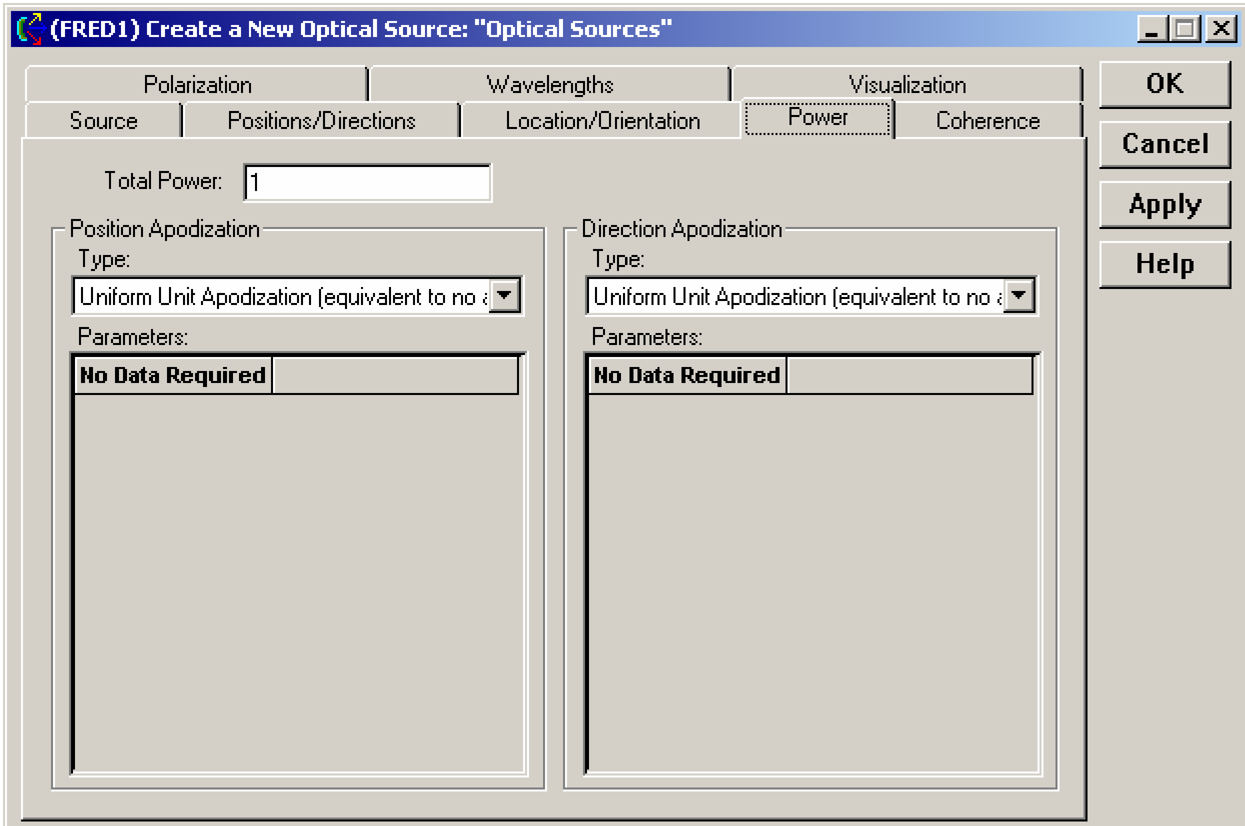
This dialog is modal - that is, it must be closed before any other work can proceed.

Create Detailed Source - Power

Description - Power (Create New and Edit/View Detailed Source…)

The Power page of the Create New and Edit/View Detailed Source… dialogs three functions:

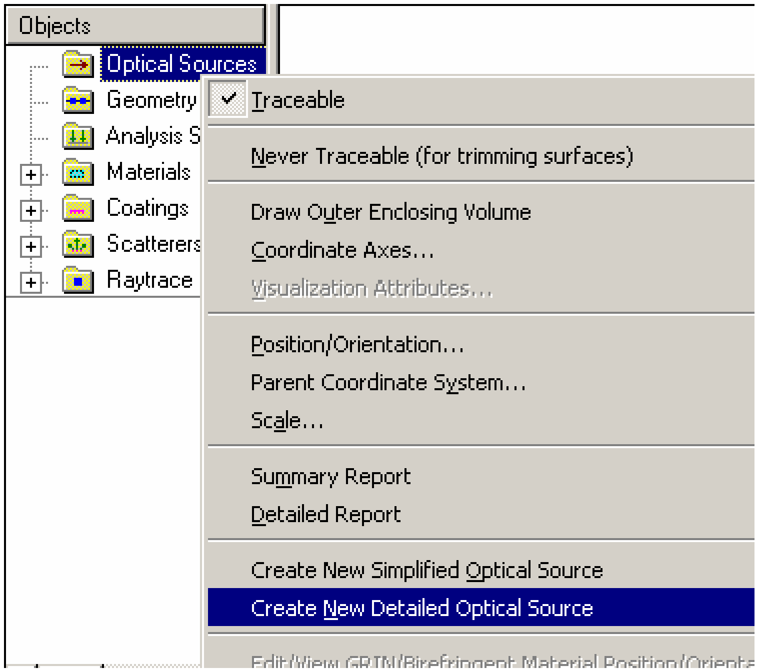
- Set the total Power of the source after the Position Apodization and Direction Apodization have been applied to the rays.
- Set the Position Apodization for the ray positions defined.
- Set the Direction Apodization for the ray directions defined.



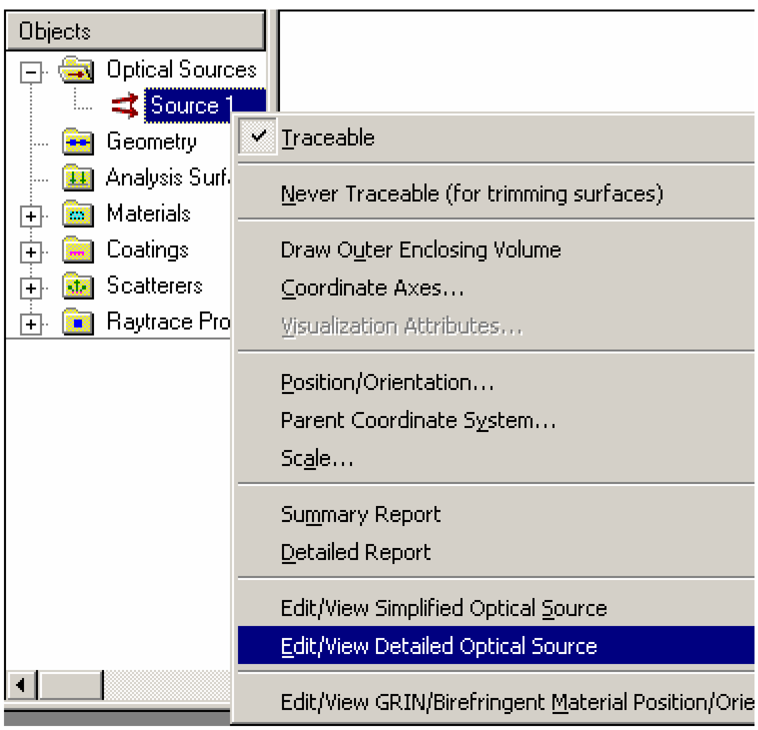
How Do I Get There? - Power (Create New and Edit/View Detailed Source...)

There are two different ways to execute this command:

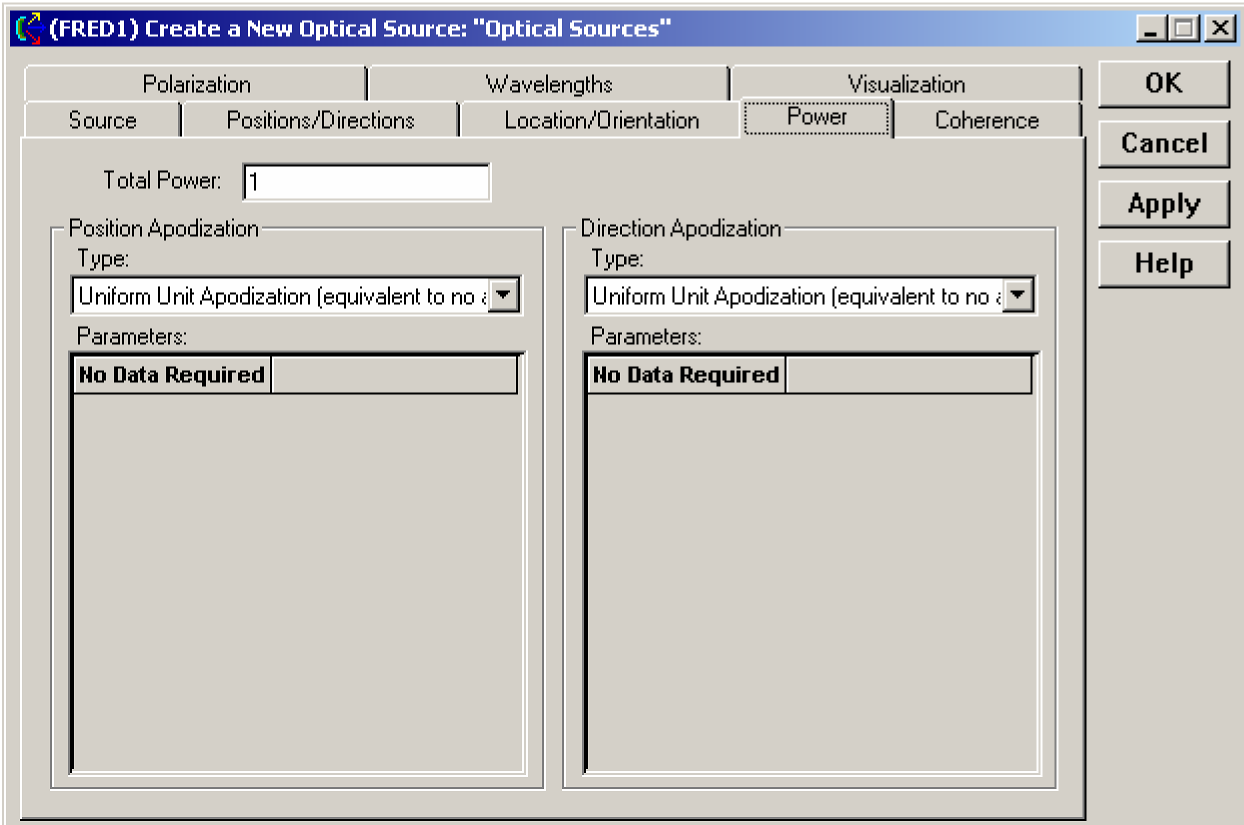
1. Right click on the Optical Sources and select Create New Detailed Optical Source… in the right click pop-up menu,



2. Right click on an Source and select Edit/View Detailed Optical Source… in the right click pop-up menu,



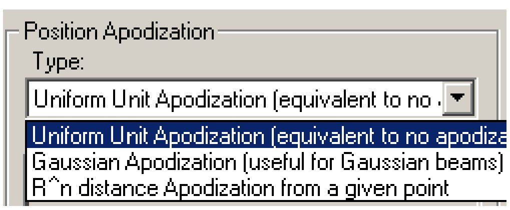
Dialog Box and Controls - Power (Create New and Edit/View Detailed Source…)



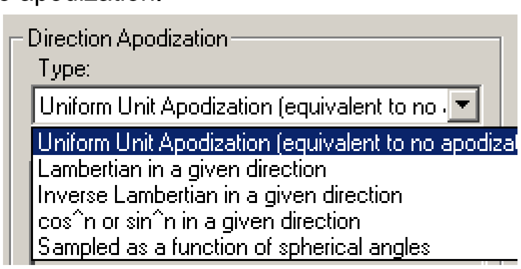
Control	Inputs	Defaults
Total Power	The total power of the source. Rays in the source are scaled ***after*** both the position and direction apodization functions have been applied.	1
Position Apodization		
Type	Pull down menu of available position apodization options: *Uniform* *Gaussian* *R^n distance from a given point*	Uniform
Direction Apodization		

Type	Pull down menu of available direction apodization options: *Uniform* *Lambertian* *Inverse Lambertian* *Cos^n or Sin^n* *Sampled (spherical angles)*	Uniform
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

There are two options for the Position Apodization of the rays besides the first option of no apodization.



There are four options for the Direction Apodization of the rays besides the first option of is no apodization.



The Position Apodization options

Uniform Unit Apodization (equivalent to no apodization)

Gaussian Apodization (useful for Gaussian Beams)

R^n Distance Apodization from a Given Point

The Direction Apodization options

Uniform Unit Apodization (equivalent to no apodization)

Lambertian in a given direction

Inverse Lambertian in a given direction

Cos^n or Sin^n in a given direction

Sampled as a function of spherical angles

See Also… - Power (Create New and Edit/View Detailed Source…)

Source

Positions / Directions

Location / Orientation

Power

Coherence

Polarization

Wavelength

Visualization

Create Detailed Source – Power - Lambertian in a Given Direction Apodization

Description

Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source…)

The Lambertian in a Given Direction Apodization option scales all the rays in the source to have a Lambertian intensity. This Lambertian option effectively apodizes the rays with a $\cos(\phi)$ factor where ϕ is a elevation angle in polar coordinates.

The Lambertian in a Given Direction Apodization option is radiometrically equivalent to having Uniform Direction Apodization and setting the source rays to be Lambertian on the Positions / Directions page. Although these two methods of generating a Lambertian source are radiometrically equivalent, they are represented with different distributions of rays. The Lambertian option on the Positions / Directions page distributes the rays equally in direction cosine space and the Isotropic option on the Positions / Directions page distributes the rays equally in angle space.

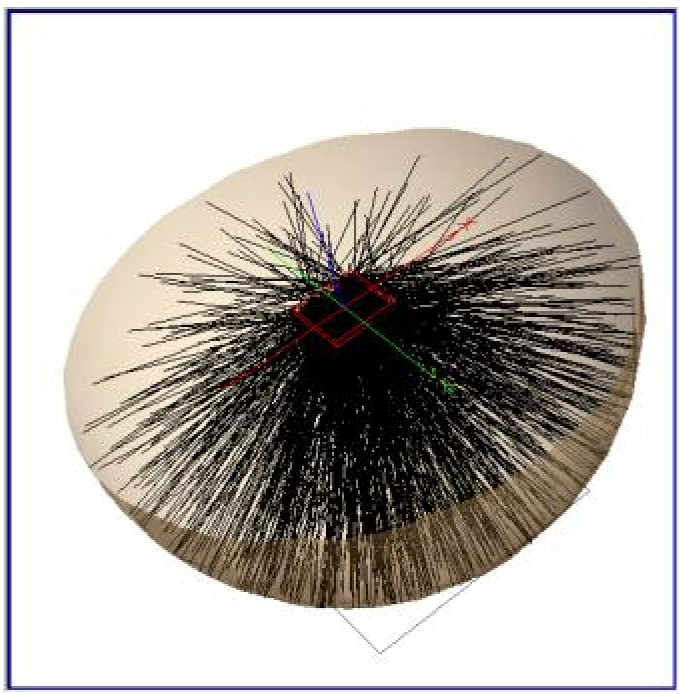


Figure 1. This figure illustrates an Isotropic plane of random rays emitting to a 90° cone with Lambertian in a Given Direction Apodization.

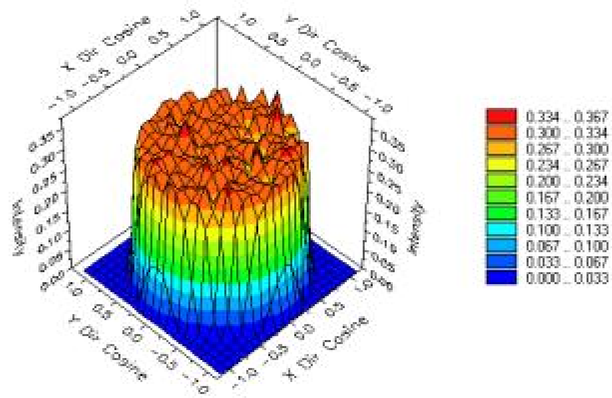
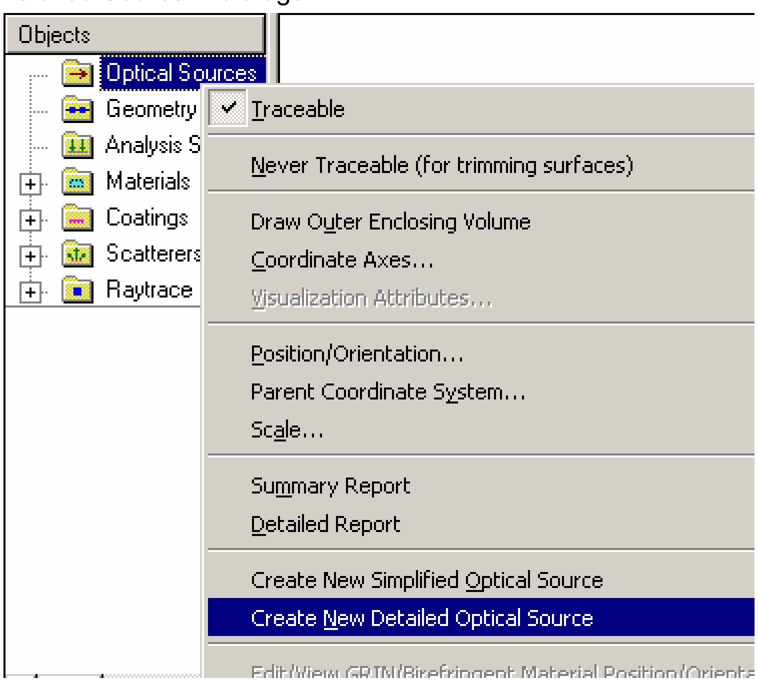


Figure 2. This Intensity Spread Function plot of an Isotropic source with a Lambertian in a Given Direction Apodization on the Power page.

How Do I Get There?

Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source…)

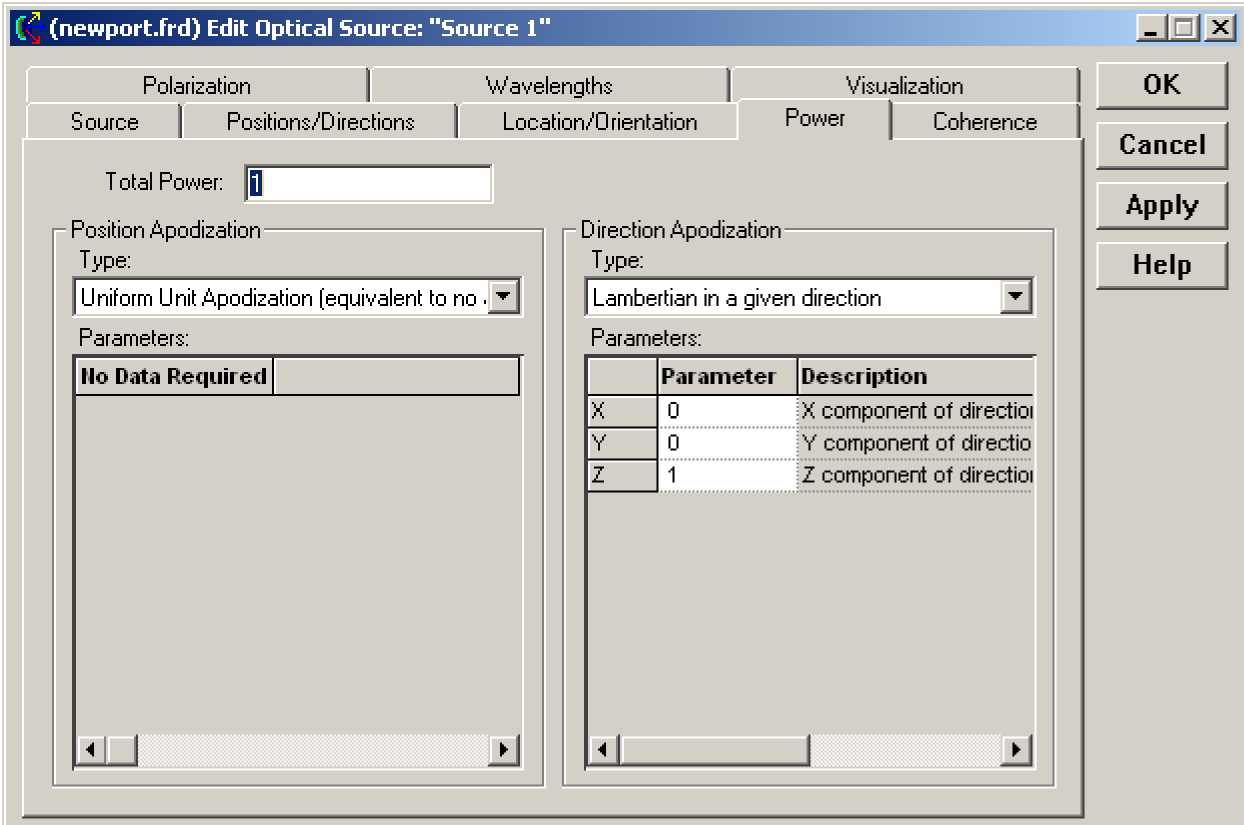
This is an option in the Power page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source…)

The Direction Apodization section of the dialog:


(newport.frd) Edit Optical Source: "Source 1"
Polarization
Wavelengths
Visualization
Source
Positions/Directions
Location/Orientation
Power
Coherence
OK
Cancel
Apply
Help
Total Power:
1
Position Apodization
Type:
Uniform Unit Apodization (equivalent to no
Parameters:
No Data Required
Direction Apodization
Type:
Lambertian in a given direction
Parameters:
Parameter
Description
X
0
X component of directio
Y
0
Y component of directio
Z
1
Z component of directio

Control	Inputs	Defaults
Total Power	The total power of the source *after* both the position and direction apodization functions have been applied to the rays.	1
Position Apodization		
Type	Pull down menu of available position apodization options.	Uniform
Parameters	There are no parameters for this option.	
Direction Apodization		
Type	Pull down menu of available direction apodization options. Choose **Lambertian in a given direction**.	Uniform
Parameters		
X	X component of direction cosine vector of the given direction for the Lambertian intensity pattern.	0
Y	Y component of direction cosine vector of the given direction for the Lambertian intensity pattern.	0
Z	Z component of direction cosine vector of the given direction for the Lambertian intensity pattern.	1
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

Create Detailed Source – Power - Inverse Lambertian in a Given Direction Apodization

Description

Inverse Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source…)

The Inverse Lambertian in a Given Direction Apodization option scales all the rays in the source to have an Inverse Lambertian intensity. The Inverse Lambertian option in effect apodizes the rays with a 1/cos(ϕ) factor where ϕ is the elevation angle in polar coordinates. If the source rays are set to be Lambertian on the Positions / Directions page and then the Inverse Lambertian in a Given Direction Apodization option would make the intensity pattern Isotropic in effect.

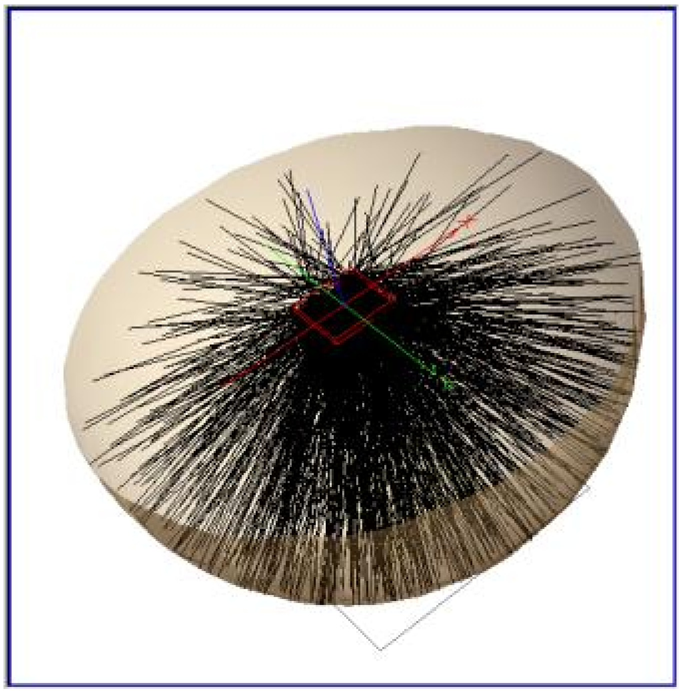


Figure 1. This figure illustrates an Isotropic plane of random rays emitting to a 90° cone with Inverse Lambertian in a Given Direction Apodization.

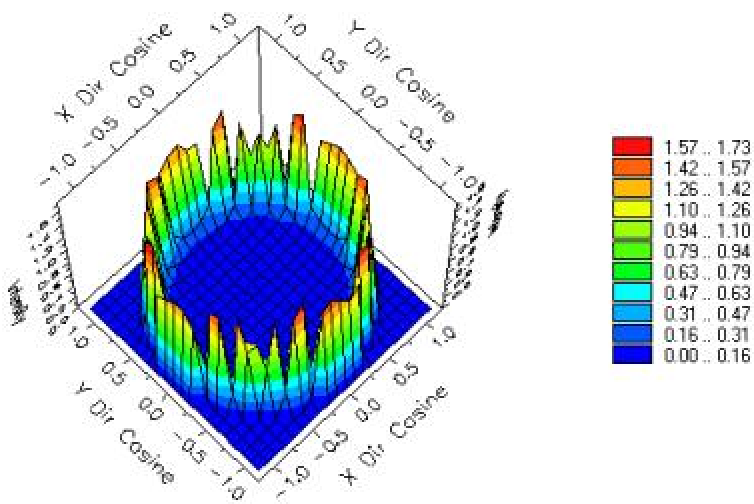
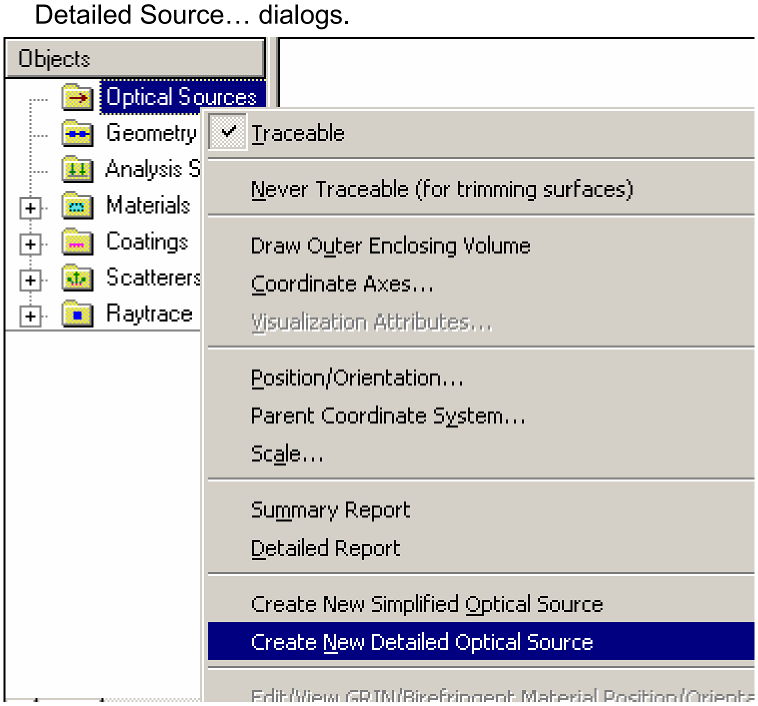


Figure 2. This Intensity Spread Function plot of an Isotropic source with a Inverse Lambertian in a Given Direction Apodization on the Power page. Note that the center of this intensity pattern in not zero as this Intensity Spread Function plot suggests.

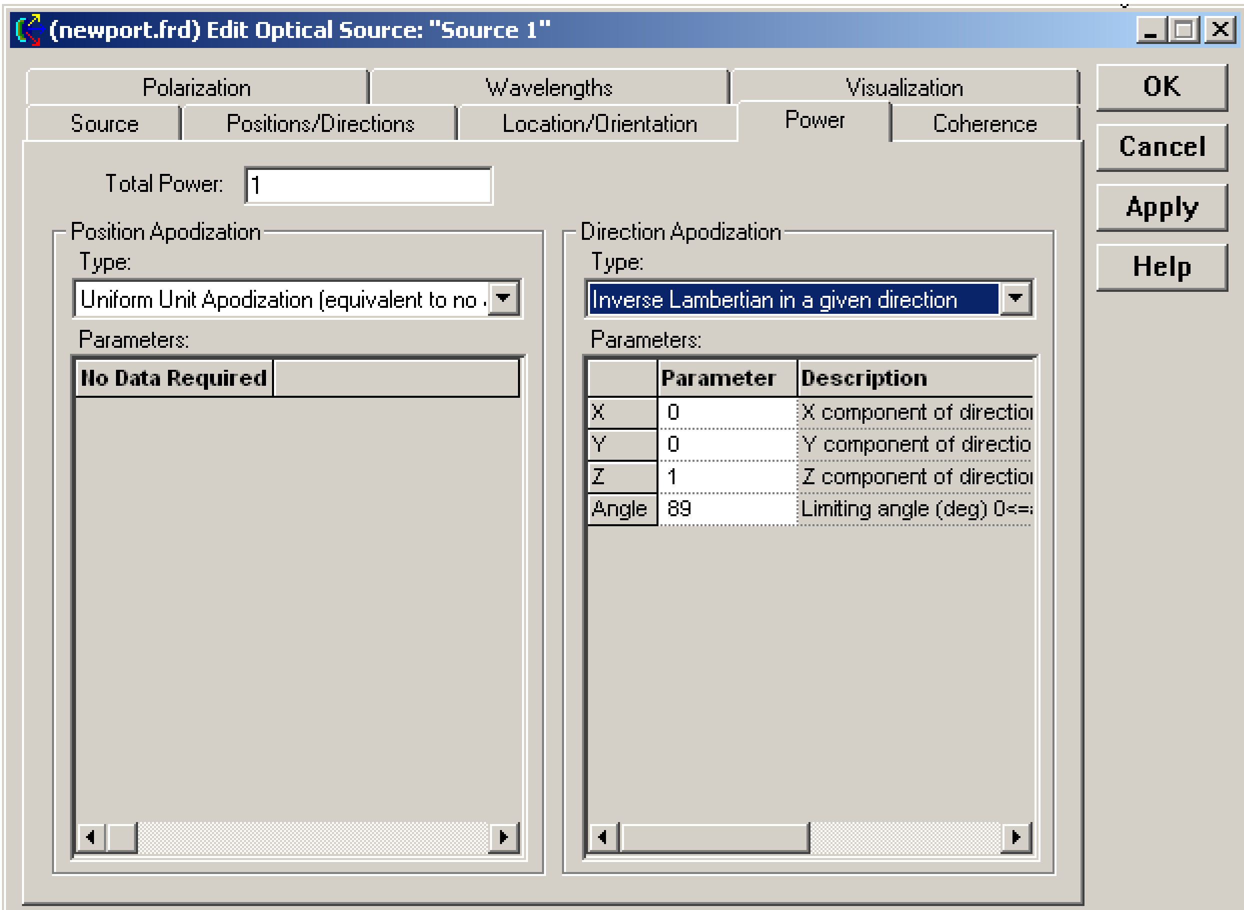
How Do I Get There?

Inverse Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source…)

This is an option in the Power page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



The Direction Apodization section of the dialog:



Control	Inputs	Defaults
Total Power:	Total power of the source *after* both the position and direction apodization functions have been applied to the rays.	1
Position Apodization		
Type:	Pull down menu of available position apodization options.	Uniform
Parameters:	There are no parameters for this option	
Direction Apodization		
Type:	Pull down menu of available direction apodization options. Choose **Inverse Lambertian in a given direction**.	Uniform
Parameters		
X	X component of direction cosine vector of the given direction for the Inverse Lambertian intensity pattern.	0
Y	Y component of direction cosine vector of the given direction for the Inverse Lambertian intensity pattern.	0
Z	Z component of direction cosine vector of the given direction for the Inverse Lambertian intensity pattern.	1
Angle	Inverse Lambertian apodization factor, $1/\cos(\phi)$, goes to infinity as ϕ approaches zero. So, this apodization pattern is limited to angle less than 90^o.	89
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

Create Detailed Source – Power - Cos^n or Sin^n in a given direction

Description

Cos^n or Sin^n in a given direction (Create New and Edit/View Detailed Source…)

The Cos^n or Sin^n in a given direction option scales all the rays in the source to have an Cos^n or Sin^n intensity.

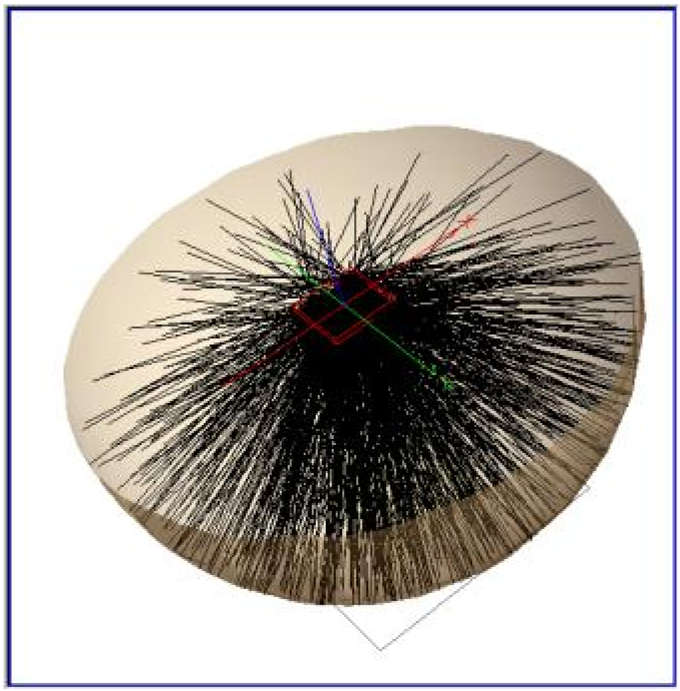


Figure 1. This figure illustrates an Isotropic plane of random rays emitting to a 90^o cone with a Cos^n or Sin^n in a given direction apodization.

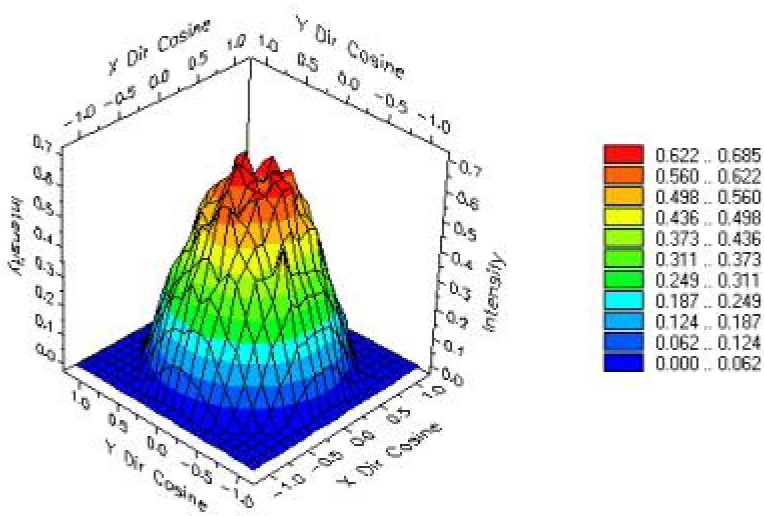
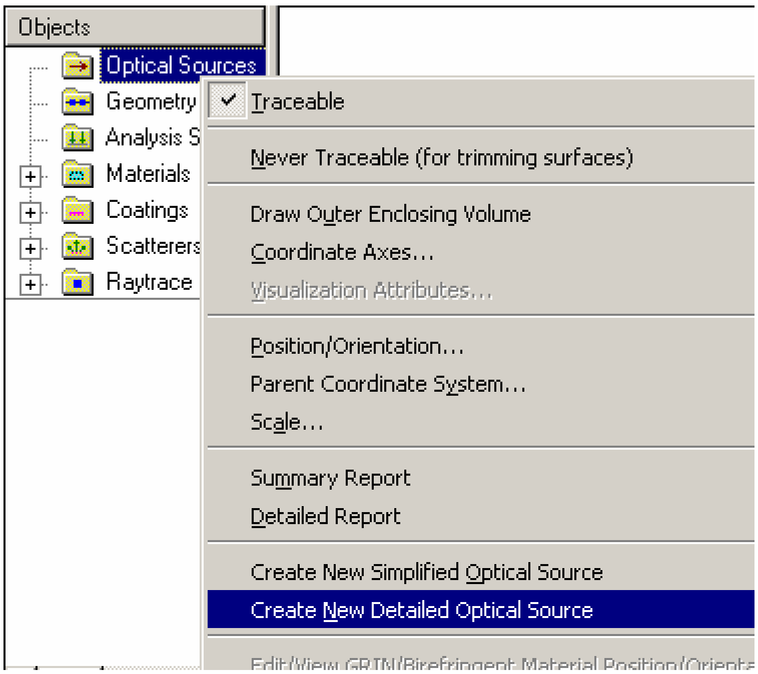


Figure 2. This Intensity Spread Function plot of an Isotropic source with a Cos^n or Sin^n in a given direction with Cos^n or Sin^n in a given direction where the Cos function was selected and the exponent set to three.

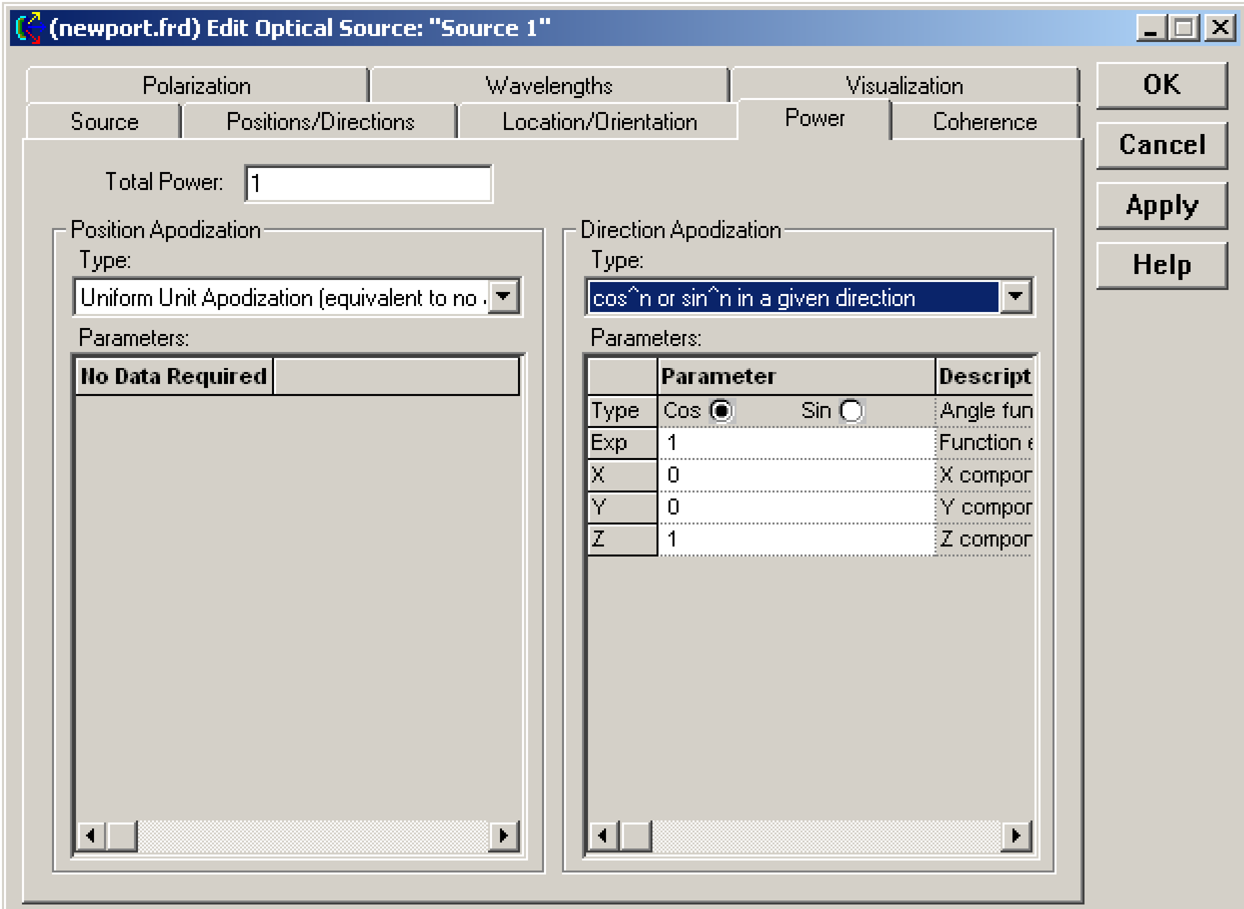
How Do I Get There?
Cos^n or Sin^n in a given direction (Create New and Edit/View Detailed Source…)

This is an option in the Power page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls
Cos^n or Sin^n in a given direction (Create New and Edit/View Detailed Source…)

The Direction Apodization section of the dialog:


(newport.frd) Edit Optical Source: "Source 1"
Polarization
Wavelengths
Visualization
Source
Positions/Directions
Location/Orientation
Power
Coherence
OK
Cancel
Apply
Help
Total Power: 1
Position Apodization
Type:
Uniform Unit Apodization (equivalent to no
Parameters:
No Data Required
Direction Apodization
Type:
cos^n or sin^n in a given direction
Parameters:
Parameter
Descript
Type Cos Sin Angle fun
Exp 1 Function
X 0 X compor
Y 0 Y compor
Z 1 Z compor

Control	Inputs	Defaults
Total Power:	Total power of the source ***after*** both the position and direction apodization functions have been applied to the rays.	1
Position Apodization		
Type	Pull down menu of available position apodization options.	Uniform
Parameters:	There are no parameters for this option.	
Direction Apodization		
Type	Pull down menu of available direction apodization options. Choose **cos^n or sin^n in a given direction**	Uniform
Parameters		
Cos/Sin	Apodization based on the Cosine or Sine function.	Cos
Exp	The exponent of the Sin or Cos function. This exponent can be positive or negative and be integer or non-integer.	1
X	X component of direction cosine vector of the given direction for the intensity pattern.	0
Y	Y component of direction cosine vector of the given direction for the intensity pattern.	0
Z	Z component of direction cosine vector of the given direction for the intensity pattern.	1
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

Create Detailed Source – Power - R^n Distance Position Apodization

Description

R^n Distance Position Apodization (Create New and Edit/View Detailed Source…)

The R^n Distance Position Apodization option scales all the rays in the source relative to their distance from the point, $\vec{P}_0$, defined in the dialog. The rays are scaled by:

$$\left[\frac{\vec{r}}{r_0}\right]^n$$

Where $\vec{r} = \left|\vec{R}_p - \vec{P}_0\right|$ is the distance from a given ray position, $\vec{R}_p$, to the reference point, $\vec{P}_0$, set in the dialog with the X, Y, and Z coordinates. This distance can be normalized with the r_0 factor. The exponent, n, can be negative or positive and integer or non-integer.

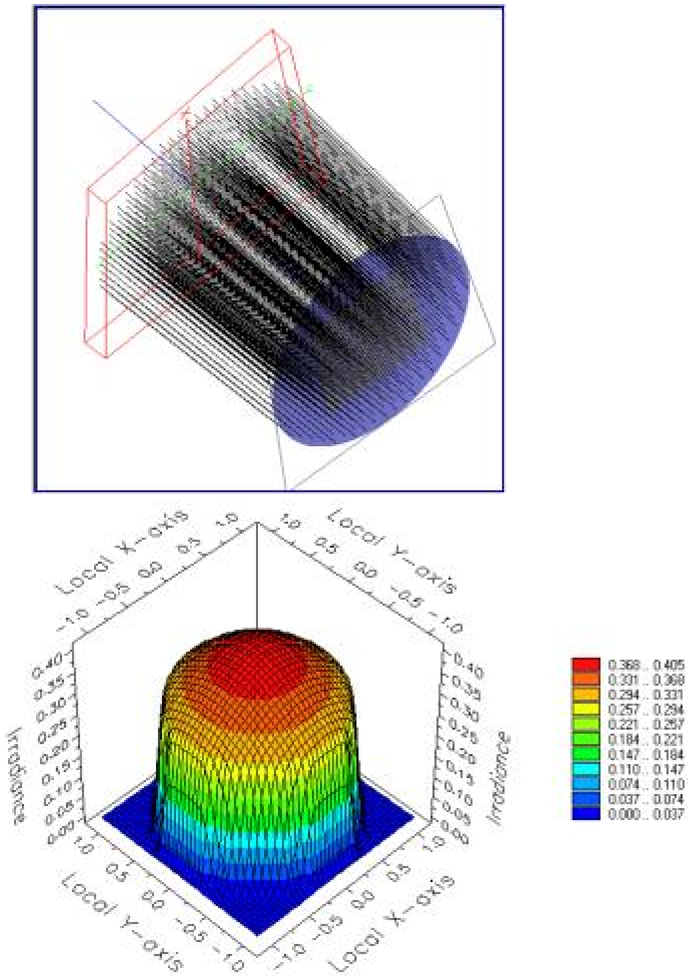
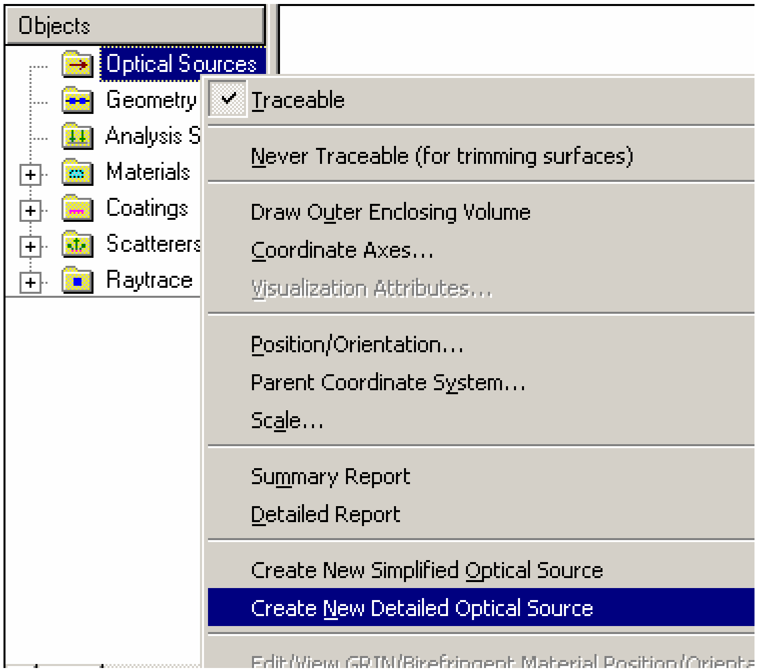


Figure 1. This first image shows the bundle of coherent rays with a 1-inch semi-diameter that have been scaled by $\left[\frac{\vec{r}}{r_0}\right]^n$ were $n = -2$, $r_0 = 1$, and $\vec{P}_0 = [0,0,1.5]$. The second image shows resulting irradiance profile.

How Do I Get There?

R^n Distance Position Apodization (Create New and Edit/View Detailed Source…)

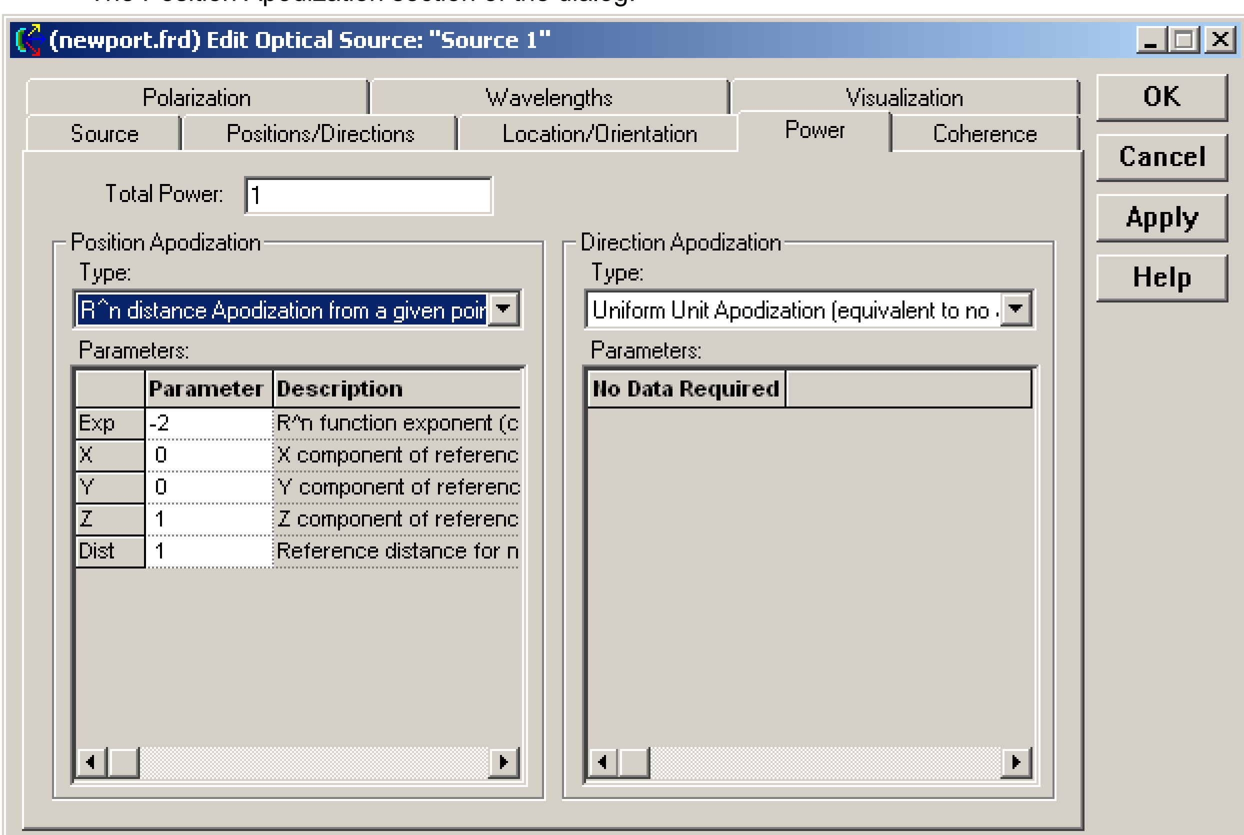
This is an option in the Power page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

R^n Distance Position Apodization (Create New and Edit/View Detailed Source…)

The Position Apodization section of the dialog:



Control	Inputs	Defaults
Total Power	Total power of the source *after* both the position and direction apodization functions have been applied to the rays.	1
Position Apodization		
Type	Pull down menu of available position apodization options. Choose **R^n distance Apodization from a given point**.	Uniform
Exp	Exponent in the $\left[\frac{\vec{r}}{r_0}\right]^n$ scale factor.	-2
X	X component in $\vec{P}_0$ vector, which is used to compute the distance $\vec{r} = \left\|\vec{R}_y - \vec{P}_0\right\|$.	0
Y	Y component in $\vec{P}_0$ vector, which is used to compute the distance $\vec{r} = \left\|\vec{R}_y - \vec{P}_0\right\|$.	0
Z	Z component in $\vec{P}_0$ vector, which is used to compute the distance $\vec{r} = \left\|\vec{R}_y - \vec{P}_0\right\|$.	1
Dist	Normalization value in the denominator of the scale factor $\left[\frac{\vec{r}}{r_0}\right]^n$.	1
Direction Apodization		
Type	Pull down menu of available direction apodization options.	Uniform
Parameters	There are no parameters for this option.	
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

Create Detailed Source – Power - Sampled as a Function of Spherical Angles

Description

Sampled as a Function of Spherical Angles (Create New and Edit/View Detailed Source…)

The Sampled as a Function of Spherical Angles option scales all the rays in the source to an arbitrary intensity pattern defined in spherical angles. Apodization factors are entered for as a function of azimuth and polar angles. Between the specified azimuth and polar angles, the apodization factor is linearly interpolated. If data is entered for only one Azimuth angle then the apodization profile is considered rotationally symmetric.

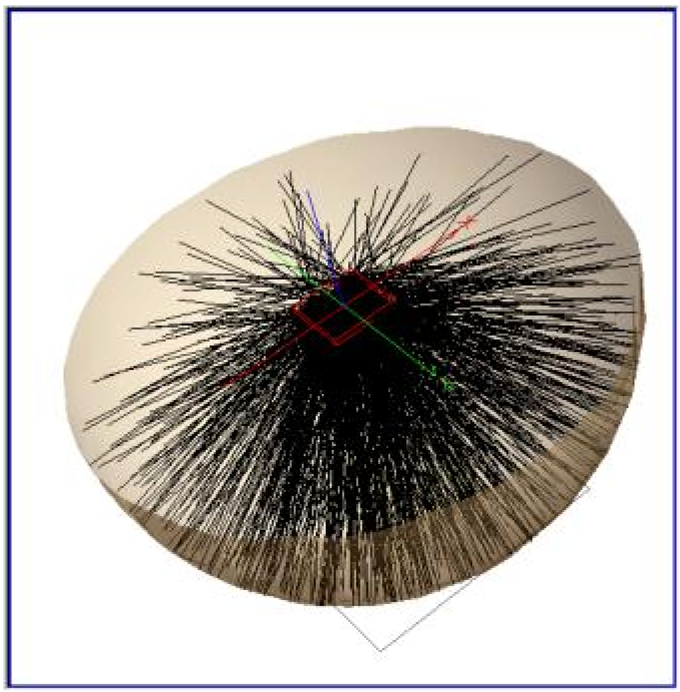
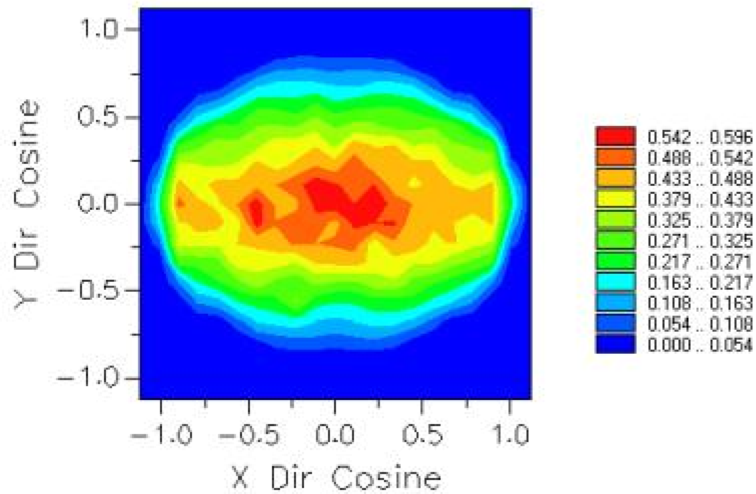


Figure 1. This figure illustrates an Isotropic plane of random rays emitting to a 90^{o} cone with a Sampled as a Function of Spherical Angles apodization.



Direction Apodization

Type:

Sampled as a function of spherical angles

Parameters:

	X	Y	Z	Description
Polar	0	0	1	Direction of polar axis
Azimuth	1	0	0	Direction of azimuth axis

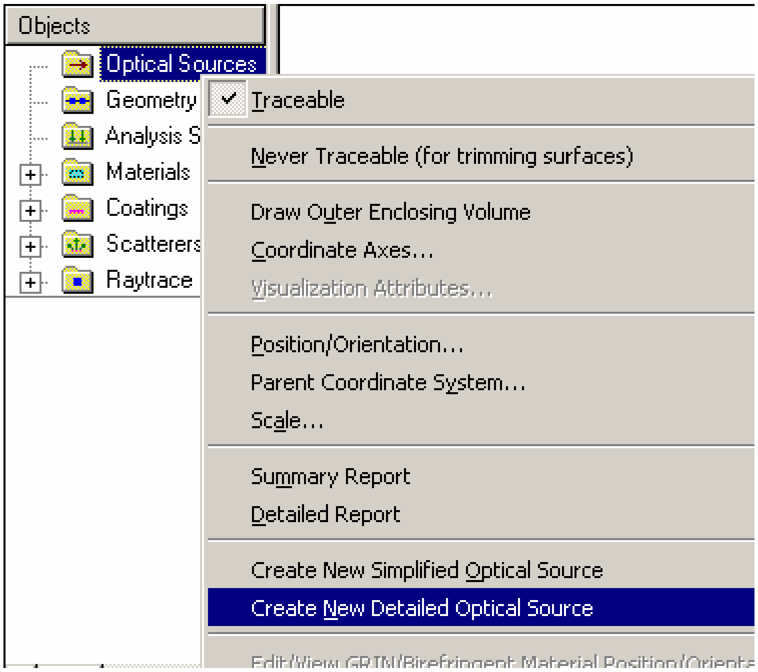
Polar angles(deg) - down, Azimuth angles(deg) - across	-180	-135	-90	-45	0	45	90	135	180
0	1	1	1	1	1	1	1	1	1
10	0.9	0.85	0.8	0.85	0.9	0.85	0.8	0.85	0.9
20	0.8	0.7	0.6	0.7	0.8	0.7	0.6	0.7	0.8
30	0.7	0.55	0.4	0.55	0.7	0.55	0.4	0.55	0.7
40	0.6	0.4	0.2	0.4	0.6	0.4	0.2	0.4	0.6
50	0.5	0.25	0.1	0.25	0.5	0.25	0.1	0.25	0.5
60	0.4	0.1	0	0.1	0.4	0.1	0	0.1	0.4
70	0.3	0	0	0	0.3	0	0	0	0.3
80	0.2	0	0	0	0.2	0	0	0	0.2
90	0	0	0	0	0	0	0	0	0

Figure 2. This Intensity Spread Function plot of an Isotropic source where the rays have been scaled with a Sampled as a Function of Spherical Angles direction apodization. The apodization factors for this pattern are shown as well.

How Do I Get There?

Sampled as a Function of Spherical Angles (Create New and Edit/View Detailed Source…)

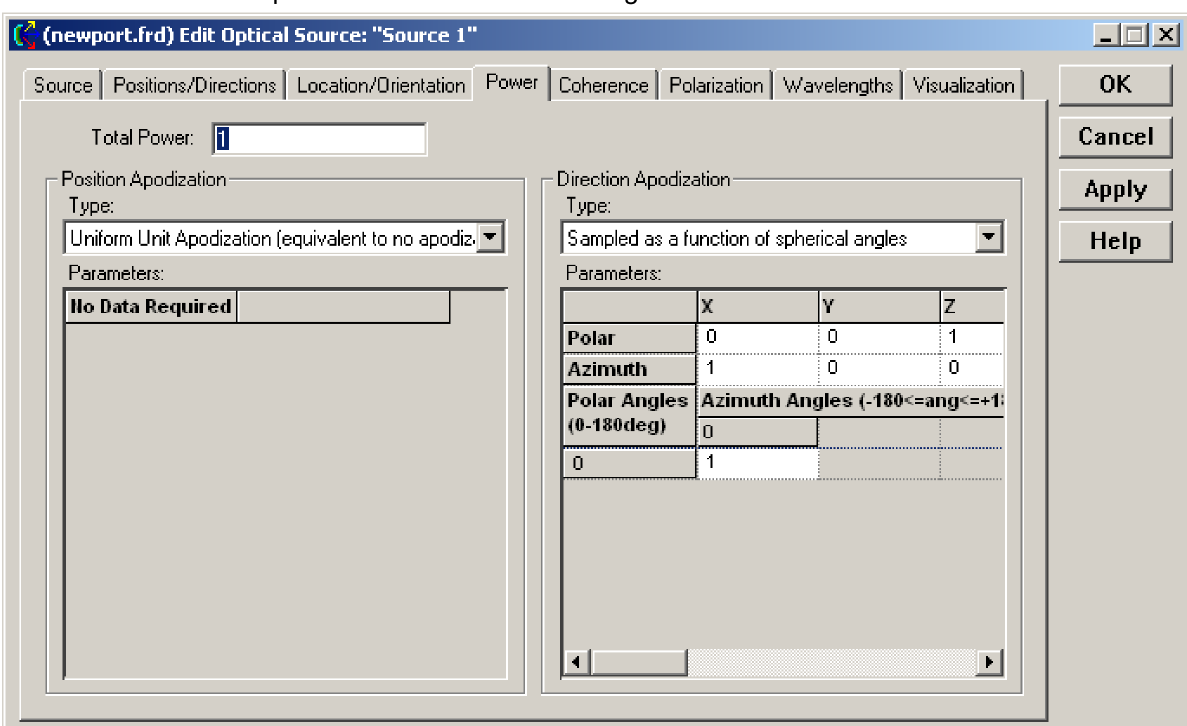
This is an option in the Power page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Sampled as a Function of Spherical Angles (Create New and Edit/View Detailed Source…)

The Direction Apodization section of the dialog:



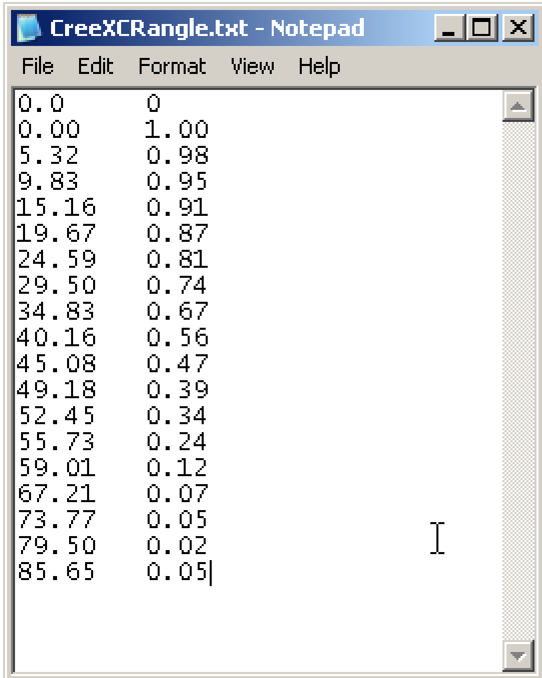
Control	Inputs	Defaults
Total Power	Total power of the source *after* both the position and direction apodization functions have been applied to the rays.	1
Position Apodization		
Type	Pull down menu of available position apodization options.	Uniform
Parameters	There are no parameters for this option.	
Direction Apodization		
Type	Pull down menu of available direction apodization options. Choose **Sampled as a Function of Spherical Angles**.	Uniform
Parameters		
Polar X, Y, Z	Direction of the polar axis in the apodization table.	0, 0, 1
Azimuth X, Y, Z	Direction of the azimuth angle in the apodization table.	1, 0, 0
Polar Angles(deg) – down, Azimuth angles(deg) - across	The apodization table is organized with the rows representing the polar angles and the columns representing the azimuth angles. Additional rows and columns can be added via a right click pop-up menu (shown in the figure above). The azimuth angles **must** be within the range of –180 to 180 and the polar angles **must** be within the range of 0 to 180. Note that previous versions of FRED limited the polar angles to 0 to 90. If polar angle data for only one azimuth angle (column) is entered, then the apodization is assumed to be rotationally symmetric. If polar data is entered for more than one azimuth angle is entered, then apodization for angles in between the entered data in linearly interpolated.	0
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

- Tabulated data can be read into this option using the subroutine below. The file containing the data should have two or more columns. The first row contains the azimuthal angles (Note the first entry in the first column of the first row is a placeholder; its value is irrelavant). Subsequent rows contain the polar angle followed by apodization values. The data format for single/multiple azimuthal angles is shown below.

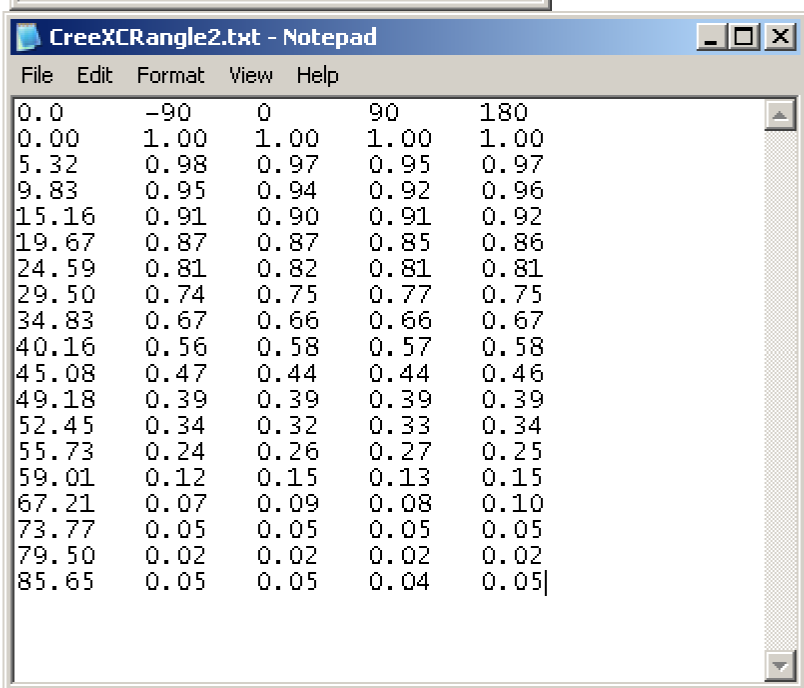
Data Format

*Single azimuthal angle (*rowz=18, colz=2*)*

*Multiple azimuthal angles (*rowz=18, colz=5*)*



0.0	0
0.00	1.00
5.32	0.98
9.83	0.95
15.16	0.91
19.67	0.87
24.59	0.81
29.50	0.74
34.83	0.67
40.16	0.56
45.08	0.47
49.18	0.39
52.45	0.34
55.73	0.24
59.01	0.12
67.21	0.07
73.77	0.05
79.50	0.02
85.65	0.05



0.0	-90	0	90	180
0.00	1.00	1.00	1.00	1.00
5.32	0.98	0.97	0.95	0.97
9.83	0.95	0.94	0.92	0.96
15.16	0.91	0.90	0.91	0.92
19.67	0.87	0.87	0.85	0.86
24.59	0.81	0.82	0.81	0.81
29.50	0.74	0.75	0.77	0.75
34.83	0.67	0.66	0.66	0.67
40.16	0.56	0.58	0.57	0.58
45.08	0.47	0.44	0.44	0.46
49.18	0.39	0.39	0.39	0.39
52.45	0.34	0.32	0.33	0.34
55.73	0.24	0.26	0.27	0.25
59.01	0.12	0.15	0.13	0.15
67.21	0.07	0.09	0.08	0.10
73.77	0.05	0.05	0.05	0.05
79.50	0.02	0.02	0.02	0.02
85.65	0.05	0.05	0.04	0.05

In the following subroutine, it is necessary to enter the dimensions of the text file matrix of numbers for the array angles as constants rows and cols. (Recall that arrays in Enable Basic are zero-indexed.)
This example reads in either of the datasets shown above by changing the value of cols from 2 (for single) to 5 (for multiple).

Subroutine

```
'call and execute subroutine
readdirapoddata "CreeXCRangle"

Sub readdirapoddata (fname As String)
Dim filename As String
Dim filedata As String
Dim values() As Double
Dim strings() As String
Dim numang As Long

Const rowz=18                    'rows of data (not counting the first row)
Const colz=2                   'number of columns
Dim angles(rowz, colz-1) As Double

sid=FindName("Source 1")

filename=CurDir & "\" & fname & ".txt"
numang=0

Open filename For Input As #1
 Do While Not EOF(1)
  Line Input #1, filedata
  n=ParseString(filedata, " ", values, strings)
   For i=0 To colz-1
    angles(numang,i)=values(i)
   Next i
  numang=numang+1
 Loop
Close #1

SetSourceDirApodSampled sid, angles, 1, 0, 0, 0, 0, 1

Print "Source apodized"
Update

End Sub
```

Create Detailed Source – Power - Uniform Direction Apodization

Description

Uniform Direction Apodization

The Uniform Direction Apodization option scales all the rays in the source to have uniform power as a function of ray direction. This is equivalent to having no direction apodization.

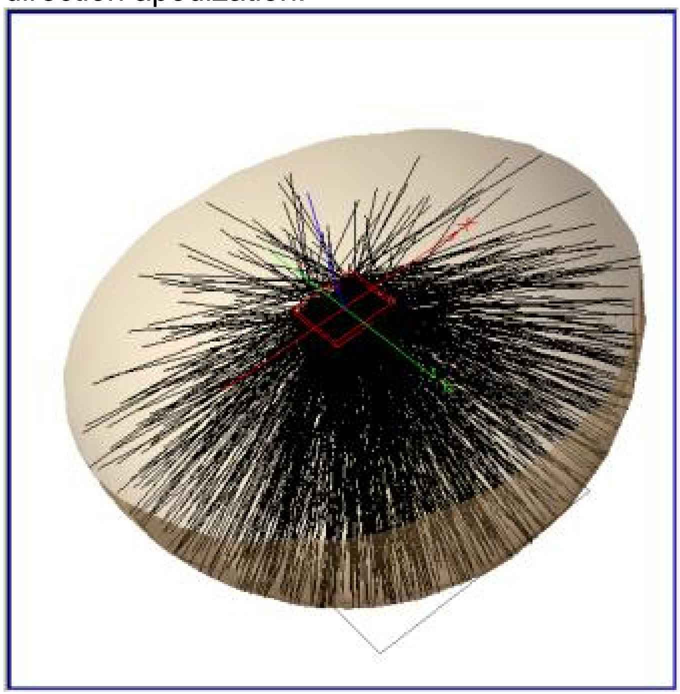


Figure 1. This figure illustrates a plane of random rays emitting to a 90° cone with Uniform Direction Apodization.

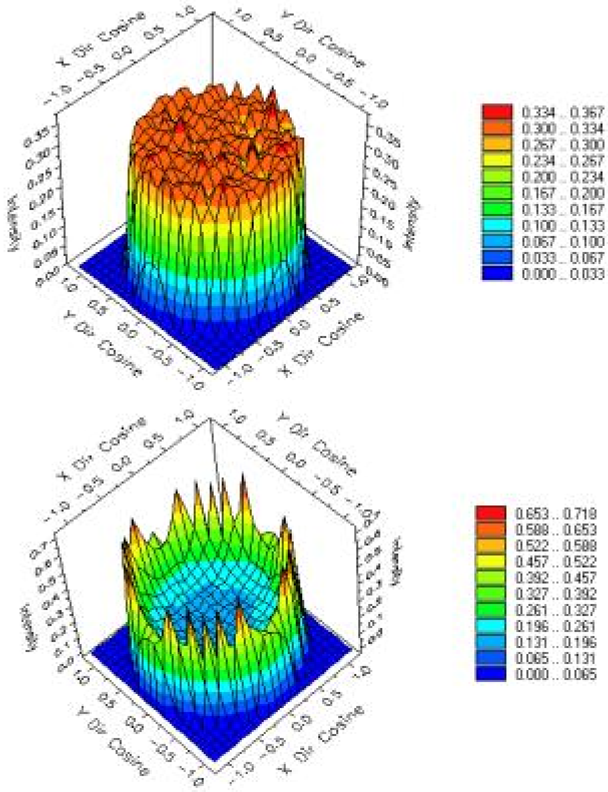
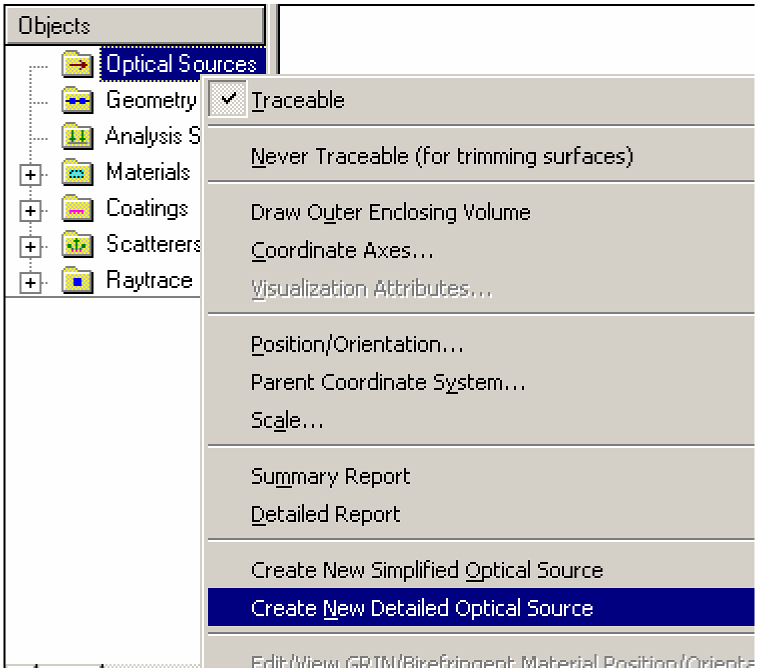


Figure 2. The first Intensity Spread Function plot is for a Lambertian source and the second Intensity Spread Function is for an Isotropic source, both have a Uniform Direction Apodization on the Power page.

How Do I Get There?

Uniform Direction Apodization

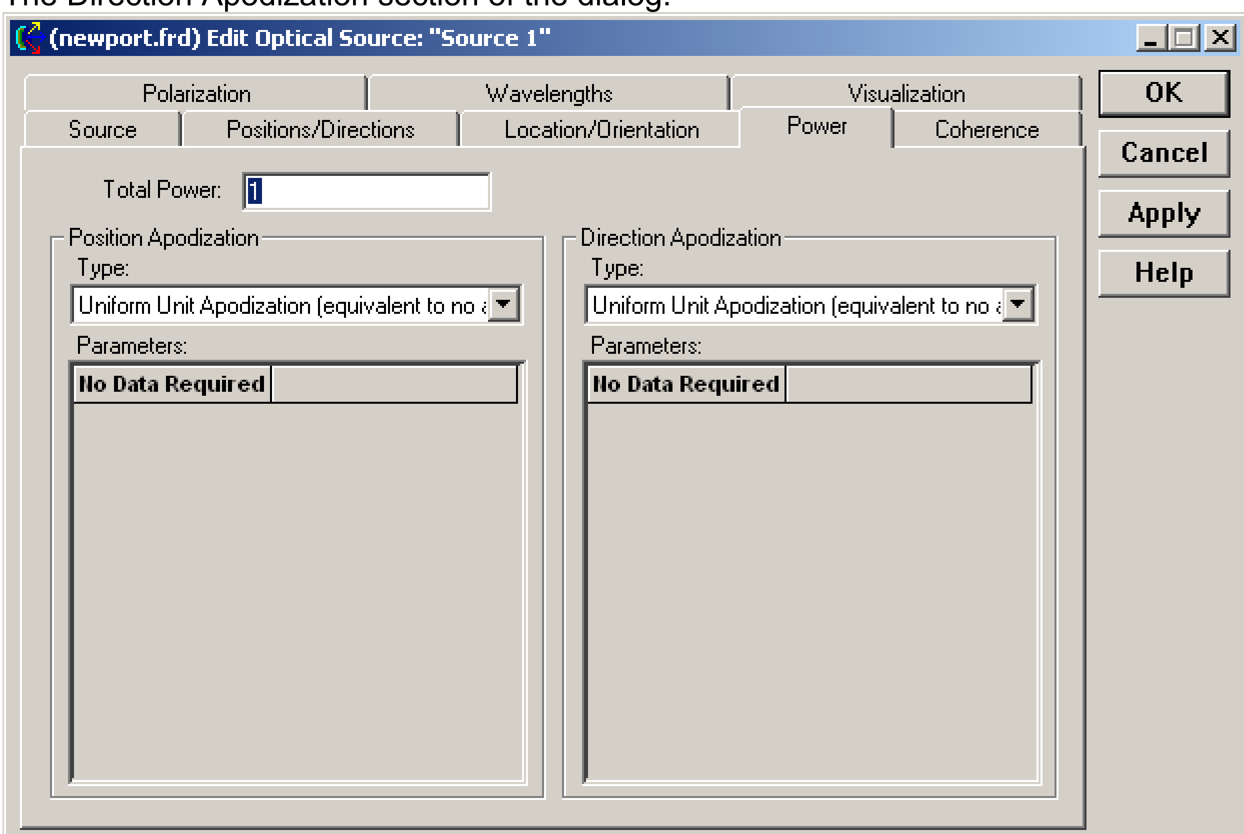
This is an option in the Power page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Uniform Direction Apodization

The Direction Apodization section of the dialog:



Control	***Inputs***	***Defaults***
Total Power	Total power of the source *after* both the position and direction apodization functions have been applied to the rays.	1
Position Apodization		
Type	Pull down menu of available position apodization options.	Uniform
Parameters:	There are no parameters for this option	
Direction Apodization		
Type:	Pull down menu of available direction apodization options.	Uniform
Parameters:	There are no parameters for this option	
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

See Also….
Uniform Direction Apodization

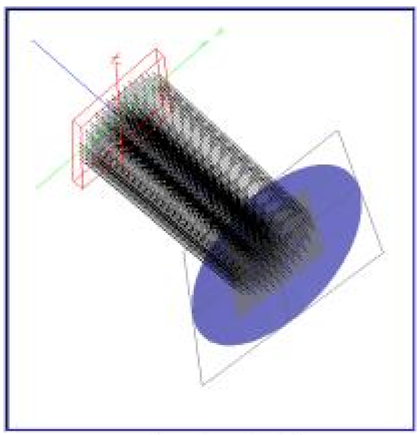
Source
Positions / Directions
Location / Orientation
Power
Coherence
Polarization
Wavelength
Visualization

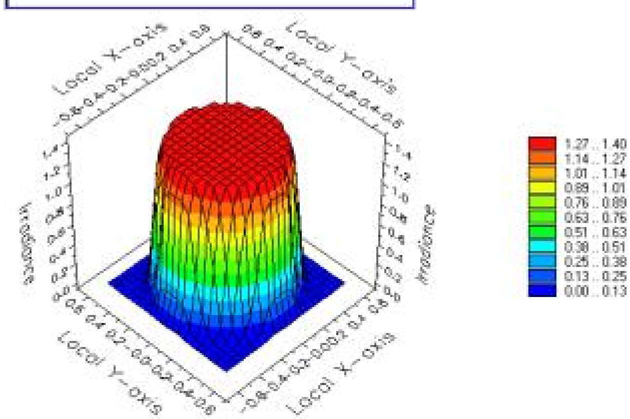
Create Detailed Source – Power - Uniform Position Apodization

Description

Uniform Position Apodization (Create New and Edit/View Detailed Source…)

The Uniform Position Apodization option scales all the rays in the source to have a uniform, equal power as a function of ray positions. This is equivalent to having not apodization.

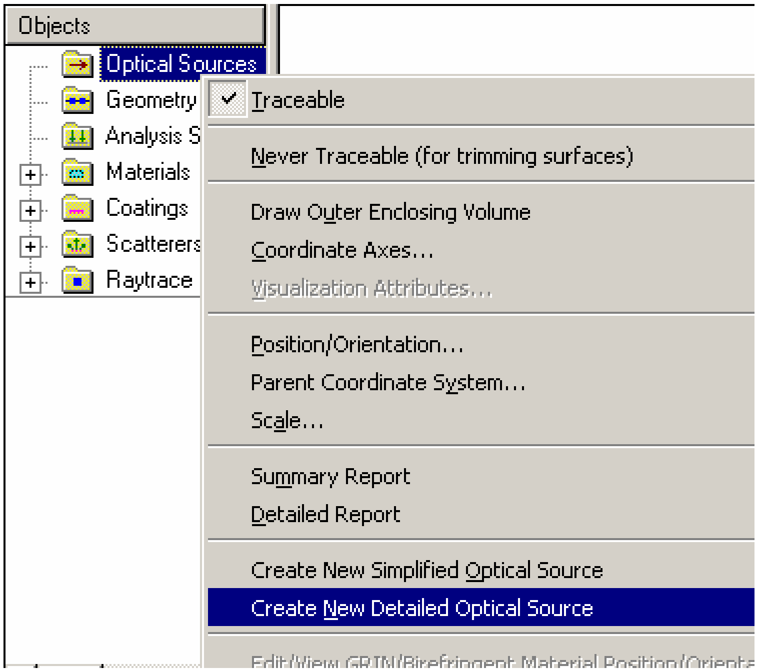




How Do I Get There?

Uniform Position Apodization (Create New and Edit/View Detailed Source…)

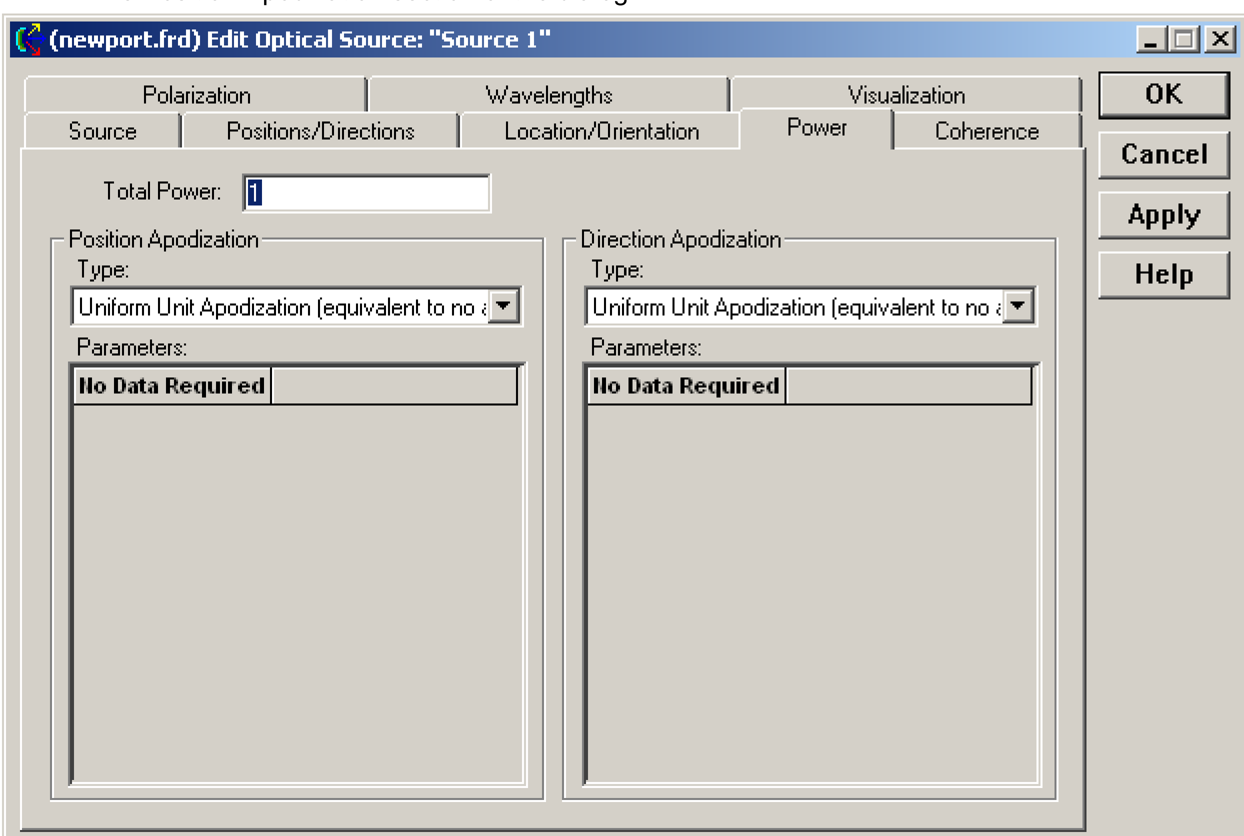
This is an option in the Power page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Uniform Position Apodization (Create New and Edit/View Detailed Source…)

The Position Apodization section of the dialog:



Control	Inputs	Defaults
Total Power	Total power of the source *after* both the position and direction apodization functions have been applied to the rays.	1
Position Apodization		
Type	Pull down menu of available position apodization options.	Uniform
Parameters:	There are no parameters for this option	
Direction Apodization		
Type:	Pull down menu of available direction apodization options.	Uniform
Parameters:	There are no parameters for this option	
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

See Also….
Uniform Position Apodization (Create New and Edit/View Detailed Source…)

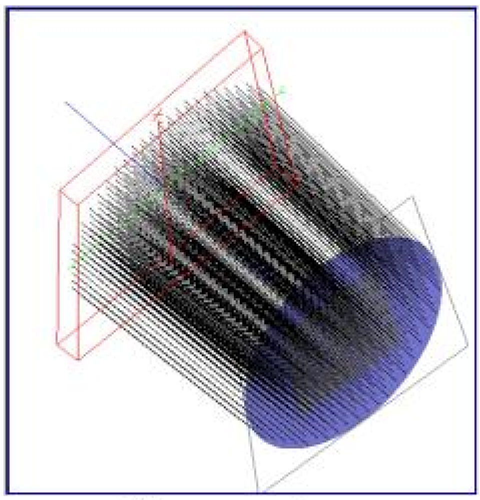
Source
Positions / Directions
Location / Orientation
Power
Coherence
Polarization
Wavelength
Visualization

Create Detailed Source – Power - Gaussian Position Apodization

Description

Gaussian Position Apodization (Create New and Edit/View Detailed Source…)

The Gaussian Position Apodization option scales all the rays in the source to have a Gaussian power profile as a function of ray position. This is useful for modeling laser beams having a TEM_{00} Gaussian mode as well as the higher order Hermite or Laguerre modes. Note that it is important that the bundle of rays is significantly larger than the $1/e^2$ Gaussian power profile semi-diameter parameter set in the Power dialog.



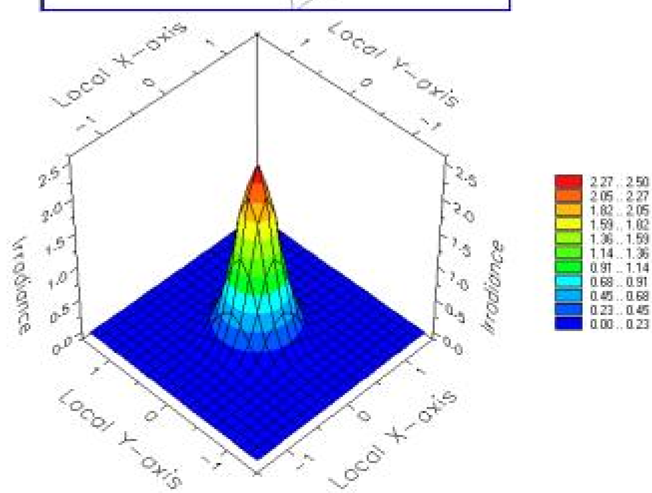


Figure 1. This first image shows the bundle of coherent rays with a 1-inch semi-diameter and the second image shows the Gaussian beam irradiance profile of these rays. Note that the $1/e^2$ Gaussian power profile semi-diameter is of the rays is 0.5.

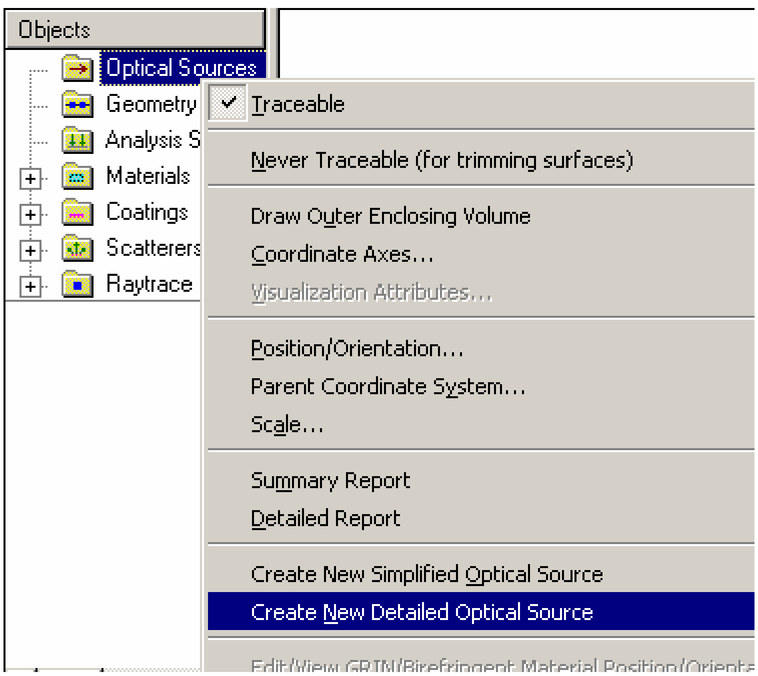
Note	If a complete Gaussian profile is desired, then the beam bundle semi diameter should be roughly 2X larger than the $1/e^2$ Gaussian power profile semi-diameter.

In the coherent case, the Gaussian beam profile is constructed with smaller Gaussian beamlets. As the number of rays in the Position/Direction page is increased, the sampling of the Gaussian profile with the Gaussian beamlets will be increased. As the ray sampling is increased, the diameter of the Gaussian beamlets is decreased resulting in Gaussian beamlets that diverge faster as they propagate. This faster divergence can result in a lower sampling on a later surface. A balance must be maintained between the increasing initial sampling of the Gaussian profile with more rays and decreasing the Gaussian beamlet divergence during propagation with fewer rays.

How Do I Get There?

Gaussian Position Apodization (Create New and Edit/View Detailed Source…)

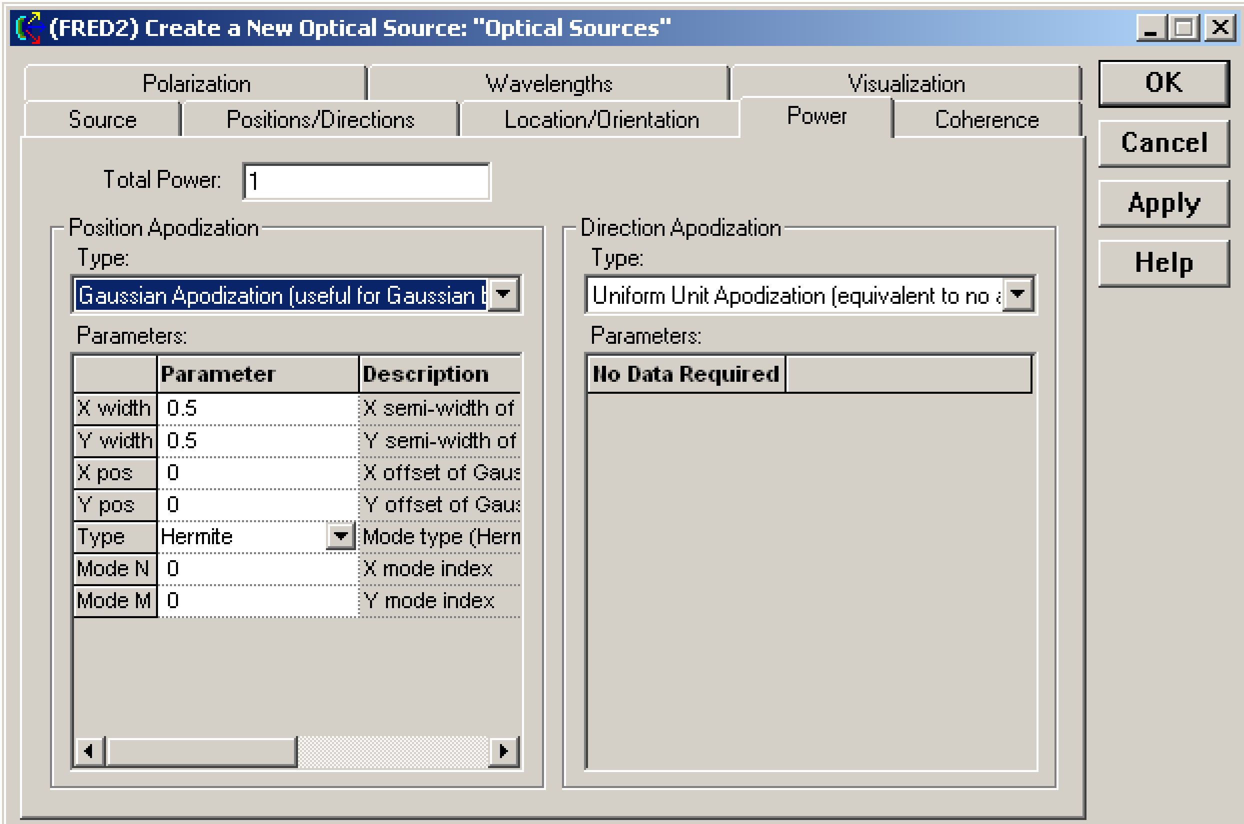
This is an option in the Power page of the Create New Detailed Source… and Edit / View Detailed Source… dialogs.



Dialog Box and Controls

Gaussian Position Apodization (Create New and Edit/View Detailed Source…)

The Position Apodization section of the dialog:


(FRED2) Create a New Optical Source: "Optical Sources"
Polarization
Wavelengths
Visualization
Source
Positions/Directions
Location/Orientation
Power
Coherence
OK
Cancel
Apply
Help
Total Power:
1
Position Apodization
Type:
Gaussian Apodization (useful for Gaussian b
Parameters:
Parameter
Description
X width
0.5
X semi-width of
Y width
0.5
Y semi-width of
X pos
0
X offset of Gaus
Y pos
0
Y offset of Gaus
Type
Hermite
Mode type (Hern
Mode N
0
X mode index
Mode M
0
Y mode index
Direction Apodization
Type:
Uniform Unit Apodization (equivalent to no a
Parameters:
No Data Required

Control	Inputs	Defaults
Total Power	Total power of the source *after* both the position and direction apodization functions have been applied to the rays.	1
Position Apodization		
Type	Pull down menu of available position apodization options. Choose **Gaussian Apodization**.	Uniform
Parameters		
X width	X semi-width of $1/e^2$ (13.5%) Gaussian power profile.	0.5
Y width	Y semi-width of $1/e^2$ (13.5%) Gaussian power profile.	0.5
X pos	X axis offset of the Gaussian power profile.	0
Y pos	Y axis offset of the Gaussian power profile.	0
Direction Apodization		
Type	Select Mode Type: *Hermite* *Laguerre* *Laguerre Cosine* *Laguerre Sine*	Hermite
Mode N	Hermite X or Laguerre radial mode number.	0
Mode M	Hermite Y or Laguerre azimuth mode number.	0
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

Create Detailed Source – Power - Amplitude/Phase Mask Modify Values

Description

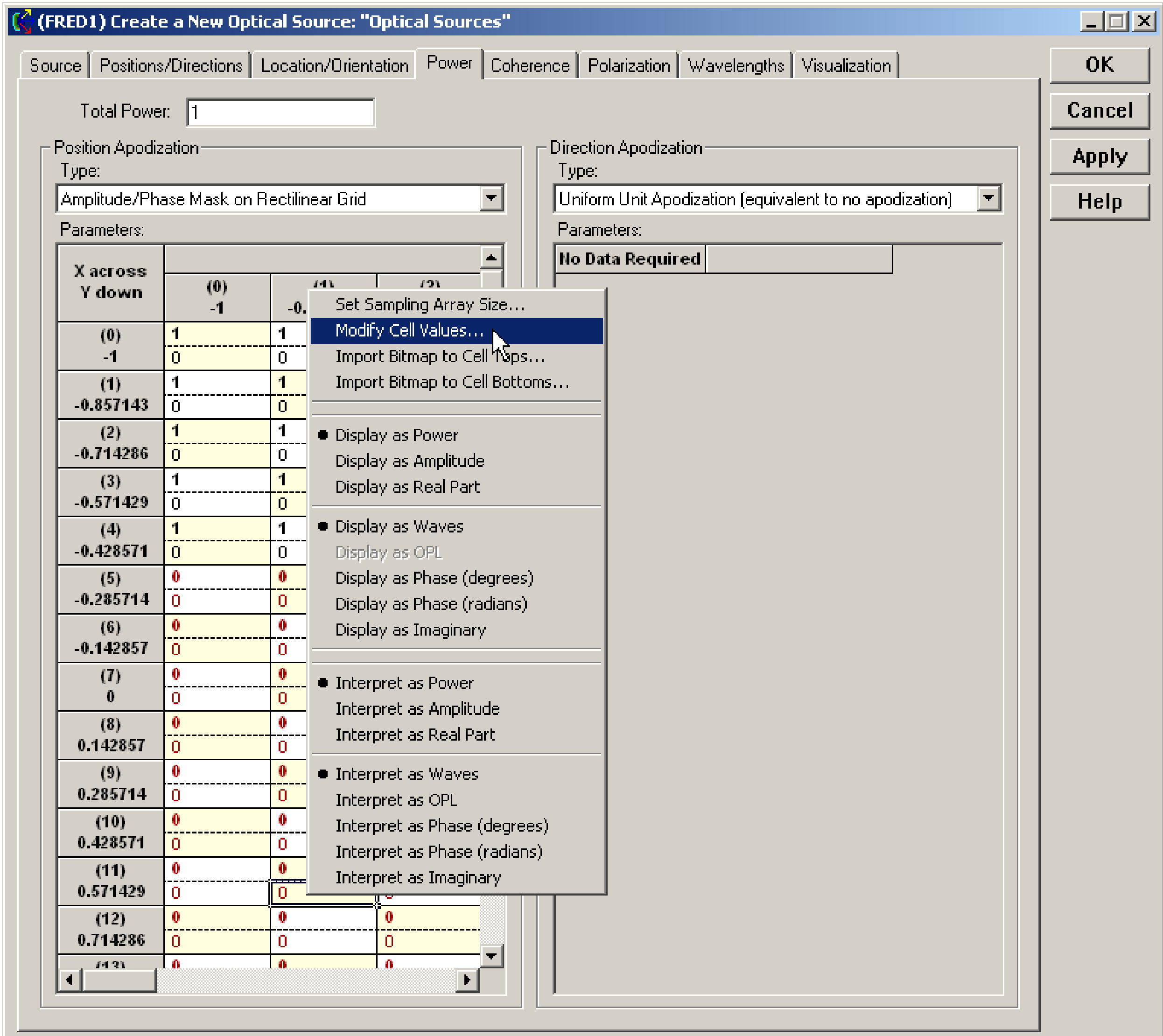
Amplitude/Phase Mask Modify Values

Specifies a subsection of the field data and modifies amplitude or phase values.

How Do I Get There?

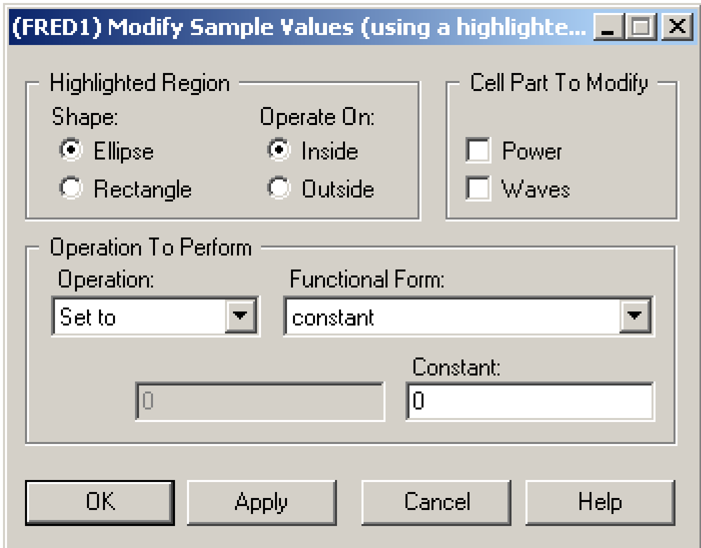
Amplitude/Phase Mask Modify Values

Modification of the Amplitude/Phase Mask values is accessed through the Detailed Source Power Tab dialog by right-clicking in the data values area:



Dialog Box and Controls

Amplitude/Phase Mask Modify Values



Control	Inputs / Description	Defaults
Highlighted Region		
Shape	Choose Ellipse or Rectangle	Ellipse
Apply the operation to	Inside or outside region	Inside
Cell Part To Modify		
Power/Waves	Modify the Power (cell tops) or Waves (cell bottom)	Unchecked
Operation to Perform		
Operation	Select from: *Set To* *Multiply by* *Add To*	Set To
Functional Form	Choose from: *Constant* *Linear (aX + bY)* *Quadratic (aX*X + bY*Y)* *Gaussian*	Constant
Input Values	Enter the (a,b) coefficients or 1/e widths per Function Form	0
OK	Accept modifications and close dialog box.	

Cancel	Discard modifications and close dialog box.	
Apply	Apply modifications and keep dialog box open.	
Help	Access this Help page.	

Application Notes

Amplitude/Phase Mask Modify Values

See Also….

Amplitude/Phase Mask Modify Values

Amplitude/Phase Mask

Sizing the Amplitude/Phase Mask

Chapter 5 - Geometry Topics and Examples

This section has examples and topics concerning building geometry in FRED.

- Element Versus Custom Element
- Introduction to Curves
- Trimming Surfaces with Collections Curves

Creating a New Surface…

Description

How Do I Get There?

Dialog box and Controls

Description - Creating a New Surface…

Surfaces can be added to elements and custom elements only. They cannot be added to the geometry node or a sub-assembly directly. For example, to add a surface to a new Fred file, first create a new Custom Element or a new Element (Lens, Doublet, or Prism) via the right mouse click menu in the Geometry folder. Then add the surface to the element, also via the right mouse click menu. Note, that if a surface is added to an Element then the Element is converted to a Custom Element.

The Creating a New Surface… dialog is very flexible and has many options. In spite of the number of options, adding a surface to an element is generally fairly simple. Follow these basic steps to enter a surface. At each steps, press the Apply button, to see the effects of the changes on the surface as you create and edit the surface. Some of the steps are not applicable to all Surfaces and all of the steps have defaults values so some of the steps can be disregarded if the defaults are acceptable.

1. Expand the Geometry folder in Tree View (left mouse clicking on the ⊞)
2. Right-click on the Custom Element to add the new surface to,
3. Choose "Create New Surface..." from the pop-up menu and a dialog box with ten separate pages will open.
4. Select the desired Surface type.
5. Adjust the Trimming Volume, i.e. aperture, of the surface.
6. Trim the surface with other Surfaces and/or Collection Curves.
7. Position the surface using Location Primitives.
8. Select the materials for both sides of the Surface.
9. Select the Coating for the Surface.
10. Select the Ray Control for this Surface.
11. Assign desired Scatter Properties.
12. Adjust the Visualization of this Surface
13. Apply Glue layers between adjacent Surfaces
14. Apply Gratings to Surface

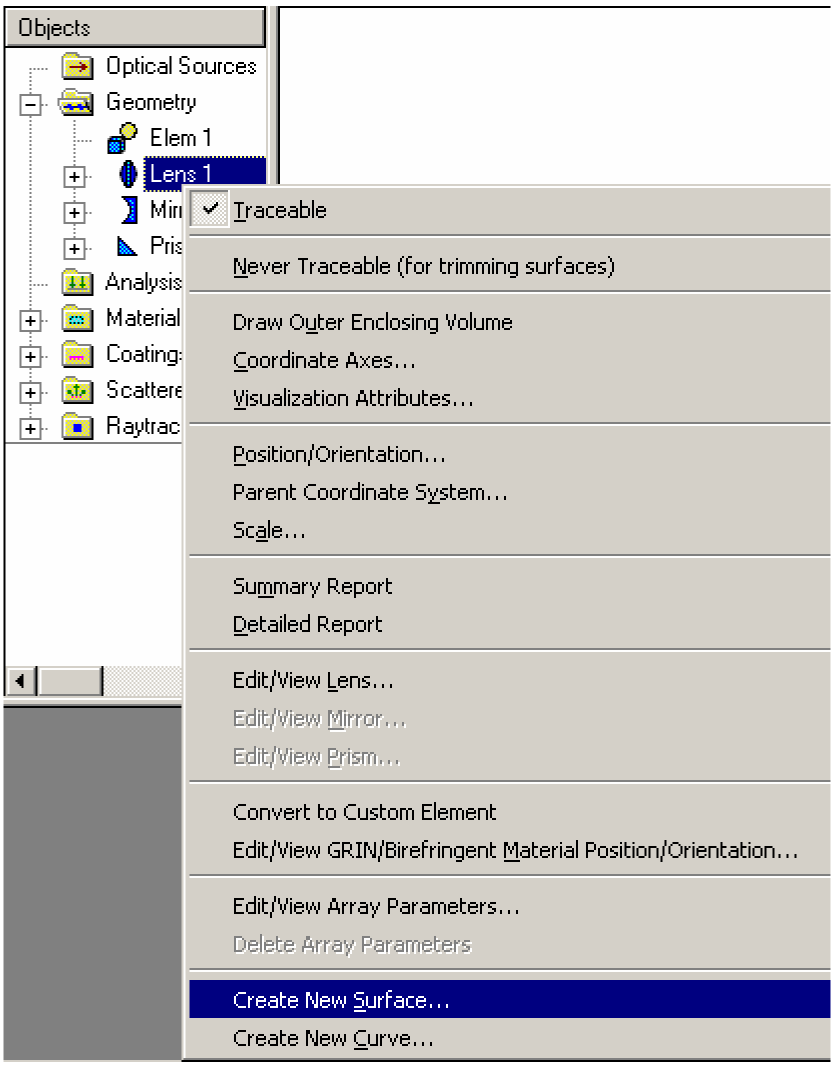
All of the ray traced objects in the geometry model are constructed with surfaces, i.e. there are no singular objects that represent a *volume* in FRED. "Volumes" are instead constructed of multiple surface objects. For example, a rectangular box is constructed from six plane surfaces. All lens, doublet, and prism elements that can be directly entered in to FRED are also collections of curves and surfaces. By the way, Curves in FRED are used to construct or trim surfaces but are not themselves ray traced.

The default surface type is a plane but there are many surface types available, including those common to most lens design programs as well as the more general surface representations found in many CAD programs.

NOTE: If you add a surface to a mirror, singlet, or doublet element, then the element automatically becomes a custom element.

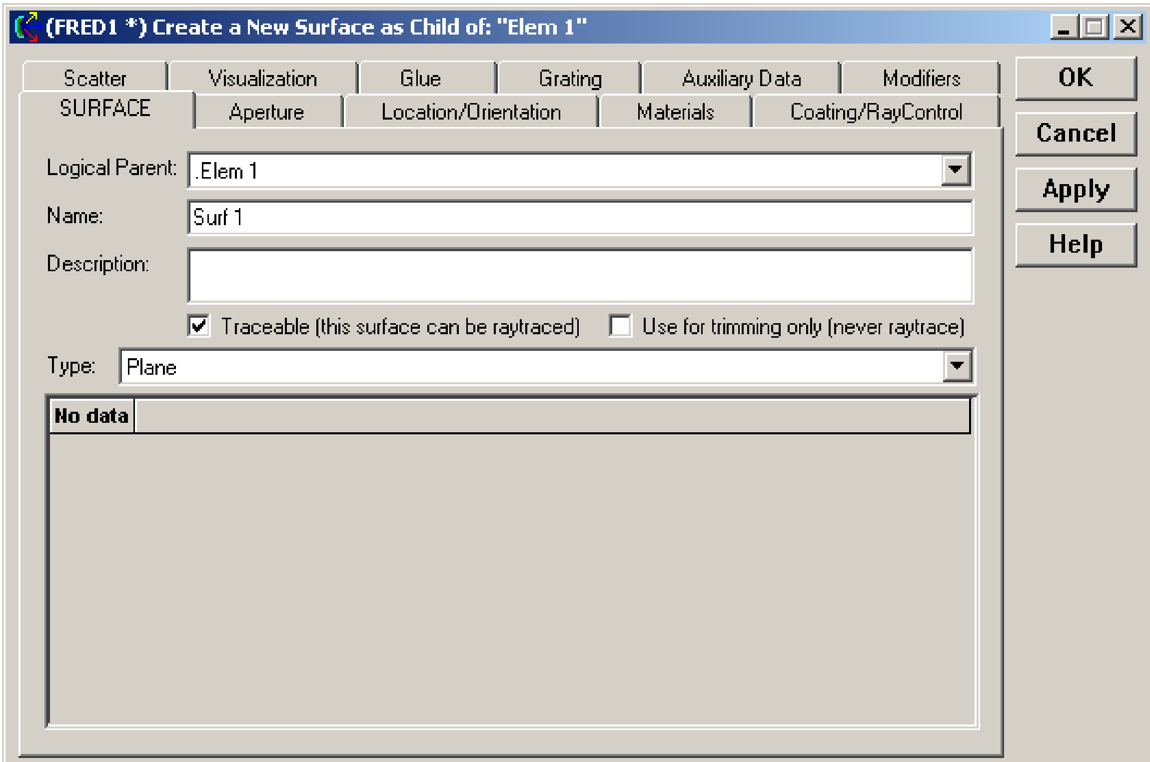
How Do I Get There? - Creating a New Surface...

Right click on the element to which you want to add surface, then select "Create New Surface…":



Dialog Box and Controls - Creating a New Surface...

There are ten tabs in the Create a New Surface… dialog box. Each page has a help file. There are hotlinks to these help files below.



Help files for each page in this dialog are available at the following hotlinks.

- The surface type page
- The aperture page
- The location/orientation page
- The materials page
- The coating / ray control page
- The scatter page
- The visualization page
- The glue page
- The grating page
- The Auxiliary Data page

Edit/View Surface...

Description - Edit / View Surface...

The **Edit / View Surface…** dialog is very flexible and has many options. In spite of the number of options, editing / viewing a surface is generally fairly simple. The following options are available when editing a surface. At each steps, press the **Apply** button to see the effects of the changes on the surface as you edit the surface. Some of the steps are not applicable to all **Surfaces** and all of the steps have defaults values so some of the steps can be skipped.

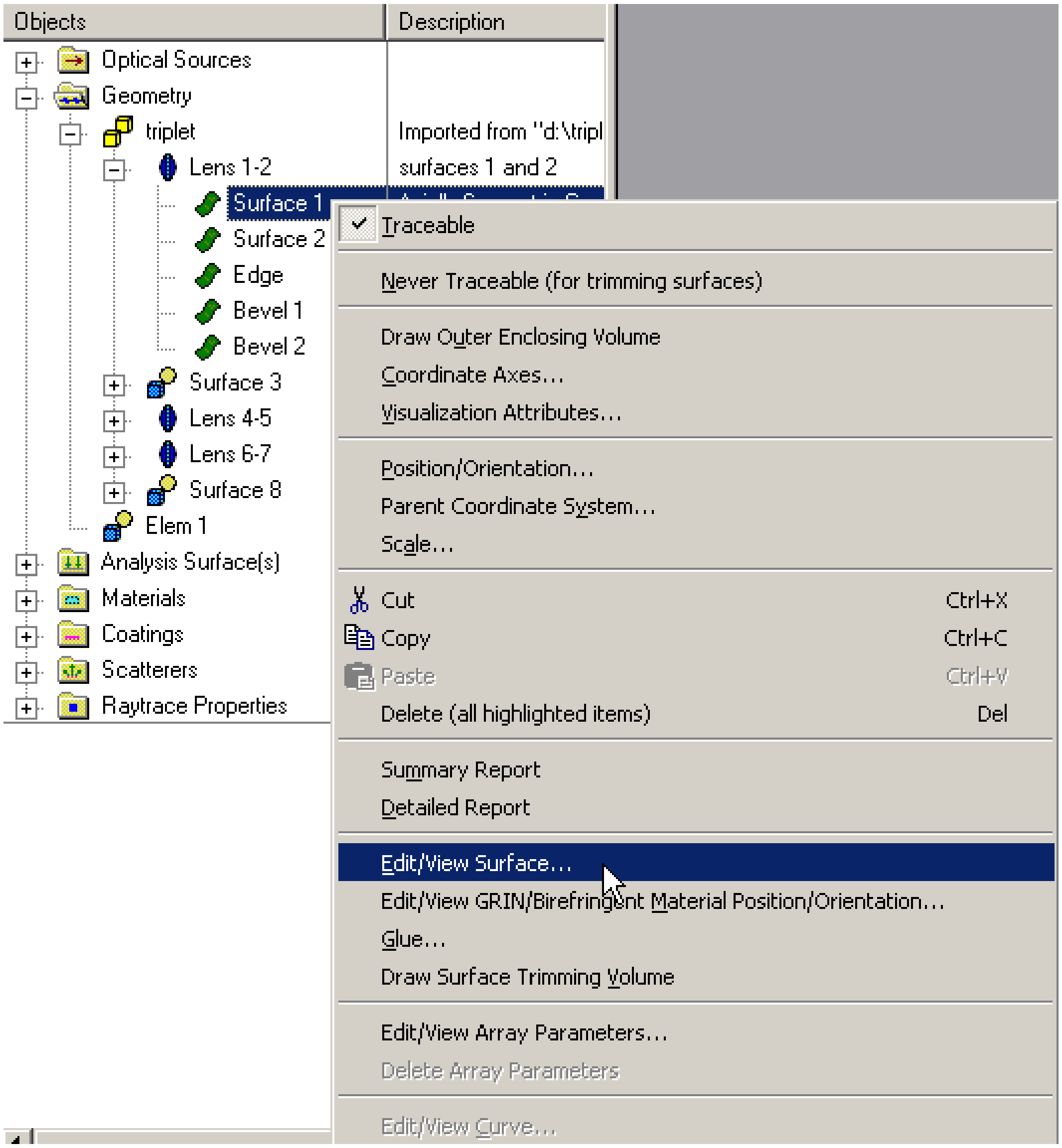
1. Expand the **Geometry** node in Tree View (left mouse clicking on the ⊞ or double click on the **Geometry** node)
2. Expand the **Custom Element** or **Element** node containing the surface to be edited (left mouse clicking on the ⊞),
3. Double click on the surface or right mouse click on the surface choose "**Edit / View Surface...**" from the pop-up menu
4. A dialog box with nine separate pages will open. The **Edit / View Surface…** dialog is exactly the same as the **Create New Surface…** dialog. A description for the available operations on each page is provided below.

- Select the desired **Surface** type.
- Adjust the **Trimming Volume**, i.e. aperture, of the surface.
- Trim the surface with other defined **Surfaces** and/or **Collection Curves**.
- Position the surface using **Location Primitives**.
- Select the materials for both sides of the **Surface**.
- Select the **Coating** for the **Surface.**
- Select the **Ray Control** for this **Surface**.
- Assign desired **Scatter Properties**.
- Adjust the **Visualization** of this **Surface**
- Apply **Glue** layers between adjacent **Surfaces**
- Apply **Gratings** to **Surface**

How Do I Get There? - Edit / View Surface...

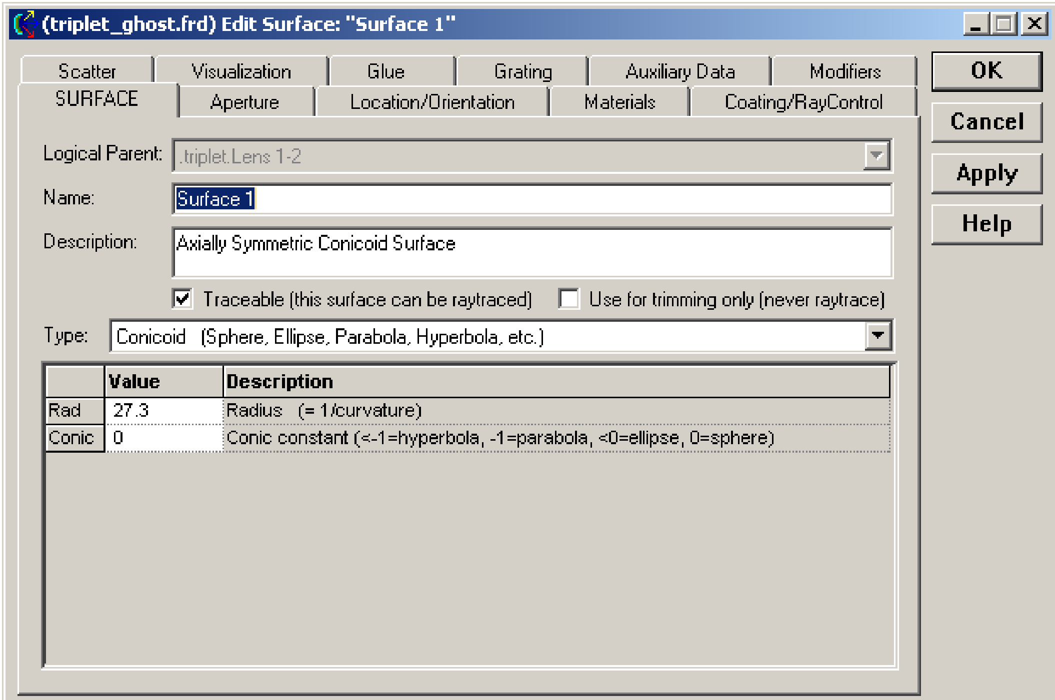
There are two different ways to execute this command:

1. Double click with the left mouse button on the surface to be edited.
2. Right click on a surface and choose "Edit / View Surface…".



Dialog Box and Controls - Edit / View Surface…

There are nine tabs in the **Edit View Surface…** dialog box. Each page has a help file. There are hotlinks to these help files below.



Help files for each page in this dialog are available at the following hotlinks.

- The surface type page
- The aperture page
- The location/orientation page
- The materials page
- The coating / ray control page
- The scatter page
- The visualization page
- The glue page
- The grating page

Applying Aperture, Trimming Volumes, and Trimming Objects

- Description
- How Do I Get There?
- Dialog box and Controls

Description

Applying Aperture, Trimming Volumes, and Trimming Objects

This dialog page allows the user to set the trimming volume outer and inner volumes. The trimming volume can be a box, ellipsoid, or cylinder. The trimming volume can also have an inner-hole (elliptical or rectangular, on-axis or decentered).

In addition, the user can trim the surface with dot products, other surfaces, and collection curves using the trimming Surfaces Specifications section on the aperture page of this dialog. A surface can be trimmed with multiple surfaces and collection curves using logical statements (AND, OR, grouping parentheses "( )", and NOT).

NOTE: Although Surfaces may be trimmed with Collection Curves, they cannot be trimmed with regular Curves, Ruled Surfaces, Extruded Surfaces, or any other surface that is generated from curves. This is because the implementation of regular Curves, Ruled Surfaces, and Extruded Surfaces does not have a mathematical form that allows for quickly evaluating what side of the object that the surface to be trimmed is on.

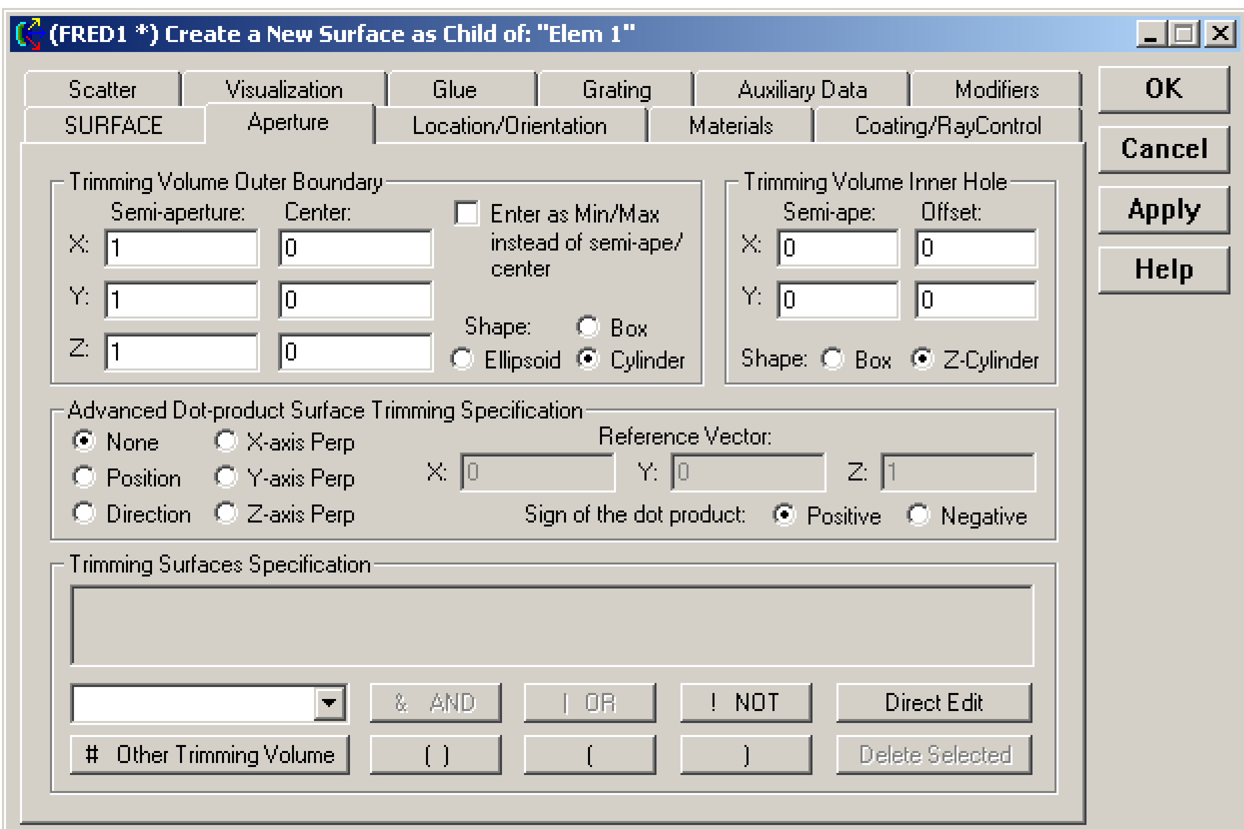
How Do I Get There?

Applying Aperture, Trimming Volumes, and Trimming Objects

This page is in the Create New Surface… and Edit/View Surface… dialogs.

Dialog Box and Controls

Applying Aperture, Trimming Volumes, and Trimming Objects



Control	Inputs	Defaults
Trimming Volume Outer Boundary		
Semi-aperture	X,Y,Z semi-diameters or min/max dimensions of the trimming volume outer.	1,1,1
Center	Trimming volume X,Y,Z center.	0,0,0
Shape	Ellipsoid, Box, Cylinder	Cylinder
Trimming Volume Inner Hole		
Semi-ape, offset	X,Y semi-diameters and offset for an inner hole boundary of the trimming hole.	Semi-ape 0,0 Offset 0,0
Shape	Box or Z-cylinder	Z-cylinder
Advanced Dot Product Surface Trimming Specification		
None Position Direction X/Y/Z axis perpendicular	Establishes the boundaries of a surface based on the local surface normal dot product with a given fixed vector. This would, for example, allow the user to exclude half of a sphere.	None
Reference Vector	Direction cosines of reference vector	0,0,1
Sign of Dot Product	Positive or negative dot product sign	Positive
Trimming Surface Specification		
Trimming Expression	Boolean expression for surfaces, collected curves and/or trimming volumes used for trimming.	blank
Dropdown	FRED surfaces, collected curves	blank
Operations	Boolean AND, OR, NOT and ()	
Direct Edit	Allows direct edit of Trimming Expression.	
Delete Selected	Deletes highlighted from Trimming Expression.	
# Other Trimming Volume	Use other FRED surfaces, collected curves from dropdown in Trimming Surface.	
OK	Accept Aperture changes and close dialog box.	
Cancel	Discard Aperture changes and close dialog box.	
Apply	Apply Aperture changes and keep dialog box open.	

Help	Access this Help page.	

See Also
Applying Aperture, Trimming Volumes, and Trimming Objects

Follow this link to Trimming Examples......

Applying Location Primitives

Description
Applying Location Primitives

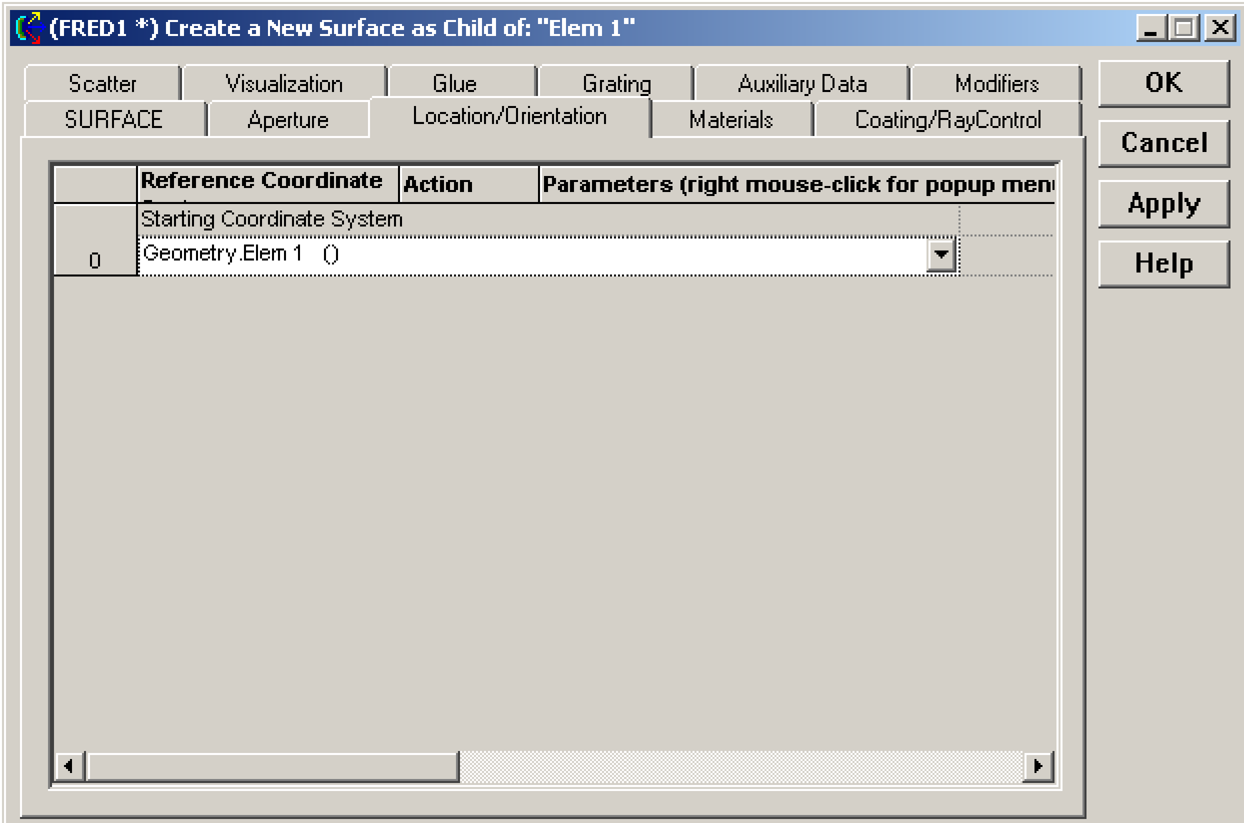
The position of a FRED entity can be set to any location and any rotation using the location primitives. In addition, each **Location Primitive**'s operation, i.e. linear transformation, can be made relative to the global coordinate system or the coordinate system of any defined FRED entity (**Surface**, **Curve**, **Custom Element**, **Element**, or **Sub-Assembly**). The coordinate system of the **Location Primitive** is called the **Parent** coordinate system.

NOTE The **Location Primitives** operate relative to the origin of the **Parent** coordinate system, which is not always the center of the object. If uncertain of where the origin of a coordinate system is, make the **Coordinate Axes** for that system visible via the right mouse click pop-up menu.

How Do I Get There?
Applying Location Primitives

This page is in the Surface Creation and Editing dialogs, as well as the Curve Creation and Editing dialogs.

Dialog Box and Controls
Applying Location Primitives



Control	*Inputs*	*Defaults*
Reference Coordinate System	The coordinate system / origin from which or about which the location modifier will operate can be selected from the drop down menu.	The parent coordinate system (system the surface was created in)
Action	The type of location modifier / primitive can be selected from the drop down menu.	Make coincident with the another coordinate system
Parameters	The parameters associated with the location modifier / primitive, i.e. distance or angle.	0

OK	Accept Location/Orientation changes and close dialog box.	
Cancel	Discard Location/Orientation changes and close dialog box.	
Apply	Apply Location/Orientation changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes

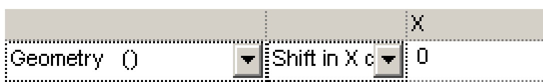
Applying Location Primitives

- 

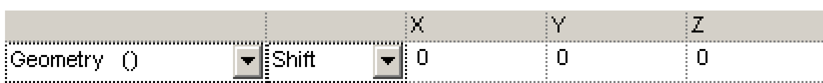
Reparent - Reparent the coordinate system to make it coincident with another coordinate system.

- 

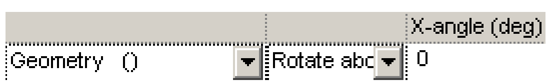
Place at - Place surface at specific XYZ point.

- 

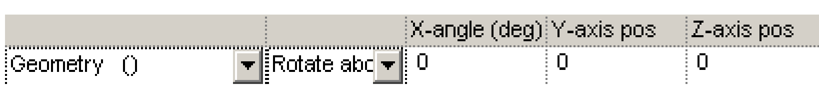
Shift in X, Y or Z - Shift only along the chosen coordinate direction.

- 

Shift - Shift in each of the three coordinate directions.

- 

Rotate about X, Y or Z - Rotate by the given angle about the selected coordinate system origin.

- 

Rotate about X,Y or Z through point YZ, XZ, or XY - Rotate by the given angle about a vector parallel to the given coordinate axis passing through the given point.

- 

Rotate about given direction - Rotate by the given angle about an arbitrary direction given by its direction cosines.

		Angle (deg)	X-pos1	Y-pos1	Z-pos1	X-pos2	Y-pos2	Z-pos2
Geometry ()	Rotate abc	0	0	0	0	0	0	1

  Rotate about given direction through point XYZ - Rotate by the given angle about a vector whose end points as X1,Y1,Z1 and X2,Y2,Z2.

		X-dir1	Y-dir1	Z-dir1	X-dir2	Y-dir2	Z-dir2	X-pos	Y-pos	Z-pos	Preserve nex	X-dir3
Geometry ()	Rotate one	0	0	1	0	0	1	0	0	0	☑ Preserve	0

  Rotate one vector into another vector - Rotate by the given angle from one vector direction into another vector direction. 'Preserve next' indicates that the vector direction Xdir3, Ydir3,Zdir3 should be in the new local coordinate system should be preserved (as much as possible) with respect to the original orientation of the Xdir3, Ydir3,Zdir3 direction.

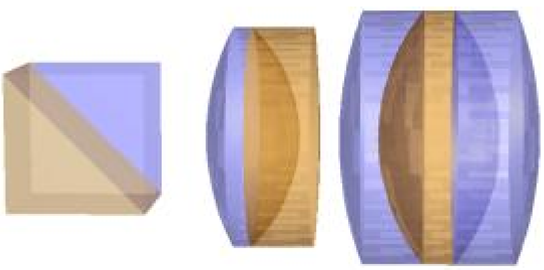
		R00	R01	R02	R10	R11	R12	R20	R21	R22	X	Y
Geometry ()	General r	1	0	0	0	1	0	0	0	1	0	0

  General Matrix - General matrix operation. The first nine elements denote rotation while the last three denote translation.

Applying Glue

Description - Applying Glue

In the development of FRED, every effort was made to realistically represent optical components as they are built in the real world. For example Doublets, triplets, and beamsplitters are modeled in FRED using a **Glue** layer between adjacent optical components. The adjacent components are placed in close proximity but not touching and a glue layer is applied between the appropriate surfaces. The three components below all have glue layers.



WARNING Multiple surfaces in FRED should not be made precisely coincident because there might be an ambiguity on which surface is being intersected by a ray. This ambiguity may result in errors that halt the ray.

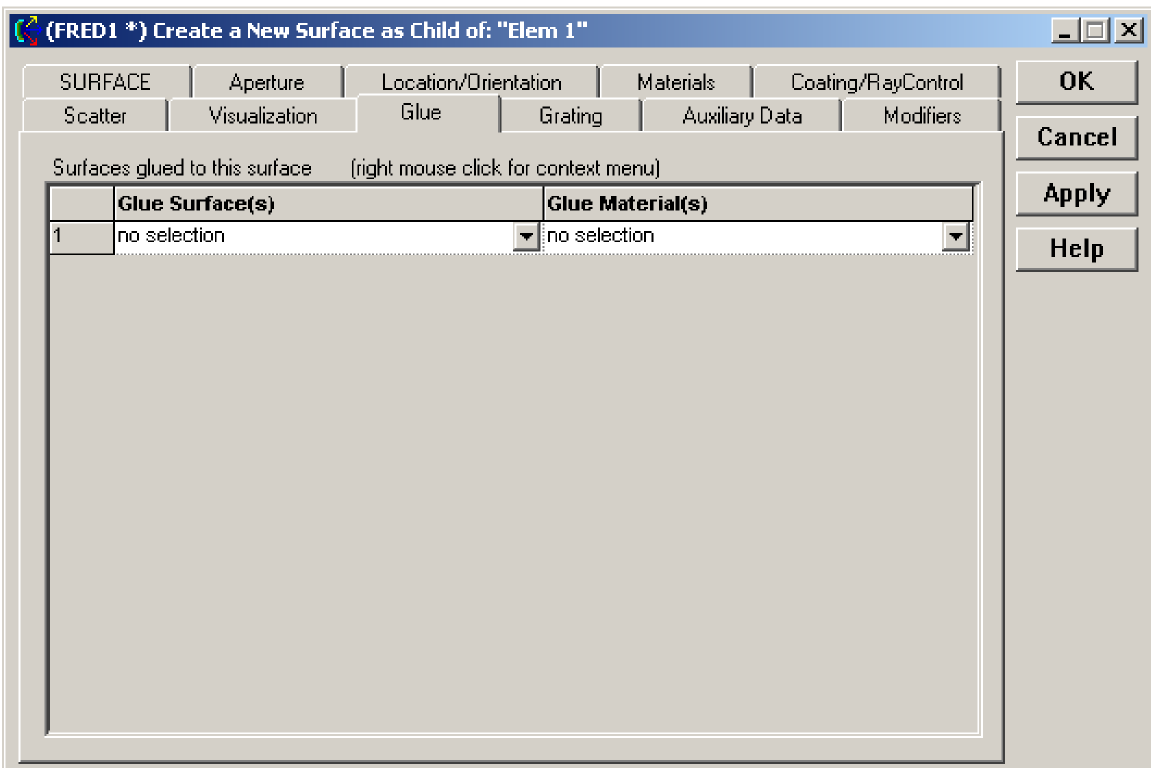
The mechanism for modeling glue between the surfaces is the **Glue** command. The **Glue** command allows the user to select the glue material and which surface to be glued to the surface being edited. More than one surface may be glued to the surface being edited and different glue materials maybe used between each surface pairs.

When the a ray intersects a surface with glued surfaces FRED first checks to see if the ray, when propagated forward, will intersect with the glued surface(s). If it will intersect, then the ray is traced assuming the glue material is present. If it does not intersect a glued surface, then it propagates assuming there is no glue. Raytracing glue layers is elucidated in the Glue layer raytracing example.

How Do I Get There? - Applying Glue

This page is in the **Create New Surface…** and **Edit/View Surface…** dialogs.

Dialog Box and Controls - Applying Glue



Control	*Inputs*	*Defaults*
Surfaces glued to this surface		
Glue Surface(s)	All the surfaces in the geometry are listed in the glue surface pull down menu.	No selection
Glue Material(s)	All the materials in the geometry are listed in the glue surface pull down menu.	No selection
OK	Create a new Surface and close dialog box.	
Cancel	Discard new Surface and close dialog box.	
Apply	Apply Glue changes and keep dialog box open.	
Help	Access this Help page.	

Examples - Applying Glue

See the Glue layer raytracing example.

ASAP Import

Description

ASAP Import

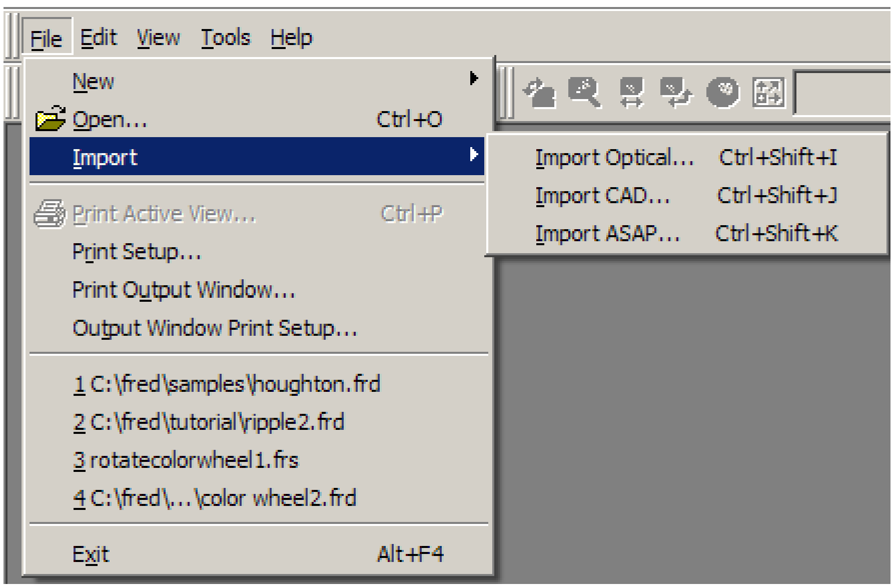
FRED can import geometry from ASAP.

How Do I Get There?

ASAP Import

There are two different ways to execute this command:

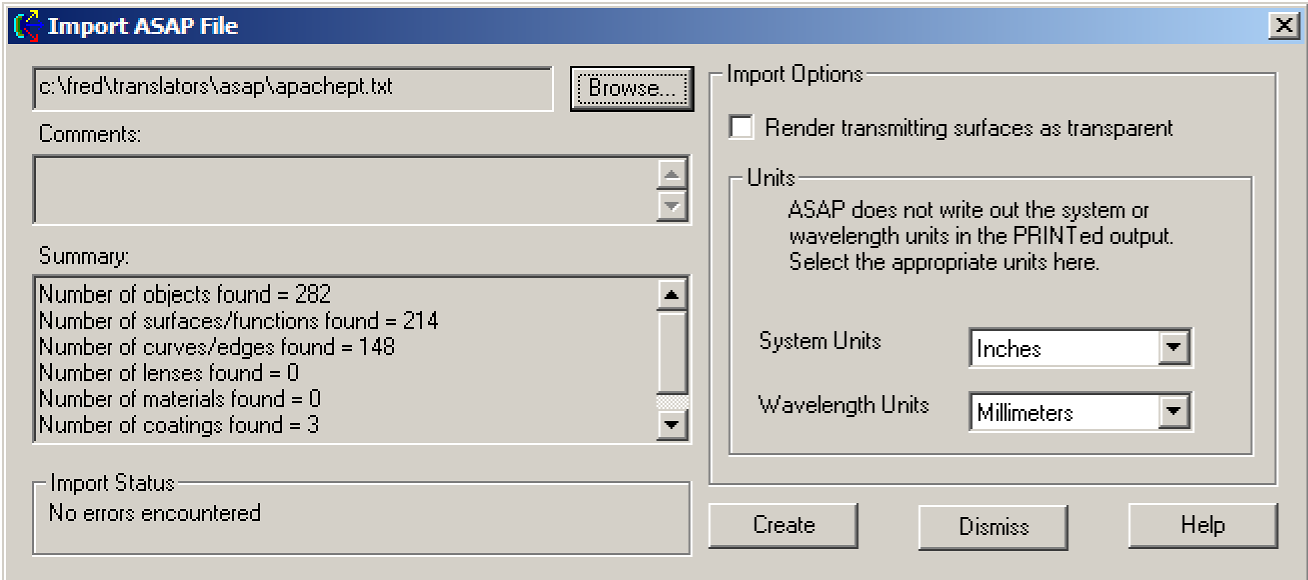
1. Menu



2. Keyboard Accelerator - Ctrl+Shift+K

Dialog Box and Controls

ASAP Import



Control	***Inputs / Description***	***Defaults***
Browse...	Choose the ASAP file to be imported. (see App Note)	
Comments	Text comments from imported file.	
Summary	Summary of imported file contents.	
Import Status	Reports import status.	
Import Options		
Render transmitting surface as transparent	Transmitting surfaces are given a "Transmit" coating and "Transmit Specular" Raytrace Control.	Unchecked
Units	Select System units and wavelength units for import.	Inches, Millimeters
Create	Create FRED model and keep dialog box open.	
Dismiss	Dismiss dialog box.	
Help	Access this Help page.	

Application Notes

ASAP Import

- FRED imports either a *.out or *.txt file format produced by ASAP's PRINT statement. The INR file format cannot be imported. Use the following code to create a FRED-compatible file in ASAP:

```
$IO OUTPUT MYFILE
PRINT
$IO OUTPUT CLOSE
```

- ASAP does not write out the system or wavelength units to the PRINTed output. These unit selection must be set by the user at import.

- Sources are not imported.

See Also….

ASAP Import

CAD Import

Lens Import

CAD Import

[Description](#)
[How Do I Get There?](#)
[Dialog Box and Controls](#)
[Application Notes](#)
[See Also…](#)

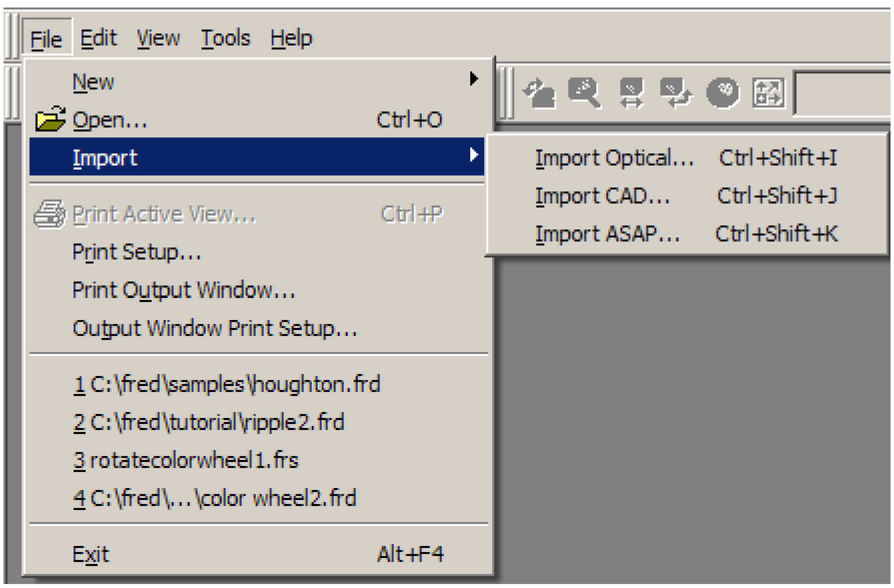
Description
CAD Import

FRED imports geometry in IGES or STEP file formats.

How Do I Get There?
CAD Import

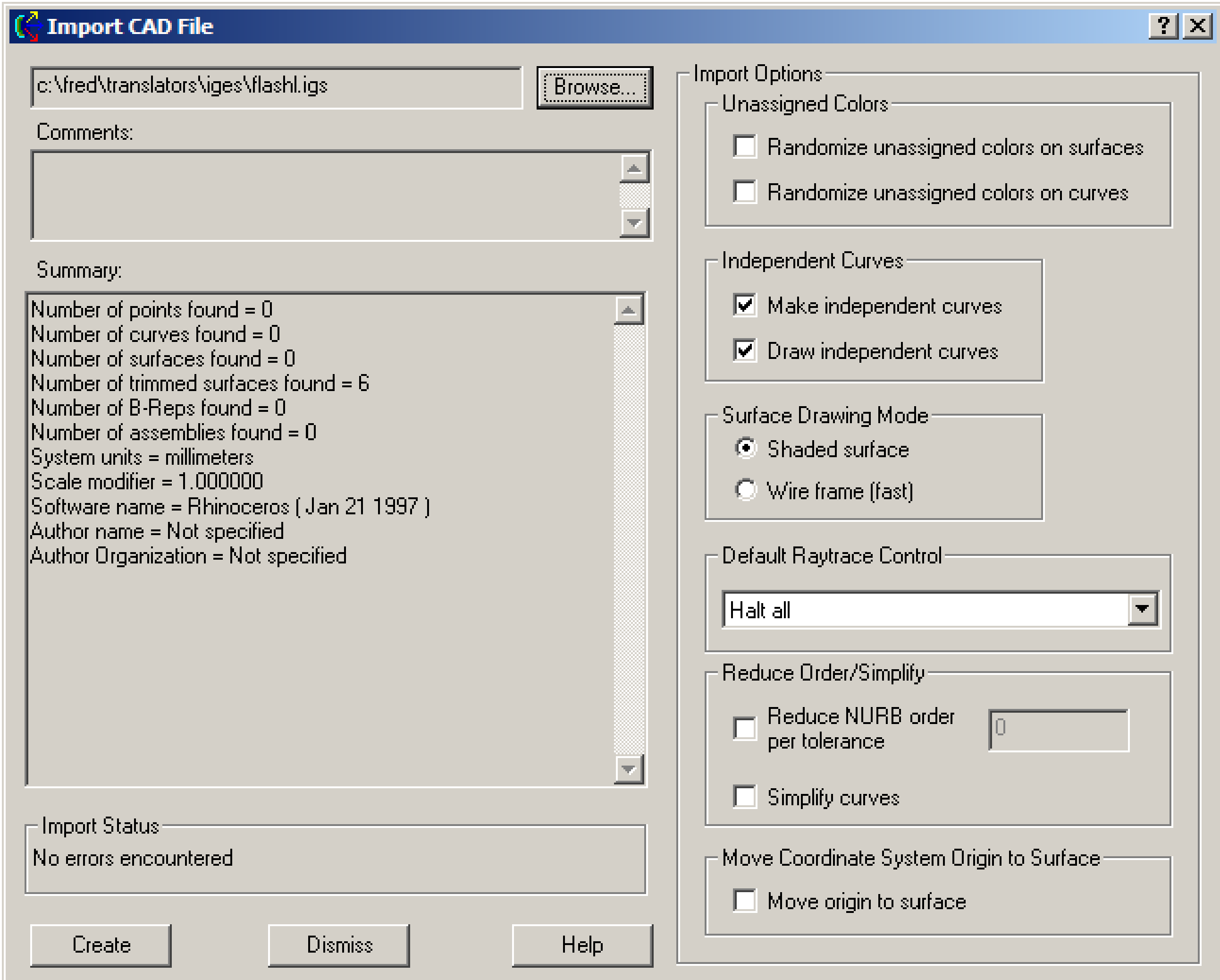
There are two different ways to execute this command:

1. Menu



2. Keyboard Accelerator - Ctrl+Shift+J

Dialog Box and Controls
CAD Import



Control	***Inputs / Description***	***Defaults***
Browse...	Choose the CAD file to be imported.	
Comments	Text comments from imported file.	
Summary	Summary of imported file contents.	
Import Status	Reports import status.	
Import Options		
Unassigned Colors	Randomizes colors for imported surfaces and curves.	Unchecked
Independent Curves	Makes and draws independent curves on import.	Checked

Surface Drawing Mode	Draws imported model as shaded surface of Wire frame (fast).	Shaded surface
Default Raytrace Control	Sets the selected Raytrace Control on imported surfaces.	Halt All
Reduce Order/Simplify	Reduces the order of imported NURBs or curves to the lowest value for which the maximum deviation between original and approximate surface is less than the given tolerance.	Unchecked
Move Coordinate System Origin to Surface	Converts the default global coordinate system of NURBs to a local coordinate system on the surface. Location of that local origin is at a position where the parametric coordinates ***u*** and ***v*** are minimum. **Note:** In the case of some trimmed surfaces, this local origin may not lie directly on the surface.	Unchecked
Create	Create FRED model and keep dialog box open.	
Dismiss	Dismiss dialog box.	
Help	Access this Help page.	

Application Notes

CAD Import

- Large models may result in slow response of the 3D view. For convenience, select Wire frame mode to increase video responsiveness and eliminate tesselation delays.
- As the order of NURB surfaces increase, so does the required trace time. Photon Engineering recommends reducing the order of NURBs to the lowest possible value consistent with the particular application to enhance raytrace speed.
- FRED internally models objects exactly as they are defined in the CAD file (as NURBs) instead of approximating with a FRED native entity. A list of IGES objects supported by FRED can be used to understand the Summary report.

- By default, NURBs are imported in the global coordinate system. As a result, NURBs do not have a local coordinate system affixed to their surface as all other FRED surfaces do. By selecting the *Move Coordinate System Origin to Surface* option, FRED endows each NURB with a local coordinate system. This local coordinate system origin is located at a point where the parametric coordinates *u* and *v* are minimum. In the case of some trimmed surfaces, the local coordinate origin may not lie directly on the surface but will be in the near vicinity.

See Also….

CAD Import

Lens Import

ASAP Import

Lens Import

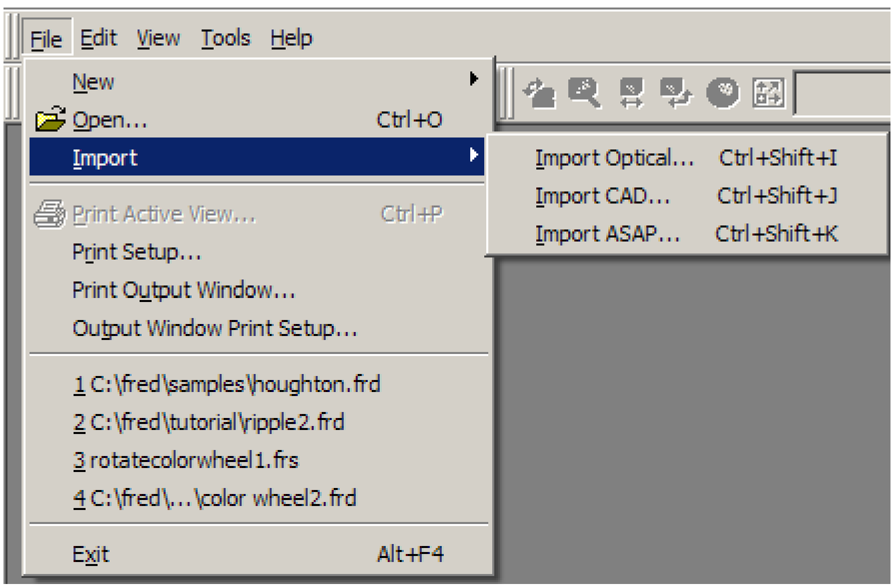
Description
Lens Import

FRED imports lens prescriptions from CodeV, Zemax and OSLO.

How Do I Get There?
Lens Import

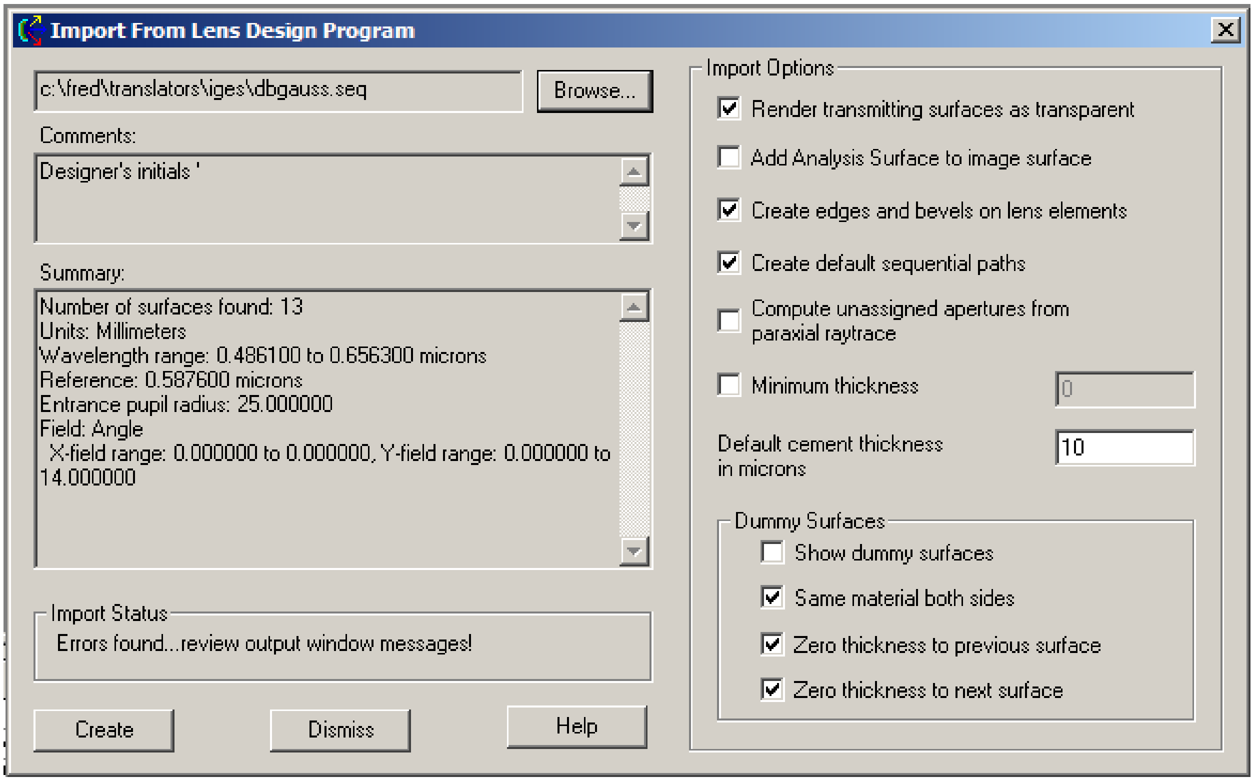
There are two different ways to execute this command:

1. from the Main Menu....



2. Keyboard Accelerator - Ctrl+Shift+I

Dialog Box and Controls
Lens Import



Control	*Inputs / Description*	*Defaults*
Browse...	Choose the lens file to be imported.	
Comments	Text comments from imported file.	
Summary	Summary of imported file contents.	
Import Status	Reports import status.	
Import Options		
Render transmitting surfaces as transparent	Transmitting surfaces are given a "Transmit" coating and "Transmit Specular" Raytrace Control.	Checked
Add Analysis Surface to image plane	Adds an Analysis Surface and and attaches it to the image plane.	Unchecked
Create edges and bevels on lens elements	Constructs edges and bevels for all lens and mirror elements. (See App Notes below)	Checked
Create default sequential paths	Creates default sequential path definition and saves path to document.	Checked
Compute unassigned apertures from paraxial raytrace	Computes and assigns apertures to those unassigned in the prescription using a paraxial raytrace.	Unchecked

Minimum thickness	Minimum thickness between adjacent elements.	Unchecked (0)
Default cement thickness in microns	Sets the default thickness of glue layers between doublets and triplets.	10
Dummy Surfaces		
Show dummy surfaces	Imports dummy surfaces when checked.	Unchecked
Same material both sides	Assigns the same material to both sides of dummy surfaces.	Checked
Zero thickness to previous/next surface	Sets a zero thickness to previous/next surfaces.	Checked
Create	Create FRED model and keep dialog box open.	
Dismiss	Dismiss dialog box.	
Help	Access this Help page.	

Application Notes

Lens Import

- Selecting the option "Create edges and bevels on lens elements" breaks standard three-surface doublets (and four surface triplets) into four surfaces (into six surfaces) and adds a default glue thickness of 10 m between the elements. This operation causes small but noticeable changes in the prescription consistent with the actual manufacture of glued elements.

- If *Compute unassigned apertures from paraxial raytrace* is not checked, then FRED will prompt the user for aperture information (see Import Apertures).

See Also….

Lens Import

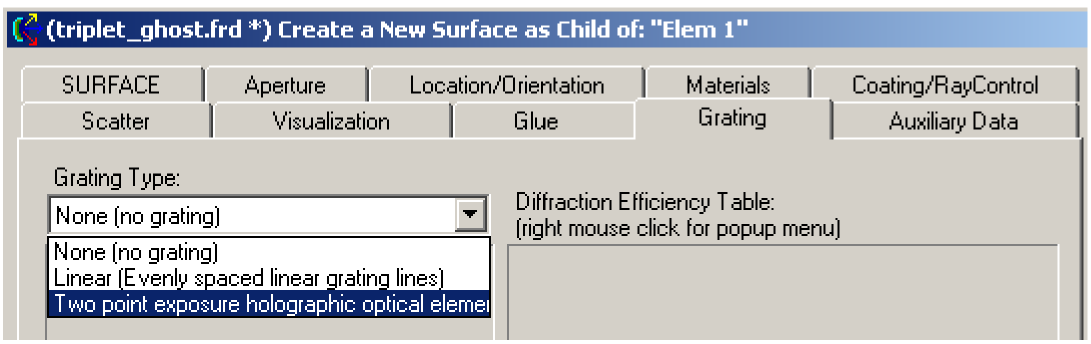
CAD Import
ASAP Import

Applying Gratings

Description

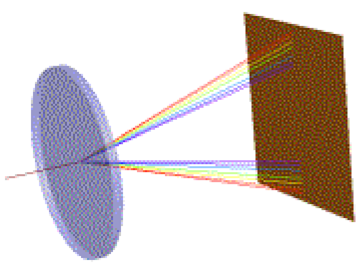
Applying Gratings

This option allows the user to apply a grating to the surface. The grating is not modeled physically as a grating in FRED. Instead, a phase profile representing the grating is added to the surface. After a ray refracts or reflects at a surface with a grating, the appropriate phase is added to the ray to model the grating affects.

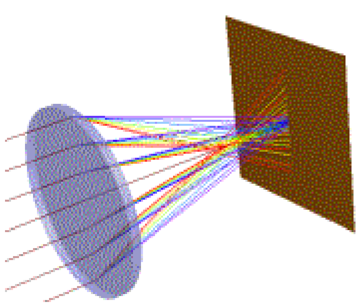


There are two types of phase gratings that can be added to a surface:

1. Linear Grating (evenly spaced linear grating lines)



2. Two point exposure holographic optical element with a polynomial phase departure option.

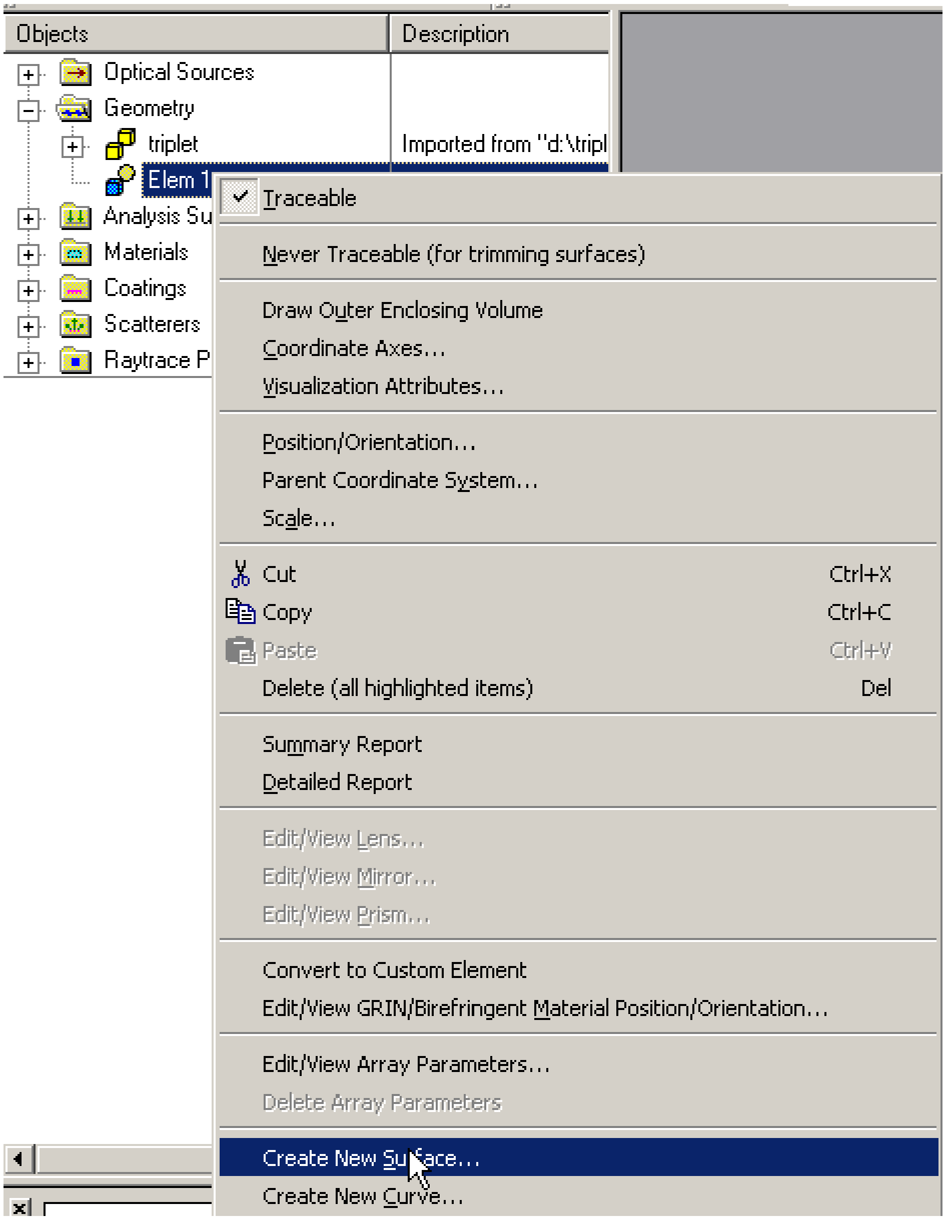


The user can also set the grating efficiency for any given order and at any given wavelength. During the raytrace, the grating efficiency rays with wavelengths inside the range of user set efficiencies are determined by linear interpolation. The grating efficiencies for rays with wavelengths outside the range of the user set wavelengths are set to the efficiency of the closest wavelength with a defined efficiency. So, if only one wavelength is defined with a diffraction efficiency, then all the wavelengths will have that same efficiency.

How Do I Get There?

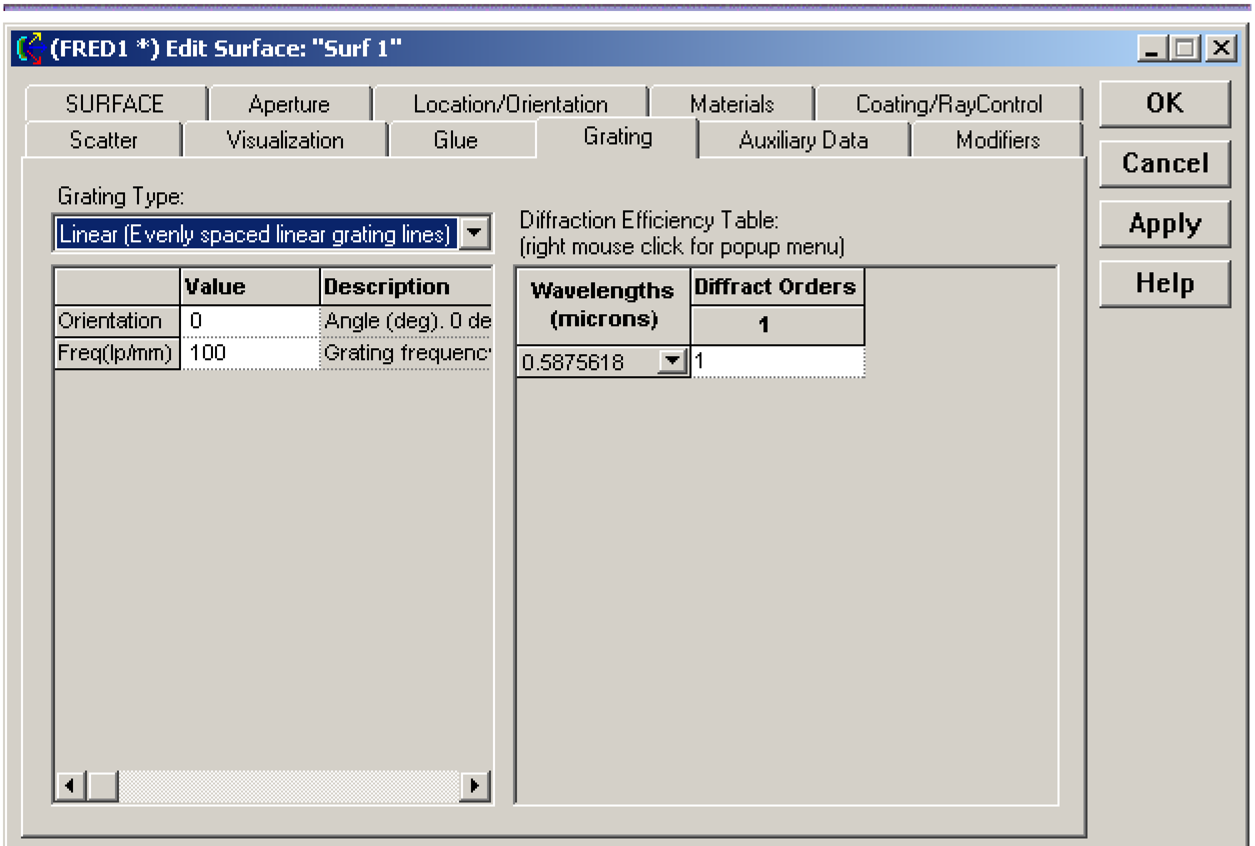
Applying Gratings

This page is in the **Create New Surface…** and **Edit/View Surface…** dialogs.

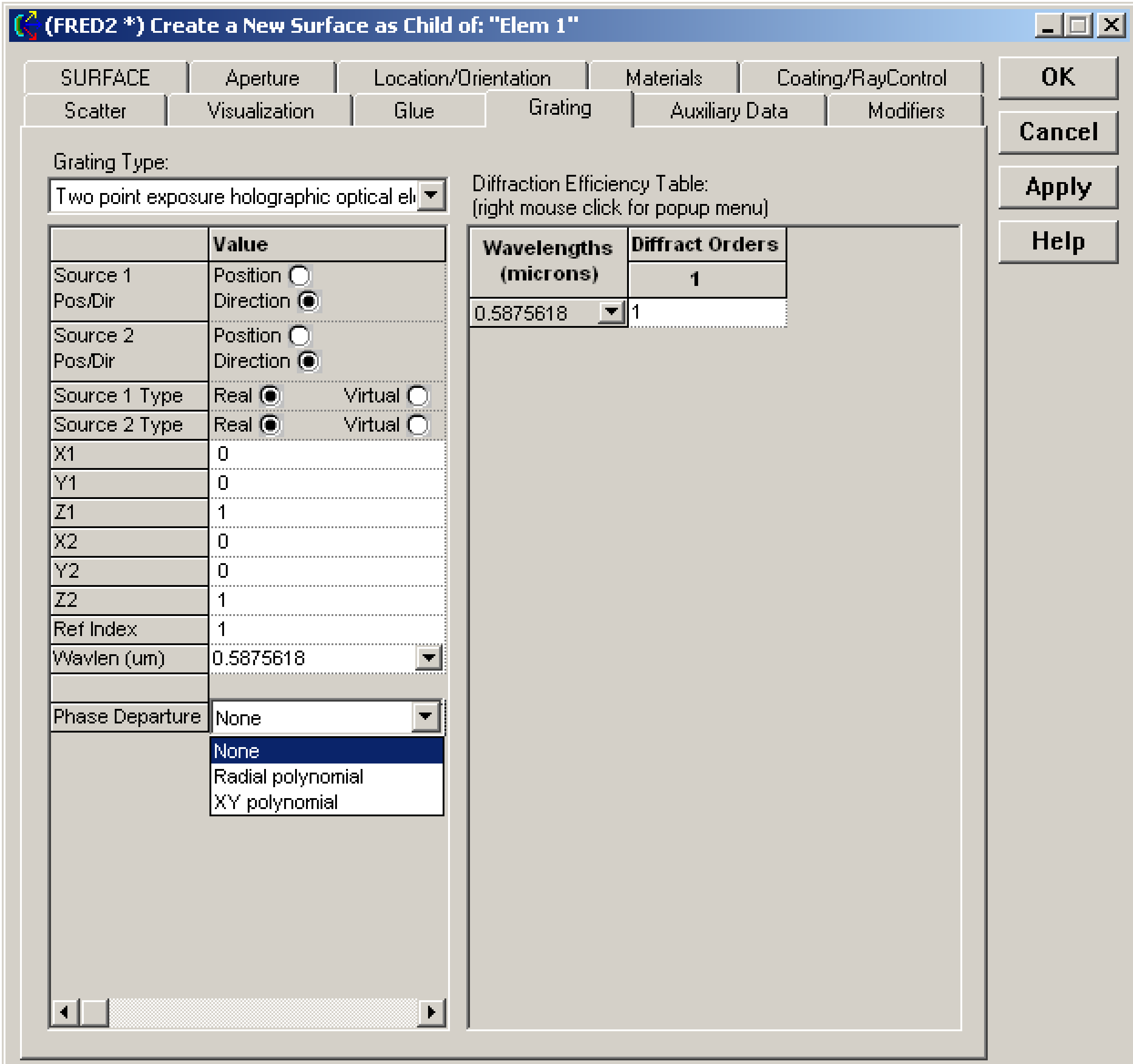


Dialog Box and Controls

Applying Gratings



Control	Inputs	Defaults
Grating Linear - Orientation	Angle of the grating in degrees relative to the coordinate system of the surface.	0
Grating Linear – Frequency	The spatial frequency of the grating in lines per millimeter.	100
Grating Linear – Diffract Order	The user can specify the diffraction efficiency into each order. Multiple orders can be appended with a right mouse click.	1
Grating Linear – Wavelength	The wavelength for the efficiency at a given order can be specified. In addition, multiple wavelengths for each order can be specified (append multiple wavelengths with a right mouse click as well).	0.5892938 [um]


(FRED2 *) Create a New Surface as Child of: "Elem 1"
SURFACE
Aperture
Location/Orientation
Materials
Coating/RayControl
Scatter
Visualization
Glue
Grating
Auxiliary Data
Modifiers
OK
Cancel
Apply
Help
Grating Type:
Two point exposure holographic optical el
Value
Source 1 Pos/Dir
Position
Direction
Source 2 Pos/Dir
Position
Direction
Source 1 Type
Real
Virtual
Source 2 Type
Real
Virtual
X1 0
Y1 0
Z1 1
X2 0
Y2 0
Z2 1
Ref Index 1
Wavlen (um) 0.5875618
Phase Departure
None
None
Radial polynomial
XY polynomial
Diffraction Efficiency Table:
(right mouse click for popup menu)
Wavelengths (microns)
Diffract Orders
1
0.5875618
1

Control	Inputs	Defaults
Source 1 Pos/Dir	Determines whether the (X1,Y1,Z1) coordinates are treated as direction cosines or a position vector.	Direction
Source 2 Pos/Dir	Determines whether the (X2,Y2,Z2) coordinates are treated as direction cosines or a position vector.	Direction
Source 1 type	Is source 1 a real or virtual source?	Real
Source 2 type	Is source 2 a real or virtual source?	Real
X1, Y1, Z1	Position or direction coordinates of the first point.	0, 0, 1
X2, Y2, Z2	Position or direction coordinates of the second point.	0, 0, 1
Ref Index	The refractive index of the media being exposed to make the holographic grating.	1.00
Wavelen (um)	The wavelength of the sources being used to expose the two point holographic grating.	0.5892938 [um]
Phase Departure	A radial or XY polynomial phase departure can be added to the two point holographic grating using this pull down menu.	None
R0 or X0Y0	Constant term for the radial or XY polynomial phase departure. Additional terms can be added by type any number including zero, 0, on this term. NOTE, you must type a number even if it is zero to get the next term in the polynomial.	0
Diffract Order	Diffraction order(s) to be raytraced. Multiple orders may be entered with via a right mouse click pop-up menu.	1
Wavelens (um)	The wavelength corresponding to the diffraction efficiency of that order. Additional wavelengths maybe added via a right mouse click pop-up menu.	0.5892938 [um]

- The Phase Departure attribute can be used to create linear or radial gratings with variable spacing. The polynomial equation for grating spacing is

$$d(y) = \frac{\lambda_{ref}}{a + 2by + 3cy^2 + \ldots\ldots}$$

where λ_{ref} is the reference wavelength.
The corresponding FRED phase function is

$$f(y) = ay + by^2 + cy^3 + \ldots\ldots$$

Example
Applying Gratings

As an example, consider the case of a linearly chirped grating of width 50mm with reference wavelength 0.5μm. There are 1250 lpm at position y=-25mm and 1500 lpm at position y=+25mm.

The polynomial equation for grating spacing is used to solve a set of equations in two variable, a & b.

d(-25) = 1/1250 = 5E-04/[a +2b*(-25)]

d(25) = 1/1500 = 5E-04/[a + 2b*(25)]

Solving these two equation simulataneously yields

a = 0.625 ;   b = 0.00125

Thus, in the Phase Departure subsection of the Grating dialog, choose XY polynomial and set

X0Y0=0
X1Y0=0
X0Y1=0.625

X2Y0=0
X1Y1=0
X0Y2=0.00125

NOTE, you must type a number even if it is zero to get the next term in the polynomial.

Applying Surface Types

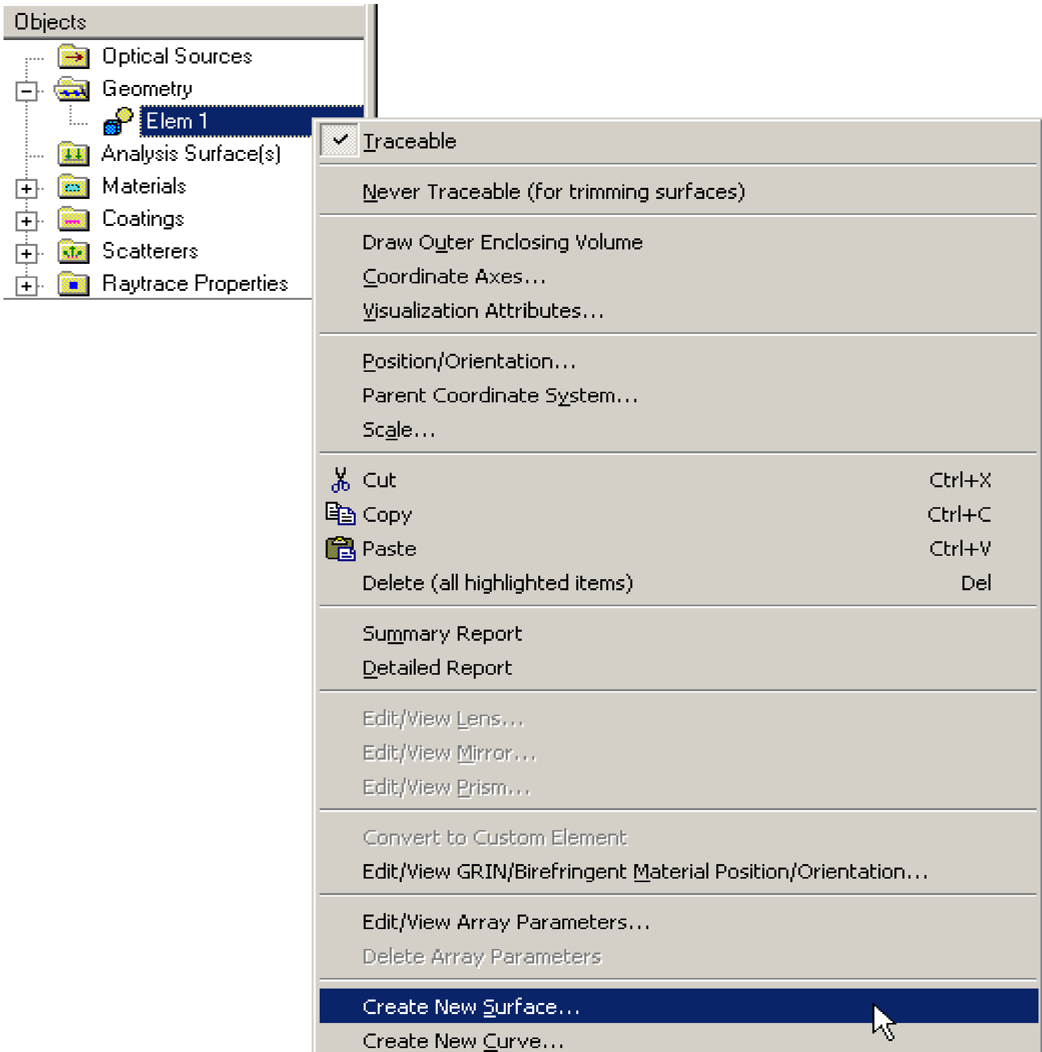
Description - Applying Surface Types

This page allows the user to select the surface type, i.e. the mathematical description of the surface. After selecting the surface type, enter any additional data required for that surface. There is a hot link below to a help page for each of the available surface types. The **Trimming Volume** is independent of the size and shape parameters entered on the **Surface** page. The **Trimming Volume** parameters on the **Aperture** page may need to be adjusted before the **Surface** appears as expected.

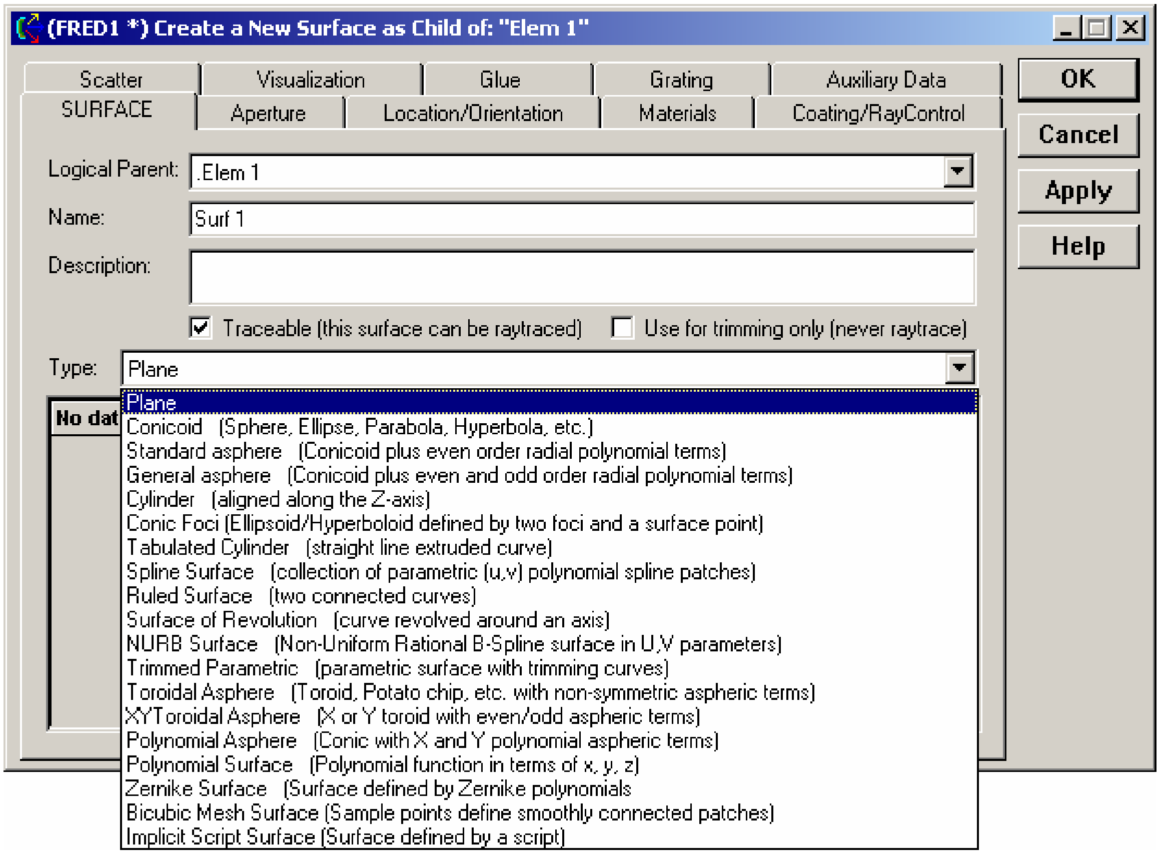
NOTE: The **Trimming Volume** is independent of the size and shape parameters entered on the **Surface** page. The **Trimming Volume** parameters on the **Aperture** page may need to be adjusted before the **Surface** appears as expected.

How Do I Get There? - Applying Surface Types

This page is part of the **Create New Surface…** and **Edit/View Surface…** dialogs.



Dialog Box and Controls - Applying Surface Types



Control	***Inputs / Description***	***Defaults***
Surface-Parent	No user inputs.	Element on which it was created
Surface-Name	An alphanumeric name of any length. Note that object names can start with numbers.	Surf n, where n is a sequential number
Surface-Description	User input description of any length	None
Surface-Type	The surface time can be selected from available surfaces in the pull-down menu	Plane

The following surface types are currently available in FRED:

- Plane
- Conicoid

Standard Asphere

General Asphere

Cylinder

Conic Foci

Tabulated Cylinder

Spline Surface

Ruled Surface

Surface of Revolution

NURB Surface

Trimmed Parametric

Toroidal Asphere

XY Toroidal Asphere

Polynomial Asphere

Polynomial Surface

Zernike Surface

Bicubic Mesh Surface

Implicit Script Surface

Applying Visualization Properties

Description - Applying Visualization Properties

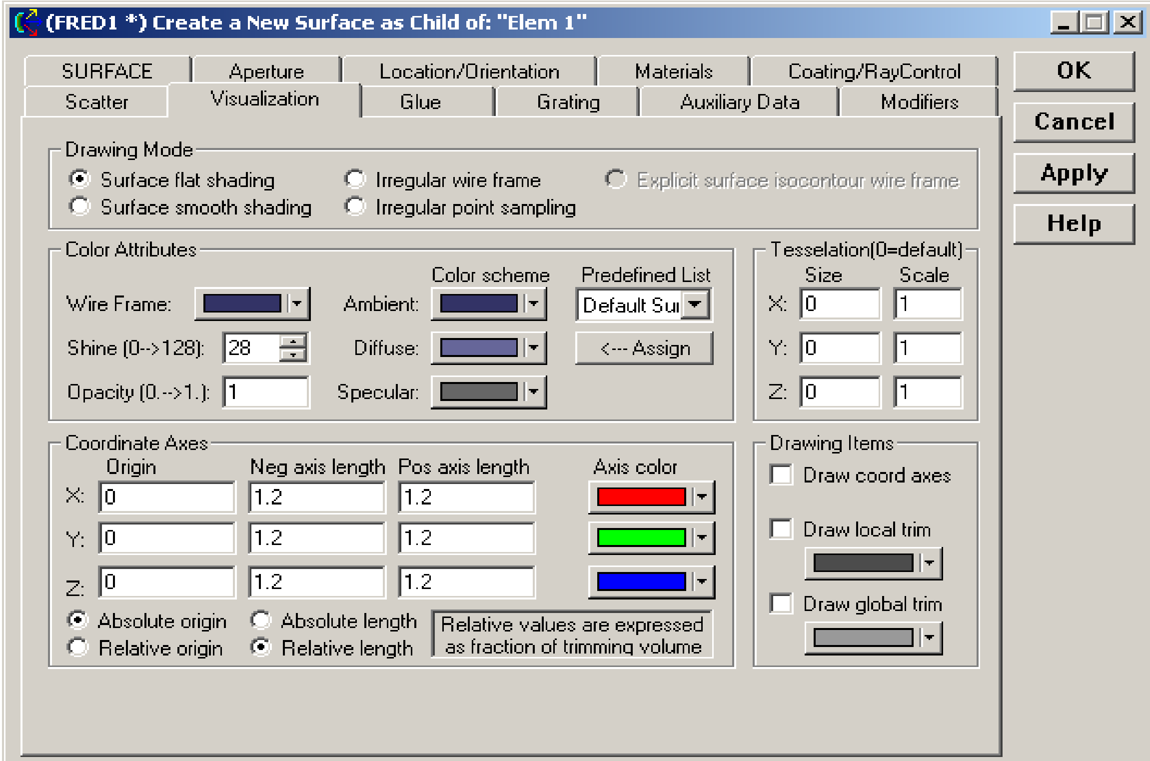
The appearance of the surface in the Visualization window can be modified on this page. The following items can be modified:

1. Drawing Mode
2. Color
3. Shine
4. Opacity
5. Tessellation (quality of the surface rendering)
6. Draw Coordinate Axes
7. Draw local Trimming Volume
8. Draw global Trimming Volume

How Do I Get There? - Applying Visualization Properties

This page is on the Surface Creation and Editing dialogs.

Dialog Box and Controls - Applying Visualization Properties



Control	*Inputs*	*Defaults*
	Drawing Mode	
Drawing Mode	The way the surface is rendered. Options are: *Surface flat shading* *Surface smooth shading* *Irregular wire frame* *Irregular point sampling* *Explicit surface isocontour wireframe*	Surface flat shading
	Color Attributes	
Attributes	The wire frame color, shine, and opacity (transparency) of the surface when it is rendered.	Colors: default Shine: 128 Opacity: 1
Color scheme	Sets ambient, diffuse, specular properties of rendered surface.	
Predefined List	Selects and assigns surface color.	Default Surface/ Curve/Grid Color
	Coordinate Axes	

Coordinate Axes	Sets the color, location, and size of the coordinate axes if they are drawn on that surface.	RGB 0,0,0 1.2, 1.2, 1.2
Tessellation		
Tesselation	The tessellation determines how finely FRED samples the surface for rendering. The smaller the scale, the finer the sampling. Fine sampling increases the amount of time required to render the surface.	Size: 0 Scale: 1
Visualization – Drawing Items	Determines whether these items will be drawn when the surface is rendered.	Unchecked
OK	Accept Visualization changes and close dialog box.	
Cancel	Discard Visualization changes and close dialog box.	
Apply	Apply Visualization changes and keep dialog box open.	
Help	Access this Help page.	

Applying Surface Deformations

Description - Applying Surface Deformations

Mathematically, deformations are implemented by shifting the zeros of the base surface's function. Let fb(x,y,z) = 0 define the base surface and fd(x,y,z) = 0 define the deforming surface.
Further, assume that the deforming surface is defined as a height map along z (e.g, fd(x,y,z) = z - gd(x,y)).
This is the "sagability" assumption. FRED doesn't enforce this, but it will generally print a warning
to the output window when it detects a deformer that's not "sagable".
When the deformation is applied to the base surface, the resulting combined surface is defined by
(ignoring coordinate system transformations):

0 = f(x,y,z) = fb(x, y, z - A*gd(x,y)) = fb(x, y, A*fd(x,y,z) - (A-1)*z)

... where A is the deformation scale factor (this scales the deforming surface's height).

Deformations can be applied to surfaces that are parts of Lens/Mirror elements. When a deformation
is applied the Lens/Mirror will use the optical surfaces to bound its outer tube, ensuring the element
won't leak rays. Currently, the bevel option is not handled correctly, so there can be leaks if a deformation is
applied to a lens/mirror with bevels.

Deformations cannot be applied to elements of a prism. The user interface tries to prevent this from
happening. If by chance the user finds a way to do this (by scripting perhaps) bad things are to be
expected.

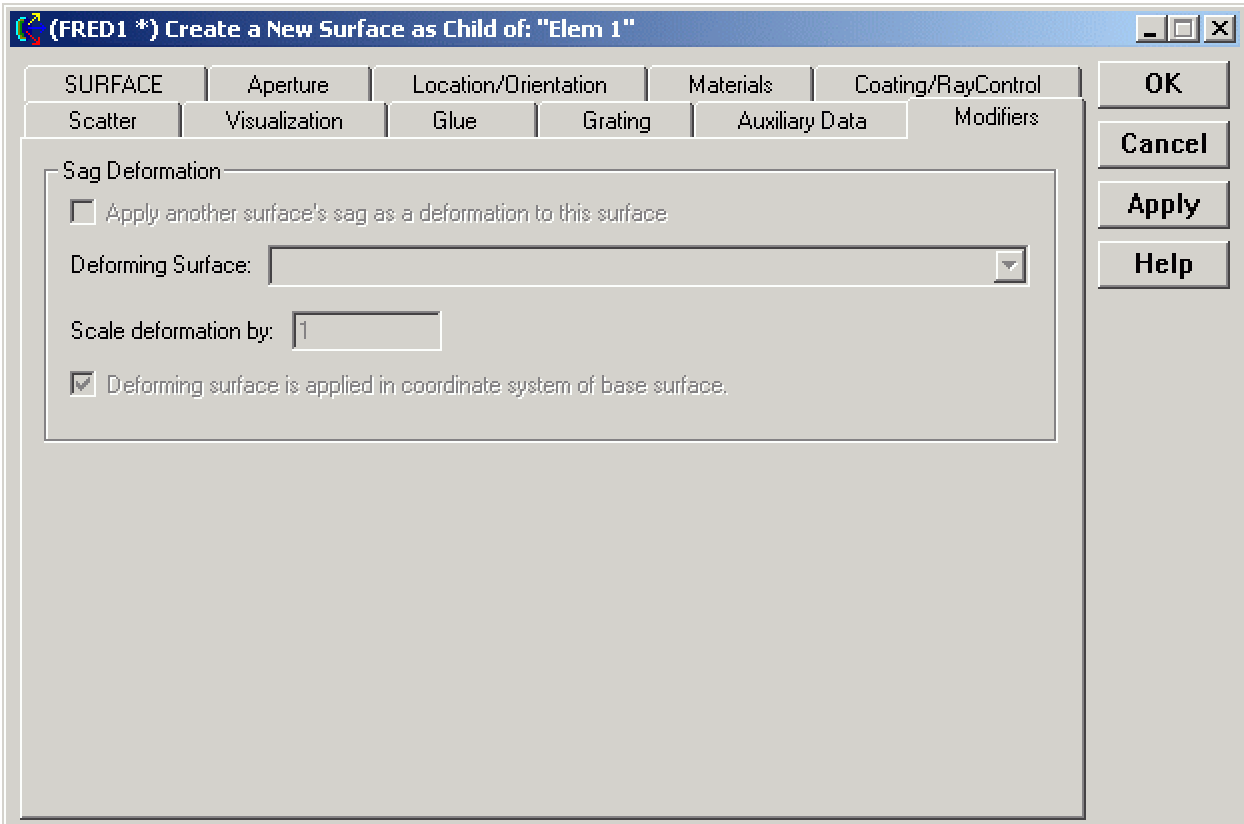
If a non-sagable deformer is selected a warning will generally be written to the output window after the
base surface is tessellated. Because tessellation can occur more than once, when such warnings occur
they are frequently seen repeated multiple times.

To apply a sampled height map as a deformer, read the data into a bicubic mesh surface and apply it
as the deforming surface.

How Do I Get There? - Applying Surface Deformations

This page is in the **Create New Surface…** and/or **Edit/View Surface…** dialogs.

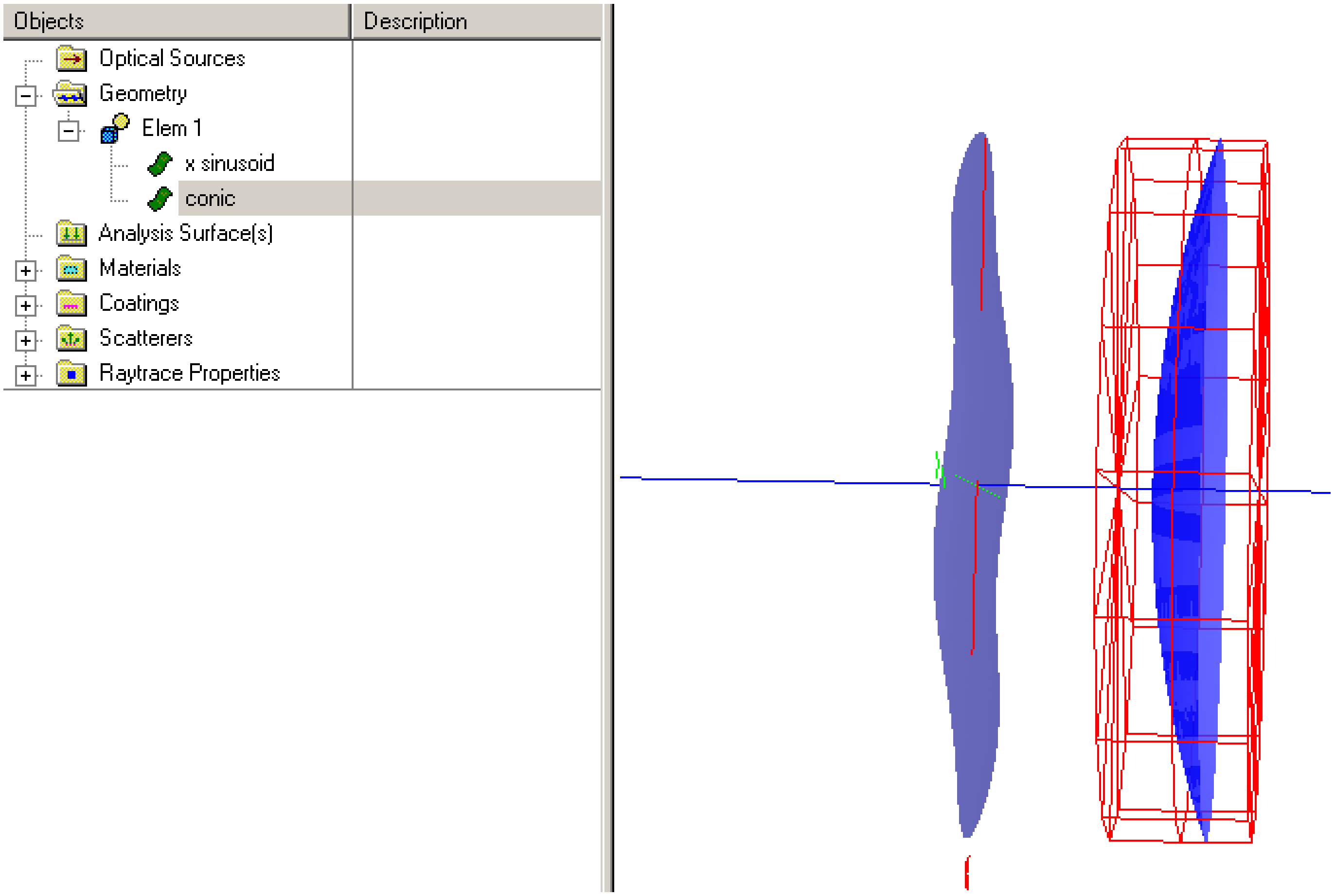
Dialog Box and Controls - Applying Surface Deformations



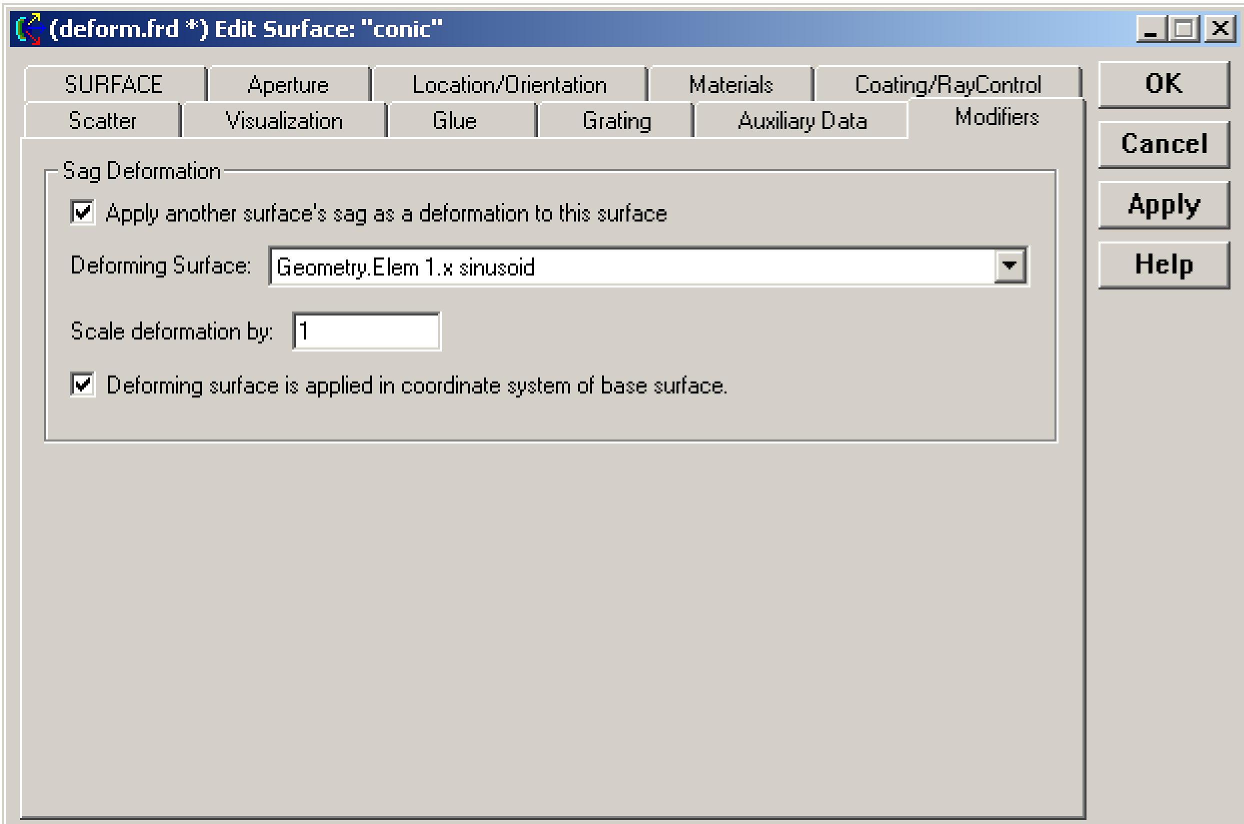
Control	Inputs	Defaults
Sag Deformation		
Apply another surface's sag as a deformation	Select whether the base surface will have a deformation	Unchecked
Deforming Surface	Choose from a list of valid deforming surfaces	All valid surfaces
Scale deformation by:	Scale factor multiplying the amplitude of the deforming surface.	1
Deforming surface is applied in coordinate system of base surface	This check box controls whether coordinates are transformed before the deformation surface is evaluated. When checked it has the effect of placing the deformer in the same coordinate system as the base surface. This could be useful, for example, if the same exact deformation is being applied to several similar base surfaces each at a different location. When not checked it has the effect of applying the deformer globally to the base surface. This would be used, for example, to apply different parts of one large deformation to the spatially correspond parts of a segmented mirror.	Unchecked
OK	Accept Deformation changes and close dialog box.	
Cancel	Discard Deformation changes and close dialog box.	
Apply	Apply Deformation changes and keep dialog box open.	
Help	Access this Help page.	

Examples

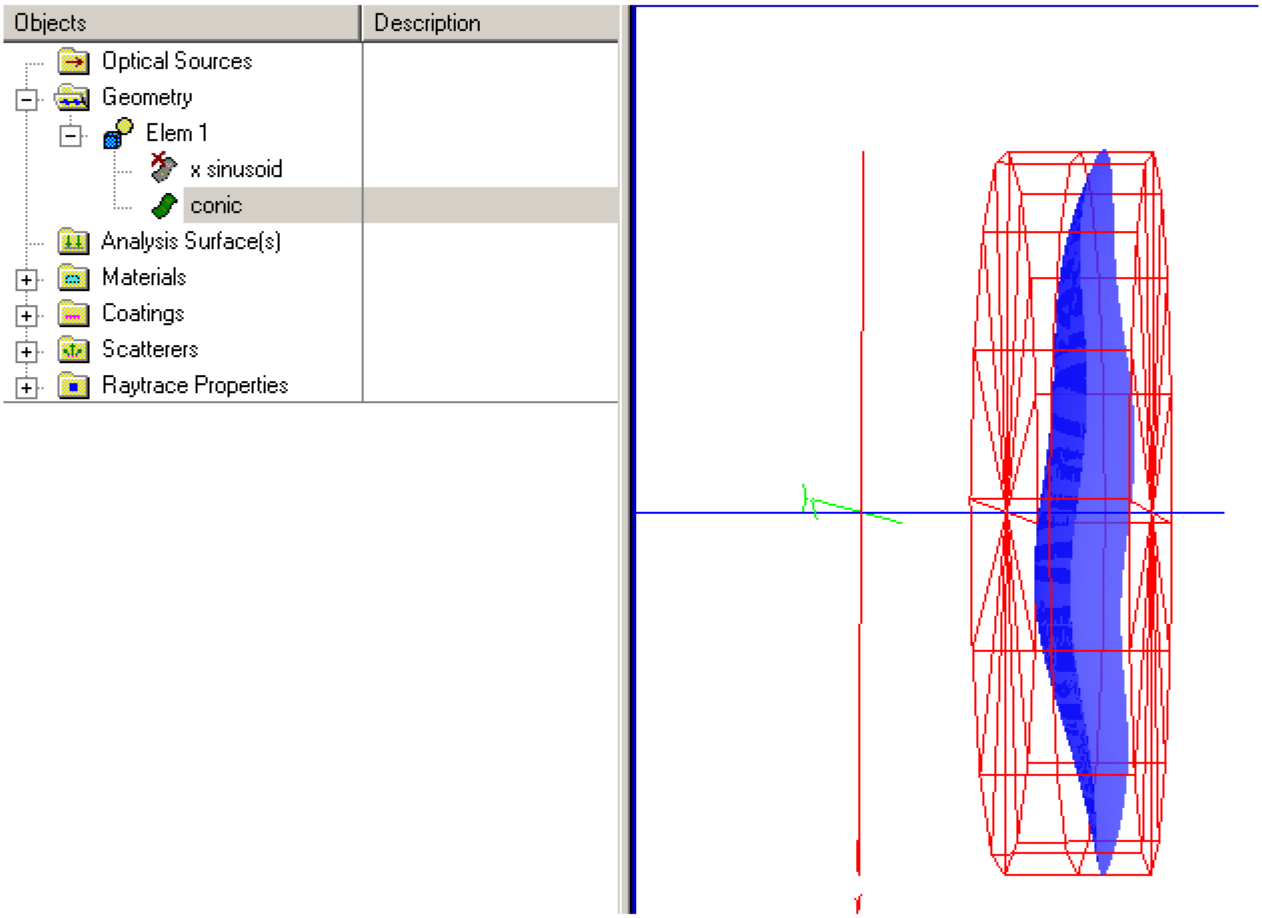
1) This short example demonstrates how a sinusoidal surface is used to deform a conic mirror. The two surfaces are shown below. The sinusoidal surface is an Implicit Script Surface.



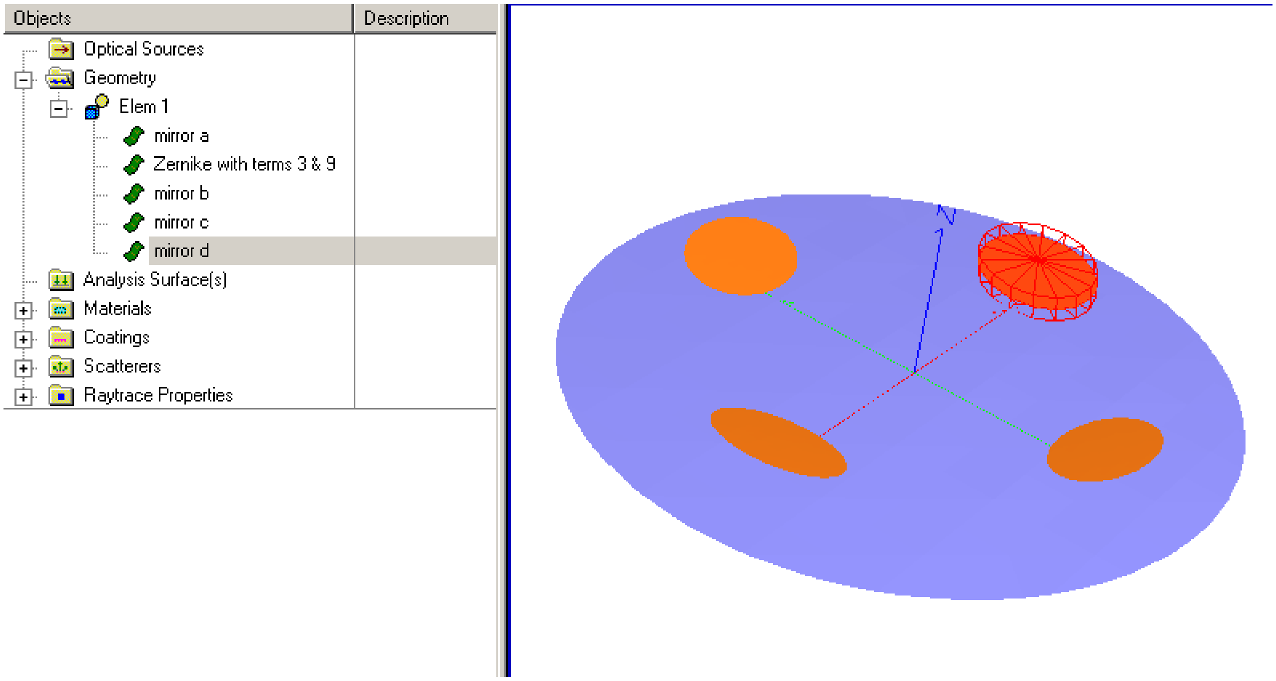
We now edit the conic surface and select the “Modifiers” tab:



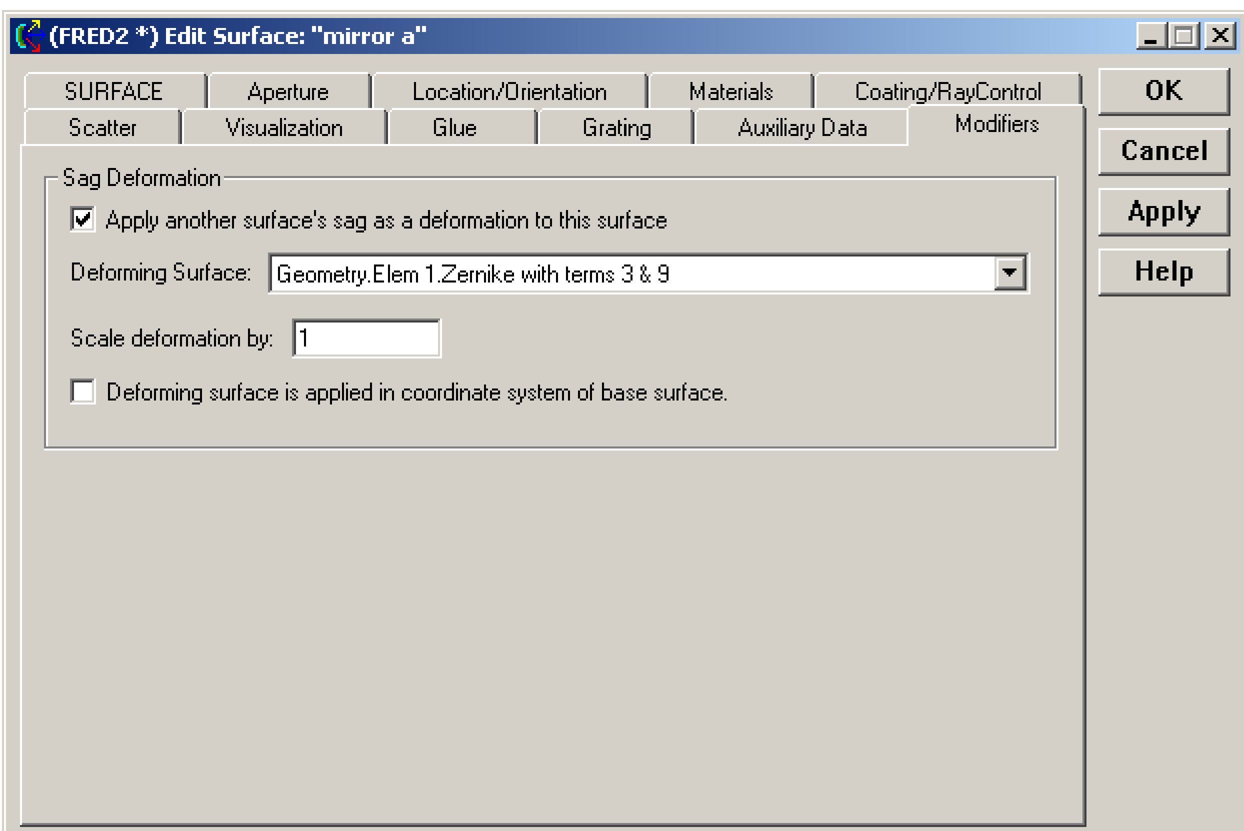
Check the “Apply another surface sag as a deformation…” to activate the deformation feature. The deforming surface “Geometry.Elem 1.x sinusoid” is selected from the dropdown list under “Deforming Surface”. The “Deforming surface is applied in coordinate system of base surface” option is checked since both surfaces have the same aperture and lie on the z-axis. To finish, click OK. The deformed surface is shown in the view below after having set the sinusoidal surface to be NotTraceable.



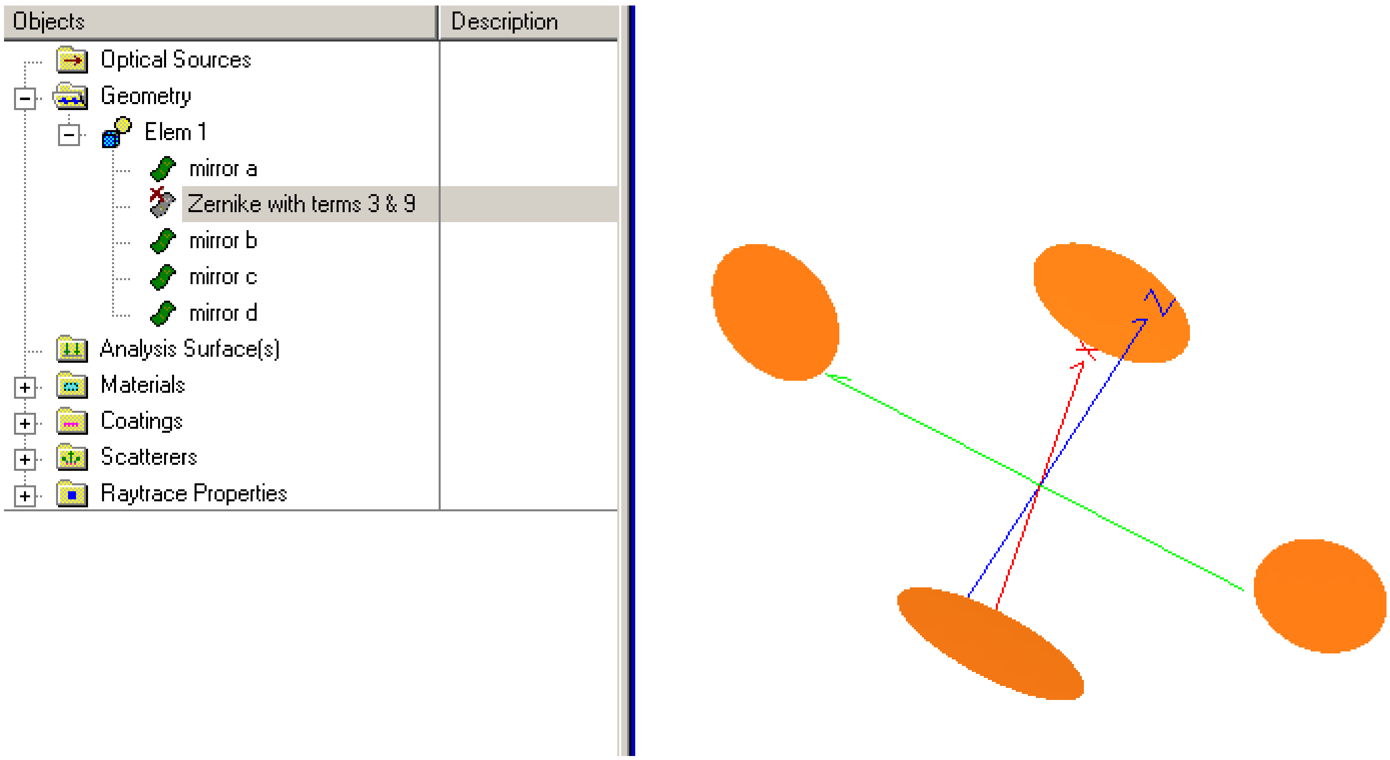
2) This next example uses a Zernike base surface to deform a set of off-axis sections of a parabolic mirror. Once again, the base and deforming surfaces are created in FRED as shown below



In this case, the desire is to use the single Zernike surface to deform each mirror section according to its radial position. Thus, the “Deforming surface is applied in coordinate system of base surface” option is unchecked which uses the deforming surface in the global coordinate system.



The end result is that the mirror sections are deformed by the single base surface.



New Custom Element

Description
New Custom Element

In the tree geometry hierarchy, there are **Sub-Assemblies**, **Elements**, **Custom Elements**, **Surfaces**, **Curves**, and **Collection Curves**.

Custom Elements and **Elements** are collections of **Surfaces**, **Curves**, and **Collection Curves**. **Surfaces** and **Curves** can only be entered into **Custom Elements**, i.e. the user cannot enter surfaces directly into the **Geometry** folder, **Elements**, or **Sub-Assemblies**.

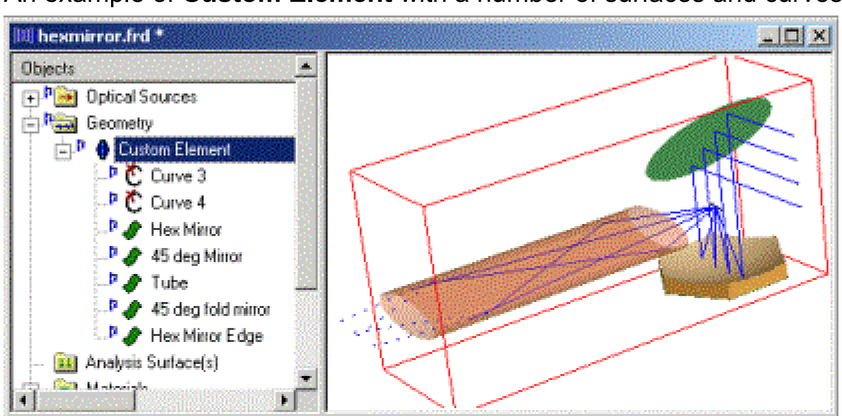
Elements are collections of surfaces constructing lenses, prisms, or mirrors that have been created with the lens, prism, and mirror dialogs or imported from the lens catalogs. The user has limited access to attributes of the surfaces in **Elements** because the surfaces are all part of a defined lens or mirror. For example, the aperture of the lens or mirror **Element** can be changed but the aperture of the individual surfaces in that **Element** cannot be changed independently.

Custom Elements can contain any number of **Surfaces** and **Curves**. But they cannot contain other **Custom Elements** or **Sub-Assemblies**. Unlike **Elements**, the user has complete access to attributes of the surfaces and curves in **Custom Elements**.

Elements can be converted to **Custom Elements** via an option in the right mouse click pop-up menu in the geometry folder.

Visualization (example)
New Custom Element

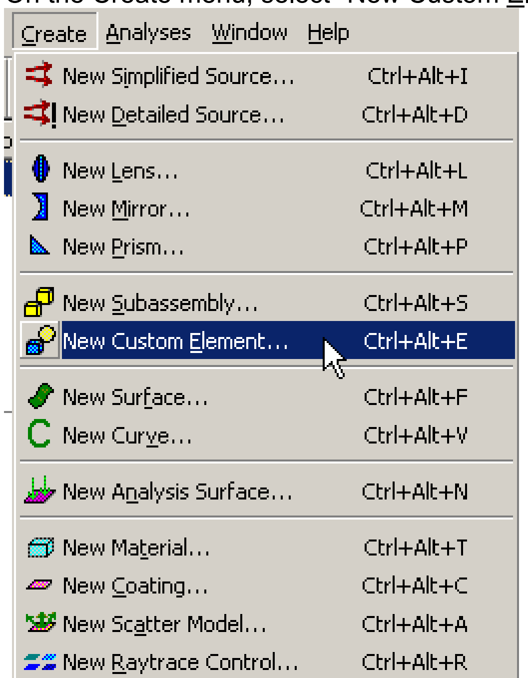
An example of **Custom Element** with a number of surfaces and curves is shown below.



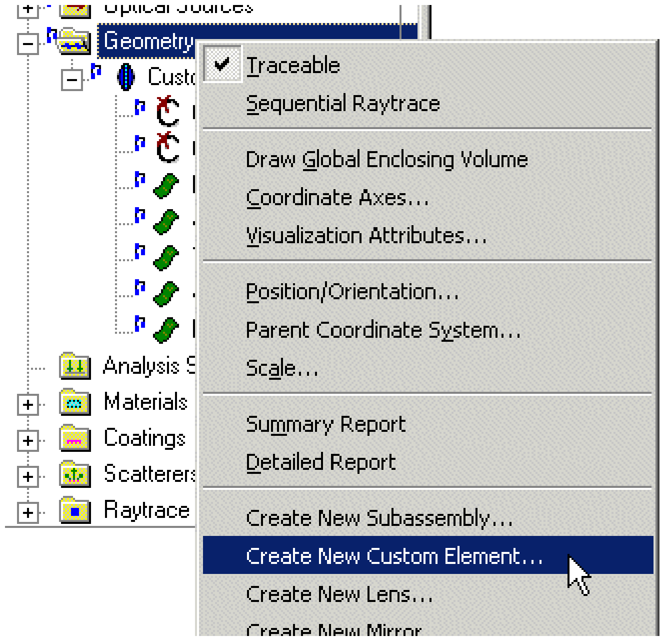
There are four ways to access this command:

1. On the Create Toolbar, click this button: 

2. On the Create menu, select "New Custom Element...".



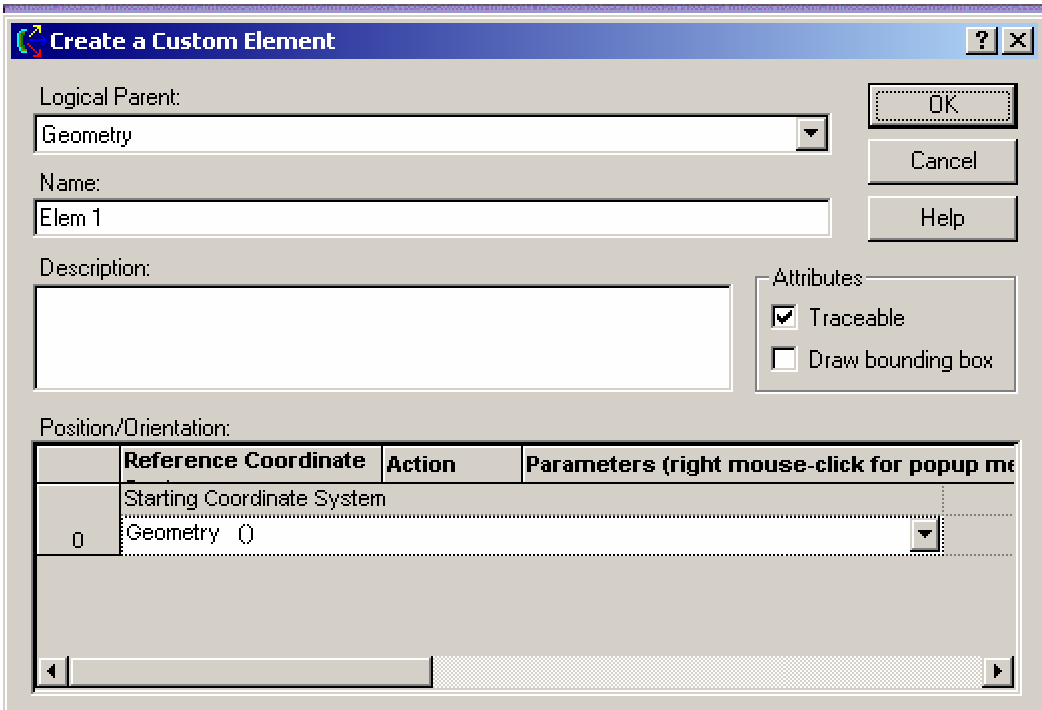
3. Select "Create New Custom Element…" in the right click pop-up menu on the Geometry node or any child node in the geometry folder



4. Use they keyboard shortcut Ctrl+Alt+E.

Dialog Box and Controls

New Custom Element



This is a modal dialog. FRED does not respond to other commands until this dialog is closed.

Control	Inputs	Defaults
Logical Parent:	Parent name of the new custom element.	name of the Subassembly highlighted when the command is given
Name:	Name for the new Custom Element.	Elem 1
Description:	Informative description for the Custom Element.	blank
Attributes		
Traceable	Makes the Custom Element affect rays during a raytrace.	Selected
Draw bounding box	Draws a box around the Custom Element.	not Selected
Position/Orientation		
Reference Coordinate System, Action, Parameters	Set reference coordinate system and append position/orientation primitives.	Coordinates system of parent, none
OK	Create new Custom Element and close the dialog box.	
Cancel	Discard new Custom Element and close the dialog box.	
Help	Access this Help page.	

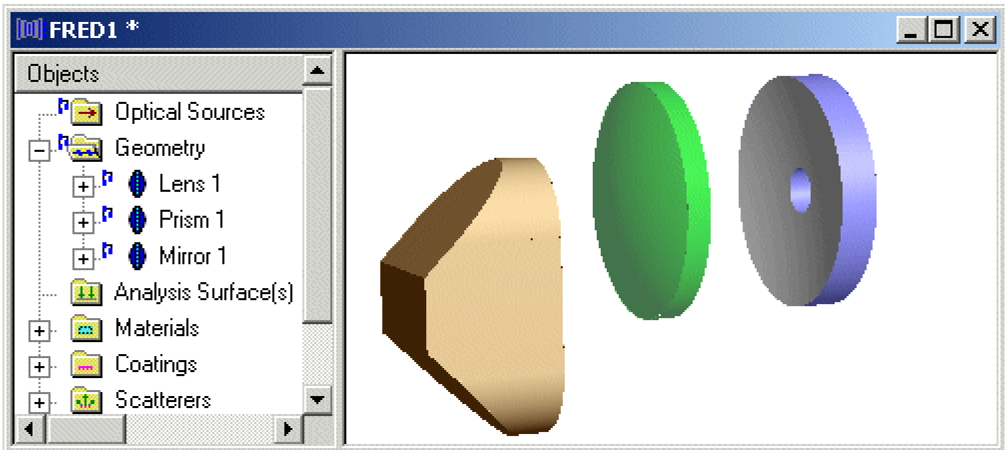
Element Versus Custom Element

Description - Element Versus Custom Element

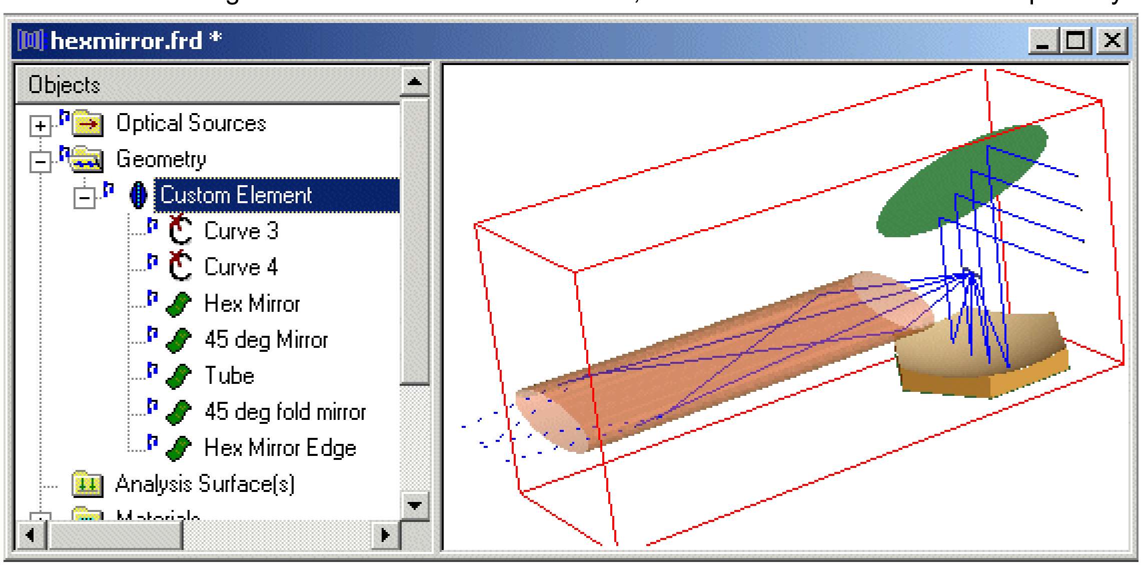
Elements in FRED are collections of **Surfaces** and **Curves** used to represent **Lenses**, **Prisms**, and **Mirrors**. The **Surface** and **Curves** in **Elements** can be viewed and edited and the **Surface** types, **Materials**, **Coatings**, **Scatter**, **Grating**, **Glue**, and **Visualization** properties can be altered but the **Surface Trimming Volumes**, i.e. apertures, cannot be altered on the individual **Surfaces**. The **Trimming Volume** can only be changed in the corresponding **Element** edit/view dialog, available in the right mouse click pop-up menu.

The advantage of an **Element** is that **Lens**, **Prism**, or **Mirror** properties can be edited vie the **Edit/View Lens…**, **Edit/View Prism…**, or **Edit/View Mirror…** dialogs respectively and all of the surfaces making up that **Element** will be updated together. In contrast, if an **Element** is converted to a **Custom Element**, then each **Surface** must be edited separately. The figure below illustrates **Prism**, **Lens**, and **Mirror Elements**.

Surfaces and **Curves** can be added to **Elements**, but when the **Element** is edited only the **Surfaces** that are part of the original **Element** change. The **Surfaces** added to the **Element** do not change unless they are edited separately.



Custom Elements are arbitrary collections of **Surfaces** and **Curves** where the user can define any geometry. A **Custom Element** with the **Trimming Volume** drawn around it is illustrated in the figure below. In a **Custom Element**, each **Surface** must be edited separately.



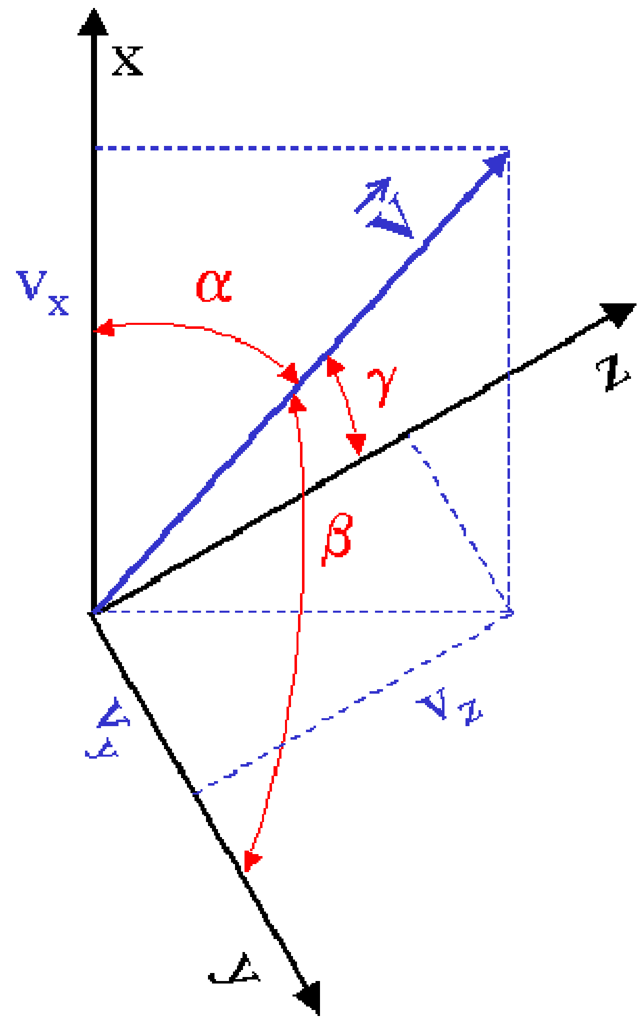
Description - Explaining Direction Cosines

The direction cosines, A,B,C, are simply the cosines of the angles, α,β,γ, made between a given vector, **V** = (ν_x,ν_y,ν_z), and the positive local X, Y, and Z axes. Note that if **V** is a unit vector, i.e. |**V**| = Sqrt[$(\nu_x)^2 + (\nu_y)^2 + (\nu_z)^2$] = 1, then the direction cosines, (A,B,C), are simply equal to the vector elements, (ν_x,ν_y,ν_z), respectively.

$$A = \cos(\alpha) = \frac{v_x}{\left|\vec{V}\right|}$$

$$B = \cos(\beta) = \frac{v_y}{\left|\vec{V}\right|}$$

$$C = \cos(\gamma) = \frac{v_z}{\left|\vec{V}\right|}$$



Once two direction cosines have been defined, for example A and B, then the third, in this case C, is defined as well through the following relationship. In the two relationships below, the direction cosines have been normalized to 1. FRED does not require that the direction cosines be normalized to one when they are entered in a dialog or macro command. But, FRED will normalize any set direction cosines entered into a FRED dialog or macro command using the relationships below.

$$A^2 + B^2 + C^2 = 1$$

$$\cos(\alpha)^2 + \cos(\beta)^2 + \cos(\gamma)^2 = 1$$

IGES Object Type Numbers and Titles

The complete list of the standard IGES entities is listed in numerical order below. The brief definitions below are quoted / paraphrased directly from IGES (Initial Graphics Exchange Specification) version 5.3 specification.

Type	Form	Name	Description
0		Null Entity	The Null Entity type is intended to be ignored by a processor. When encountered by a processor, this entity shall be skipped over and not processed.
100		Circular Arc Type	A circular arc is a connected portion of a circle which has distinct start and terminate points. The definition space coordinate system is always chosen so that the circular arc lies in a plane either coincident with, or parallel to, the Xt and Yt plane. Supported in FRED as a Circular Arc.
102		Composite Curve Entity	A composite curve is a continuous curve that results from the grouping of certain individual constituent entities into a logical unit. A composite curve is defined as an ordered list of entities consisting of point, connect point, and parameterized curve entities (excluding the Composite Curve Entity).
104		Conic Arc Type	A conic arc is a bounded connected portion of a conic curve which has distinct start and terminate points. The parent conic curve is either an ellipse, a parabola, or a hyperbola.
106	1-3	Copious Data Entity	This entity stores data points in the form of pairs, triples, or sextuples. An interpolation flag value signifies which of these forms is being used.
106	11-13	Linear Path Entity	The linear path is an ordered set of points in either 2- or 3-dimensional space. These points define a series of linear segments along the consecutive points of the path.
106	20-21	Centerline Entity	The Centerline Entity takes one of two forms. The first appears as crosshairs and is normally used in conjunction with circles. The second type is a construction between 2 positions.
106	31-38	Section Entity	A Section Entity is a defined as a Copious Data Entity. The form number describes how the data are to be interpreted. These descriptions are included for compatibility with previous versions of the specification. The Sectioned Area Entity (Type 230) provides a more compact method for transferring this information.
106	40	Witness Line Entity	A Witness Line Entity is a Copious Data Entity that contains one or more straight line segments associated with drafting

			entities of various types.
106	63	Simple Closed Planar Curve Entity	A Simple Closed Planar Curve defines the boundary of a region in the X-Y coordinate space.
108		Plane Entity	The Plane Entity can be used to represent an unbounded plane, as well as a bounded portion of a plane.
110	0	Line Entity	A line is a bounded, connected portion of a straight line which has distinct start and termination points.
110	1-2	Line Entity	Form 1 is a semi-bounded line bounded on one end and unbounded on the other end. Form 2 is an unbounded line, i.e. an infinite line.
112		Parametric Spline Curve Entity	The Parametric Spline Curve is a sequence of parametric polynomial segments.
114		Parametric Spline Surface Entity	The Parametric Spline Surface is a grid of parametric polynomial patches.
116		Point Entity	A point is defined by its coordinates in definition space.
118		Ruled Surface Entity	A ruled surface is formed by moving a line connecting points of equal relative arc length (Form 0) or equal relative parametric value (Form 1) on two parametric curves from a start point to a terminate point on the curves. The parametric curves may be points, lines, conics, parametric splines, rational B-Splines, composite curves, or any parametric curves defined in the specification.
120		Surface of Revolution Entity	A surface of revolution is defined by an axis of rotation (which shall be a line entity (Type 110, Form 0), a generatrix, and start and terminate rotation angles. The surface is created by rotating the generatrix about the axis of rotation through the start and terminating angles.
122		Tabulated Cylinder Entity	A tabulated cylinder is a surface formed by moving a line segment called the generatrix parallel to itself along a curve called the directrix. This curve may be a line, circular arc, conic arc, parametric spline curve, rational B-spline curve, composite curve, or any parametric curve defined in this specification.
123		Direction Entity	A direction entity is a non-zero vector in Euclidean 3-space that is defined by its three components with respect to the coordinate axes.
124		Transformation Matrix Entity	The transformation matrix entity transforms three-row column vectors by means of a matrix multiplication and then a vector addition.
125		Flash Entity	A flash entity is a point in the ZT=0 plane that defines the

			location of a specific instance of a particular closed area.
126		Rational B-Spline Curve Entity	The rational B-Spline curve may represent analytic curves of general interest.
128		Rational B-Spline Surface Entity	The rational B-spline surface represents various analytical surfaces of general interest.
130		Offset Curve Entity	The Offset Curve Entity defines the data necessary to determine the curve offset from a given base curve C.
132		Connect Point Entity	A Connect Point Entity defines a point of connection for zero, one, or more entities.
134		Node Entity	The node entity is a geometric point used in the definition of a finite element.
136		Finite Element Entity	A finite element is defined by an element topology (i.e. node connectivity), along with physical and material properties.
138		Nodal Displacement and Rotation Entity	The nodal displacement and rotation entity is used to communicate finite element post processing data. It contains the incremental displacement and rotations (expressed in radians) for each load case and each node in the model.
140		Offset Surface Entity	The offset surface is a surface defined in terms of an existing surface.
141		Boundary Entity	The Boundary Entity identifies a surface boundary consisting of a set of curves lying on the surface.
142		Curve on a Parametric Surface Entity	The curve on a parametric surface entity associates a given curve with a surface and identifies the curve as lying on the surface.
143		Bounded Surface Entity	The bounded surface entity is used to represent trimmed surfaces. The surfaces and trimming curves are assumed to be represented parametrically.
144		Trimmed (Parametric) Surface Entity	Equivalent to a Trimmed Parametric surface in FRED.
146		Nodal Results Entity	Not supported by FRED.
148		Element Results Entity	Not supported by FRED.
150		Block Entity	Represents a rectangular block. Not supported in FRED.
152		Right Angular Wedge Entity	A 3D block object with four rectangular faces and two quadratic faces. Not supported in FRED.
154		Right Circular Entity	A 3D cylinder object. Not supported in FRED.

156		Right Circular Cone Frustum Entity	A 3D cone object which may or may not come to a point. Not supported in FRED.
158		Sphere Entity	A sphere object defined as a point and a radius in 3 dimensions. Not supported in FRED.
160		Torus Entity	A circle revolved around an axis in the same plane as the circle. Not supported in FRED.
162		Solid of Revolution Entity	A solid 3D object formed by rotating a planar shape through an angle about an axis. Not supported in FRED.
164		Solid of Linear Extrusion Entity	A solid 3D object formed by extruding a planar shape through a distance. Not supported in FRED.
168		Ellipsoid Entity	A solid 3D object formed by rotating an ellipse about its major axis 180 degrees. Not supported in FRED.
180		Boolean Tree Entity	An IGES entity that supports Boolean logical operations. Not supported in FRED.
182		Selected Component Entity	An IGES entity that supports a selected component of a CSG solid. Not supported in FRED.
184		Solid Assembly Entity	Not supported by FRED.
186		Manifold Solid B-Rep Object Entity	Not supported by FRED.
190		Plane Surface Entity	A plane surface. Not supported in FRED; the FRED plane is defined differently. This type is neither read in nor written out.
192		Right Circular Cylindrical Surface Entity	A cylinder defined by a point, a direction, and a radius. Not supported in FRED.
194		Right Circular Conical Surface Entity	A cone defined by a point, an axis direction, a radius, and an angle. Not supported in FRED.
196		Spherical Surface Entity	A sphere defined by a point and a surface (not a solid). Not supported in FRED.
198		Toroidal Surface Entity	A surface defined by a point, an axis, and two radii. Not supported in FRED.
202		Angular Dimension Entity	IGES entity that represents the annotation of an angle measurement. Not supported in FRED.

204		Curve Dimension Entity	IGES entity that represents the annotation of the length of a curve. Not supported in FRED.
206		Diameter Dimension Entity	IGES entity that represents the annotation of the diameter of a circular arc. Not supported in FRED.
208		Flag Note Entity	IGES entity that represents an annotation flag. Not supported in FRED.
210		General Label Entity	IGES entity that represents a general note. Not supported in FRED.
212		General Note Entity	IGES entity that represents a set of text strings. Not supported in FRED.
213		New General Note Entity	IGES entity like type 212 but able to accommodate more text characteristics. Not supported in FRED.
214	1-12	Leader (Arrow) Entity	IGES entity representing an arrow head point. Not supported in FRED.
216		Linear Dimension Entity	IGES entity that represents a dimension between two points. Not supported in FRED.
218		Ordinate Dimension Entity	IGES entity that represents a set of dimensions from a common base line. Not supported in FRED.
220		Point Dimension Entity	IGES entity that represents a text string surrounded by a circle or hexagon, annotating a point. Not supported in FRED.
222	0-1	Radius Dimension Entity	IGES entity that represents a point where annotating text is surrounded by a circle. Not supported in FRED.
228	0-1	General Symbol Entity	IGES entity that represents a set of notes that annotate a point, surrounded by a geometry entity. Not supported in FRED.
230		Sectioned Area Entity	IGES entity that represents an area that is filled with a line pattern. Not supported in FRED.
302		Associativity Definition Entity	IGES entity that represents a group. Not compatible with the FRED group.
304	1-2	Line Font Definition Entity	IGES entity that represents a line font. Not supported by FRED.
306		MACRO Definition Entity	IGES entity that represents a macro. Not supported by FRED.

308		Subfigure Definition Entity	IGES entity that allows for multiple instances of the same object. Not supported by FRED.
310		Text Font Definition Entity	IGES entity that defines the appearance of characters in a text font. Not supported by FRED.
312		Text Display Template Entity	IGES entity that sets parameters for displaying information from another entity. Not supported by FRED.
314		Color Definition Entity	IGES entity that stores the RGB color information for an entity. Not supported in FRED.
316		Units Data Entity	IGES entity that stores information about the unit's of a model in an IGES file. Not supported by FRED.
320		Network Subfigure Definition Entity	IGES entity similar to the type 308 subfigure definition, used to define a specialized subfigure. Not supported by FRED.
322		Attribute Table Definition Entity	IGES entity that defines a table of attributes for an entity. Not supported by FRED.
402		Associativity Instance Entity	Identifies the type of associativity relation between two entities. Not supported by FRED.
402	1	Group Associativity	IGES entity that allows a collection of entities to be maintained as one. Not supported by FRED.
402	3	Views Visible Associativity	IGES entity that defines an associativity to a view entity. Not supported by FRED.
402	4	Views Visible, Color, Line Weight Associativity	IGES entity that defines an associativity between view entities of differing display styles. Not supported by FRED.
402	5	Entity Label Display Associativity	IGES entity that defines an association between displays for entity labels. Not supported by FRED.
402	7	Group Without Back Pointers Associativity	IGES entity that defines an association between groups without back pointers. Not supported by FRED.
402	9	Single Parent Associativity	IGES entity that defines an association between a single parent and multiple entities. Not supported by FRED.
402	12	External Reference File Index	IGES entity that defines an association between definitions in separate files. Not supported by FRED.

		Associativity	
402	13	Dimensioned Geometry Associativity	Deprecated by type 402 form 21. Not supported by FRED.
402	14	Ordered Group with Back Pointers Associativity	IGES entity that defines an association between ordered groups with back pointers. Not supported by FRED.
402	15	Ordered Group, no Back Pointers Associativity	IGES entity that defines an association between ordered groups without back pointers. Not supported by FRED.
402	16	Planar Associativity	IGES entity that defines an association between coplanar entities. Not supported by FRED.
402	18	Flow Associativity	IGES entity that defines an association between two entities with a flow path. Not supported by FRED.
402	19	Segmented Views Visible Associativity	IGES entity that defines an association between display parameters for two or more curves. Not supported by FRED.
402	20	Piping Flow Associativity	IGES entity that defines an association for a single fluid flow path. Not supported by FRED.
402	21	Dimensioned Geometry Associativity	IGES entity that defines an association between a dimension entity and the geometry entities it is dimensioning. Not supported by FRED.
404		Drawing Entity	IGES entity that defines a collection of annotation entities. Not supported by FRED.
406		Property Entity	IGES entity that contains numerical or textual data. Not supported by FRED.
406	1	Definition Levels Property	Not supported by FRED.
406	2	Region Restriction Property	Not supported by FRED.
406	3	Level Function Property	Not supported by FRED.
406	4	(OBSOLETE) – Region Fill Property	Not supported by FRED.

406	5	Line Widening Property	Not supported by FRED.
406	6	Drilled Hole Property	Not supported by FRED.
406	7	Reference Designator Property	Not supported by FRED.
406	8	Pin Number Property	Not supported by FRED.
406	9	Part Number Property	Not supported by FRED.
406	10	Hierarchy Property	Not supported by FRED.
406	11	Tabular Data Property	Not supported by FRED.
406	12	External Reference File List Property	Not supported by FRED.
406	13	Nominal Size Property	Not supported by FRED.
406	14	Flow Line Specification Property	Not supported by FRED.
406	15	Name Property	Not supported by FRED.
406	16	Drawing Size Property	Not supported by FRED.
406	17	Drawing Units Property	Not supported by FRED.
406	18	Intercharacter Spacing Property	Not supported by FRED.
406	19	Line Font Property	Not supported by FRED.
406	20	Highlight Property	Not supported by FRED.
406	21	Pick Property	Not supported by FRED.
406	22	Uniform Rectangular Grid Property	Not supported by FRED.
406	23	Associativity Group Type	Not supported by FRED.

		Property	
406	24	Level to LEP Layer Map Property	Not supported by FRED.
406	25	LEP Artwork Stackup Property	Not supported by FRED.
406	26	LEP Drilled Hole Property	Not supported by FRED.
406	27	Generic Data Property	Not supported by FRED.
406	28	Dimension Units Property	Not supported by FRED.
406	29	Dimension Tolerance Property	Not supported by FRED.
406	30	Dimension Display Data Property	Not supported by FRED.
406	31	Basic Dimension Property	Not supported by FRED.
406	32	Drawing Sheet Approval Property	Not supported by FRED.
406	33	Drawing Sheet ID Property	Not supported by FRED.
406	34	Underscore Property	Not supported by FRED.
406	35	Overscore Property	Not supported by FRED.
406	36	Closure Property	Not supported by FRED.
408		Singular Subfigure Instance Entity	Not supported by FRED.
410	1	Perspective View Entity	Not supported by FRED.
412		Rectangular Array Subfigure	Not supported by FRED.

		Instance Entity	
414		Circular Array Subfigure Instance Entity	Not supported by FRED.
416		External Reference Entity	Not supported by FRED.
418		Nodal Load / Constraint Entity	Not supported by FRED.
420		Network Subfigure Instance Entity	Not supported by FRED.
422		Attribute Table Instance Entity	Not supported by FRED.
422	0	Attribute Table Instance	Not supported by FRED.
422	1	Attribute Table Instance	Not supported by FRED.
430		Solid Instance Entity	Not supported by FRED.
502	1	Vertex List Entity	Not supported by FRED.
504		Edge List Entity	Not supported by FRED.
508		Loop Entity	Not supported by FRED.
510		Face Entity	Not supported by FRED.
514		Shell Entity	Not supported by FRED.

Chapter 6 – How to Create Curves and Curve-based Surfaces

Introduction to Curves and Curve-based Surfaces

Description

Introduction to Curves and Curve-based Surfaces

FRED has a number of implicit, or curve-based surface types: the **Tabulated Cylinder**, the **Ruled Surface**, and the **Surface of Revolution**. These surfaces allow for a great deal of flexibility to generate complicated surface geometries, but have some simple rules and limitations that do not apply to more conventional surface functions.

First among these is that an implicit surface cannot be used to trim another surface. This is because the surfaces are generated as parametric functions, and, as such, do not have an easily identifiable positive and negative side. In other words, the +Z direction of the local surface normal, which is used to establish rules for trimming, is ambiguous. However, these surfaces are bounded and can be trimmed by function-based surface types.

Second, at least some portion of the generating curve must be located inside the bounding volume of the surface. Only that portion of the curve inside the bounding volume will be created. Putting both the curve and the surface in the same coordinate system most easily satisfies this requirement.

Third, curves are used to create surfaces, not volumes, although a fully enclosed volume may be the end result. For example, a rod lens uses a surface of revolution to create the cylinder must also include separate surfaces for each end to close the volume. Failure to do so may result in ray failures because FRED may propagate a ray that sees a change in the refractive index as it exits the volume occupied by the cylinder without intersecting a surface. Without a surface intersection, FRED cannot propagate the ray.

Curves

FRED has number of simple curve types. In general, each curve is defined parametrically over an interval from [0,1]. The starting point is always at u = 0 and the ending point is at u = 1.

Curves alone are not traceable.

A brief description of each curve type follows.

Line segment

This is the simplest curve type. It is defined as the line connecting the point $(x, y, z)_{start}$ with the point $(x, y, z)_{end}$.

Type: Line segment (defined by start and end points)

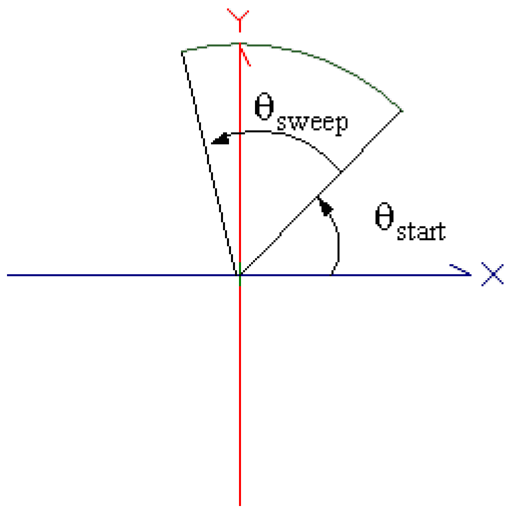
	Start Point	End Point
X	0	1
Y	0	0
Z	0	0

Circular arc

As the name implies, this is a simple circular arc. By default, it is defined in the local XY plane. It is centered at (x_0, y_0) and has a radius r. The start and end points for the arc are given by the start angle and the sweep angle, respectively. These are polar angles are measured in degrees, counter-clockwise from the X-axis ($\theta = 0$). Both the start and sweep angles can be between 0 and 360 degrees.

Type: Circular arc

	Value	Description
Center X	0	X coordinate of the center
Center Y	0	Y coordinate of the center
Radius	1	Radius of the arc
Start Angle	0	Start angle (deg). CCW from X-axis (0 to 360 degrees)
Sweep Angle	360	Sweep angle (deg). CCW from start angle (0 to 360 degrees)



Conic arc

Type: Conic arc (defined by coefficients of quadratic equation)

	Value	Description
	Curve described by: A*X*X+B*X*Y+C*Y*Y+D*X+E*Y+F=0	
A	1	Coefficient of X*X term
B	0	Coefficient of X*Y term
C	1	Coefficient of Y*Y term
D	0	Coefficient of X term
E	0	Coefficient of Y term
F	-1	Constant term
Start X	1	Curve's starting X value
Start Y	0	Curve's starting Y value
End X	1	Curve's ending X value
End Y	0	Curve's ending Y value

The **conic arc** is a more general form of the **circular arc**. It is used primarily for IGES™ import. It is defined by the equation

$$f(x,y) = Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$$

The function f(x,y) is a second-degree curve if both A and C are not 0. The curve is a parabola if the product AC = 0. The curve is an ellipse if the product AC > 0. It is a circle if A=C. The curve is a hyperbola if the product AC < 0. The B coefficient represents a rotation of the coordinate axes. If B = 0, the curves are not rotated about the local x- and y-axes. The D and E coefficients represent coordinate shifts.

User inputs include the desired coefficients and the range of values over which the curve is defined: x_{start}, y_{start} and x_{end}, y_{end}. These points do not have to lie on the curve. Rather they define the polar angle subtended by the curve, analogous to the convention used for the circular arc. The starting angle is simply

$$\theta_{start} = \arctan\left(\frac{y_{start}}{x_{start}}\right)$$

Likewise, the ending angle is

$$\theta_{end} = \arctan\left(\frac{y_{end}}{x_{end}}\right)$$

Parabola

A parabola in y has the form Ey = Ax^2 + Bxy + Dx + F. For any such parabola, the coefficients A and E cannot be zero and the C coefficient must be zero. The B and D coefficients rotate and shift the curve, respectively. The coefficient F is a constant offset that moves the curve up and down along the y-axis.

Ellipse

An ellipse centered at the point (x_0, y_0) has the form

$$\frac{(x - x_0)^2}{a^2} + \frac{(y - y_0)^2}{b^2} = 1$$

where a and b are the semi-major and semi-minor axis lengths, respectively. The coefficient values A..F can be found by equating the two forms. To create an ellipse in which both *a* and *b* are known and is not rotated in the XY-plane, the conversion to the curve coefficients is found in Table 1.

Table 1 Coefficient Conversion for an Ellipse

Curve Coefficient	Value
A	$\frac{1}{a^2}$
B	0
C	$\frac{1}{b^2}$
D	$-2A \cdot x_0$
E	$-2C \cdot y_0$
F	$\frac{D^2}{4A} + \frac{E^2}{4C} - 1$

If the conic constant *k* and the radius of curvature *r* are known, then *a* and *b* can be computed using the following relationships (-1 < *k* ≤ 0).

$$a = \frac{r}{1 + k}$$

$$b = a \cdot \sqrt{1 + k}$$

Hyperbola

A hyperbola centered at the point (x_0, y_0) has the form

$$\frac{(x - x_0)^2}{a^2} - \frac{(y - y_0)^2}{b^2} = 1$$

which describes a curve that intersects the x-axis (A > 0, C < 0). If the signs are reversed (A < 0, C > 0) the curve intersects the y-axis. The terms *a* and *b* do not have the same geometric significance for a hyperbola as they do for an ellipse and are not used except to calculate the asymptotes of the curve

$$y - y_0 = \pm \frac{a}{b}(x - x_0)$$

When A > 0 both x_{start} and x_{end} should be greater than zero. Further, y_{start} and y_{end} should be chosen so that the start and ending angles are between the asymptote lines. When A < 0, chose y_{start} and y_{end} greater than zero and x_{start} and x_{end} to be between the asymptote lines. Following these rules will help avoid unexpected results arising from the creation of multiple branches of the curve.

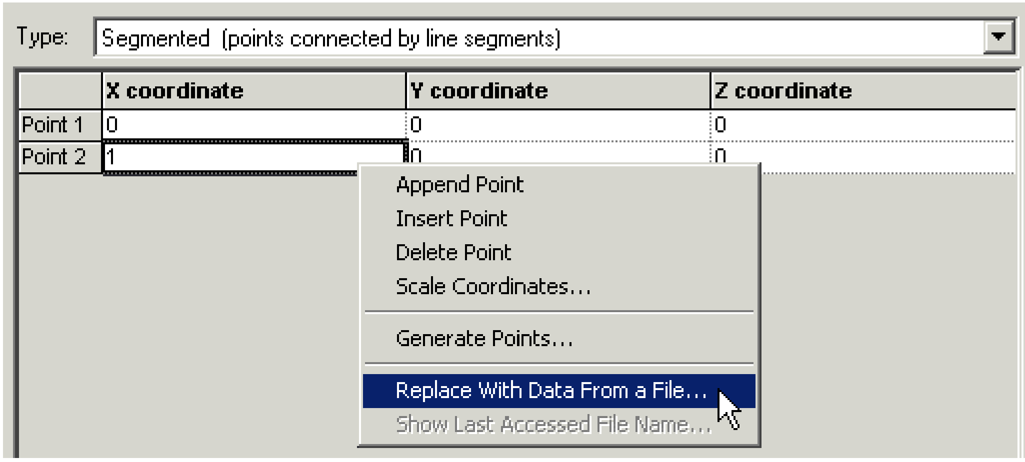
The curve coefficients for the hyperbola are analogous to those of the ellipse except A and C have opposite signs. Table 2 shows a similar coefficient conversion based on knowledge of *a* and *b*.

Table 2 Coefficient Conversion for a Hyperbola (A>0)

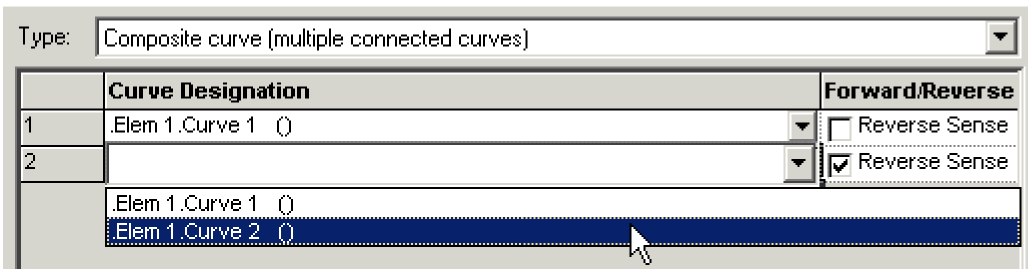
Curve Coefficient	Value
A	$\frac{1}{a^2}$
B	0
C	$\frac{1}{-b^2}$
D	$-2A \cdot x_0$
E	$-2C \cdot y_0$
F	$\frac{D^2}{4A} + \frac{E^2}{4C} - 1$

<u>*Segmented*</u>

A segmented curve is simply a collection of points in (x, y, z) connected by straight lines. It is not necessary for the curve to be closed and FRED will not automatically close the surface. To close the surface, simply enter the same coordinates for the last point as were entered for the first. A right mouse click in the active cell area in the dialogue box allows for row addition or deletion. In addition, FRED can read an ASCII text file of consisting of rows of X, Y, and Z points separated by spaces.



Composite Curve

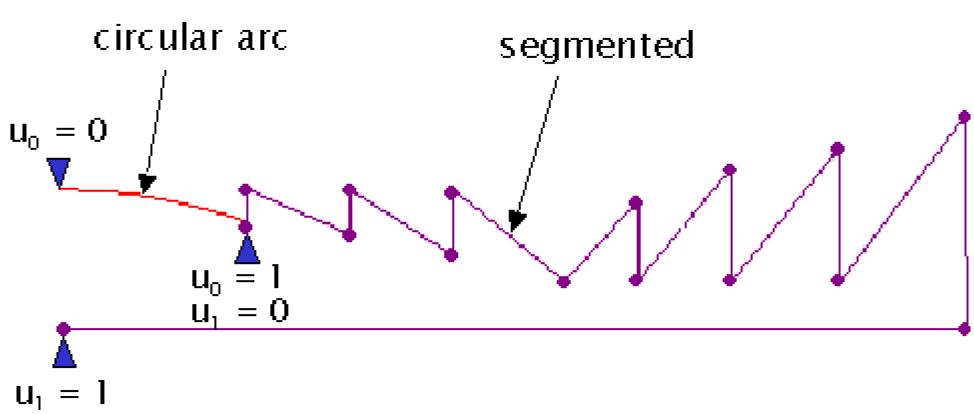


A composite curve is two or more curves joined in the following fashion,

start→ end, start→ end, .., start→ end

The start point (u_n = 0) of each subsequent curve is coincident with the end point (u_{n-1} = 1) of the previous curve. The Reverse Sense check box flips the starting and ending points of the curve. When 2 or more curves are joined, the parameterization is renormalized so that the curve starts at $u_{composite}$ = 0 and ends at $u_{composite}$ = 1. The curves do not need to be the same type. Multiple composite curves can be joined as well.

In the following example, a composite curve is used to create a ‘lighthouse’ lens profile. The composite curve joins a circular arc and a number of segmented curves. Note that the curve is ‘open’.



If the segments are not properly positioned, FRED issues an error message. A common error is to have the parameterization reversed so that FRED is trying to connect the start point of one curve to the start point of a different curve, which is an invalid operation. It is often useful (but not required) to define the curves in that same coordinate system. The composite curve should also be located in the proper coordinate system as well. After creating the composite curve, it is recommended that each component curve be placed in the coordinate system of the composite. This way, the composite curve can be repositioned anywhere in the system and the component curves will automatically follow.

Any curve used to create the composite can be edited. Changes are reflected automatically. The rules governing the endpoint connections must still be obeyed. If a composite curve is copied, FRED automatically creates a duplicate set of the generating curves.

Spline

The spline is a parametric curve used mainly in the representation of CAD geometry. The position vector P along the curve as a function of the parameter t is given by

$$P(t) = \sum_{i=1}^{n+1} B_i \, N_{i,k}(t) \qquad t_{min} < t < t_{max}\ , \qquad 2 \le k \le n+1$$

Knots or 'breakpoints' given in ascending order define the parametric range of the variable t.

For the ith normalized B-spline basis function of order k (degree = k-1), the basis functions $N_{i,k}(t)$ are defined by the Cox-de Boor recursion formulas:

$$N_{i,1}(t) = \quad 1 \quad \text{if } x_i \le t \le x_{i+1}\ , \qquad 0 \quad \text{otherwise}$$

and

$$N_{i,k}(t) = (t - x_i)\cdot N_{i,k-1}(t) \,/\, (x_{i+k-1} - x_i) \; + \; (x_{i+k} - t)\cdot N_{i+1,k-1}(t) \,/\, (x_{i+k} - x_{i+1})$$

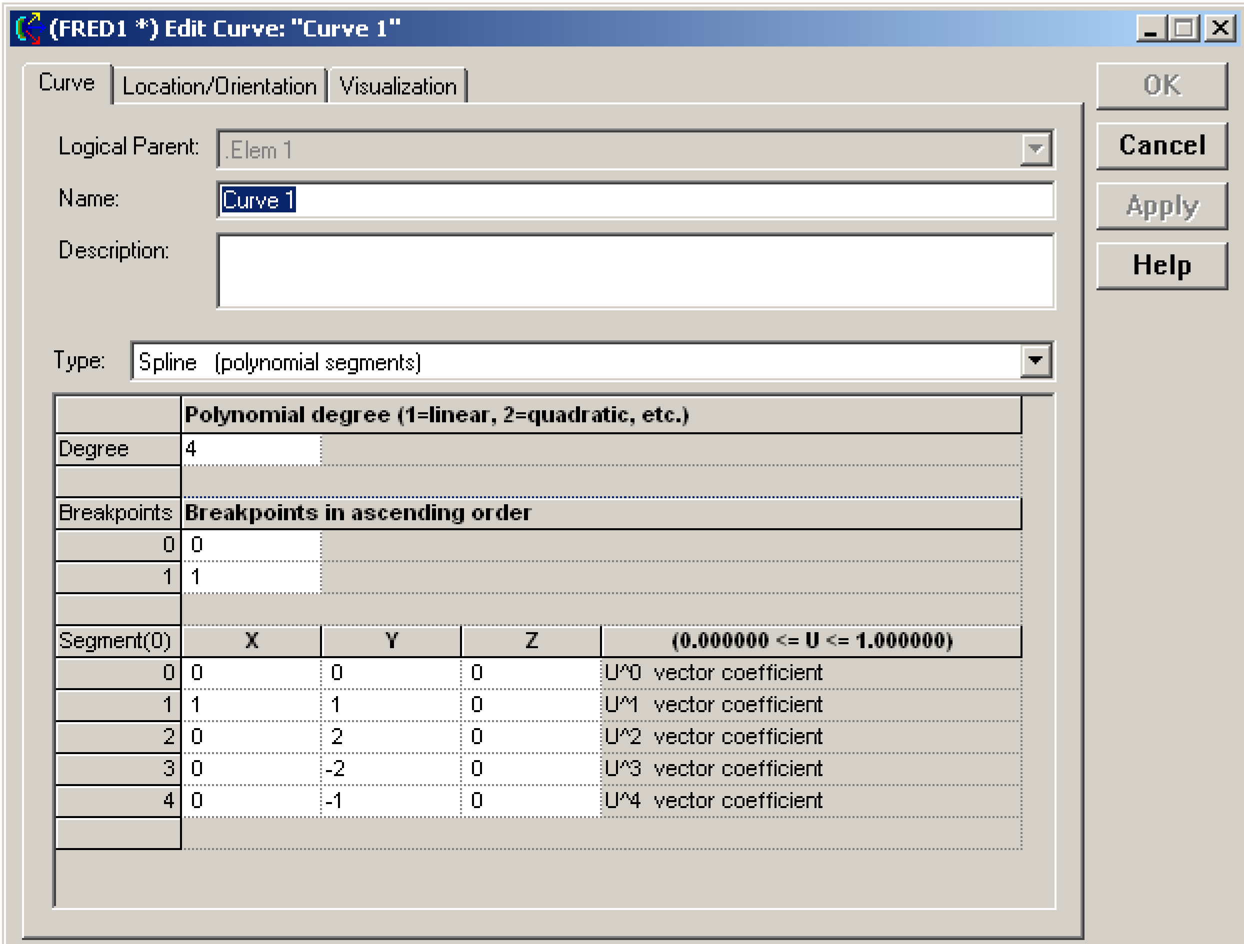
As an example, consider a 5th order (degree = 4) curve defined over the breakpoint values <0 1>. The basis functions are then

$$N_{1,1} = 1\ ; \quad N_{1,2} = t\ ; \quad N_{1,3} = t^2\ ; \quad N_{1,4} = t^3\ ; \quad N_{1,4} = t^4$$

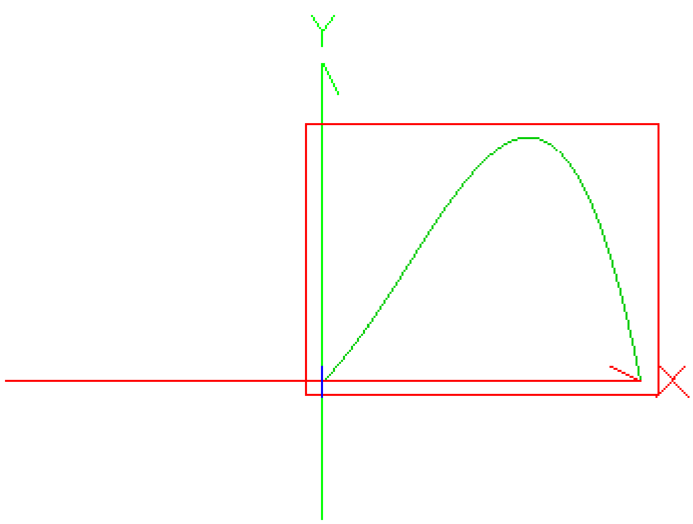
These basis functions amount to the following polynomial expression with the U^n vector coefficients a, b, c, d, & f:

$$P(t) = a + b\cdot t + c\cdot t^2 + d\cdot t^3 + f\cdot t^4$$

Consider the polynomial curve defined by $y(x) = x + 2x^2 - 2x^3 - x^4$. The dialog box below shows this curve cast in the form of a spline curve.



The x-coordinate is given by $P_x(t) = t$ and the y-coordinate by $P_y(t) = t + 2 \cdot t^2 - 2 \cdot t^3 - x^4$. As expected, FRED draws this curve in the 3D View:



Spline curve representing the polynomial $y(x) = x + 2x^2 - 2x^3 - x^4$.

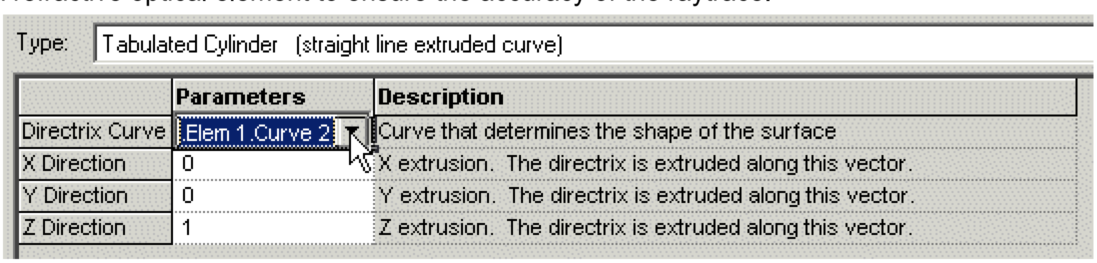
Other curve types

FRED also has a number of special curve types that are used primarily to import IGES™ files and lenses from CODE V™, OSLO™, and ZEMAX™. These surface types are: *NURB* (Non-Uniform Rational B-spline), *Spline* (polynomial segments), and *Aperture Curve Collection*. FRED automatically creates the fit coefficients for the NURB and Spline curves during a CAD system import. The user is not required to enter points manually. The Aperture Collection Curve is used to create complex or segmented apertures on a single surface (instead of creating multiple copies of the same surface). These curves must be closed and are used only to establish trimming boundaries in the aperture settings for the surface. Aperture curves will be created automatically during a lens file import. The user can also create and apply them manually.

Surface types

Tabulated Cylinder

The Tabulated Cylinder is a simple extrusion of a curve. The user is prompted for the directrix (generating) curve and the length of the extrusion (in lens units) along each of the local x-, y-, and z-axes. These lengths are used to form the vector that orients the extrusion axis. Although not a requirement, the curve is typically extruded along the axis perpendicular to the plane containing the generating curve. Except for extrusions in the plane of the curve, the cross section of an extrusion taken in the plane containing the generating curve has the exact same shape and form as the generating curve. Extrusions in the plane of the curve result in sheets with (possibly) irregular edges. If the curve is not closed, the neither will be the surface. It may be necessary to add the sides and ends separately if the surface is to be used as a refractive optical element to ensure the accuracy of the raytrace.


Type: Tabulated Cylinder (straight line extruded curve)

	Parameters	Description
Directrix Curve	Elem 1.Curve 2	Curve that determines the shape of the surface
X Direction	0	X extrusion. The directrix is extruded along this vector.
Y Direction	0	Y extrusion. The directrix is extruded along this vector.
Z Direction	1	Z extrusion. The directrix is extruded along this vector.

Some examples of the tabulated cylinder are shown in the following figures.

The picture on the left shows an extrusion of the ‘lighthouse’ lens profile perpendicular to the plane of the curve. The picture on the right shows an extrusion in the plane of the same curve.

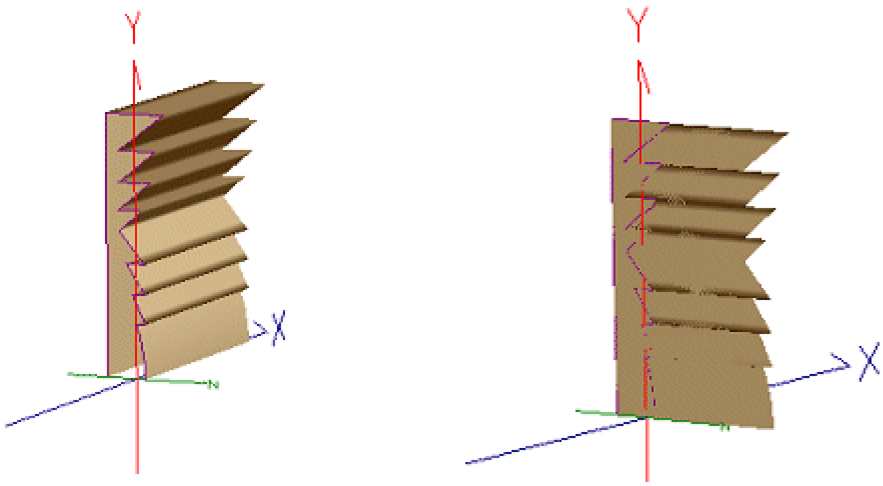


Figure 1

Figure 2 shows the extrusion of a parabolic curve defined in the YZ-plane along the X-axis. Figure 3 shows the extrusion of a parabolic curve defined in the YZ-plane along an arbitrary axis. Note that any cross-section of the surface taken in the YZ-plane will have the same shape and dimensions as the base curve.

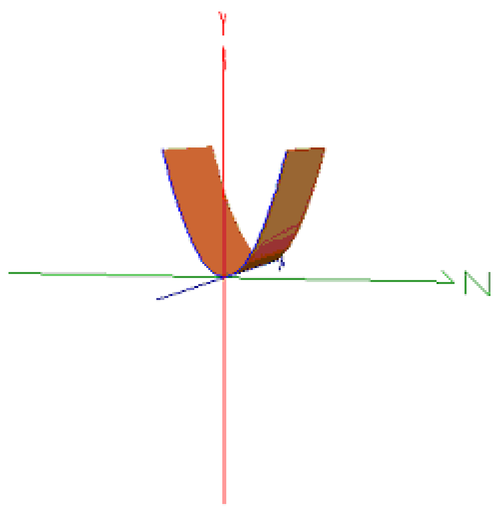


Figure 2

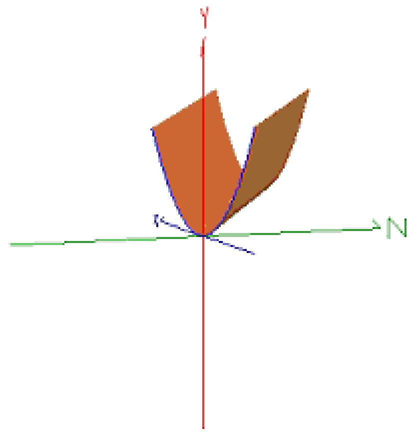


Figure 3

Surface of Revolution

A **Surface of Revolution** spins a curve about an arbitrary axis. The user is prompted for the generating curve, the start and ending rotation angles, and the local (x, y, z) coordinates for the rotation axis. Positive angles are measured counter-clockwise from the plane containing the generating curve. The start angle must be less than the end angle. The rotation axis is along the line connecting start and end points, entered by the user. Remember that FRED only creates surfaces. A closed volume requires bounding surfaces.

Type: Surface of Revolution (curve revolved around an axis)

	Start Parameters	End Parameters	Description
Generatrix Curve	.Elem 1.Curve 1		Curve that determines the shape of the surface
Rotation Angles	0	360	Starting and ending rotation angles (deg). Ending angle > starting angle.
X Coord	0	0	Rotation axis X coords for starting and ending points on the rotation axis
Y Coord	0	0	Rotation axis Y coords for starting and ending points on the rotation axis
Z Coord	0	1	Rotation axis Z coords for starting and ending points on the rotation axis

Figure 4 shows two examples of a **surface of revolution**. The surface on the left shows a complete revolution. The surface on the right is only partially revolved, with the start and end angles shown.

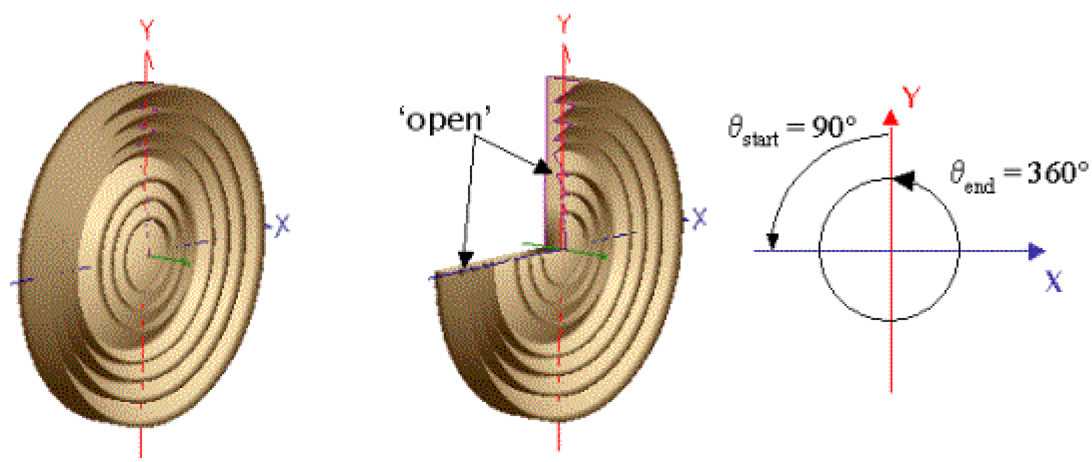


Figure 4

Figure 5 shows the same curve revolved around a tilted rotation axis.

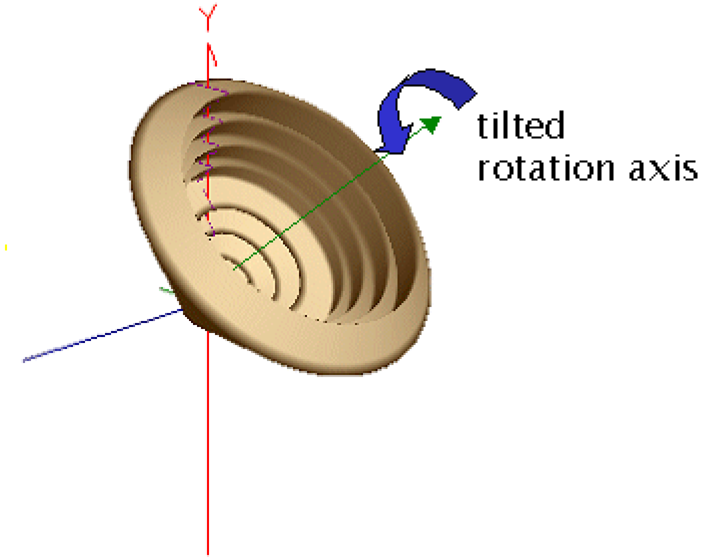


Figure 5

Another example of a surface of revolution is a torus, which is simply a circle (Circular Arc) revolved around an offset axis, as shown in Figure 6.

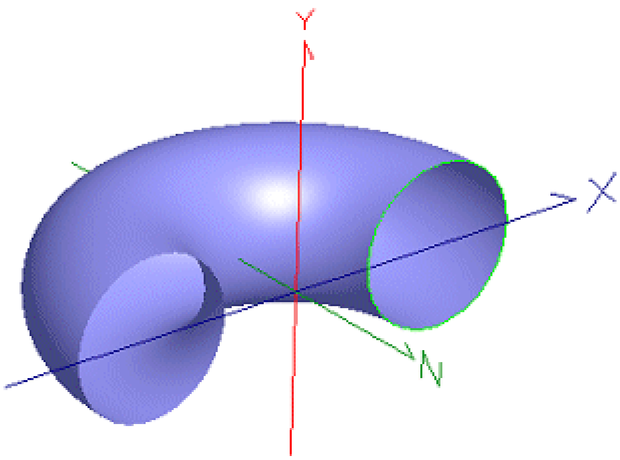


Figure 6

A cone can be generated in a similar fashion, as shown in Figure 7. The cone was created by revolving a line segment defined in the YZ-plane about the z-axis.

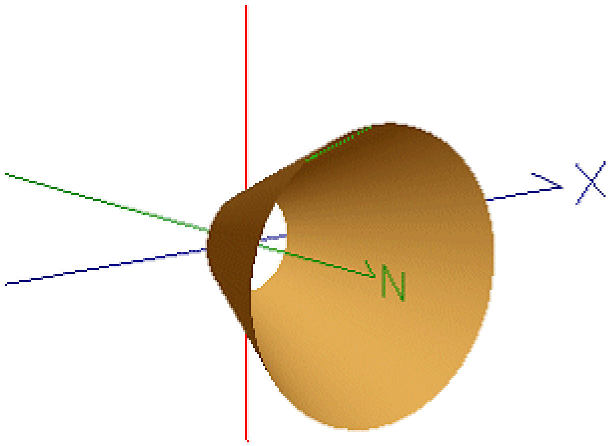
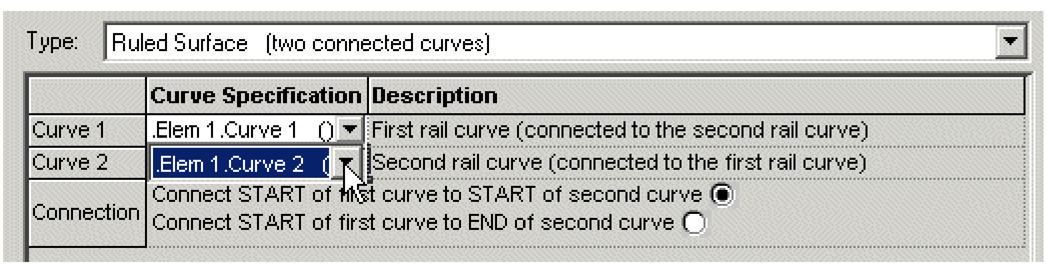


Figure 7

Ruled surface

The **Ruled Surface** type connects two curves. The curves may be of any type, open or closed, and do not have to have the same shape. The rule for connecting the two curves is selected by the user as one of two options. The first option is the default condition. It connects the start of the first curve to the start of the second curve. When this option is selected, each point *u* on curve 1 is connected to the same point *u* on curve 2. The second option connects the start of the first curve to the end of the second curve. Each point *u* on curve 1 is connected to the point 1-*u* on curve 2. This option is often the best choice if the curves are defined in opposite directions, i.e., clockwise and counter-clockwise for closed curves or with *u* increasing along +X and –X for open curves. A quick check of the system view after any change has been applied is usually sufficient to determine if the desired surface has been created.



Type: Ruled Surface (two connected curves)

	Curve Specification	Description
Curve 1	.Elem 1.Curve 1 ()	First rail curve (connected to the second rail curve)
Curve 2	.Elem 1.Curve 2 (	Second rail curve (connected to the first rail curve)
Connection	Connect START of first curve to START of second curve ◉ Connect START of first curve to END of second curve ○	

The most common application of the **Ruled Surface** is to create a tube with different shapes on each end. Likewise, apertures, such as a round disk with a square hole in the center (really a zero length cylinder) can be modeled with this surface type (Figure 8) by connecting the inner square to the outer circle. As a side note, a much more efficient way to create a similar aperture is to start with a simple **Plane** surface. The ruled surface generates a smoother surface than the function based **Cylinder** surface when one or both of the ends has sharp corners.

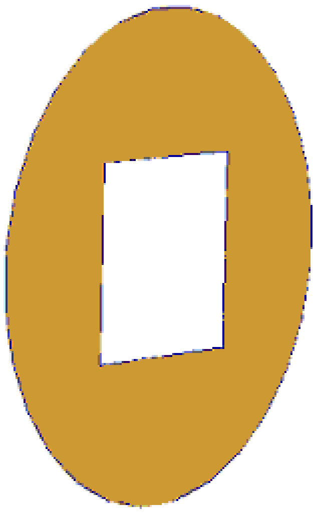


Figure 8

The following figures illustrate a **Ruled Surface** created with a square (**Segmented**) curve and a circle (**Circular arc**) to illustrate how the two curves are connected. Figure 9 shows a cylinder surface that is twisted because the starting points on each curve are rotated 45 degrees with respect to one another. In Figure 10, the curves have been properly oriented to create the 'correct' surface. The twist is removed by rotating the first square curve about its local z-axis.

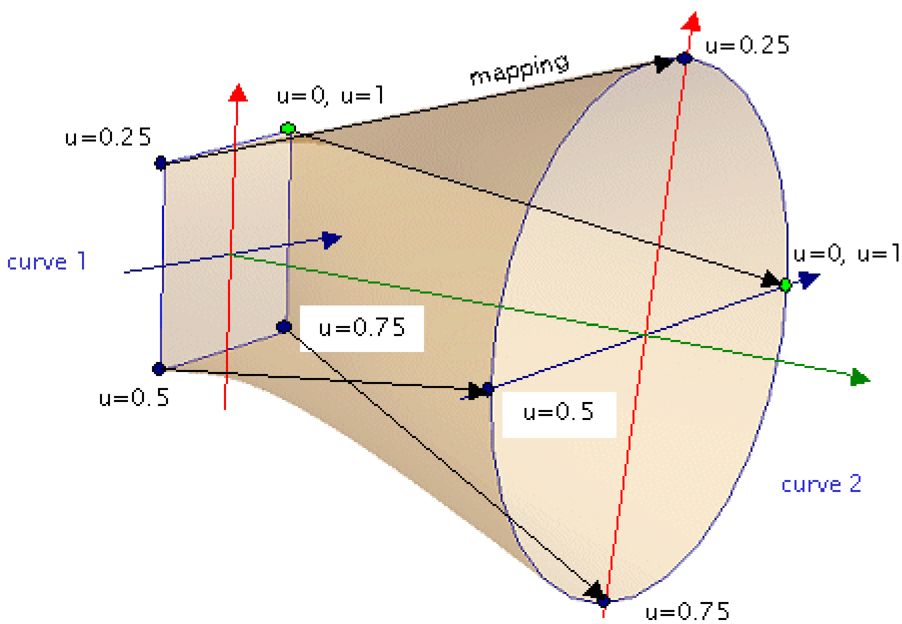


Figure 9

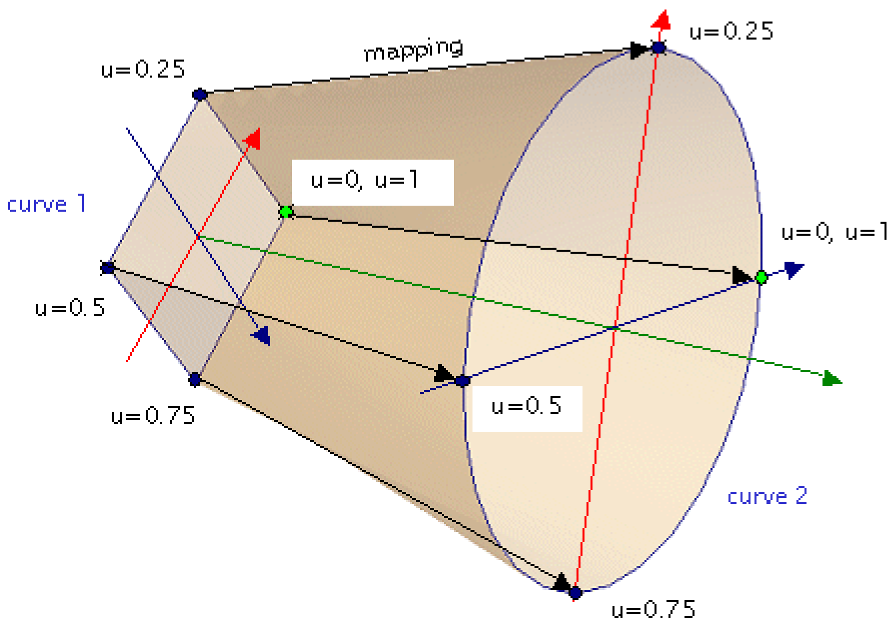


Figure 10

- Values for x, y, and z are all evaluated in the local coordinate system of the surface (or curve). Limits for x, y, and z are determined by the trimming volume outer boundary settings.
- Curves and surfaces do not need to be defined in the same coordinate system. However, at least some portion of the generating curve must lie within the trimming volume outer boundary settings.
- A curve-based surface cannot be used to trim another surface.
- Copied surfaces also create duplicate generating curves.
- The same curve may be used to create multiple surfaces.

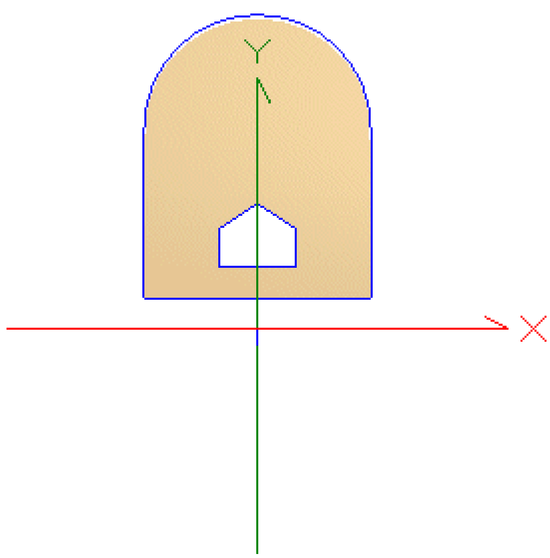
Complex Surface Apertures: Aperture Curve Collection

Description - Complex Surface Apertures: Aperture Curve Collection

Complex surface trimming boundaries or apertures can be created using the Aperture Curve Collection curve type. These are a special set of closed curves that are extruded into trimming surfaces that can then be applied to any FRED surface type. An aperture curve collection can be used to define inner and outer boundaries, holes, segmented apertures, etc. They are applied to the surface in the Trimming Surfaces Specification box, found under the Aperture tab of a Surface Dialog. An aperture curve collection can only be created from one or more closed curves.

Visualization (example) - Complex Surface Apertures: Aperture Curve Collection

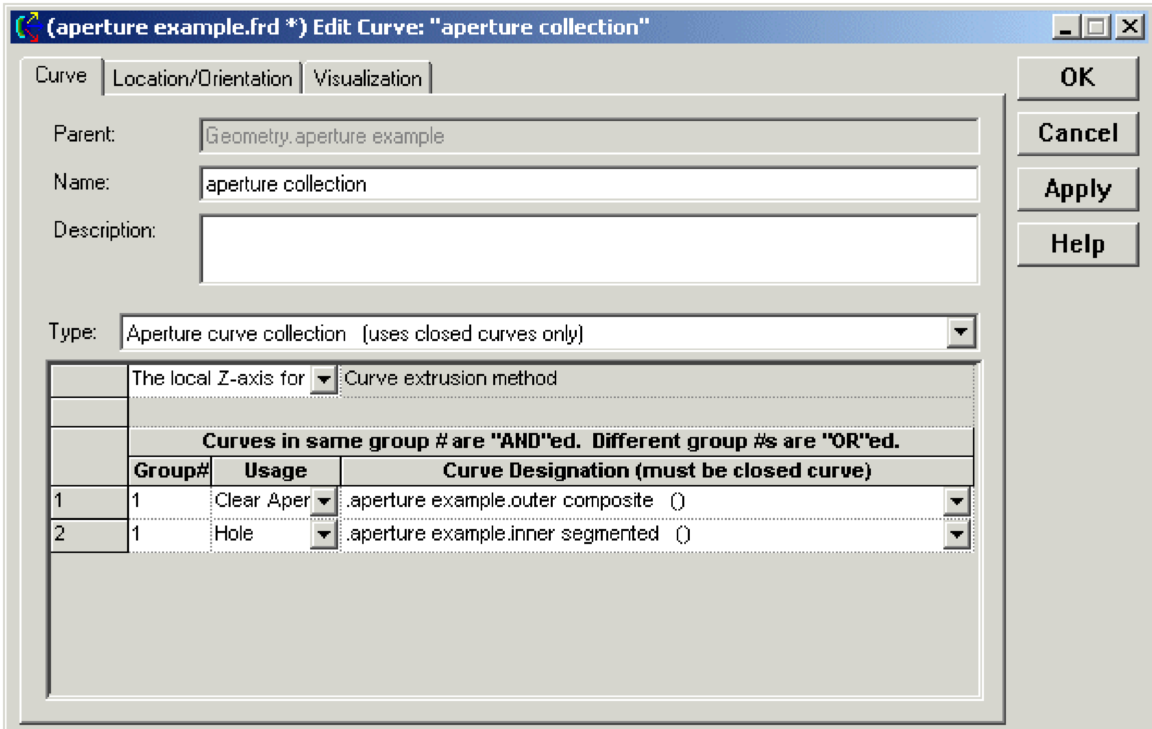
The surface shown in the following figure has been trimmed by a single aperture curve collection.



How Do I Get There? - Complex Surface Apertures: Aperture Curve Collection

An aperture curve collection is defined under a Custom Element node.

Dialog Box and Controls - Complex Surface Apertures: Aperture Curve Collection



Control	Inputs	Defaults
Parent	None.	Gives the parent object of the aperture curve collection. The aperture curve collection is always located under a Custom Element node.
Name	Name of curve.	Curve *n*
Description	Descriptive text for curve.	blank
Type	Select 'Aperture curve collection' from the list of available curve types.	Circular arc
Curve extrusion method	Specifies the orientation and direction of the trimming surface extrusion.	Each curve is extruded along its local Z axis.
Group#	Enter the Group number of each curve. The Group number tells	All curves are "AND"ed together. The Group number is

	FRED how to combine multiple curves.	1.
Usage	Choose one of the following: *Clear Aperture* *Edge* *Obscuration* *Hole* This control describes what happens to the area inside the curve.	Clear Aperture
Curve Designation	Select the closed curve or curves from the pull down list.	None
OK	Create curve collection and close dialog box.	
Cancel	Discard curve collection changes and close dialog box.	
Apply	Apply curve collection changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Complex Surface Apertures: Aperture Curve Collection

- Line and arc segments must be joined together as a Composite Curve prior to specification as an Aperture Curve Collection.
- The curves defining the aperture curve collection must be closed. That is, the end point and the start point are the same and there are no gaps anywhere along the length of the curve.
- An aperture curve collection can contain one or more closed curves. The closed curves do not have to be connected.
- Usage definitions:
  - Clear Aperture (default) – Keep the area of the surface inside the curve boundary. In the absence of an Edge specification, the surface is trimmed to the shape specified by the Clear Aperture. If an Edge is specified, then the Edge becomes the outer boundary of the surface and the Clear Aperture defines the region of the surface that will interact with the incident rays.
  - Edge – The curve represents the physical outer boundary of the surface. In the absence of a Clear Aperture, any ray striking the surface inside the Edge is

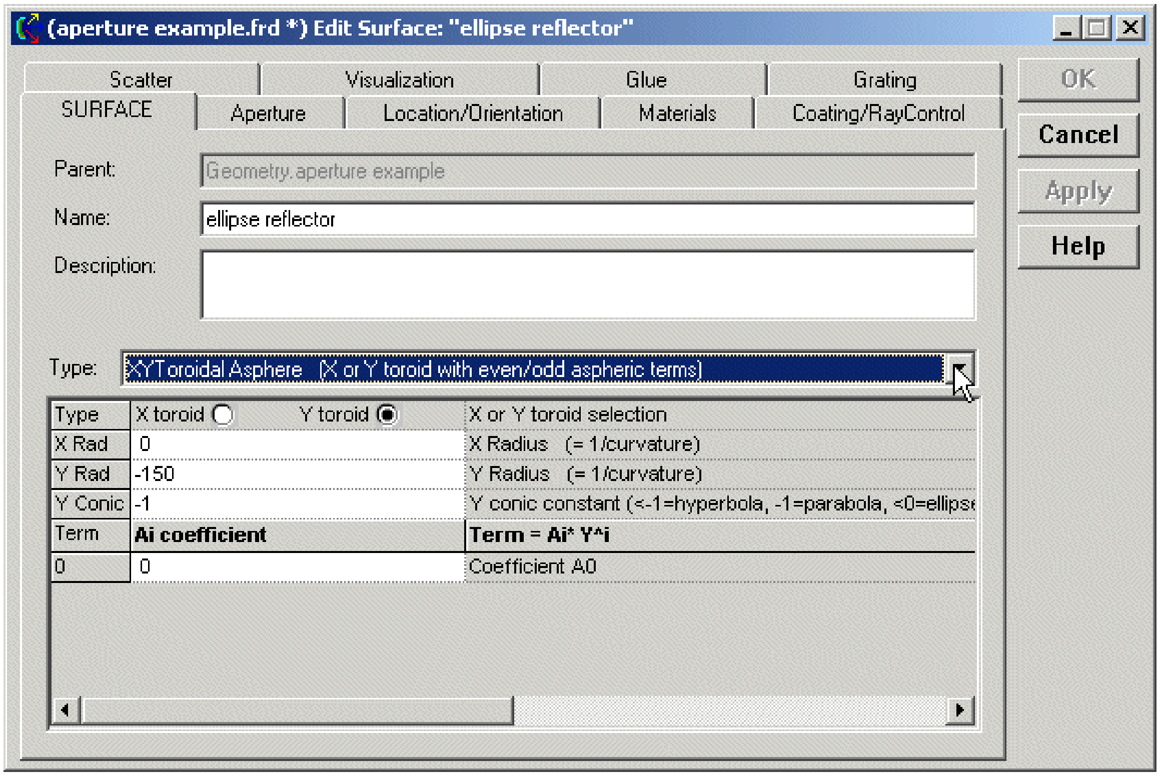
halted. When used in conjunction with a Clear Aperture, the following rules apply:
    - Rays incident outside of the area delineated by the Edge miss the surface
    - Rays incident on the surface area inside of the Edge and outside of the Clear Aperture are halted on the surface
    - Rays incident on the surface area inside of both the Edge and the Clear Aperture will interact with the surface according to the Raytrace Control and Coating specifications
  - Obscuration – Halt all rays incident on the area of the surface that lies inside the curve. This control does not trim the surface.
  - Hole – The area inside the curve is removed from the surface.
- Group definitions:
  - AND – The resulting surface is the area represented by the intersection (overlap) of all the curves in the group. An annular ring is a Clear Aperture "AND"ed with a Hole.
  - OR – The resulting surface is the area represented by the union (combination) of all the curves in the group. A segmented surface can be represented by a collection of "OR"ed apertures.

Examples - Complex Surface Apertures: Aperture Curve Collection

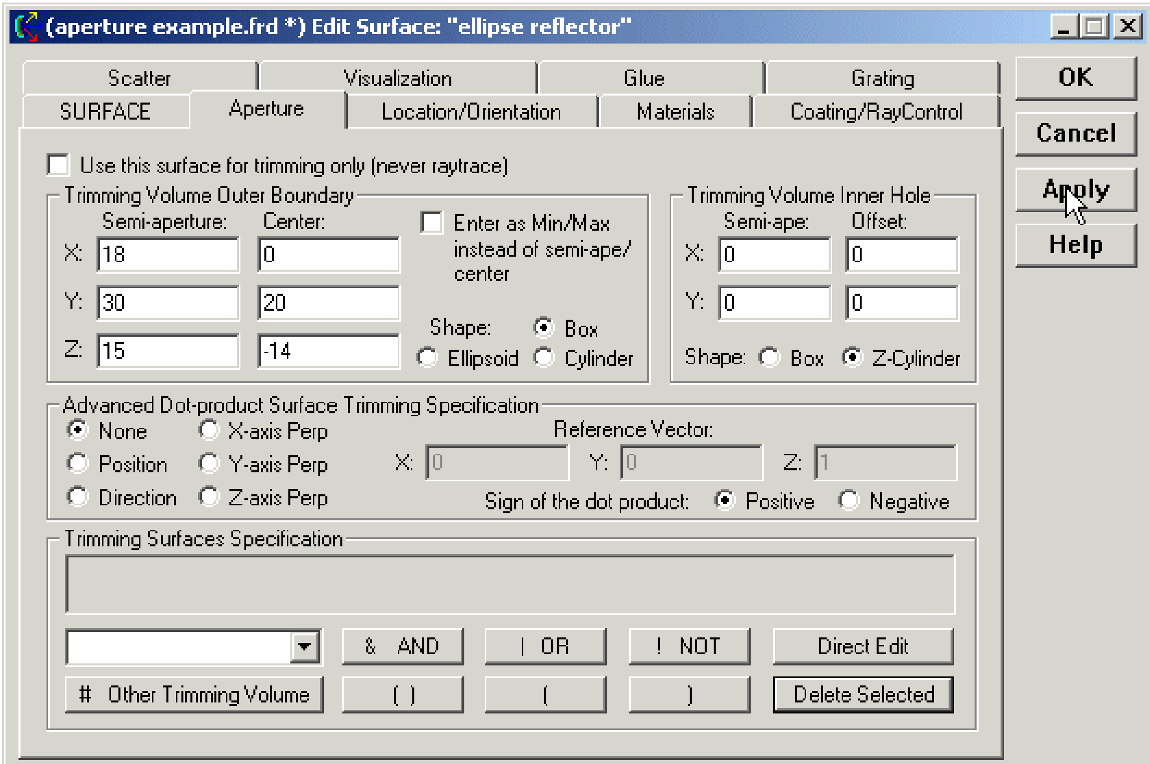
The following example illustrates the use of an aperture curve collection to trim the outer edge of a surface and cut an unusual shaped hole through the center. The surface is an XY Toroidal Asphere with an eccentric rectangular aperture. The aperture curve collection is composed of two curves: a Segmented curve for the inner hole and a Composite curve for the outer boundary (clear aperture). The surface is reflecting.

Create the base surface

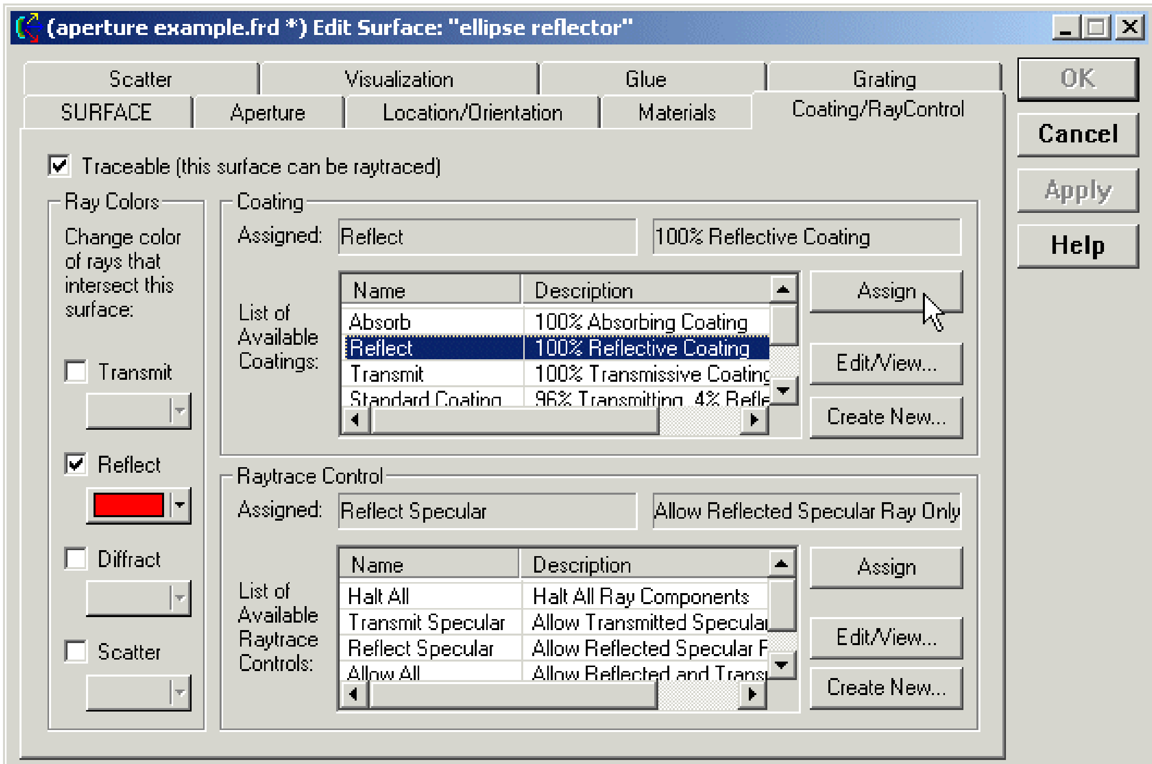
Create or add a Custom Element node. Right click on the node and select Create a New Surface from the list of options. Go to the Surface tab and change the surface type from Plane to XY Toroidal Asphere, and enter the values shown below. Enter the appropriate values for the X and Y curvatures. Left click Apply to accept the changes.



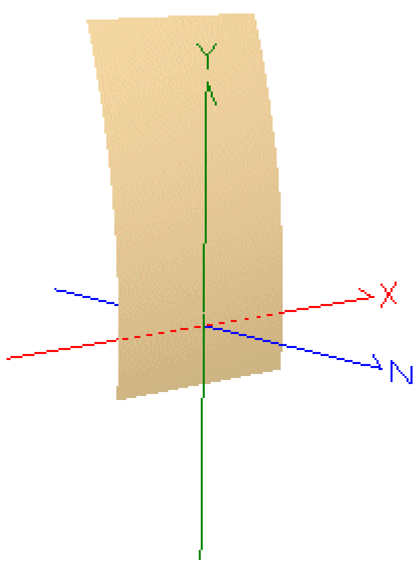
Go to the Aperture tab and change the default *Trimming Volume Outer Boundary* to a box 36 units wide in X, 60 units tall in Y, centered at Y = 20 units, and 30 units deep in Z, centered at Z = -14 units, as shown in the dialog below. Left click on Apply to accept the changes.



Go to the **Coating/RayControl** tab to edit the raytrace properties of the surface. We are going to make the surface reflecting. To do so, first go to the *Coating* section and, with a left click, select the coating *Reflect* and then left click on the Assign button to apply the coating to the surface. Go to the *Raytrace Control* section and select *Reflect Specular* from the list with a left click. Assign the raytrace control property to the surface with a left click on the Assign button. Finally, change the color of the reflected rays by checking the box next to *Reflect* in the Ray Colors section. Choose a color different than that of the incident rays. Click on Apply to accept the changes, or OK to accept the changes and to close the dialog.



This is what the surface looks like in the Visualization window with the color set to Tan and the render mode set to Smooth Shading.



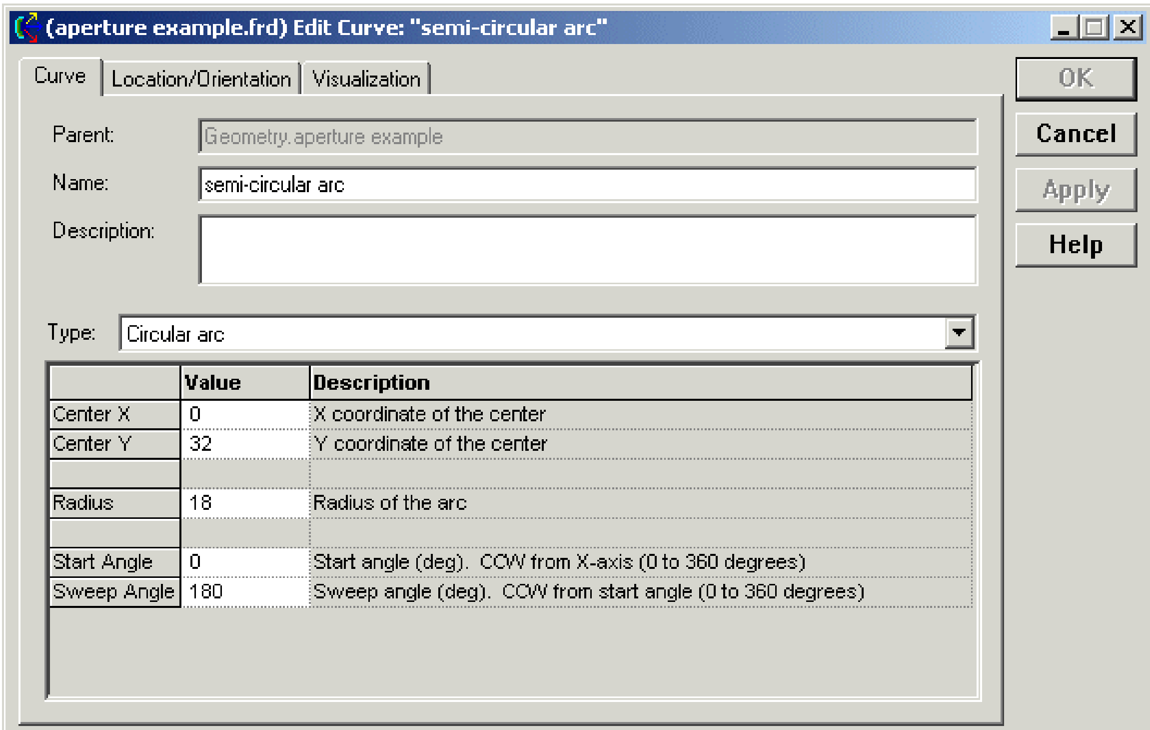
Create the outer boundary

The outer boundary of the surface will be a Composite curve **[insert link to CURVES]**, which is a connected set of line segments and arcs. Each segment is a separate curve. FRED parameterizes every curve from 0 to 1 so that every curve, regardless of its shape, starts at u=0 and ends at u=1. A Composite curve connects multiple segments in the following fashion:

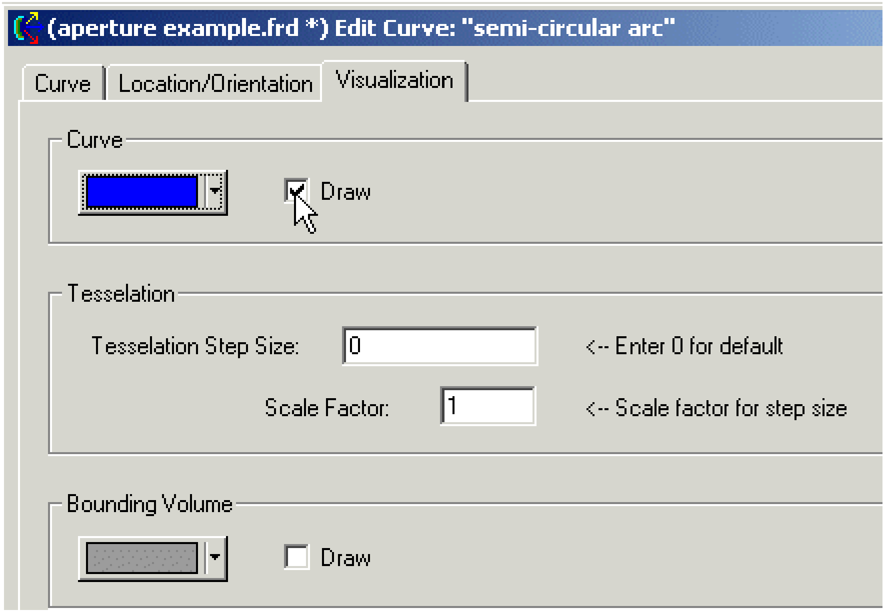
Start→End, Start→End,…,Start→End

The end of Curve N must coincide exactly with the start of Curve N+1 in order for the two to join. FRED renormalizes the parameterization after joining so that the new curve once again starts at u=0 and ends at u=1. In order for a Composite curve to be used in an Aperture Curve Collection, the curve must be ‘closed’, meaning that the start and end points coincide.

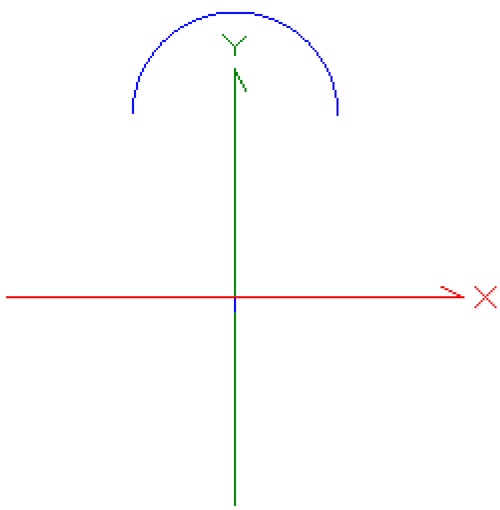
The first curve in the outer boundary is a semi-circular arc with a radius of 18 units and centered at Y = 32.



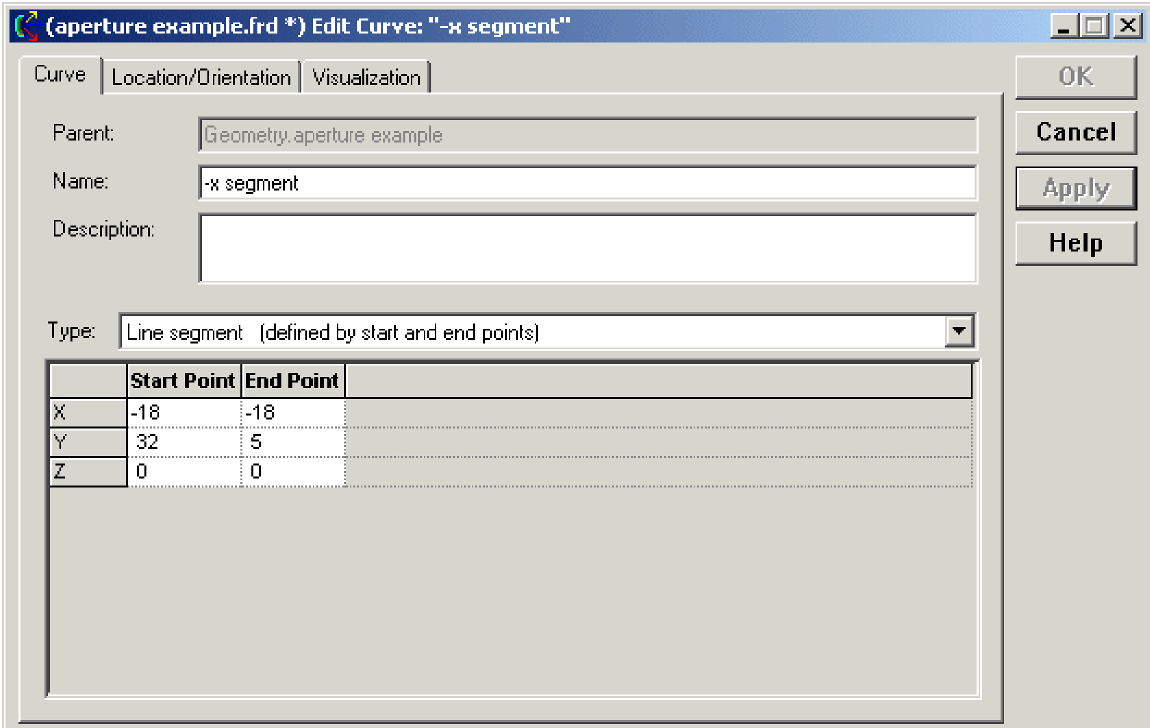
The start angle is simply the angle, in degrees, of the starting point of the arc. It is measured counter-clockwise from the local X axis and can take any value from 0 to 360 degrees. For this example, use 0. Note that since the arc is not centered in the local coordinate system, the starting point will be physically located at (X,Y) = (18,32). The sweep angle is angle subtended by the arc, in degrees, beginning at the start angle. It too can take any value between 0 and 360 degrees, independent of the start angle. Enter a sweep angle of 180 degrees to trace a semi-circular arc. Go to the Visualization tab and click the check box next to Draw to render the curve in the selected color.



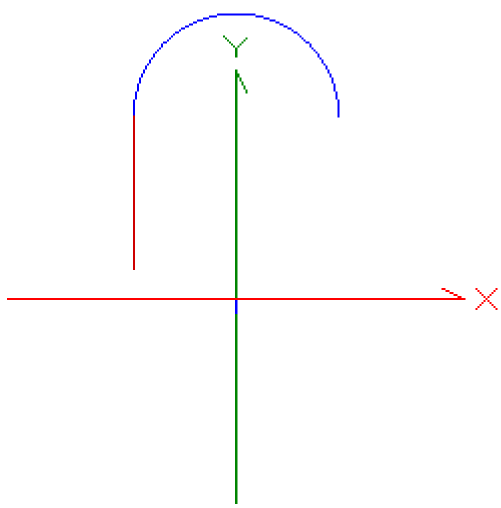
Left click on Apply to accept the changes or OK to accept the changes and close the dialog. The resulting curve is shown below.



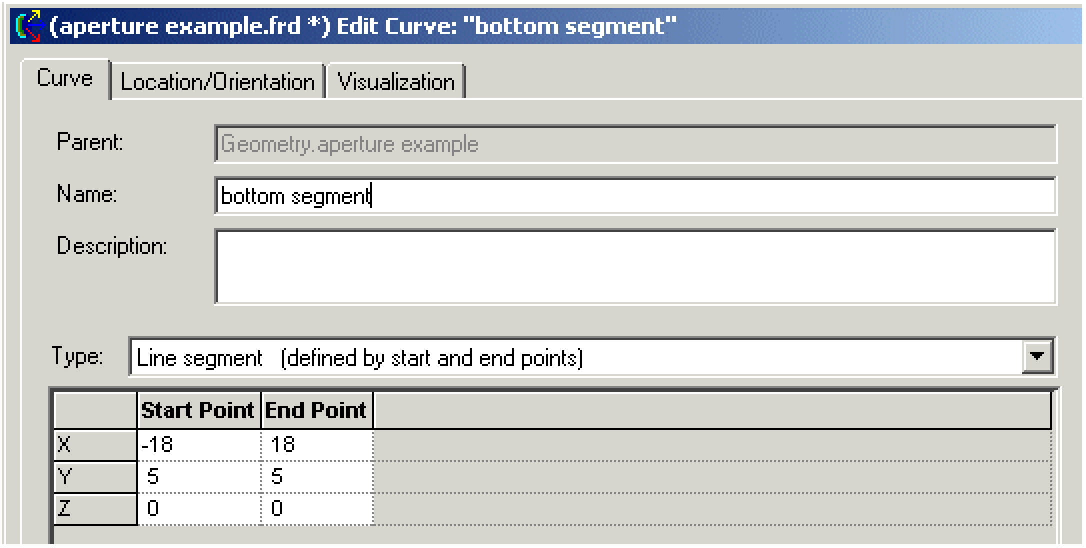
The next curve in the sequence is a simple line segment, beginning at local coordinates (X,Y,Z) = (-18,32,0) and ending at (X,Y,Z) = (-18,5,0). Using the right click pop-up menu, choose **Create a New Curve** from the list of options and select the curve type "Line segment," as shown below. Note that the start of the segment is coincident with the end of the semi-circular arc created above. Make the changes shown below, make the curve visible, and left click on Apply to accept the changes or OK to accept the changes and close the dialog.



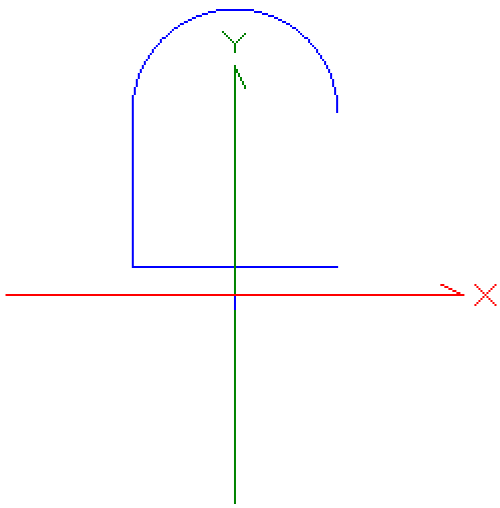
The two curves together look like this.



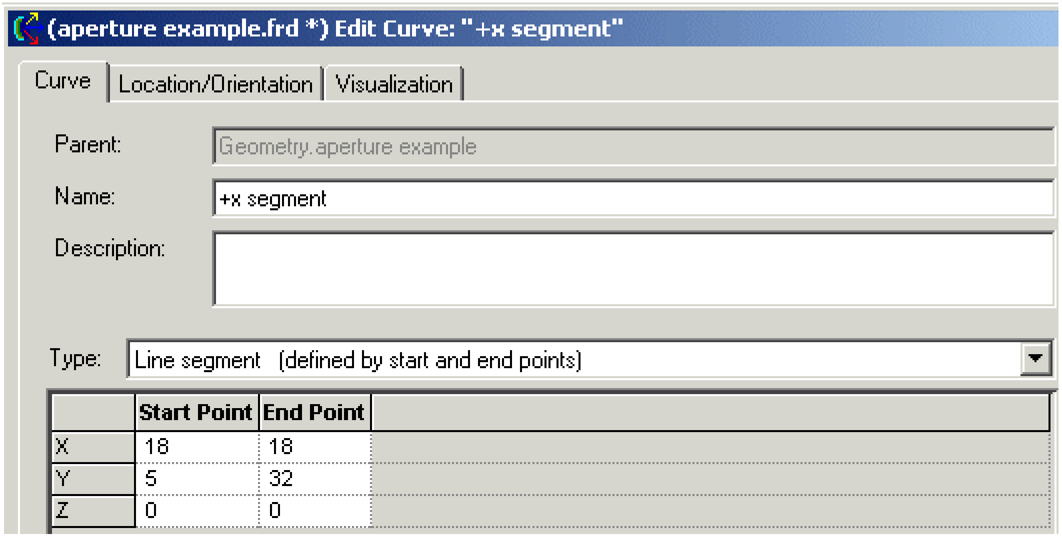
The third segment is a line starting at (X,Y,Z) = (-18,5,0) and ending at (X,Y,Z) = (18,5,0). It is created and rendered in the same way as the previous segment.



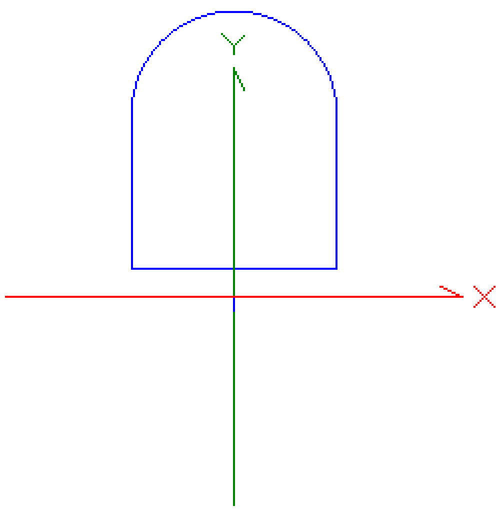
The three curves together look like this.



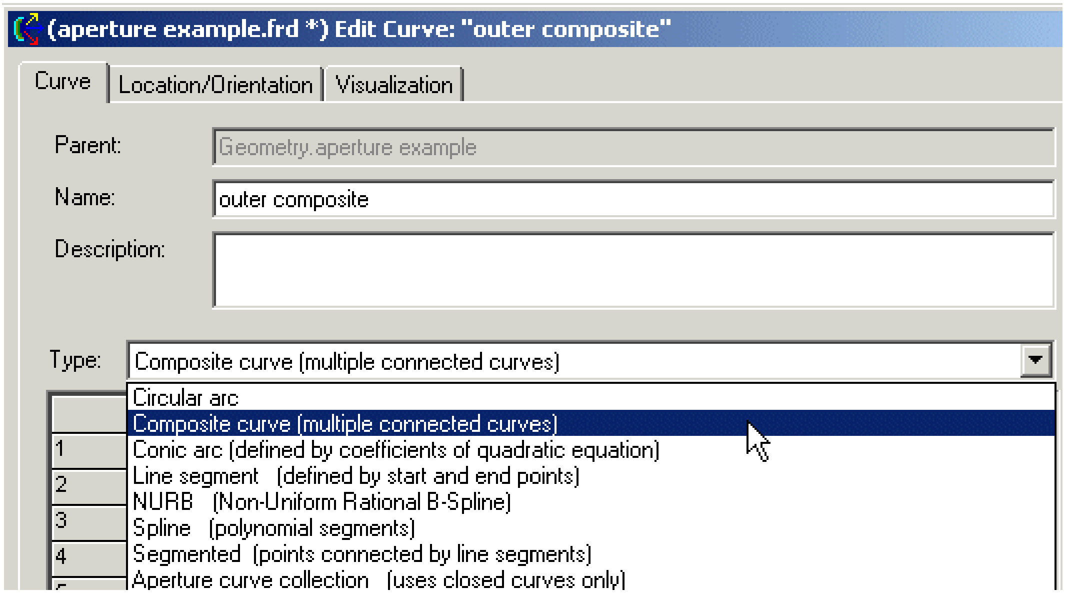
The last line segment encloses the area. It begins at (X,Y,Z) = (18,5,0) and ends at (X,Y,Z) = (18,32,0). It is created and rendered in the same way as the previous segment.



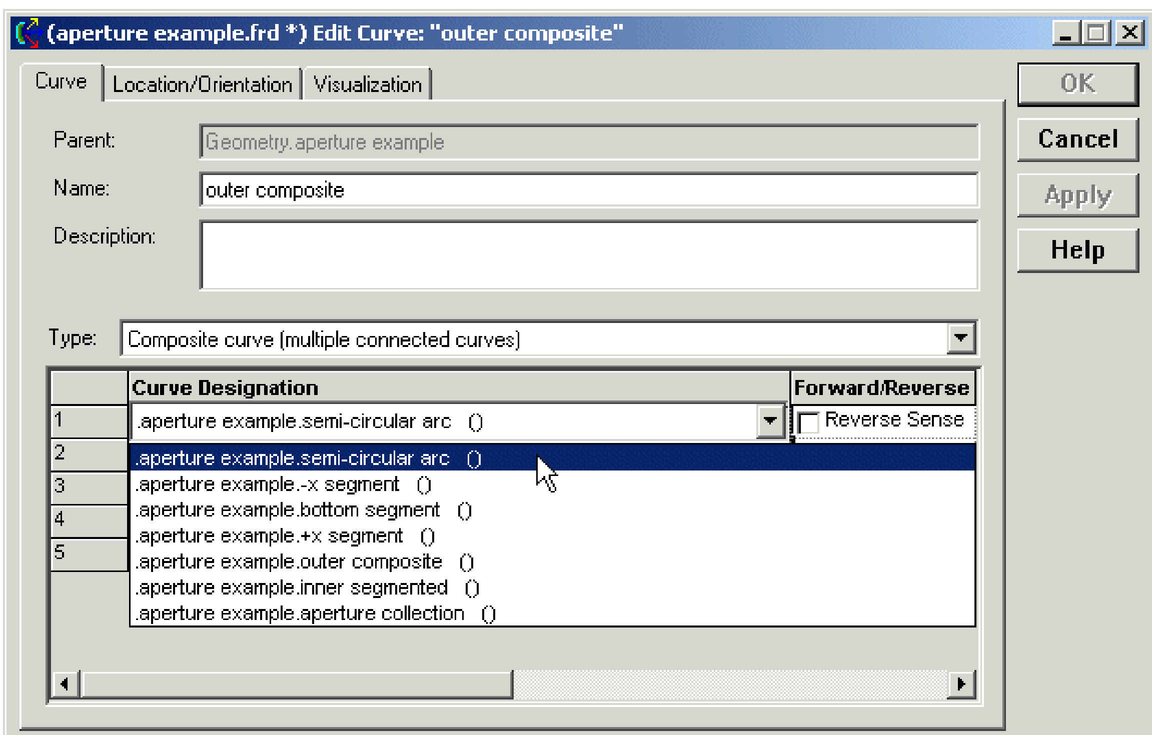
The outer boundary of the mirror will look like the following.



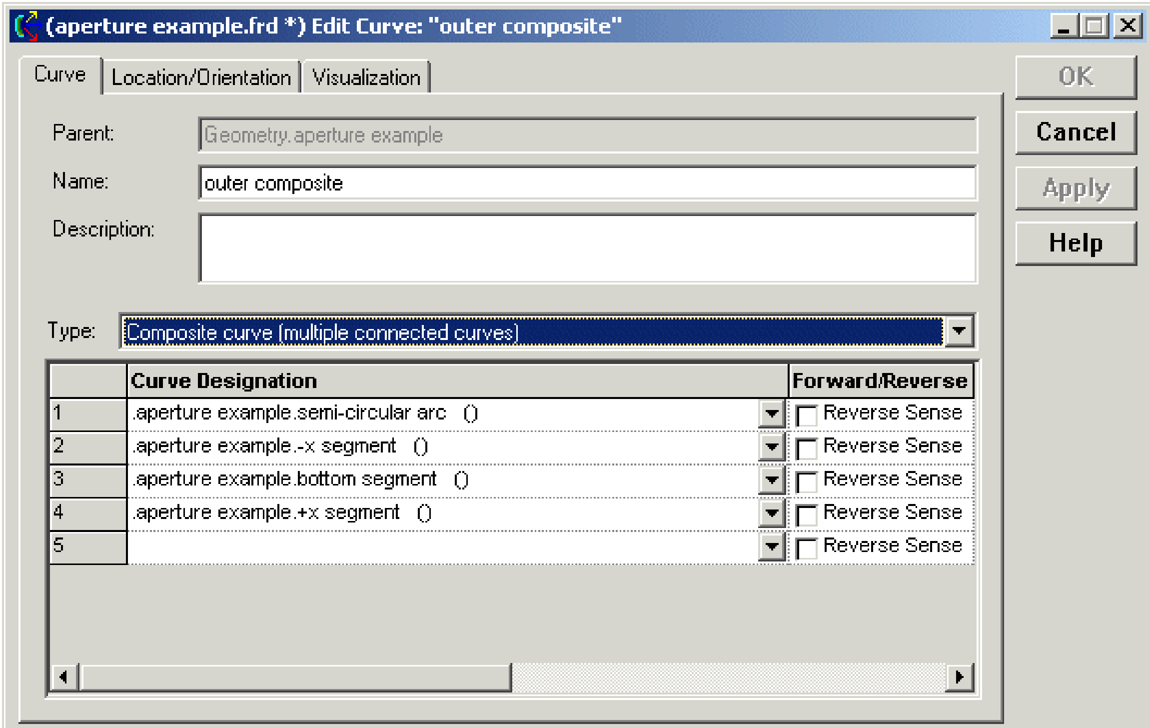
The next step is to create a Composite Curve that combines the four curves that we have just defined into a single curve for subsequent use in the Aperture Curve Collection. To create a Composite Curve, go to the right click pop-up menu and choose Create a New Curve and select the Composite curve type. Name it 'outer composite.'



Once the Composite curve type is selected, left click on the pull-down menu button under in the *Curve Designation* box and choose the semi-circular arc from the list of available curves, as shown below.



The remaining curves are added in the following order (moving counterclockwise around the group): '-x segment' (curve 2), 'bottom segment' (curve 3), '+x segment' (curve 4). The completed dialog is as follows.



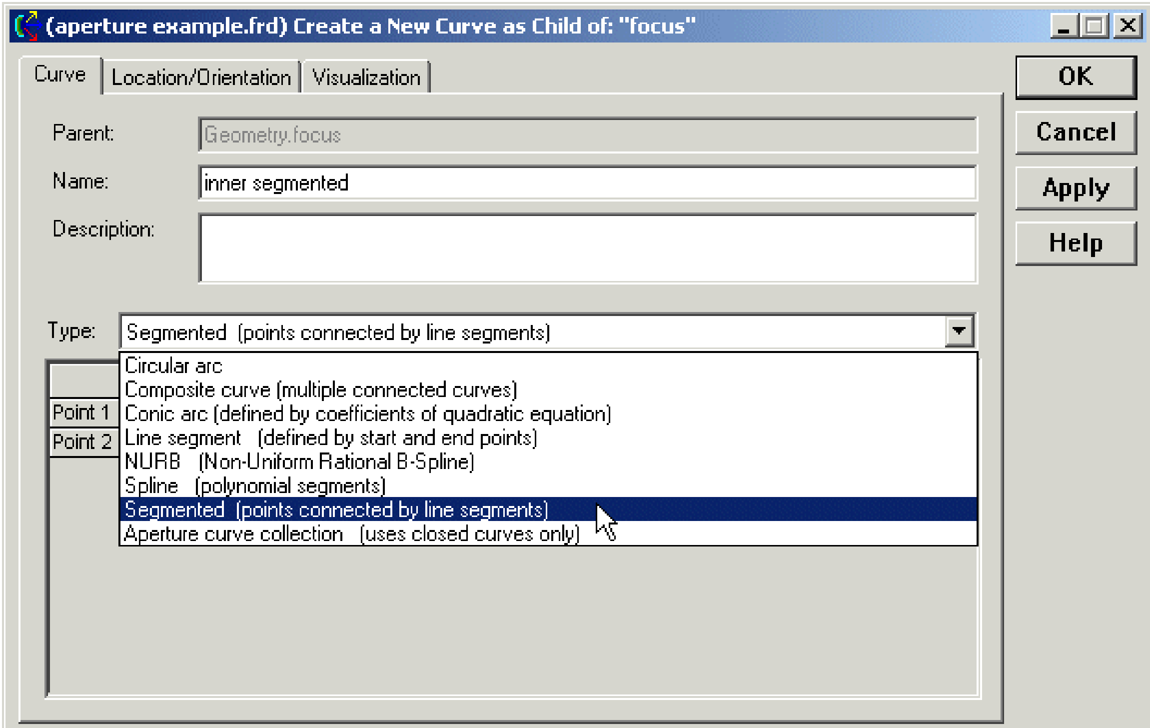
WARNING The end of each curve must coincide exactly with the start of the subsequent curve in order for FRED to create a composite curve. If this condition is not met, then FRED pops up a warning dialog and omits the curve in question from the final construction.

Note Checking the Reverse Sense box switches the start and end points of the curve in question, as may be required to successfully connect the curves.

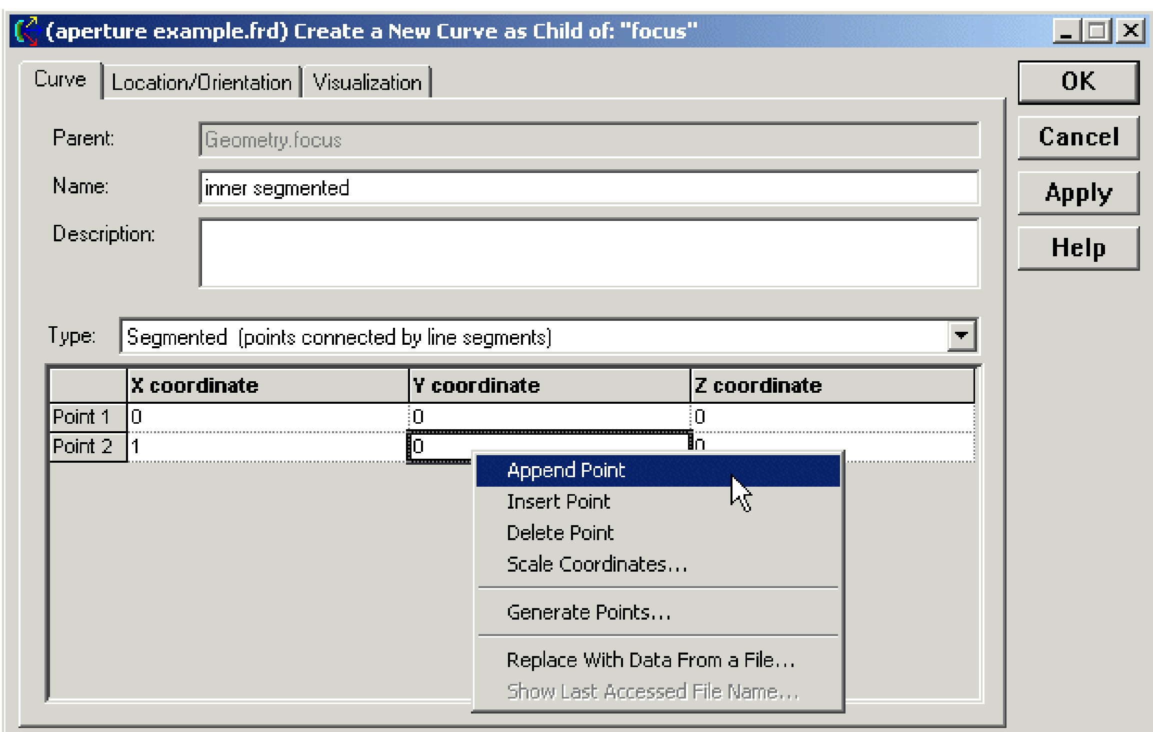
Note To avoid inadvertently separating the curves at some later time, either make the coordinate system every curve in the referenced list coincident with the coordinate system of the composite curve, or put all the curves, including the composite curve, into the same coordinate system.

Create the inner hole

The hole in the center of the surface is a **Segmented** curve type. This curve consists of a collection of (X,Y,Z) points connected by simple line segments. It can used, for example, to create a square or a rectangle. The data points can be entered manually in the curve dialog or instead read from an ASCII text file containing rows of (X,Y,Z) coordinates. We will use the manual entry in this example. Go to the **Custom Element** node containing the outer boundary curve just described. Using the right click pop-up menu, select **Create a New Curve** and choose a **Segmented** curve type, as shown below. For this example the Name of the curve is ‘inner segmented.’



By default, the curve is created with two points already defined. We will edit these after adding four rows (for 6 points total). To add a row, right click inside the spreadsheet area at the bottom of the dialog and select the option *Append Point*, as shown below. Repeat this 3 more times.



Once all the rows have been added, edit the enter the following (X,Y,Z) values for the 6 points

Point 1: (-6,10,0)

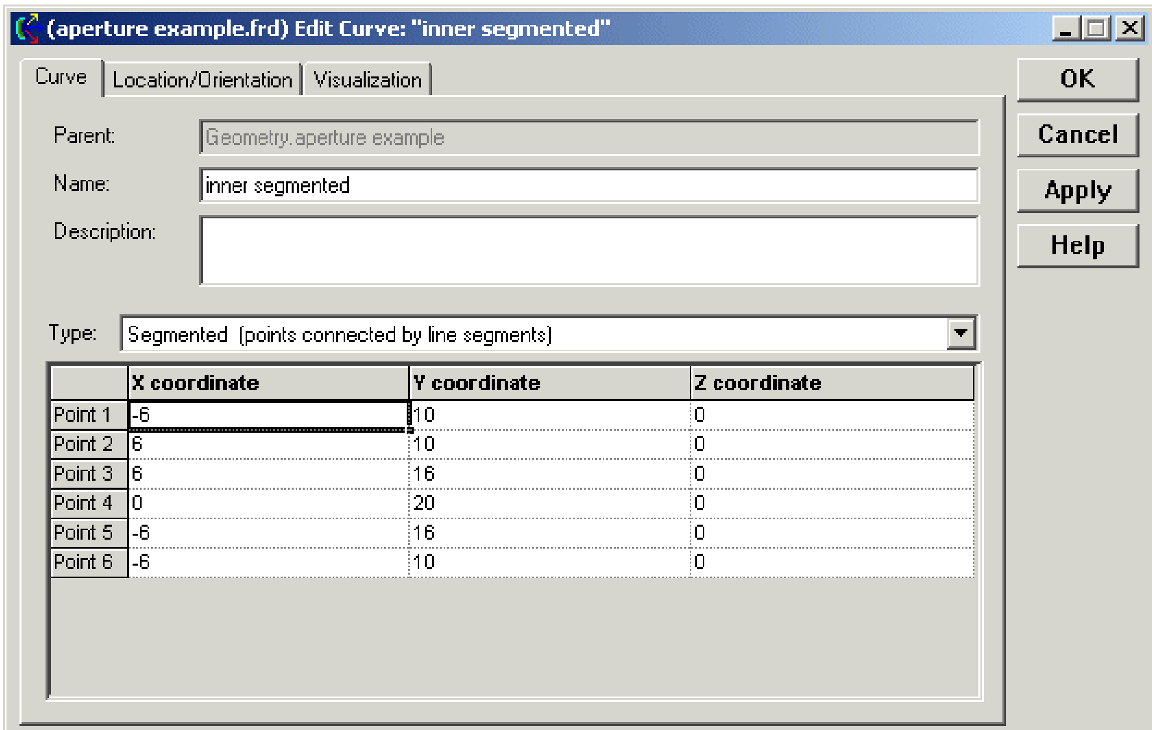
Point 2: (6,10,0)

Point 3: (6,16,0)

Point 4: (0,20,0)

Point 5: (-6,16,10)

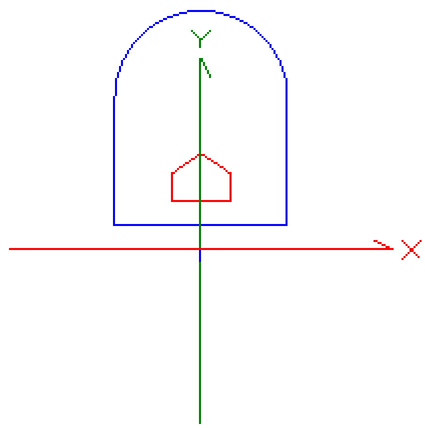
Point 6: (-6,10,0)



Note	In order to fully enclose an area with a segmented curve, the start and end coordinates must be the same.

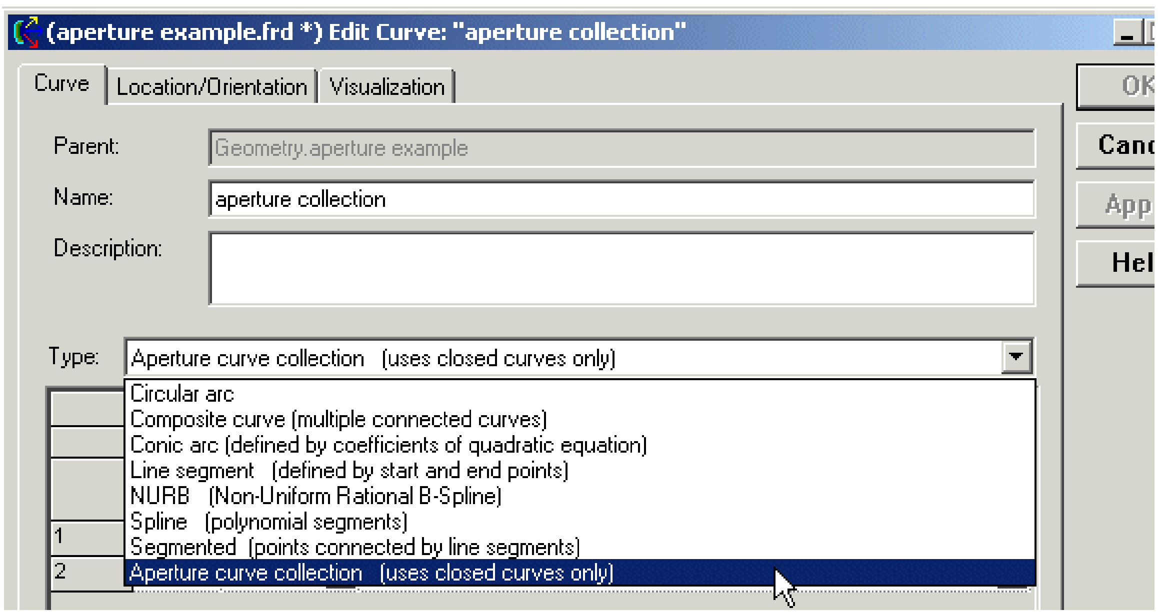
Left click on **Apply** to accept the changes, or **OK** to accept the changes and close the dialog.

The outer and inner rendered curves should look like the following figure.

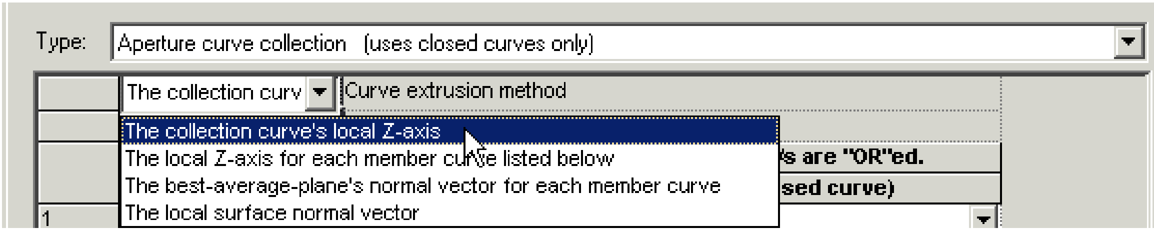


Create and apply the aperture collection curve to the surface

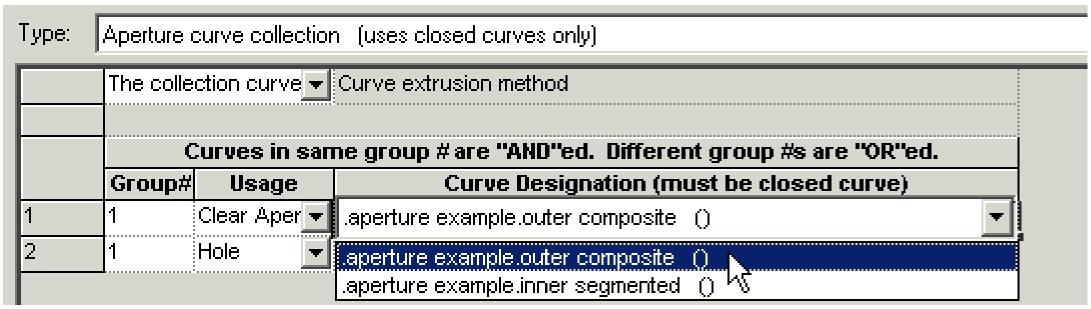
The last step is to now create the Aperture Curve Collection using the two curves defined in this example thus far: ‘outer composite’ and ‘inner segmented’. Once again, go to the **Custom Element** node containing the surface you would like to trim and all of the curves defined so far. Using the right click pop-up menu, choose **Create a New Curve** and select the curve type *Aperture curve collection*.



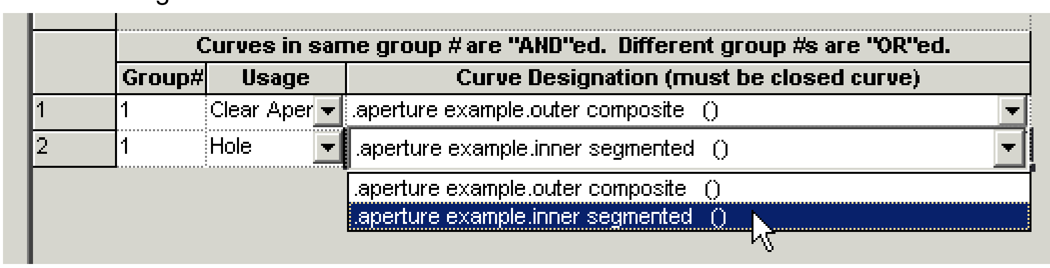
Recall that FRED uses the Aperture curve collection to create an extruded surface that modifies the boundaries of the surface it is applied to. The user can specify the extrusion method from a list of options. Left click on the pull-down button next to ‘Curve extrusion method’ and choose *The collection curve’s local Z-axis*. The extrusion extends to infinity in both directions along the defined axis. Further, the extrusion is never rendered or raytraced.



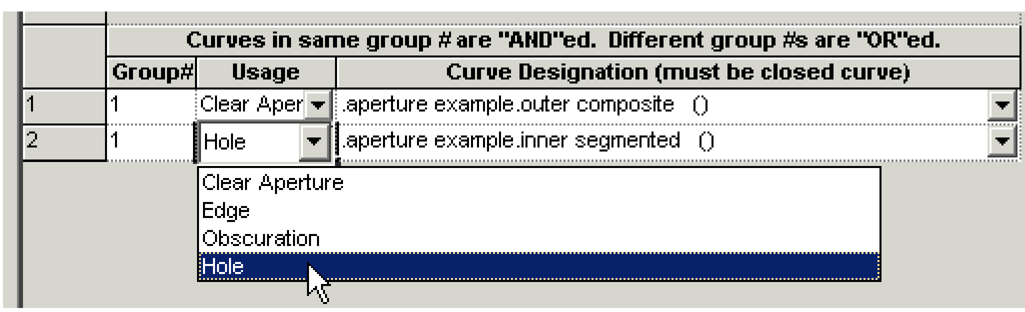
The first curve is the outer boundary. Go to the pull-down menu and select the curve '*…outer composite'* from the list of available curves. Note that FRED will only list closed curves in this dialog.



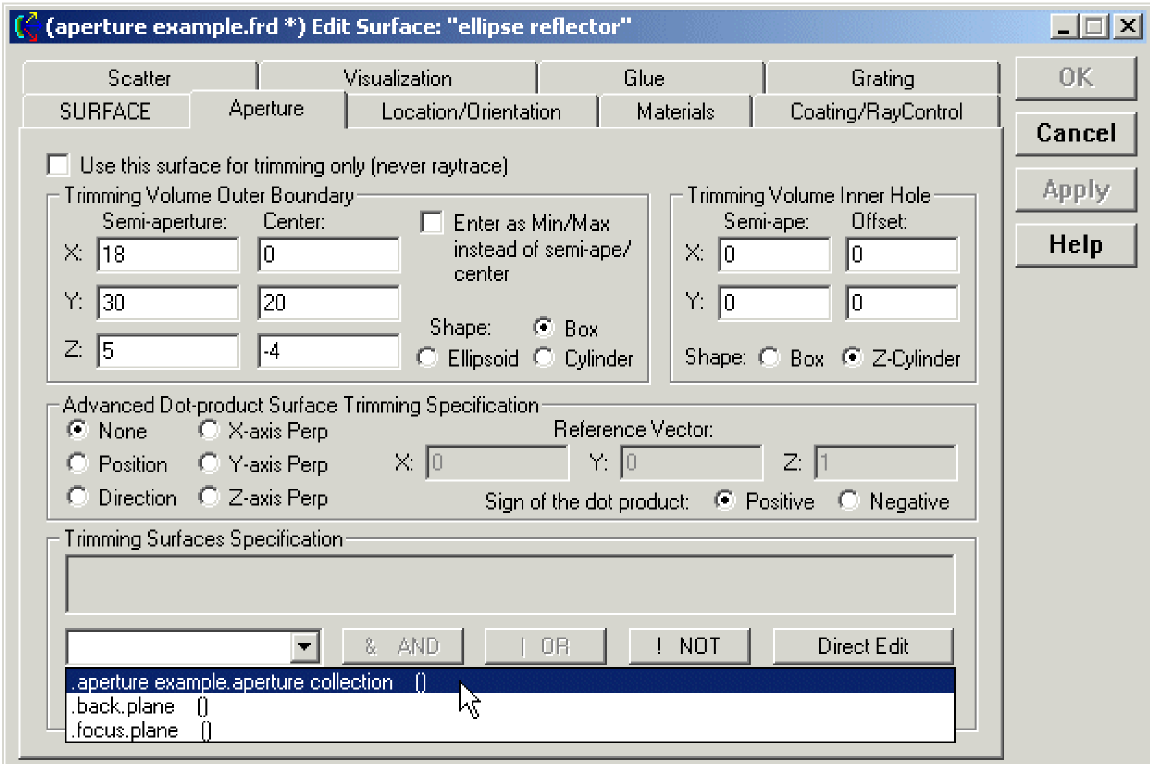
Append a new row by right clicking in the spreadsheet area and selecting that option from the list. Once again, display the pull down menu for the list of available curves and choose the curve '…inner segmented' from the list.



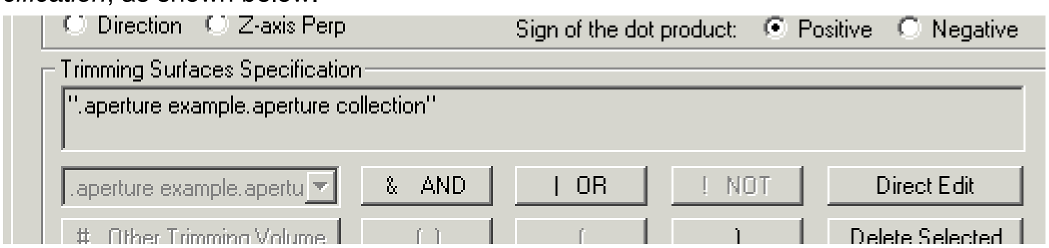
Make the second curve a **Hole** by selecting it from the pull down menu in the **Usage** column.



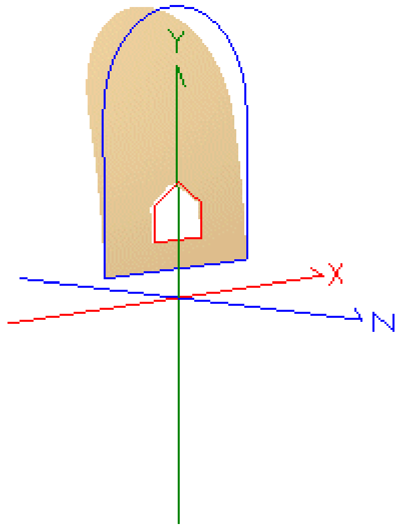
Notice that the group number for the two curves is the same. This means that their operations will be "AND"ed together so that FRED will keep the area of the surface outside of the **Hole** and inside of the **Clear Aperture**. Left click on the **Apply** button to accept the changes or OK to accept the changes and to close the dialog. At this point we can now use the aperture curve collection to trim the surface we created in the early stages of this exercise. To do so, right click on the surface and choose the option **Edit/View Surface**. Go to the **Aperture** tab and under *Trimming Surface Specification* click on the pull down menu button and select the curve '…aperture collection' that we just created.



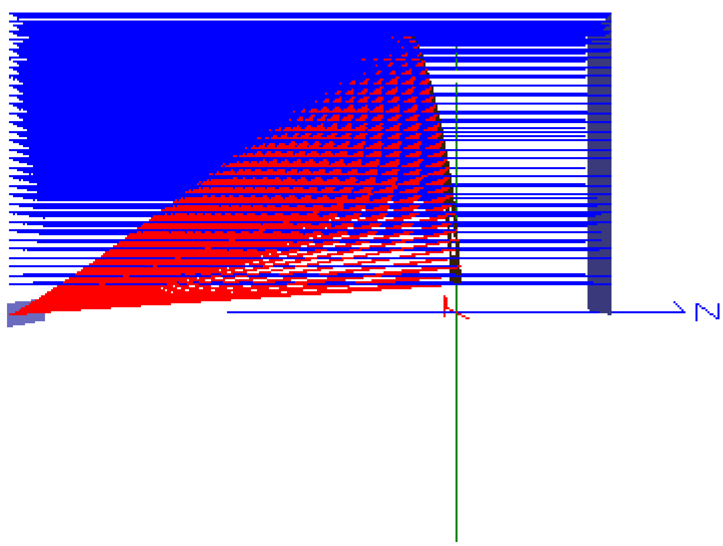
After selection, the curve name will appear in the box under *Trimming Surface Specification*, as shown below.

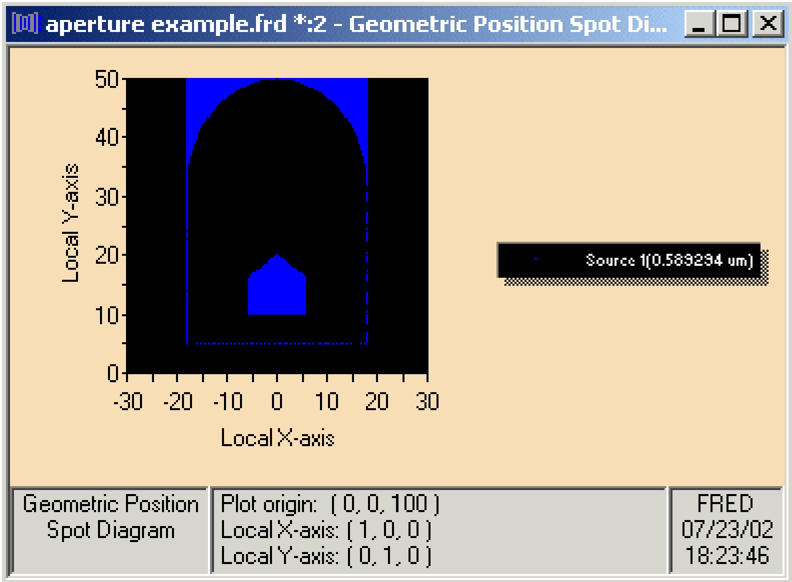


Left click on the **Apply** button to accept the changes or OK to accept the changes and to close the dialog. The surface should now look like the following.



Tracing and rendering a rectangular grid of collimated rays at the surface produces the following results. In the first figure, the reflected rays (shown in red) come to a line focus. In the second figure, a Positions Spot Diagram shows the rays that missed (passed through or around) the surface.




aperture example.frd *:2 - Geometric Position Spot Di...
Local Y-axis
50
40
30
20
10
0
-30
-20
-10
0
10
20
30
Local X-axis
Source 1(0.589294 um)
Geometric Position Spot Diagram
Plot origin: (0, 0, 100)
Local X-axis: (1, 0, 0)
Local Y-axis: (0, 1, 0)
FRED
07/23/02
18:23:46

Chapter 7 – Analysis Topics and Examples

This section has examples and topics concerning building geometry in FRED.

- How **Analysis Surfaces** are sized.

Analysis Planes

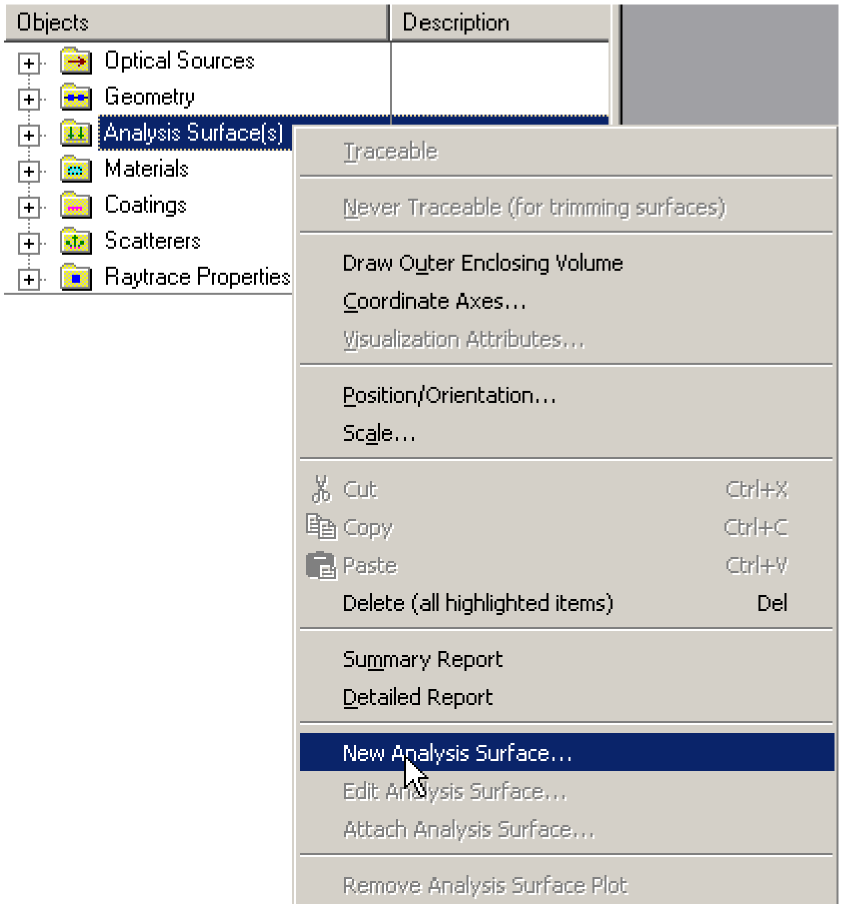
Description - Analysis Planes

Analysis Planes are used to evaluate ray distributions on **Surfaces** or **Sources**. All of the Analysis options: Position Spot Diagram, Polarization Spot Diagram, Directional Spot Diagram, Irradiance Spread Function, Intensity Spread Function, Energy Density, Coherent Scalar Wave Field require their use. An Analysis Plane does not intercept rays, so it is ignored in during the raytrace. Instead, Analysis Planes contain one or more ray filters that are used select the rays to be evaluated in the Analysis option. Created rays can be analyzed before and after they are raytraced. This process is made easier by **Attaching** an **Analysis Plane** to a **Surface** or a **Source**, which moves the analysis plane to be coincident and sets the appropriate ray filter to select the rays on the **Surface** or **Source**. **Analysis Planes** can only be used in conjunction with **Surface** or **Source** entities. More than one **Analysis Plane** can be attached to a surface or source. Further, an **Analysis Plane** need not be used exclusively to evaluate ray positions or angles; it may evaluate both simultaneously.

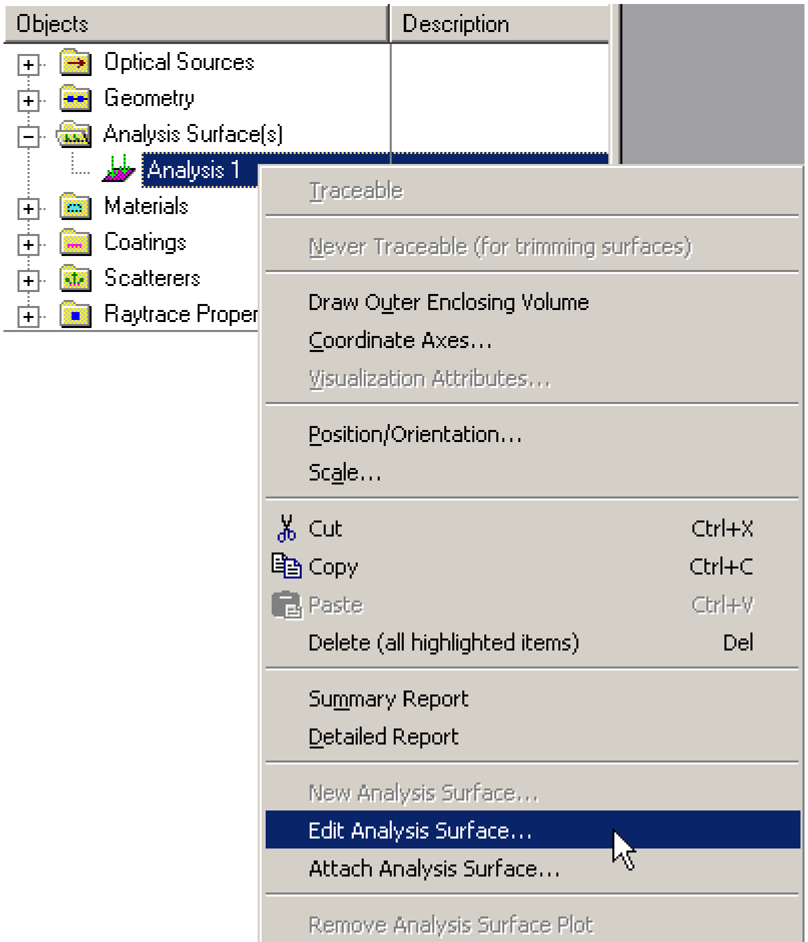
How Do I Get There? - Analysis Planes

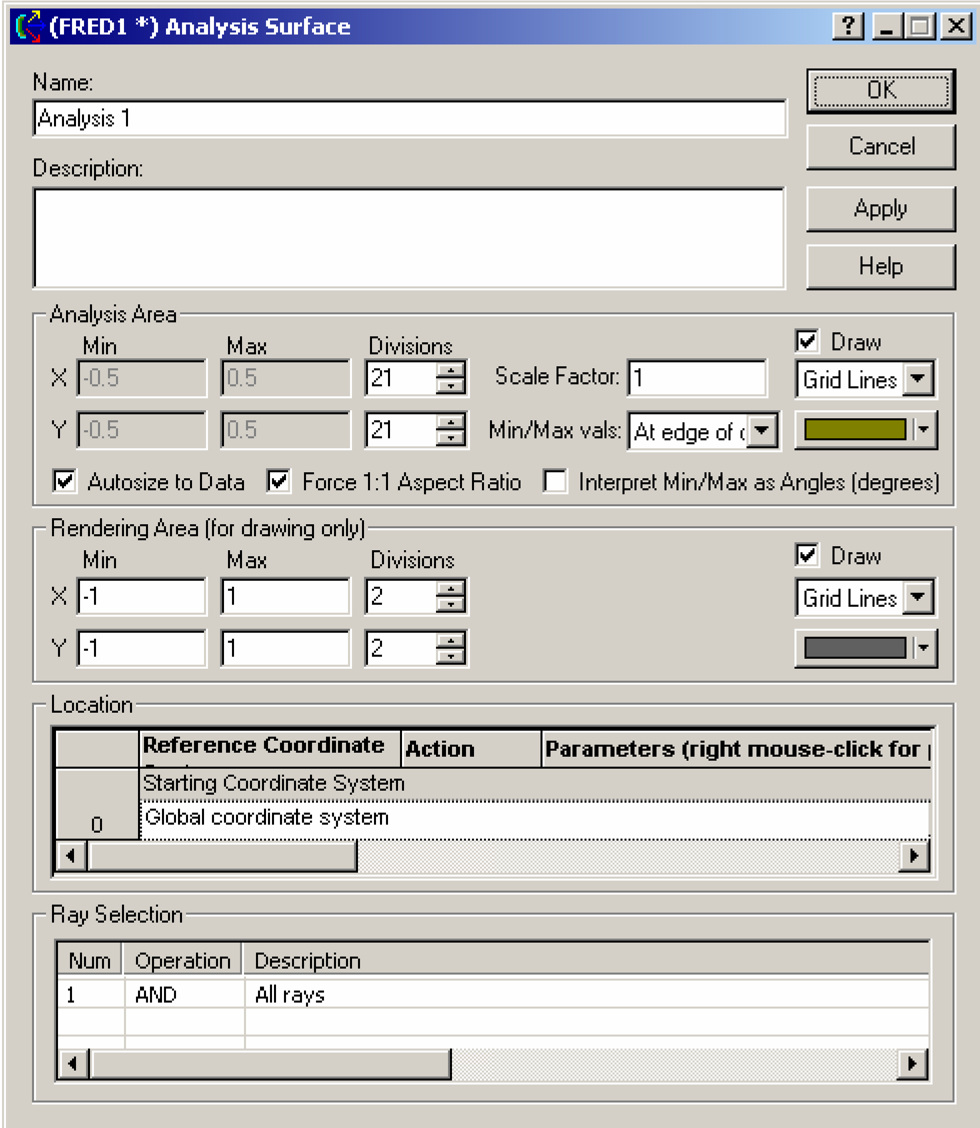
The Analysis Planes dialog is opened in one of two ways.

1. As a new Analysis Plane. Right mouse click on the Analysis Surfaces(s) folder to open a pop-up menu and select the option 'New Analysis Plane.'



2. Edit an existing Analysis Plane. Expand the Analysis Surfaces folder, right mouse click on the Analysis Plane to be modified to open the pop-up menu, and select the option 'Edit Analysis Plane.'


Objects
Description
Optical Sources
Geometry
Analysis Surface(s)
Analysis 1
Materials
Coatings
Scatterers
Raytrace Proper
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Scale...
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
New Analysis Surface...
Edit Analysis Surface...
Attach Analysis Surface...
Remove Analysis Surface Plot



Control	Inputs	Defaults
Name	Enter the Name of the Analysis Plane (required).	Analysis *n*
Description	Enter a brief description of the analysis plane (optional).	blank
Analysis Area		
X/Y min max	Minimum/maximum X/Y window dimensions.	+/- 0.5
Divisions	Enter the number of cells (pixels) across and down the analysis plane.	21 x 21

Scale Factor	Enter the scale factor to apply to the Analysis Plane dimensions.	1
Draw	Check this box to draw the Analysis Surface. Choose appearance/color of the plane using the pull-down menu.	Checked, Grid Lines, Copper
Autosize to Data	Check this box to automatically size the Analysis Plane based upon ray data only.	Checked
Force 1:1 aspect ratio	Check this box to force 1:1 aspect ratio on the Analysis Plane dimensions. FRED automatically chooses the largest dimension if checked.	Checked
Interpret Min/Max as Angles	Check this box to interpret window dimensions as angles.	Unchecked
Min/Max values	At center or edge of window.	At edge
Rendering Area		
Min/Max, Divisions	Minimum and maximum X and Y coordinates and the number of divisions between each for rendering the Analysis Plane. For rendering purposes only.	X (-1,1) Y (-1,1) 21
Draw	Check this box to draw the rendering area. Select the render mode and color using the pull-down menu.	Checked, Grid Lines, Gray
Location		
Table	Selects the Reference coordinate system and relative location of the Analysis Plane.	Global origin
Ray Selection		
Table	Tabulates the ray selection criteria. Right mouse click to open the ray filter dialog.	AND All rays
OK	Create a new Analysis Surface and close dialog box.	
Cancel	Discard Analysis Surface and close dialog box.	
Apply	Apply Analysis Surface changes and keep dialog box open.	
Help	Access this Help page.	

- All new analysis planes are created at the origin of the global coordinate system.
- The default ray filter is 'All rays,' which will include every ray that has been created and/or traced.
- An analysis plane does not stop any rays. It is not a physical surface in the model.
- An analysis plane may be used simultaneously for Position and Angular (intensity) spread functions or spot diagrams.
    - For position, the size of the analysis plane is given in system units
    - For angle, the size of the analysis plane is given by the X and Y direction cosines, measured from the surface normal. The default entries of -1 to 1 for both X and Y covers all angles in the hemisphere sitting over the Analysis Plane.
    - Auto-sizing for coherent sources usually results in the Analysis Plane being too small. Set the size manually instead.
- Attaching an analysis plane to a surface (or source) does 2 things:
    - It moves the analysis plane to be coincident with the local origin of the surface or source.
        - Coincidence is not a requirement. If the analysis plane is separated from the surface, FRED simply projects rays from the surface or source along their current trajectories until they intersect the shifted analysis plane.
    - It imposes a ray selection filter that tells FRED to consider only the rays currently halted on the surface or created on the source
        - Multiple filters can be ANDed and ORed together. A context menu to edit the Ray Selection Criterion is available with a right mouse click inside the Ray Selection spreadsheet area.
    - An analysis plane is attached to a surface or a source by one of two methods:
        - Using a drag and drop from the analysis surface to the surface or source.
        - Selecting the option 'Attach Analysis Plane' using a right mouse click pop-up menu.
    - An analysis plane can only be attached to a single Surface or a single Source.
- An analysis plane is required for all of the following options:
    - Position Spot Diagram – a conventional spot diagram showing the ray intercept location on the analysis plane. Rays lying on a curved surface are projected directly onto the analysis plane. Default plot colors are the same as the rendered color for the source.
    - Polarization Spot Diagram – show the polarization ellipses of satisfying the Ray Selection Criterion assigned to the analysis plane. The source(s) must be polarized.
    - Directional Spot Diagram – show the direction cosine projection of the rays satisfying the Ray Selection Criterion assigned to the analysis plane. Ray directions are plotted in the coordinate system of the analysis plane. Default plot colors are the same as the rendered color for the source.
    - Irradiance Spread Function – plot the power/unit area of the rays satisfying the Ray Selection Criterion assigned to the analysis plane. Rays lying on a curved surface are propagated along their trajectories until they intercept the analysis plane. Use this option with a coherent source to generate a point spread function.

- o Intensity Spread Function – plot the power/unit solid angle of the rays satisfying the Ray Selection Criterion assigned to the analysis plane.Ray directions are plotted in the coordinate system of the analysis plane.
- o Energy Density – Coherent sources only. Plots the flux/unit volume of all rays satisfying the Ray Selection Criterion assigned to the analysis plane.
- o Coherent Scalar Wave Field – Coherent sources only. Plots the complex field of all rays satisfying the Ray Selection Criterion assigned to the analysis plane.

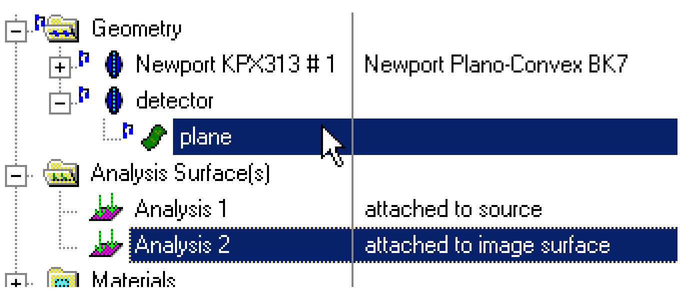
- For Sources, the Analysis options are typically used to evaluate the ray distribution after they have been created, but before they have been traced.
- For Surfaces, the Analysis options are typically used to evaluate the ray distribution at the conclusion of the raytrace.
- At the conclusion of any Analysis operation, FRED prints a table of summary data to the output window:
  - o Number of valid rays (coherent, incoherent, polarized).
  - o Total power.
  - o Total average irradiance or intensity = Total power/area of analysis plane.
  - o Valid average irradiance or intensity = Total power/total area of valid pixels. A valid pixel contains at least one ray.
  - o Analysis plane and pixel dimensions.

Examples - Analysis Planes...

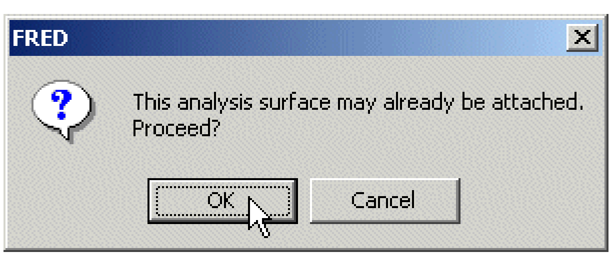
Example 1 – Attach an Analysis Plane to a Surface/Source

Method 1: Drag and Drop

Create a new Analysis Plane or expand the Analysis Surface(s) folder and left mouse click on an available analysis plane. While holding the left mouse button down, move the cursor to the desired surface or source. Release the mouse button.



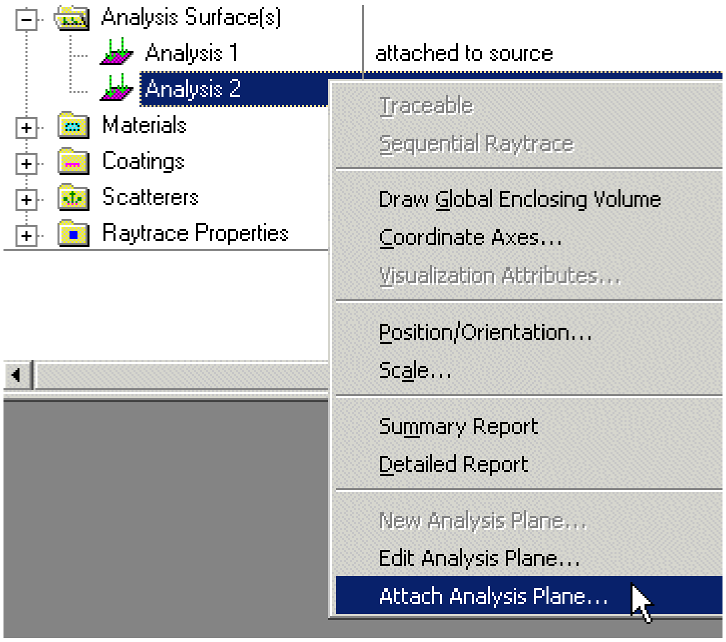
If the analysis plane was already attached, a warning dialog pops up to confirm replacement.



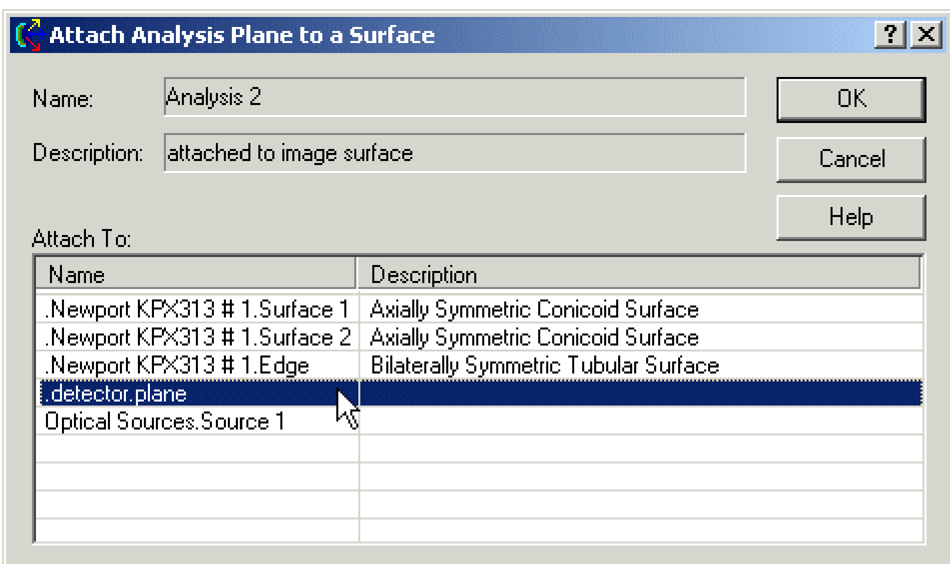
Left mouse click on OK to proceed or Cancel to halt the drag and drop operation.

Method 2: Attach with the pop-up menu

Right mouse click on an existing analysis plane and select ‘Attach Analysis Plane’ from the list of options. to open a dialog to Attach Analysis Plane to Surface.



This opens a dialog to Attach Analysis Plane to Surface.

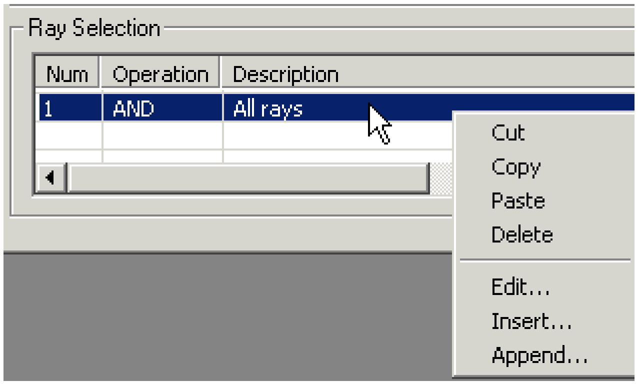


Select the appropriate surface with a left mouse click and then choose OK to accept and close the dialog. As with the drag and drop, if the analysis plane is already attached, a warning dialog asking for an override pops up. Choose OK to complete or Cancel to quit the operation.

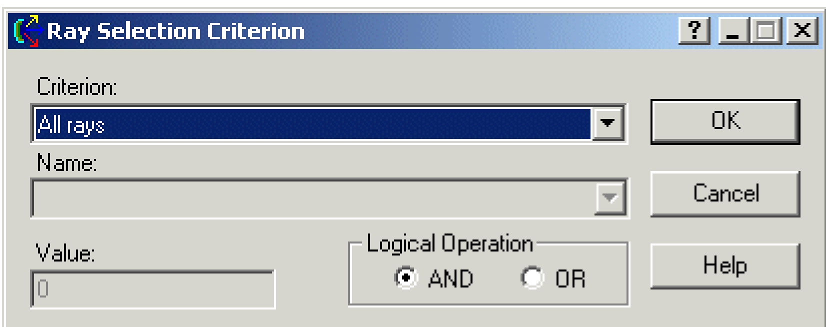
<u>Example 2 – Opening the Ray Selection Criterion dialog</u>

Open the Analysis Plane Dialog. Move the cursor down to the Ray Selection spreadsheet. The ‘Num’ heading is simply a counter for the number of ray filters. The ‘Operation’ heading contains the logical operation between subsequent filters. The options are either a logical AND or a logical OR. These operations are evaluated in sequential order. There is no explicit parenthetic grouping. The last column is the 'Description,' which is actual criterion that will be used to select rays. The 'Operation' and 'Description' can only be edited using the Ray Selection Criterion dialog.

Right mouse click in this region to open a pop-up context menu, as shown below.



The '*Cut*,' '*Copy*,''*Paste*,'and '*Delete*' options all operate on the selected row. The '*Edit...*', '*Insert...*', and '*Append...*' options all open the Ray Selection Criterion dialog, shown below.



See Also....- Analysis Planes...

For more detailed descriptions of Analysis Surfaces and their uses, select from among the following links.

- Analysis Plane Dialog
- Attach Analysis Plane Dialog
- Ray Selection Criterion Dialog

Analysis Tools:

Position Spot Diagram

Polarization Spot Diagram

Directional Spot Diagram

Irradiance Spread Function

Intensity Spread Function

Energy Density

Coherent Scalar Wave Field

The following Tutorial shows how Analysis Planes can be used.

Building a Cassegrain

Ray Selection Criterion

Description

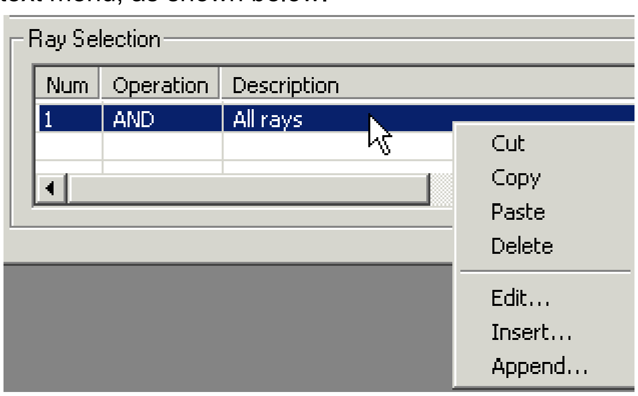
Ray Selection Criterion

Ray Selection Criterion dialog is used to select the ray filters that are applied to Analysis Planes.

How Do I Get There?

Ray Selection Criterion

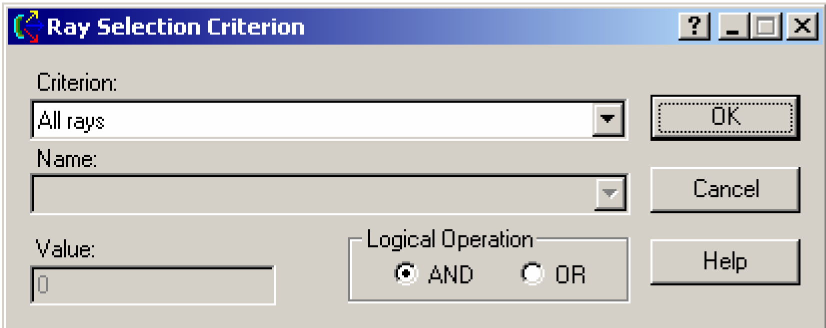
The Ray Selection Criterion dialog can be opened only from within the Ray Selection Region inside the Analysis Plane Dialog. Right mouse click in this region to open a pop-up context menu, as shown below.



The ‘*Edit…*’, ‘*Insert…*’, and ‘*Append…*’ options all open the Ray Selection Criterion dialog.

Dialog Box and Controls

Ray Selection Criterion



Control	Inputs	Defaults
Criterion:	Choose the ray selection criterion from the pull down menu.	All rays
Name:	Choose relevant object from the pull down menu. Name depends on the Criterion selection.	blank
Value:	Numeric entry for ray selection. This also depends on the Criterion selection.	0
Logical Operation	Choose relational AND or OR for Criterion selection.	AND
OK	Accept Ray Selection Criterion and close dialog box.	
Cancel	Discard Ray Selection Criterion and close dialog box.	
Apply	Apply Ray Selection Criterion and keep dialog box open.	
Help	Access this Help page.	

Application Notes

Ray Selection Criterion…

- The default ray filter is ‘All rays,’ which will include every ray that has been created and/or traced.
- Logical operations for multiple filters are carried out sequentially. There is no explicit parenthetic grouping.
    - The filters are applied to every ray. Each filter returns a TRUE or FALSE.

    - TRUE → the ray satisfies the criterion
    - FALSE → the ray does not satisfy the criterion
  - The order of operation is important.
  - Every operation is evaluated.
  - Only the rays returning a TRUE at the end of the evaluation sequence are kept. Some examples:
    - TRUE AND TRUE OR FALSE = TRUE (ray is considered)
    - TRUE AND FALSE = FALSE (ray is not considered)
    - TRUE AND FALSE OR TRUE = TRUE
    - TRUE OR TRUE AND FALSE = FALSE
    - FALSE AND FALSE OR TRUE = TRUE
- The currently available ray selection criteria are:
  - All rays
  - No rays
  - Coherent rays
  - Incoherent rays
  - Polarized rays
  - Unpolarized rays
  - Rays on the specified surface → can be applied to sources as well
  - Rays NOT on specified surface → can be applied to sources as well
  - Rays from the specified source
  - Rays NOT from the specified source
  - Rays in the specified material
  - Rays NOT in the specified material
  - Every Nth ray
  - All rays EXCEPT every Nth ray
  - Incoherent power <= Value
  - Incoherent power > Value
  - Optical path length <= Value
  - Optical path length > Value
  - Wavelength <= Value
  - Wavelength > Value
  - X <= Value in the specified coordinate system
  - X > Value in the specified coordinate system
  - Y <= Value in the specified coordinate system
  - Y > Value in the specified coordinate system
  - Z <= Value in the specified coordinate system
  - Z > Value in the specified coordinate system
  - X direction component <= Value in the specified coordinate system (between -1 and 1, inclusive)
  - X direction component > Value in the specified coordinate system (between -1 and 1, inclusive)

- Y direction component <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Y direction component > Value in the specified coordinate system (between -1 and 1, inclusive)
- Z direction component <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Z direction component > Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from X axis <= Value in the specified coordinate system
- Radial distance from X axis > Value in the specified coordinate system
- Radial distance from Y axis <= Value in the specified coordinate system
- Radial distance from Y axis > Value in the specified coordinate system
- Radial distance from Z axis <= Value in the specified coordinate system
- Radial distance from Z axis > Value in the specified coordinate system
- Radial distance from X direction <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from X direction > Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from Y direction <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from Y direction > Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from Z direction <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from Z direction > Value in the specified coordinate system (between -1 and 1, inclusive)
- Ray on the specified ray path
- Ray NOT on the specified ray path
- Scattered ray
- Not Scattered ray
- Scatter ancestry equal to Value
- Scatter ancestry NOT equal to Value
- Scatter ancestry <= Value
- Scatter ancestry > Value
- Specular rays
- Not Specular rays
- Specular ancestry equal to Value
- Specular ancestry NOT equal to Value
- Specular ancestry <= Value
- Specular ancestry > Value
- Total ray intersection count equal to Value
- Total ray intersection count Not equal to Value
- Total ray intersection count <= Value
- Total ray intersection count > Value

- Consecutive ray intersection count equal to Value
- Consecutive ray intersection count NOT equal to Value
- Consecutive ray intersection count <= Value
- Consecutive ray intersection count > Value
- Rays with ray errors
- Rays with no ray errors
- Ray number N
- All rays not ray number N
- Ray numbers <= N
- Ray numbers > N

- When an analysis plane is attached to a surface or a source, the default ray selection criterion is changed from 'All rays' to 'Rays on the specified surface.' This can be edited.

WARNING: When the ray selection spreadsheet contains multiple entries, FRED does not overwrite the criteria for an analysis plane attached to Object 'A' if it is subsequently attached to Object 'B.' The location of the Analysis Plane will move to be coincident with the new object, however the ray filters are not automatically updated to include Object 'B', which could lead to unexpected results. The filters should be edited and verified manually.

See Also….

Ray Selection Criterion…

For more detailed descriptions of Analysis Surfaces and their uses, select from among the following links.

Analysis Surface(s)

Analysis Plane Dialog

Attach Analysis Plane Dialog

Analysis Tools:

Position Spot Diagram

Polarization Spot Diagram

Directional Spot Diagram

Irradiance Spread Function

Intensity Spread Function

Energy Density

Coherent Scalar Wave Field

The following Tutorial shows how Analysis Planes can be used.

Building a Cassegrain

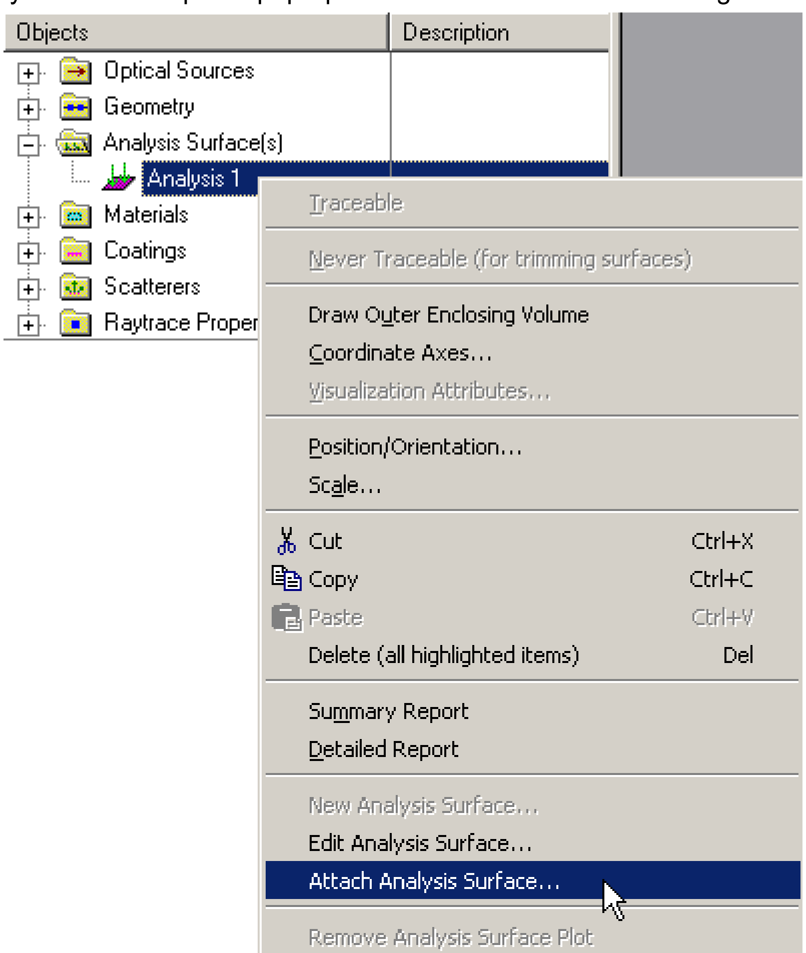
Attach Analysis Plane

Description - Attach Analysis Plane

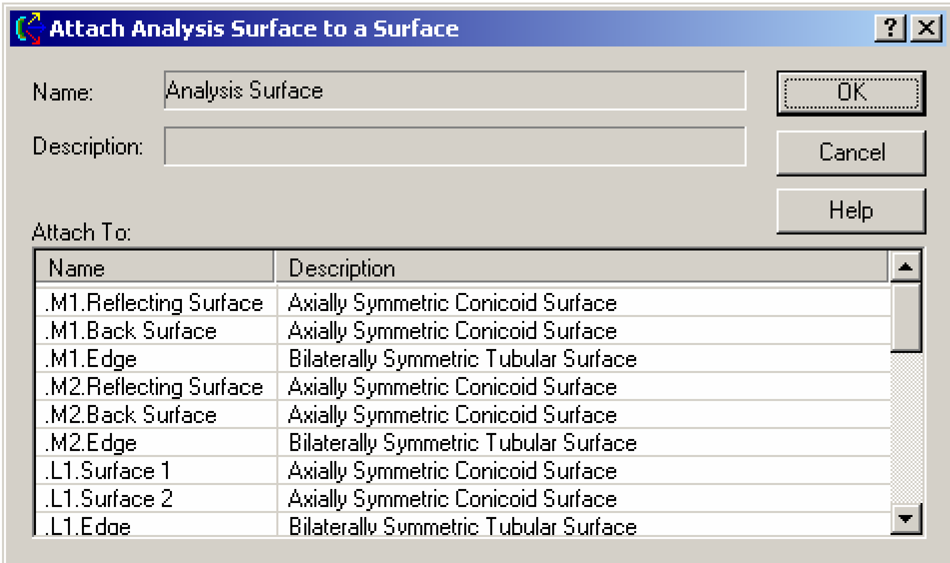
The Attach Analysis Plane dialog is used to manually select which surface or source the Analysis Plane will be attached to. Attaching an Analysis Plane has two effects. First, it moves the Analysis Plane to be coincident with the selected entity. The coordinate system of the Analysis Plane is re-parented to that of the entity. Any movement of the entity causes the Analysis Plane to move as well. Second, attaching an Analysis Plane to an entity replaces the existing Ray Selection Criterion.

How Do I Get There? - Attach Analysis Plane

The Attach Analysis Plane dialog is opened by right mouse clicking on an existing Analysis Plane to open a pop-up context menu and then selecting '*Attach Analysis Plane...*'



Dialog Box and Controls - Attach Analysis Plane



Control	Inputs	Defaults
Name:	None	Name of the Analysis Plane
Description:	None	Description of the Analysis Plane
Attach To		
Name and Description	Choose the Surface or Source entity that the Analysis Plane will be attached to.	None
OK	Attach Analysis Surface and close dialog box.	
Cancel	Close dialog box without attaching Analysis Surface.	
Help	Access this Help page.	

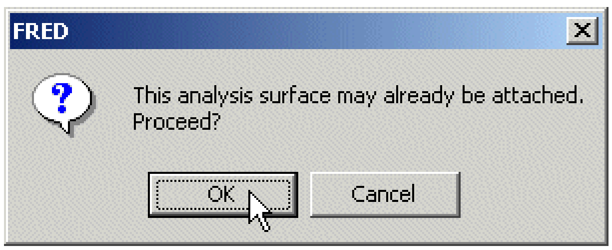
Application Notes - Attach Analysis Plane...

- The default ray filter is ‘All rays,’ which will include every ray that has been created and/or traced.
- The default location for a new Analysis Plane is at the origin of the global coordinate system.
- An analysis plane can only be attached to a single Surface or a single Source entity.

- When an analysis plane is attached to a surface or a source, the default Attach Analysis Plane is changed from 'All rays' to 'Rays on the specified surface.' This can be edited.

WARNING When the ray selection criteria includes multiple entries, FRED does not overwrite the criteria for an analysis plane attached to Object 'A' if it is subsequently attached to Object 'B.' The location of the Analysis Plane will move to be coincident with the new object, however, which could lead to unexpected results. The filters should be edited and verified manually.

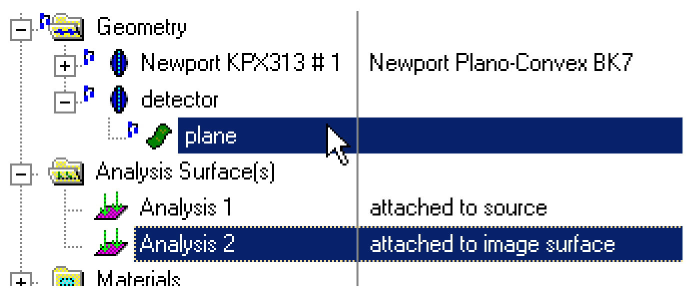
- An Analysis Plane can also be attached via the drag and drop method (see Examples).
- If an Analysis Plane is already attached to different entity, FRED pops up a dialog requesting confirmation before completing the action.



Examples - Attach Analysis Plane...

Example 1 – Drag and Drop to Attach an Analysis Plane to a Surface/Source

Create a new Analysis Plane or expand the Analysis Surface(s) folder and left mouse click on an Analysis Plane. While holding the left mouse button down, move the cursor to the desired surface or source. Release the mouse button.



If the Analysis Plane was already attached, a warning dialog pops up to confirm replacement.

See Also…. - Attach Analysis Plane…

For more detailed descriptions of Analysis Surfaces and their uses, select from among the following links.

Analysis Plane Dialog

Attach Analysis Plane Dialog

Ray Selection Criterion Dialog

Analysis Tools:

Position Spot Diagram

Polarization Spot Diagram

Directional Spot Diagram

Irradiance Spread Function

Intensity Spread Function

Energy Density

Coherent Scalar Wave Field

The following Tutorial shows how Analysis Planes can be used.

Building a Cassegrain

Chapter 8 - Defining and Applying Materials

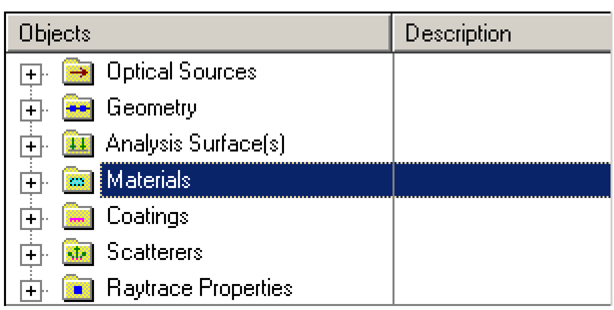
Materials

Description - Materials

The **Materials** folder contains all of the default and optional user-defined Materials. The default materials Air, Vacuum, and Standard Glass are all defined as Sampled Materials. Once created, a material type (i.e. Sampled Material or Model Material) cannot be changed. Glass catalog materials may be added to the folder as well. This is done automatically with a lens import or copy from another FRED model.

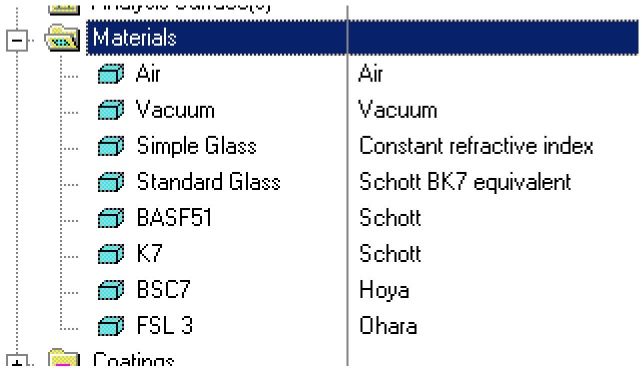
Visualization (example) - Materials

The **Materials** folder is near the middle of the tree.



How Do I Get There? - Materials

A left click on the [+] symbol next to the folder name will expand the tree.

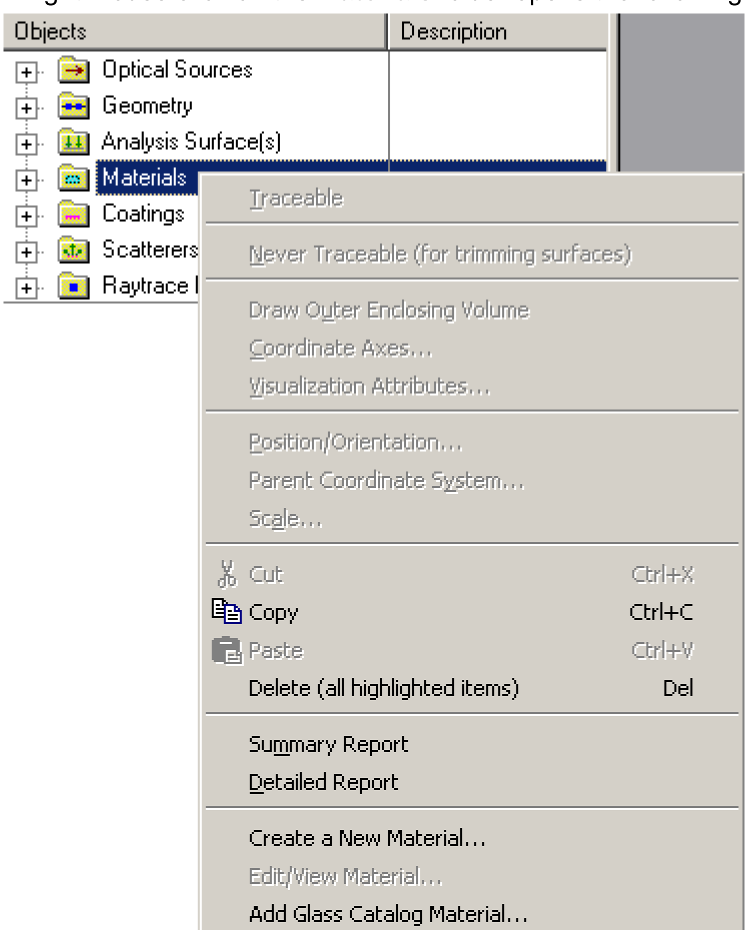


A left click on the ⊟ symbol next to an open folder will collapse the tree.

Sampled Materials and Model Materials can be edited and viewed with a right mouse click on the name and selecting the Edit/View option, or by simply double clicking on the material name. Glass catalog materials cannot be edited or viewed directly.

Dialog Box and Controls - Materials

A right mouse click on the **Materials** folder opens the following context menu.



The first option available on the context menu is a ‘*Summary Report*.’

When this option is selected, FRED prints a list the Materials in the model and a brief description of each.

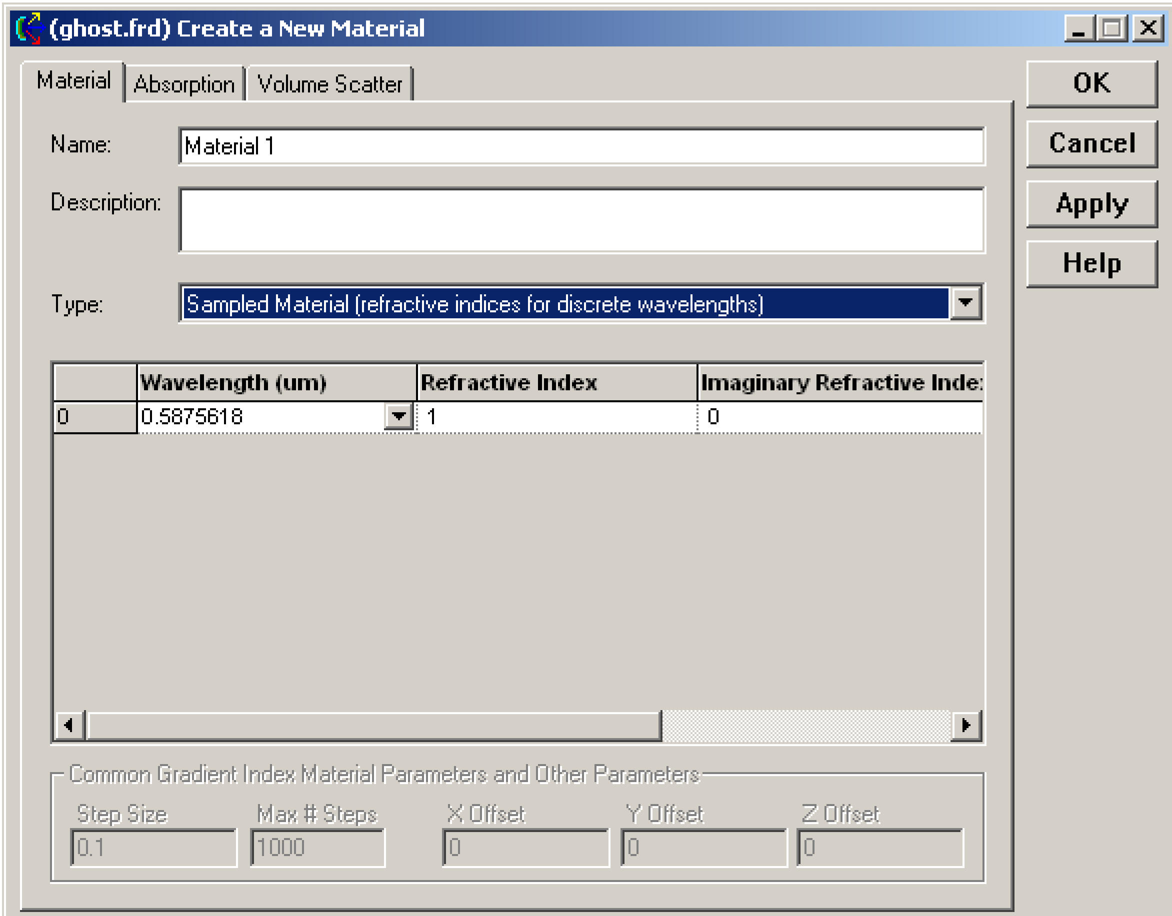
MATERIALS			
Air		Air	
Vacuum		Vacuum	
Simple Glass		Constant refractive index	
Standard Glass		Schott BK7 equivalent	
BASF51		Schott	
K7		Schott	
BSC7		Hoya	
FSL 3		Ohara	

The second option available on the right click menu is a ‘*Detailed Report*.’

When this option is selected, FRED prints a detailed summary of all of the material properties. The output is too large to display, but includes names, dispersion coefficients, a table of refractive index as a function of wavelength, and more.

The third option available is to ‘*Create a New Material…*’

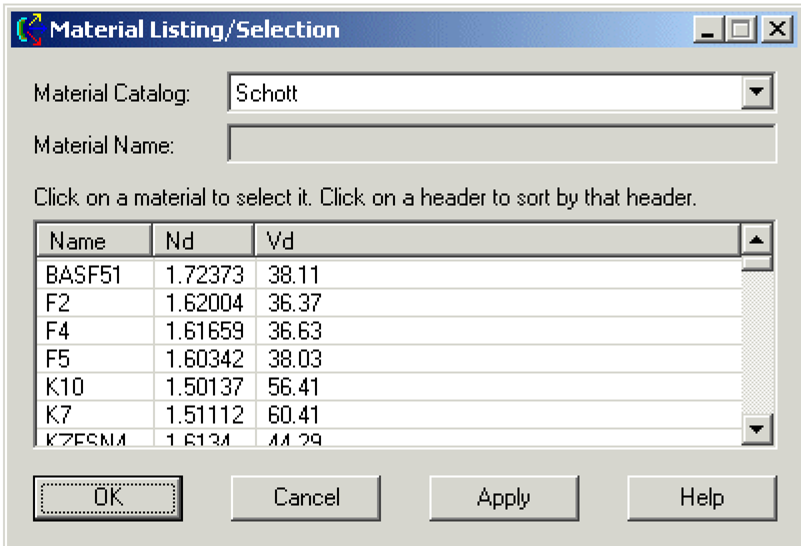
Selecting this option opens the (New) Material Dialog. This is just one of a number of ways to access this dialog.



Use this dialog to enter refractive index data as sampled points (Sampled Material) or by its Nd and Vd values (Model Material).

The last option available on the context menu is to add a new catalog material.

This selection option opens the following dialog, which provides access to a number of vendor material databases supplied with FRED.



Application Notes - Materials

- Default material properties
  - o Air – Sampled Material, constant refractive index, n = 1.0
  - o Vacuum – Sampled Material, constant refractive index, n = .999707 (relative to Air)
  - o Simple Glass – Sampled Material, constant refractive index, n = 1.5
  - o Standard Glass – Schott BK-7 equivalent glass, cannot be edited
- The Material Type (either Sampled or Model Material) cannot be changed after a new material has been created.
- Copies between FRED models will always transfer new material and coating information.
- A new material can be applied to a surface via drag and drop onto that surface

See Also - Materials

The following links contain details about editing existing materials and adding new ones.

Sampled Material

Model Material

Glass Catalog Material

Description - Applying Materials

This dialog page allows the user to select the two materials associated with a surface.

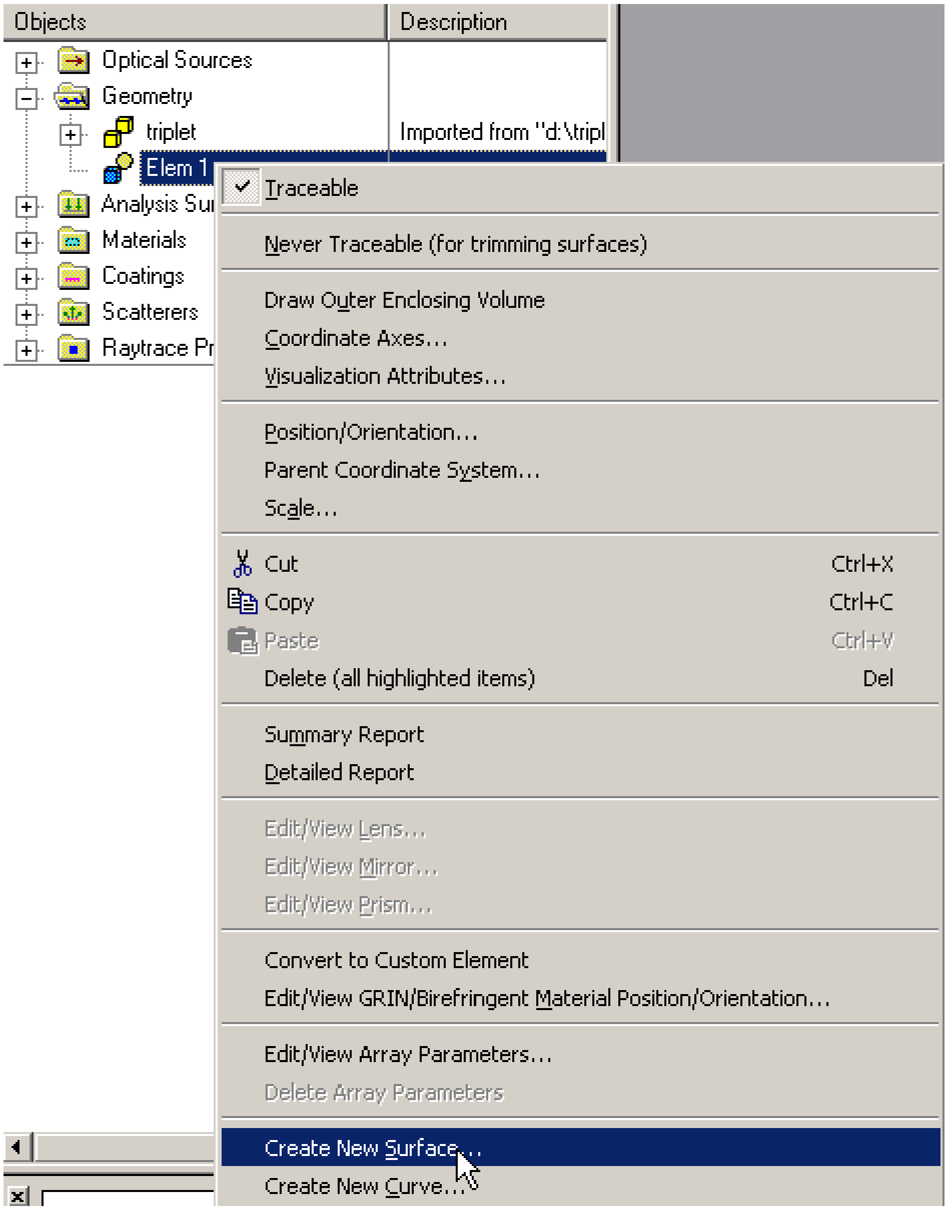
Any of the materials defined in the current FRED document file may be assigned to the surface. In addition, catalog materials and new materials can be added to the FRED document from this dialog. The process for adding a catalog material or new material is described in Creating New Materials… and Add Catalog Material help files. In addition, the user defined materials can be edited from this dialog. The materials added from catalogs cannot be edited directly at this time.

The ray data stored during a raytrace includes the currently assigned material and when the ray intersects the surface a check of the ray's currently assigned material against the two surface materials is performed. If the ray's currently assigned material matches one of the two surface materials, then the program knows that the other material is the next material. If no match is made between the ray's currently assigned material and the two materials assigned to the surface, then the ray is stopped and a warning is issued at the end of the ray trace.

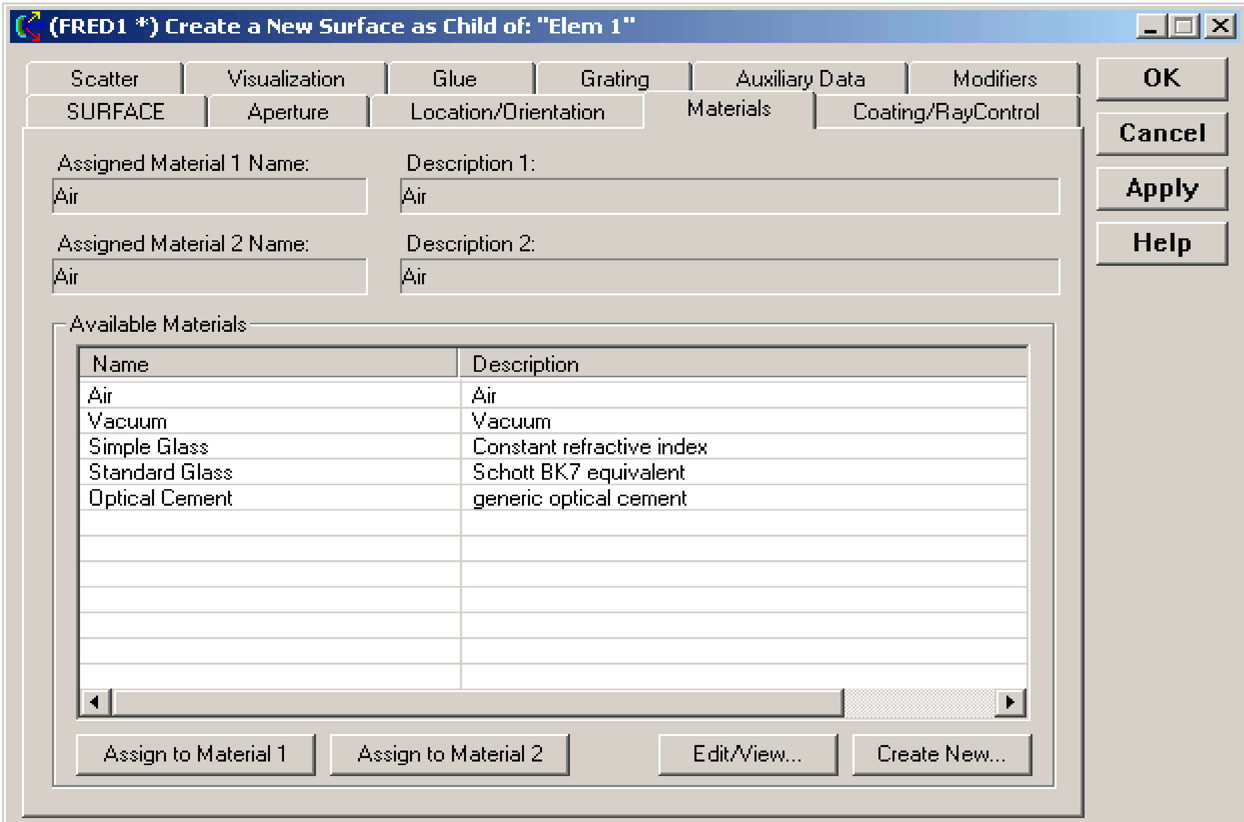
NOTE or TIP It does not matter what order the materials are assigned in this dialog because the ray knows what material it is in when it intersects the surface.

How Do I Get There? - Applying Materials

This page is in the Create New Surface… and Edit/View Surface… dialogs.


Objects
Description
Optical Sources
Geometry
triplet
Imported from "d:\tripl
Elem 1
Analysis Su
Materials
Coatings
Scatterers
Raytrace Pr
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Applying Materials



Control	***Inputs***	***Defaults***
Assign Material 1 Name	List the name/description of Material 1.	Air
Assign Material 2 Name	List the name/description of Material 2.	Air
Available Material	Select/highlight a material with a left mouse click and then press the Assign to Material 1 or 2 button. Materials can be edited, viewed, or added to the list.	Existing Materials
OK	Accept Material changes and close dialog box.	
Close	Discard Material changes and close dialog box.	
Apply	Apply Material changes and keep dialog box open.	
Help	Access this Help page.	

Edit/Create a New Sampled Material

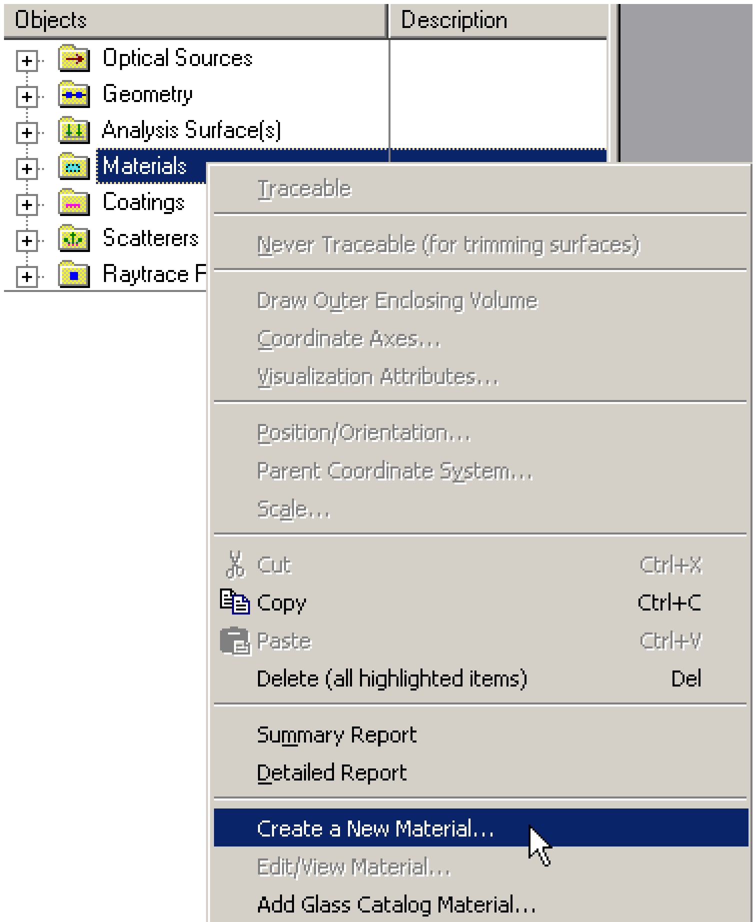
Description - Edit/Create a New Sampled Material

A Sampled Material uses a table of wavelengths and refractive indices to define a material type not found in the default glass catalogs. The refractive index can have real and imaginary parts (i.e., for metals). The table can be entered by hand, read from a simple text file, or entered using the Digitization tool. The default materials Air, Vacuum, and Standard Glass are all defined as Sampled Materials. Once created, a material Type (i.e. Sampled Material or Model Material) cannot be changed.

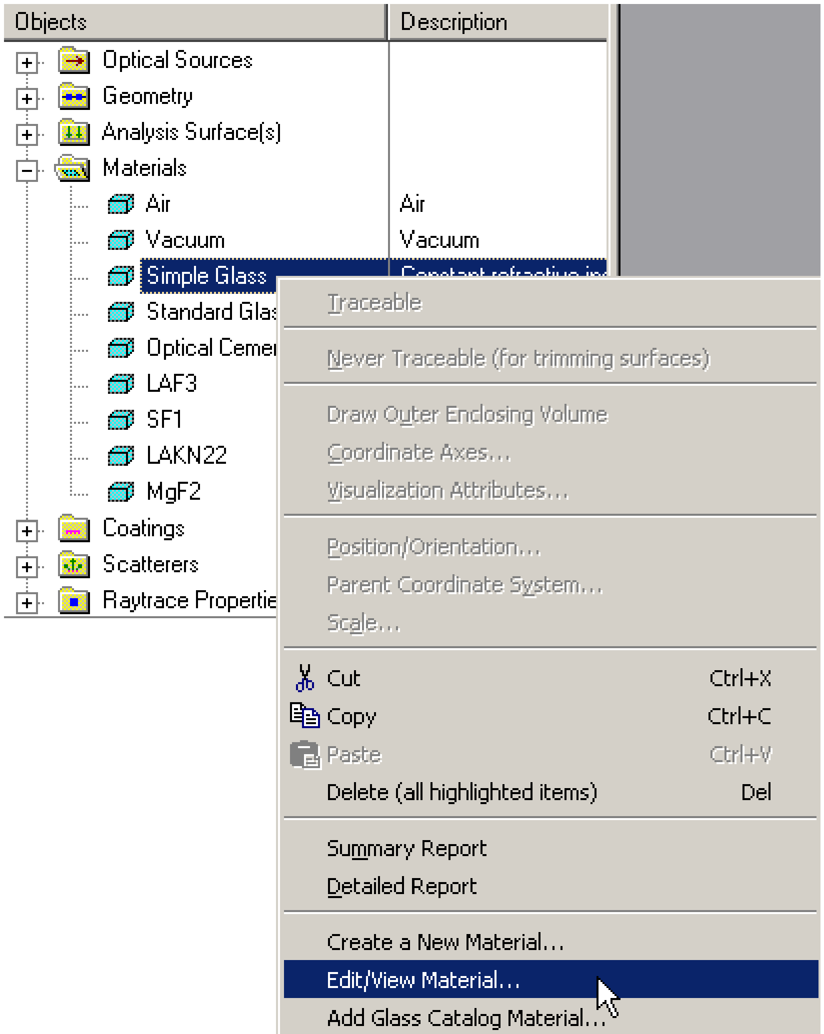
How Do I Get There? - Edit/Create a New Sampled Material

There are four ways to open a Material dialog.

1. Right mouse click on the Materials folder to open a context menu and select the option '*Create a New Material…*'

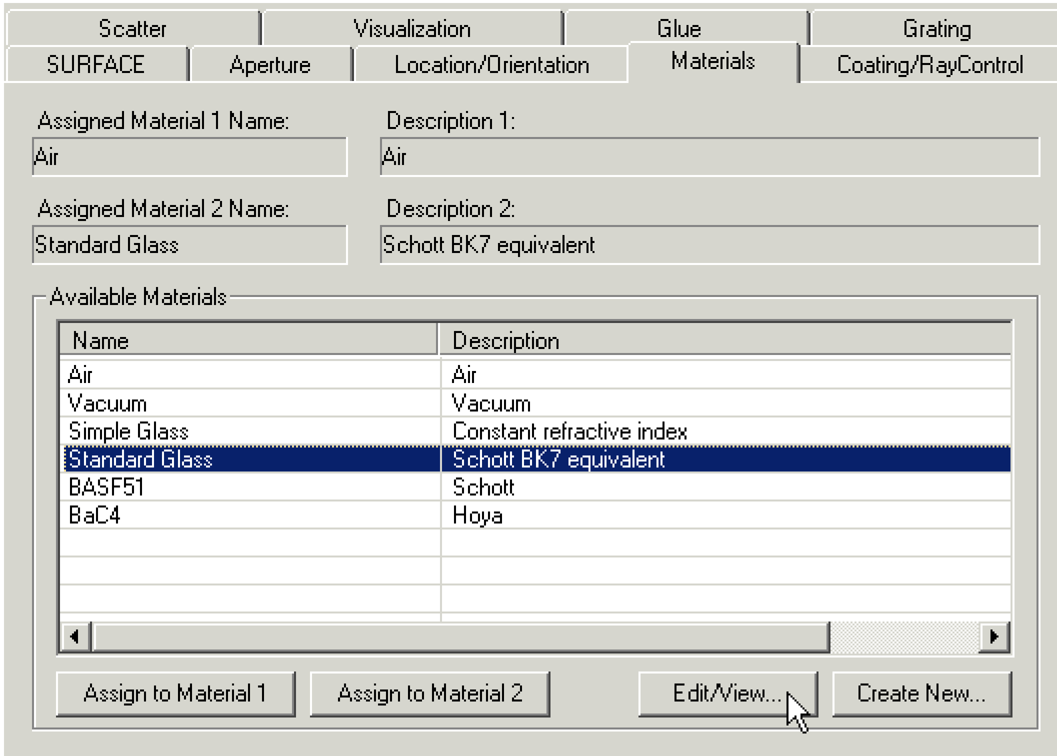


2. Expand the Materials folder and right mouse click on a specific material to open the pop-up context menu and select the option '*Edit/View Materials…*'

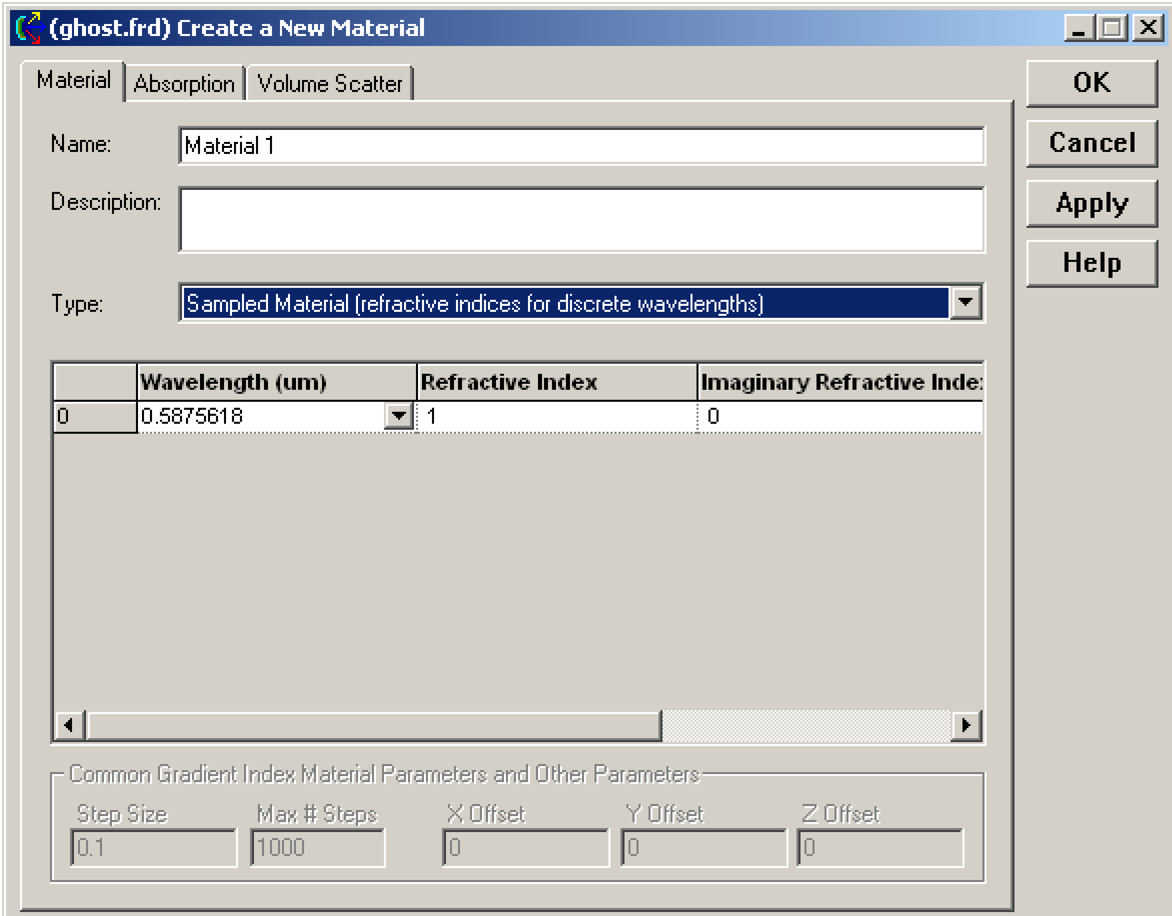


3. Expand the Materials folder and, using the left mouse button, double click on the material name.

4. From the Materials tab in the **Surface** dialog, select a material and left mouse click on either the '*Edit/View…*' or '*Create New…*' material button.



Dialog Box and Controls - Edit/Create a New Sampled Material



Control	***Inputs***	***Defaults***
Name	Material name	Material n
Description	Brief description of the material.	blank
Type	Select the data format.	Sampled Material
Wavelength	Enter 1 or more wavelengths in micrometers.	0.589
Refractive Index	Enter the refractive index of the material at the defined wavelength.	1
Imaginary Refractive Index	Enter the imaginary part of the refractive index (i.e., for metals).	0
OK	Accept changes and close dialog box.	
Cancel	Cancel changes and close dialog box.	
Help	Help	

The imaginary component of the refractive index is directly proportional to the absorption (or gain) coefficient at the associated wavelength via the following formula: a = (2pi * n' / wav) where "a" is the absorption coefficient, "wav" is the wavelength and "n'" is the imaginary part of the refractive index at that wavelength.   Absorption is specified with a positive value, no absorption is specified with a value of zero, and gain may be specified with a negative value.

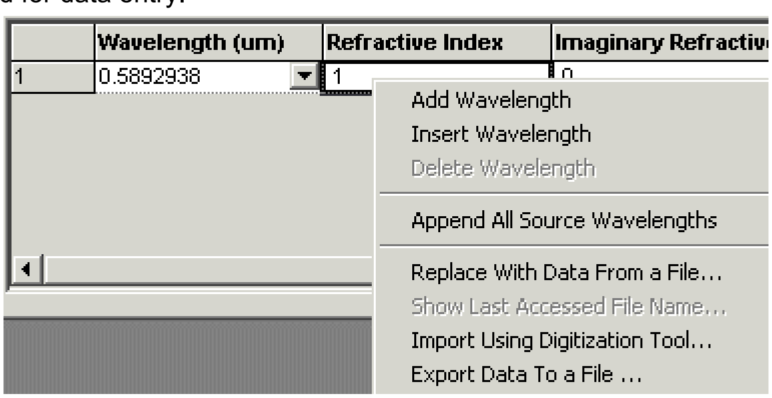
Application Notes - Edit/Create a New Sampled Material

- FRED linearly interpolates refractive index data between sampled wavelengths. If the source wavelength lies outside the minimum or maximum sampled wavelengths, then the interpolated refractive index equal to that of the nearest sampled wavelength.
- Summary data for all materials currently contained in the Materials folder can be displayed by right mouse clicking on the materials folder and selecting either the '*Summary Report*' for a short summary table or the '*Detailed Report*' for a complete listing of all the material properties.

- The Material type (either Sampled or Model Material) cannot be changed after a new material has been created.
- Copies between FRED models will always transfer new material and coating information.
- A new material can be applied to a surface via drag and drop onto that surface

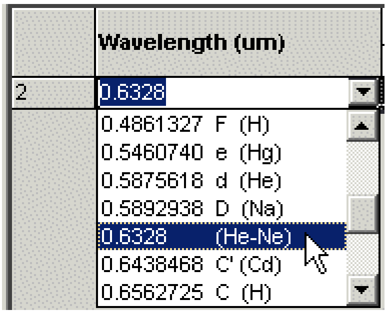
Examples - Edit/Create a New Sampled Material

The following examples illustrate how to use the context menu to enter, modify, import, and export data. The context menu is available with a right click inside the spreadsheet area used for data entry.



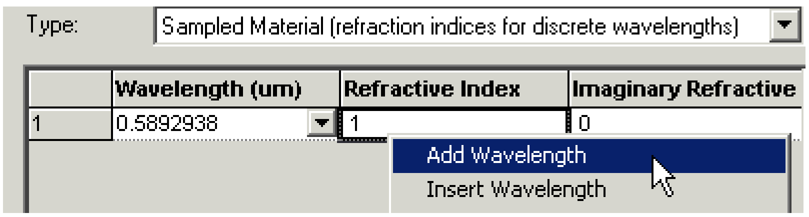
Example 1: Changing the wavelength

Changing the material wavelength is accomplished by either directly typing the new wavelength (in microns) into the wavelength cell, or by selecting a new wavelength the list of predefined values available using the pull down menu. The predefined wavelengths in FRED include a large number of atomic emission lines in addition to a number of common laser wavelengths. Use the scroll bar on the right side of the list to scan through the entire range.



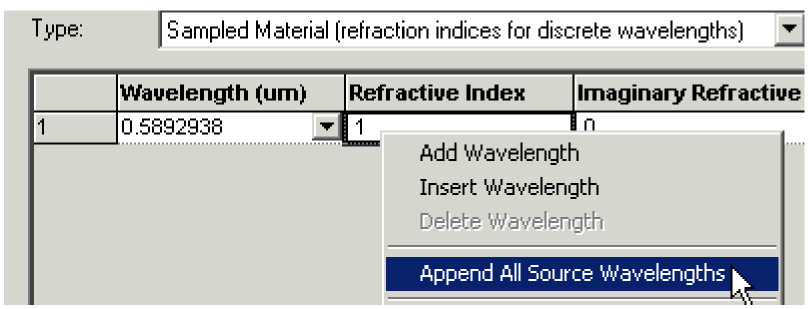
Example 2: Adding or Inserting a wavelength

From the context menu, select either '*Add Wavelength*' or '*Insert Wavelength*.' *Add Wavelength* automatically appends the new wavelength row to the end of the list. *Insert Wavelength* puts the new wavelength row before the currently selected row. By default, the new wavelength is always 0.5893 microns. Change this value as appropriate. The wavelength order of entry is not important.



Example 3: Appending all source wavelengths

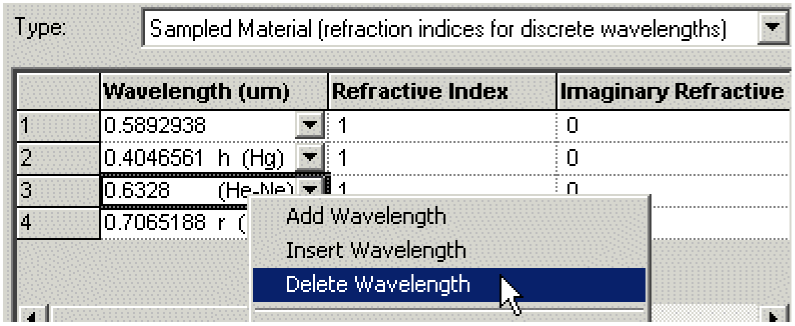
By selecting the '*Append All Source Wavelengths*' from the context menu, FRED automatically appends a row for every unique wavelength defined by all the Sources currently in the model.



Note that once entered, any wavelength value can be changed.

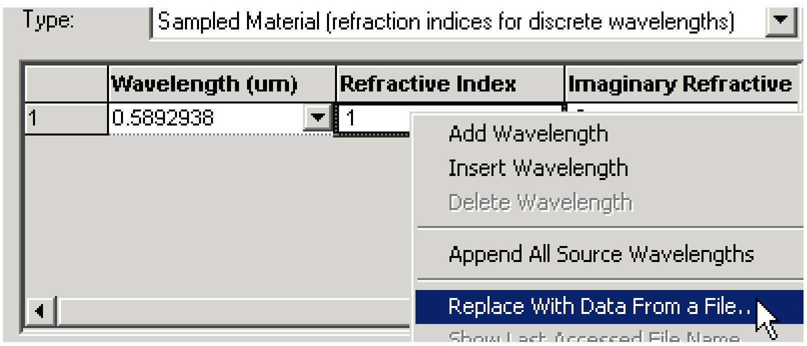
Example 4: Deleting Wavelength Rows

If multiple wavelengths have been entered, any wavelength row can be deleted with a right click on the desired wavelength and selecting the *Delete Wavelength* option on the context menu.

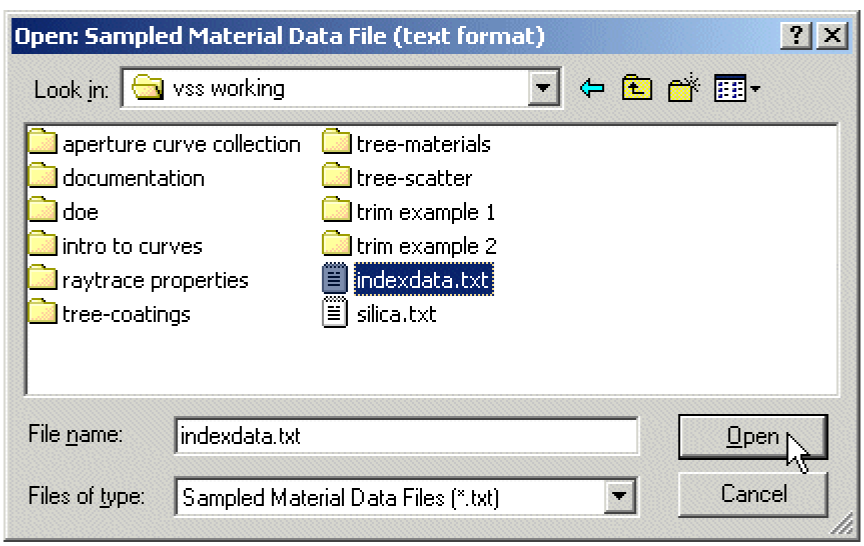


Example 5: Importing refractive index data from a file

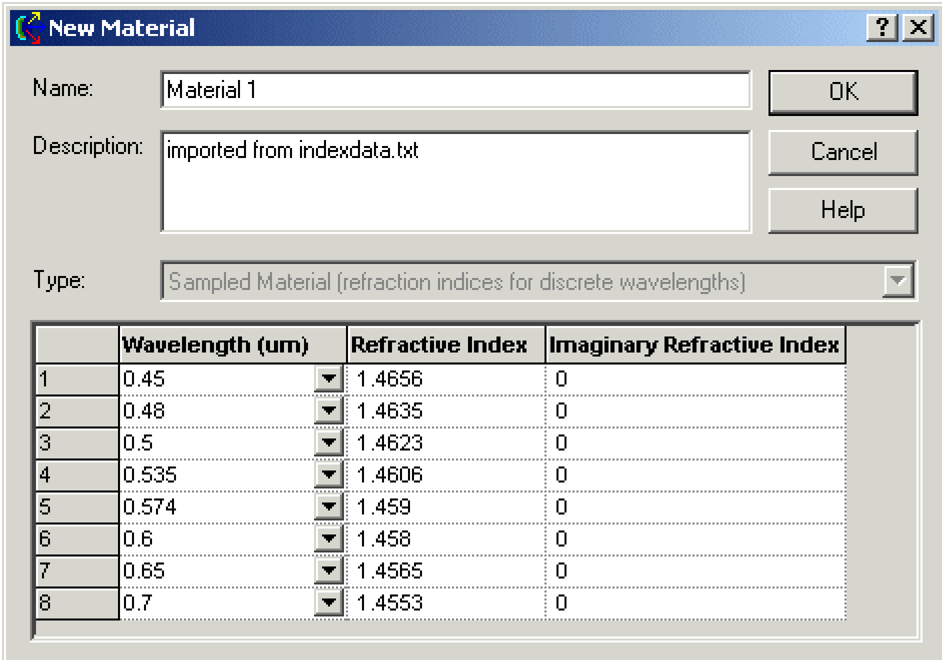
An alternative to manual data entry is to import the wavelength and refractive index data from an ASCII text file. The file should have on each row: *wavelength* (in microns), *refractive index*, *imaginary refractive index*. Delimeters may be any combination of spaces, commas, or tabs. Open the context menu and select '*Replace With Data From a File*.'



This will open a dialog showing the file list of the current working directory. The directory can be changed using the conventional Windows navigation tools. The file type must be ASCII text, but the extension is not important. Select the file and left click on the '*Open*' button to finish.



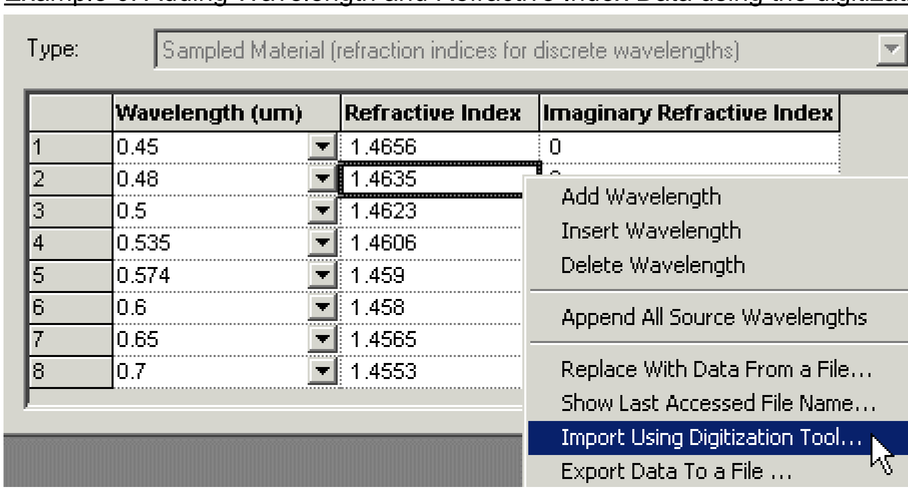
The Material table will be filled with the new data. Any existing entries will be overwritten.



FRED can recall the name of the source file used to import the data by selecting the option '*Show Last Accessed File Name…*' from the context menu. FRED will pop a dialog with the source file name. Left mouse click on OK to close.

-

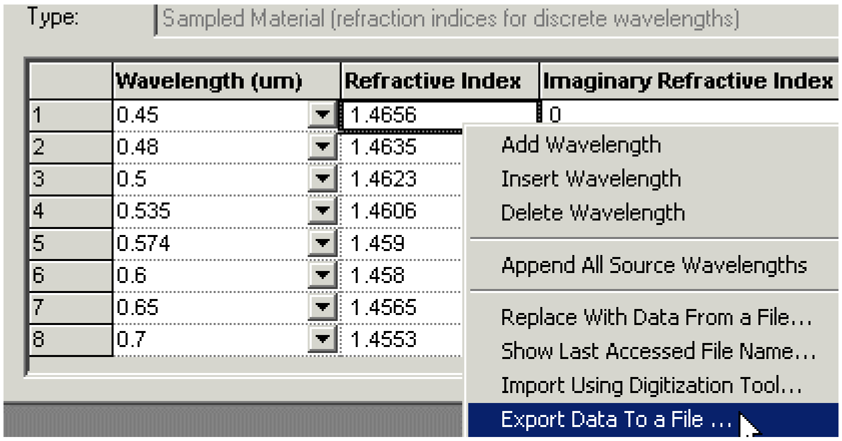
Example 6: Adding Wavelength and Refractive Index Data using the digitization tool



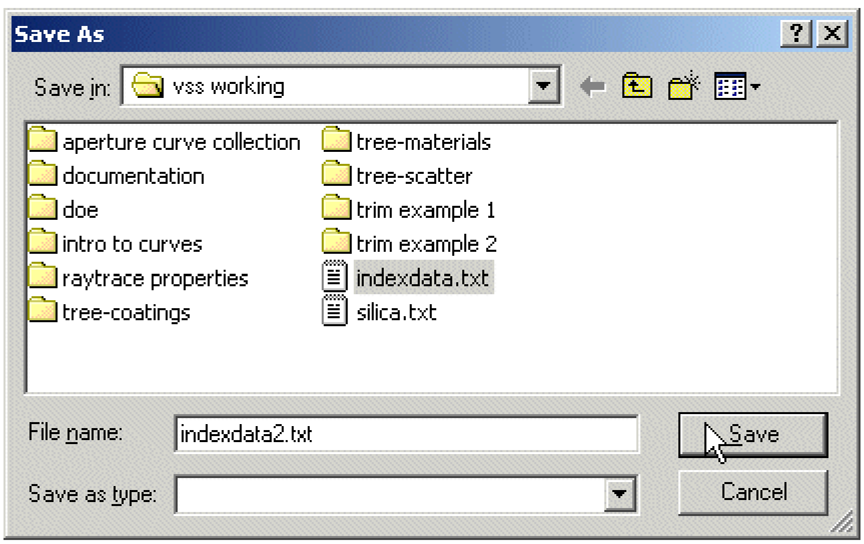
An alternate way of entering wavelength and refractive index data is to use the Digitization tool internal to FRED. Selecting '*Import Using Digitization Tool…* ' from the context menu opens a FRED utility that allows the user to grab data from a bitmapped image. The image file may be created by scanning a plot of refractive index vs. wavelength or by copying an image into a bitmap file. Once loaded, the user sets the length of the ordinate axes to set the plot scale and then grabs each data point with a left mouse click on the curve. There is no limit to the number of data points that can be entered. This utility is available to many other FRED functions as well.

-
Example 7: Export Data To a File

All wavelength and index data can be exported to an ASCII text file.



This opens a dialog showing the file list of the current working directory. The directory can be changed using the conventional Windows navigation tools. The file type must be ASCII text, but the extension is not important. Select a file to overwrite or type in a new file name and left mouse click on the *Save* button to finish.



The data format is exactly as shown in the dialog:

Wavelength, Refractive Index, Imaginary Refractive Index

See Also - Edit/Create a New Sampled Material

Click on this link to show information about the **Materials** folder.

Materials

The following links contain details about other options for editing existing materials and adding new ones.

Model Material

Glass Catalog Material

Edit/Create a New Model Material

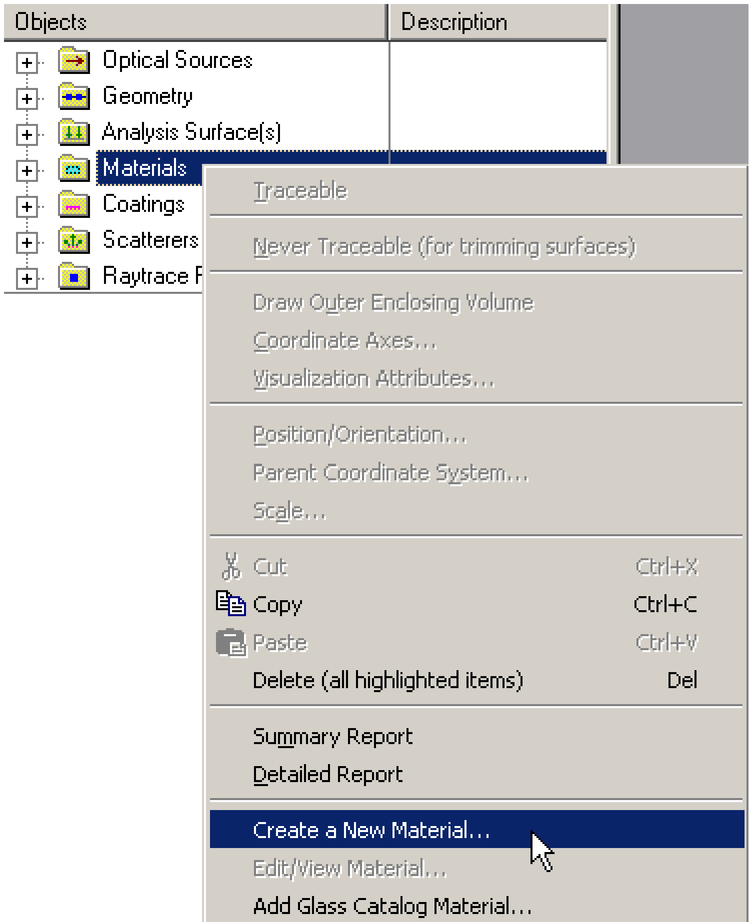
Description - Edit/Create a New Model Material

A Model Material uses the refractive index and the Abbe V-number at the helium ‘d’ line (0.587562 microns) to define the material properties. This material type is an alternative to the Sampled Material for creating a glass model that is not available from any of the default catalogs. Once created, a material type (i.e. Sampled Material or Model Material) cannot be changed.

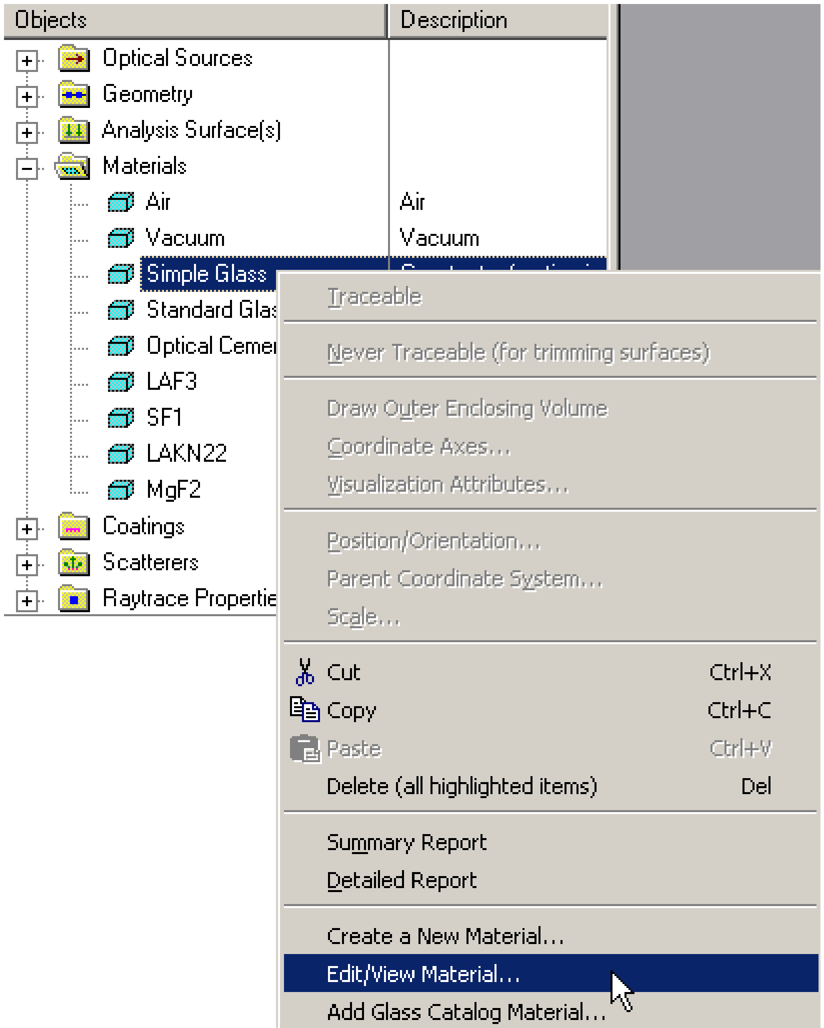
How Do I Get There? - Edit/Create a New Model Material

There are four ways to open a Material dialog.

1. Right click on the Materials folder to open a the pop-up menu and select the option ‘*Create a New Material…*’

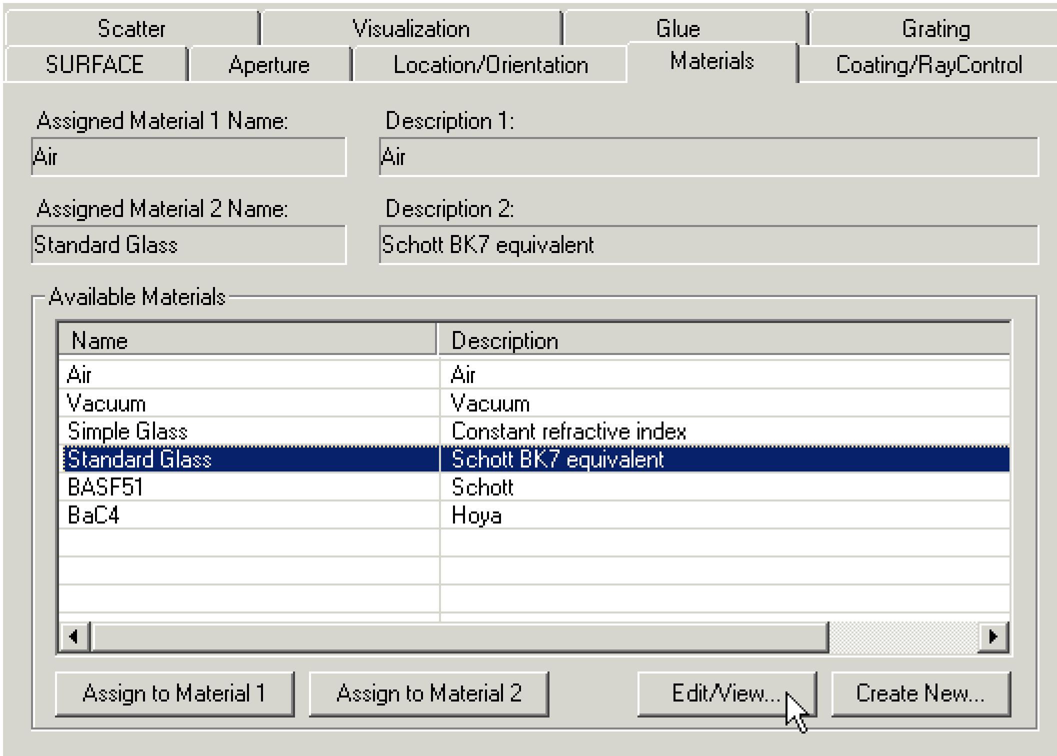


2. Expand the Materialsfolder and right mouse click on a specific material open a pop-up menu and select the option '*Edit/View Materials…*'

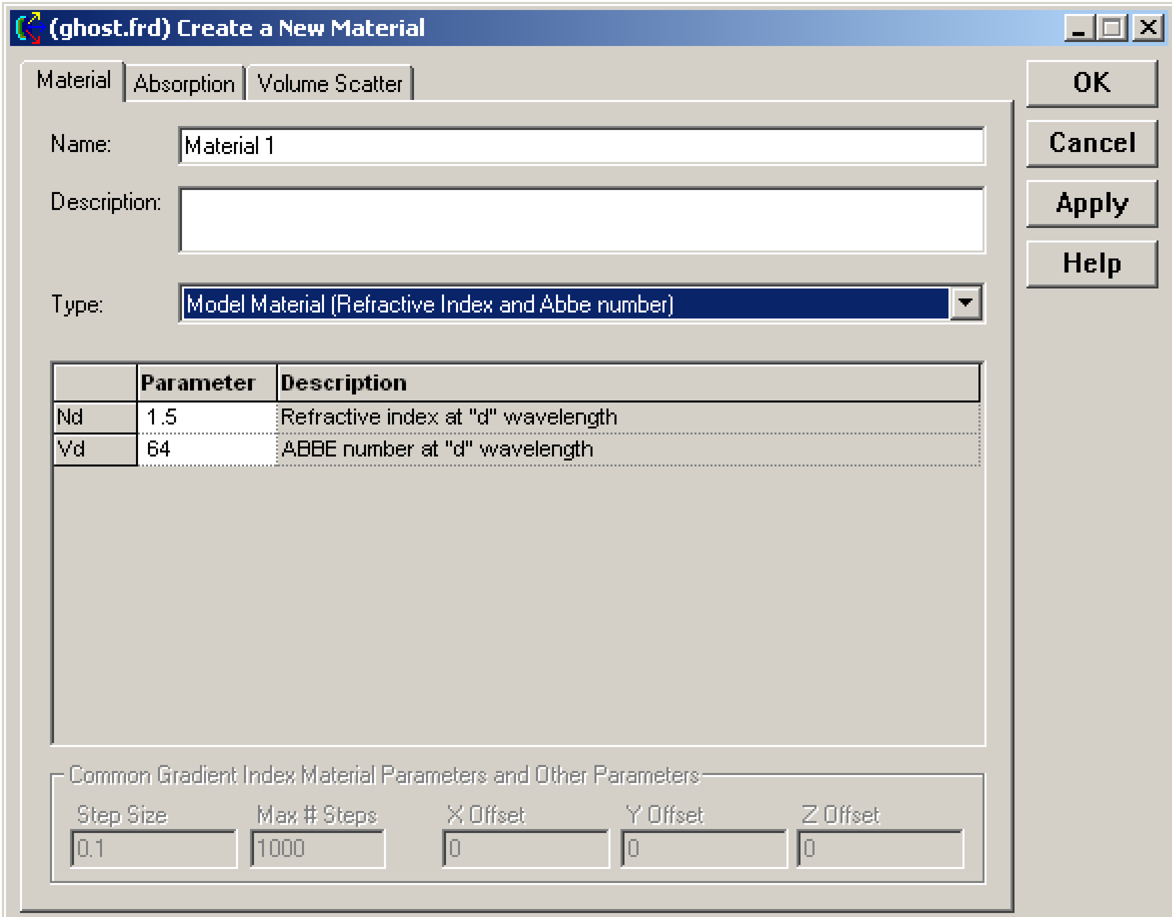


3. Expand the Materials folder and double left mouse click on the material name.

4. From the Materials tab in the **Surface** dialog, select a material and left mouse click on either the '*Edit/View…*' or '*Create New…*' material button.



Dialog Box and Controls - Edit/Create a New Model Material



Control	***Inputs***	***Defaults***
Name	Required. Enter a material name.	Material n
Description	Optional. Enter a brief description of the material.	None.
Type	Select Model Material from the pull down menu	Sampled Material
Nd	Enter the refractive index at the 'd' wavelength	1.5
Vd	Enter the ABBE number at the 'd' wavelength	64
OK	Accept changes and close the dialog	
Cancel	Cancel changes and close the dialog	
Help	Help	

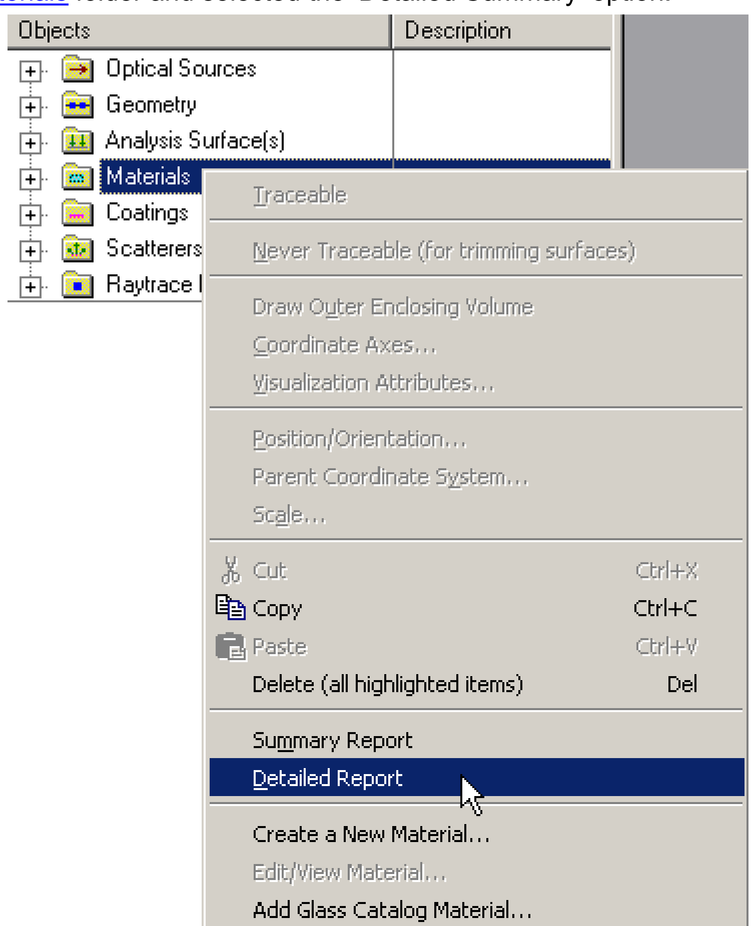
Application Notes - Edit/Create a New Model Material

- The Model Material calculates non-linear refractive index values for an extended wavelength range based on the Nd and Vd settings.
- Summary data for all materials currently contained in the Materials folder can be displayed by right mouse clicking on the materials folder and selecting either the '*Summary Report*' for a short summary table or the '*Detailed Report*' for a complete listing of all the material properties.

- The Material type (either Sampled or Model Material) cannot be changed after a new material has been created.
- Copies between FRED models will always transfer new material and coating information.
- A material can be applied to a surface via drag and drop onto that surface.

Examples - Edit/Create a New Model Material

Refractive index data for a Model Material can be displayed by right mouse clicking on the Materials folder and selected the 'Detailed Summary' option.



This option prints a detailed list of material properties for all the materials contained in the folder. The view below shows just one portion of the output. The Model Material properties are Nd = 1.8 and Vd = 43. The wavelength list is generated by searching through all the existing sources defined in the model for unique wavelengths. It does not matter if the source is designated Traceable or Not Traceable.

Wavelength vs. Real Refractive Index Table							
Wavelength units are um							
0.4358343	0.4861327	0.546074	0.5892938	0.6328	0.6562725	0.7065188	Name
1	1	1	1	1	1	1	Air
1.82450429	1.81291653	1.80418883	1.79984843	1.79651726	1.79503696	1.79242341	Model Material

See Also - Edit/Create a New Model Material

Click on this link to show information about the **Materials** folder.

Materials

The following links contain details about other options for editing existing materials and adding new ones.

Sampled Material

Glass Catalog Material

Add Volume Scatter - Henyey-Greenstein

Description

How Do I Get There?

Dialog Box and Controls

Application Notes

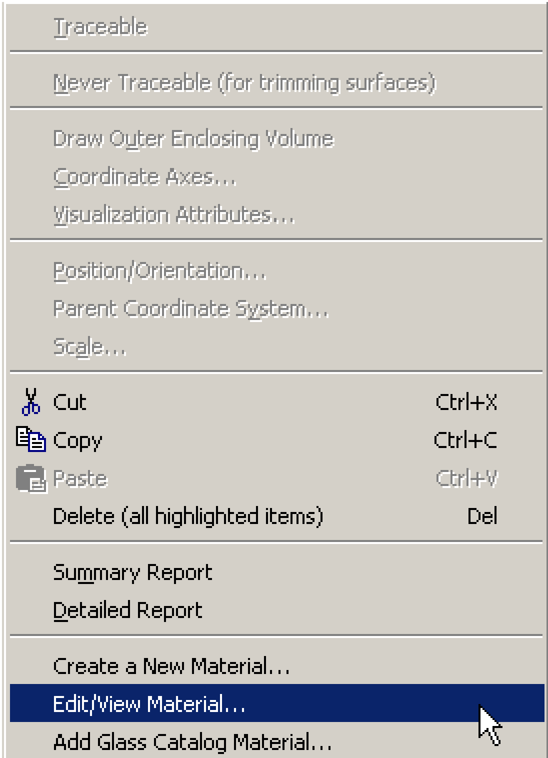
See Also…

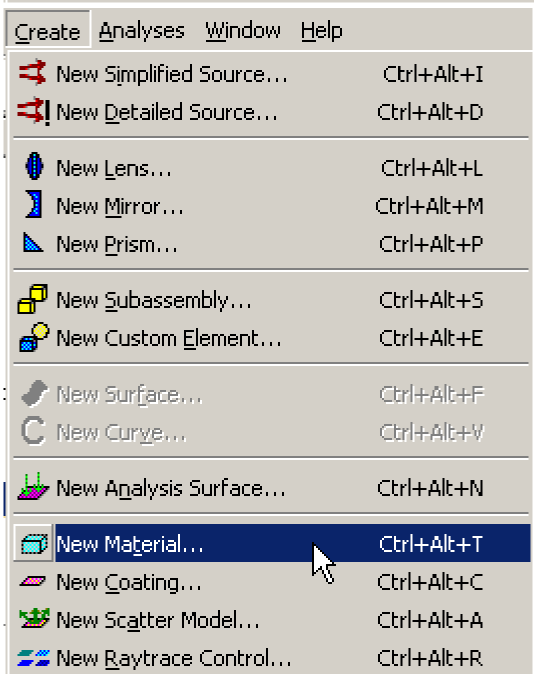
Description - Add Volume Scatter - Henyey-Greenstein

Adds a Henyey-Greenstein volume scatter model to a material. This model, originally developed for simulation of scatter in astronomical observation, has found application in the bio-medial field.

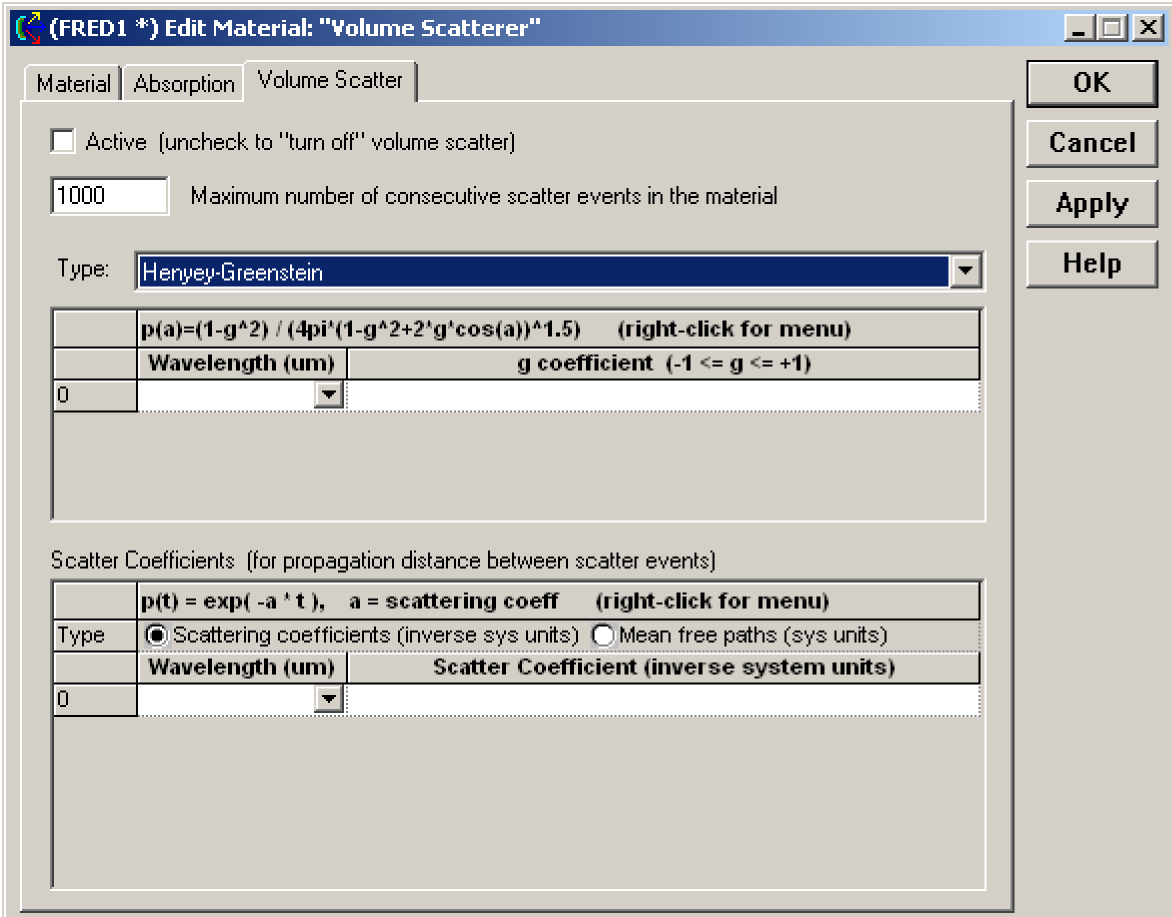
How Do I Get There? - Add Volume Scatter - Henyey-Greenstein

This command is accessed through the Tree or from the main menu:





Dialog Box and Controls - Add Volume Scatter - Henyey-Greenstein



Control	***Inputs / Description***	***Defaults***
Active	Turns volume scattering on or off	Unchecked
Maximum number of …….	Sets the maximum number of consecutive scatter events allowed in the material.	1000
Type	Sets model type: *None* or *Henyey-Greenstein*	None
Wavelength	Wavelengths corresponding to g-coefficients	blank
g-coefficient	Sets the g-coefficient (-1 <= g <= +1)	blank
Scatter Coefficients		
Type	Specify a scattering coefficient or the mean-free paths	scattering coefficients
Wavelength	Wavelengths corresponding to Scatter Coefficient/Mean-free Path	blank

Scatter Coefficient/Mean-free Path	Scatter coefficient (inverse system units) Mean-free Path (system units)	blank
OK	Accept settings and close dialog box.	
Cancel	Discard changes and close dialog box.	
Apply	Accept changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Add Volume Scatter - Henyey-Greenstein

- The angular distribution associated with the Henyey-Greenstein volume scatter model is given by

$$p(\theta) = \frac{1}{4\pi} \cdot \frac{1-g^2}{\left(1+g^2-2g\cos(\theta)\right)^{3/2}}$$

- The scattering anisotopy parameter g varies in the range -1 ≤ g ≤ +1; g=-1 corresponding to total backward scattering, g=0 to isotropic (Rayliegh) scattering and g=+1 to total forward scattering (Mie scattering for large particles).

- Concentration can be specified in terms of a scattering coefficient *a* (inverse system units) or as mean-free path (system units).

- A useful reference on the subject of tissue scattering is ***Tissue Optics*** by Valery Tuchin, ISBN 0-8194-3459-0, published by SPIE.

See Also - Add Volume Scatter - Henyey-Greenstein

Material - Absorption

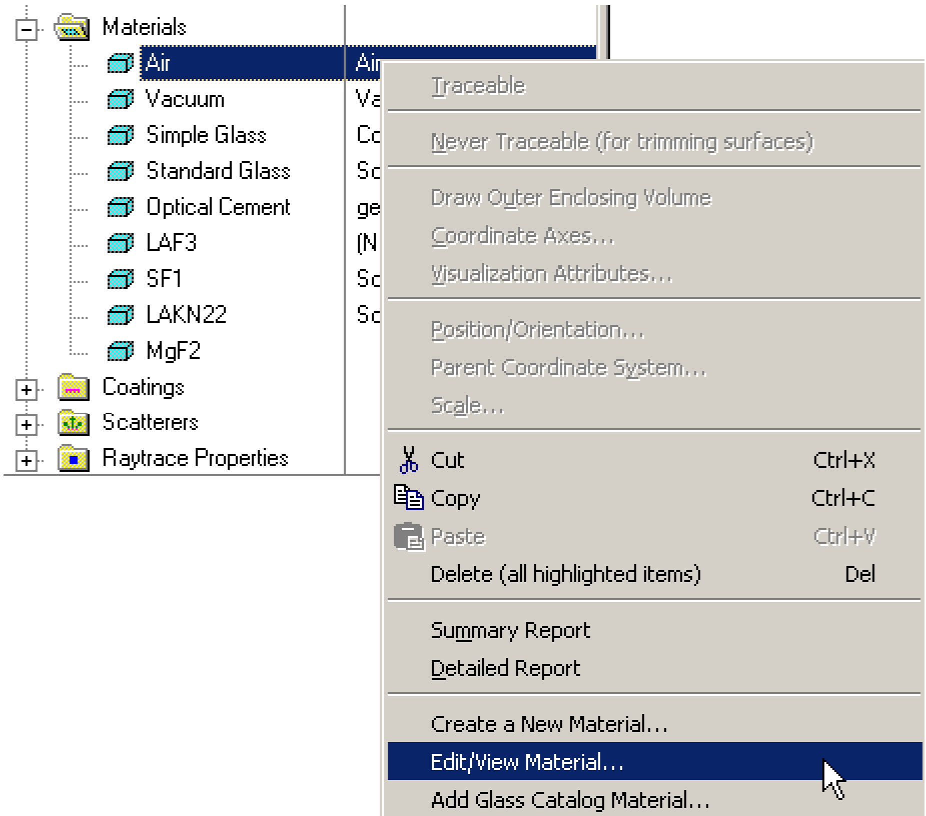
Description - Material - Absorption

Adds absorption properties to any material. Absorption entered by this method overrides imaginary refractive indicies.

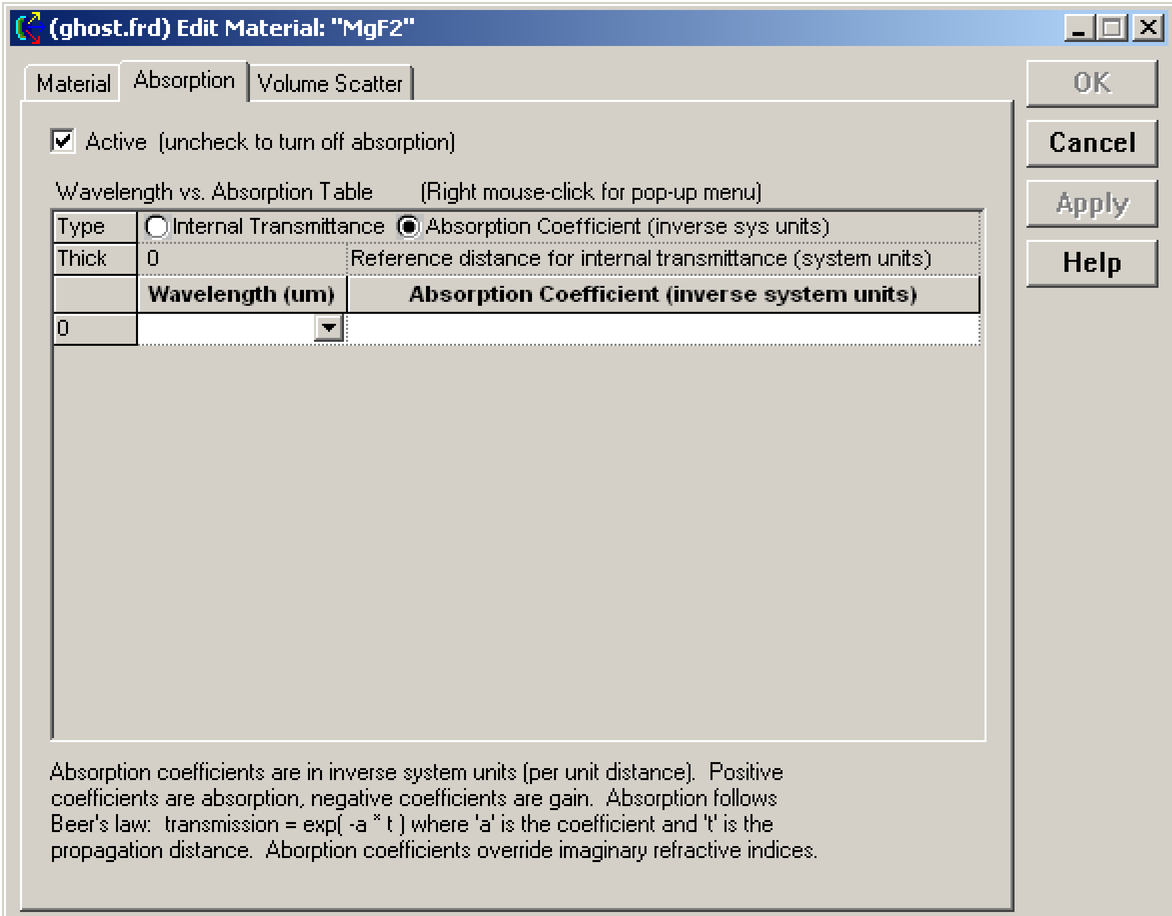
How Do I Get There? - Material - Absorption

This command is accessed through the Tree drop-down menu:

1. Menu



Dialog Box and Controls - Material - Absorption



Control	***Inputs / Description***	***Defaults***
Active	Enables or disables this absorption feature	Checked
Wavelength vs Absorption Table		
Type	Specifies absorption data as Internal Transmittance or Absorption Coefficient	Absorption Coefficient
Thick	Reference distance for Internal Transmittance data	0
Wavelength	Wavelength for corresponding absorption coefficient	blank
Absorption Coefficient	Absorption coefficient for corresponding wavelength	blank
OK	Accept absorption data and close dialog box	
Cancel	Discard changes and close dialog box	

Apply	Apply absorption data and keep dialog box open	
Help	Access this Help page	

Application Notes - Material - Absorption

- This absorption model follows Beer's Law; I/I_o=Exp[-□L]
- Absorption data is specified in inverse system units.

See Also - Material - Absorption

Edit/View Material
Volume Scatter

Chapter 9 - Coatings

Description - Coatings

The **Coatings** folder contains the default and optional user entered Coatings that are applied to every surface in FRED. Used in conjunction with **Raytrace Controls**, coatings specify the relative transmission, reflection, or absorption of every ray incident on the surface. The default coatings are 100% Absorb, 100% Reflect, %100 Transmit, Standard Coating, and Uncoated (Bare). The user can edit any one of these except Uncoated, which requires no additional entries.

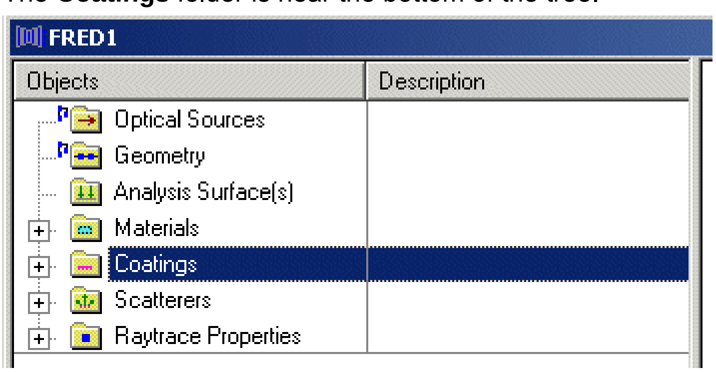
WARNING Changing the default Coatings can have unexpected consequences. It is recommended that the user create a new coating if different functionality is required.

The default Absorb, Reflect, Transmit, and Standard coatings are Sampled Coatings. Other coating options include Uncoated (Bare), Thin Film Layered, General Sampled Coating, and Polarizer/Waveplate Coatings.

NOTE While FRED allows the user to change the coating parameters for an existing coating, FRED does not allow the user to change a Coating type once it has been defined.

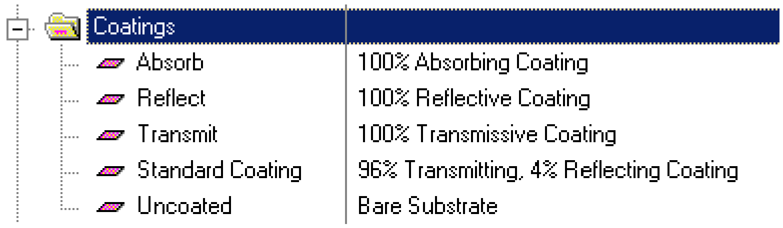
Visualization (example) - Coatings

The **Coatings** folder is near the bottom of the tree.



How Do I Get There? - Coatings

A left click on the ⊞ symbol next to the folder name will expand the tree.

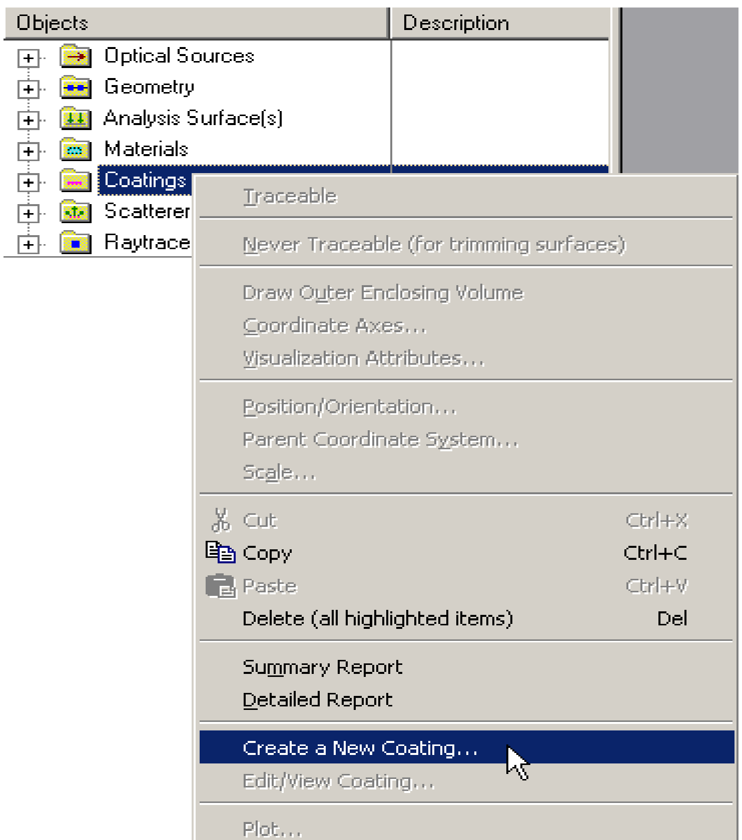


A left click on the ⊟ symbol next to an open folder will collapse the tree.

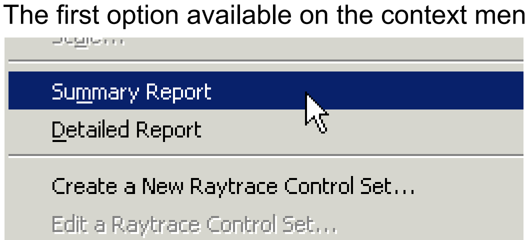
Existing Coatings can be edited and viewed with a right mouse click on the name and selecting the Edit/View option, or by simply double clicking on the coating name.

Dialog Box and Controls - Coatings

A right mouse click on the **Coatings** folder opens the following context menu.



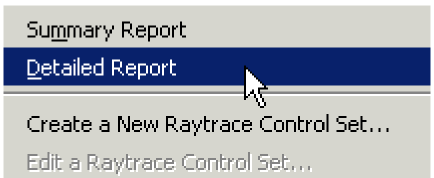
The first option available on the context menu is a '*Summary Report*.'



When this option is selected, FRED prints a list the coatings in the model and a brief description of each.

COATINGS	
Absorb	100% Absorbing Coating
Reflect	100% Reflective Coating
Transmit	100% Transmissive Coating
Standard Coating	96% Transmitting, 4% Reflecting Coating
Uncoated	Bare Substrate

The second option available on the right click menu is a '*Detailed Report*.'

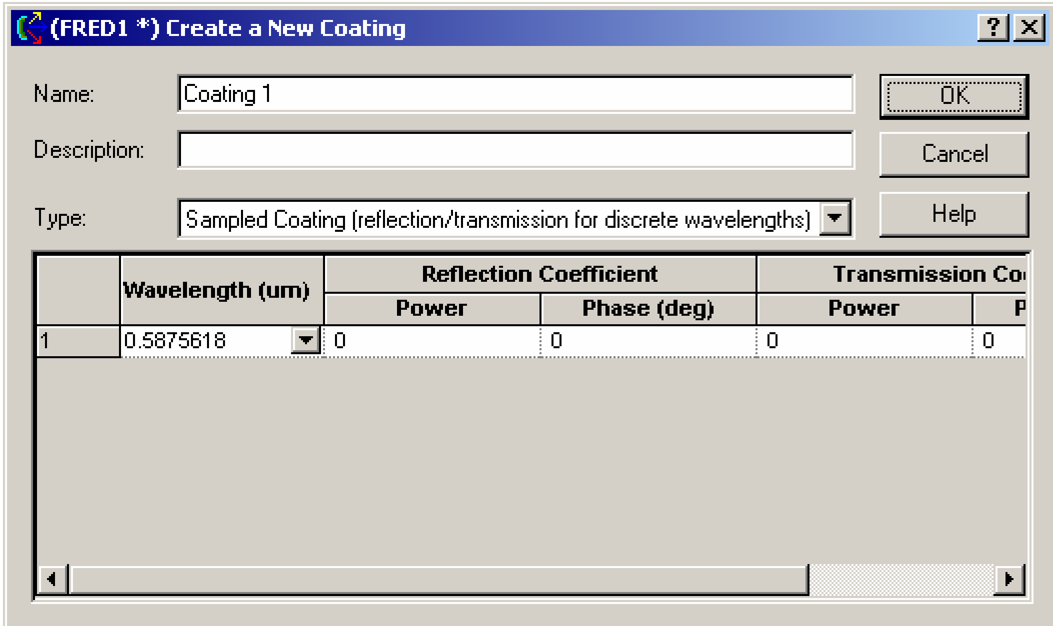


When this option is selected, FRED prints a detailed summary of all of the coating properties.

COATINGS					
Sampled Coatings					
Wavelength	Refl Power	Refl Phase (deg)	Trans Power	Trans Phase (deg)	Name
1	0	0	0	0	Absorb
1	1	0	0	0	Reflect
1	0	0	1	0	Transmit
1	0.04	0	0.96	0	Standard Coating
Thin Film Coatings					
none defined					
Bare Substrate Coatings					
Uncoated		Bare Substrate			
General Sampled Coatings					
none defined					

The third option available is to '*Create a New Coating...*'

Selecting this option opens the Coating Dialog. This is just one of four ways to access this dialog.



Control	Inputs	Defaults
Name	Enter a name for the Coating here.	Coating *n*
Description	Enter a short alpha-numeric description of the Coating here.	blank
Type	Select the coating type from the pull-down menu. Options are: *Sampled Coating* *Uncoated (Bare)* *Thin Film Layered* *General Sampled Coating* *Polarizer/Waveplate Coatings*	Sampled Coating
OK	Create a new Coating and close dialog box.	
Cancel	Discard new Coating and close dialog box.	
Help	Access this Help page.	

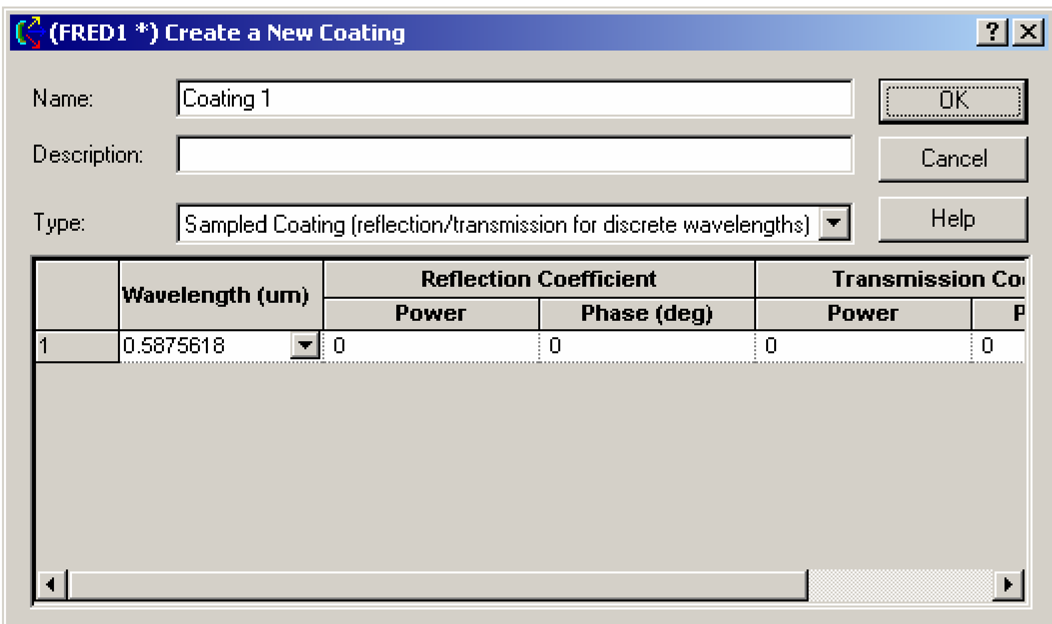
Application Notes - Coatings

- Coatings are applied after **Raytrace Controls**.
- With the exception of **Lens**, **Mirror**, and **Prism** elements, the Coating for every surface created in FRED is 100% Absorbing by default, which stops ray propagation.

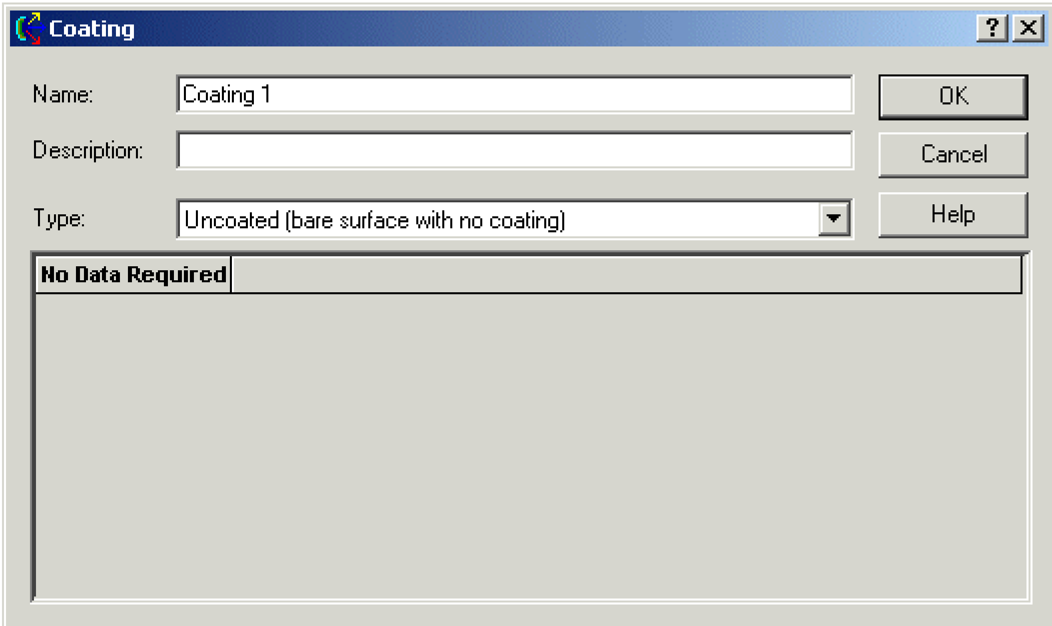
- o The default coatings for a lens that was imported from a catalog or entered as a element are 100% Transmitting coatings on the front and back surfaces and 100% Absorbing on the edges and bevels (if any).
  - o The surface coating types for a prism imported from a catalog or entered as a primitive will vary according to function, but the coatings will be selected from the default set.
  - o The default coatings for a Mirror element are 100% Reflective on the reflecting surface and 100% Absorbing on the back surface, edge, and bevels.
- Copies between FRED models will always transfer material and coating information, as appropriate.

Examples - Coatings

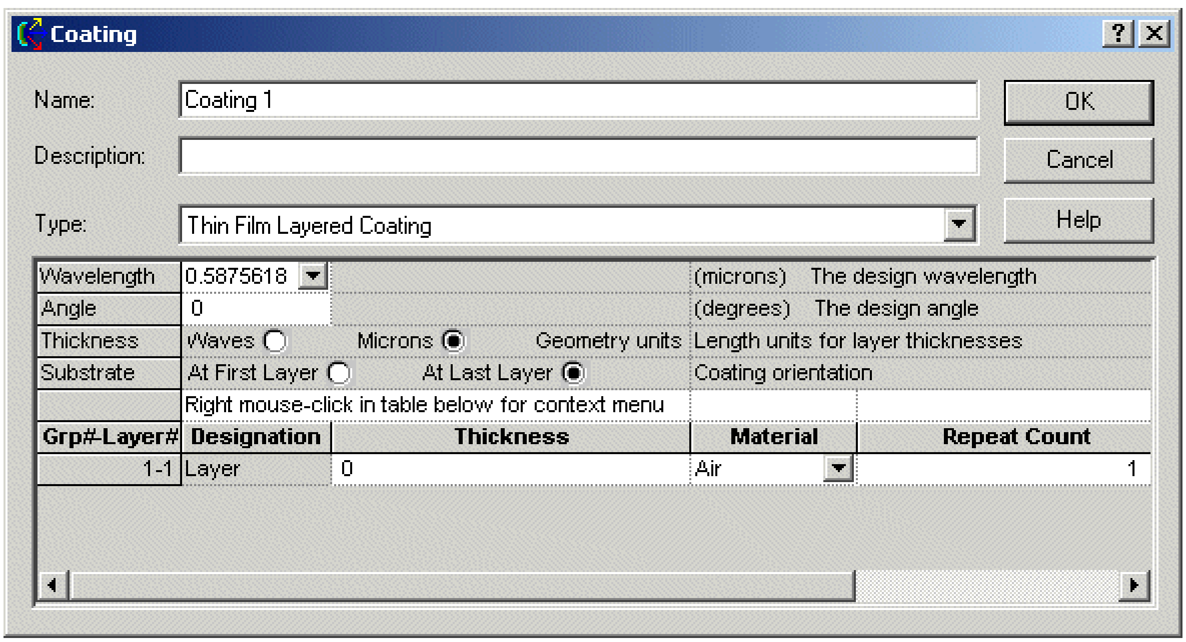
Coating Dialogs: Sampled Coating



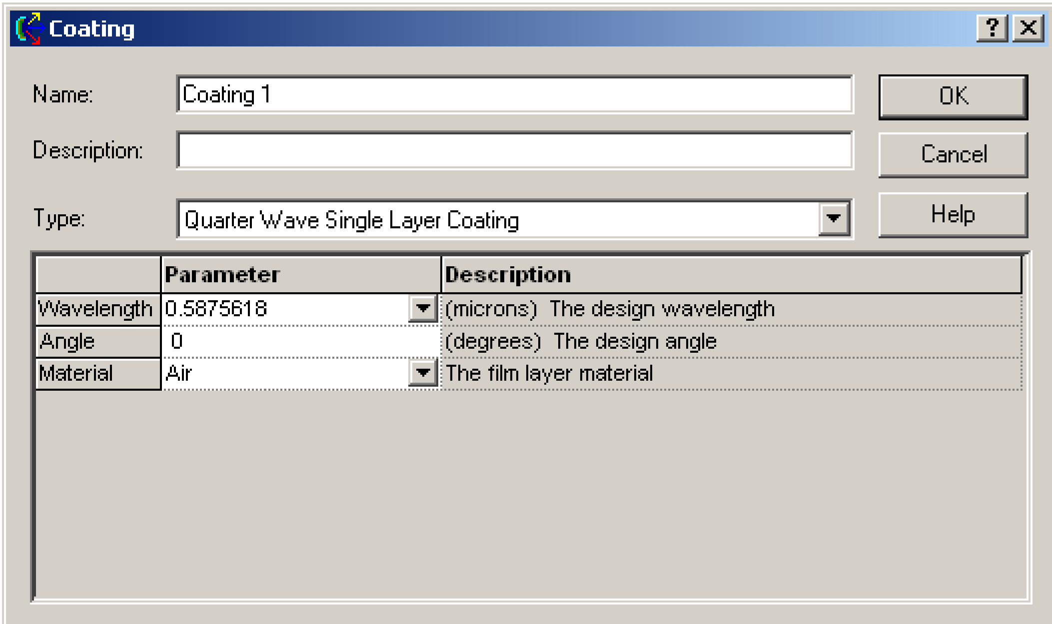
Coating Dialogs: Uncoated



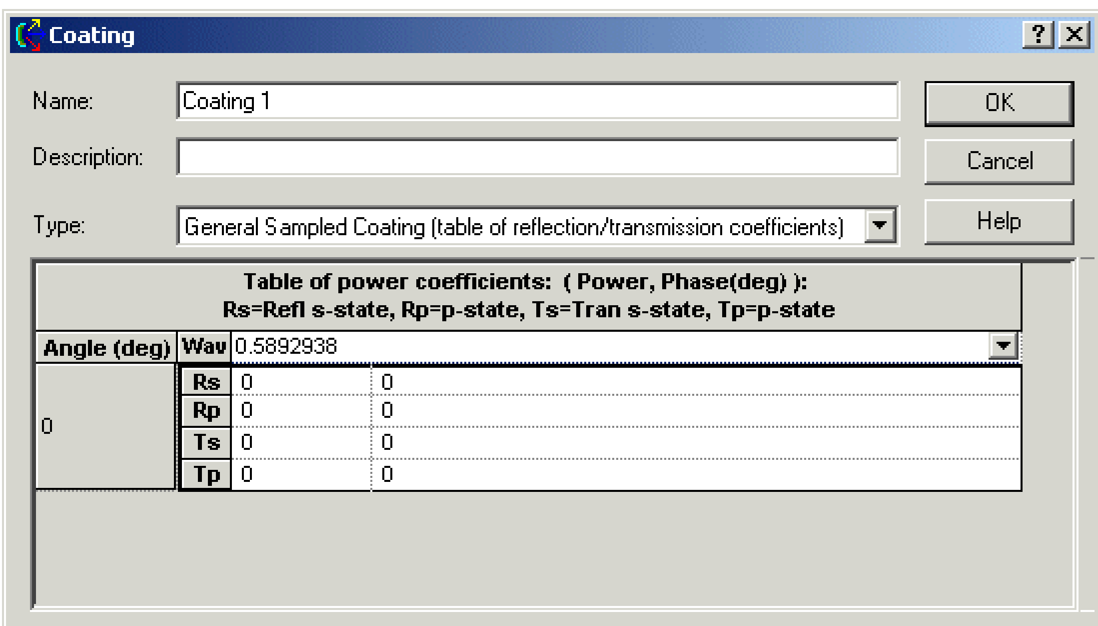
Coating Dialogs: Thin Film Layered Coating



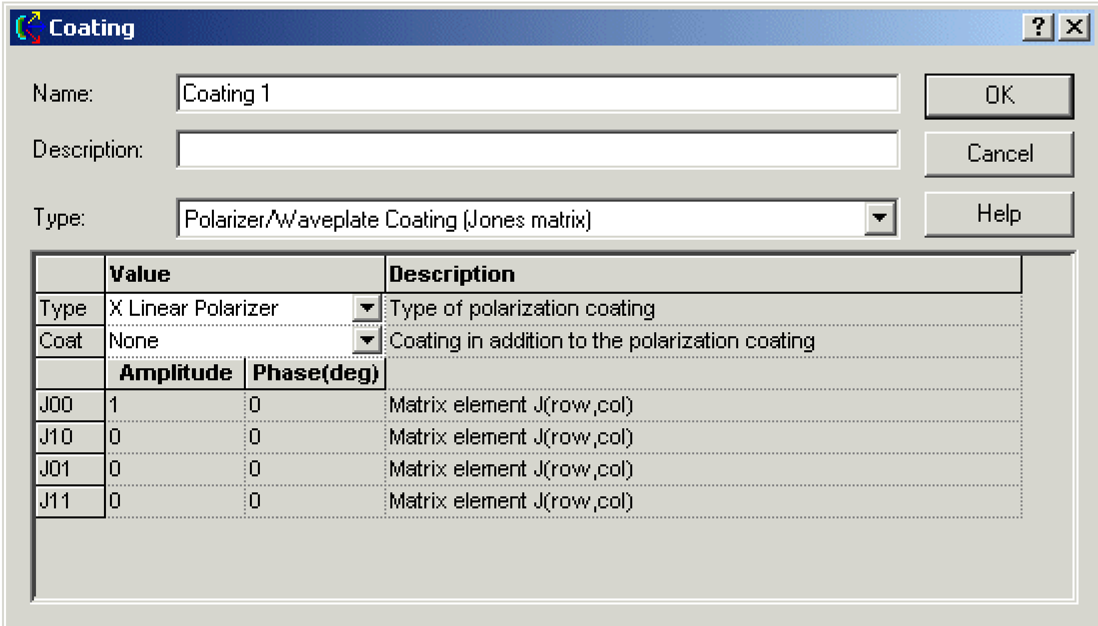
Coating Dialogs: Quarter Wave Single Layer Coating



Coating Dialogs: General Sampled Coating



Coating Dialogs: Polarizer/Waveplate Coating



See Also... - Coatings

The following links contain details about each of the coating models.

- Sampled Coating
- Uncoated
- Thin Film Layered Coating
- General Sampled Coating
- Polarizer/Waveplate Coating
- Quarter Wave Single Layer Coating

Applying Ray Controls and Coatings

Description - Applying Ray Controls and Coatings

This dialog page allows the user to select the surface coating and ray controls associated with a surface.

Any of the Coatings and Ray Controls defined in the current FRED document file may be assigned to the surface. In addition, new Coatings and Ray Controls can be added to the FRED document from this dialog. The process for adding a Coatings and Ray Controls are described in Creating New Coatings… and Creating New Ray Control… help files. In addition, the currently defined Coatings and Ray Controls can be edited from this dialog.

The coating determines power in the transmitted, reflected, total internal reflected (TIR), and absorbed rays based on the angle of incidence, polarization, and wavelength of the ray.

The ray controls determine whether transmitted, refracted, reflected, total internal reflected, split (due to Fresnel reflections), and/or scattered rays will be traced from the surface.

When a ray intersects this surface, FRED follows the this procedure:

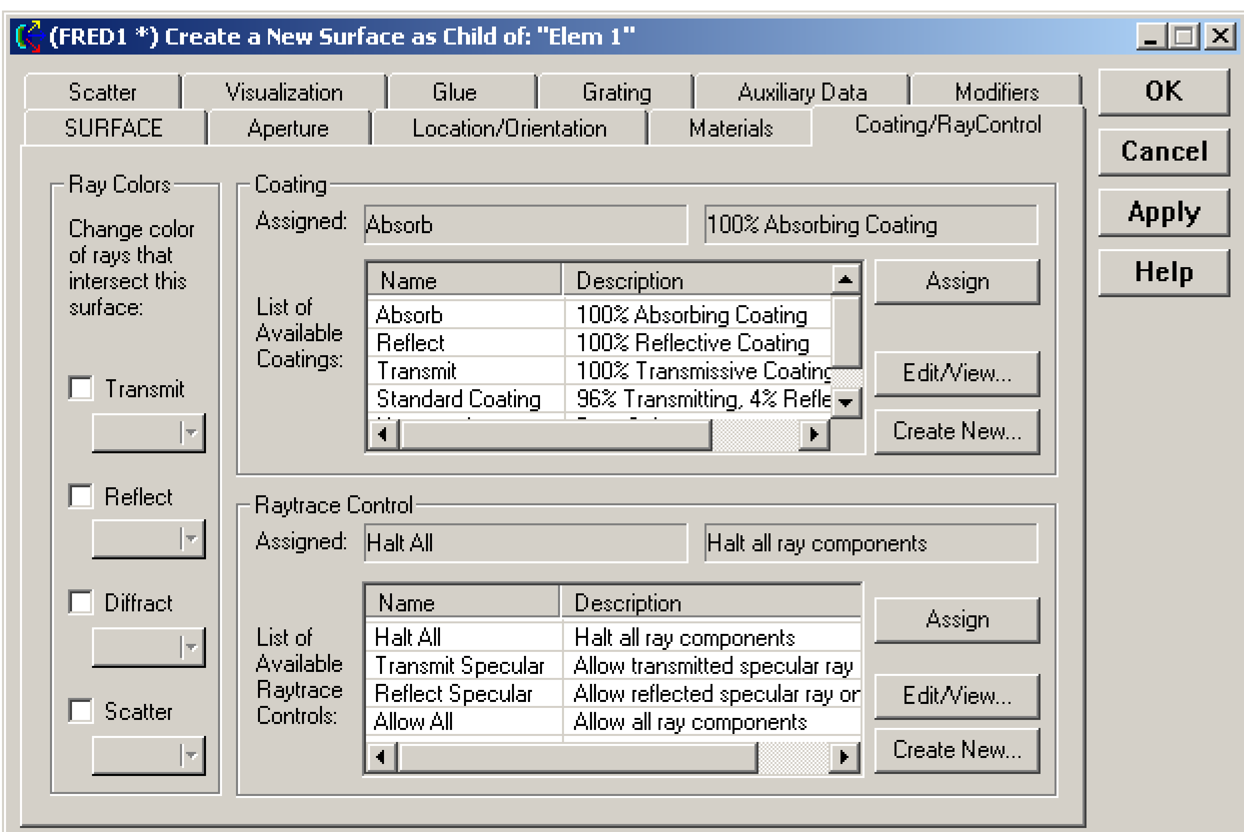
1. First check the Ray Controls to determine what rays can be traced from the surface.
2. Then check the coating to determine what rays can be generated at the coating
3. Then check to see if there are scatter properties assigned to this surface
4. Then determine where the scatter rays are directed.
5. Generate the rays that meet all four criteria, i.e. rays that can be ray traced, would be generated by the coating, meet the scatter properties, and have the correct direction
6. Assign power to the created rays according to the coating and scatter properties.

NOTE or TIP When a ray intersects a surface, the Ray Controls are checked first and then the Coating. Further, the Ray Control check is a "yes" or "no" check where as the Coating check requires a calculation. Therefore, the fastest way to stop rays during a raytrace is to use the Ray Controls.

How Do I Get There? - Applying Ray Controls and Coatings

This page is in the **Create New Surface…** and **Edit/View Surface…** dialogs.

Dialog Box and Controls - Applying Ray Controls and Coatings



Control	*Inputs*	*Defaults*
Ray Colors		
Transmit Reflect Diffract Scatter	Ray color can be changed based upon whether rays transmit, reflect, diffract, or scatter. Useful for tracking rays or identifying paths in the visualization window.	No change in color
Coating		
Coating	Assigns coating to surface. Coating properties establish what portion of the incident ray is reflected, transmitted, and absorbed. Coatings can be edited, viewed, or added to the list.	Absorb
Raytrace Control		
Raytrace Control	Assigns Raytrace controls to surface. Raytrace controls determine which possible rays will be traced from the surface after the intersection. Raytrace controls can be edited, viewed, or added to the list.	Halt All
OK	Accept Coating/RayControl changes and close dialog box.	
Close	Discard Coating/RayControl changes and close dialog box.	
Apply	Apply Coating/RayControl changes and keep dialog box open.	
Help	Access this Help page.	

Edit or Create a New General Sampled Coating

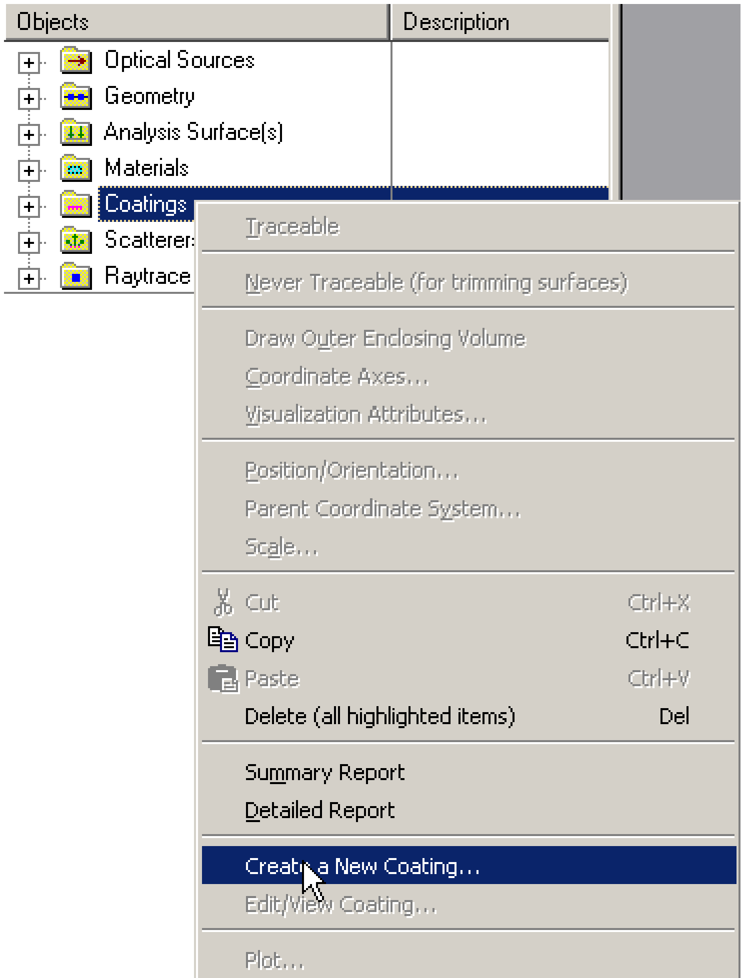
Description - Edit or Create a New General Sampled Coating

The General Sampled Coating type in FRED takes user-entered data for relative reflectivity, transmissivity, and phase change for S- and P-polarized light for one or more specified wavelengths and applies them to the surface. The General Sampled Coating type is similar to the Sampled Coating, but also allows for angular variation of the coating properties and includes polarization effects if the incident ray is polarized. The reflectivity and transmission coefficients cannot sum to more than one. It is not necessary to use the system wavelengths. If more than one wavelength is entered, FRED performs a linear interpolation to calculate the coefficients between adjacent wavelengths. If the system wavelength is outside the range specified in the coating dialog, then the coefficients are equal to those of the next highest or lowest wavelength in the range, as appropriate.

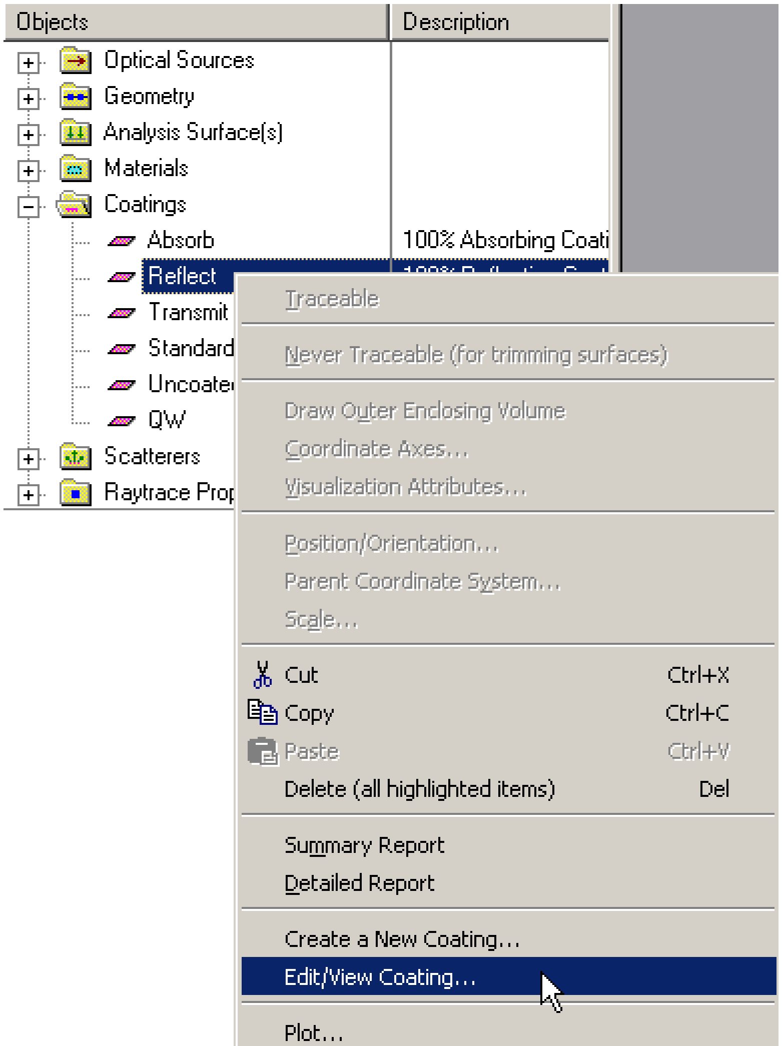
How Do I Get There? - Edit or Create a New General Sampled Coating

There are four ways to open a Coating dialog.

1. Right mouse click on the Coatings folder to open a context menu and select the option '*Create a New Coating…*'.

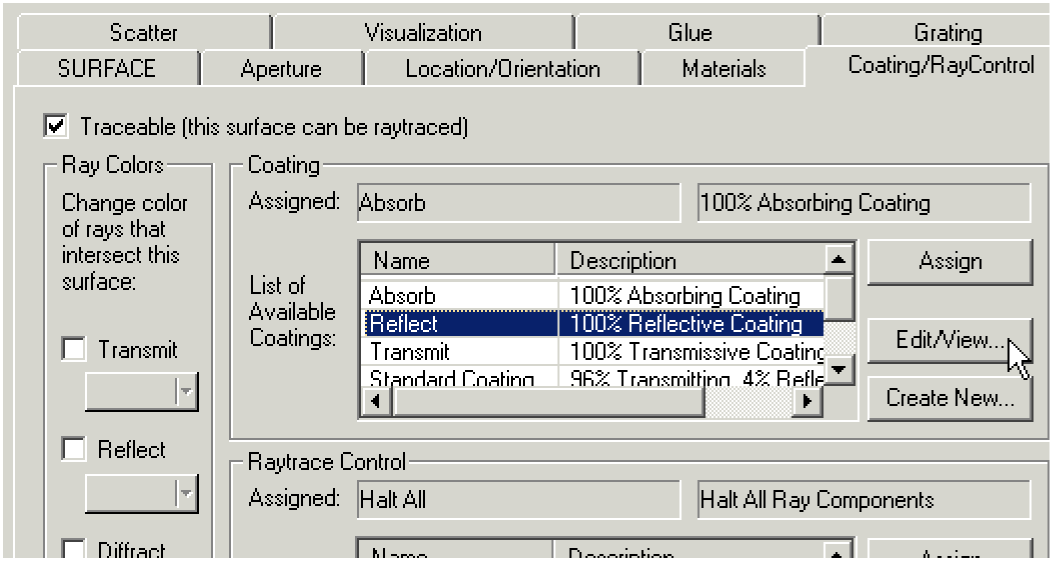


2. Expand the Coatings folder and right mouse click on a specific coating open pop-up context menu and select the option '*Edit/View Coating…*'.

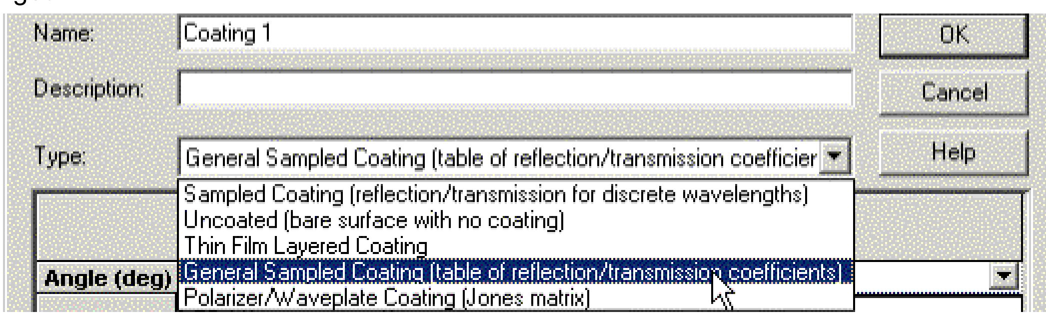


3. Expand the Coatings and, using the left mouse button, double click on the coating name.

4. From the Coating/RayControl tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.

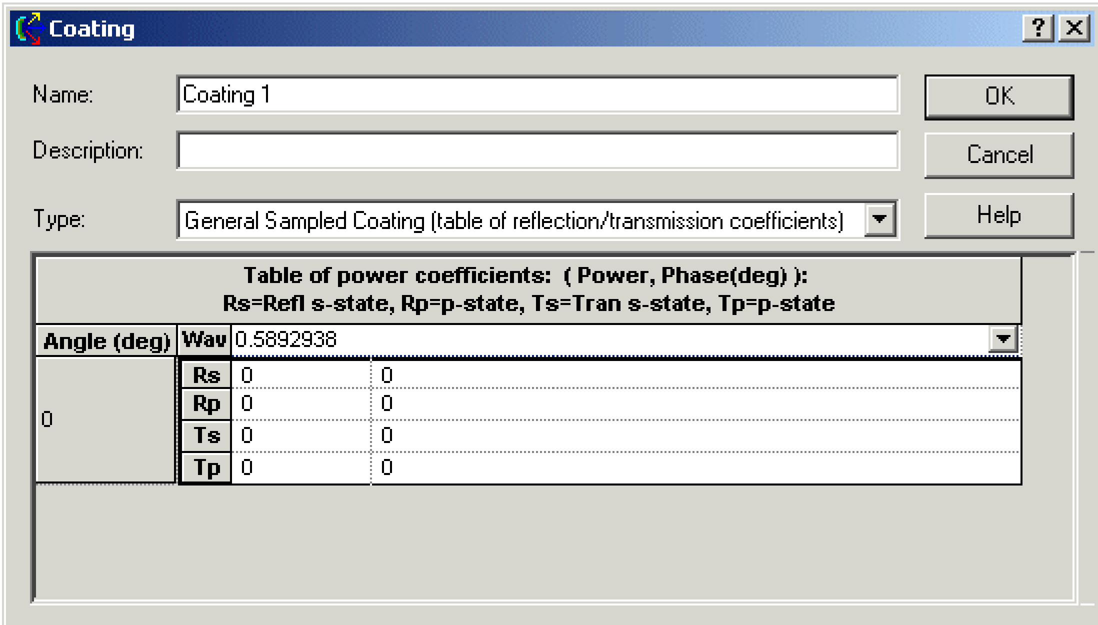


Once the Coating dialog has been opened, the General Sampled Coating type can be selected from the list of options on the pull-down menu only if it is a new coating. Otherwise the Coating Type entry is grayed out (non-selectable) and only the coefficients can be changed.



Dialog Box and Controls - Edit or Create a New General Sampled Coating

The General Sampled Coating dialog is shown below.



Control	Inputs	Defaults
Name	Enter the name of the Coating here	Coating *n*
Description	Enter a short alpha-numeric description of the Coating here	None
OK	Click on this button to accept changes and to close the dialog	None
Cancel	Click on the button to close the dialog. You will lose any changes.	None
Help	Get dialog help	None
Type	Select the General Sampled Coating type from the pull-down menu.	Sampled Coating
Wav	Enter coating wavelength(s) in microns	0.589
Rs	Enter the coefficient Rs for the relative reflected power of s-polarized light in column 1 and the phase change on reflection in degrees in column 2	0, 0
Rp	Enter the coefficient Rp for the relative reflected power of p-polarized light in column 1 and the phase change on reflection in degrees in column 2	0, 0

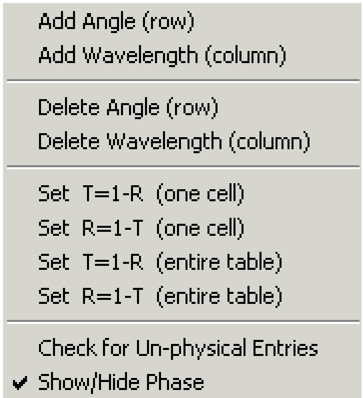
Ts	Enter the coefficient Ts for the relative transmitted power of s-polarized light in column 1 and the phase change on transmission in degrees in column 2	0, 0
Tp	Enter the coefficient Tp for the relative transmitted power of p-polarized light in column 1 and the phase change on transmission in degrees in column 2	0, 0

Application Notes - Edit or Create a New General Sampled Coating

- Polarized rays
  - To ensure energy conservation, the sum of the reflection and transmission coefficients for each polarization state cannot exceed 1:
    - Rs+Ts ≤ 1
    - Rp+Tp ≤ 1
    - FRED does not automatically check for conservation of energy. Improper entries (i.e., Rs = 1, Ts = 1) can result in a net power gain, which is not physical. If requested, FRED can run a simple check to verify energy conservation (see example below)
  - Every polarized ray is decomposed into orthogonal (S and P) polarization states relative to the local coordinate axes of the surface. The coefficients Rs and Ts apply to the S-polarized component. Likewise, the coefficients Rp and Tp apply only to the P-polarized component.
- Unpolarized rays
  - FRED uses the average of the S- and P-polarized reflection coefficients to determine the power of the reflected ray component
  - FRED uses the average of the S- and P-polarized transmission coefficients to determine the power of the transmitted ray component
  - The averaging process may result in the sum of the transmitted and reflected power being less than the incident power in the ray
  - The General Sampled Coating will not polarize a ray from an unpolarized source
- FRED linearly interpolates coefficients between angles and wavelengths.
- Coatings are used in conjunction with the Raytrace Controls to determine ray propagation.
  - To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection
  - To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission
  - Scattered rays are subject to the same limitations. Currently, an absorbing surface cannot generate scattered rays.
- Copies between FRED models will always transfer new material and coating information.
- Once defined, a coating type cannot be changed.

Examples - Edit or Create a New General Sampled Coating

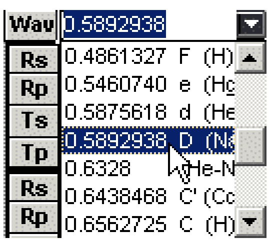
The following examples show how to edit input data and explain the uses of the various options available on the right click pop-up context menu.



-

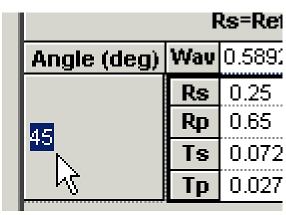
Example 1: Edit the Design Wavelength

Changing the coating wavelength is accomplished by either directly typing the new wavelength (in microns) into the wavelength cell, or by selecting a new wavelength the list of predefined values available using the pull down menu. The predefined wavelengths in FRED include a large number of atomic emission lines in addition to a number of common laser wavelengths. Use the scroll bar on the right side of the list to scan through the entire range.



Example 2: Edit the Design Angle

The design angle(s) can be changed by selecting the Angle box with a left mouse click and typing the new value.



Example 3: Adding/Deleting Angle Rows and Wavelength Columns

Right mouse click in the data entry region to open the context menu and select the appropriate option to add or delete an angle row or wavelength column. The order of entry is not important. New entries are always appended to the end of the list. At least one angle row and one wavelength column is required, but there is no upper limit on the number of angles or wavelengths. FRED will linearly interpolate between angles and wavelengths, as appropriate.

Add Angle (row)
Add Wavelength (column)

Delete Angle (row)
Delete Wavelength (column)

Table of power coefficients: (Power, Phase(deg)):
Rs=Refl s-state, Rp=p-state, Ts=Tran s-state, Tp=p-state

Angle (deg)	Wav	0.4046561 h (Hg)		Wav	0.7065188 r (He)	
40	Rs	0.96	0	Rs	0.96	0
	Rp	0.9	0	Rp	0.9	0
	Ts	0.04	0	Ts	0.04	0
	Tp	0.1	0	Tp	0.1	0
50	Rs	0.9	0	Rs	0.9	0
	Rp	0.8	0	Rp	0.8	0
	Ts	0.1	0	Ts	0.1	0
	Tp	0.2	0	Tp	.2	0

Based on the settings in the box above, a unit power linearly polarized ray at a wavelength of 0.55 microns and equal S and P components incident on the surface at an angle of 45 degrees will be split into a reflected and transmitted component. Relative to the power in the incident ray, the reflected component will have a relative power equal to 0.93*S + 0.85*P = 0.89. The transmitted component will have a relative power equal to 0.07*S + 0.15*P = 0.11, as shown below.

Ray Count	Incoherent Power	Name
1	0.11	.Subassembly 1.detector.transmitted
1	0.89	.Subassembly 1.detector.reflected
2	1	TOTALS

Example 4: Autofilling data

FRED can automatically fill transmission or reflection coefficient data when one of the following options is selected from the right click pop-up menu.

Set T=1-R (one cell)
Set R=1-T (one cell)
Set T=1-R (entire table)
Set R=1-T (entire table)

A single cell refers to a single wavelength and a single angle, as shown below.

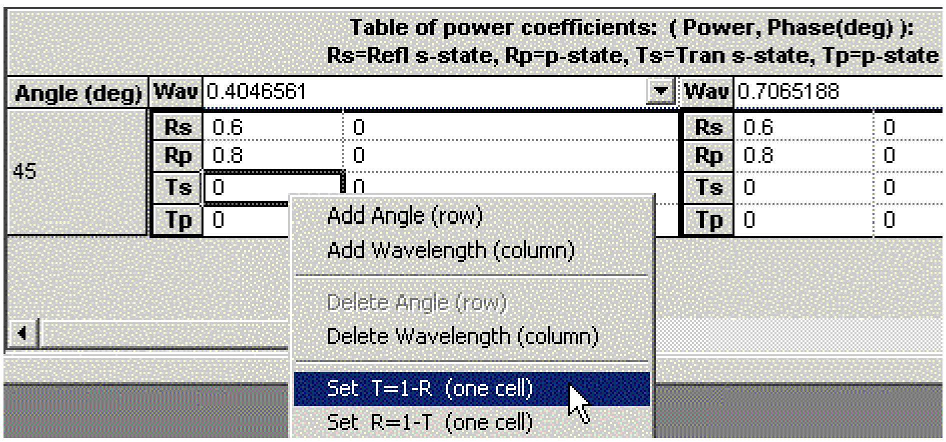
Angle (deg)	Wav	0.4046561 h (Hg)	
40	Rs	0.96	0
	Rp	0.9	0
	Ts	0.04	0
	Tp	0.1	0

The entire table refers to all wavelengths and all angles.

Table of power coefficients: (Power, Phase(deg)): Rs=Refl s-state, Rp=p-state, Ts=Tran s-state, Tp=p-state						
Angle (deg)	Wav	0.4046561 h (Hg)		Wav	0.7065188 r (He)	
40	Rs	0.96	0	Rs	0.96	0
	Rp	0.9	0	Rp	0.9	0
	Ts	0.04	0	Ts	0.04	0
	Tp	0.1	0	Tp	0.1	0
50	Rs	0.9	0	Rs	0.9	0
	Rp	0.8	0	Rp	0.8	0
	Ts	0.1	0	Ts	0.1	0
	Tp	0.2	0	Tp	.2	0

The rules for the autofill is based on the following: For any single cell, Rs+Ts=1, Rp+Tp=1.

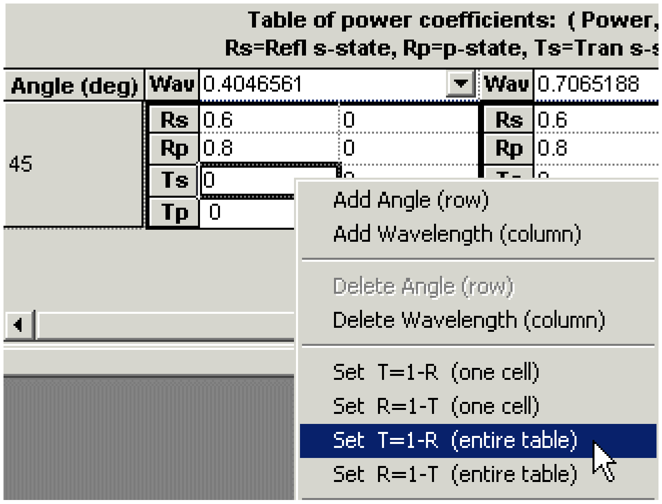
Autofilling T for a single cell:



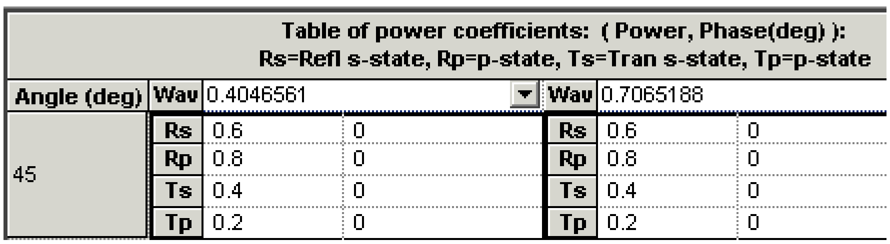
The result is

Table of power coefficients: (Power, Phase(deg)): Rs=Refl s-state, Rp=p-state, Ts=Tran s-state, Tp=p-state						
Angle (deg)	Wav	0.4046561		Wav	0.7065188	
45	Rs	0.6	0	Rs	0.6	0
	Rp	0.8	0	Rp	0.8	0
	Ts	0.4	0	Ts	0	0
	Tp	0.2	0	Tp	0	0

Autofilling T for the entire table:

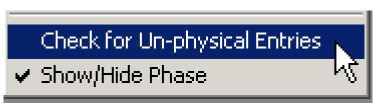


The result is



Example 5: Check for Un-physical Entries

When this option is selected from the right click pop-up menu, FRED sums the transmission and reflection coefficients to check to see if Rs+Ts≤1 and Rp+Tp≤1. FRED returns a dialog with the result, but does not alter the entries.



Example 6: Show/Hide Phase

Clearing the check next to this option on the right click pop-up menu hides the phase column in each cell.

See Also… - Edit or Create a New Sampled Coating

The following links contain details about each of the remaining coating models.

Sampled Coating

Uncoated

Thin Film Layered Coating

Polarizer/Waveplate Coating

For details about Raytrace Controls, select the following link.

Raytrace Controls

Edit or Create a New Thin Film Layered Coating

Description - Edit or Create a New Thin Film Layered Coating

Use the Thin Film Layered Coating in FRED to create a single or multilayer thin film coating that can be attached to any substrate material. FRED uses the characteristic matrix of the coating to determine reflection and transmission properties as a function of wavelength and angle of incidence. Only those materials contained in the Materials folder on the tree can be used to define the multilayer coating. Coating thickness can be entered is waves or physical thickness. There is no limit to the number of layers that can be contained in a coating stack.

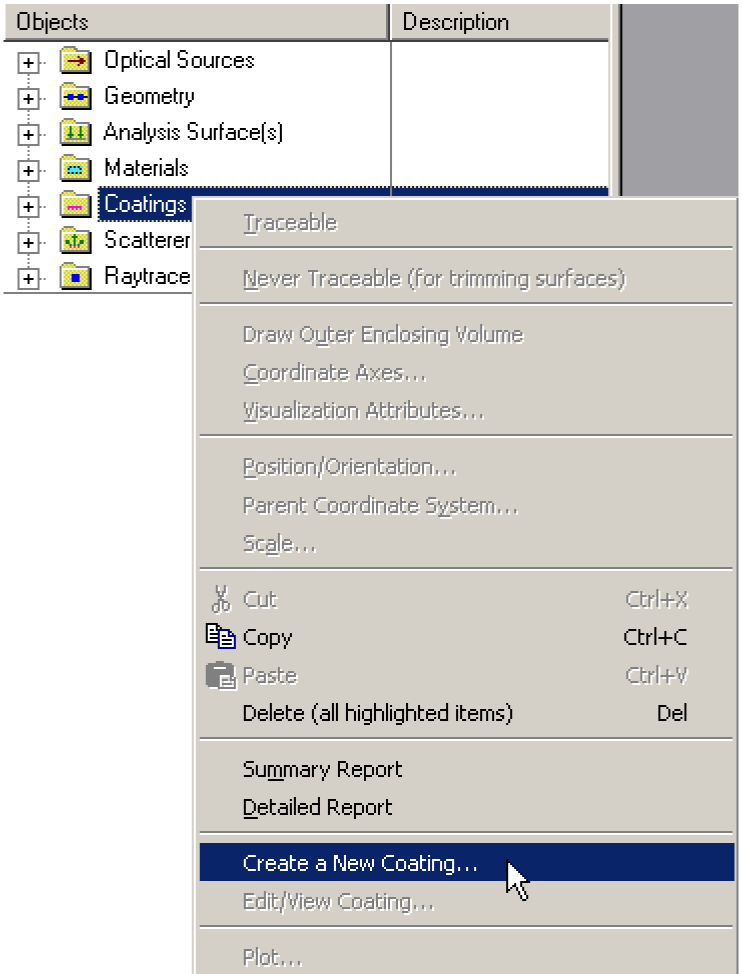
Visualization (example) - Edit or Create a New Thin Film Layered Coating

None.

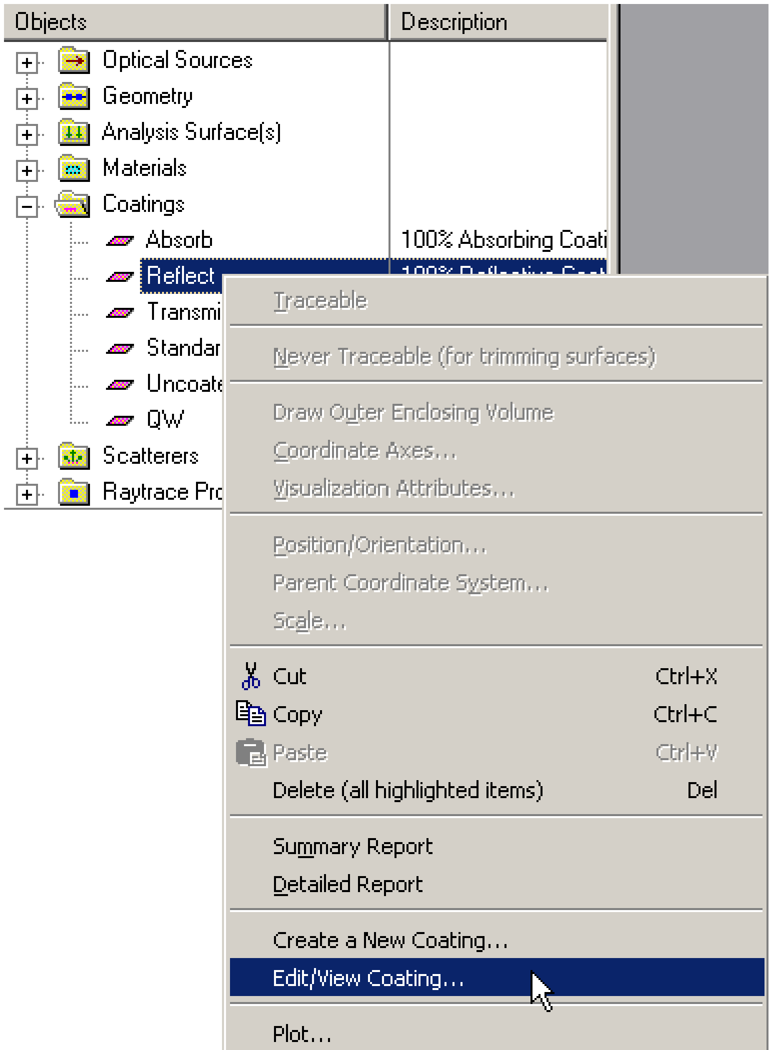
How Do I Get There? - Edit or Create a New Thin Film Layered Coating

There are four ways to open a Coating dialog.

1. Right mouse click on the Coatings folder to open a context menu and select the option '*Create a New Coating…*'.

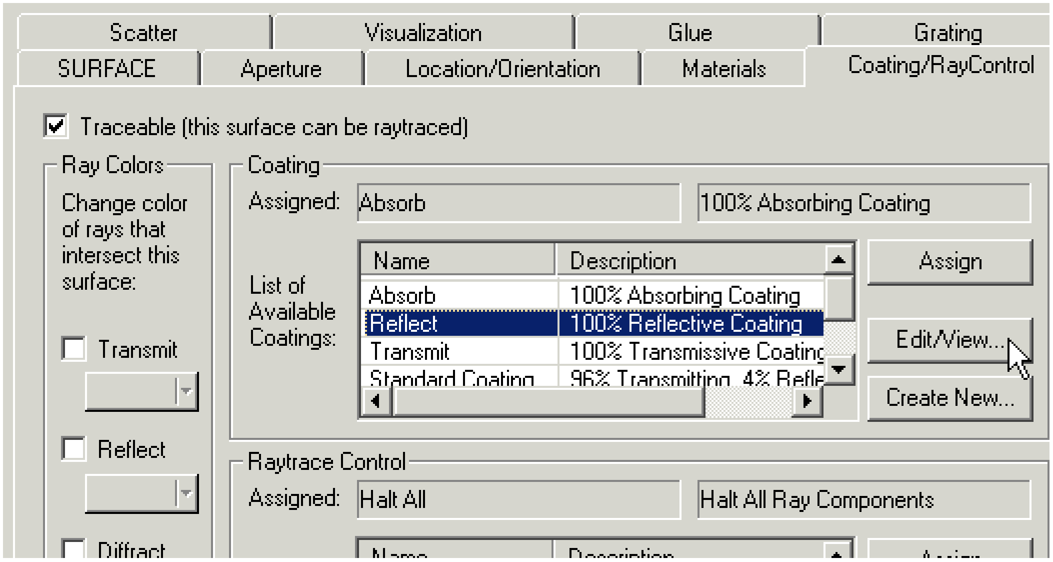


2. Expand the Coatings folder and right mouse click on a specific coating open the pop-up context menu and select the option '*Edit/View Coating…*'.

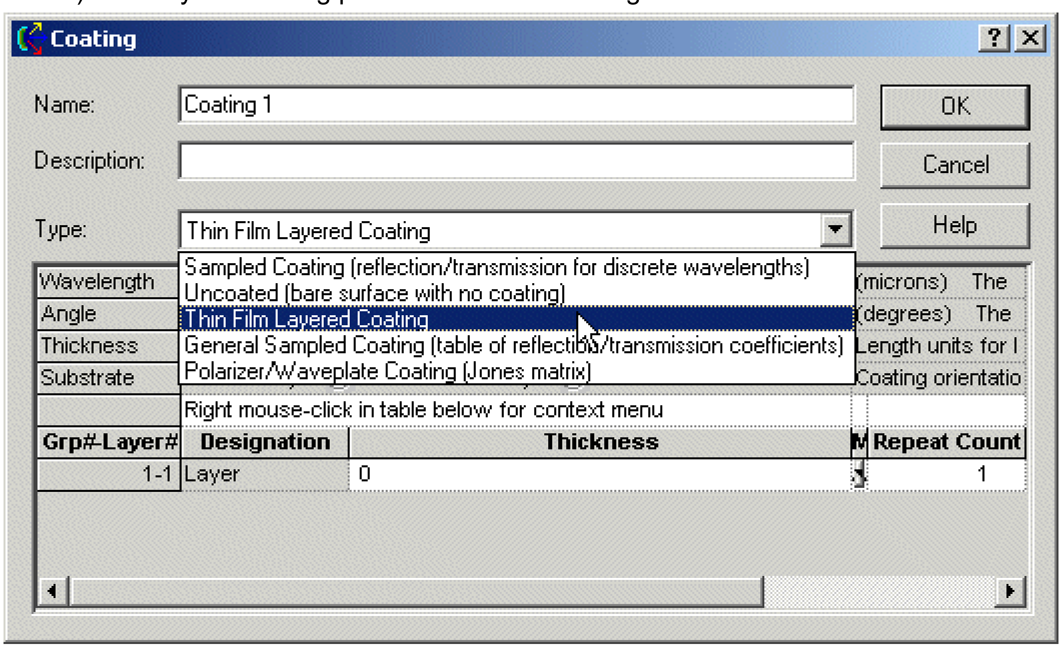


3. Expand the Coatings and, using the left mouse button, double click on the coating name.

4. From the Coating/RayControl tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.

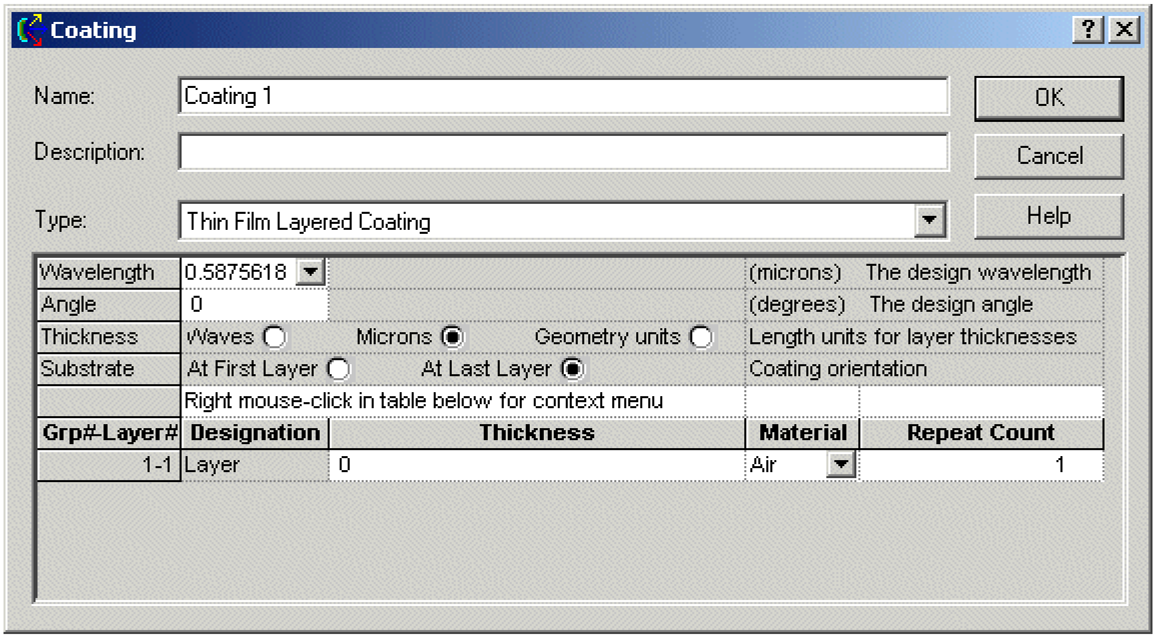


Once the Coating dialog has been opened, the Thin Film Layered Coating option can be selected if it is a new coating. Otherwise, the Coating Type entry is grayed out (non-selectable) and only the coating parameters can be changed.



Dialog Box and Controls - Edit or Create a New Thin Film Layered Coating

The Thin Film Layered Coating dialog is shown below.



Control	Inputs	Defaults
Name	Enter the name of the Coating here.	Coating *n*
Description	Enter a short alpha-numeric description of the Coating here.	None
OK	Click on this button to accept changes and to close the dialog.	None
Cancel	Click on the button to close the dialog. You will lose any changes.	None
Help	Get dialog help.	None
Type	Select the Thin Film Layered Coating type from the pull-down menu.	Sampled Coating
Wavelength	Enter the coating design wavelength in microns.	0.589
Angle	Enter the coating design angle in degrees.	0 (normal incidence)
Thickness	Enter the length units for layer thicknesses.	Microns
Substrate	Enter substrate location (top or bottom).	At Last Layer
Grp#-Layer#	Grp# refers to the coating group; multiple layers may be assigned to a single group.	1-1
Thickness	Enter the layer thickness in the selected units.	0
Material	Enter the coating material from the pull-down menu.	Air

Repeat Count	Number of times the layer or group is repeated.	1

Application Notes - Edit or Create a New Thin Film Layered Coating

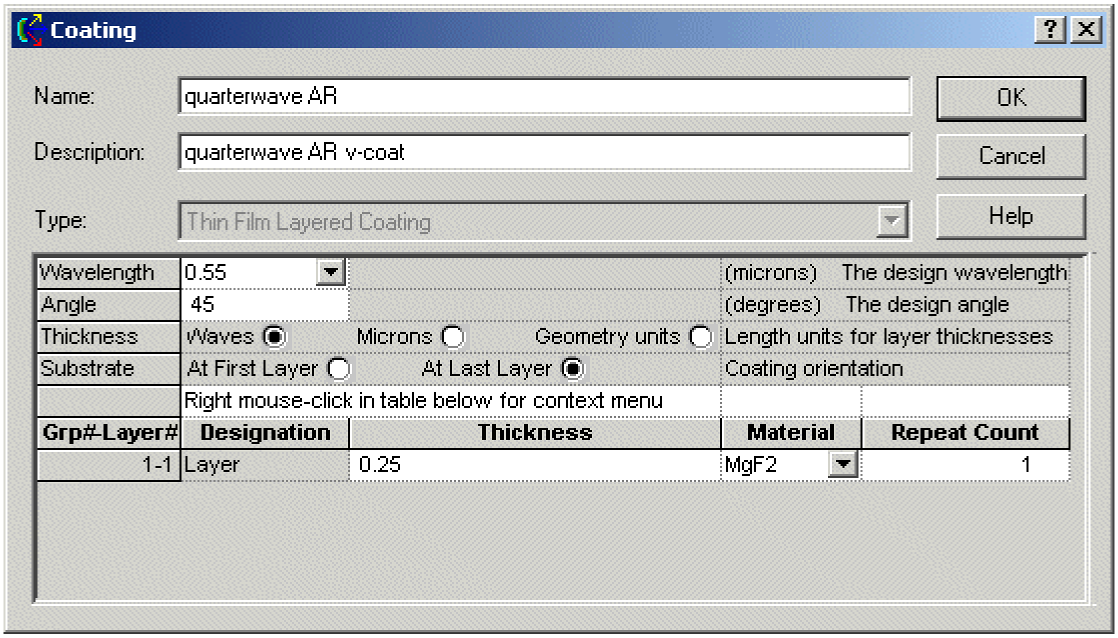
- Only the materials contained in the **Materials** folder can be used to define a coating. The material entry must be completed first.
- Coatings are used in conjunction with the **Raytrace Controls** to determine ray propagation.
    - To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection
    - To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission
    - Scattered rays are subject to the same limitations. Currently, an absorbing surface cannot generate scattered rays.
- Copies between FRED models will always transfer new material and coating information.
- Once defined, a coating type cannot be changed.

Examples - Edit or Create a New Thin Film Layered Coating

The following examples illustrate how to apply the dialog controls for some commonly used multilayer thin film designs.

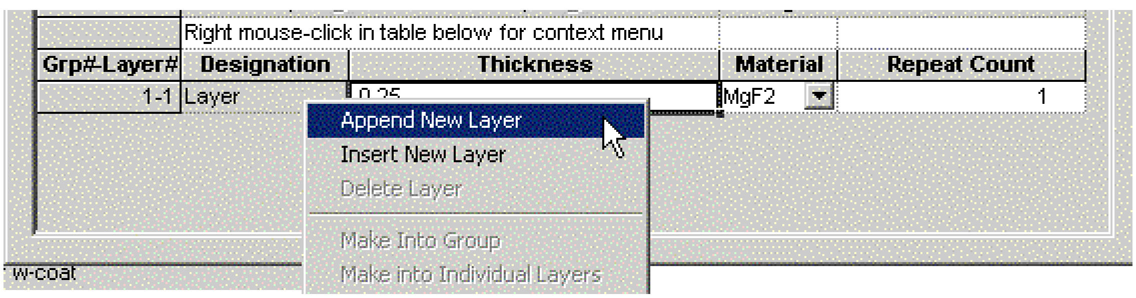
Example 1 – Quarter Wave AR coating

This example shows a single layer quarter wave thickness magnesium fluoride (n = 1.38) coating. It is sometimes referred to as V-coat because this describes the shape of the reflectance curve as a function of wavelength. For this example, minimum reflectance is achieved at a wavelength of 0.55 microns at a 45-degree angle of incidence. Note that the Wavelength, Angle, and Thickness settings are all used by FRED to calculate the physical thickness of the layer. The incident media is air and the substrate material is glass.

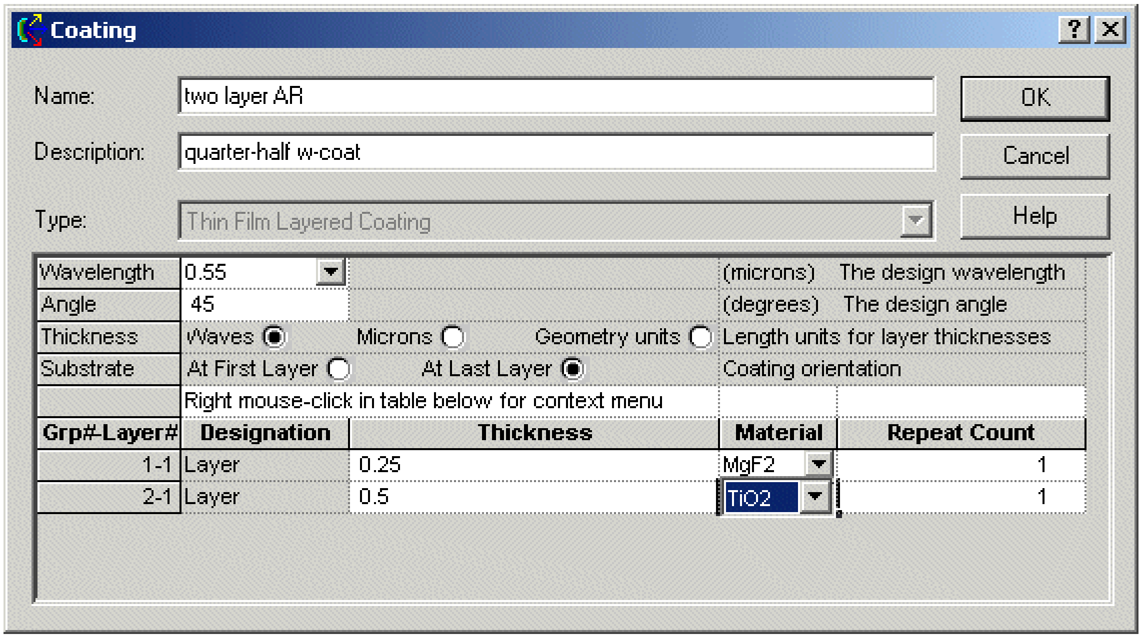


Example 2 – 2 layer AR coating

This example shows a coating with 2 thin film layers. Coating layers are appended, inserted, or deleted using the context menu that pops up with a right mouse click.



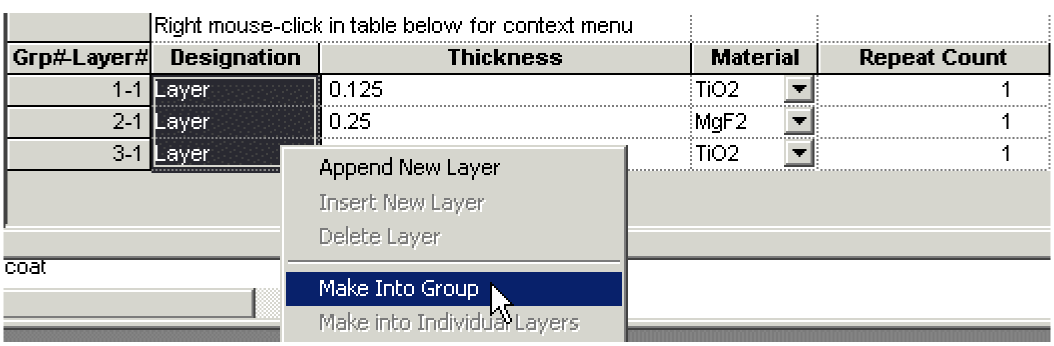
The second layer is a high index coating (Ti02, n = 2.2) one half-wave thick.



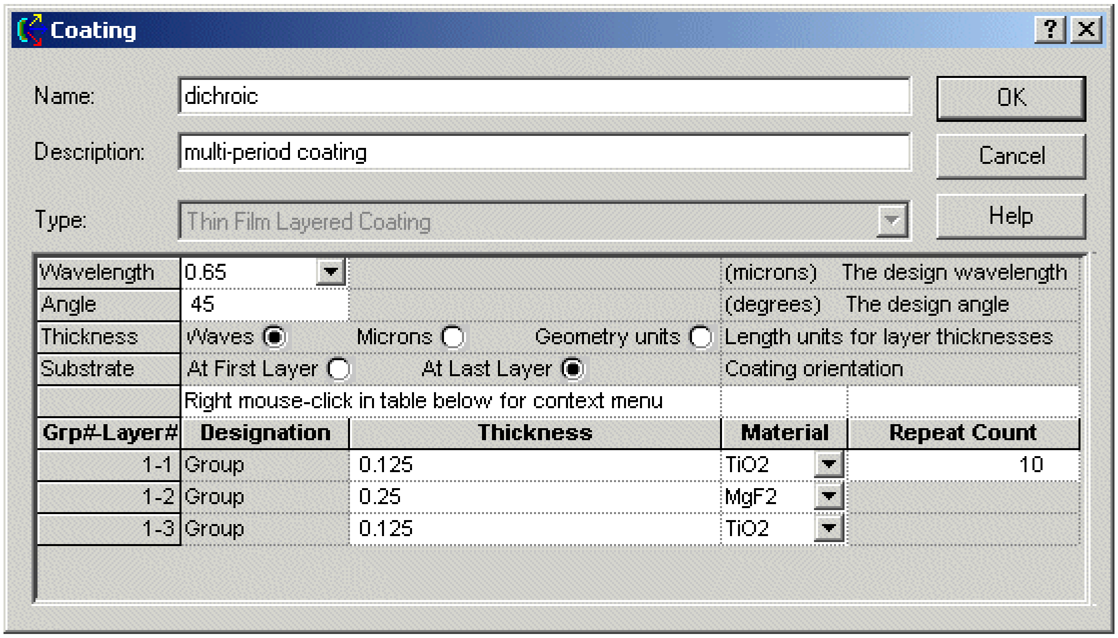
The incident media for this coating is air and the substrate is glass. The order of intersection is Air | MgF2 | Ti02 | Glass. Note that the Group number of the second layer has been incremented by one. FRED allows grouping and repetition of multiple layers, as shown in the next example.

Example 3 – Dichroic Filter

This example shows a 3 layer coating sequence that is repeated multiple times. To group a sequence of layers, select the first layer in the sequence with a left mouse click and, while holding down the mouse button, drag the pointer down to the last layer. In this case, all three layers are highlighted. Release the left mouse button and right click to pop-up the context menu. Select the option '*Make Into Group*, ' as shown below.



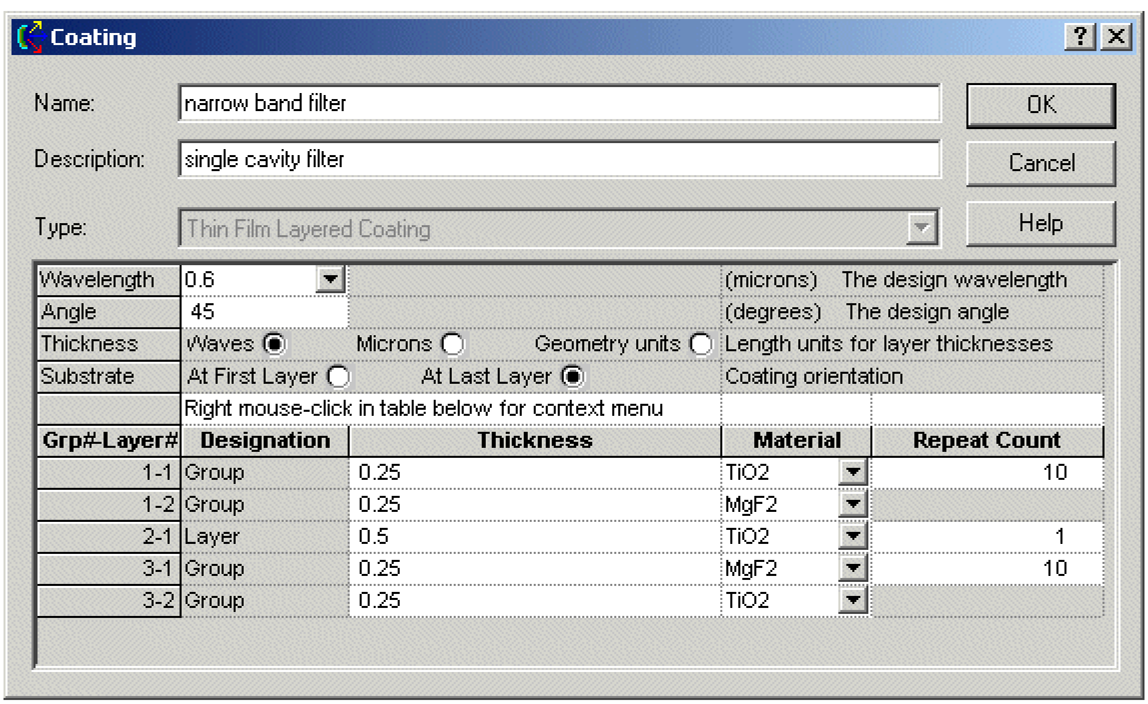
The resulting coating dialog looks like this.



The **Repeat Count** is the number of times this coating sequence is repeated. Note that the group number for all three layers is the same. A group can be undone by again dragging the mouse over all the layers in the group, opening the context menu with a right mouse click, and selecting the option '*Make into Individual Layers*'. The **Repeat Count** is automatically reset to 1 when a coating group is split into layers.

Example 4 – Narrowband Filter

A narrowband filter is constructed using long sequences of alternating high and low quarter wave layers separated by a half-wave high index layer, as shown below.



See Also… - Edit or Create a New Thin Film Layered Coating

The following links contain details about each of the remaining coating models.

Sampled Coating

Uncoated

General Sampled Coating

Polarizer/Waveplate Coating

For details about Raytrace Controls, select the following link.

Raytrace Controls

Uncoated (Bare) Surfaces

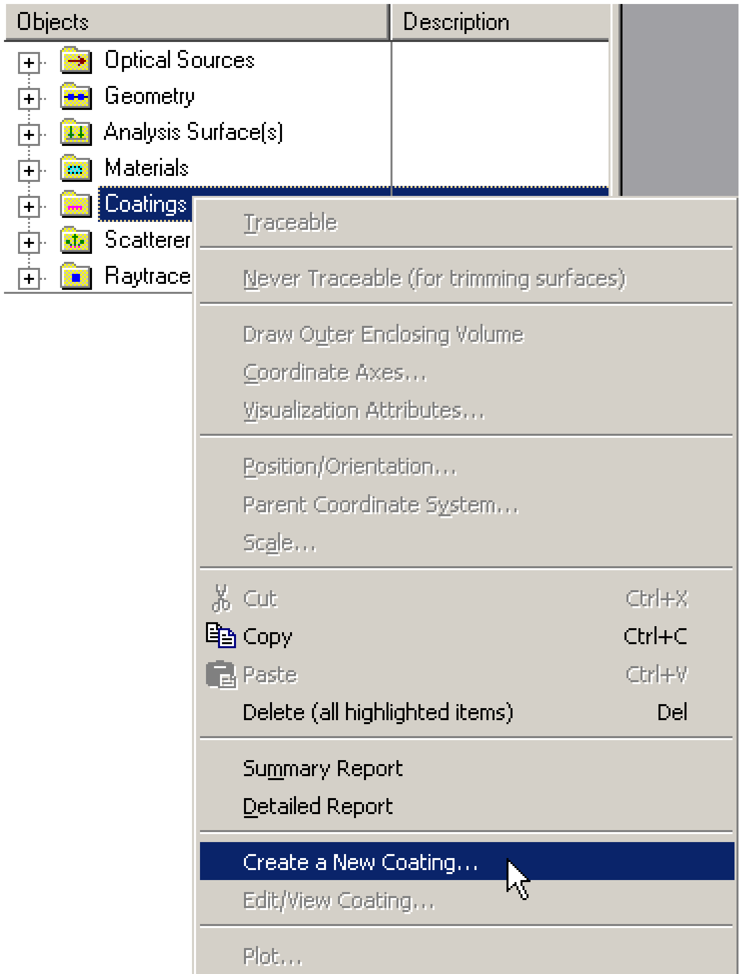
Description - Uncoated (Bare) Surfaces

The Uncoated (Bare) coating type in FRED has no user entries. When a ray intersects an Uncoated surface, FRED calculates the Fresnel reflection and transmission coefficients based on the refractive index change, angle of incidence, and wavelength. Refractive indices can be real (dielectrics) or imaginary (metals).

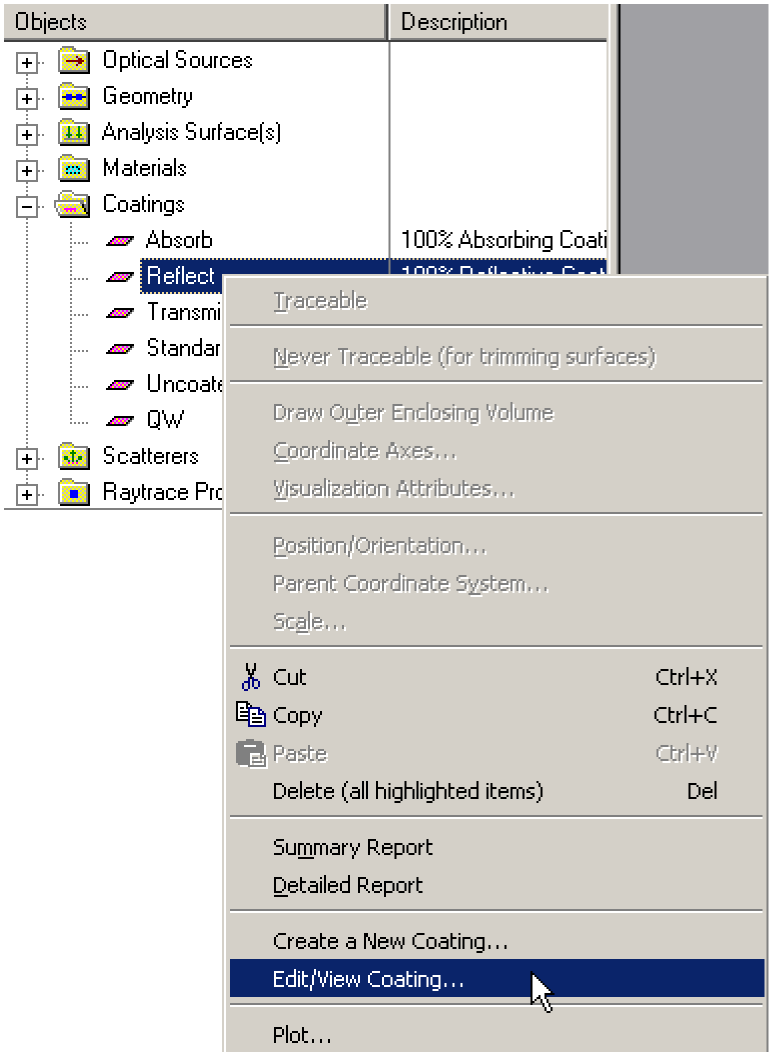
How Do I Get There? - Uncoated (Bare) Surfaces

There are four ways to open a Coating dialog.

1. Right mouse click on the Coatings folder to open a the pop-up menu and select the option '*Create a New Coating…*'.

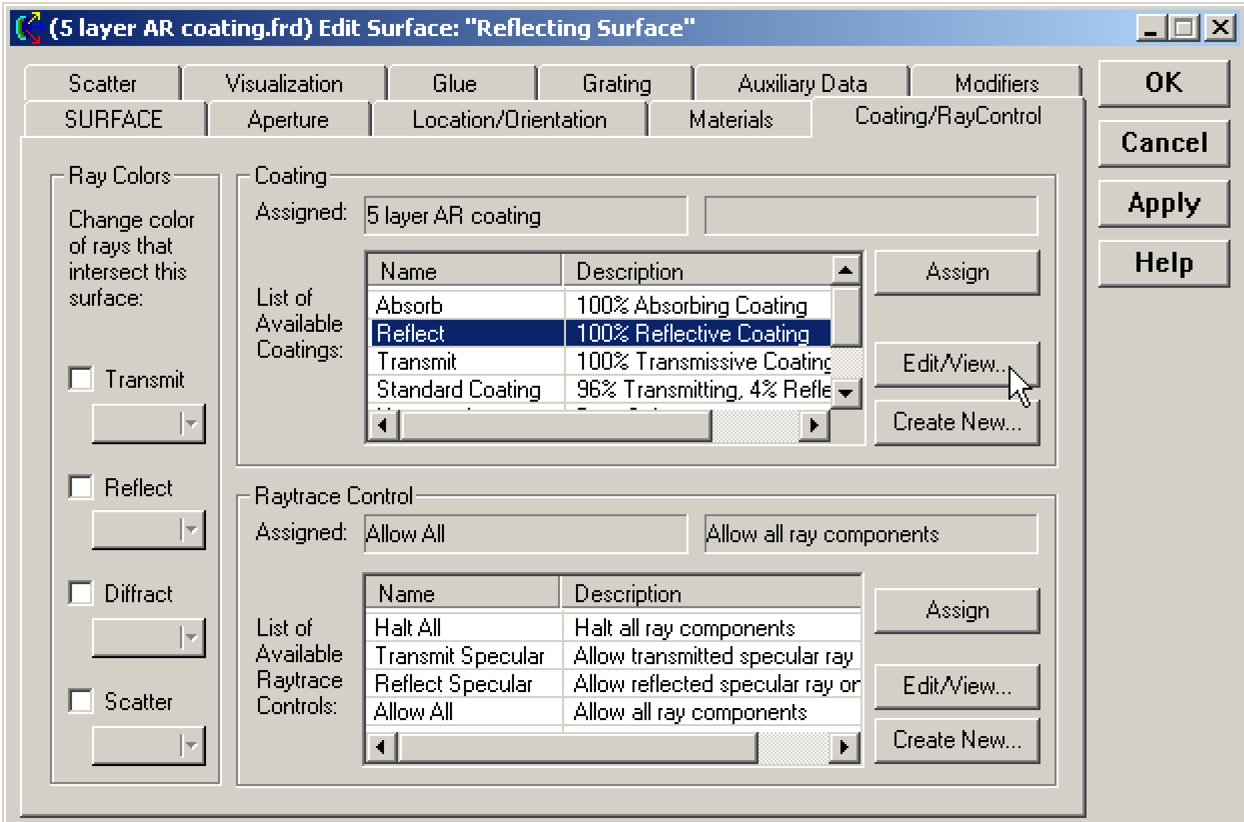


2. Expand the Coatings folder and right mouse click on a specific coating to open a pop-up context menu and select the option '*Edit/View Coating…*'.

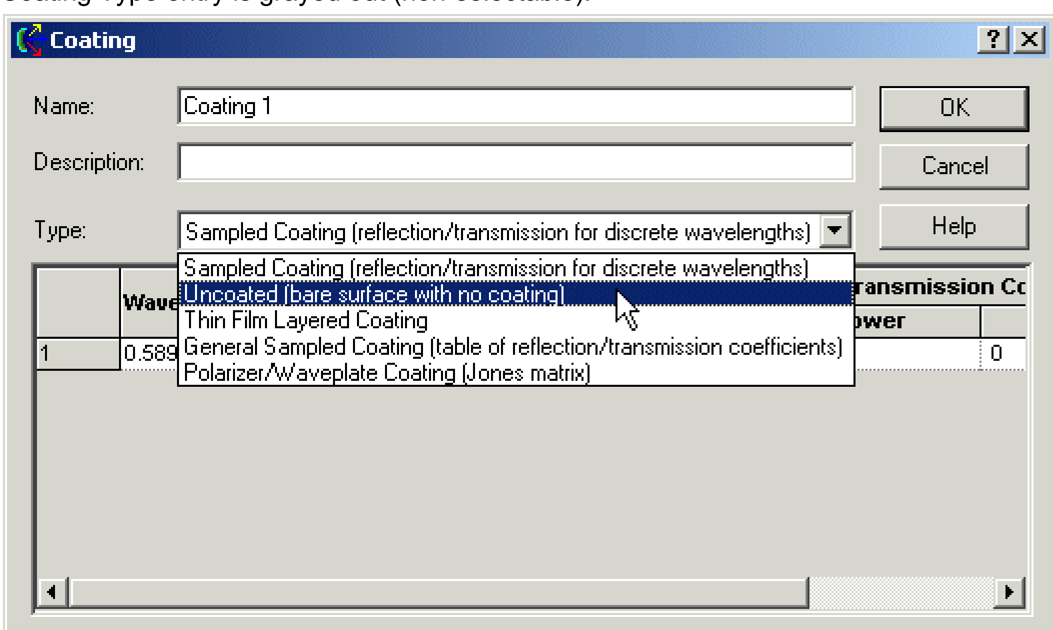


3. Expand the Coatings folder and, using the left mouse button, double click on the coating name.

4. From the Coating/RayControl tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.

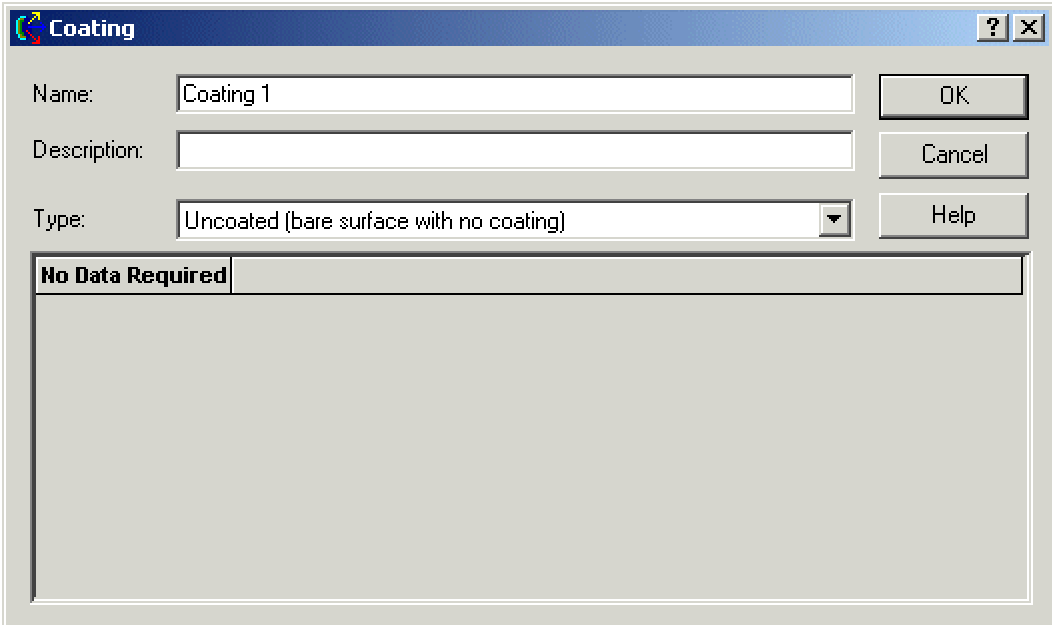


Once the Coating dialog has been opened, the Uncoated or Bare coating type can be selected from the list of options on the pull-down menu only if it is a new coating. Otherwise the Coating Type entry is grayed out (non-selectable).



Dialog Box and Controls - Uncoated (Bare) Surfaces

The Uncoated (Bare) coating dialog is shown below.



Control	Inputs	Defaults
Name	Enter the name of the Coating here.	Coating *n*
Description	Enter a short alpha-numeric description of the Coating here.	None
OK	Click on this button to accept changes and to close the dialog.	None
Cancel	Click on the button to close the dialog. You will lose any changes.	None
Help	Get dialog help.	None
Type	Select the Uncoated type from the pull-down menu.	Sampled Coating

Application Notes - Uncoated (Bare) Surfaces

- Coatings are use in conjunction with the Raytrace Controls to determine ray propagation.
  - To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection
  - To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission

- Scattered rays are subject to the same limitations. Currently, an absorbing surface cannot generate scattered rays.

- Copies between FRED models will always transfer new material and coating information.
- Once defined, a coating type cannot be changed.

See Also… - Uncoated (Bare) Surfaces

The following links contain details about each of the remaining coating models.

Sampled Coating

Thin Film Layered Coating

General Sampled Coating

Polarizer/Waveplate Coating

For details about Raytrace Controls, select the following link.

Raytrace Controls

Edit or Create a New Polarizer/Waveplate

Description - Edit or Create a New Polarizer/Waveplate

The Polarizer/Waveplate coating type in FRED is used to create ideal polarizing optics. The coating type consists of a number of pre-defined polarizers and waveplates as well as one user-definable polarizing coating. The coatings are defined using Jones matrices and apply only to transmitted rays. This coating type can be kept as a standalone coating or it can be combined with any other existing coating that is contained in the model.

How Do I Get There? - Edit or Create a New Polarizer/Waveplate

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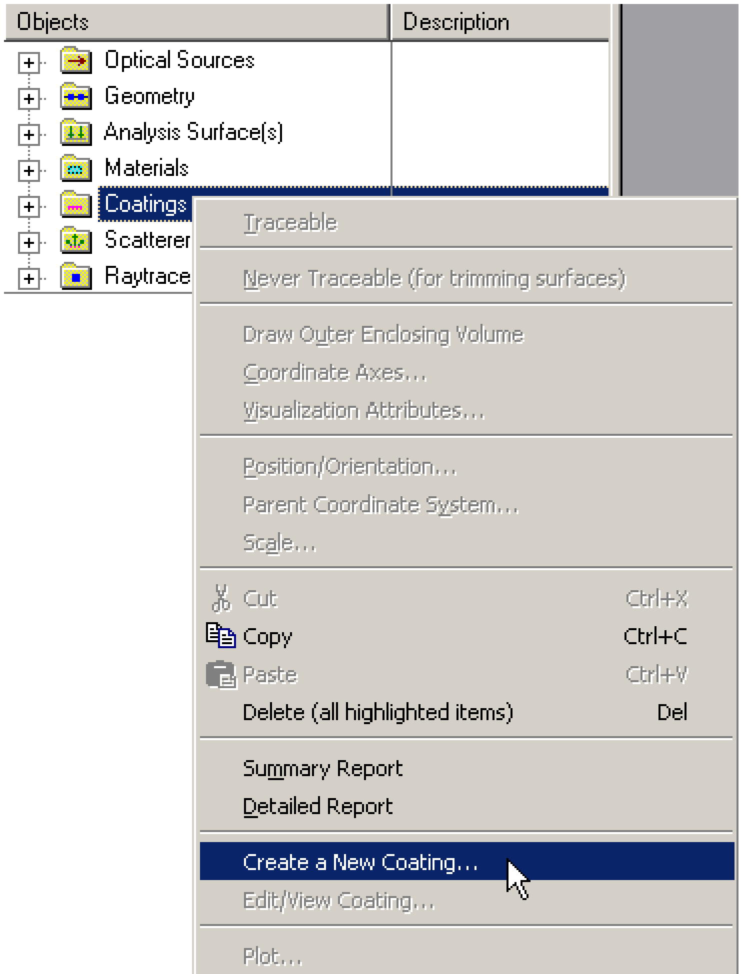
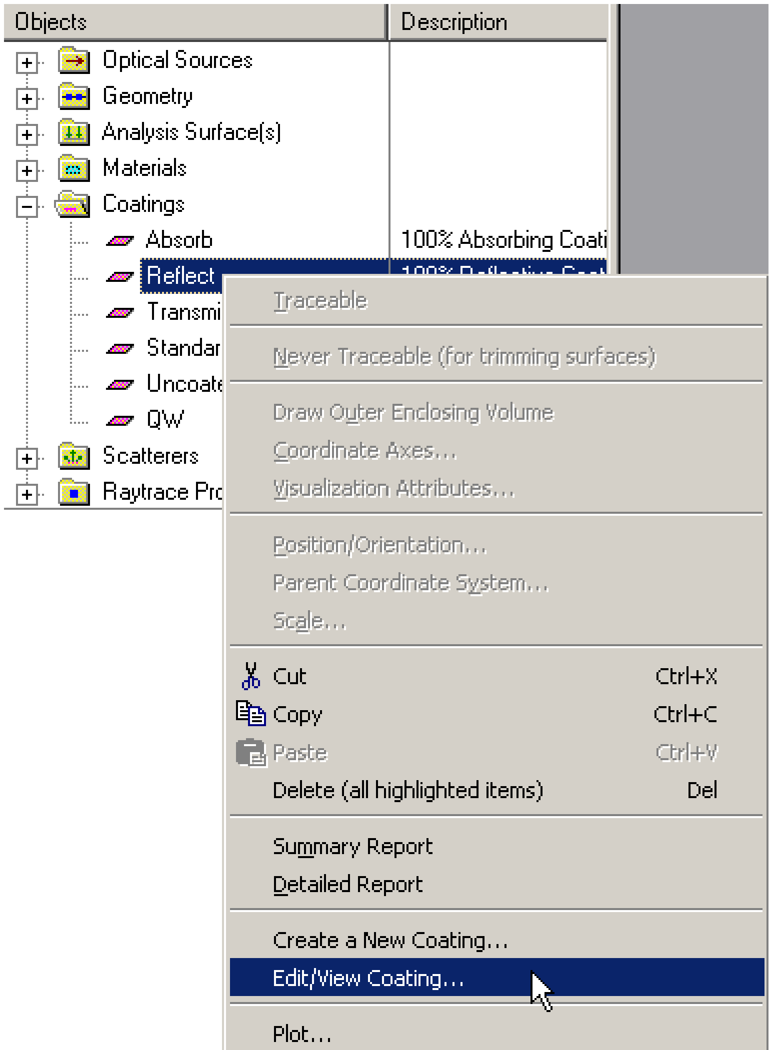
There are four ways to open a Coating dialog.

1. Right mouse click on the Coatings folder to open a context menu and select the option '*Create a New Coating…*'.

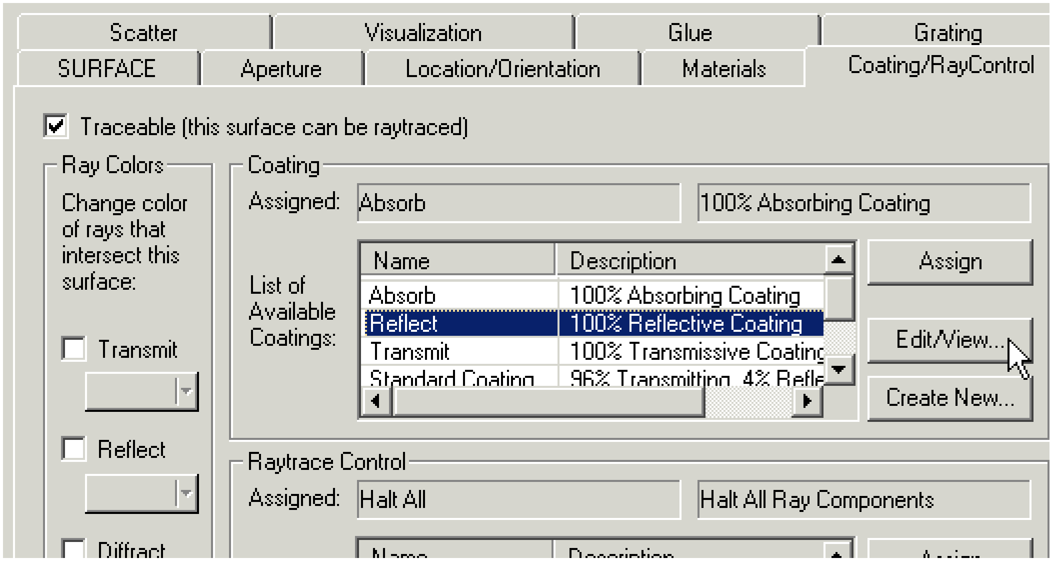


2. Expand the Coatings folder and right mouse click on a specific coating open a pop-up menu and select the option '*Edit/View Coating…*'.

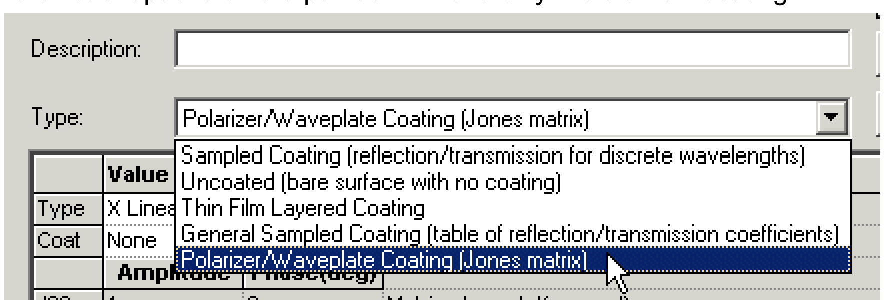


3. Expand the Coatings folder and, using the left mouse button, double click on the coating name.

4. From the Coating/RayControl tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.

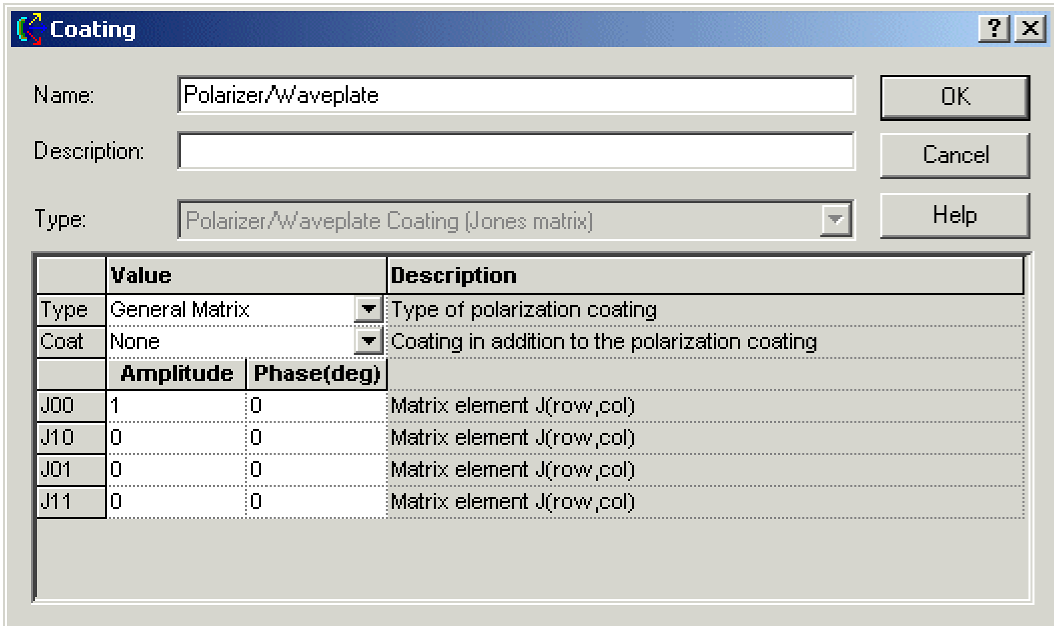


Once the Coating dialog has been opened, the Polarizer/Waveplate type can be selected from the list of options on the pull-down menu only if it is a new coating.



Dialog Box and Controls - Edit or Create a New Polarizer/Waveplate

The Polarizer/Waveplate Coating dialog is shown below.



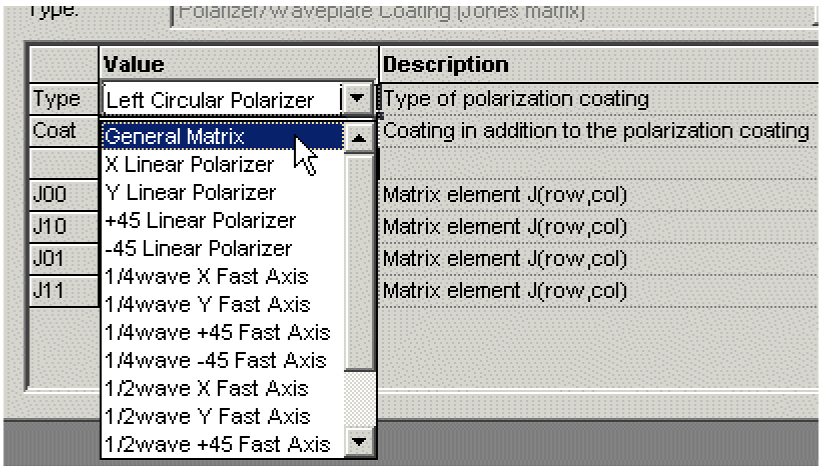
<u>*Control*</u>	<u>*Inputs*</u>	<u>*Defaults*</u>
Name	Enter the name of the Coating here	Coating *n*
Description	Enter a short alpha-numeric description of the Coating here	None
Type	Select the Polarizer/Waveplate type from the pull-down menu.	Sampled Coating
OK	Click on this button to accept changes and to close the dialog	None
Cancel	Click on the button to close the dialog. You will lose any changes.	None
Help	Get dialog help	None
Type	Select the type of polarization coating using the pull-down menu	X Linear Polarizer
Coat	Select any other coating to be used in combination with the polarization coating using the pull-down menu	None
J00	Enter the amplitude and phase of the J00 (row,col) Jones matrix element	0, 0
J10	Enter the amplitude and phase of the J10 (row,col) Jones matrix element	0, 0
J01	Enter the amplitude and phase of the J01 (row,col) Jones matrix element	0, 0

J11	Enter the amplitude and phase of the J11 (row,col) ones matrix element	0, 0

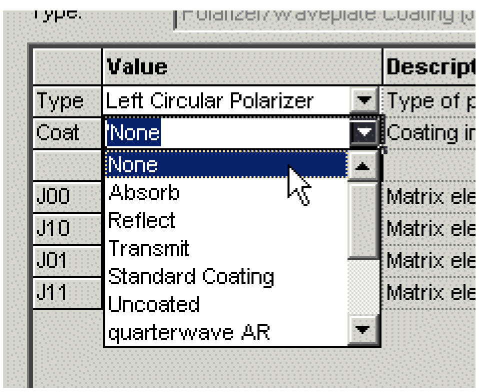
Application Notes - Edit or Create a New Polarizer/Waveplate

- The Jones matrix is applied only to transmitted rays.
  - A reflected ray is generated only if the polarizer is combined with a reflecting coating.
  - The polarizer will not affect the power of the reflected ray.
- The electric field vector of a polarized ray is decomposed into orthogonal components relative to the local z-axis of the surface. Any component of the electric field that projects onto the z-axis is not affected by the polarizer.
  - This case can arise when the direction of a ray is not parallel to the z-axis; i.e. a linear polarizer with its transmission axis parallel to the local X-axis will transmit a portion of any ray linearly polarized in the Y direction because the electric field has a component along the z-axis. The relative power of the transmitted component increases with angle of incidence.
- Polarized rays
  - The orientation of the fast axis (waveplates) or transmission axis (polarizers) is defined in the local coordinate system of the surface.
  - The electric field vector of polarized rays incident on the surface are decomposed into orthogonal components in the local coordinate system of the surface. The X and Y components are acted upon by the coating, the Z component is not.
  - Polarizing coatings are insensitive to wavelength.
- Unpolarized rays
  - In the absence of any other coating specification, the transmitted flux of an unpolarized ray incident on any of the linear polarizers is reduced by half.
  - In the absence of any other coating specification, the flux of an unpolarized ray incident on any of the waveplates is maintained on transmission.
  - A linear polarizer will polarize an unpolarized ray. Any other type will not.
- Coatings are used in conjunction with the **Raytrace Controls** to determine ray propagation.
  - To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection.
  - To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission.
  - Scattered rays are subject to the same limitations. Currently, an absorbing surface cannot generate scattered rays.
- Copies between FRED models will always transfer new material and coating information.
- Once defined, a coating type cannot be changed.

The following examples show all of the available polarization coatings. These are selected from the pull-down menu in the Type column.

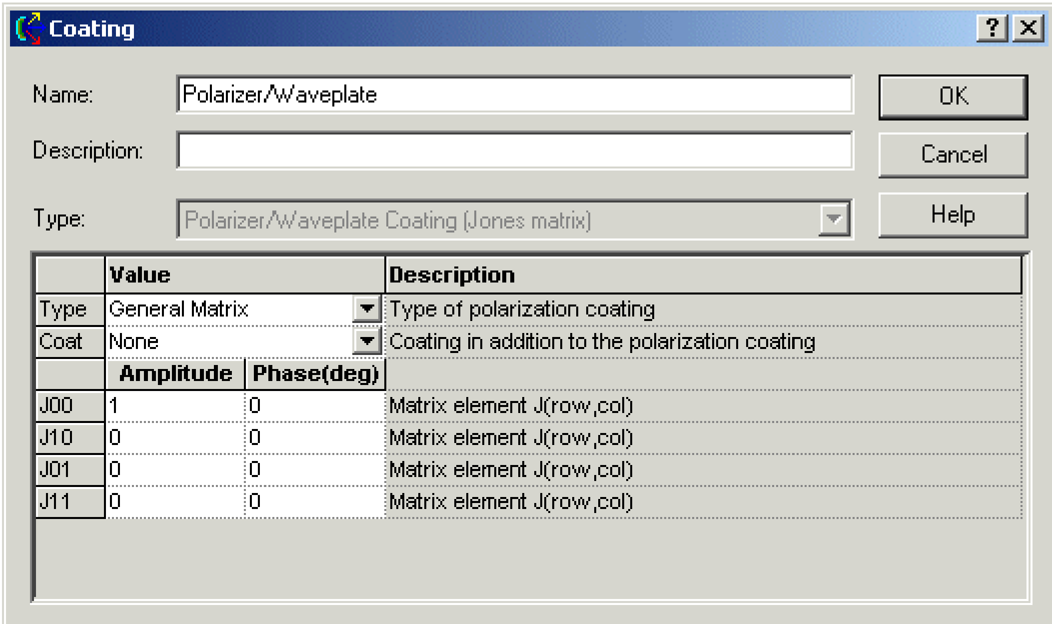


A polarizing coating can be combined with any other coating defined in the model. Use the pull-down menu in the Coat column to select one.



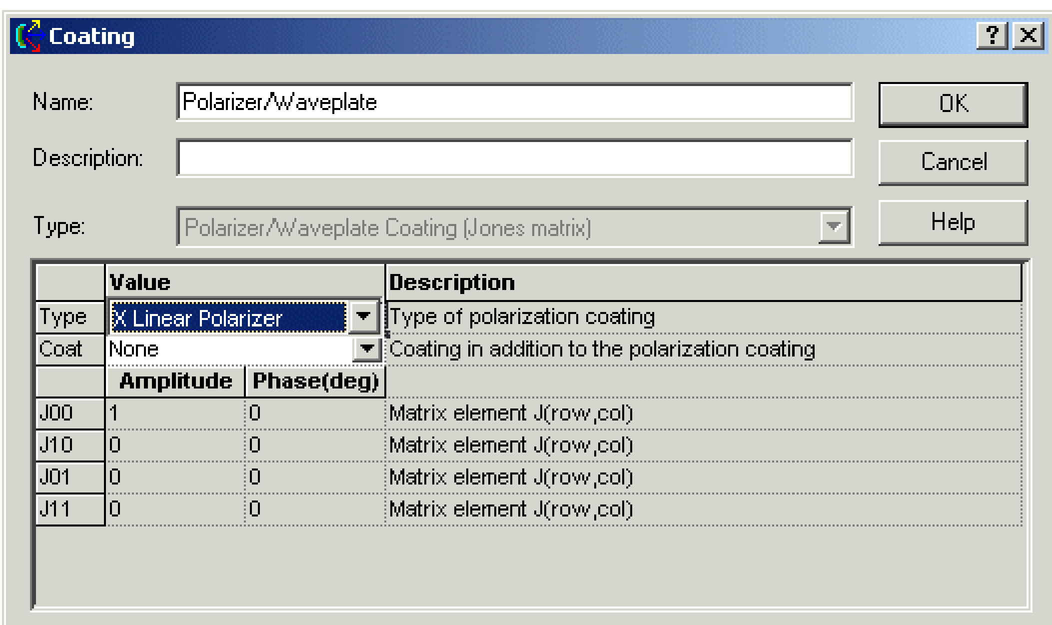
General Matrix

This is the only polarizing coating that can be edited by the user. Manually enter values for the amplitude and phase angle (in degrees) for each of the Jones matrix element. A positive phase angle advances the relative phase and a negative phase angle retards it.



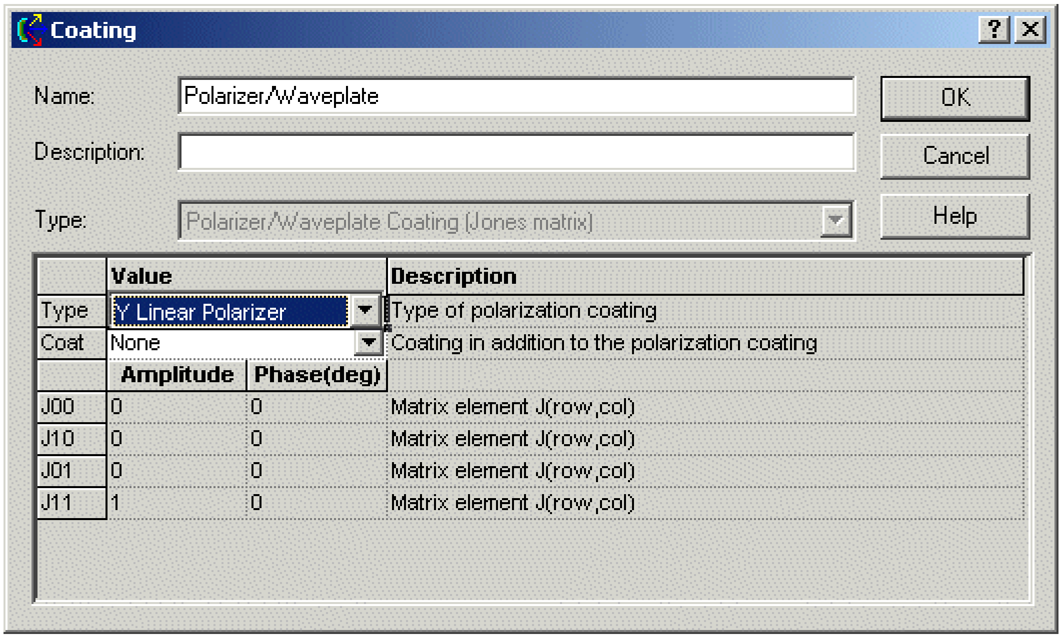
X Linear Polarizer

The transmission axis is parallel to the local X-axis of the surface.



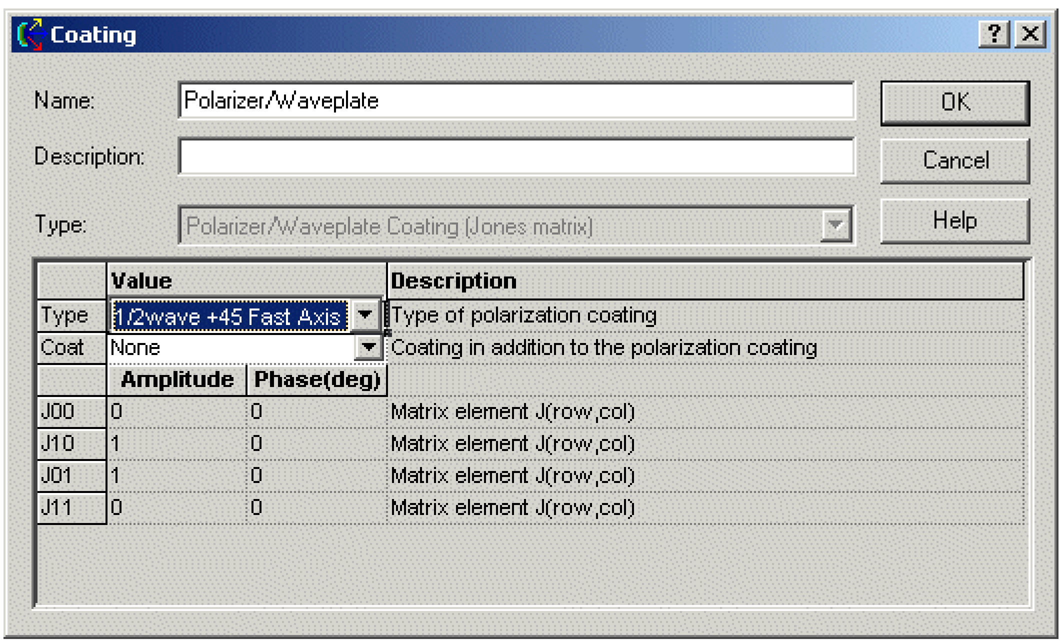
Y Linear Polarizer

The transmission axis is parallel to the local Y-axis of the surface.



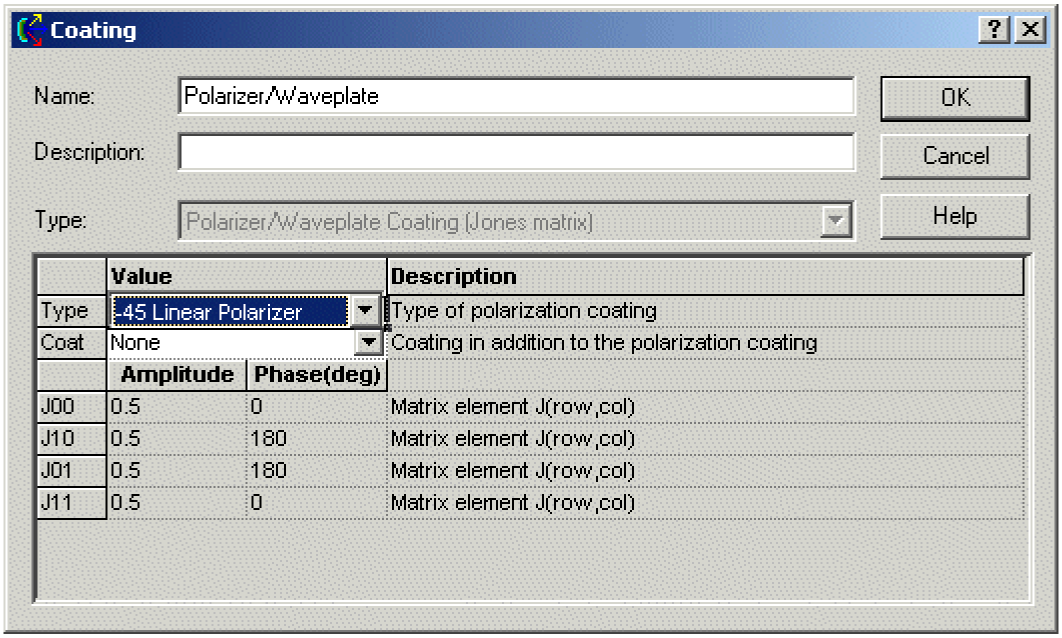
+45 Linear Polarizer

The transmission axis is rotated 45 degrees about the local Z-axis of the surface.



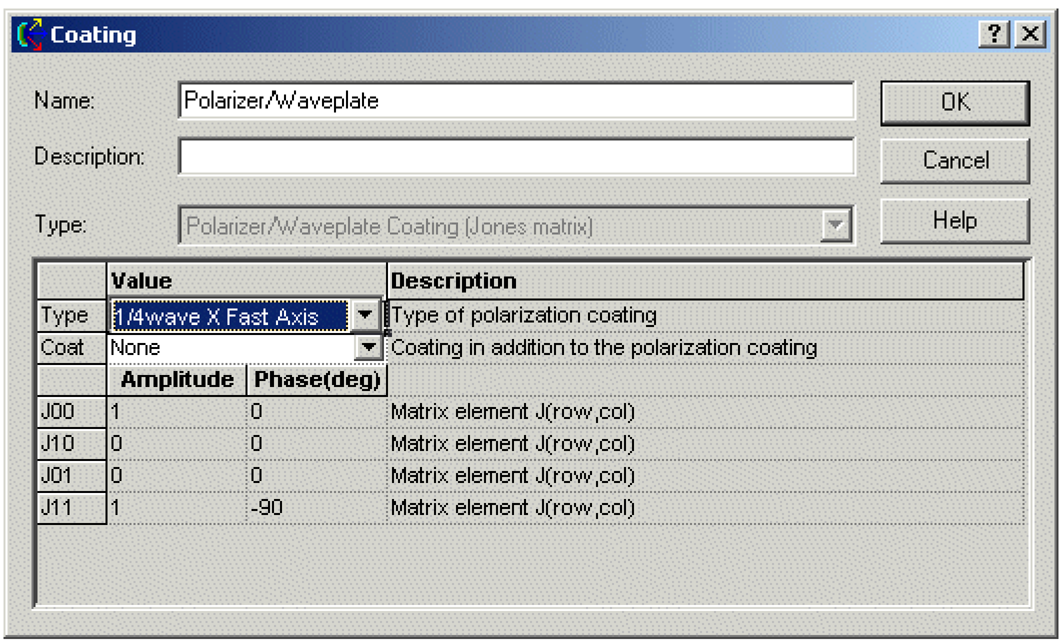
-45 Linear Polarizer

The transmission axis is rotated -45 degrees about the local Z-axis of the surface.



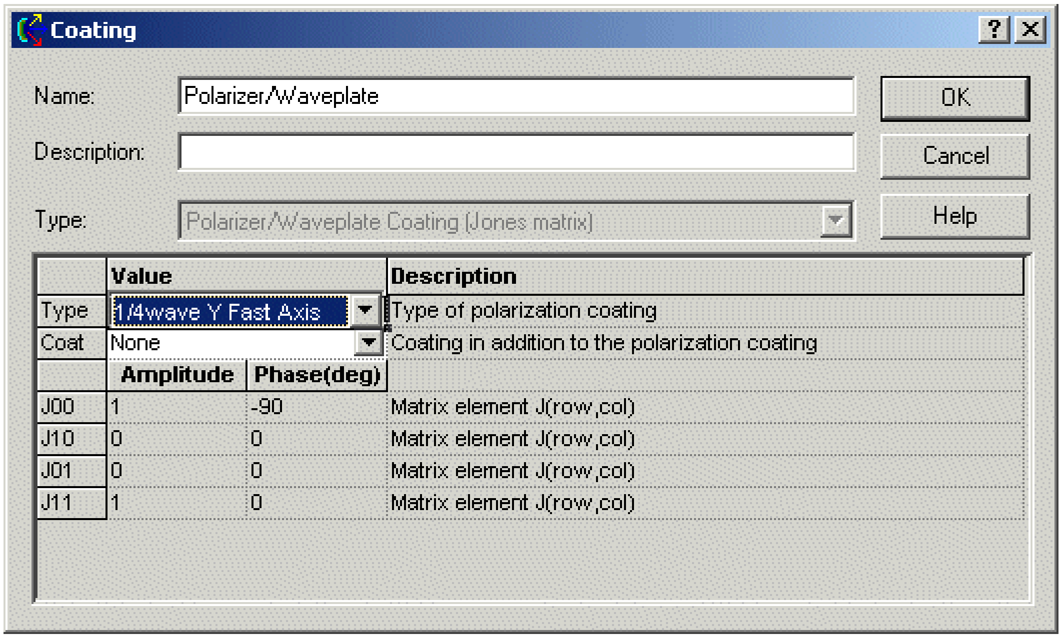
1/4 Wave X Fast Axis

The fast axis is of the waveplate is parallel to the local X-axis of the surface.



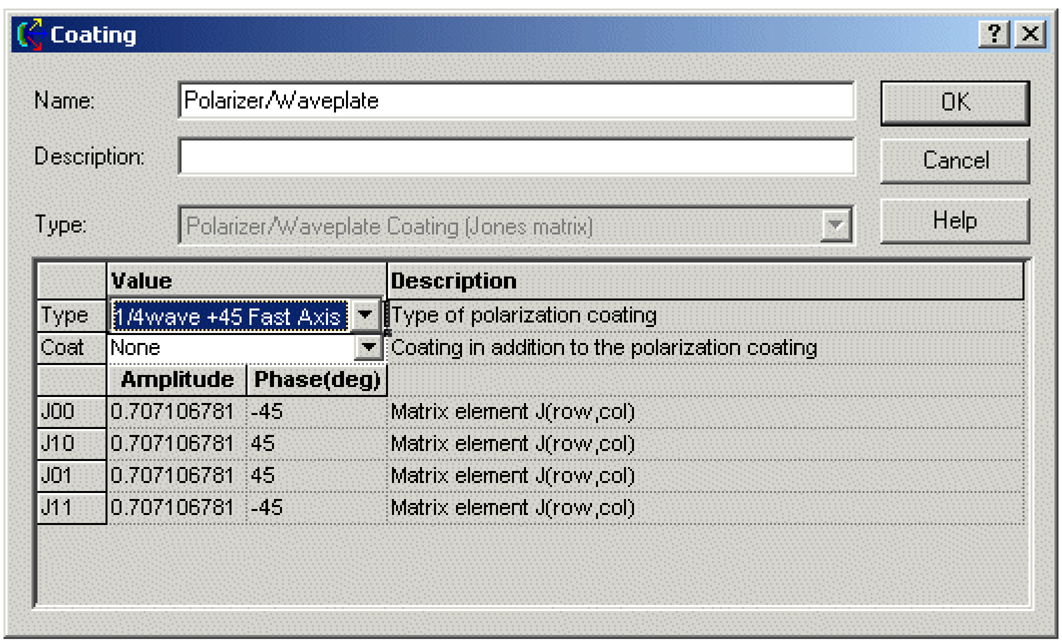
1/4 Wave Y Fast Axis

The fast axis is of the waveplate is parallel to the local Y-axis of the surface.



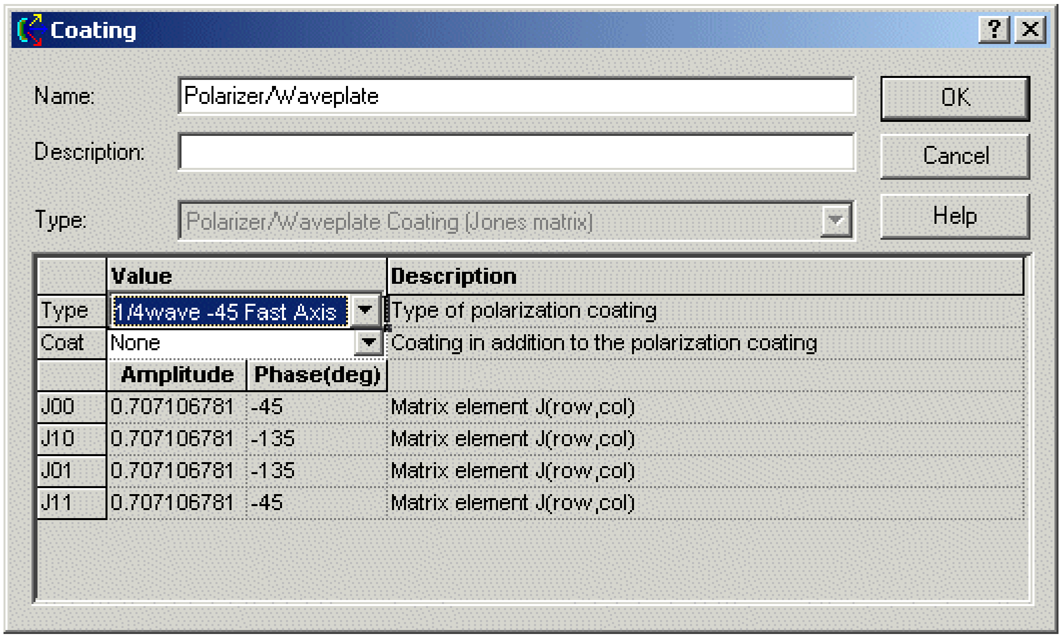
1/4 Wave +45 Fast Axis

The fast axis is of the waveplate is rotated 45 degrees about the local Z-axis of the surface.



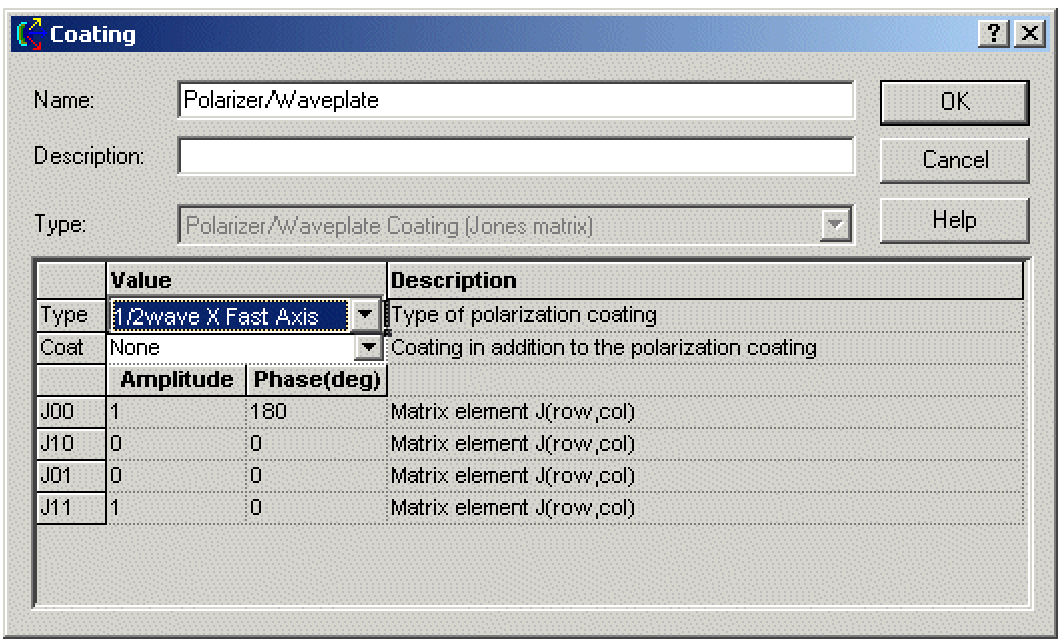
1/4 Wave -45 Fast Axis

The fast axis is of the waveplate is rotated -45 degrees about the local Z-axis of the surface.



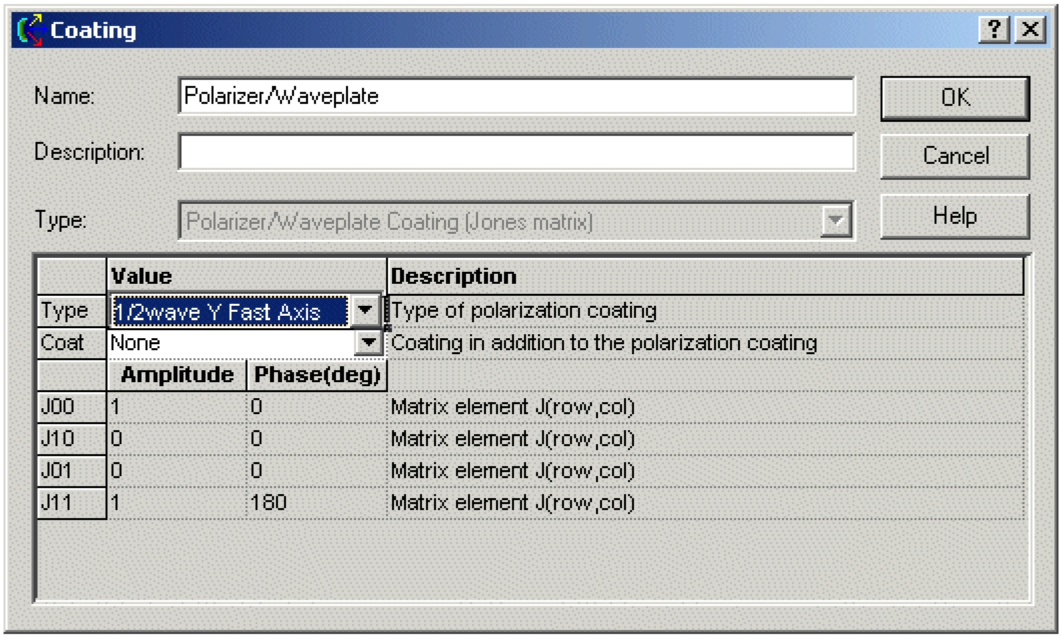
1/2 Wave X Fast Axis

The fast axis is of the waveplate is parallel to the local X-axis of the surface.



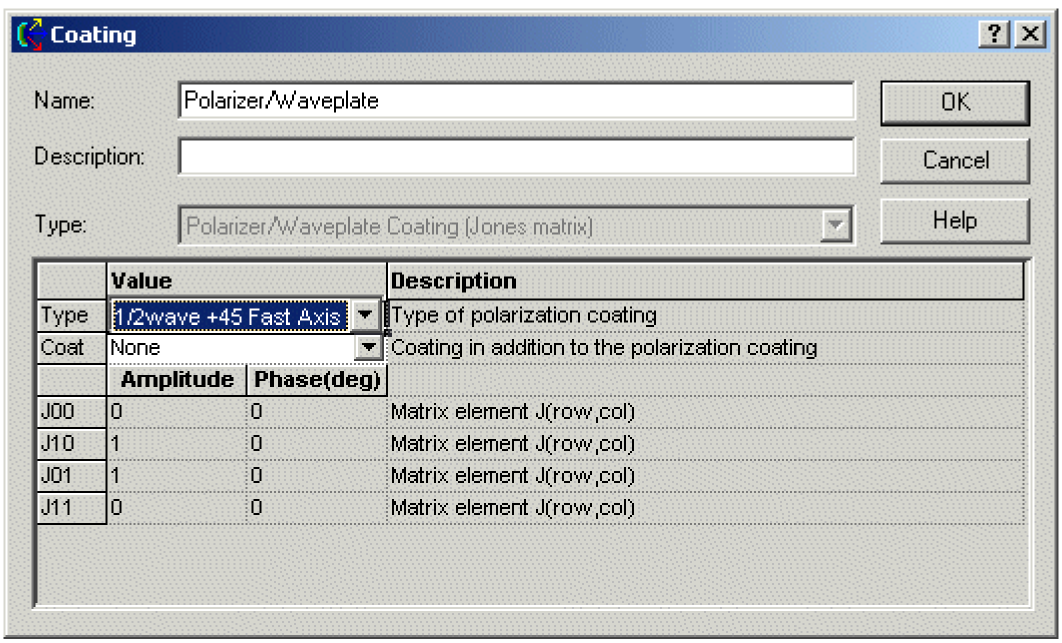
1/2 Wave Y Fast Axis

The fast axis is of the waveplate is parallel to the local Y-axis of the surface.



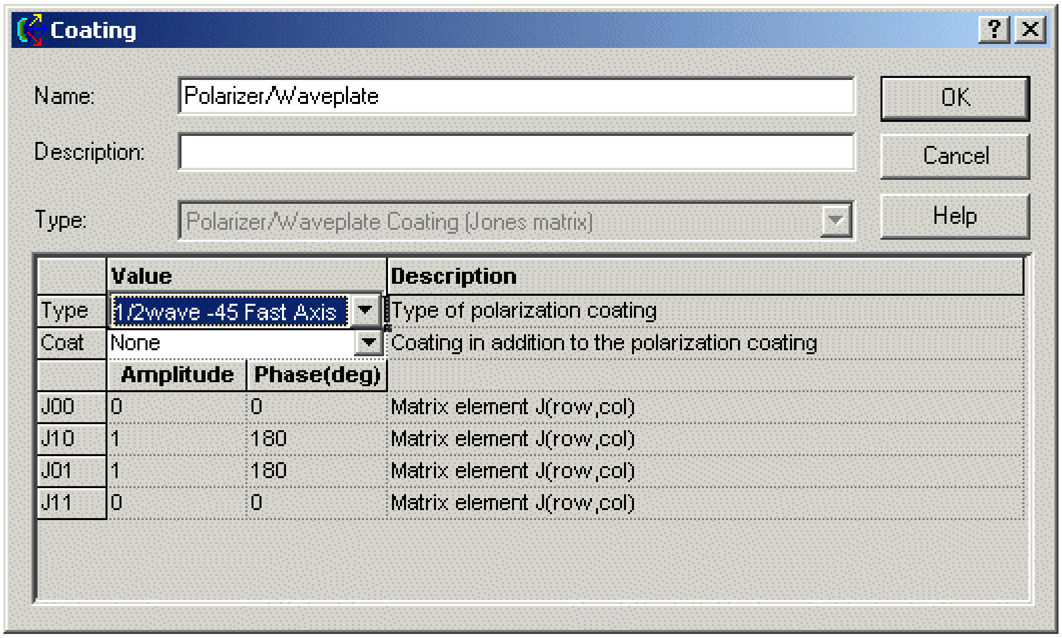
1/2 Wave +45 Fast Axis

The fast axis is of the waveplate is rotated 45 degrees about the local Z-axis of the surface.



1/2 Wave -45 Fast Axis

The fast axis is of the waveplate is rotated -45 degrees about the local Z-axis of the surface.



See Also... - Edit or Create a New Sampled Coating

The following links contain details about each of the remaining coating models.

Sampled Coating

Uncoated

General Sampled Coating

Thin Film Layered Coating

For details about Raytrace Controls, select the following link.

Raytrace Controls

For reference information regarding Jones Matrices, select the following link.

Optical References

Chapter 10 - Scatterers

Description
Scatterers

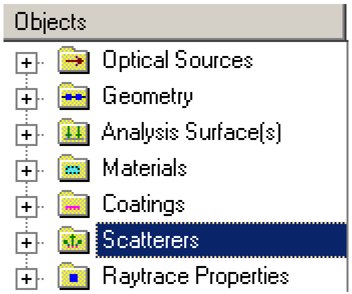
The **Scatterers** folder contains the default and optional user entered scatter models that may be applied to any surface in FRED. Each model calculates the appropriate three-dimensional Bidirectional Scatter Distribution Function (BSDF) based on the incident ray angles and orientation of the local surface normal. Alternate definitions of the BSDF are the Bidirectional Reflectance Distribution (BRDF) and the Bidirectional Transmission Distribution Function (BTDF).

FRED comes with three default scatter models: Black Lambertian (4% reflectivity diffuse black), White Lambertian (96% reflectivity diffuse white), and Harvey-Shack (polished surface). Additionally, parametric models for the following types of scatterers are also available in FRED: Flat Black Paint (TIS), ABg, Surface Particle (Mie), and Phong. More than one type of scatter model can be applied to a surface. Reflected and transmitted scatter components are allowed or halted per the **Raytrace Controls** currently applied to the surface. Every scatter surface must have at least one scatter direction, which can be set automatically, using the menu bar option **Tools: Determine Scatter Importance Sampling**, or manually, from the **Scatter** tab in the **Surface** dialog. Every scatter direction is applied to every scatter model assigned to the surface.

NOTE	Only the coefficients for an existing scatter model can be changed. Once created, the model Type (i.e., Lambertian, TIS, Harvey-Shack, ABg, Mie, Phong) is permanent. A new scatter model must be created and assigned to geometry objects to change the scatter model type.

Visualization (example)
Scatterers

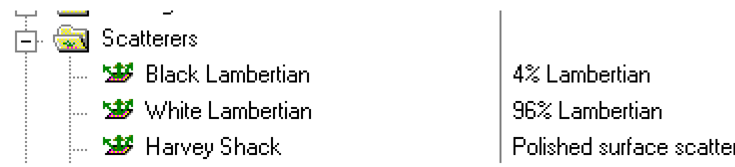
The **Scatterers** folder is near the bottom of the tree.



How Do I Get There?

Scatterers

A left click on the ⊞ symbol next to the folder name will expand the tree.

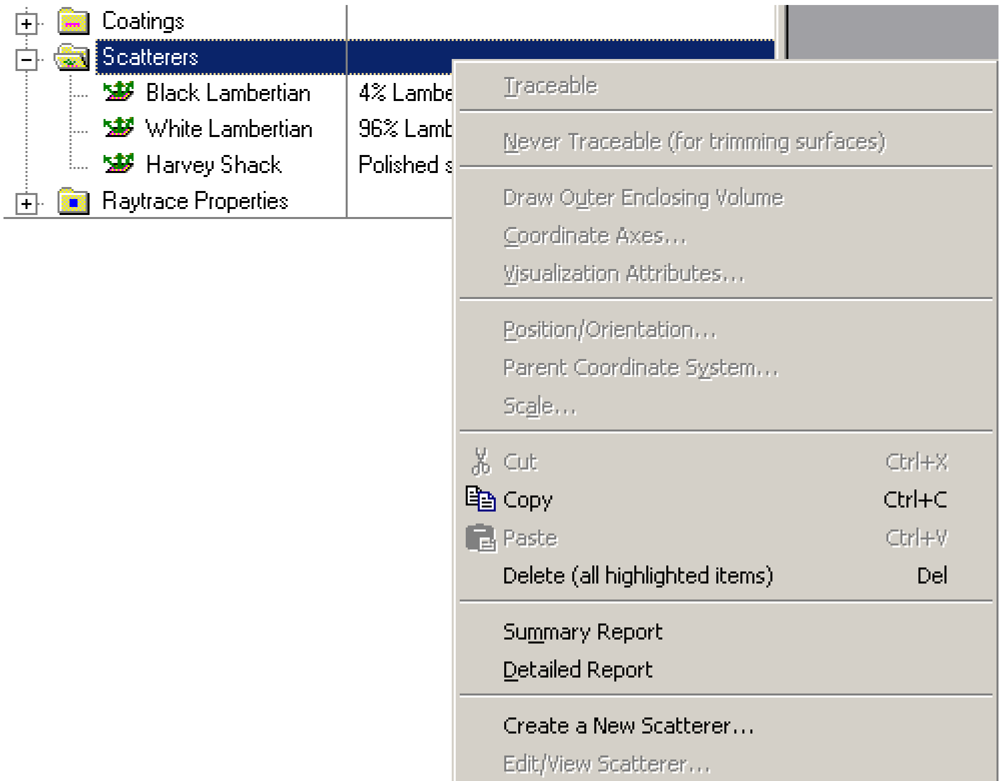


A left mouse click on the ⊟ symbol next to an open folder will collapse the node.

Dialog Box and Controls

Scatterers

A right mouse click on the **Scatterers** folder opens the following context menu.



The first option available on the context menu is a '*Summary Report*.'

When this option is selected, FRED prints a list the Scatterers in the model and the Description of each.

SCATTER SPECIFICATIONS:		
Black Lambertian		
	Description:	4% Lambertian
White Lambertian		
	Description:	96% Lambertian
Harvey Shack		
	Description:	Polished surface scatter

The second option available on the right click menu is a '*Detailed Report*.'

When this option is selected, FRED prints a detailed summary of all of the existing scatter model properties.

SCATTER SPECIFICATIONS:		
Black Lambertian		
Scatter Type:	Lambertian	
Description:	4% Lambertian	
Reflectivity:	0.04	
White Lambertian		
Scatter Type:	Lambertian	
Description:	96% Lambertian	
Reflectivity:	0.96	
Harvey Shack		
Scatter Type:	Harvey Shack	
Description:	Polished surface scatter	
BSDF at B-B0:	0.1	
Slope:	-1.5	
Shoulder:	0.01	

The third option available is to '*Create a New Scatterer…*'

Selecting this option opens the Scatter Dialog. This is just one of four ways to access this dialog.

Application Notes

Scatterers

- Definitions:
  - o BSDF – Bidirectional Scatter Distribution Function = Brightness (L) / Incident Irradiance (E)

- Units are inverse steradians (sr^{-1})
- Defined over a hemisphere = 2π steradians

o BRDF – Bidirectional Reflectance Distribution Function – BSDF for reflected scatter

o BTDF – Bidirectional Transmission Distribution Function – BSDF for transmitted scatter

o Total Integrated Scatter (TIS) – total scattered power from a surface divided by the incident power. It is an integral of the BSDF carried out over the hemisphere.

- TIS is related to RMS surface roughness by the following expression

$$TIS = \left(\frac{2\pi(\Delta n)\sigma_{rms}}{\lambda} \right)^2$$

  - Δn = change in refractive index change across the surface boundary. Note: $\Delta n = -2n_0$ for reflected scatter
  - σ_{rms} = RMS surface roughness
  - λ = wavelength of incident light
  - Valid only when $\sigma_{rms} << \lambda$

o Projected solid angle (PSA) – projected area of a surface divided by the distance squared

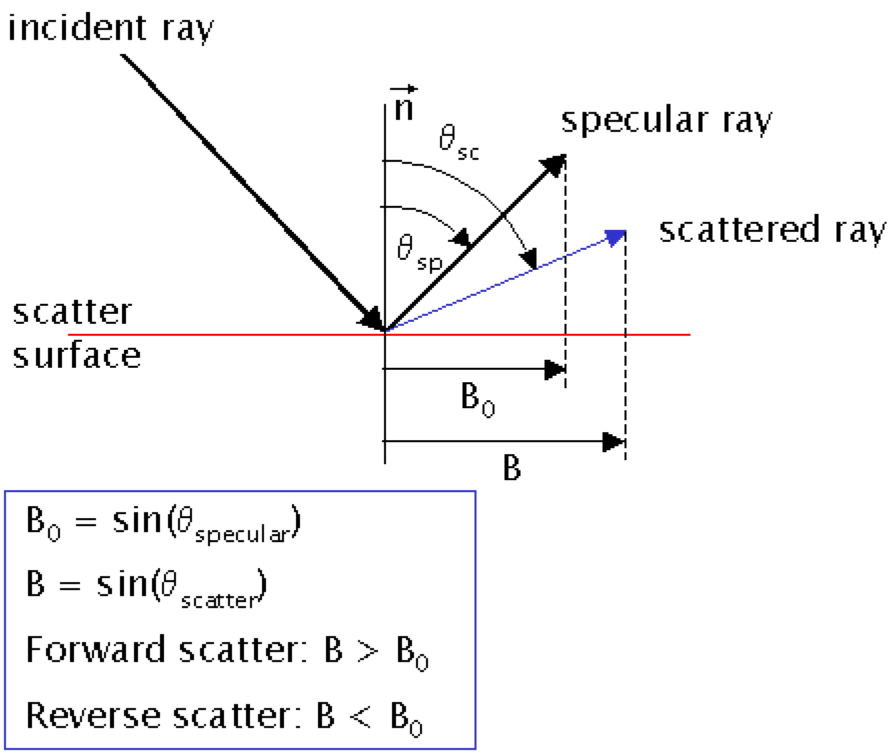
- PSA for a hemisphere = π
- PSA for a tilted plane = $A*\cos(\theta)/d^2$

o Lambertian surface – any surface with equal scatter (brightness) in all directions.

- $BSDF_{lambertian} = TIS/\pi$

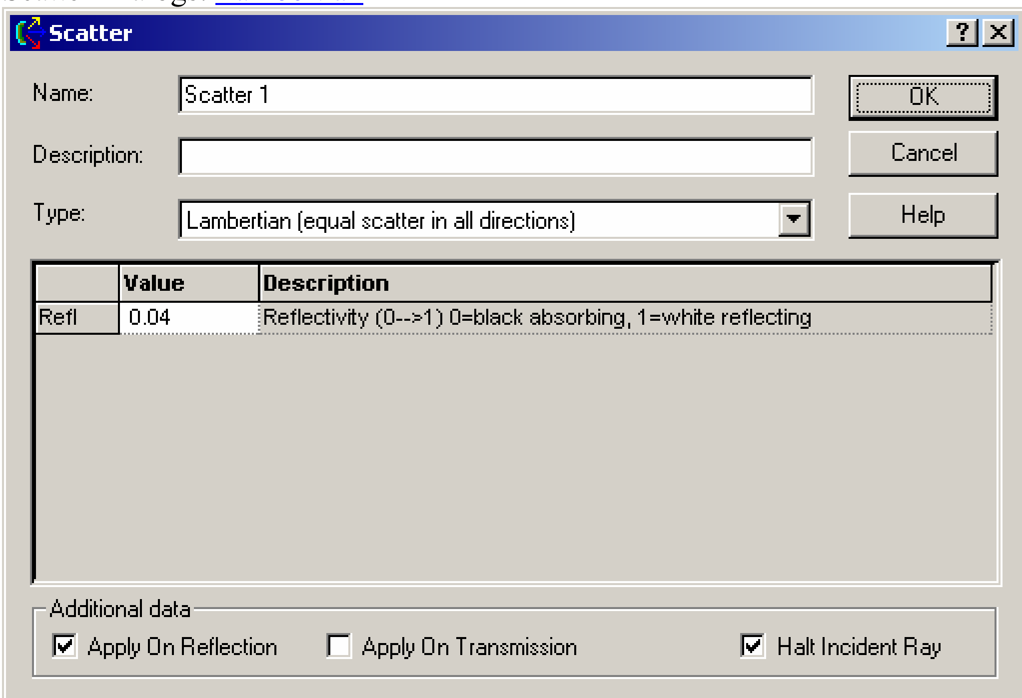
o Plane of incidence – the plane containing both the incident and specular rays. The 2-dimensional representation of the BSDF commonly shown in the plane of incidence as a function of $B-B_0$ or $\log(|B-B_0|)$.

- B_0 = sine of the angle from the surface normal to the specular ray in the plane of incidence
- B = sine of the angle from the surface normal to the scattered ray in the plane of incidence
- In the case of forward scatter → $B > B_0$
- In the case of reverse or back scatter → $B < B_0$

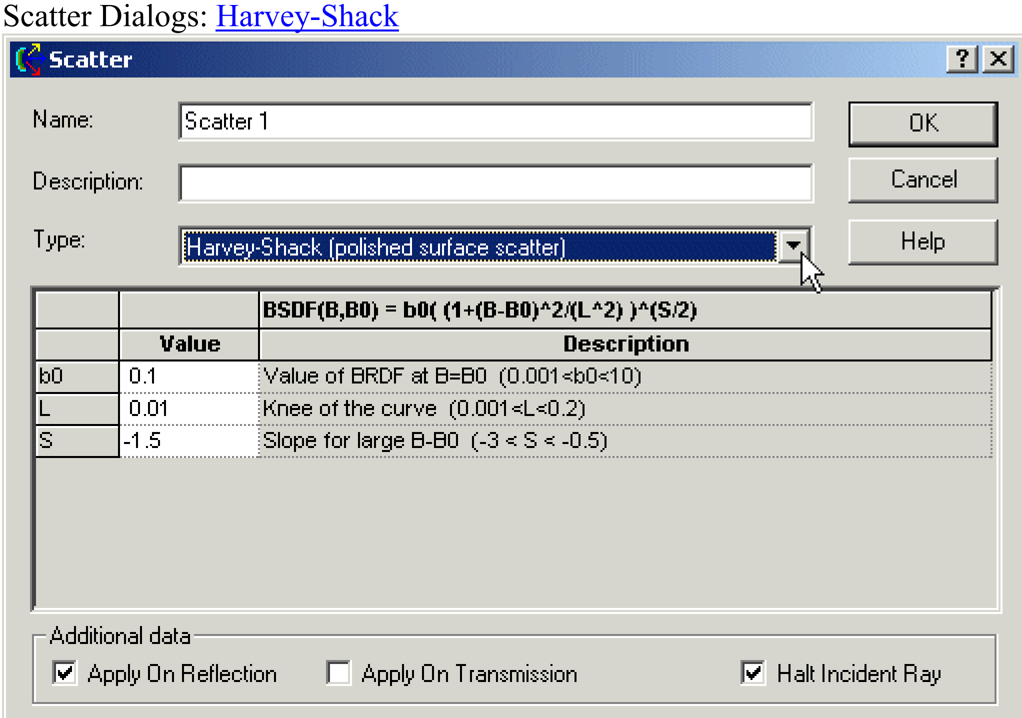


- Conservation of energy:
  - For hemispherical scatter, the product of the BSDF and the PSA must be less than or equal to one.
  - The total power contained in the incident beam is equal to the sum of the reflected, transmitted, scattered, and absorbed components:
    - $P_{incident} = R_{specular} + R_{scatter} + T_{specular} + T_{scatter} + A$
    -
- **Coating** specifications on a surface apply only to specular rays.
- Allowable scatter directions are determined by the **Raytrace Controls**.

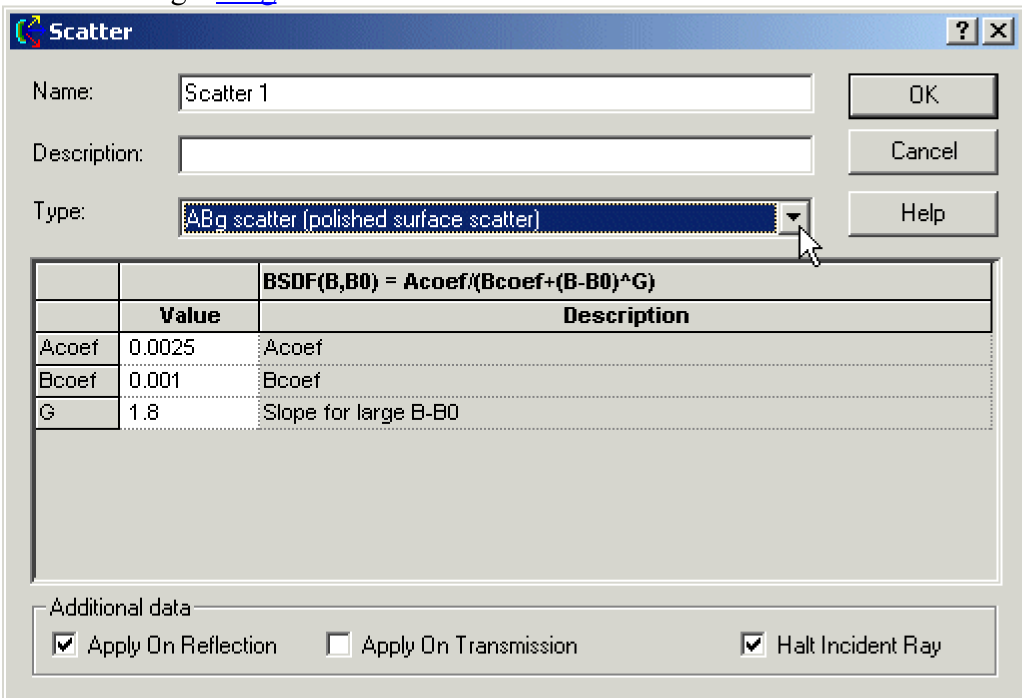
Scatter Dialogs: Lambertian



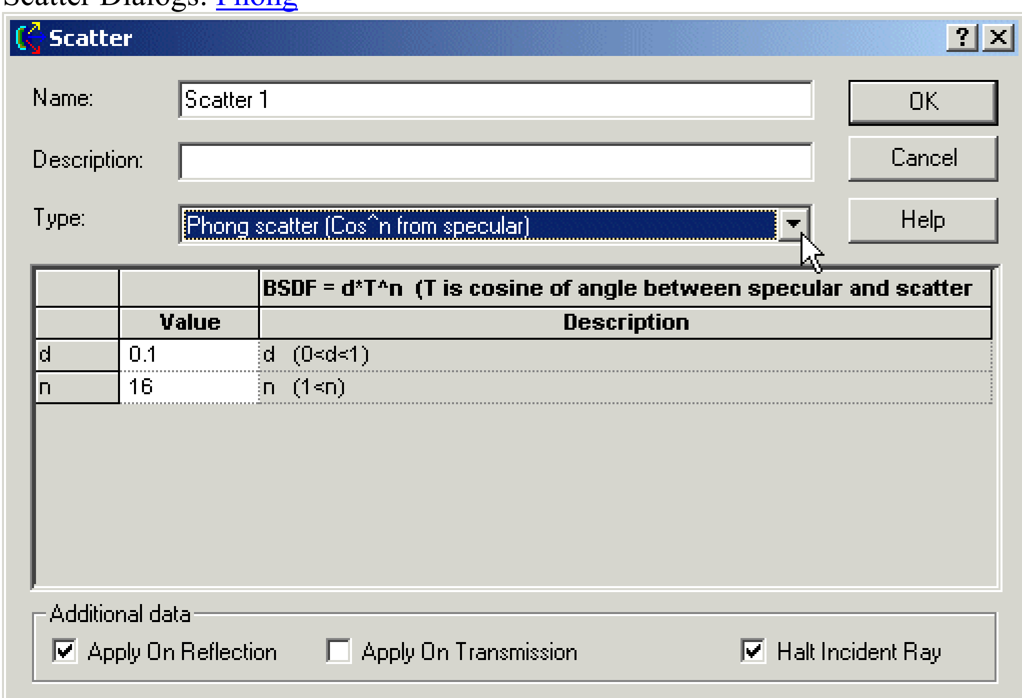
Scatter Dialogs: Harvey-Shack



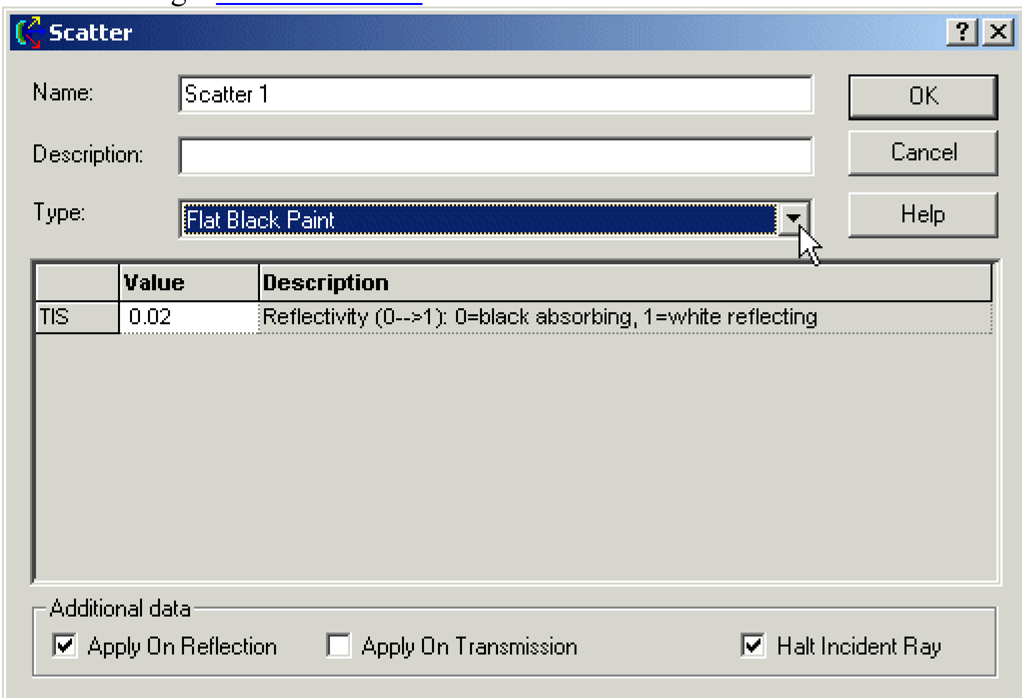
Scatter Dialogs: ABg



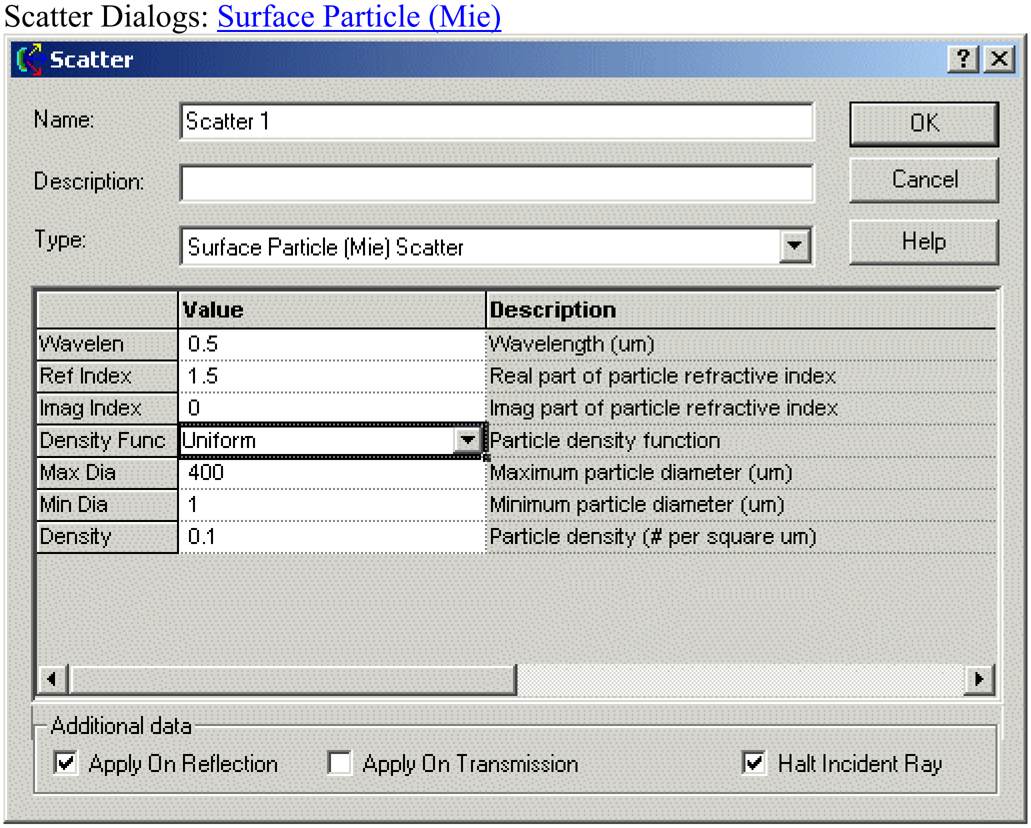
Scatter Dialogs: Phong



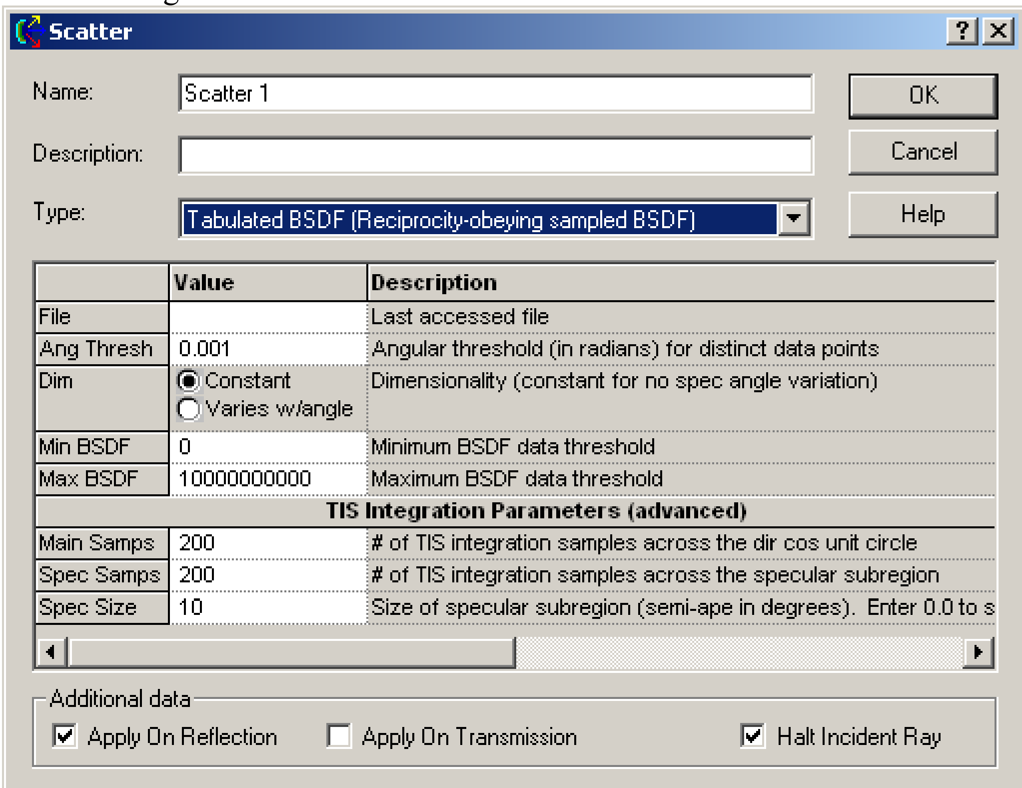
Scatter Dialogs: Flat Black Paint



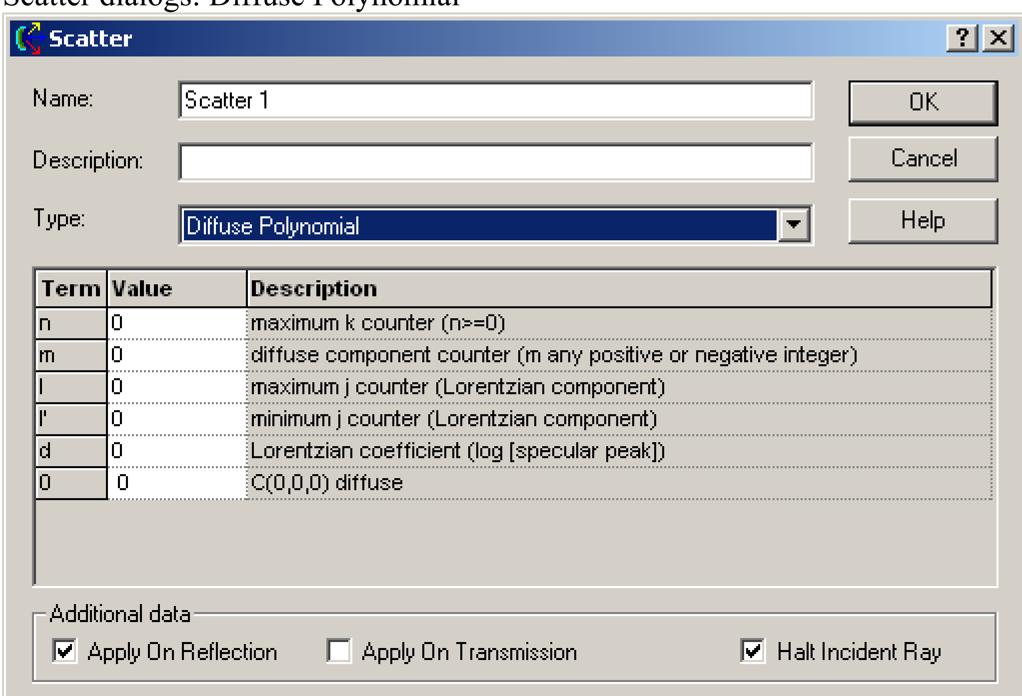
Scatter Dialogs: Surface Particle (Mie)



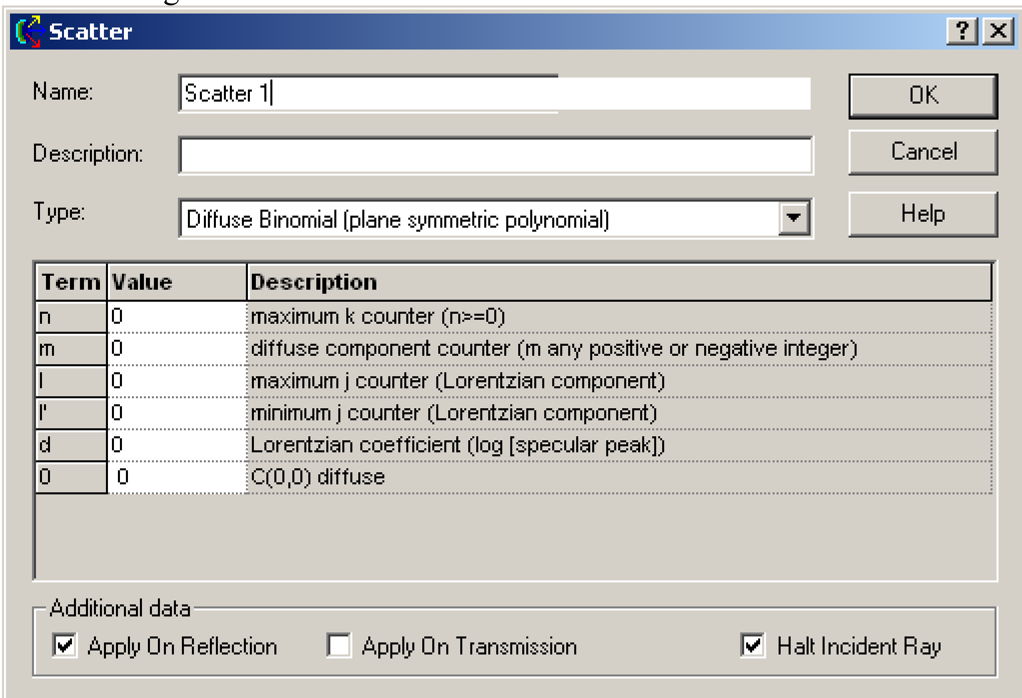
Scatter dialogs: Tabulated BSDF



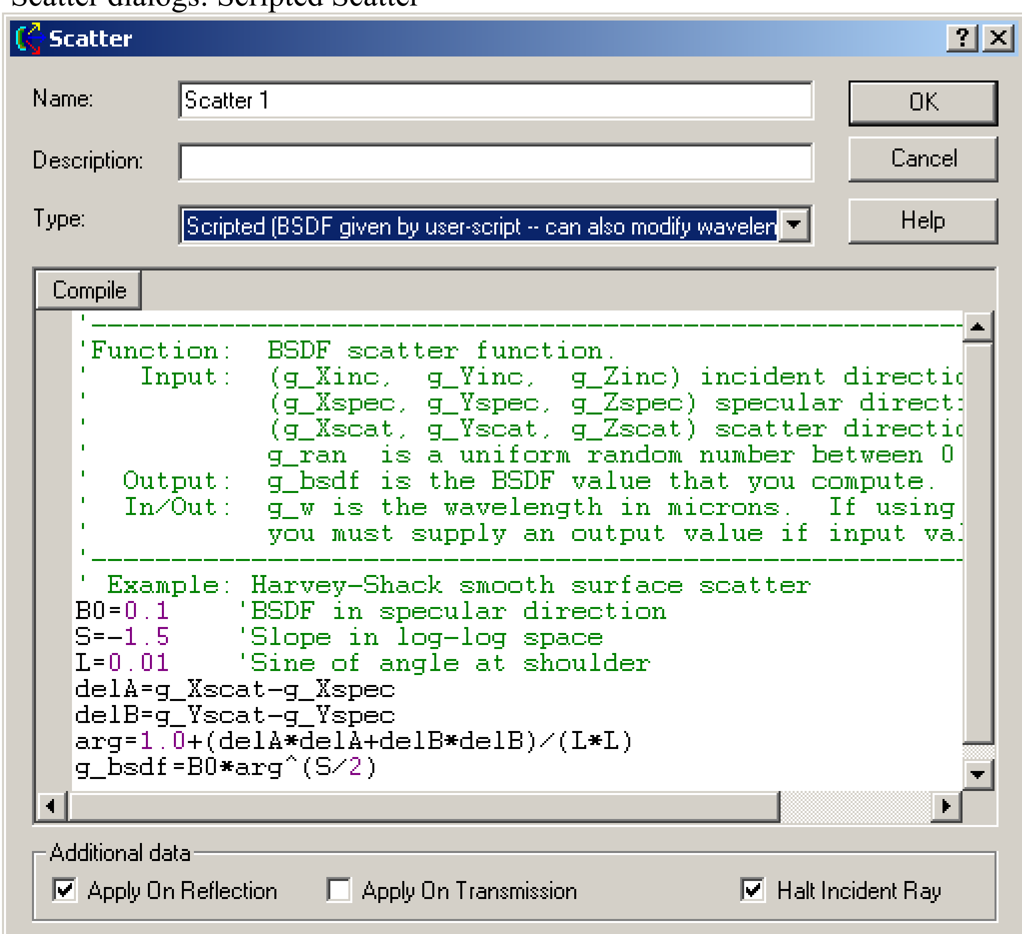
Scatter dialogs: Diffuse Polynomial



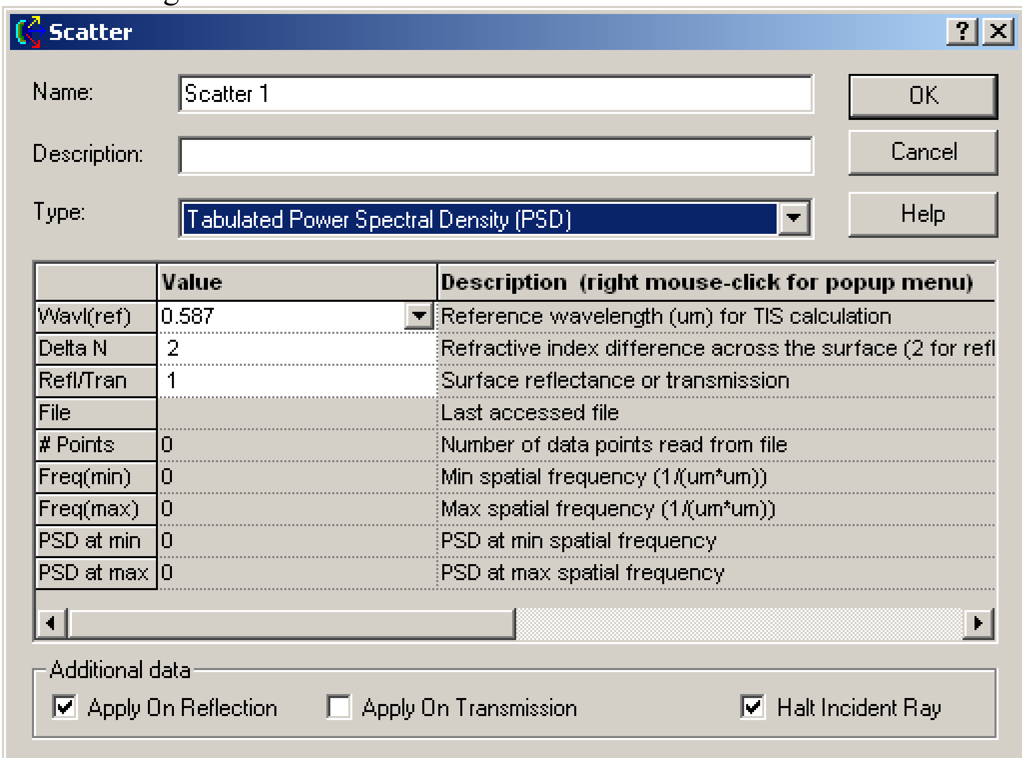
Scatter dialogs: Diffuse Binomial



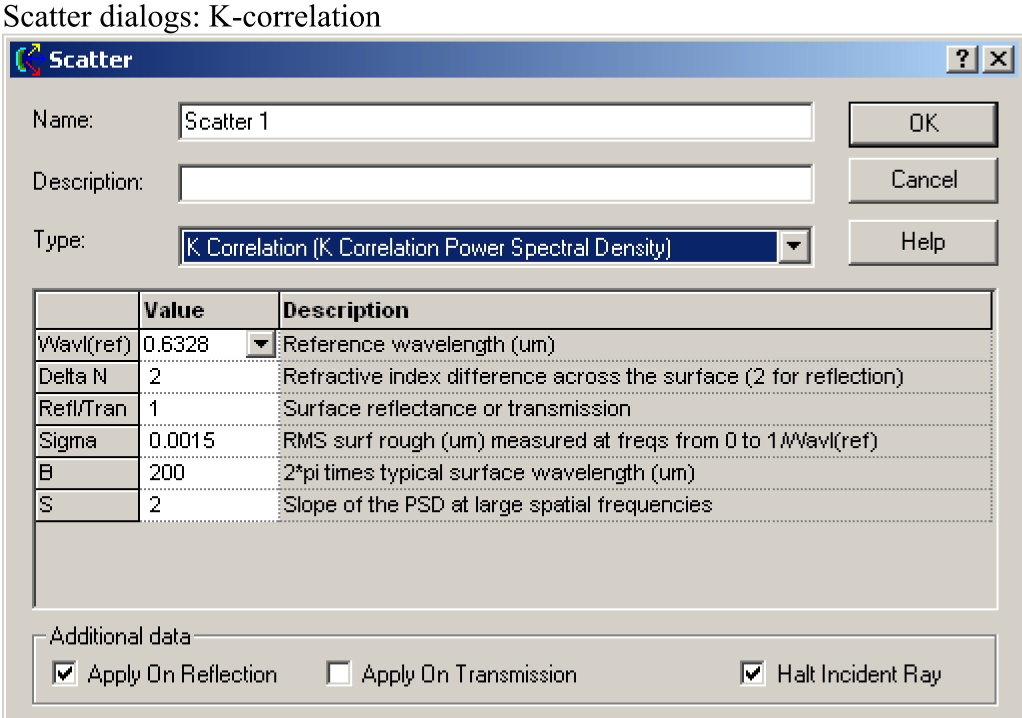
Scatter dialogs: Scripted Scatter



Scatter dialogs: Tabulated PSD



Scatter dialogs: K-correlation



See Also…

Scatterers

The following links contain details about each of the scatter models.
Lambertian for diffuse scatter
Harvey-Shack for polished surface scatter
ABg for polished surface scatter
Phong scatter – $\cos^n$ from specular
Flat Black Paint – specify Total Integrated Scatter (TIS)
Surface Particle (Mie) – for particulate contamination
Tabulated BSDF - measured BSDF
Diffuse Polynomial - for painted surfaces
Diffuse Binomial - for painted surfaces
Scripted Scatter - general scatter model (allows ray wavelengths to be changed)
Tabulated PSD - for measured power spectral density
K-correlation -

Applying Scatter Properties

- Description
- How Do I Get There?
- Dialog box and Controls

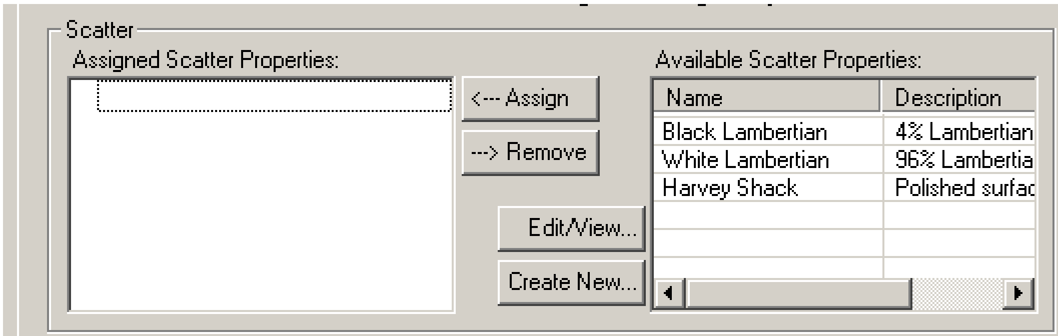
Description

Applying Scatter Properties

This dialog page allows the user to select the **Scatter Properties** associated with a surface.

This dialog has two sections: **Scatter Properties** and **Scatter Ray Directions Properties**. Making a surface scatter requires both assigning **Scatter Properties** in the first section and defining a solid angle to scatter rays in the second section.

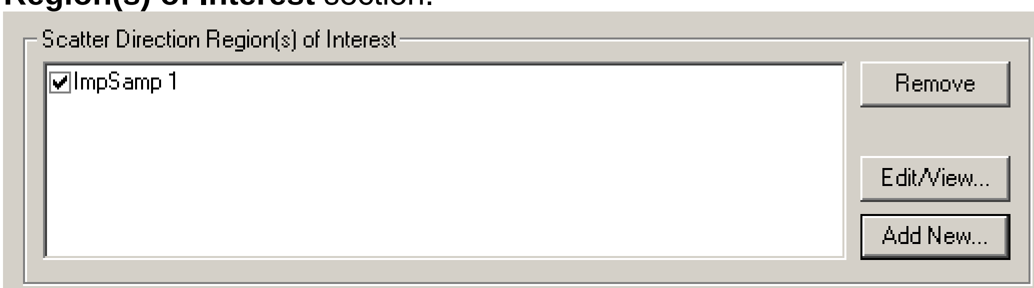
In the first section, one or more Scatter Properties currently defined in the FRED document can be assigned to the surface. Highlighting the desired property and pressing the assign button will assign **Scatter Properties** to the surface. The **Scatter Properties** settings can be edited/viewed and new **Scatter Properties** can be defined from this dialog. Please see the help for the **Create New Scatterer…** dialog for more information on how to edit and add new **Scatter Properties.**



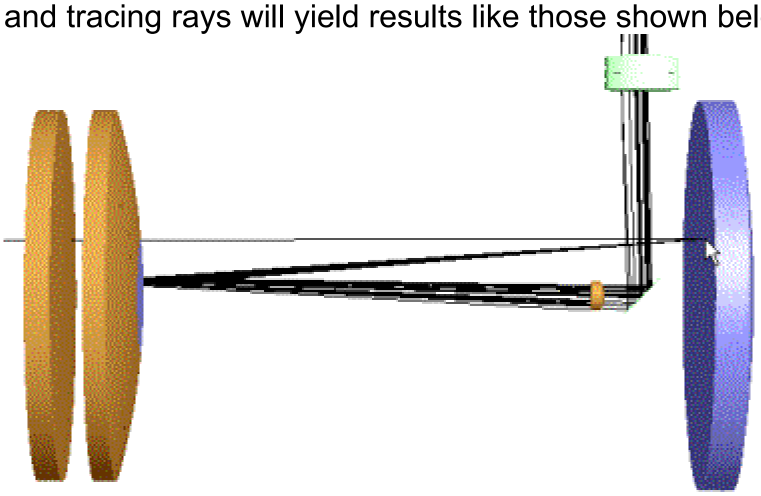
TIP	More than one scatter property can be added to a surface.

Pressing the button, Add New..., will open a dialog for setting the scatter solid angle that rays scattered off this surface into. The solid angle may be described in a number of ways including the example below where 25 rays have been scattered into a 0.5 degree cone angle around the specular reflection.

Pressing OK will add this solid angle specification to the **Scattered Direction Region(s) of Interest** section.



Applying these **Scatter Properties** to the primary mirror of the Houghton sample and tracing rays will yield results like those shown below..



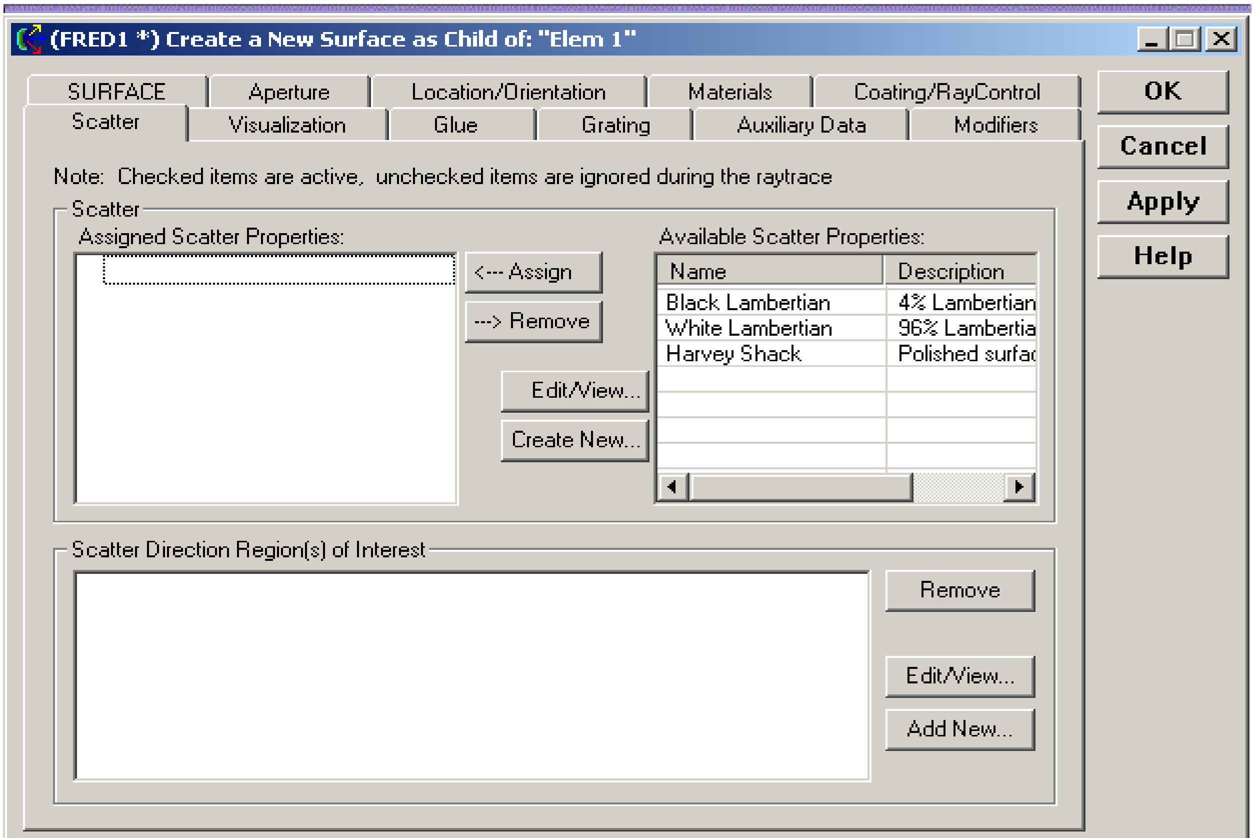
The important thing to note about the power of the rays scattered into the selected small solid angle is that they have same power as they would if they were scattered into a full hemisphere (2□ steradians) and they happened to fall into this selected small solid angle. By selecting a smaller solid angle, the same radiometric transfer is achieved but with much better sampling of the solid angle(s) of interest. The radiometric transfer is no longer valid if any of the solid angles overlap. In the overlap areas, the radiometric transfer would be approximately twice the expected value because in the overlap region rays for both selected solid angles carry the correct flux for that region of the total solid angle.

WARNING The radiometric transfer is no longer valid if any of the selected solid angles overlap.

How Do I Get There?

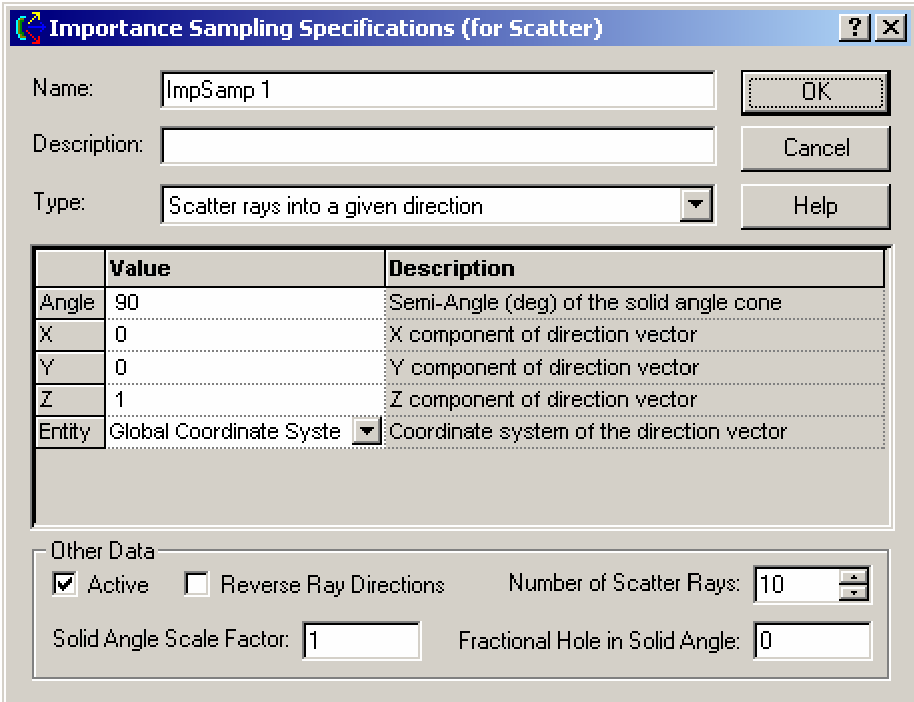
Applying Scatter Properties

This page is in the **Create New Surface…** and **Edit/View Surface…** dialogs.



Control	***Inputs***	***Defaults***
Scatter		
Assigned Scatter Properties	Lists scatter properties assigned to this surface.	Blank
Assign	Assigns a highlighted **Scatter Property** in the **Available Scatter Properties** list to the surface.	
Remove	Removes a highlighted **Scatter Property** in the **Assigned Scatter Properties** list from the surface.	
Available Scatter properties:	List of the available defined **Scatter Properties**. The **Scatter Properties** listed here are the same as those listed in the **Tree**. The user may add additional **Scatter Properties** in this dialog or via the **Tree** directly using the right click pop-up menu.	Black Lambertian, White Lambertian, and a polished surface Harvey Shack Model.

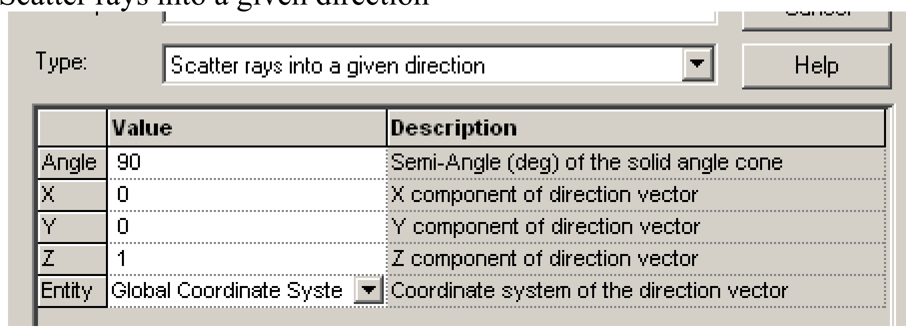
Edit/View…	Edit/View existing **Available Scatter Properties**.	
Create New…	Create new Scatter Properties and add to **Available Scatter Properties** list.	
Scatter Direction Region(s) of Interest		
List	List of the scatter directions or regions assigned to this surface.	blank
Remove	Removes a highlighted scatter designation in the **Scatter Direction Region of Interest** list from the surface.	
Edit/View…	Edit/View existing **Scatter Direction Region of Interest**.	
Add New…	Add new Scatter Properties and add to **Scatter Direction Region of Interest** list.	
OK	Accept Scatter changes and close dialog box.	
Cancel	Discard Scatter changes and close dialog box.	
Apply	Apply Scatter changes and keep dialog box open.	
Help	Access this Help page.	



Control	***Inputs***	***Defaults***
Name	Name of this scattering solid angle to be assigned to this surface	ImpSamp1
Description	Informative description of Importance Sampling Specification	Blank
Type	Drop down menu of the available solid angle descriptions. Available options include: 1. Scatter rays through a close curve 2. Scatter rays into given direction 3. Scatter rays toward an entity 4. Scatter rays toward a point 5. Scatter rays into the specular direction 6. Scatter rays toward an ellipsoidal volume *NOTE: Each of these options is described in more detail below.*	Scatter rays into a given direction
Other Data		
Number of scatter rays	Sets the number of rays to be scattered into this solid angle per incident ray.	10
Solid angle scale factor	Sets the solid angle scale factor. This is useful when scattering towards an entity.	1
Reverse Ray Directions	This will reverse the direction of the scatter rays at the time of scatter event.	Not Selected

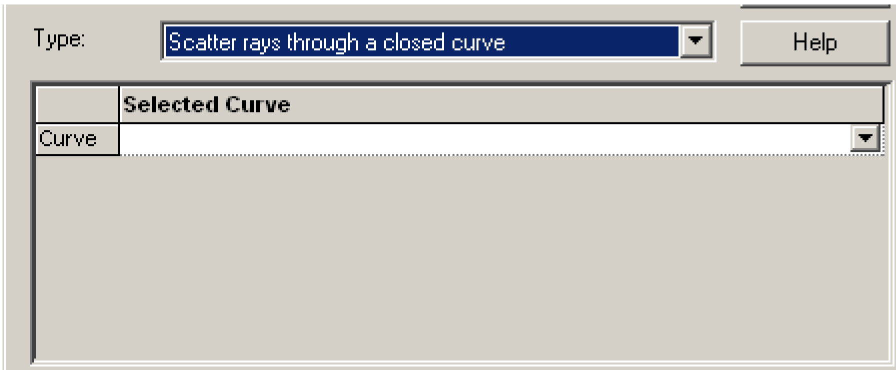
Fractional hole in Solid Angle	Allows a central hole in the solid angle to be defined, in effect making an annular solid angle region.	0
OK	Accept Importance Sampling Specifications changes and close dialog box.	
Cancel	Discard Importance Sampling Specifications changes and close dialog box.	
Help	Access this Help page.	

Scatter rays into a given direction



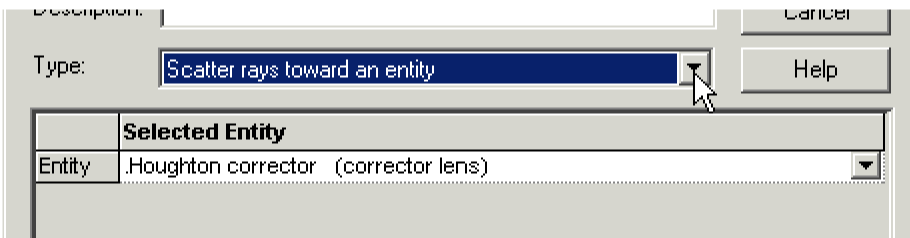
Control	***Inputs***	***Defaults***
Angle	The angle around the direction vector defined.	90
X	X component of the direction cosine.	0
Y	Y component of the direction cosine.	0
Z	Z component of the direction cosine, note that the relationship between these angles is: $X^2 + Y^2 + Z^2 = 1$.	1
Entity	Coordinate system of the direction vector.	Global Coordinate system

Scatter rays through a closed curve



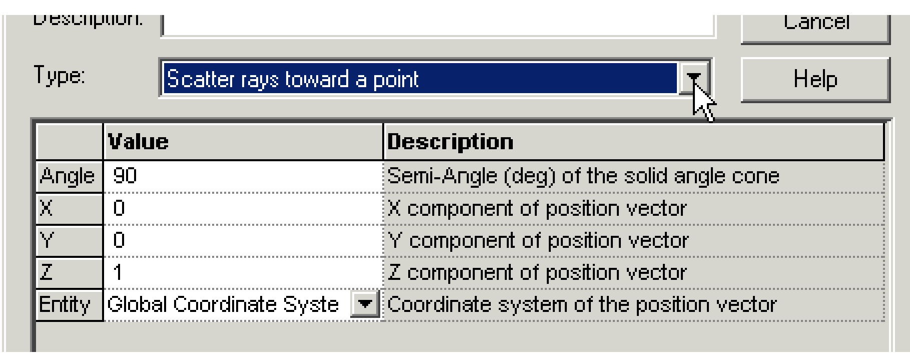
Control	*Inputs*	*Defaults*
Curve	Pull down menu of all the curves defined in the FRED document. Only the closed curves will be listed in the pull down menu.	Blank

Scatter rays toward an entity



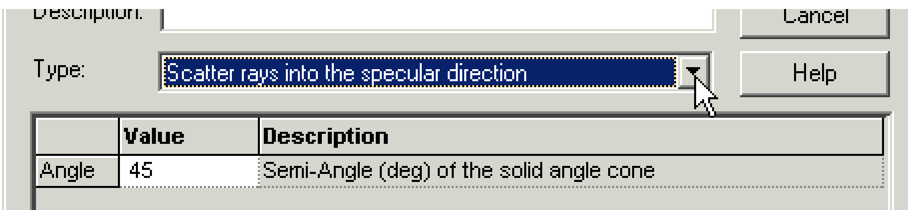
Control	*Inputs*	*Defaults*
Entity	Pull down menu of all the objects defined in the FRED document.	Blank

Scatter rays toward a point



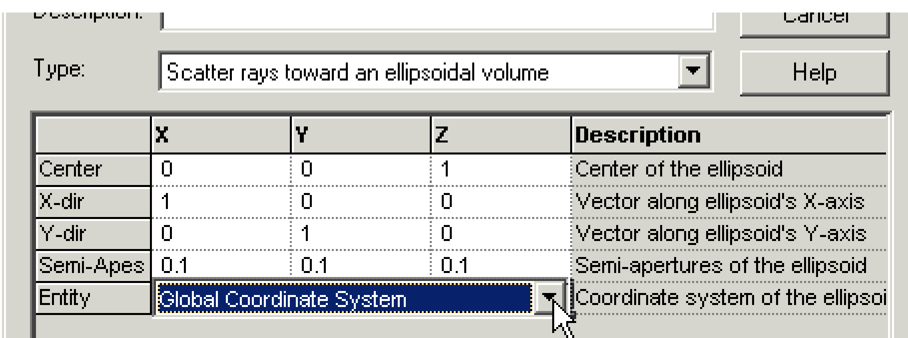
Control	*Inputs*	*Defaults*
Angle	The angle around the direction vector defined.	90
X	X component of the position vector to the point.	0
Y	Y component of the position vector to the point.	0
Z	Z component of the position vector to the point.	1
Entity	Coordinate system of the direction vector.	Global Coordinate system

Scatter rays into the specular direction



Control	*Inputs*	*Defaults*
Angle	Semi-angle around the specular direction of the reflected or refracted parent ray.	45

Scatter rays towards an ellipsoidal volume



Control	*Inputs*	*Defaults*
Center	X, Y, and Z coordinates of the center of the ellipsoid.	0,0,1

X-dir	Vector along the ellipsoid's X-axis.	1,0,0
Y-dir	Vector along the ellipsoid's Y-axis.	0,1,0
Semi-Apes	Semi-apertures of the ellipsoid in the X, Y, and Z directions.	0.1, 0.1, 0.1
Entity	Coordinate system of the ellipsoid coordinates.	Global Coordinate system

Edit/Create New Scatter Model – ABg

Description

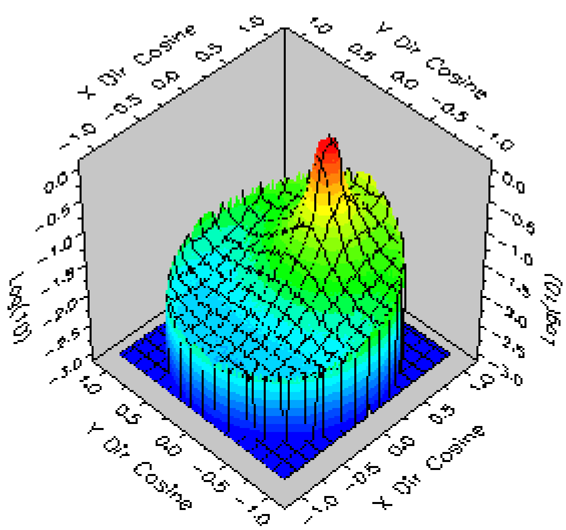
Edit/Create New Scatter Model - ABg

Like the Harvey-Shack scatter model, the ABg scatter model describes a smooth surface BSDF. It has a logarithmic falloff from specular, with a slope parameter given by G. It can apply on both transmission and reflection if the Raytrace Controls allow it.

Visualization (example)

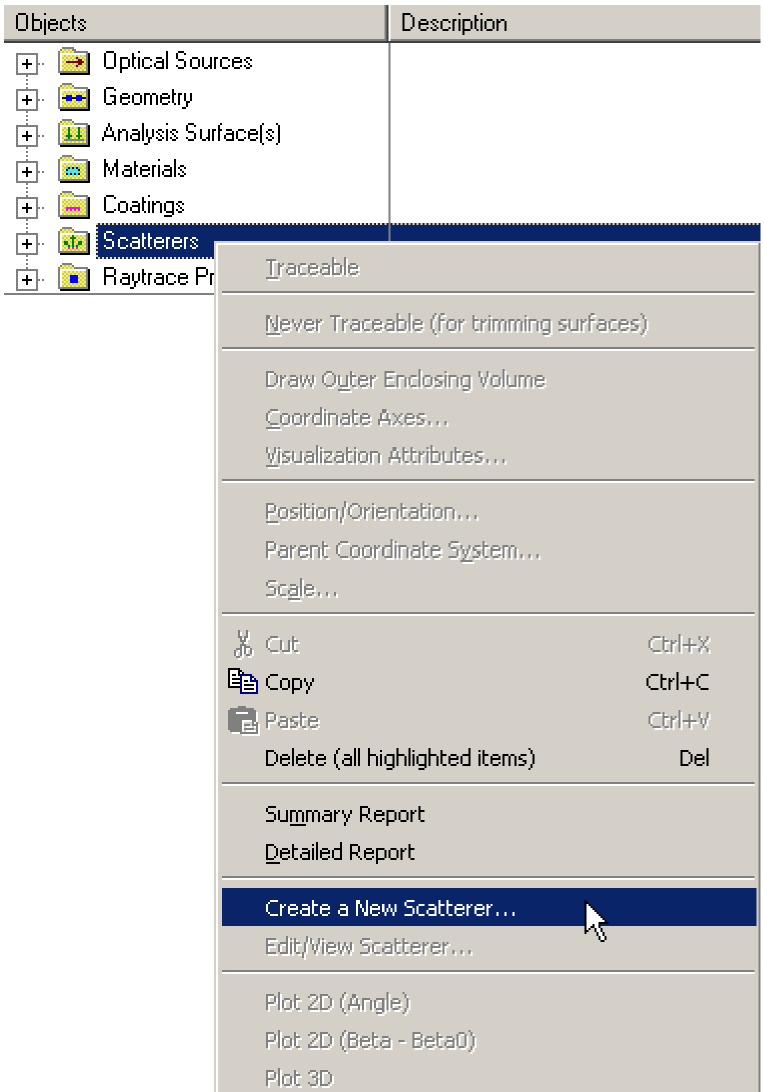
Edit/Create New Scatter Model - ABg

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The ABg scatter parameters are Acoef = .0025, Bcoef = .001, G = 1.8. The specular angle is 30 degrees.

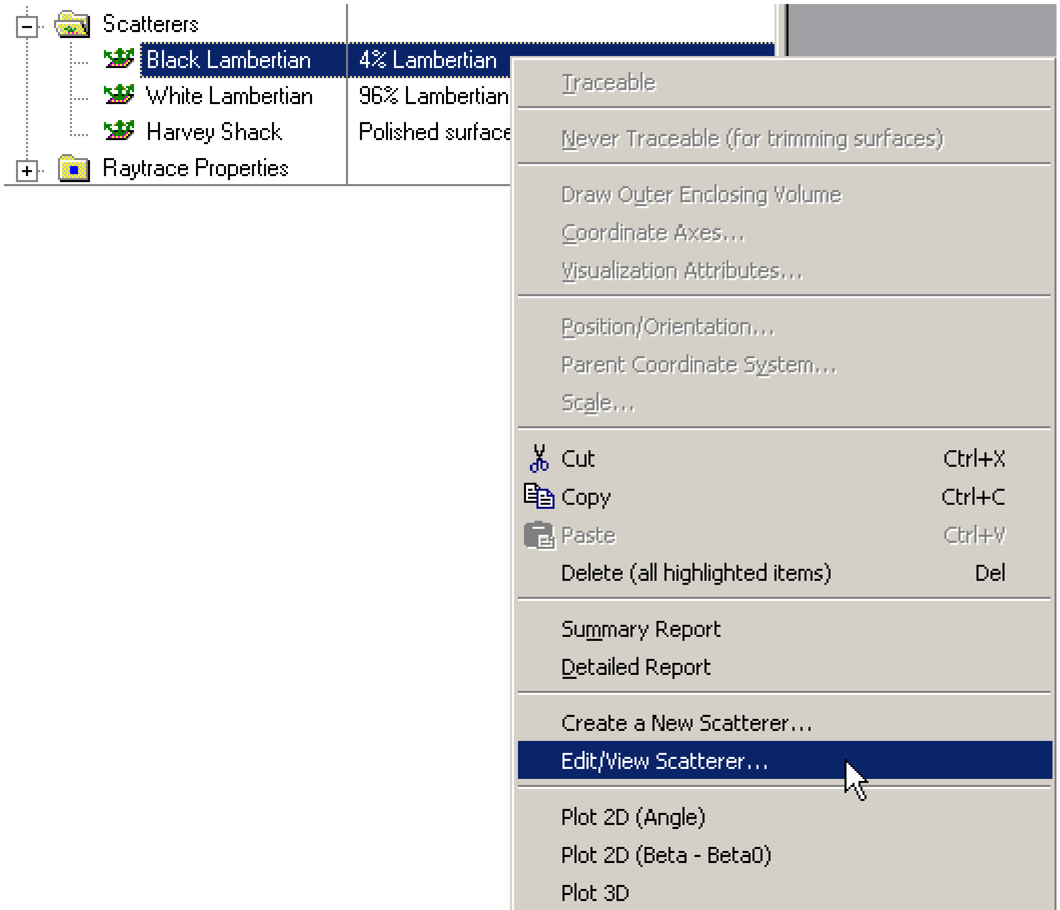


There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option '*Create a New Scatterer…*'

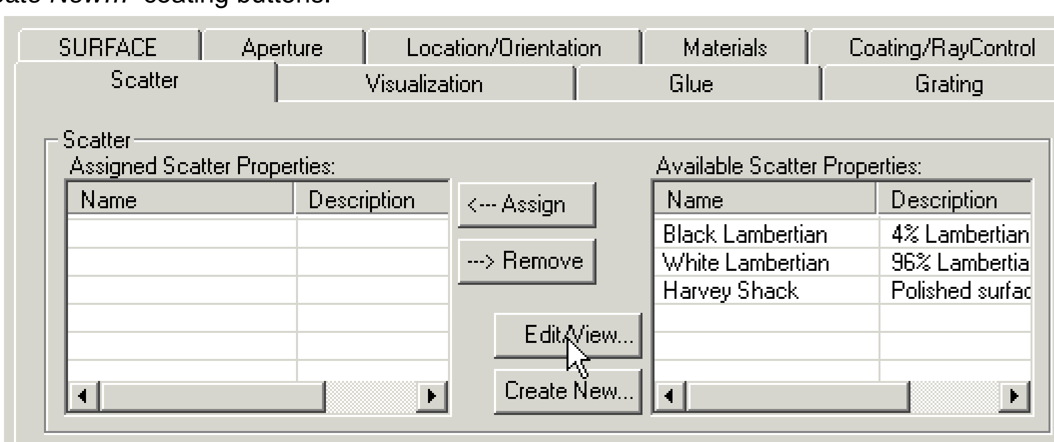


2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer…*'.

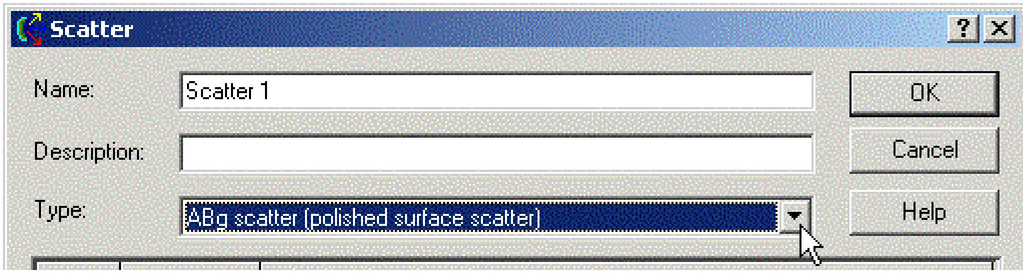


3. Expand the Scatterers folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the Surface dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.



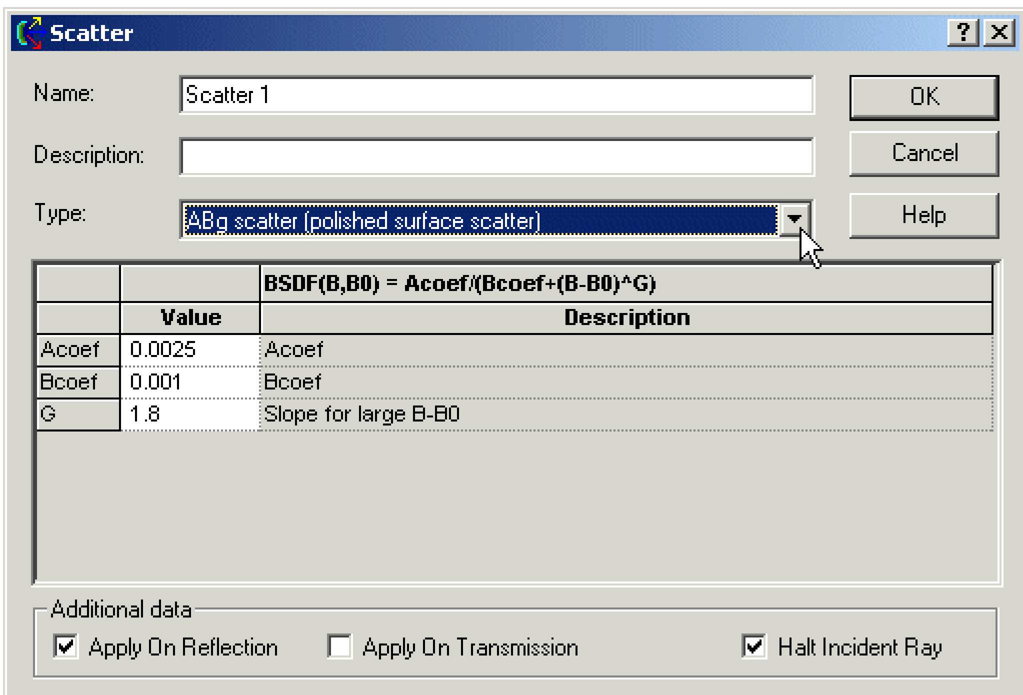
When the Scatter dialog has been opened, select ABg scatter from the list of available models.



After a new Scatter model has been created, the model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls

Edit/Create New Scatter Model - ABg



Control	Inputs	Defaults
Name	Name of the model (required).	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **ABg scatter** from the pull down menu.	Lambertian
Acoef	Value of the A coefficient.	0.0025
Bcoef	Value of the B coefficient.	.001

G	Slope of the BSDF at large B-B0.	1.8
Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Script Commands
Edit/Create New Scatter Model - ABg

Commands

- **Subroutines**
  AddAbgScatter *YourScatter*
  SetAbgScatter *IndexInScatterList*, *YourScatter*
  GetAbgScatter *IndexInScatterList*, *YourScatter*
- **Functions**
  None

Associated Data Type

- **Type Name**
  T_ABGSCATTER
- **Type Members**
  Name – (string) holds the name of the model. Default is an empty string.
  Description – (string) holds the description of the model. Default is an empty string.
  Acoef – (double) The value of the A coefficient. Default is 0.
  Bcoef - (double) The value of the B coefficient. Default is 0.
  G - (double) The value of the BSDF slope at large B-B0. Default is 0.
  ApplyRefl – (Boolean) Applies the scatter model on reflection. Default is False.
  ApplyTrans - (Boolean) Applies the scatter model on transmission. Default is False.
  HaltIncident - (Boolean) Halts the incident ray. Default is False.

Examples

- This example adds an ABg Scatter model to the FRED file associated with this script.

```
Dim s As T_ABGSCATTER
s.Name = "Example ABg Scatter"
s.Description = "Sample from FRED documentation"
s.Acoef = 0.0002
s.Bcoef = 0.002
s.G = 3.0
s.ApplyRefl = true
s.ApplyTrans = true
s.HaltIncident = true
AddAbgScatter s
```

- This example sets the fourth Scatter model's name to "Example ABg Scatter 2", as long as that scatter model is an ABg scatter model. It fails if it is any other scatter type.

```
Dim s As T_ABGSCATTER
s.Name = "Example ABg Scatter 2"
SetAbgScatter4, s
```

- This example gets the fourth Scatter model and prints its name, as long as that scatter model is an ABg scatter model. It fails if it is any other scatter type.

```
Dim s As T_ABGSCATTER
GetAbgScatter4, s
Print s.Name
```

Application Notes

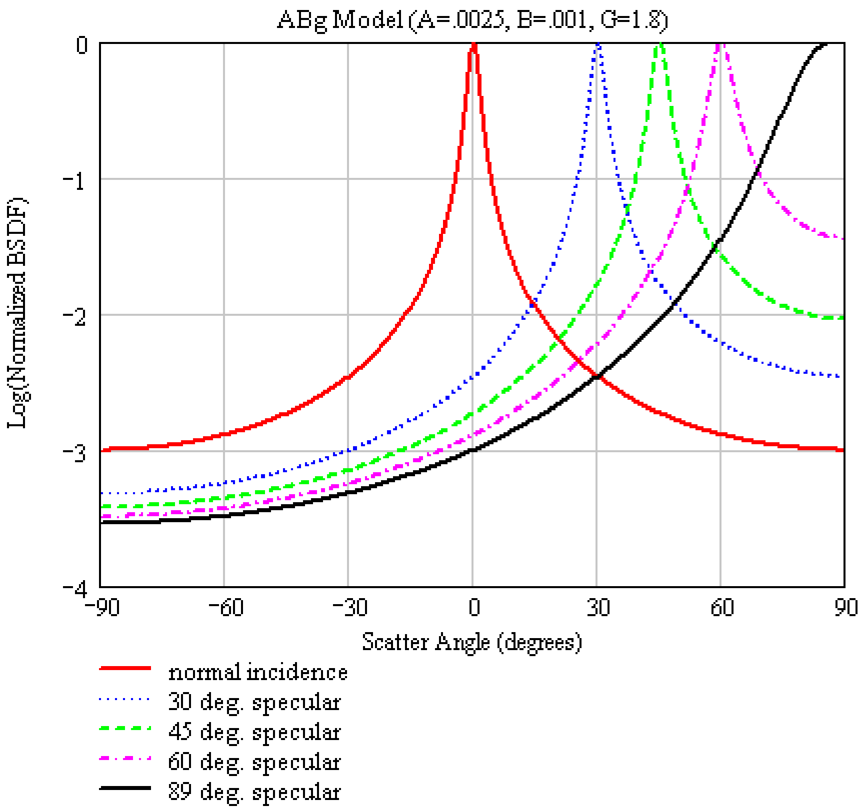
Edit/Create New Scatter Model - ABg

- The Bidirectional Scatter Distribution Function (BSDF) for the ABg model is defined as
  - $$BSDF = \frac{Acoef}{Bcoef + (|B - B0|)^{G}}$$
- The ABg model is linear shift invariant, which means that the BSDF depends only on the difference between the sine of the specular angle (B0) and the sine of the scattered angle (B). B and B0 are always taken in the plane of the incident ray. Angles are measured relative to the surface normal.
- The relative scattered ray power in the specular direction (B-B0 = 0) is Acoef/Bcoef multiplied by the projected solid angle in the specular direction. This product cannot exceed 1 for a 100% scattering surface or the relative ray power contained in the specular ray(s). Failure to satisfy this restriction violates conservation of energy.
- The ABg model is wavelength invariant.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the **Surface Dialog**.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

The following examples show a series of line plots of the log(normalized ABg BSDF) as a function of scatter angle for specular angles of 0, 30, 45, 60, and 89 degrees.

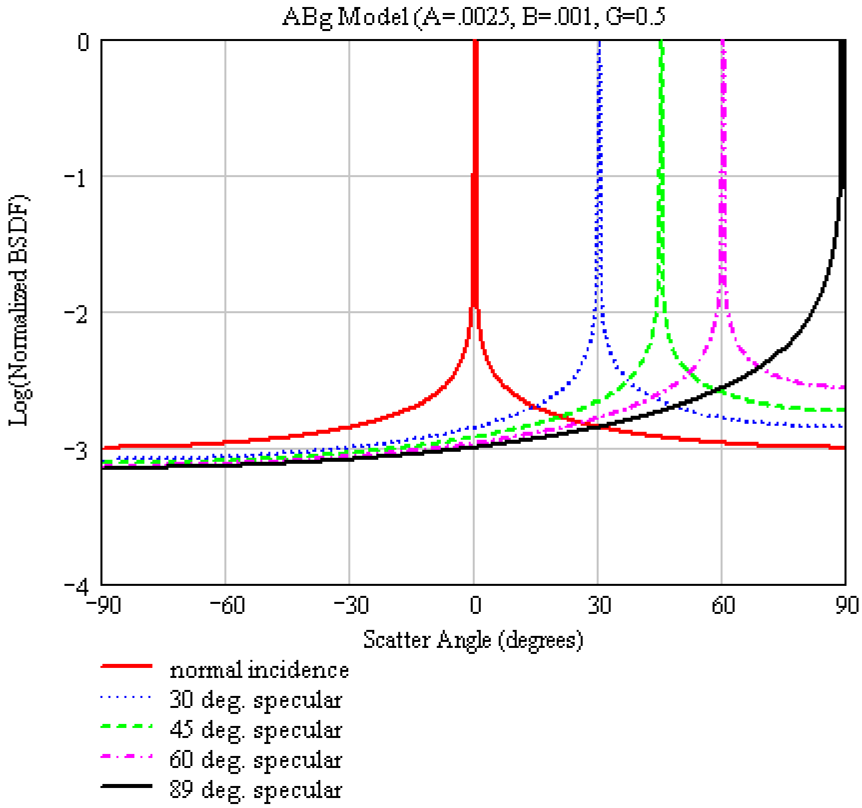
Example 1

The ABg scatter parameters for the following plot are Acoef = .0025, Bcoef = .001, G = 1.8.



Example 2

The ABg scatter parameters for the following plot are Acoef = .0025, Bcoef = .001, G = 0.5, which has the effect of narrowing the distribution function so that the bulk of the scattered light more closely follows the specular path. A small value a G is more appropriate for a smooth specular surface.



See Also….

Edit/Create New Scatter Model - ABg

The following links contain details about each of the scatter models:

- Lambertian – for diffuse scatter
- Harvey-Shack – for polished surface scatter
- Flat Black Paint – specify Total Integrated Scatter (TIS)
- Phong scatter – $\cos^n$ from specular
- Surface Particle (Mie) – for particulate contamination
- Tabulated BSDF – measured BSDF data
- Tabulated PSD – measured PSD data
- K-Correlation – analytic PSD

Edit/Create New Scatter Model – Flat Black Paint

Description

Edit/Create New Scatter Model - Flat Black Paint

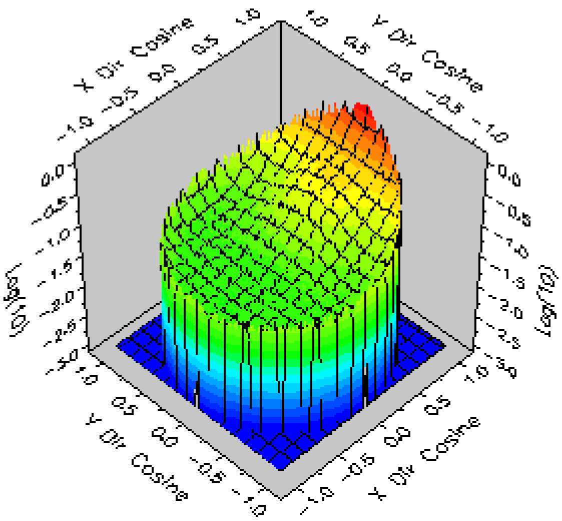
The generic Flat Black Paint BSDF is a parametric scatter model that has only one user input: the Total Integrated Scatter (TIS) at normal incidence. FRED takes the TIS value and scales the BSDF accordingly. The BSDF used in this model is a complex 3 dimensional polynomial fit to the scatter distribution from a flat surface treated with a generic flat black paint. It is near Lambertian at normal incidence. At large angles of incidence there is significant scatter in the (forward) specular direction, which is a characteristic of all flat black paints.

WARNING	The TIS entry is for normal incidence. If this entry is greater than 0.25, the scattered power at high angles of incidence can exceed the incident power, which violates conservation of energy. Use with caution.

Visualization (example)

Edit/Create New Scatter Model - Flat Black Paint

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The Flat Black Paint scatter parameters are TIS = 0.02. The specular angle is 30 degrees.

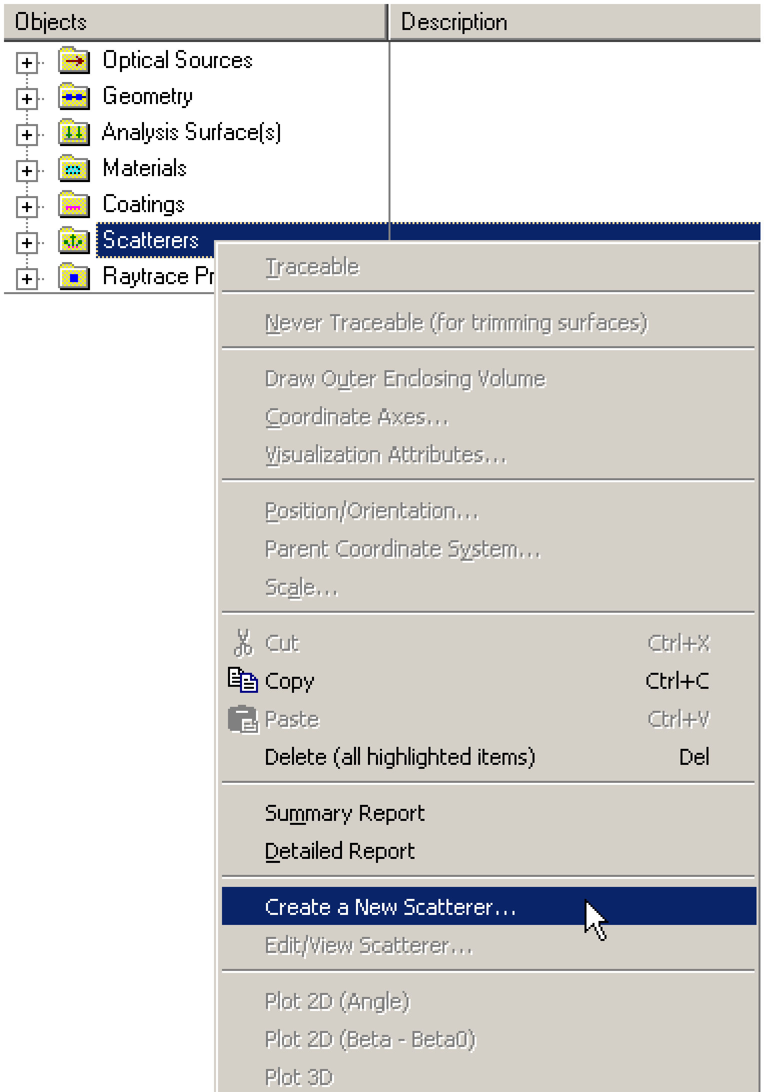


How Do I Get There?

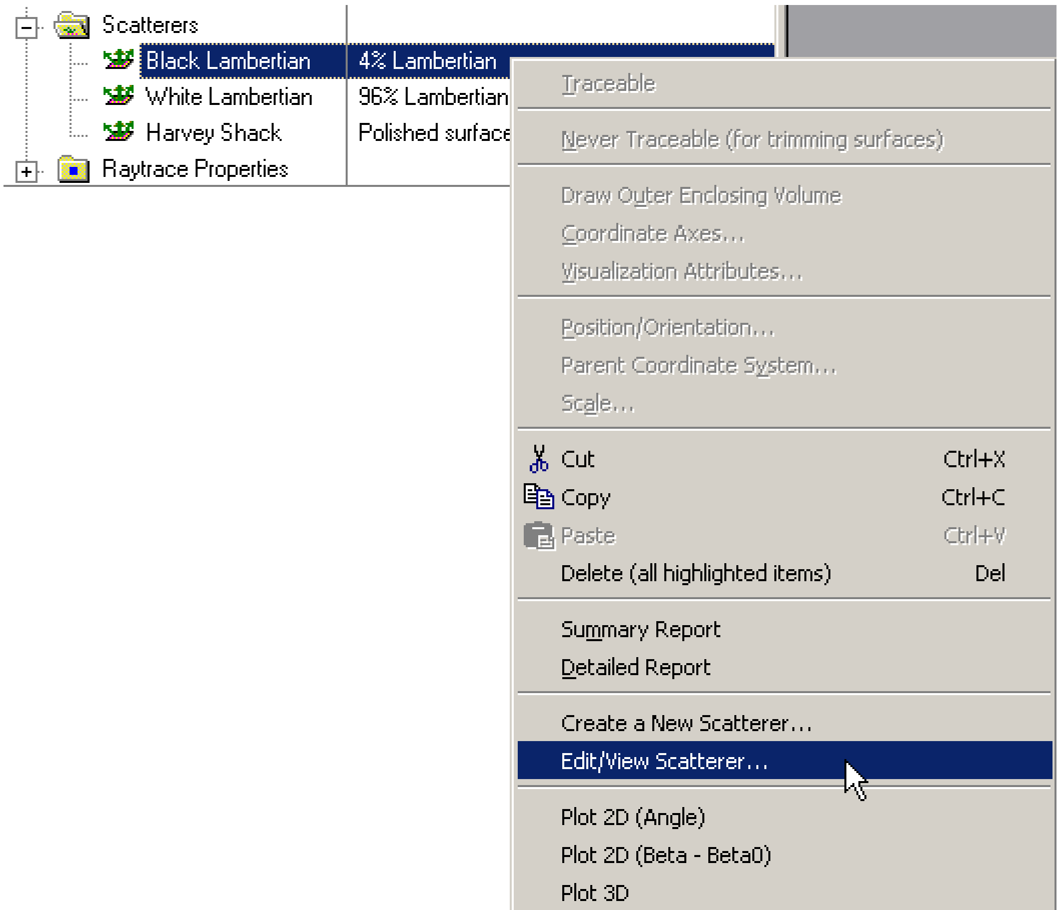
Edit/Create New Scatter Model - Flat Black Paint

There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option '*Create a New Scatterer…*'

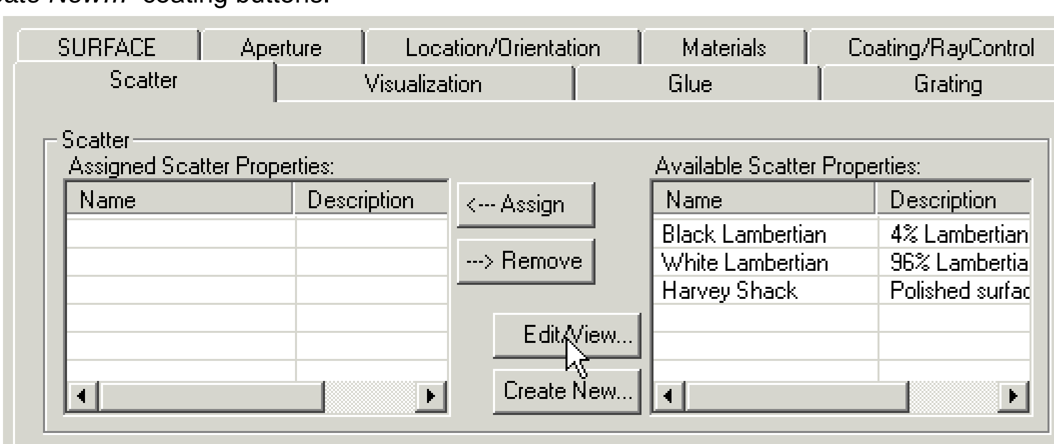


2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer…*'.

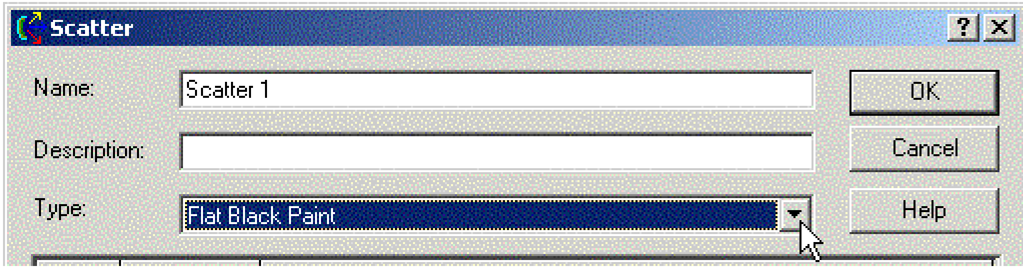


3. Expand the Scatterers folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the Surface dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.



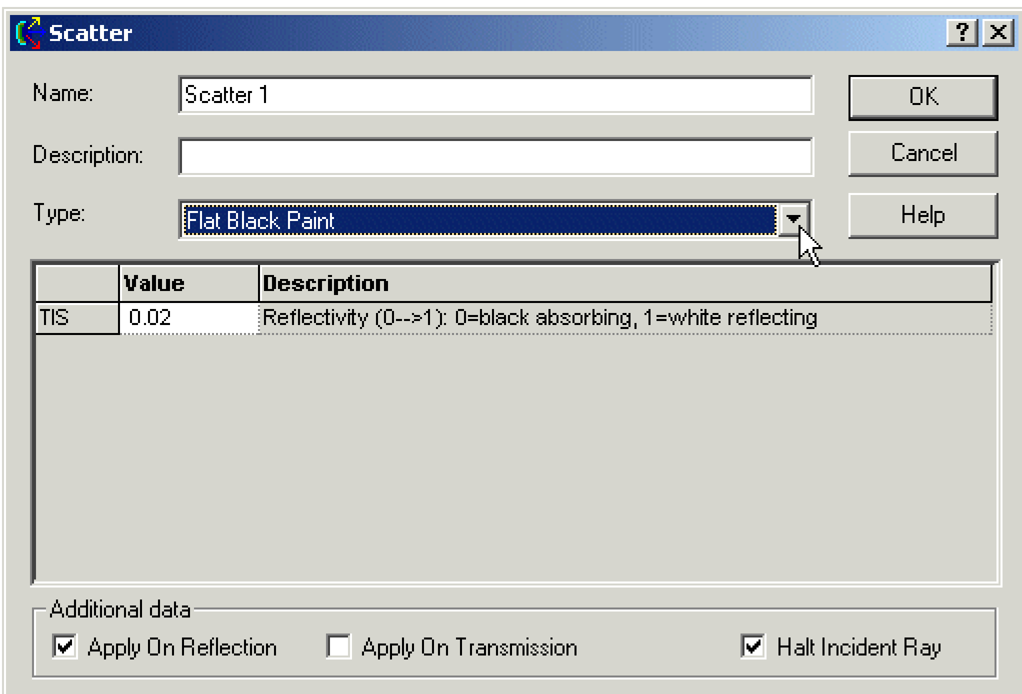
When the Scatter dialog has been opened, select Flat Black Paint from the list of available models.



After a new Scatter model has been created, its model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls

Edit/Create New Scatter Model - Flat Black Paint



Control	*Inputs*	*Defaults*
Name	Name of the model (required).	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Flat Black Paint** from the pull down menu.	Lambertian
TIS	Value of the Total Integrated Scatter (TIS) between 0 and 1.	0.02

Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Script Commands
Edit/Create New Scatter Model - Flat Black Paint

Commands

- **Subroutines**
  AddBlackPaint *YourScatter*
  SetBlackPaint *IndexInScatterList*, *YourScatter*
  GetBlackPaint *IndexInScatterList*, *YourScatter*
- **Functions**
  None

Associated Data Type

- **Type Name**
  T_BLACKPAINT
- **Type Members**
  Name – (string) holds the name of the mode. Default is an empty string.
  Description – (string) holds the description of the model. Default is an empty string.
  Refl – (double) The value of the Normal Incidence Reflectivity coefficient. Default is 0.
  Vd – (double) holds the ABBE number at the 'd' wavelength. Default is 0.
  ApplyRefl – (Boolean) Applies the scatter model on reflection. Default is False.
  ApplyTrans – (Boolean) Applies the scatter model on transmission. Default is False.
  HaltIncident – (Boolean) Halts the incident ray. Default is False.

Examples

- This example adds a Black Paint Scatter model to the FRED file associated with this script.

```
Dim s As T_BLACKPAINT
s.Name = "Black Paint Example"
s.Description = "Sample from FRED documentation"
s.Refl = 0.02
s.ApplyRefl = true
s.ApplyTrans = true
s.HaltIncident = true
AddBlackPaint s
```

- This example sets the fourth Scatter model's name to "Black Paint Example 2", as long as that scatter model is a Black Paint model. It fails if it is any other scatter type.

```
Dim s As T_BLACKPAINT
s.Name = "Black Paint Example 2"
SetBlackPaint4, s
```

- This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Black Paint model. It fails if it is any other scatter type.

```
Dim s As T_BLACKPAINT
GetBlackPaint4, s
Print s.Name
```

Application Notes

Edit/Create New Scatter Model - Flat Black Paint

- This model is intended to represent a generic black paint.
- The TIS entry is measured at normal incidence. FRED uses this entry as an offset to shift the magnitude of the BSDF up and down, but the functional form of the distribution is unchanged.
- The TIS scatter model is wavelength invariant.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the Surface Dialog.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

See Also….

Edit/Create New Scatter Model - Flat Black Paint

The following links contain details about each of the scatter models:

- Lambertian – for diffuse scatter
- Harvey-Shack – for polished surface scatter
- ABg – for polished surface scatter
- Phong scatter – $\cos^n$ from specular
- Surface Particle (Mie) – for particulate contamination
- Tabulated BSDF – measured BSDF data
- Tabulated PSD – measured PSD data

K-Correlation – analytic PSD

Edit/Create New Scatter Model – Harvey-Shack

Description

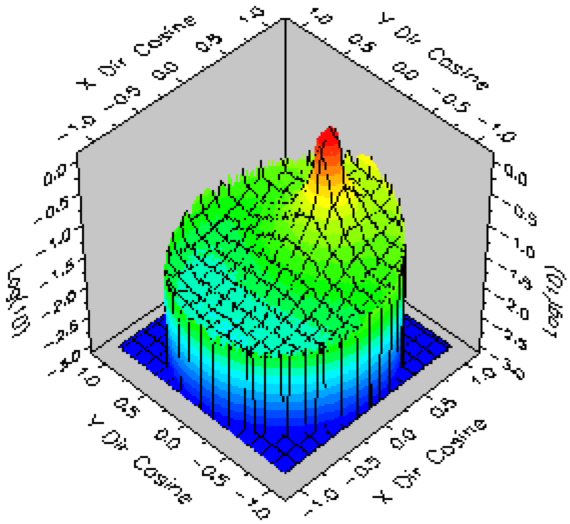
Edit/Create New Scatter Model - Harvey-Shack

The Harvey-Shack scatter model is generally applied to smooth optical surfaces. This model uses a rollover specification (L) that transitions the BSDF to a constant value (b0) at near-specular angles. Large angle scatter is linear in log space with a slope parameter S, which typically lies between –1 and –2.5. The model can be applied in both transmission and reflection if the Raytrace Controls allow it.

Visualization (example)

Edit/Create New Scatter Model - Harvey-Shack

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The Harvey-Shack scatter parameters are b0 = 0.1, L = .01, and S = -1.5. The specular angle is 30 degrees.

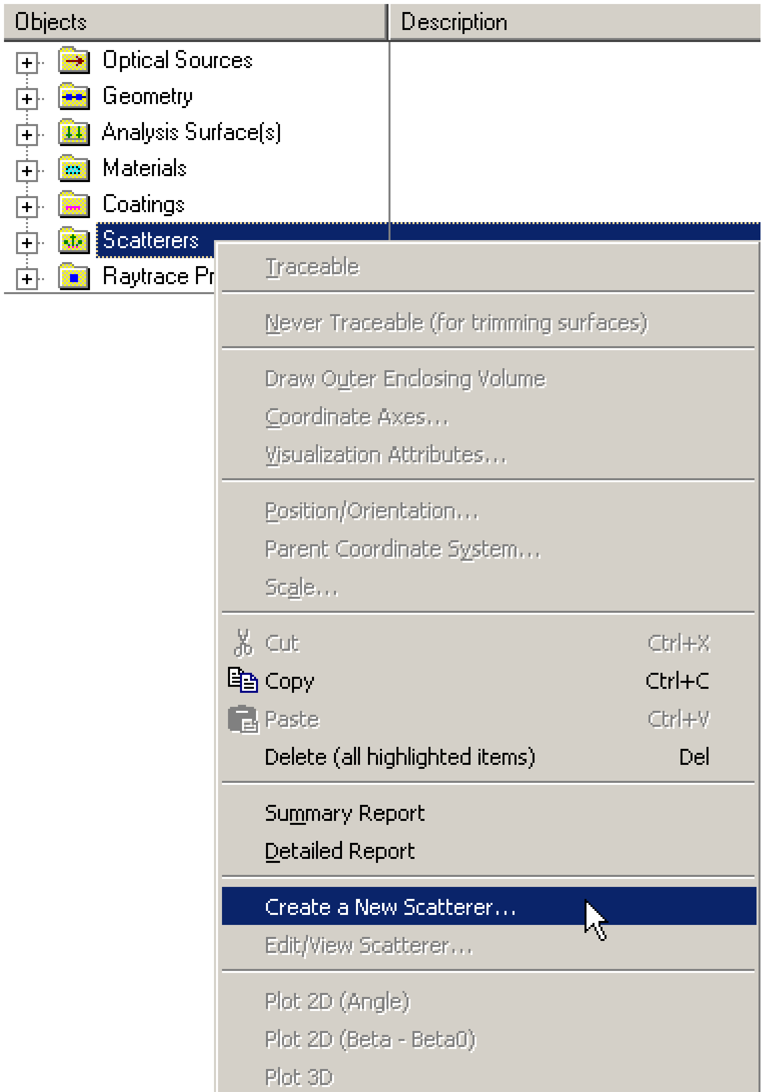


How Do I Get There?

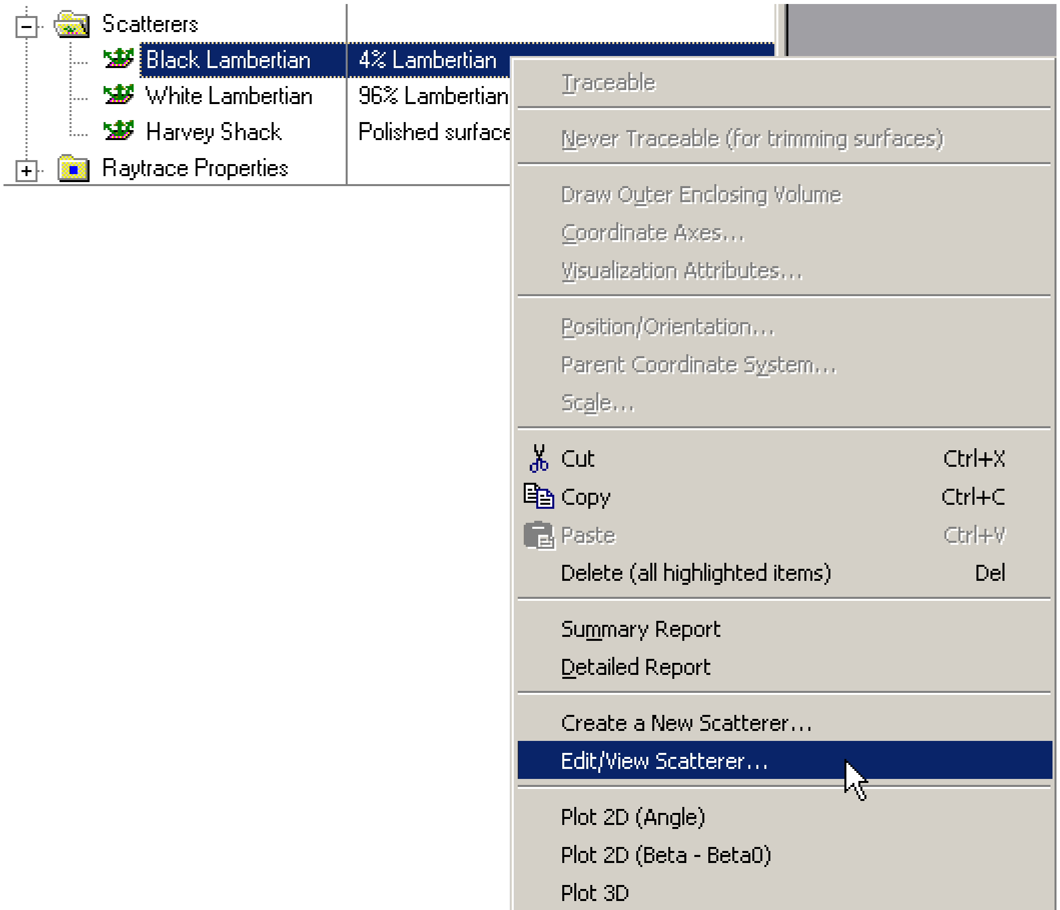
Edit/Create New Scatter Model - Harvey-Shack

There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option '*Create a New Scatterer…*'

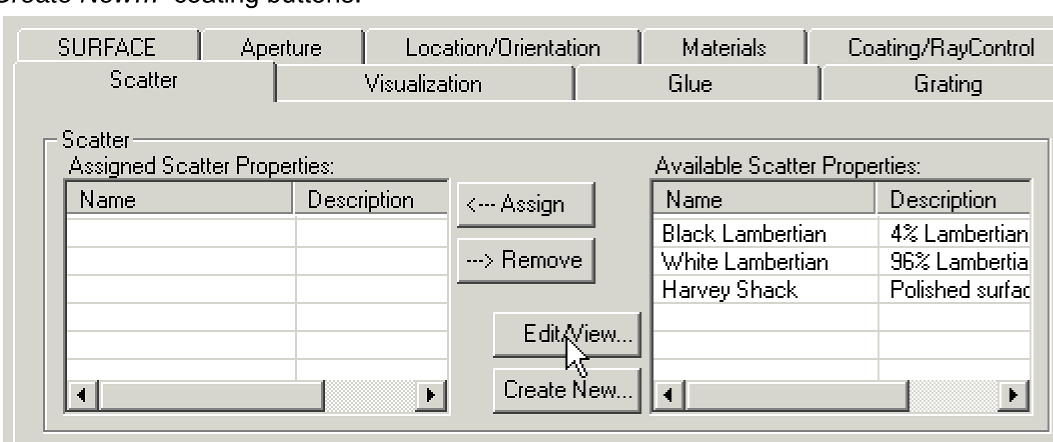


2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer…*'.

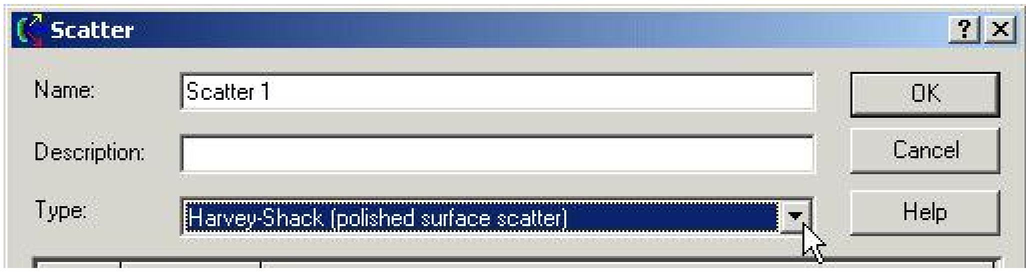


3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.



When the Scatter dialog has been opened, select Harvey-Shack scatter from the list of available models.

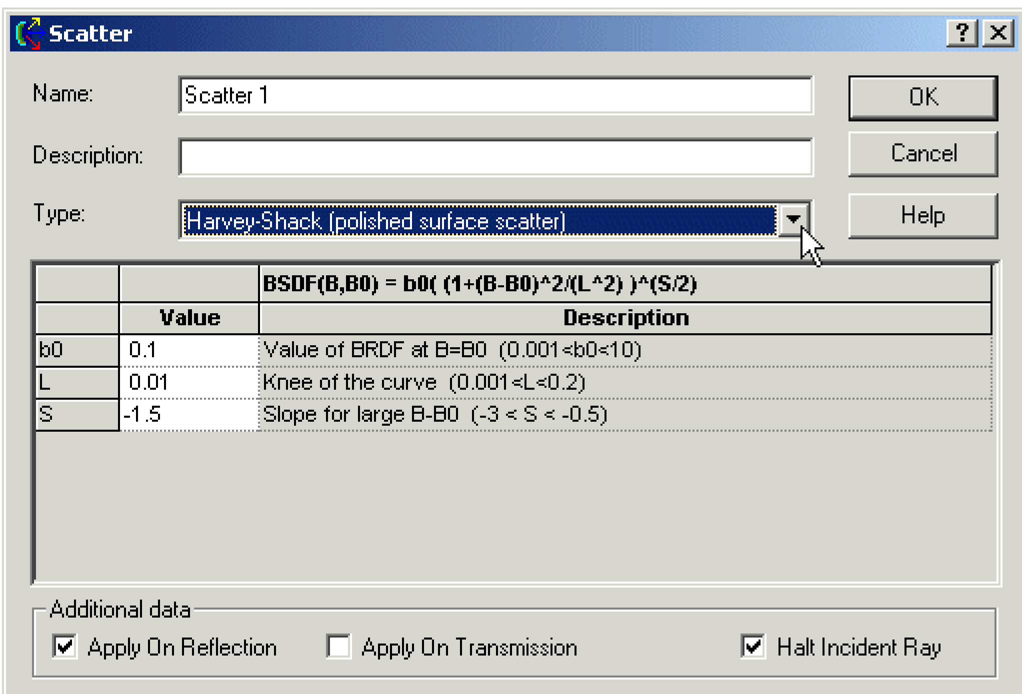


After a new Scatter model has been created, the model Type cannot be changed. Only the input parameters can be changed

.

Dialog Box and Controls

Edit/Create New Scatter Model - Harvey-Shack



Control	Inputs	Defaults
Name	Name of the model (required).	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Harvey-Shack** from the pull down menu.	Lambertian
B0	Value of the BRDF at B = B0.	0.1

L	Value of the near specular BSDF rollover point (L=B-B0).	.01
S	Slope of the BSDF at large B-B0.	-1.5
Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Script Commands

Edit/Create New Scatter Model - Harvey-Shack

Commands

- **Subroutines**

  AddHarveyShackScatter *YourScatter*
  SetHarveyShackScatter *IndexInScatterList*, *YourScatter*
  GetHarveyShackScatter *IndexInScatterList*, *YourScatter*

- **Functions**

  None

Associated Data Type

- **Type Name**

  T_HARVEYSHACKSCATTER

- **Type Members**

  Name – (string) Holds the name of the model. Default is an empty string.

  Description – (string) Holds the description of the model. Default is an empty string.

  B0 – (double) Value of the BRDF when B=B0. Default is 0.

  L – (double) Knee of the curve. Default is 0.

  S – (double) Slope for large B-B0. Default is 0.

  ApplyRefl – (Boolean) Applies the scatter model on reflection. Default is False.

  ApplyTrans – (Boolean) Applies the scatter model on transmission. Default is False.

  HaltIncident – (Boolean) Halts the incident ray. Default is False.

Examples

- This example adds a Harvey-Shack Scatter model to the FRED file associated with this script.

```
Dim s As T_HARVEYSHACKSCATTER
s.Name = Harvey-Shack Example"
s.Description = "Sample from FRED documentation"
s.b0 = 0.2
s.L = 0.02
s.S = -2
s.ApplyRefl = true
s.ApplyTrans = true
s.HaltIncident = true
AddHarveyShackScatter s
```

- This example sets the fourth Scatter model's name to "Harvey-Shack Example 2", as long as that scatter model is a Harvey-Shack model. It fails if it is any other scatter type.

```
Dim s As T_HARVEYSHACKSCATTER
s.Name = "Harvey-Shack Example 2"
SetLambertianScatter4, s
```

- This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Harvey-Shack model. It fails if it is any other scatter type.

```
Dim s As T_HARVEYSHACKSCATTER
GetHarveyShackScatter4, s
Print s.Name
```

Application Notes

Edit/Create New Scatter Model - Harvey-Shack

- The Bidirectional Scatter Distribution Function (BSDF) for the Harvey-Shack model is defined by the following function
   - $$BSDF = b_0 \left(1 + \frac{(B - B0)^2}{L^2} \right)^{S/2}$$
- The Harvey-Shack model is linear shift invariant, which means that the BSDF depends only on the difference between the sine of the specular angle (B0) and the sine of the scattered angle (B). B and B0 are always taken in the plane of the incident ray. Angles are measured relative to the surface normal.
- The relative scattered ray power in the specular direction (B-B0 = 0) is b0 multiplied by the projected solid angle in the specular direction. This product cannot exceed 1 for a 100% scattering surface or the relative ray power contained in the specular ray(s). Failure to satisfy this restriction violates conservation of energy.
- The BSDF at large angles is linear in the log space of B-B0. The slope of the line is S with S < -1. A typical value for S is between –2.5 and –1.
- This form of the Harvey-Shack model has a near specular roll-off angle (or shoulder) located at B-B0 = L. The default setting is .01 radians (0.573 degrees), which represents a good quality (low RMS roughness) surface.
- The Harvey-Shack model is wavelength invariant.

- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the **Surface Dialog**.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

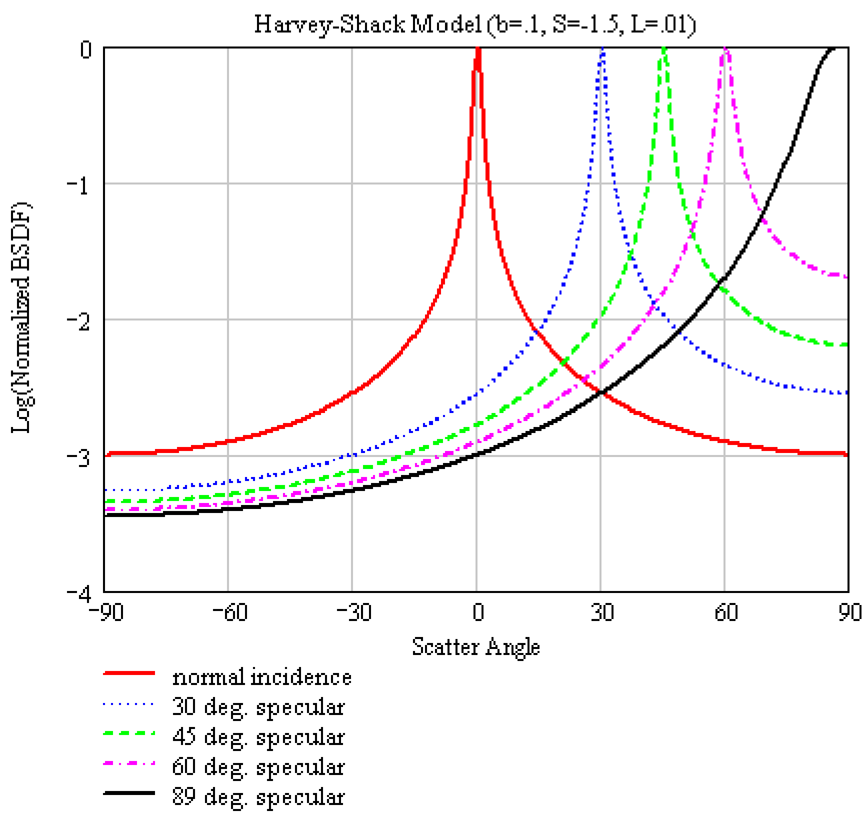
Examples

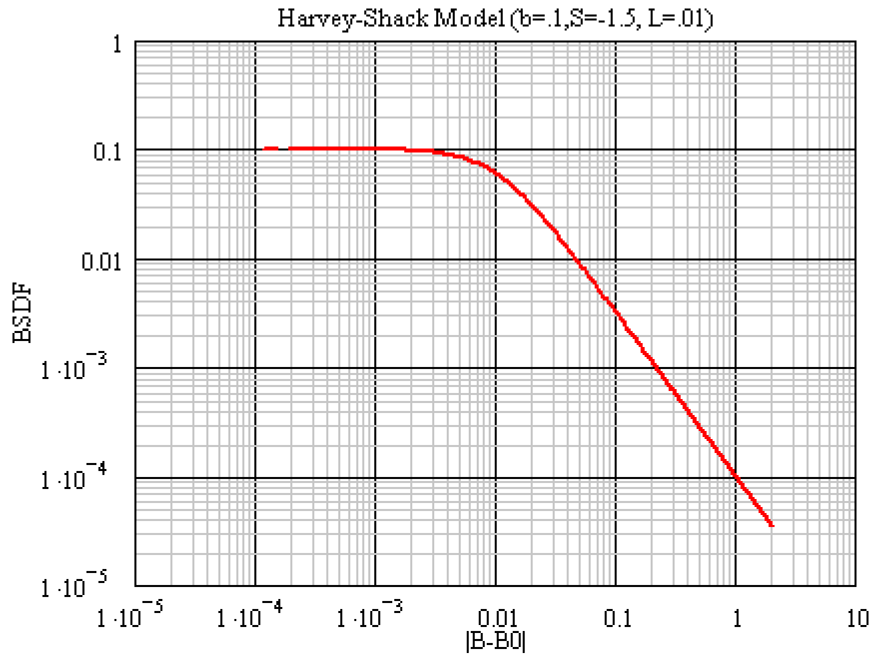
Edit/Create New Scatter Model - Harvey-Shack

The following examples show a series of line plots of the Harvey-Shack BSDF as a function of scatter angle for specular angles of 0, 30, 45, 60, and 89 degrees. To illustrate the effect that changing L and S have on the scatter distribution, it is helpful to look at the function in log space. Each pair of plots to follow will show the angle space plot (as above) and its corresponding large angle specular log space plot. The ordinate axes for the log space plots are BSDF on the Y-axis, and |B-B0| on the X-axis.

Example 1

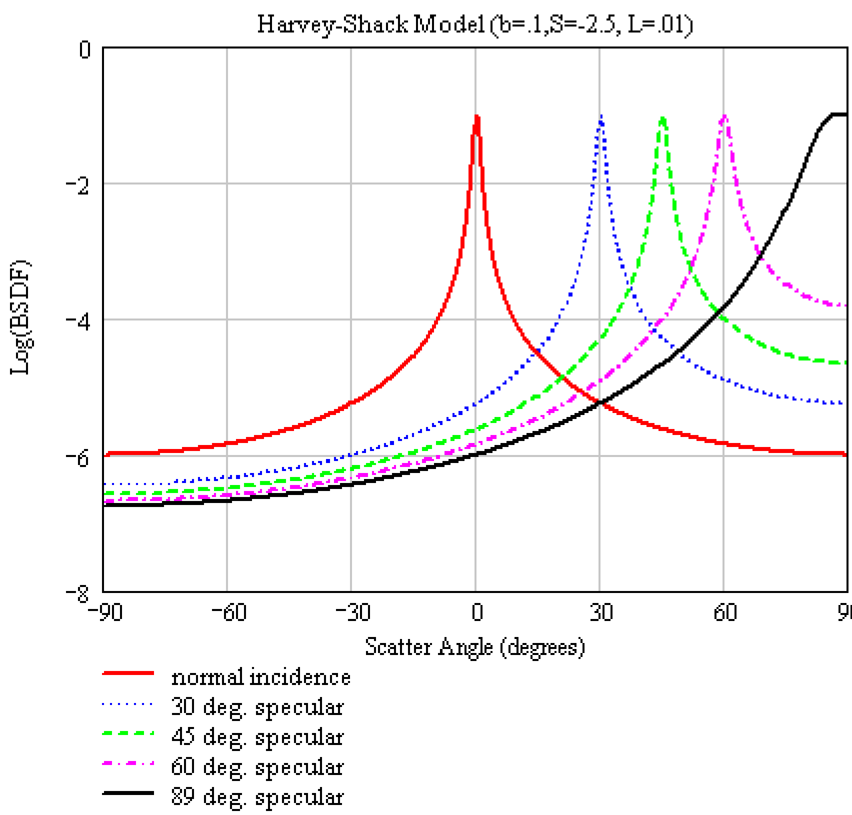
The Harvey-Shack scatter parameters are b0 = 0.1, L = .01, and S = -1.5.

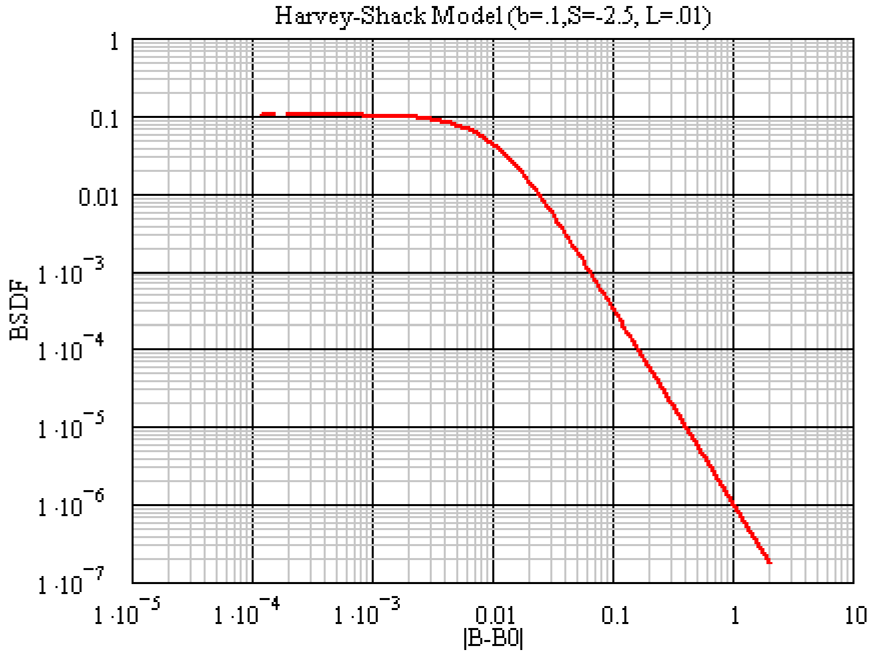




Example 2

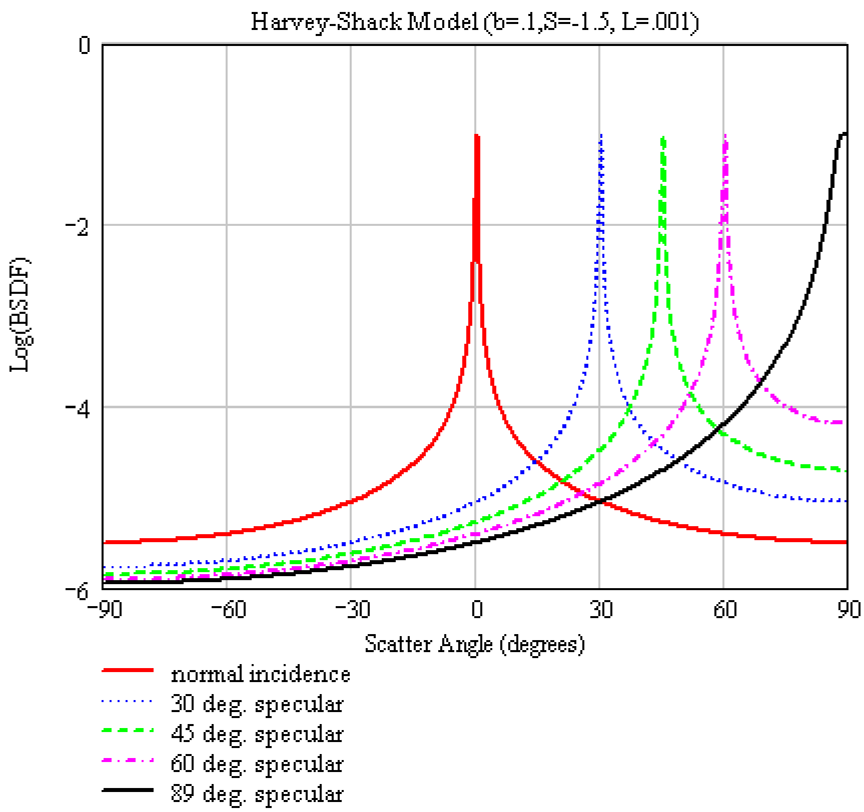
The Harvey-Shack scatter parameters are b0 = 0.1, L = .01, and S = -2.5. Changing the value of S from –1.5 to –2.5 causes the large angle scatter to fall off more rapidly.

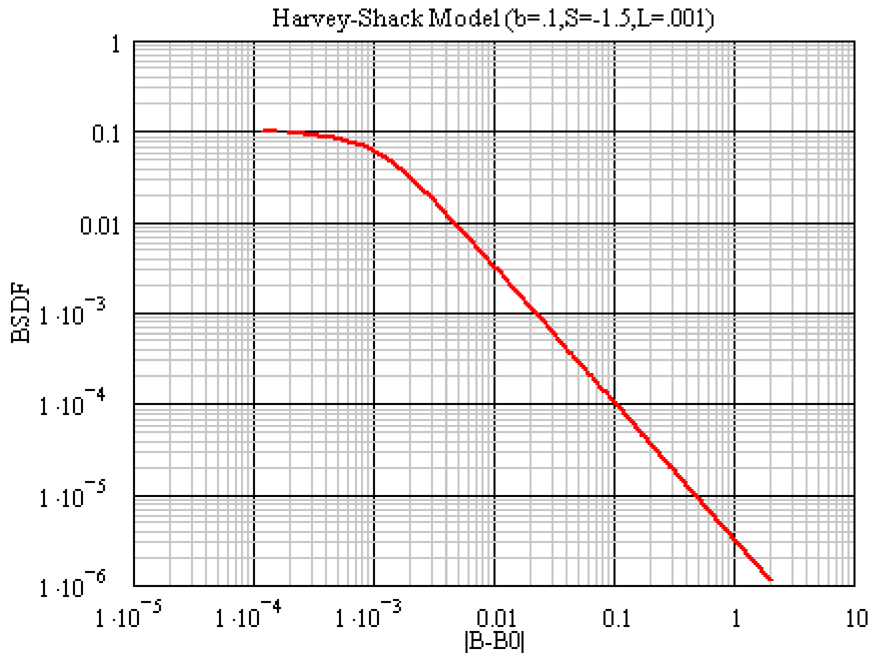




Example 3

The Harvey-Shack scatter parameters are b0 = 0.1, L = .001, and S = -1.5. Changing the value of L from .01 to .001 shifts the roll-off angle closer to specular, which has the effect of directing more of the scattered light into the specular direction. This also attenuates large angle scatter.





See Also….

Edit/Create New Scatter Model - Harvey-Shack

The following links contain details about each of the scatter models:

- Lambertian – for diffuse scatter
- ABg – for polished surface scatter
- Flat Black Paint – specify Total Integrated Scatter (TIS)
- Phong scatter – $\cos^n$ from specular
- Surface Particle (Mie) – for particulate contamination
- Tabulated BSDF – measured BSDF data
- Tabulated PSD – measured PSD data
- K-Correlation – analytic PSD

Edit/Create New Scatter Model - Lambertian

Description

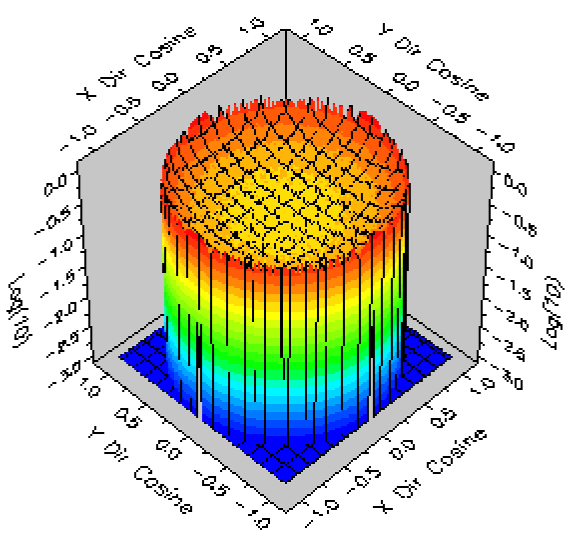
Edit/Create New Scatter Model - Lambertian

The Lambertian scatter model is typically used to simulate a perfect diffuser. Unlike other models, the BSDF does not depend on either the angle of incidence or the specular ray direction(s). The predefined models Black Lambertian and White Lambertian are both of this type.

Visualization (example)

Edit/Create New Scatter Model - Lambertian

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The Lambertian scatter parameter is reflectivity = 0.04. The specular angle is 30 degrees.

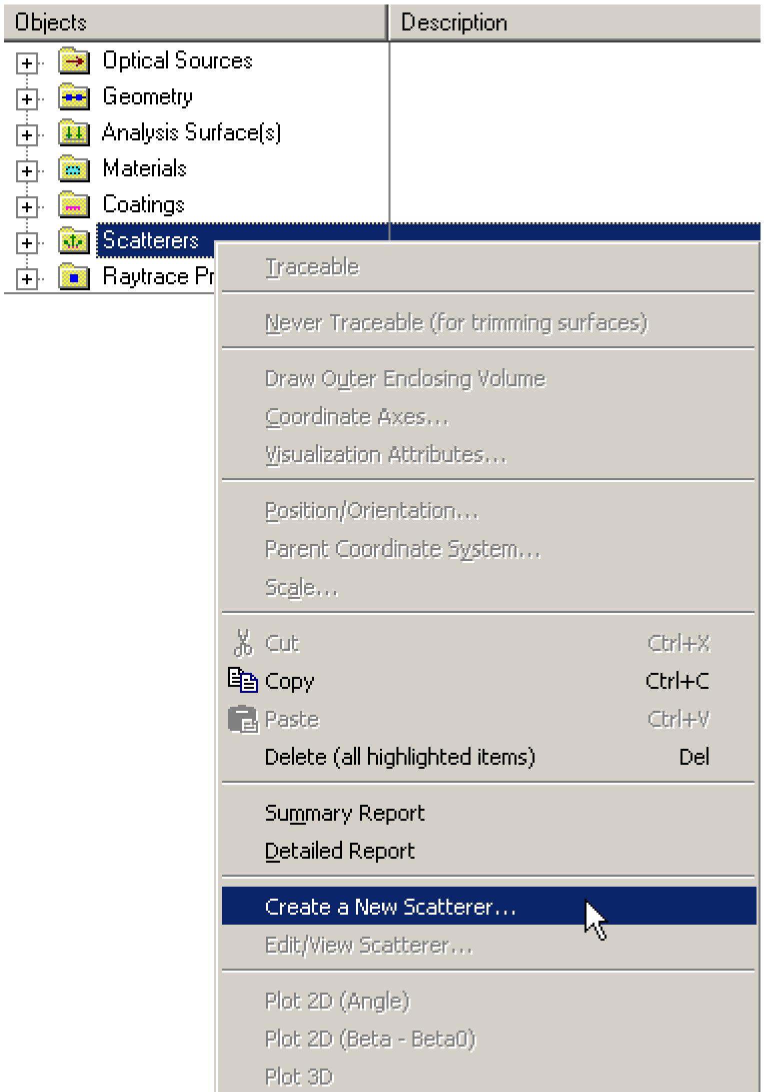


How Do I Get There?

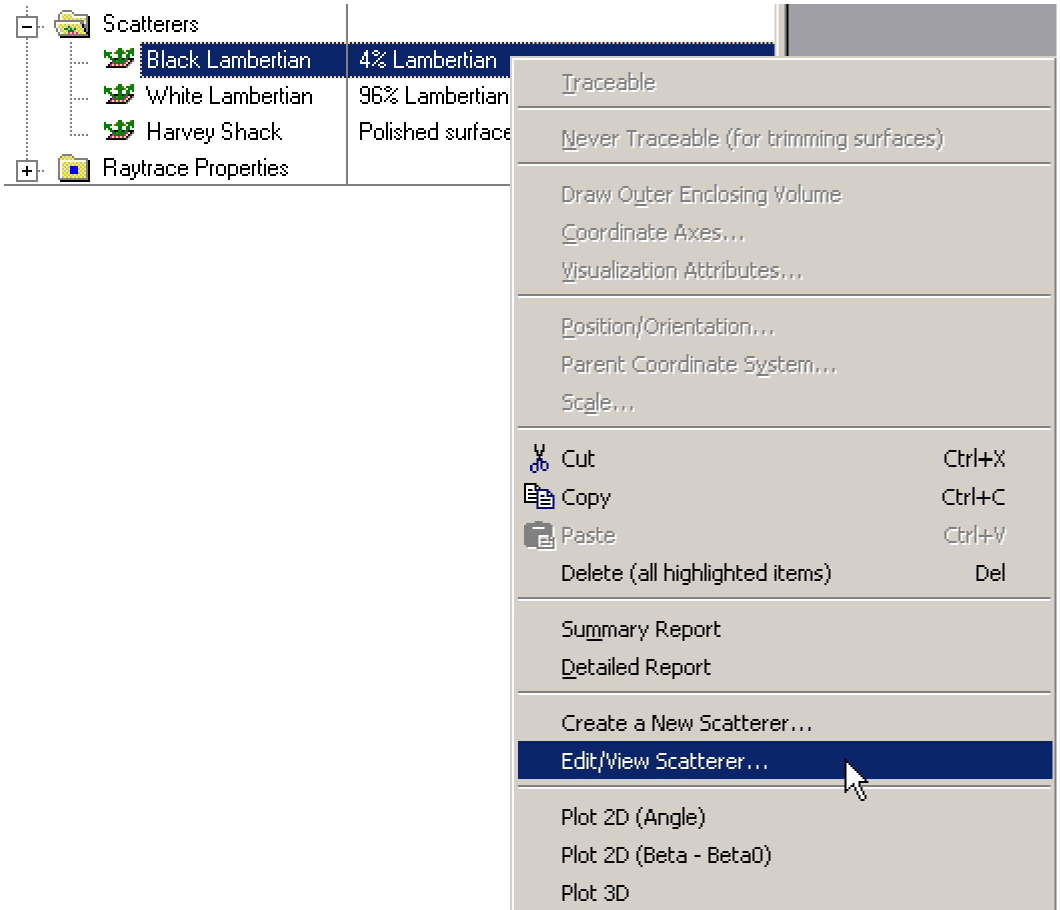
Edit/Create New Scatter Model - Lambertian

There are four ways to open a Scatter model dialog.

1. Right click on the **Scatterers** folder to open a the pop-up menu and select the option '*Create a New Scatterer…*'

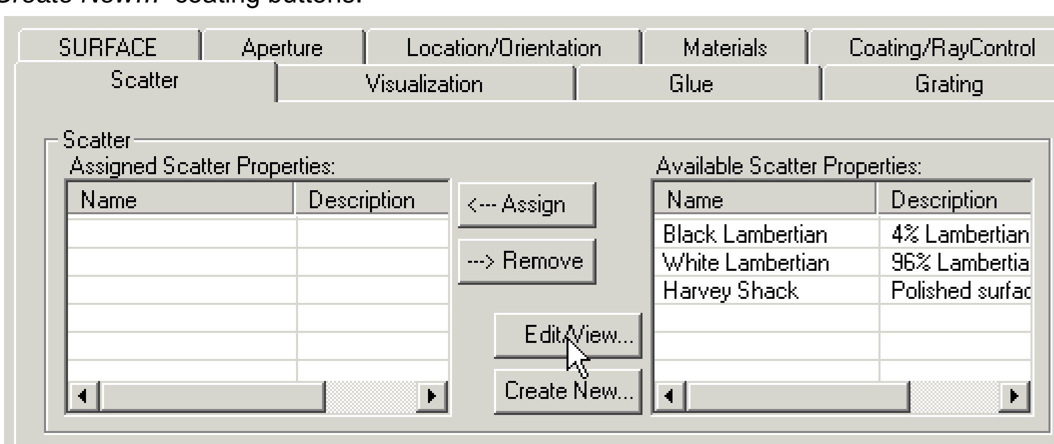


2. Expand the **Scatterers** folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer…*'.



3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.

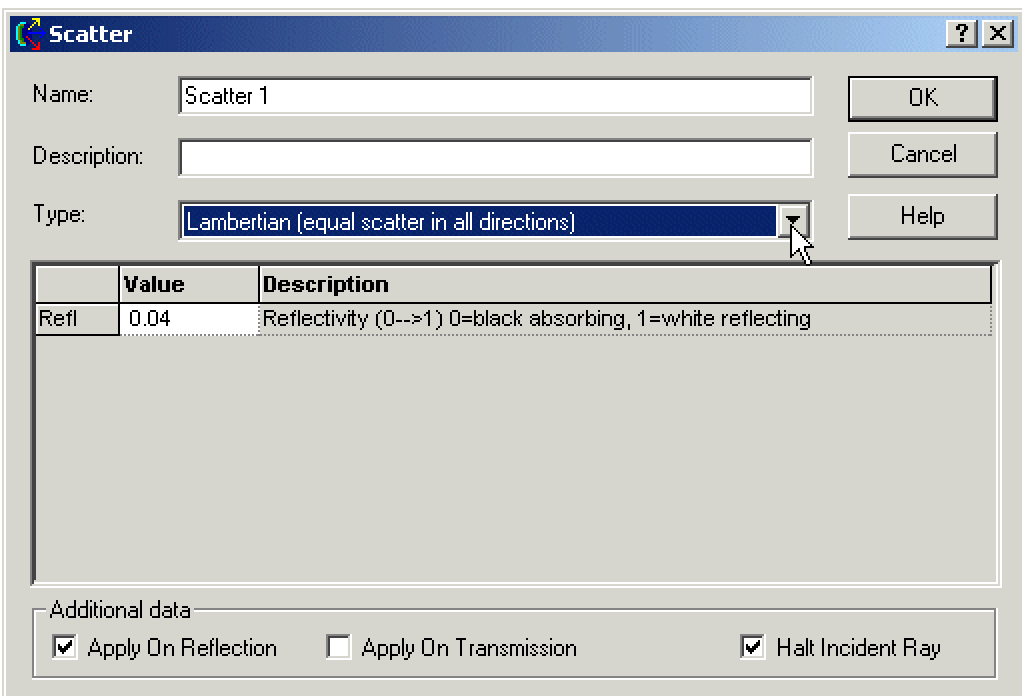


When the Scatter dialog has been opened, select Lambertian from the list of available models.

After a new Scatter model has been created, its model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls

Edit/Create New Scatter Model - Lambertian



Control	Inputs	Defaults
Name	Name of the model (required).	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Lambertian** from the pull down menu.	Lambertian
Refl	Diffuse reflectance of the scatter surface.	0.04
Additional data		

Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Script Commands

Edit/Create New Scatter Model - Lambertian

Commands

- **Subroutines**

  AddLambertianScatter *YourScatter*
  SetLambertianScatter *IndexInScatterList*, *YourScatter*
  GetLambertianScatter *IndexInScatterList*, *YourScatter*

- **Functions**

  None

Associated Data Type

- **Type Name**

  T_LAMBERTIANSCATTER

- **Type Members**

  Name – (string) Holds the name of the model. Default is an empty string.

  Description – (string) Holds the description of the model. Default is an empty string.

  Refl – (double) The value of the Reflectivity coefficient. Default is 0.

  ApplyRefl – (Boolean) Applies the scatter model on reflection. Default is False.

  ApplyTrans – (Boolean) Applies the scatter model on transmission. Default is False.

  HaltIncident – (Boolean) Halts the incident ray. Default is False.

Examples

- This example adds a Lambertian Scatter model to the FRED file associated with this script.

```
Dim s As T_LAMBERTIANSCATTER
s.Name = "Lambertian Example"
s.Description = "Sample from FRED documentation"
s.Refl = 0.05
```

```
s.ApplyRefl = true
s.ApplyTrans = true
s.HaltIncident = true
AddLambertianScatter s
```

- This example sets the fourth Scatter model's name to "Lambertian Example 2", as long as that scatter model is a Lambertian model. It fails if it is any other scatter type.

```
Dim s As T_LAMBERTIANSCATTER
s.Name = "Lambertian Example 2"
SetLambertianScatter4, s
```

- This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Lambertian model. It fails if it is any other scatter type.

```
Dim s As T_LAMBERTIANSCATTER
GetLambertianScatter4, s
Print s.Name
```

Application Notes

Edit/Create New Scatter Model - Lambertian

- The Lambertian scatter model has no specular component. The scatter distribution function is completely independent of the angles of incidence, reflection, and transmission. It represents an ideal diffusing surface.
- Reflectivity must be between 0 and 1. This setting is independent of the Coating specification on the surface, which applies only to specular rays. Reflectivity near zero approximates a perfect absorber. Conversely, reflectivity approaching a value of 1 approximates a perfect diffuse reflecting surface as might be found in an integrating sphere. White paper is has a Lambertian reflectivity of about 0.8.
- The Lambertian scatter model is wavelength invariant.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Forward (i.e. transmitted) and reverse (i.e., reflected) scatter can be modeled by specifying two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the Surface Dialog.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

See Also….

Edit/Create New Scatter Model - Lambertian

The following links contain details about each of the scatter models:

Harvey-Shack – for polished surface scatter
ABg – for polished surface scatter
Flat Black Paint – specify Total Integrated Scatter (TIS)
Phong scatter – $\cos^n$ from specular
Surface Particle (Mie) – for particulate contamination
Tabulated BSDF – measured BSDF data
Tabulated PSD – measured PSD data

K-Correlation – analytic PSD

Edit/Create New Scatter Model – Mie

Description

Edit/Create New Scatter Model - Mie

The Surface Particle (Mie) Scatter model is used to calculate scatter from particulate contamination on otherwise smooth optical surfaces. Particulates are assumed to be spheres of varying size distributed uniformly on the surface. The size distribution of the particles can take one of several forms: Uniform, Gaussian, mil standard (MIL-1246C or IEST-STD-1246D) or Sampled. User inputs include the incident wavelength, the real and imaginary parts of the particle refractive index, the minimum and maximum particle diameters, and the particle density. The calculation relies on a numeric integration of the scatter distribution over the range of particle sizes. The BSDF for a uniform particle distribution is uniform in direction cosine space. The BSDF for both the Gaussian and the MIL-1246C distribution is peaked in the specular direction. Note that a large difference between the minimum and maximum particle sizes substantially increases the duration of the calculation. The model can be applied in both transmission and reflection if the Raytrace Controls allow it.

Visualization (example)

Edit/Create New Scatter Model - Mie

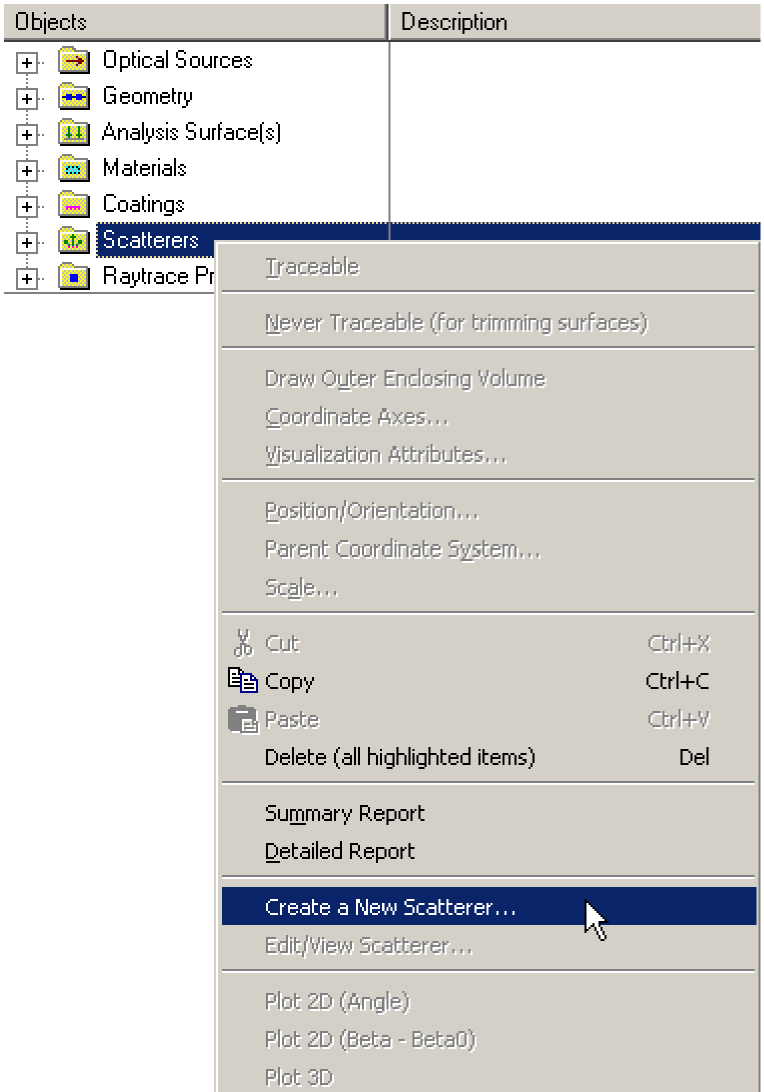
See Examples.

How Do I Get There?

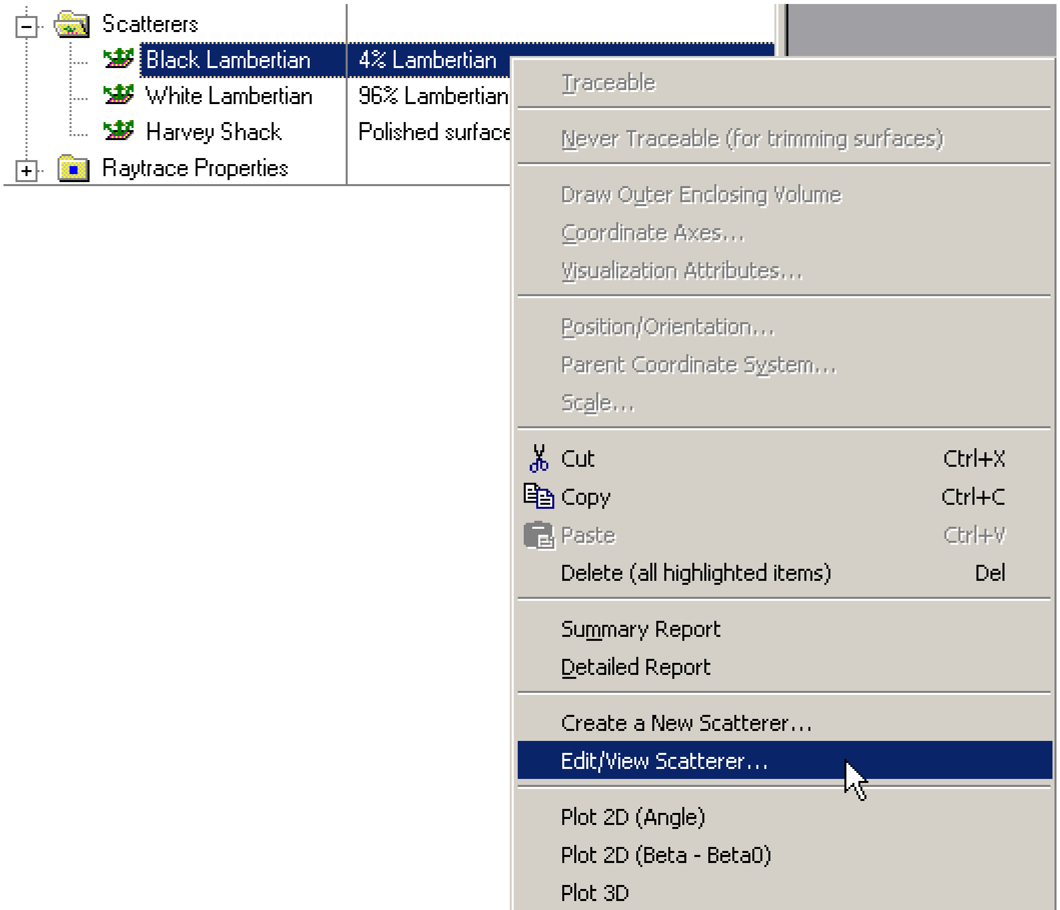
Edit/Create New Scatter Model - Mie

There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option '*Create a New Scatterer…*'

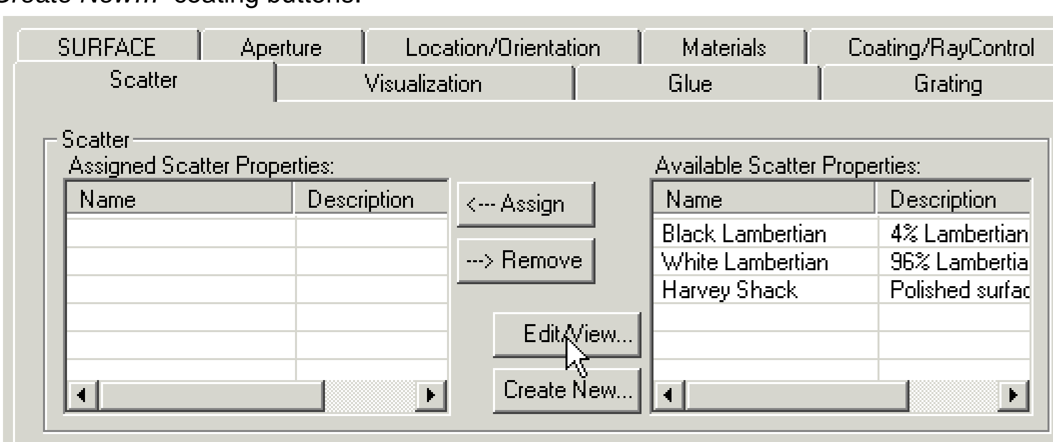


2. Expand the **Scatterers** folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer...*'.

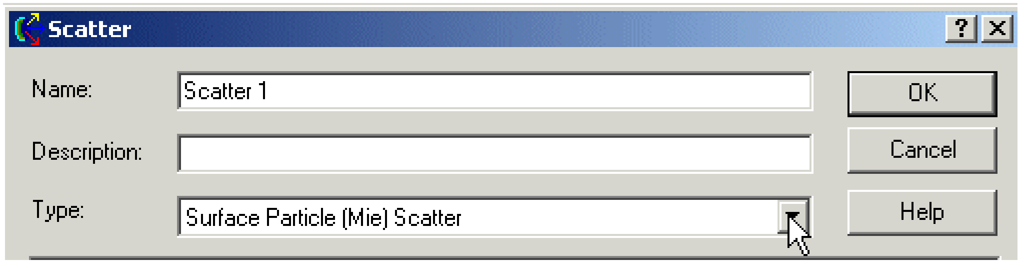


3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.



When the Scatter dialog has been opened, select Surface Particle (Mie) Scatter from the list of available models.



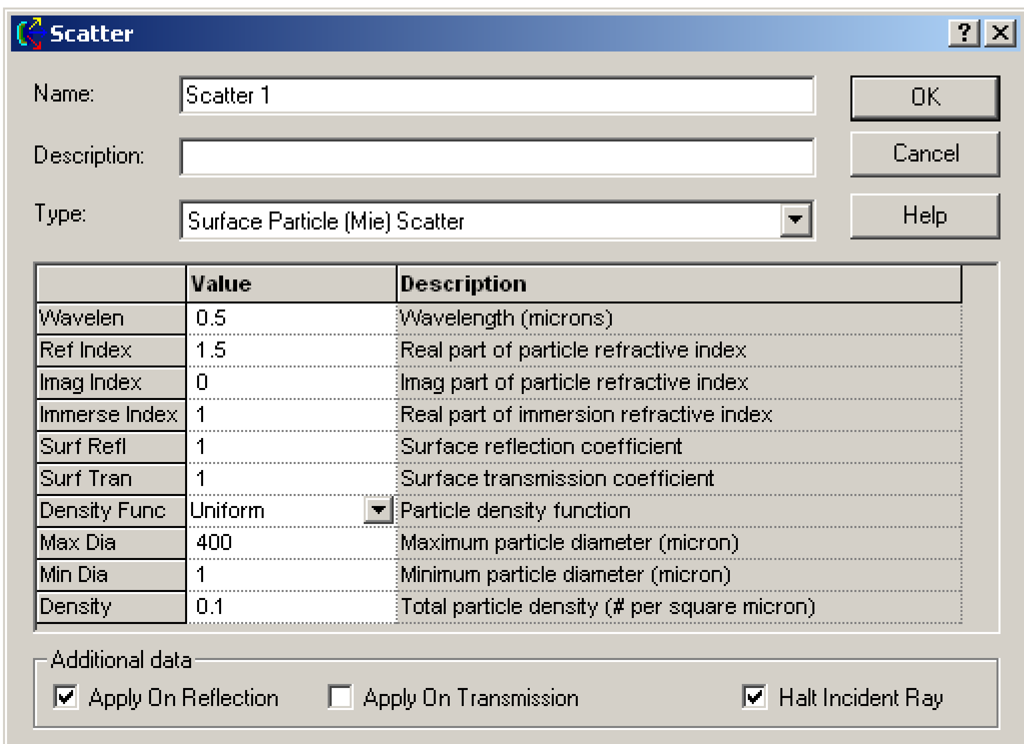
After a new Scatter model has been created, the model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls

Edit/Create New Scatter Model - Mie

The Surface Particle (Mie) Scatter dialog has four forms: Uniform, Gaussian, MIL-standard. and Sampled.

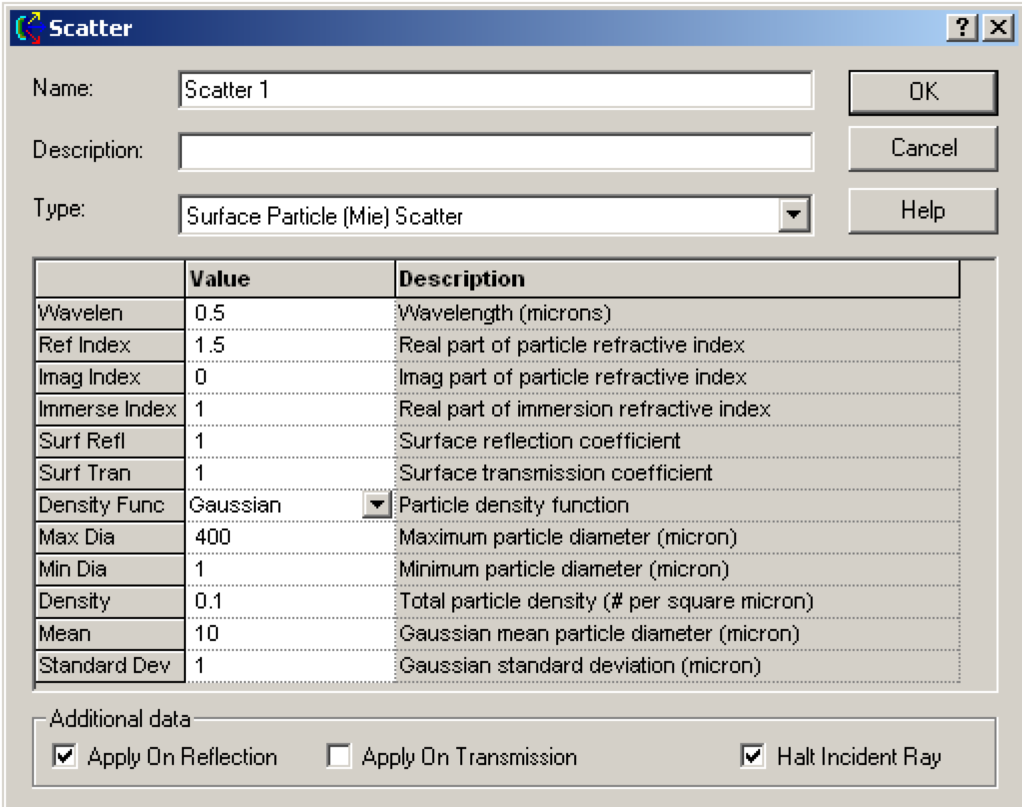
Uniform Particle Size Distribution



	Value	Description
Wavelen	0.5	Wavelength (microns)
Ref Index	1.5	Real part of particle refractive index
Imag Index	0	Imag part of particle refractive index
Immerse Index	1	Real part of immersion refractive index
Surf Refl	1	Surface reflection coefficient
Surf Tran	1	Surface transmission coefficient
Density Func	Uniform	Particle density function
Max Dia	400	Maximum particle diameter (micron)
Min Dia	1	Minimum particle diameter (micron)
Density	0.1	Total particle density (# per square micron)

Control	Inputs	Defaults
Name	Name of the model (required)	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Surface Particle (Mie) Scatter** from the pull down menu.	Lambertian
Model Specification		
Wavelen	Wavelength in microns for the scatter calculation.	0.5
Ref Index	Real part of the refractive index of the particles.	1.5
Imag Index	Imaginary part of the refractive index of the particles.	0
Immerse Index	Refractive index of material in which particles are immersed (usually air).	1
Surf Refl	Reflectance of surface to which particles are attached. (see App Notes below)	1
Surf Tran	Transmittance of surface to which particles are attached. (see App Notes below)	1
Density Func	Particle size distribution function; choose **Uniform**.	Uniform
Max. Dia	Maximum particle diameter in microns	400
Min. Dia	Minimum particle diameter in microns.	1
Density	Particle density in particles per square micron.	0.1
Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

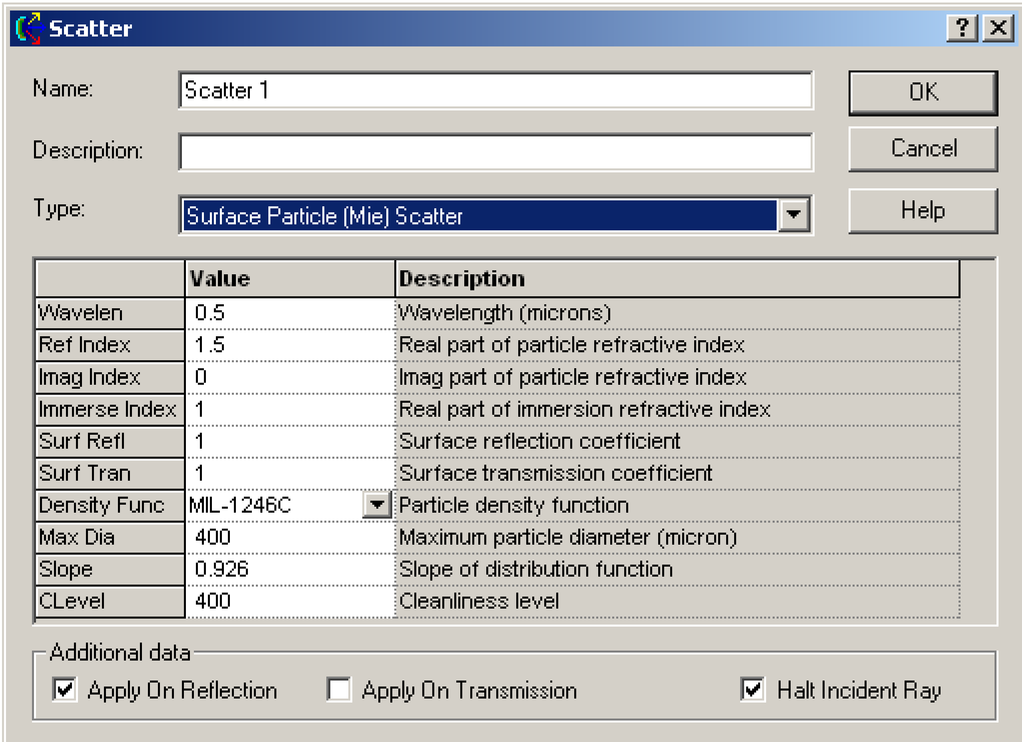
Gaussian Particle Size Distribution



Control	***Inputs***	***Defaults***
Name	Name of the model (required).	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Surface Particle (Mie) Scatter** from the pull down menu.	Lambertian
Model Specification		
Wavelen	Wavelength in microns for the scatter calculation.	0.5
Ref Index	Real part of the refractive index of the particles.	1.5
Imag Index	Imaginary part of the refractive index of the particles.	0
Immerse Index	Refractive index of material in which particles are immersed (usually air).	1

Surf Refl	Reflectance of surface to which particles are attached. (see App Notes below)	1
Surf Tran	Transmittance of surface to which particles are attached. (see App Notes below)	1
Density Func	Particle size distribution function; choose **Gaussian**.	Uniform
Max. Dia	Maximum particle diameter in microns.	400
Min. Dia	Minimum particle diameter in microns.	1
Density	Particle density in particles per square micron.	0.1
Mean	Mean particle diameter in microns.	10
Standard Deviation	Standard deviation of particle sizes in microns.	1
Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

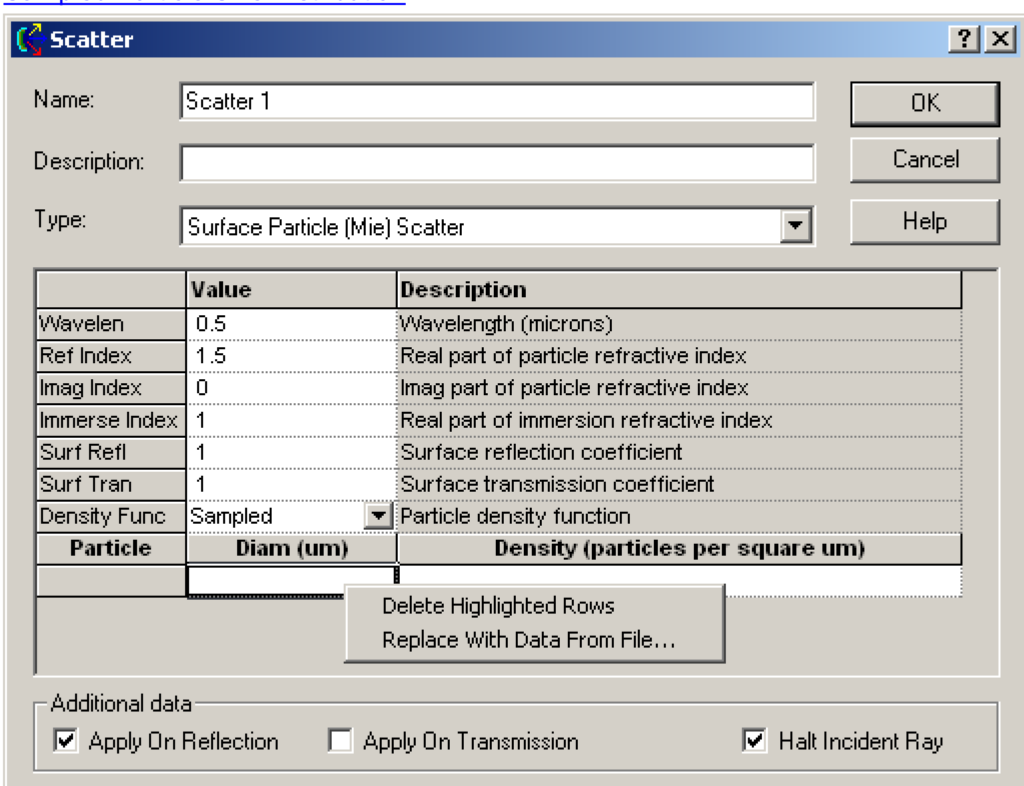
MIL-1246C or IEST-STD-1246D Particle Size Distributions



Control	Inputs	Defaults
Name	Name of the model (required)	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Surface Particle (Mie) Scatter** from the pull down menu.	Lambertian
Model Specification		
Wavelen	Wavelength in microns for the scatter calculation.	0.5
Ref Index	Real part of the refractive index of the particles.	1.5
Imag Index	Imaginary part of the refractive index of the particles.	0
Immerse Index	Refractive index of material in which particles are immersed (usually air).	1
Surf Refl	Reflectance of surface to which particles are attached. (see App Notes below)	1
Surf Tran	Transmittance of surface to which particles are attached. (see App Notes below)	1

Density Func	Particle size distribution function; choose **MIL-1246C** or **IEST-STD-1246D**.	Uniform
Max. Dia	Maximum particle diameter in microns.	400
Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Sampled Particle Size Distribution



Control	Inputs	Defaults
Name	Name of the model (required)	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Surface Particle (Mie) Scatter** from the pull down menu.	Lambertian
Model Specification		
Wavelen	Wavelength in microns for the scatter calculation.	0.5
Ref Index	Real part of the refractive index of the particles.	1.5
Imag Index	Imaginary part of the refractive index of the particles.	0
Immerse Index	Refractive index of material in which particles are immersed (usually air).	1
Surf Refl	Reflectance of surface to which particles are attached. (see App Notes below)	1
Surf Tran	Transmittance of surface to which particles are attached. (see App Notes below)	1
Density Func	Particle size distribution function; choose **Sampled**.	Uniform
Data	Particle diameter, Particle density (number per μm^2). Data can be read from a file or entered manually.	blank
Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Commands

- **Subroutines**
  AddMieScatter *YourScatter*
  SetMieScatter *IndexInScatterList*, *YourScatter*
  GetMieScatter *IndexInScatterList*, *YourScatter*
- **Functions**
  None

Associated Data Type

- **Type Name**
  T_MIESCATTER
- **Type Members**

  Name – (string) Holds the name of the model. Default is an empty string.

  Description – (string) Holds the description of the model. Default is an empty string.

  Wavelen – (double) Wavelength used for the scatter calculation. Default is 0.

  RefIndex – (double) Real part of the particle refractive index. Default is 0.

  ImagIndex – (double) Imaginary part of the particle refractive index. Default is 0.

  MaxDia – (double) Maximum particle diameter, in microns. Default is 0.

  MinDia – (double) Minimum particle diameter, in microns. Default is 0.

  Density – (double) Particle density, in number per square micron. Default is 0.

  Function – (String) Specifies the density function to use when calculating the scatter. Default is an empty string. Possible values are "MIL-1246C", "Uniform", or "Gaussian". Compilation and calculation fail if any other string is specified.

  ApplyRefl – (Boolean) Applies the scatter model on reflection. Default is False.

  ApplyTrans – (Boolean) Applies the scatter model on transmission. Default is False.

  HaltIncident – (Boolean) Halts the incident ray. Default is False.

Examples

- This example adds a Mie Scatter model to the FRED file associated with this script.

```
Dim s As T_MIESCATTER
s.Name = "Mie Scatter Example"
s.Description = "Sample from FRED documentation"
s.Wavelen = 0.6
s.RefIndex = 1.6
s.ImagIndex = 0
s.MaxDia = 300
s.MinDia = 1
s.Density = 0.2
s.Function = "Gaussian"
s.ApplyRefl = true
s.ApplyTrans = true
s.HaltIncident = true
AddMieScatter s
```

- This example sets the fourth Scatter model's name to "Mie Example 2", as long as that scatter model is a Mie model. It fails if it is any other scatter type.

```
Dim s As T_MIESCATTER
s.Name = "Mie Example 2"
SetMieScatter4, s
```

- This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Mie model. It fails if it is any other scatter type.

```
Dim s As T_MIESCATTER
GetScatter4, s
Print s.Name
```

Application Notes

Edit/Create New Scatter Model - Mie

- The Mie scatter model is not linear shift invariant, which means that the BSDF depends the angle of incidence of the specular ray.
- The scatter distribution function for the Uniform particle size distribution is uniform in direction cosine space.
- The scatter distribution functions for the Gaussian and the MIL-1246C particle size distributions have a strong component in the specular direction, and a smaller reverse component in the opposite direction as the incident ray.
- The Mie model is weakly wavelength dependent. It is not generally necessary to enter additional Mie scatter models for all of the system wavelengths unless they span a large range.
- The maximum particle size for the MIL-1246C model is equivalent to the contamination (or cleanliness level). Level 200 or lower is a pristine surface. Level 600 is typical for visibly clean optics. Level 1000 or higher is appropriate for visibly dirty optics.
- The integration time for the calculation is directly proportional to the range of particle sizes.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the Surface Dialog.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.
- The Mie model now allows a constant reflectance and transmittance to be specified for the surface to which the model is attached. In the past, this model assumed R=1 when used in reflection.

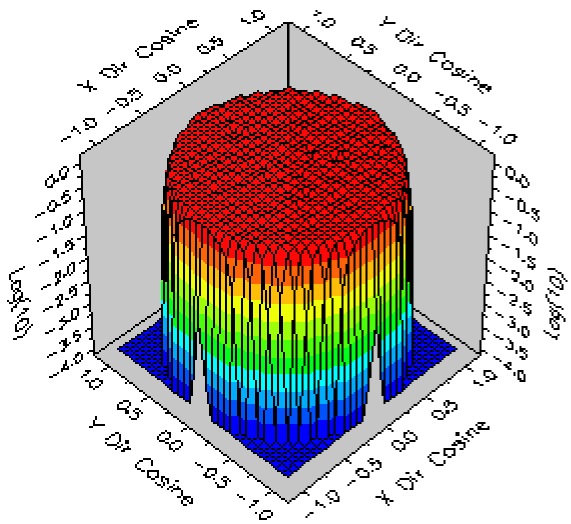
Examples

Edit/Create New Scatter Model - Mie

The following examples show a series of 3-dimensional surface log plots of the normalized reflected BSDF (BRDF) as a function of scatter angle for 30 degrees angle of incidence.

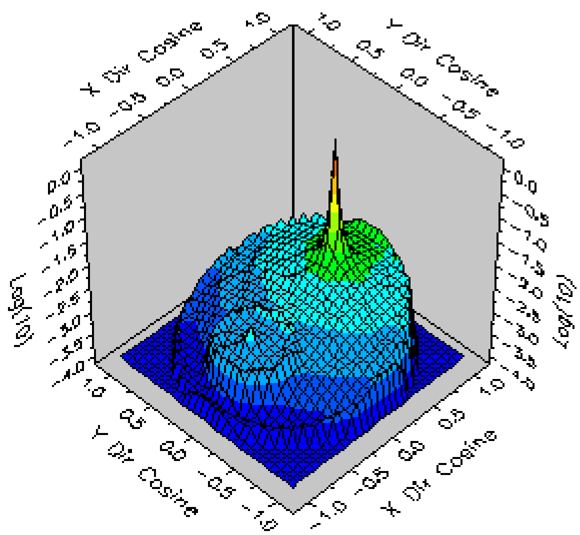
Example 1 – Uniform Particle Size Distribution

The Mie scatter parameters are: Wavelen = 0.5 microns, Ref Index = 1.5, Imag Index = 0, Maximum Particle Size = 400 microns, Minimum Particle Size = 1 micron, Density = 0.1 particles per square micron. For a large range of particle sizes, this scatter model is close to Lambertian.



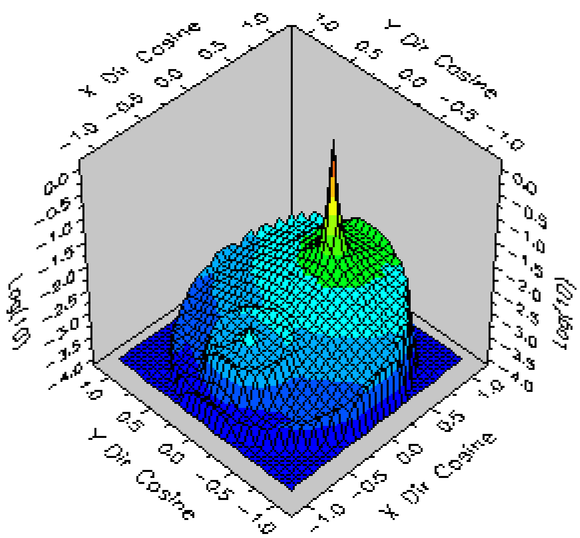
Example 2 – Gaussian Particle Size Distribution

The Mie scatter parameters are: Wavelen = 0.5 microns, Ref Index = 1.5, Imag Index = 0, Maximum Particle Size = 400 microns, Minimum Particle Size = 1 micron, Mean Particle Size = 10 microns, Standard Deviation = 1 micron, Density = 0.1 particles per square micron.



Example 3 – MIL-1246C Particle Size Distribution

The Mie scatter parameters are: Wavelen = 0.5 microns, Ref Index = 1.5, Imag Index = 0, Maximum Particle Size = 400 microns (= Level 400).



See Also....

Edit/Create New Scatter Model - Mie

The following links contain details about each of the scatter models:

- Lambertian – for diffuse scatter
- Harvey-Shack – for polished surface scatter
- ABg – for polished surface scatter
- Flat Black Paint – specify Total Integrated Scatter (TIS)
- Phong scatter – $\cos^n$ from specular
- Tabulated BSDF – measured BSDF data
- Tabulated PSD – measured PSD data
- K-Correlation – analytic PSD

Edit/Create New Scatter Model – Tabulated Data

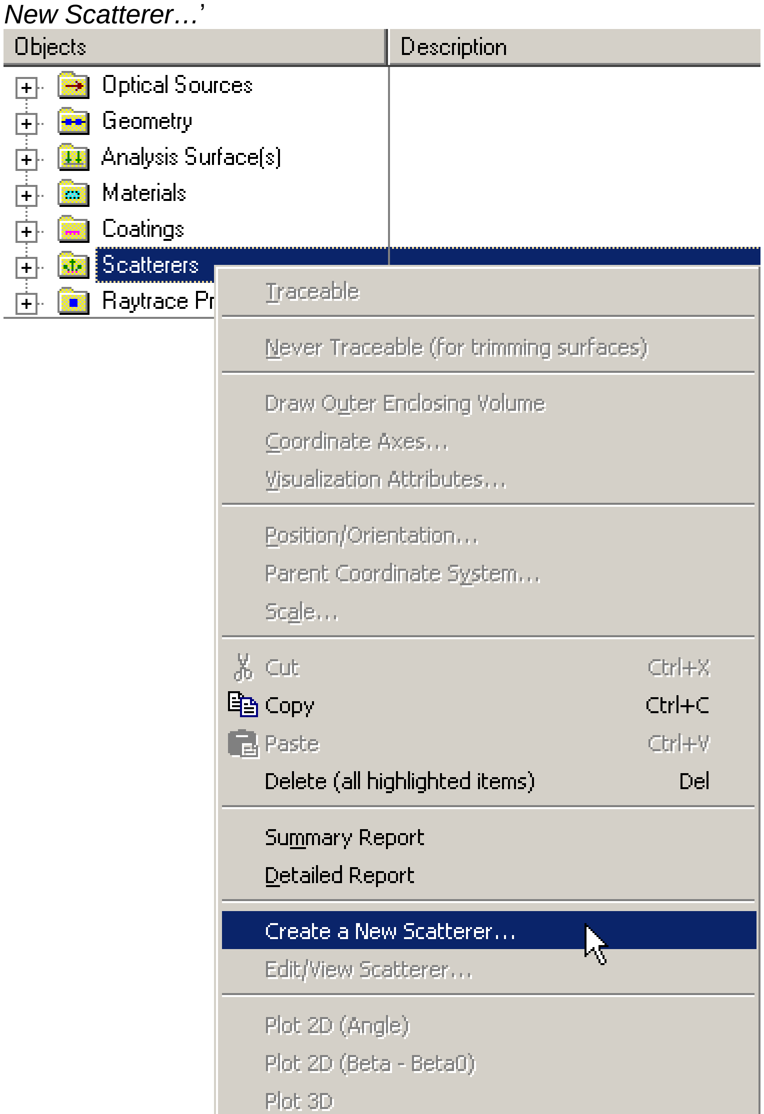
Description
How Do I Get There?
Dialog box and Controls
Script Commands
Application Notes
See Also...

Description - Edit/Create New Scatter Model - Tabulated Data

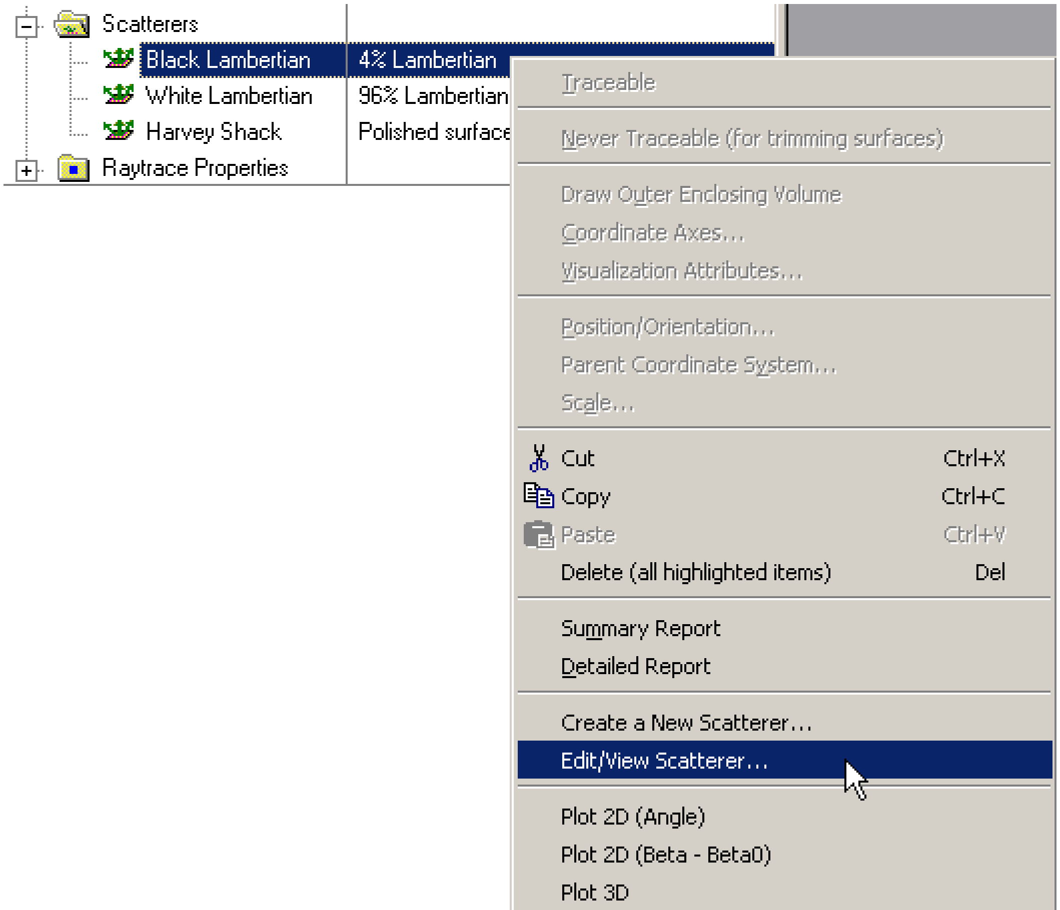
Model is based upon tabulated data given in polar coordinates. It can apply on both transmission and reflection if the Raytrace Controls allow it. Data can be read from a text file in column format.

How Do I Get There? - Edit/Create New Scatter Model - Tabulated Data

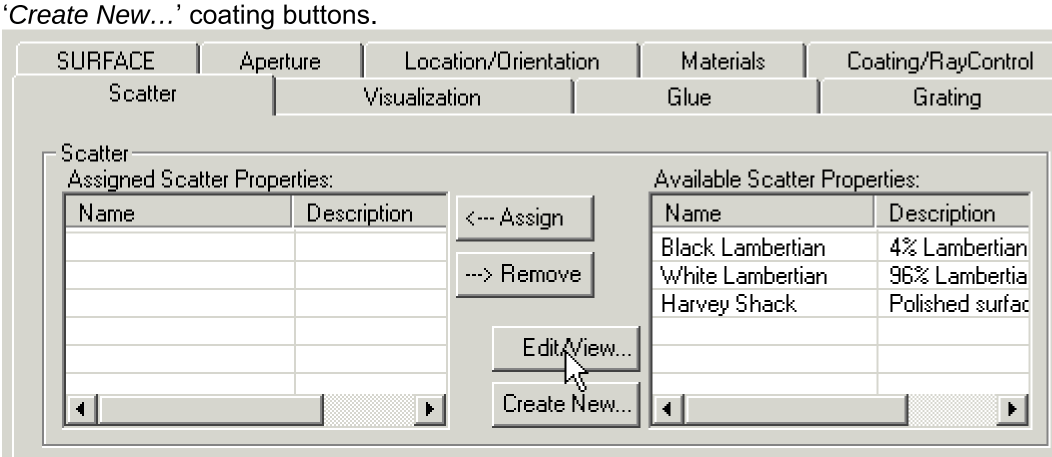
There are four ways to open a Scatter model dialog.
1. Right click on the Scatterers folder to open a the pop-up menu and select the option '*Create a New Scatterer…*'



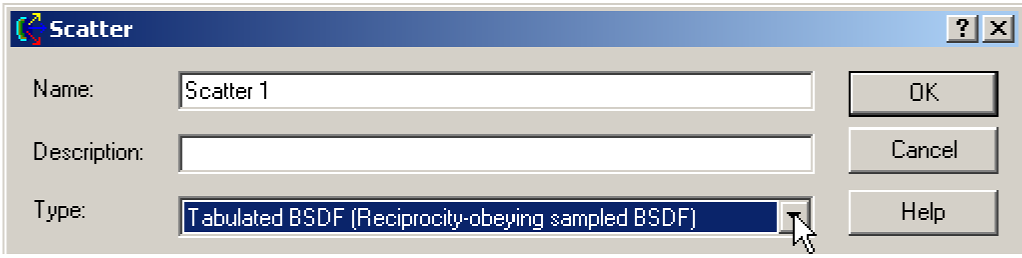
2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer…*'.



3. Expand the Scatterers folder and double left mouse click on the scatter model name.
4. From the Scatter tab in the Surface dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.

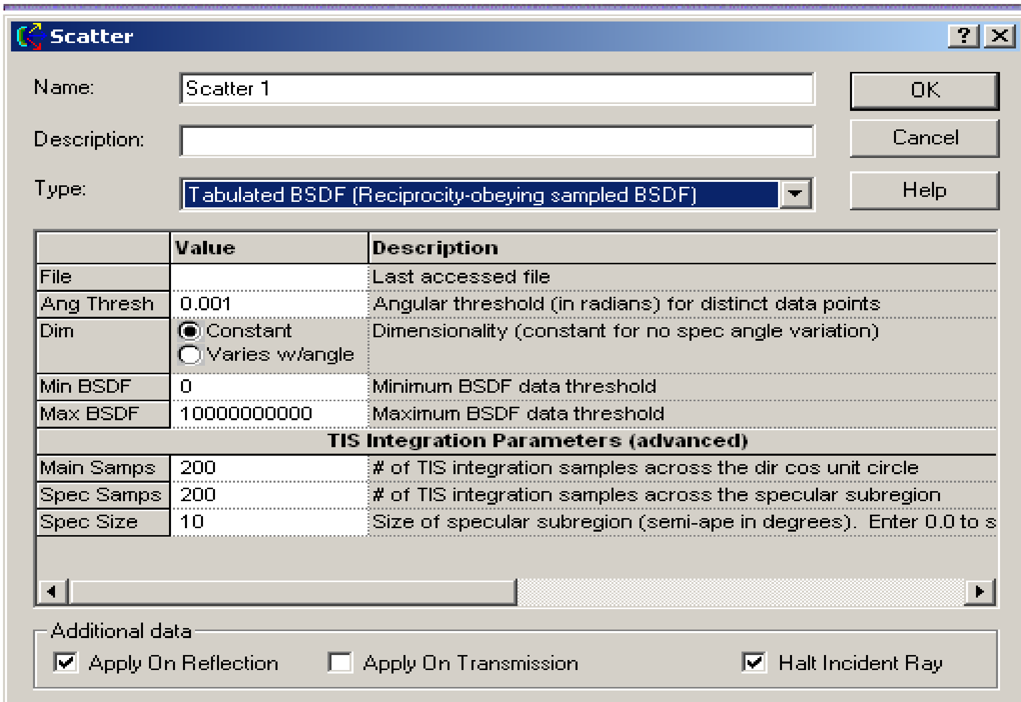


When the Scatter dialog has been opened, select Tabulated scatter from the list of available models.



After a new Scatter model has been created, the model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls - Edit/Create New Scatter Model - Tabulated Data



Control	***Inputs***	***Defaults***
Name	Name of the model (required).	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Tabulated BSDF** from the pull down menu.	Lambertian
label	Last file accessed by "Replace with Data from a File"	blank
ang	Angular threshold (radians)	0.001
d	Dimensionality. Constant or varies with angle.	Constant

Min/Max BSDF	Slope of the BSDF at large B-B0.	0, 1e+11
Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Script Commands - Edit/Create New Scatter Model - Tabulated Data

Commands

- **Associated Subroutines**

AddTabulatedScatter
InitTabulatedScatter
SetTabulatedScatter
GetTabulatedScatter

Associated Data Type

- **Type Name**

T_TABULATEDSCATTER

- **Type Members**

Name – (string) holds the name of the model. Default is an empty string.
Description – (string) holds the description of the model. Default is an empty string.
Filename – (string) File name.
Type - (long) Type.
CollapseTol - (double) The value of the BSDF slope at large B-B0. Default is 0.
MinBSDF - (double) Minimum allows BSDF value. default=0
MaxBSDF - (double) Maximum allowed BSDF value. default=10000000000
ApplyRefl – (Boolean) Applies the scatter model on reflection. Default is False.
ApplyTrans - (Boolean) Applies the scatter model on transmission. Default is False.
HaltIncident - (Boolean) Halts the incident ray. Default is False.

Example

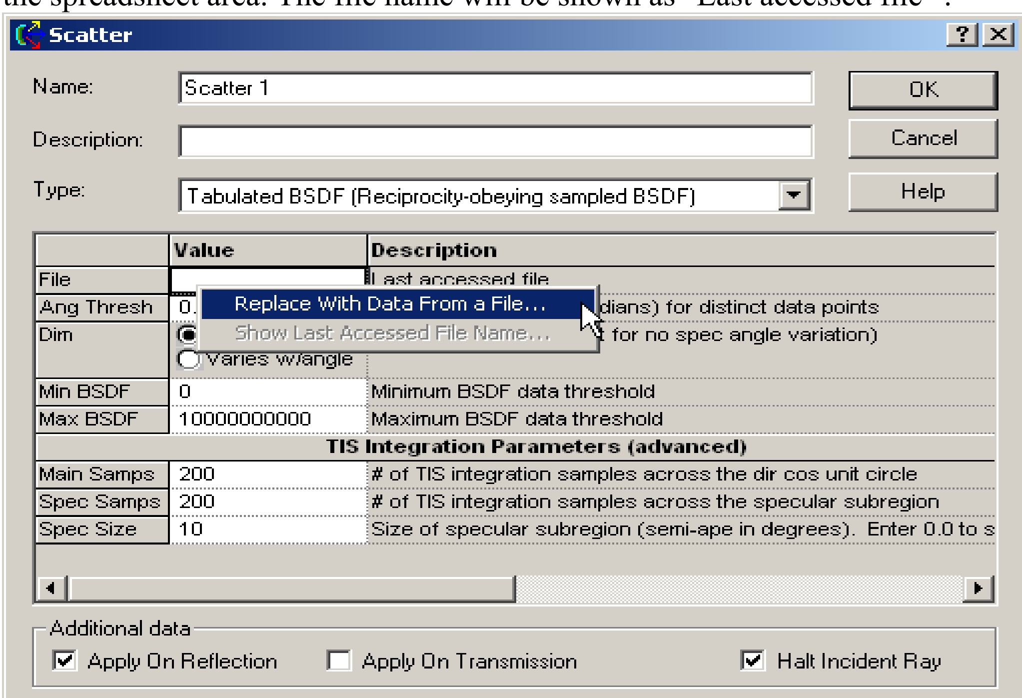
- This example adds a Tabulated Scatter model to the FRED file from data in a script:

```
  Dim tab3 As T_TABULATEDSCATTER ' scripted tabulated scatter
InitTabulatedScatter tab3
 tab3.Name="scripted tabulated scatter"
 tab3.Description="Reciprocity-obeying sampled BSDF"
 tab3.FileName="myScripted"

  Dim A03(10) As Double
Dim B03(10) As Double
Dim A3(10) As Double
```

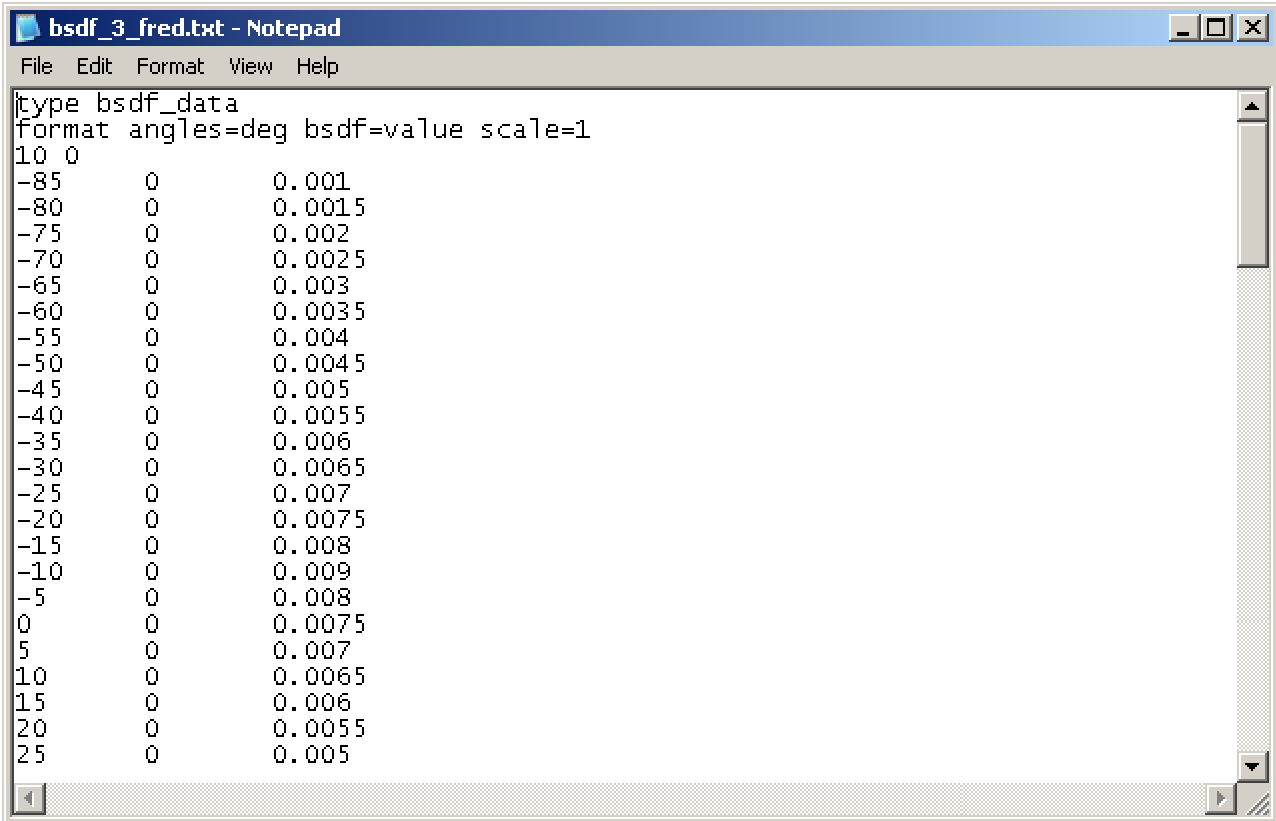
```
Dim B3(10) As Double
Dim BSDF3(10) As Double
 A03(0)=10 : B03(0)=0 : A3(0)=-80 : B3(0)=0 : BSDF3(0)=0.105
 A03(1)=10 : B03(1)=0 : A3(1)=-64 : B3(1)=0 : BSDF3(1)=0.104
 A03(2)=10 : B03(2)=0 : A3(2)=-48 : B3(2)=0 : BSDF3(2)=0.103
 A03(3)=10 : B03(3)=0 : A3(3)=-32 : B3(3)=0 : BSDF3(3)=0.102
 A03(4)=10 : B03(4)=0 : A3(4)=-16 : B3(4)=0 : BSDF3(4)=0.101
 A03(5)=10 : B03(5)=0 : A3(5)=0 : B3(5)=0 : BSDF3(5)=0.1
 A03(6)=10 : B03(6)=0 : A3(6)=16 : B3(6)=0 : BSDF3(6)=0.099
 A03(7)=10 : B03(7)=0 : A3(7)=32 : B3(7)=0 : BSDF3(7)=0.098
 A03(8)=10 : B03(8)=0 : A3(8)=48 : B3(8)=0 : BSDF3(8)=0.097
 A03(9)=10 : B03(9)=0 : A3(9)=64 : B3(9)=0 : BSDF3(9)=0.096
 A03(10)=10 : B03(10)=0 : A3(10)=80 : B3(10)=0 : BSDF3(10)=0.095

  s3=AddTabulatedScatter( tab3, A03, B03, A3, B3, BSDF3 )
```

Application Notes - Edit/Create New Scatter Model - Tabulated Data

- Data can be read from a text file in column format. Load the file by right-clicking in the spreadsheet area. The file name will be shown as "Last accessed file" :



File format is shown here and is the standard format also used for binomial/polynomial datasets:




```
type bsdf_data
format angles=deg bsdf=value scale=1
10 0
-85	0	0.001
-80	0	0.0015
-75	0	0.002
-70	0	0.0025
-65	0	0.003
-60	0	0.0035
-55	0	0.004
-50	0	0.0045
-45	0	0.005
-40	0	0.0055
-35	0	0.006
-30	0	0.0065
-25	0	0.007
-20	0	0.0075
-15	0	0.008
-10	0	0.009
-5	0	0.008
0	0	0.0075
5	0	0.007
10	0	0.0065
15	0	0.006
20	0	0.0055
25	0	0.005
```

- The Tabulated Scatter model is wavelength invariant.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the **Surface Dialog**.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

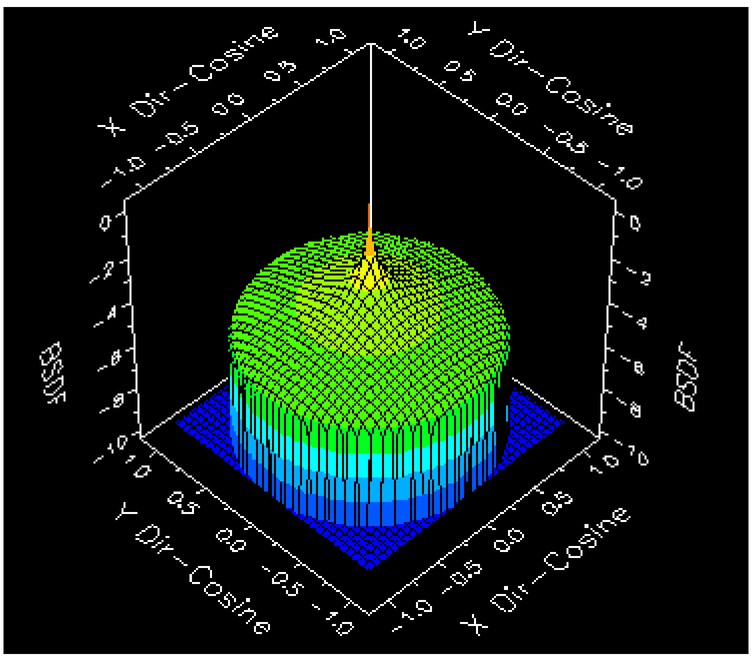
See Also - Edit/Create New Scatter Model - Tabulated Data

The following links contain details about each of the scatter models.
ABg for smooth surface scatter
Lambertian for diffuse scatter
Harvey-Shack for polished surface scatter
Phong scatter – $\cos^n$ from specular
Flat Black Paint – specify Total Integrated Scatter (TIS)
Surface Particle (Mie) – for particulate contamination

Edit/Create New Scatter Model – K-Correlation

Description
K-Correlation Scatter Model

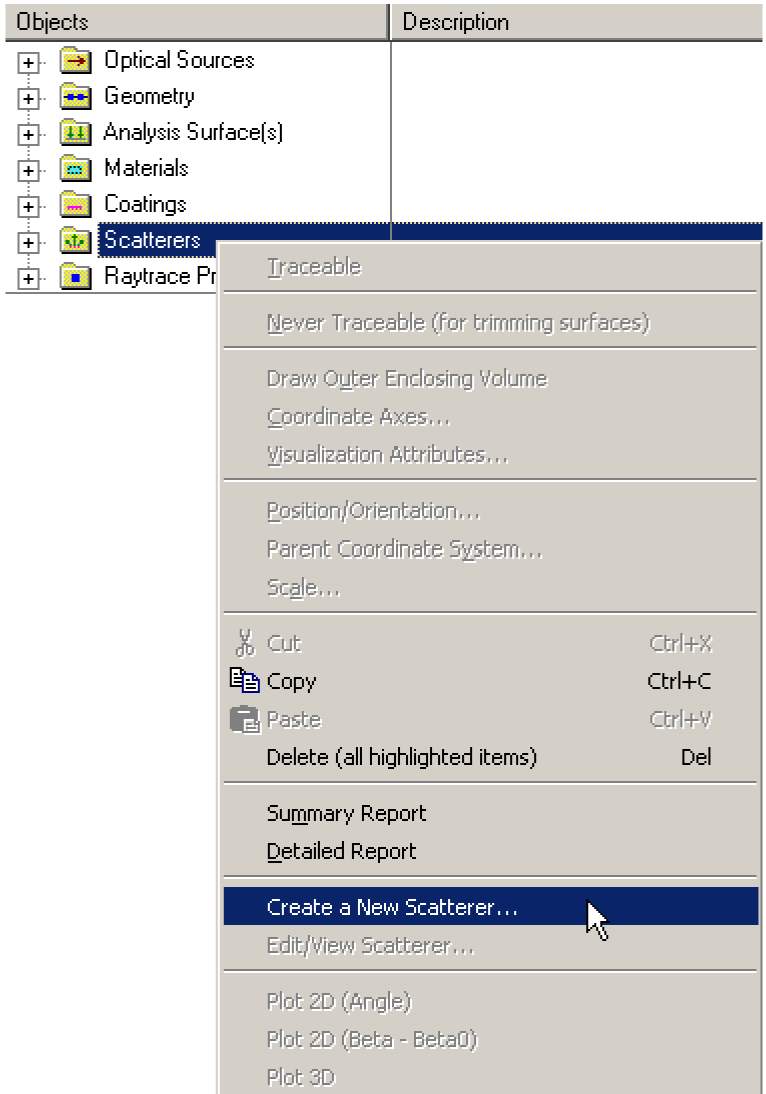
The K-correlation scatter model is used to represent Power Spectral Density (PSD) measurements which can be fit to a specific algebraic form, namely a straight line on a log-log plot of PSD versus frequency.



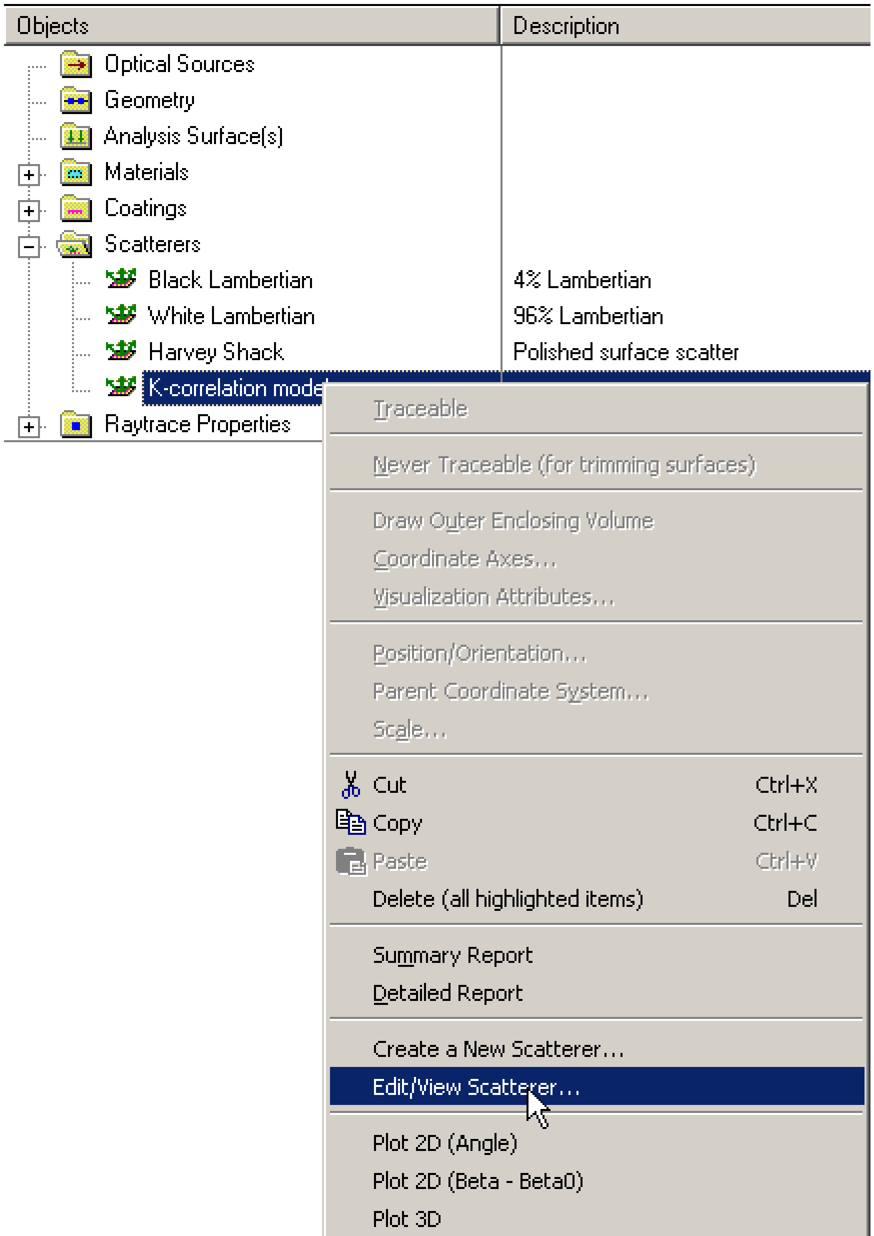
How Do I Get There?
K-Correlation Scatter Model

There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option '*Create a New Scatterer…*'

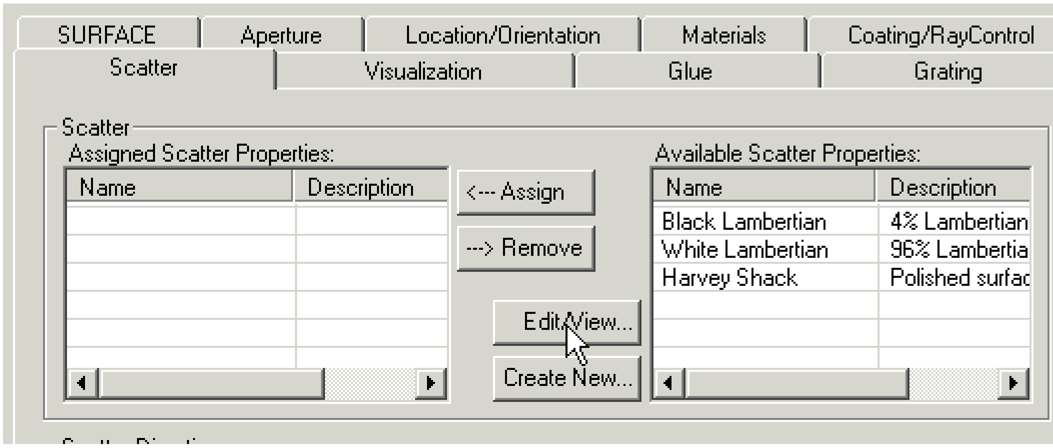


2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer…*'.



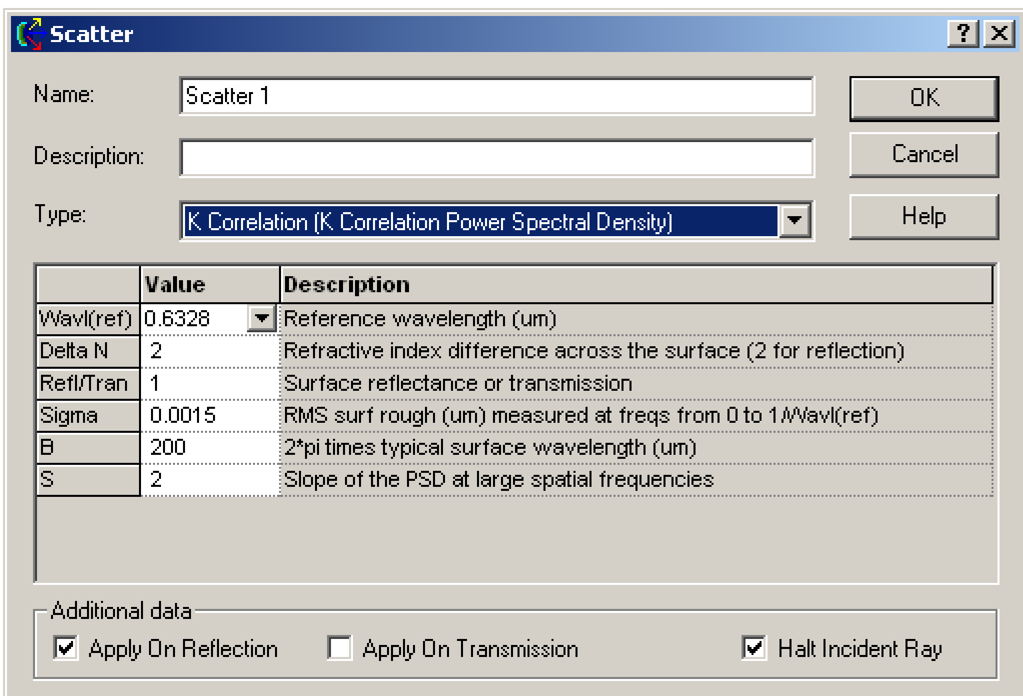
3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.



Dialog Box and Controls

K-Correlation Scatter Model



Control	***Inputs / Description***	***Defaults***
Name	Name of the model (required).	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **K Correlation** from the pull down menu.	Lambertian

Wavl(ref)	Reference wavelength.	default wavelength
Delta N	Refractive index difference between incident and substrate material. For reflection, Delta N = 2.	2
Refl/Tran	Reflectance/transmittance of surface.	1
Sigma	RMS surface roughness (um) measured at frequencies from 0 to 1/Wavl(ref).	0.0015
B	2π time typical surface wavelength (um).	200
S	Slope of PSD at large spatial frequencies.	2
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Application Notes

K-Correlation Scatter Model

- The K-Correlation scatter model is defined by

$$S(f) = \frac{A'}{\left[1+(Bf)^2\right]^{(c+1)/2}}$$

where

$$A' = \frac{\Gamma\left[(c+1)/2\right]}{2\sqrt{\pi}\,\Gamma(c/2)}$$

- The value of A is determined by low-frequency behavior. The parameter B is related to correlation length. C determines the rate of fallof or slope of the PSD at high frequencies.

- Reference material for this model can be found in Chapter 4 of *Optical Scattering Measurement and Analysis* by John Stover (references).

See Also….

K-Correlation Scatter Model

The following links contain details about each of the scatter models:

Lambertian – for diffuse scatter
Harvey-Shack – for polished surface scatter
ABg – for polished surface scatter
Flat Black Paint – specify Total Integrated Scatter (TIS)
Phong scatter – $\cos^n$ from specular
Surface Particle (Mie) – for particulate contamination
Tabulated BSDF – measured BSDF data
Tabulated PSD – measured PSD data

Edit/Create New Scatter Model – Phong

Description

Edit/Create New Scatter Model - Phong

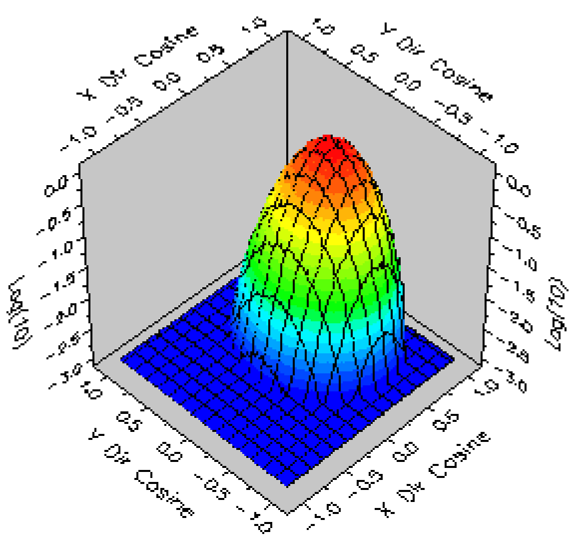
The Phong scatter model simulates a quasi-Gaussian scatter distribution function in which the BSDF is proportional to T^n where T is the cosine of the angle between the specular and scattered rays. It can apply on both transmission and reflection if the Raytrace Controls allow it.

WARNING: Use of the Phong scatter model can result in non-physical effects for specular angles near grazing incidence (see Examples below). Use with caution.

Visualization (example)

Edit/Create New Scatter Model - Phong

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The Phong scatter parameters are d = 0.1 and n = 16. The specular angle is 30 degrees.

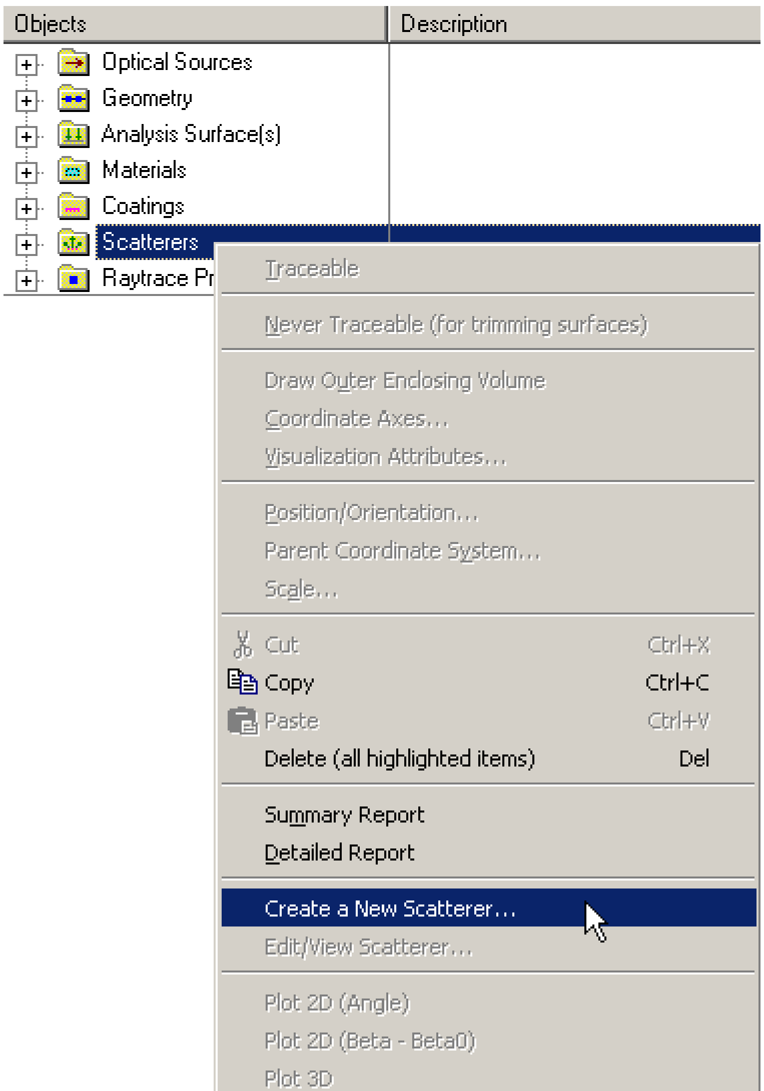


How Do I Get There?

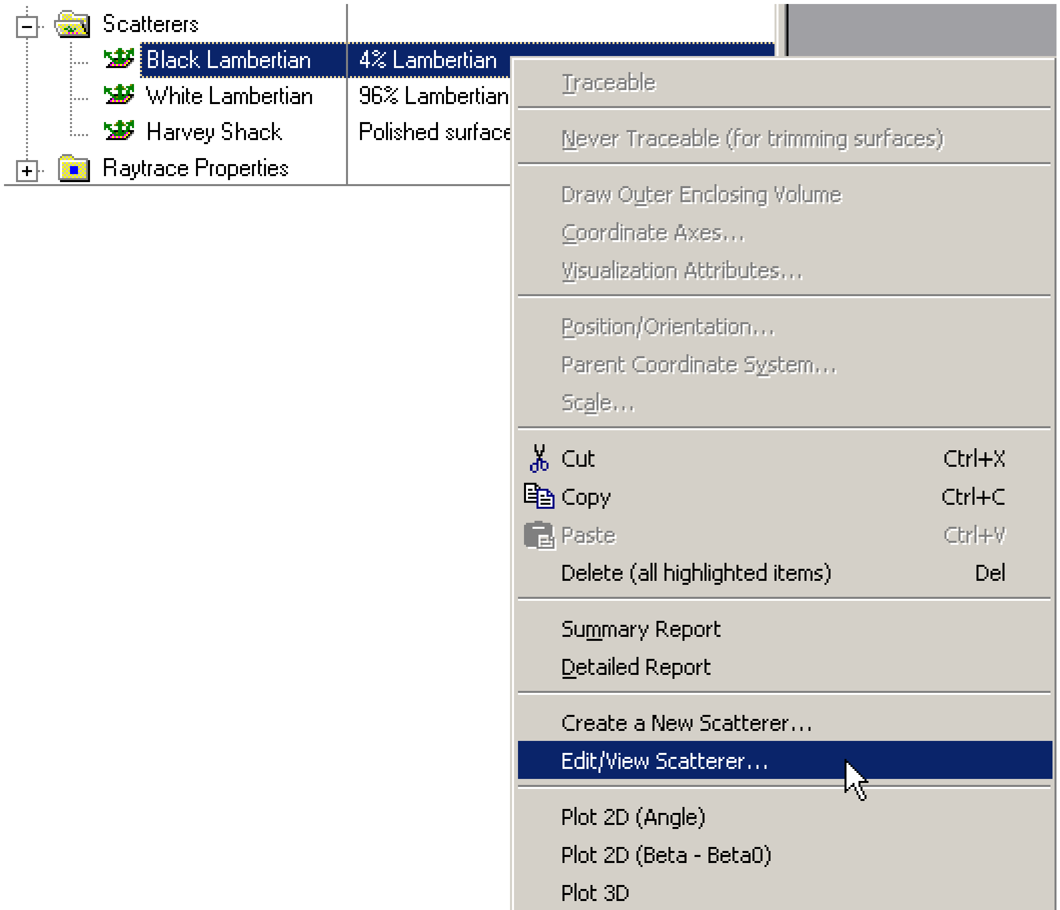
Edit/Create New Scatter Model - Phong

There are four ways to open a Scatter model dialog.

1. Right click on the **Scatterers** folder to open a the pop-up menu and select the option '*Create a New Scatterer…*'

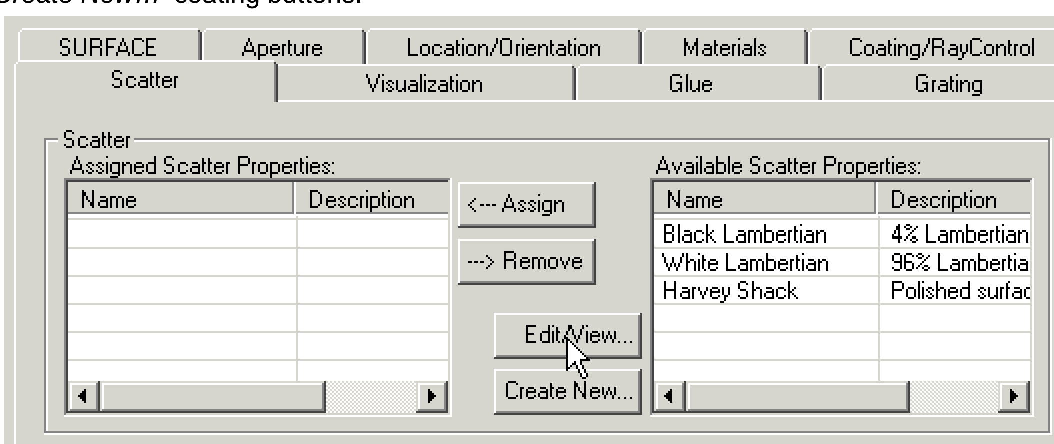


2. Expand the **Scatterers** folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer…*'.

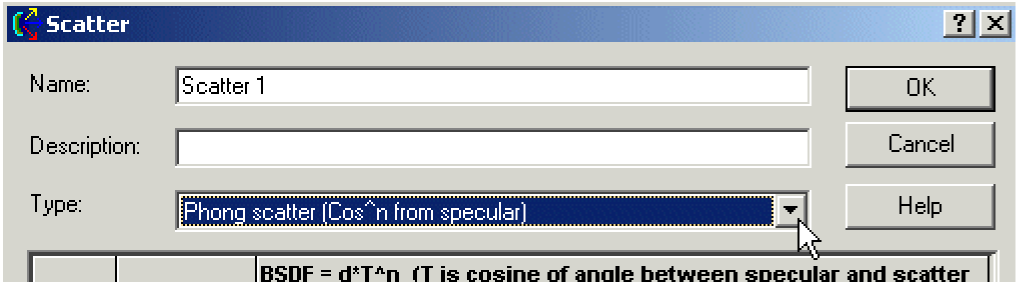


3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.



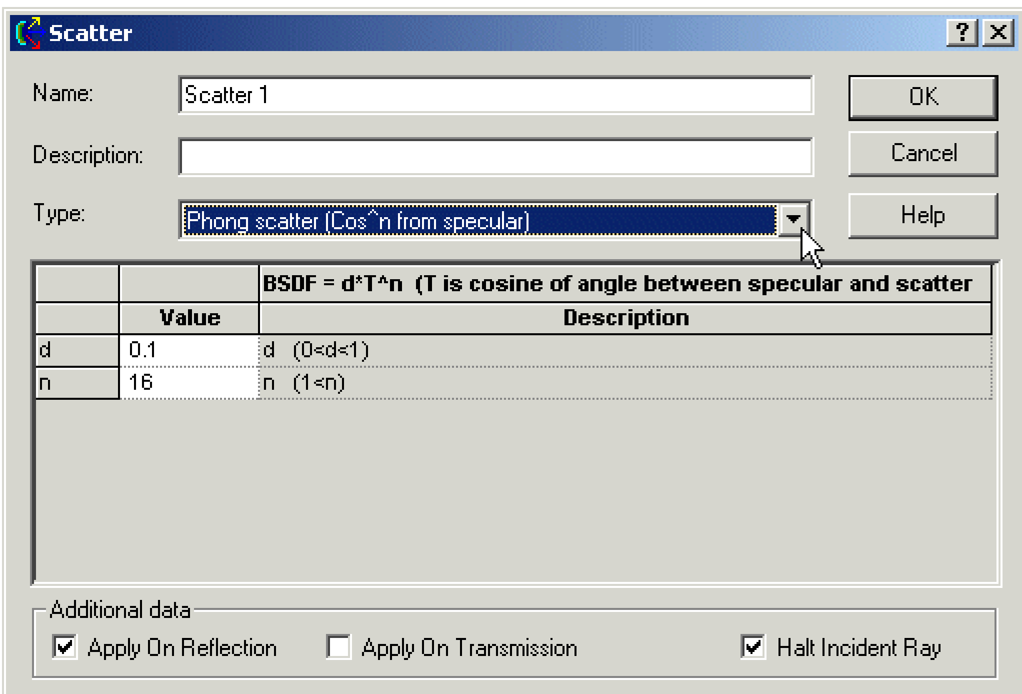
When the Scatter dialog has been opened, select Phong scatter from the list of available models.



After a new Scatter model has been created, its model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls

Edit/Create New Scatter Model - Phong



Control	Inputs	Defaults
Name	Name of the model (required).	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Phong** from the pull down menu.	Lambertian
d	Value of d between 0 and 1.	0.1

n	Value of the exponent greater than 1.	16
Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Script Commands

Edit/Create New Scatter Model - Phong

Commands

- **Subroutines**

  AddPhongScatter *YourScatter*
  SetPhongScatter *IndexInScatterList*, *YourScatter*
  GetPhongScatter *IndexInScatterList*, *YourScatter*

- **Functions**

  None

Associated Data Type

- **Type Name**

  T_PHONGSCATTER

- **Type Members**

  Name – (string) Holds the name of the model. Default is an empty string.

  Description – (string) Holds the description of the model. Default is an empty string.

  d – (double) Holds the d parameter as shown in the above dialog. Default is 0.

  n – (double) Holds the n parameter as shown in the above dialog. Default is 0.

  ApplyRefl – (Boolean) Applies the scatter model on reflection. Default is False.

  ApplyTrans – (Boolean) Applies the scatter model on transmission. Default is False.

  HaltIncident – (Boolean) Halts the incident ray. Default is False.

Examples

- This example adds a Phong Scatter model to the FRED file associated with this script.

```
Dim s As T_PHONGSCATTER
s.Name = "Phong Example"
s.Description = "Sample from FRED documentation"
s.d = 0.05
s.n =
s.ApplyRefl = true
s.ApplyTrans = true
s.HaltIncident = true
AddPhongScatter s
```

- This example sets the fourth Scatter model's name to "Phong Example 2", as long as that scatter model is a Phong model. It fails if it is any other scatter type.

```
Dim s As T_PHONGSCATTER
s.Name = "Phong Example 2"
SetPhongScatter4, s
```

- This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Phong model. It fails if it is any other scatter type.

```
Dim s As T_PHONGSCATTER
GetPhongScatter4, s
Print s.Name
```

Application Notes

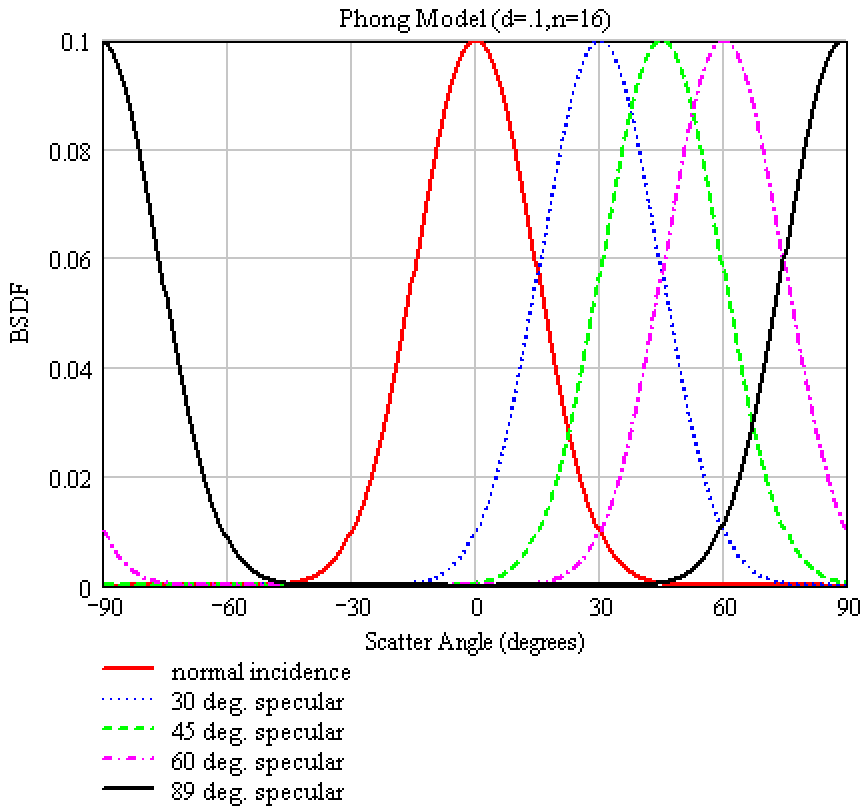
Edit/Create New Scatter Model - Phong

- The Bidirectional Scatter Distribution Function (BSDF) for the Phong model is defined by the following function
  - $BSDF = d \cdot \cos(\theta_{scatter} - \theta_{specular})^n$
- The Phong model is linear shift invariant, which means that the BSDF depends only on the cosine of the difference between the specular angle and the scattered angle). The scattered and specular angles are always taken in the plane of the incident ray. Angles are measured relative to the surface normal.
- The relative scattered ray power in the specular direction is d multiplied by the projected solid angle in the specular direction. This product cannot exceed 1 for a 100% scattering surface or the relative ray power contained in the specular ray(s). Failure to satisfy this restriction violates conservation of energy.
- The BSDF for the Phong model at large specular angles can result in a split distribution in angle space that is the result of the distribution wrapping across the scatter angle boundary from 90 to –90 degrees.
- The Phong model is wavelength invariant.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the **Surface Dialog**.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

The following examples show line plots of the Phong BSDF as a function of scatter angle for specular angles of 0, 30, 45, 60, and 89 degrees for n=16 and n=24. Notice that the distribution wraps across the scatter angle boundary from 90 degrees to –90 degrees for large specular angles.

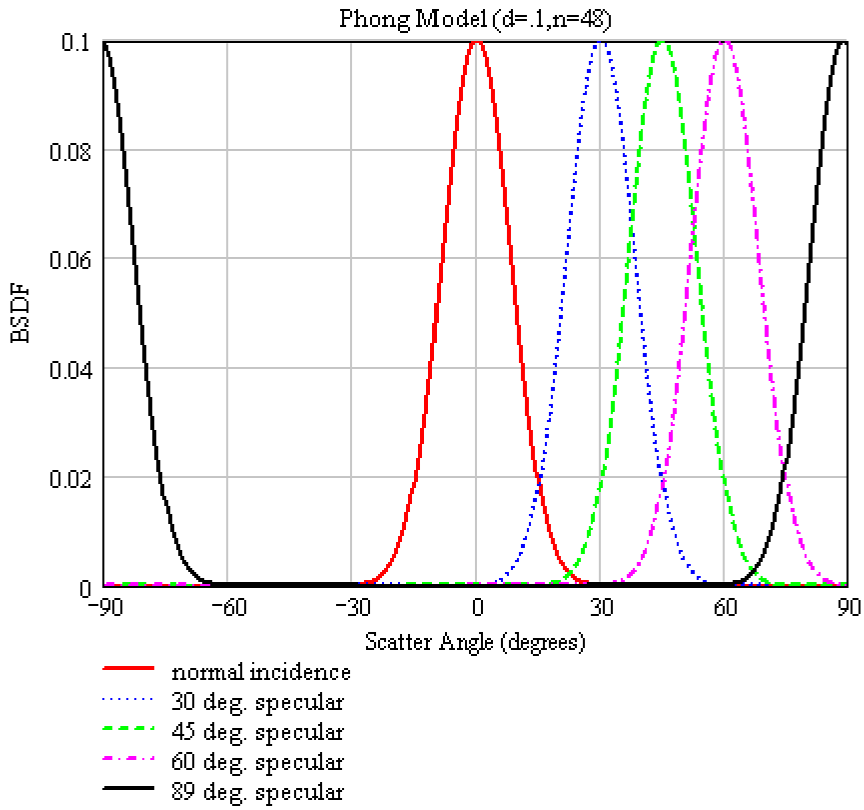
Example 1

The Phong scatter model settings are d = 0.1 and n = 16.



Example 2

The Phong scatter model settings are d = 0.1 and n = 48. Increasing the value of n has the effect of narrowing the linewidth of the distribution function so that more light is scattered near the specular angle.



See Also….

Edit/Create New Scatter Model - Phong

The following links contain details about each of the scatter models:

- Lambertian – for diffuse scatter
- Harvey-Shack – for polished surface scatter
- ABg – for polished surface scatter
- Flat Black Paint – specify Total Integrated Scatter (TIS)
- Surface Particle (Mie) – for particulate contamination
- Tabulated BSDF – measured BSDF data
- Tabulated PSD – measured PSD data
- K-Correlation – analytic PSD

Edit/Create New Scatter Model – Tabulated PSD

Description

Tabulated PSD

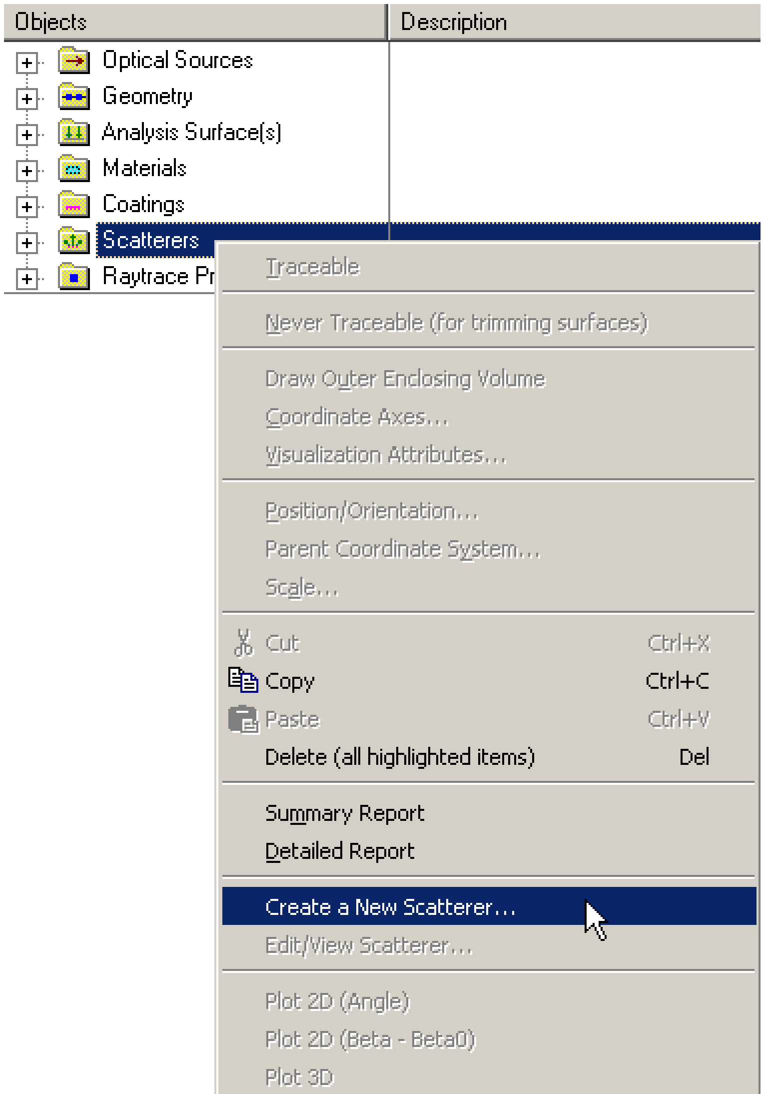
The Tabulated Power Spectral Density (PSD) scatter model accepts measured PSD data and creates an interpolated BSDF model.

How Do I Get There?

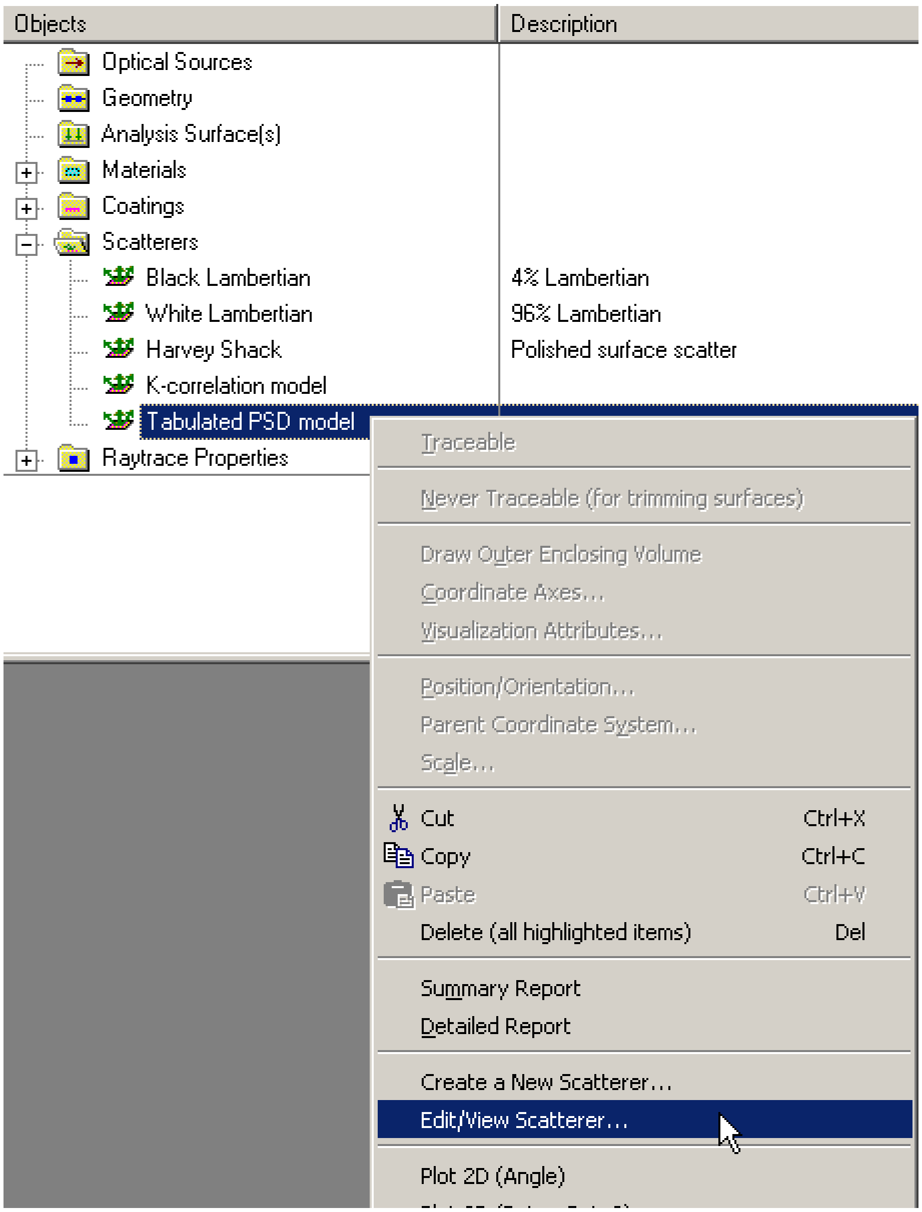
Tabulated PSD

There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option '*Create a New Scatterer…*'

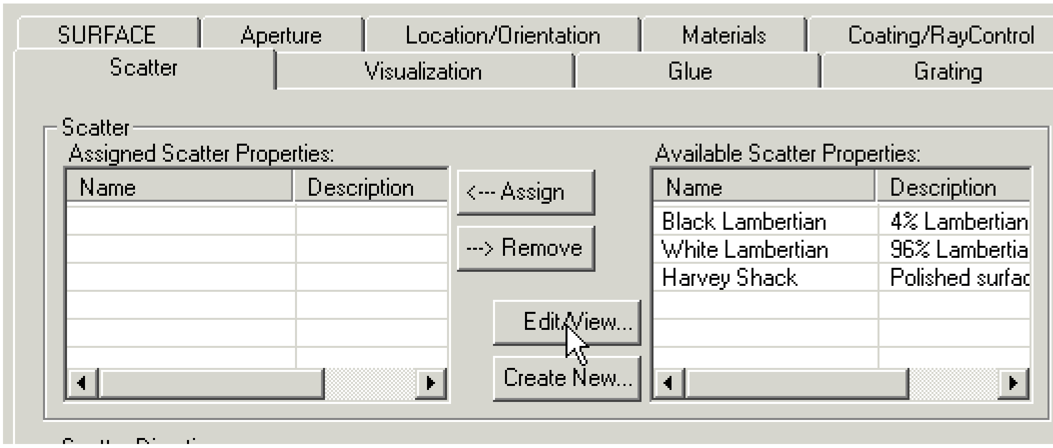


2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer…*'.



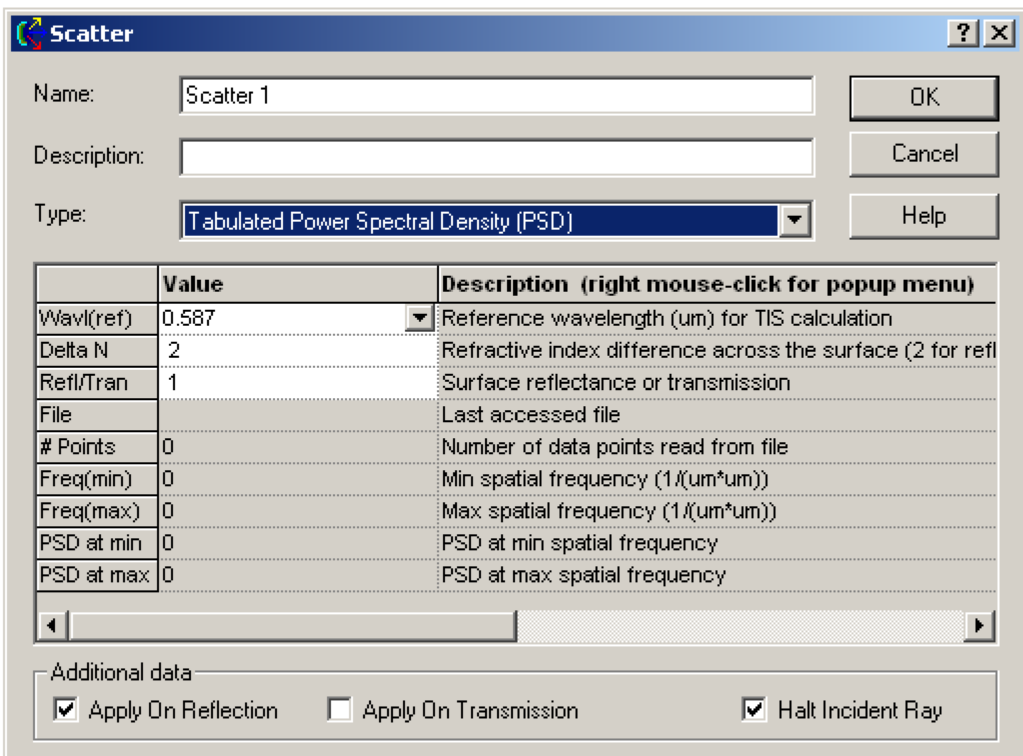
3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View…*' or '*Create New…*' coating buttons.



Dialog Box and Controls

Tabulated PSD



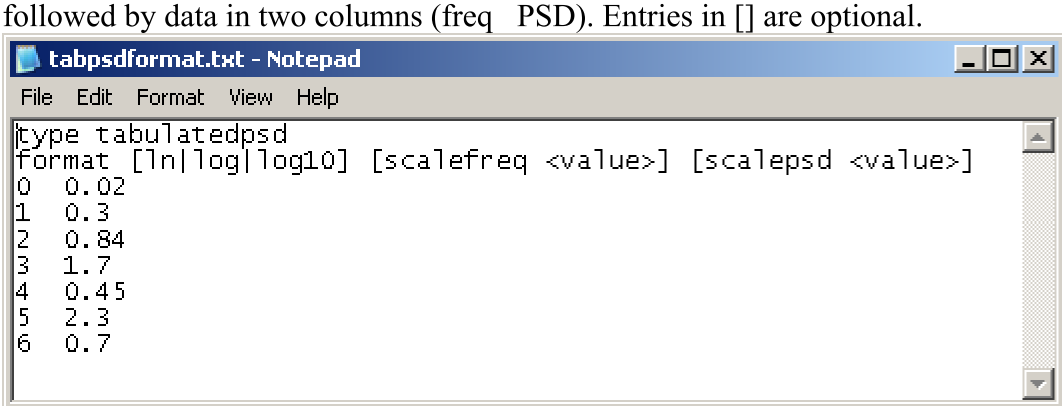
Control	***Inputs / Description***	***Defaults***
Name	Name of the model (required).	Scatter *n*
Description	Alpha-numeric text describing the model (optional).	blank
Type	Choose **Tabulated Power Spectral Density** from the pull down menu.	Lambertian

Wavl(ref)	Reference wavelength	0.587
Delta N	Refractive index difference between incident and substrate material. For reflection, Delta N = 2.	2
Refl/Tran	Reflectance/transmittance of surface.	1
File	Full path to file containing measured data.	blank
# Points	Number of data points in file.	0
Freq(min/max)	Minimum and maximum frequency represented in file data.	0,0
PSD at min	PSD value at minimum.	0
PSD at max	PSD value at maximum.	0
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Application Notes

Tabulated PSD

The file format for Tabulated PSD data is shown below. There is a two line header followed by data in two columns (freq PSD). Entries in [] are optional.



```
tabpsdformat.txt - Notepad
File Edit Format View Help
type tabulatedpsd
format [ln|log|log10] [scalefreq <value>] [scalepsd <value>]
0   0.02
1   0.3
2   0.84
3   1.7
4   0.45
5   2.3
6   0.7
```

See Also….

Tabulated PSD

The following links contain details about each of the scatter models:

- Lambertian – for diffuse scatter
- Harvey-Shack – for polished surface scatter
- ABg – for polished surface scatter
- Phong scatter – $\cos^n$ from specular
- Flat Black Paint – specify Total Integrated Scatter (TIS)
- Surface Particle (Mie) – for particulate contamination
- Tabulated BSDF – measured BSDF data
- K-Correlation – analytic PSD

Chapter 11 - Raytrace Properties

Raytrace Control

Description

Raytrace Control

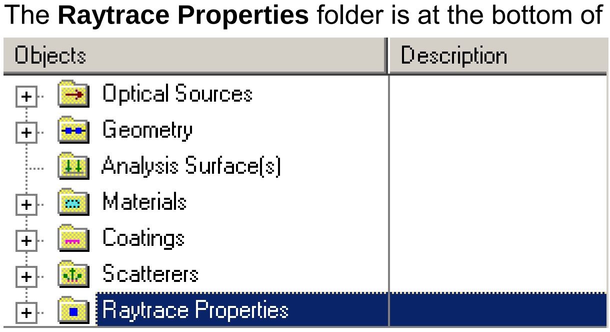
The **Raytrace Properties** folder contains the default and optional user entered raytrace control settings that are applied to every surface in FRED. Raytrace Properties tell FRED how to propagate every ray that intersects a surface. The default controls are Halt All, Transmit Specular, Reflect Specular, and Allow All. The user can edit any one of these or create additional controls.

WARNING	Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is required.

Visualization (example)

Raytrace Control

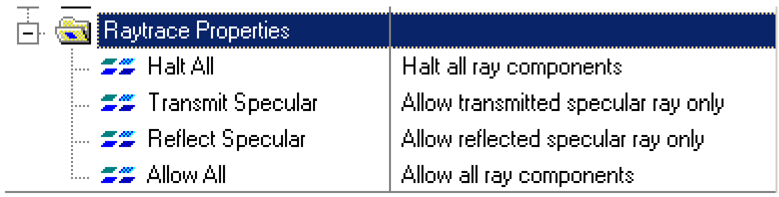
The **Raytrace Properties** folder is at the bottom of the tree.



How Do I Get There?

Raytrace Control

A left click on the ⊞ symbol next to the folder name will expand the tree.

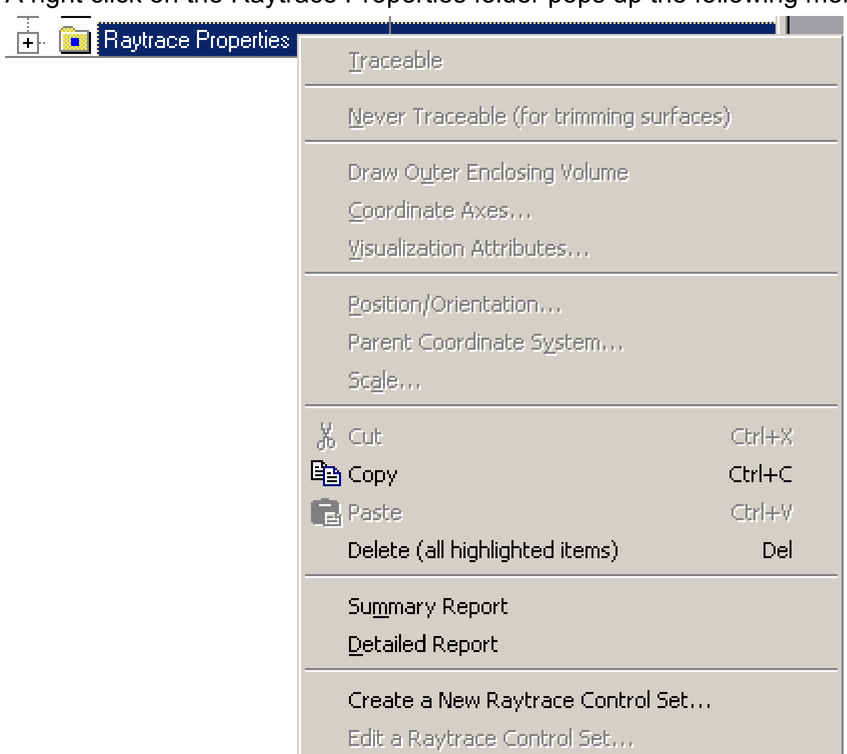


A left click on the ⊟ symbol next to an open folder will collapse the tree.
Existing Raytrace Controls can be edited via a right mouse click.

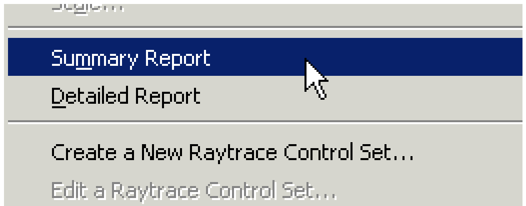
Dialog Box and Controls

Raytrace Control

A right click on the Raytrace Properties folder pops up the following menu.



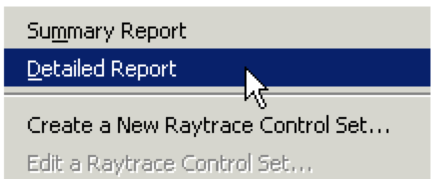
The first option available on the right click menu is a Summary Report.



When this option is selected, FRED prints a list of all the Raytrace Property controls in the model as well as any descriptive text associated with each.

RAYTRACE CONTROLS	
Halt All	Halt All Ray Components
Transmit Specular	Allow Transmitted Specular Ray Only
Reflect Specular	Allow Reflected Specular Ray Only
Allow All	Allow Reflected and Transmitted Specular Rays

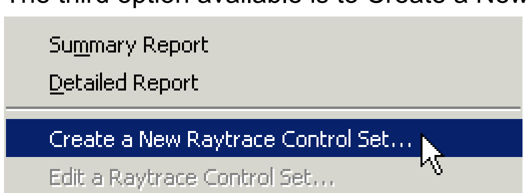
The second option available on the right click menu is a Detailed Report.



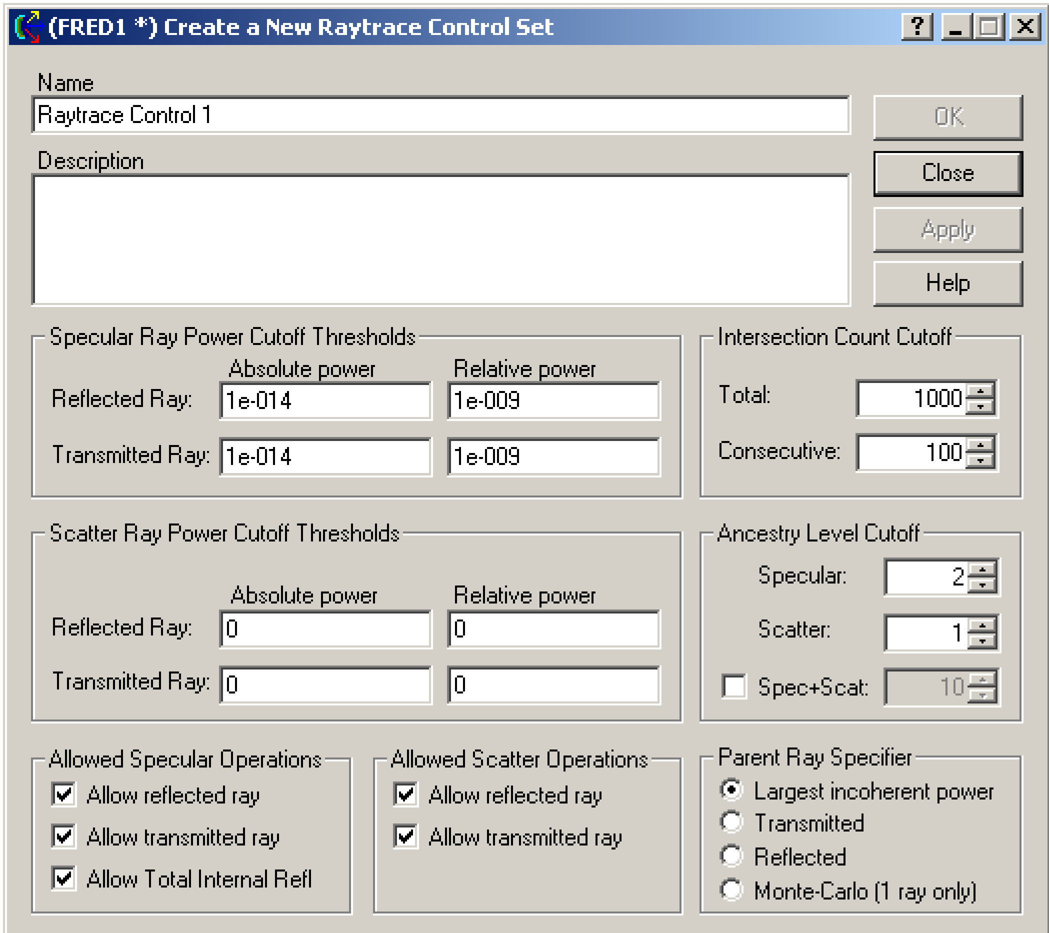
When this option is selected, FRED prints a detailed summary of all of the Raytrace Property controls.

RAYTRACE CONTROLS						
Allow Tran	Parent	Max spec lvl	Max total	Rel trans pwr	Abs trans pwr	Name
Allow Refl	Allow TIR	Max scat lvl	Max consec	Rel refl pwr	Abs refl pwr	
N	Largest Incoherent Power	2	1000	1e-9	1e-14	Halt All
N	N	1	10	1e-9	1e-14	
Y	Largest Incoherent Power	2	1000	1e-9	1e-14	Transmit Specular
N	N	1	10	1e-9	1e-14	
N	Largest Incoherent Power	2	1000	1e-9	1e-14	Reflect Specular
Y	N	1	10	1e-9	1e-14	
Y	Largest Incoherent Power	2	1000	1e-9	1e-14	Allow All
Y	Y	1	10	1e-9	1e-14	

The third option available is to Create a New Raytrace Control Set…



Selecting this option opens the Raytrace Control Dialog. This is one of 3 ways to access this dialog.



Control	Inputs	Defaults
Name	Name of the Raytrace Control.	Raytrace Control *n*
Description	Alpha-numeric description of the Raytrace Control.	blank
Specular Ray Power Cutoff Thresholds		
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	1e-009
Scatter Ray Power Cutoff Thresholds		

Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	0
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	0
Intersection Count Cutoff		
Total	This value sets the maximum number of surface intersections for each ray.	1000
Consecutive	This value sets the number of consecutive intersections each ray can have with a single surface.	10
Ancestry Level Cutoff		
Specular	This value sets the maximum number of Specular generations that can be split.	2
Scatter	This value sets the maximum number of Scatter generations that can be split.	1
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)
Allowed Specular Operations		
Allow reflected ray	Check this box to allow propagation of the reflected ray component.	Checked
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Checked
Allow Total Internal Reflection	Check this box to allow propagation a ray that undergoes Total Internal Reflection.	Checked
Allowed Scatter Operations		
Allow reflected ray	Check this box to allow propagation of the reflected scatter component.	Checked
Allow transmitted ray	Check this box to allow propagation of the transmitted scatter component.	Checked
Parent Ray Specifier		
Largest incoherent power	Check this radio button to allow FRED to determine the Parent ray following a surface intersection.	Selected
Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected

Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
OK	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

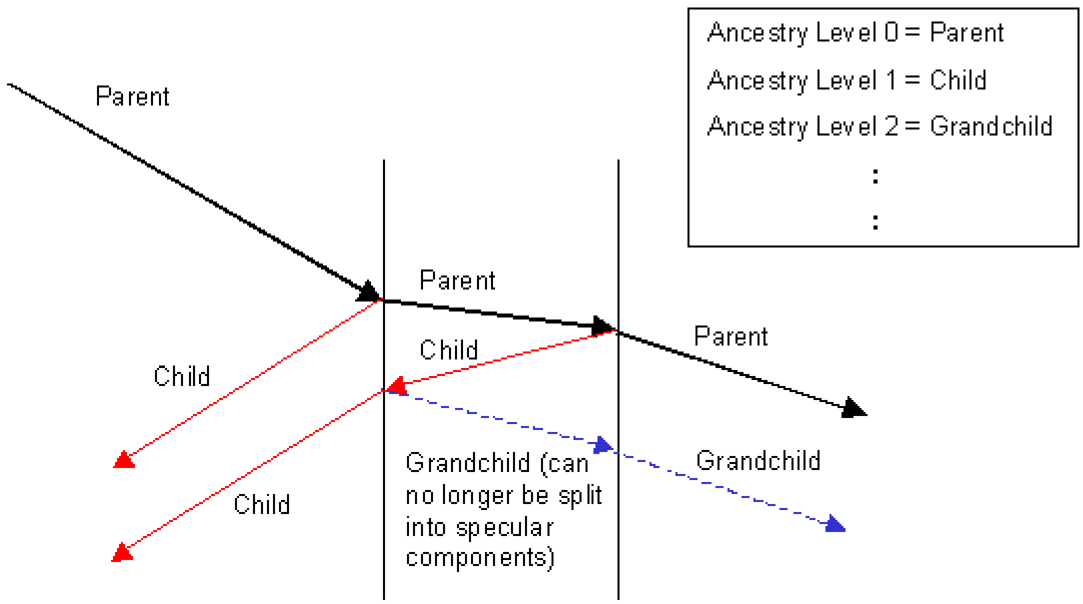
Application Notes

Raytrace Control

- Raytrace Controls are applied before **Coatings**.
- Coatings are use in conjunction with the Raytrace Controls to determine ray propagation.
  - o To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection
  - o To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission
- Scattered rays are subject to the same limitations.
- Relative and Absolute power cutoffs apply to both coherent and incoherent rays
- With the exception of **Lens**, **Mirror**, and **Prism** components, the Raytrace Control for every surface created in FRED is Halt All, which stops ray propagation.
- The Ancestry levels in FRED are used to determine whether or not a ray can be split at an interface. On creation, the Ancestry Level is automatically set to 0. That is to say, every ray is a Parent ray. When a propagated ray intersects a surface, if allowed, the ray can be split into reflected and transmitted specular components and 1 scatter component. The Parent ray specifier tells FRED which component maintains the Ancestry Level of the incident ray. The Ancestry level for any split ray that is not the Parent is incremented by 1. If the Ancestry level exceeds the cutoff, then the ray is halted. Otherwise, the ray continues to propagate.
  - o Ancestry levels for specular and scatter components are completely independent of one another.
  - o If the Parent Ray Specifier is set to 'Largest Incoherent Power' and both the reflected and transmitted components have equal power, then FRED automatically makes the transmitted ray the Parent

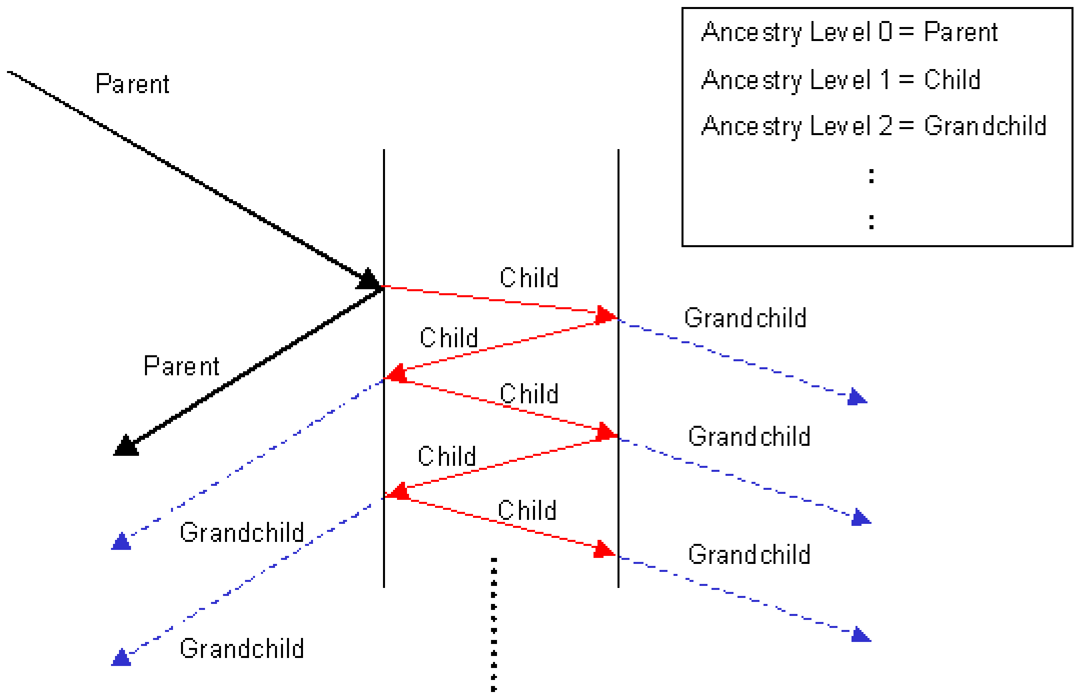
The following examples illustrate Parentage and Ancestry Level splitting. In the first 2 examples, the Specular Ancestry Cutoff has been set to Level 2, which means that Grandchildren rays can no longer be split into specular components. Because the Scatter Ancestry Level has been set to 0, the Raytrace Control will not allow any ray to scatter, even if a **Scatter Property** has been assigned to the surface. The third example shows a scattering surface. Note that since the reflected specular ray is the Parent, all of the scattered rays will maintain the Specular Ancestry Level of the incident ray.

Example 1



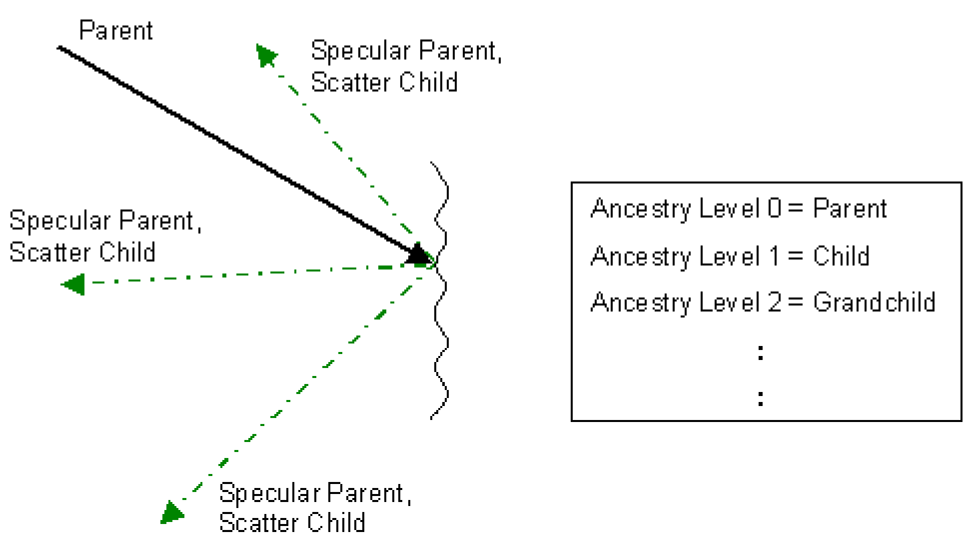
Parent = Transmitted Ray, Specular Ancestry Level = 2, Scatter Ancestry Level = 0 (No Scatter)

Example 2



Parent = Reflected Ray, Specular Ancestry Level = 2, Scatter Ancestry Level = 0 (No Scatter)

Example 3



Parent = Reflected Ray, Specular Ancestry Level = 2, Scatter Ancestry Level = 1

See Also….

Raytrace Control

To view the default Raytrace Control settings select the following links

Halt All

Transmit Specular

Reflect Specular

Allow All

Default Raytrace Controls – Allow All

Description

How Do I Get There?

Dialog box and Controls

Description

Default Raytrace Controls – Allow All

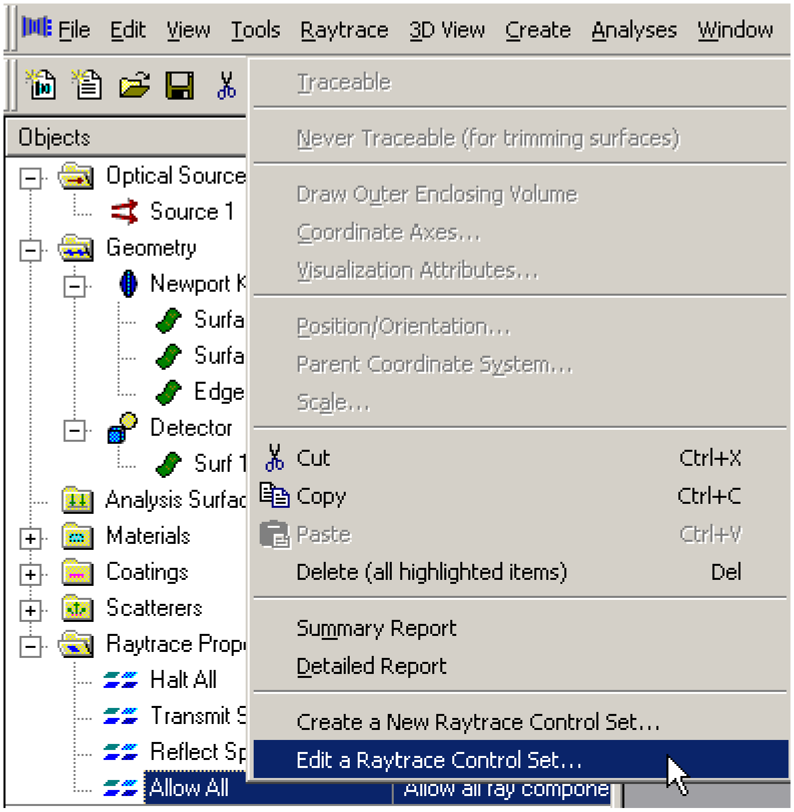
The Reflect Specular raytrace control allows both reflected and transmitted rays to propagate if the flux (power) exceeds the specified thresholds. This control also allows Total Internal Reflection.

WARNING: Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is required.

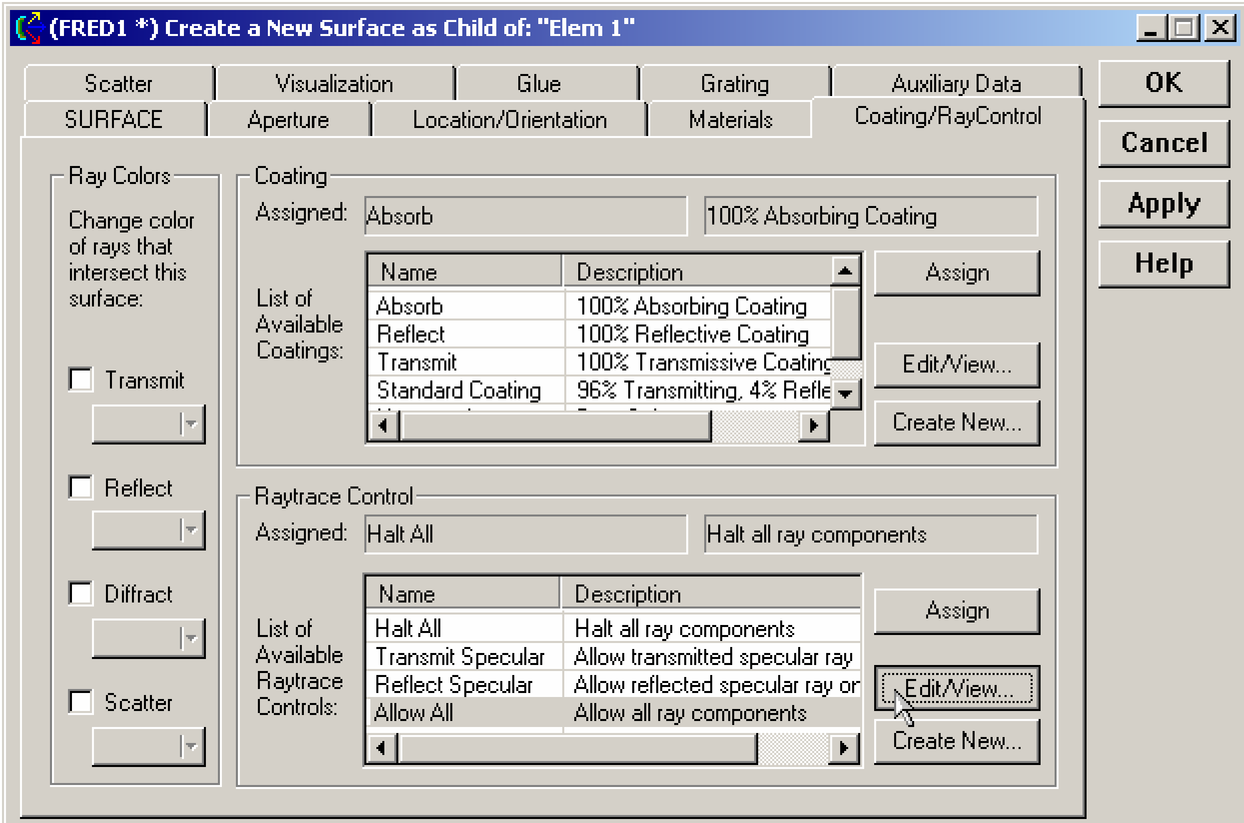
How Do I Get There?

Default Raytrace Controls – Allow All

The dialog can be reached with a right click on the Allow All control under the Raytrace Properties folder.

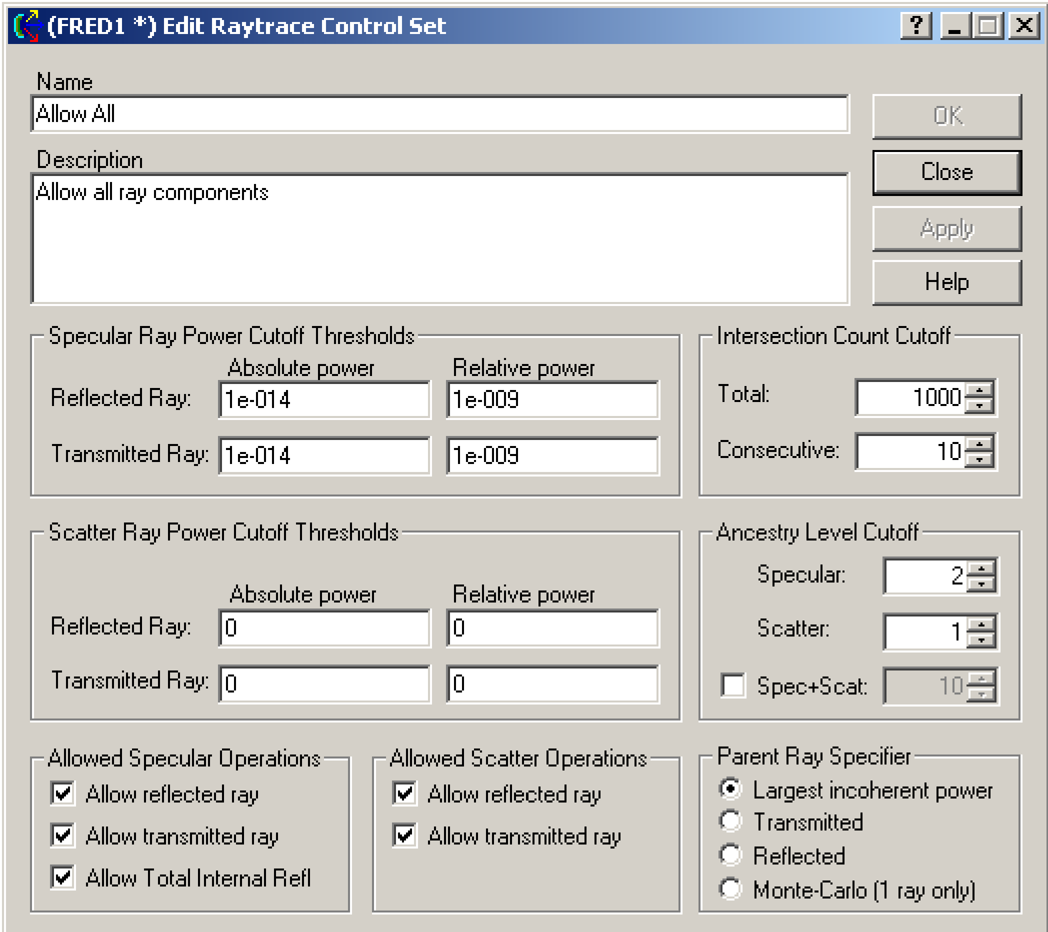


The Dialog can also be reached using the Edit/View button under the Coating/Raytrace Control tab in the Edit/View Surface or Create a New Surface Dialogs.



[Dialog Box and Controls](#)

Default Raytrace Controls – Allow All



Control	***Inputs***	***Defaults***
Name	Name of the Raytrace Control.	Allow All
Description	Alpha-numeric description of the Raytrace Control.	Allow reflected and transmitted specular rays
Specular Ray Power Cutoff Thresholds		
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	1e-009
Scatter Ray Power Cutoff Thresholds		

Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	0
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	0
Intersection Count Cutoff		
Total	This value sets the maximum number of surface intersections for each ray.	1000
Consecutive	This value sets the number of consecutive intersections each ray can have with a single surface.	10
Ancestry Level Cutoff		
Specular	This value sets the maximum number of Specular generations that can be split.	2
Scatter	This value sets the maximum number of Scatter generations that can be split.	1
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)
Allowed Specular Operations		
Allow reflected ray	Check this box to allow propagation of the reflected ray component.	Checked
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Checked
Allow Total Internal Reflection	Check this box to allow propagation a ray that undergoes Total Internal Reflection.	Checked
Allowed Scatter Operations		
Allow reflected ray	Check this box to allow propagation of the reflected scatter component.	Checked
Allow transmitted ray	Check this box to allow propagation of the transmitted scatter component.	Checked
Parent Ray Specifier		
Largest incoherent power	Check this radio button to allow FRED to determine the Parent ray following a surface intersection.	Selected
Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected

Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
OK	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

See Also….

Default Raytrace Controls – Allow All

For a detailed explanation of Raytrace Controls, select the following link

Raytrace Controls

To view the remaining default Raytrace Control settings select the following links

Halt All

Transmit Specular

Reflect Specular

Default Raytrace Controls – Halt All

Description

How Do I Get There?

Dialog box and Controls

See Also...

Description

Default Raytrace Controls – Halt All

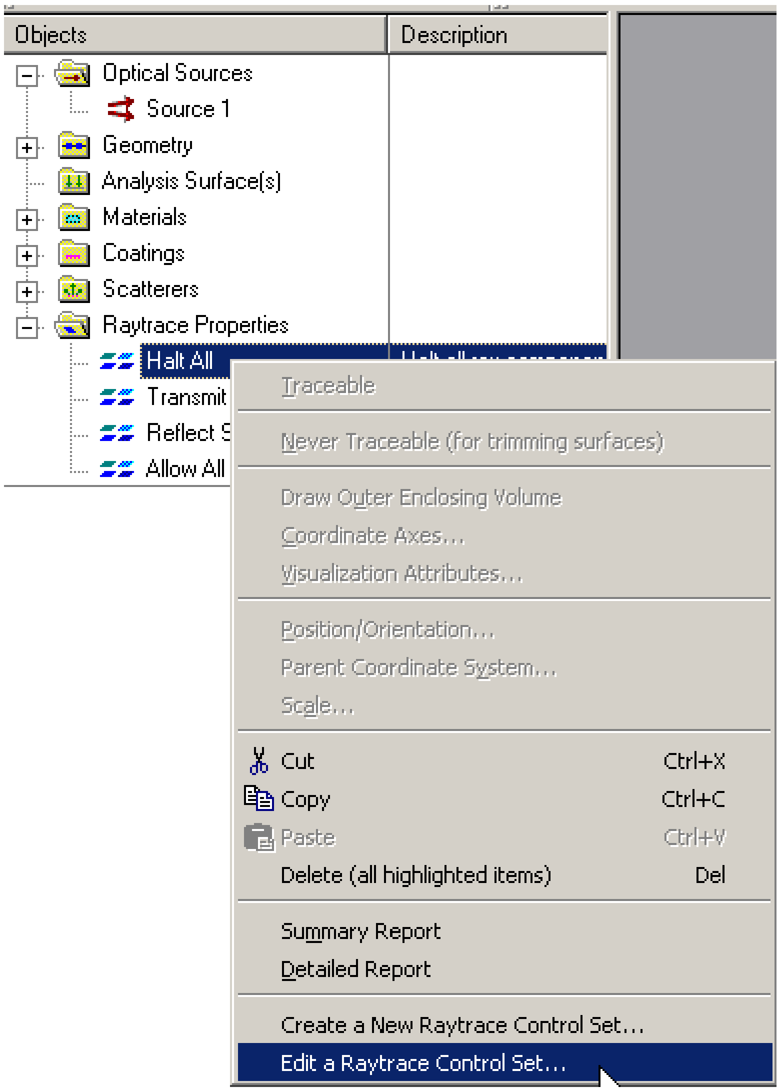
The Halt All raytrace control stops all rays incident on the surface.

WARNING Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is required.

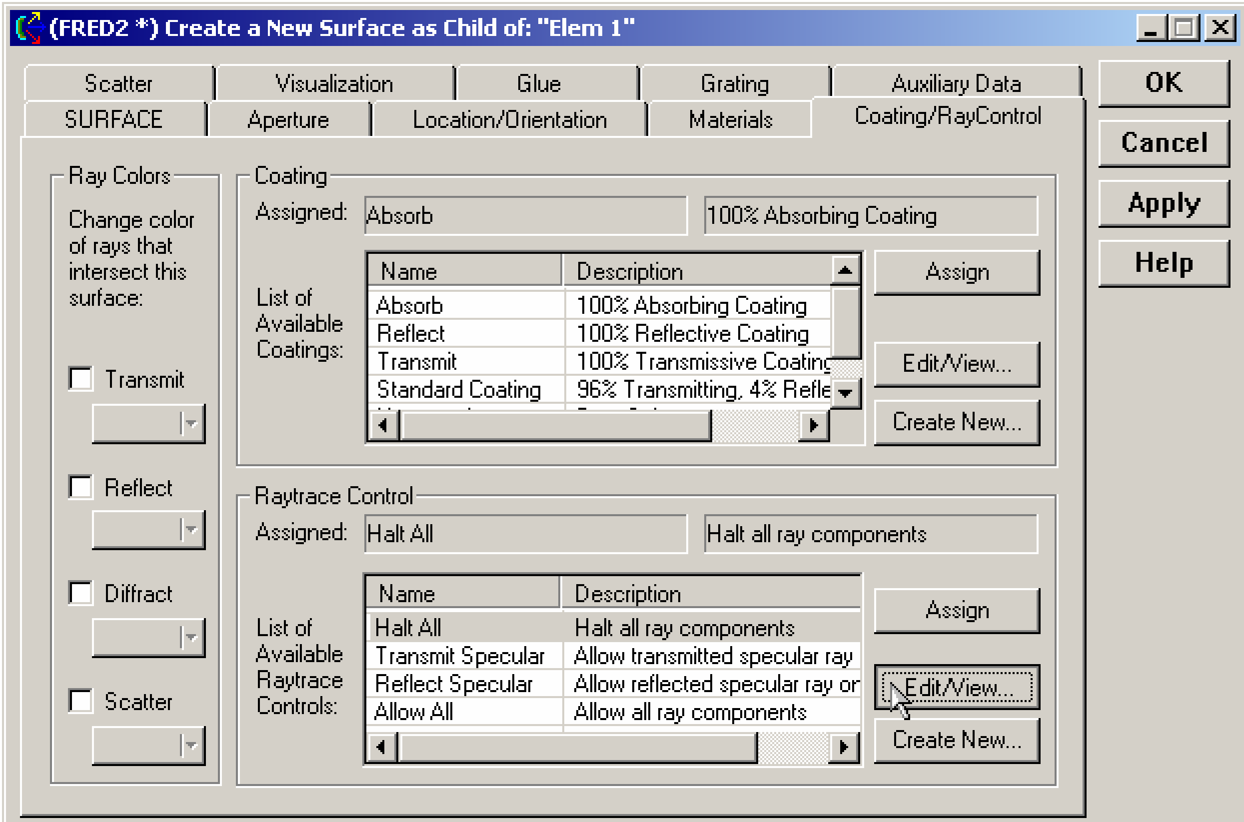
How Do I Get There?

Default Raytrace Controls – Halt All

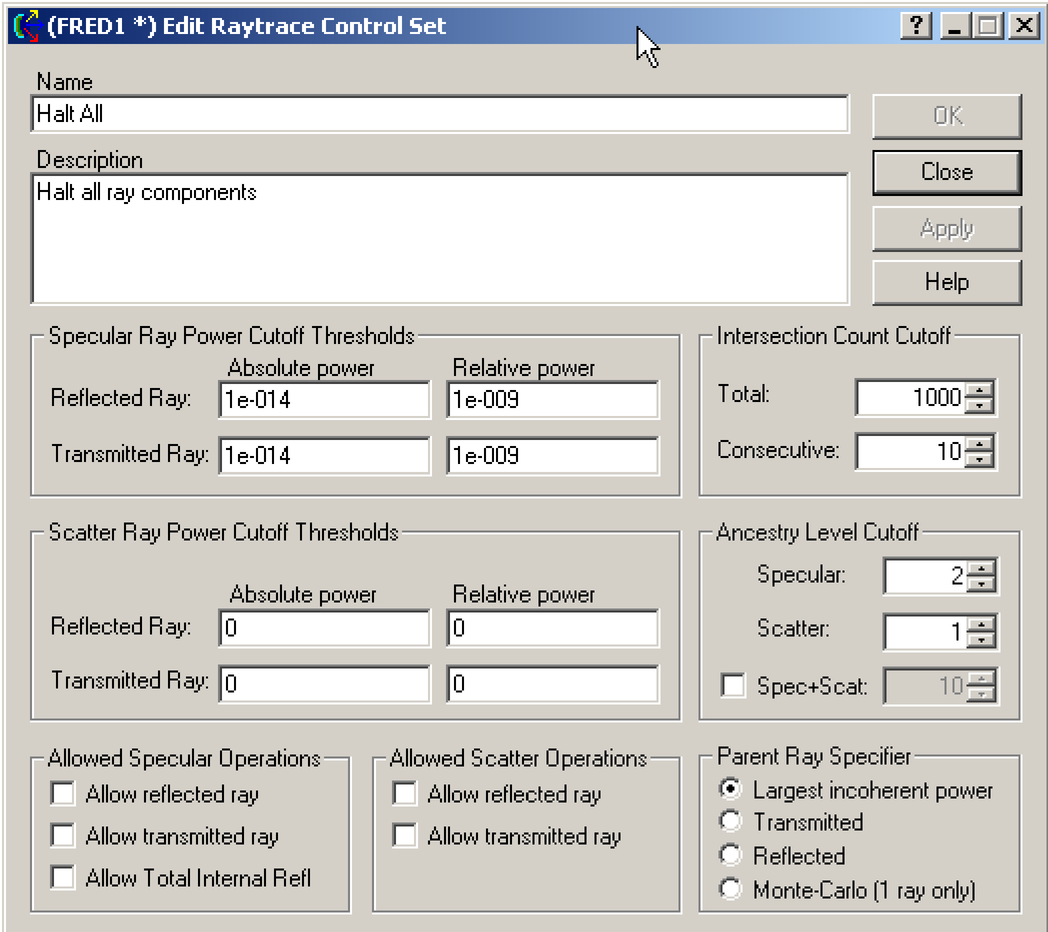
The dialog can be reached with a right click on the Halt All control under the Raytrace Properties folder.



The Dialog can also be reached using the Edit/View button under the Coating/Raytrace Control tab in the Edit/View Surface or Create a New Surface Dialogs.



Dialog Box and Controls
Default Raytrace Controls – Halt All



Control	***Inputs***	***Defaults***
Name	Name of the Raytrace Control.	Halt All
Description	Alpha-numeric description of the Raytrace Control.	Halt All ray components
Specular Ray Power Cutoff Thresholds		
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	1e-009
Scatter Ray Power Cutoff Thresholds		

Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	0
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	0
Intersection Count Cutoff		
Total	This value sets the maximum number of surface intersections for each ray.	1000
Consecutive	This value sets the number of consecutive intersections each ray can have with a single surface.	10
Ancestry Level Cutoff		
Specular	This value sets the maximum number of Specular generations that can be split.	2
Scatter	This value sets the maximum number of Scatter generations that can be split.	1
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)
Allowed Specular Operations		
Allow reflected ray	Check this box to allow propagation of the reflected ray component.	Unchecked
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Unchecked
Allow Total Internal Reflection	Check this box to allow propagation a ray that undergoes Total Internal Reflection.	Unchecked
Allowed Scatter Operations		
Allow reflected ray	Check this box to allow propagation of the reflected scatter component.	Unchecked
Allow transmitted ray	Check this box to allow propagation of the transmitted scatter component.	Unchecked
Parent Ray Specifier		
Largest incoherent power	Check this radio button to allow FRED to determine the Parent ray following a surface intersection.	Selected

Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected
Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
OK	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

See Also….

Default Raytrace Controls – Halt All

For a detailed explanation of Raytrace Controls, select the following link

Raytrace Controls

To view the remaining default Raytrace Control settings select the following links

Transmit Specular

Reflect Specular

Allow All

Default Raytrace Controls – Reflect Specular

Description

How Do I Get There?

Dialog box and Controls

Description

Default Raytrace Controls – Reflect Specular

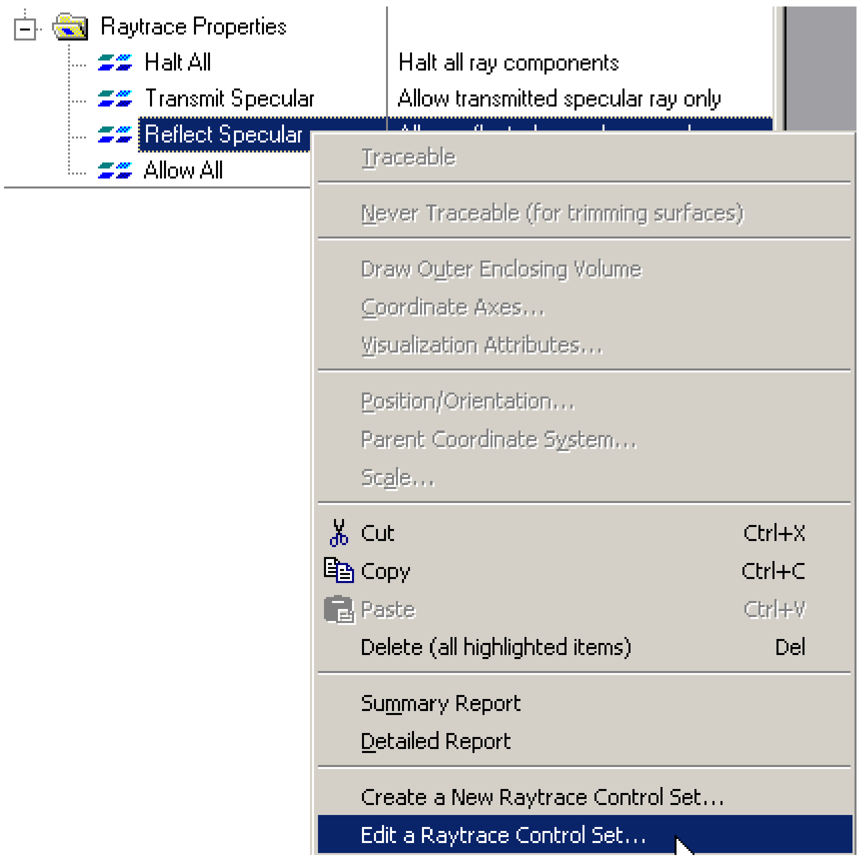
The Reflect Specular raytrace control allows only reflected rays to propagate if the flux (power) exceeds the specified thresholds. This control does not allow Total Internal Reflection.

WARNING Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is required.

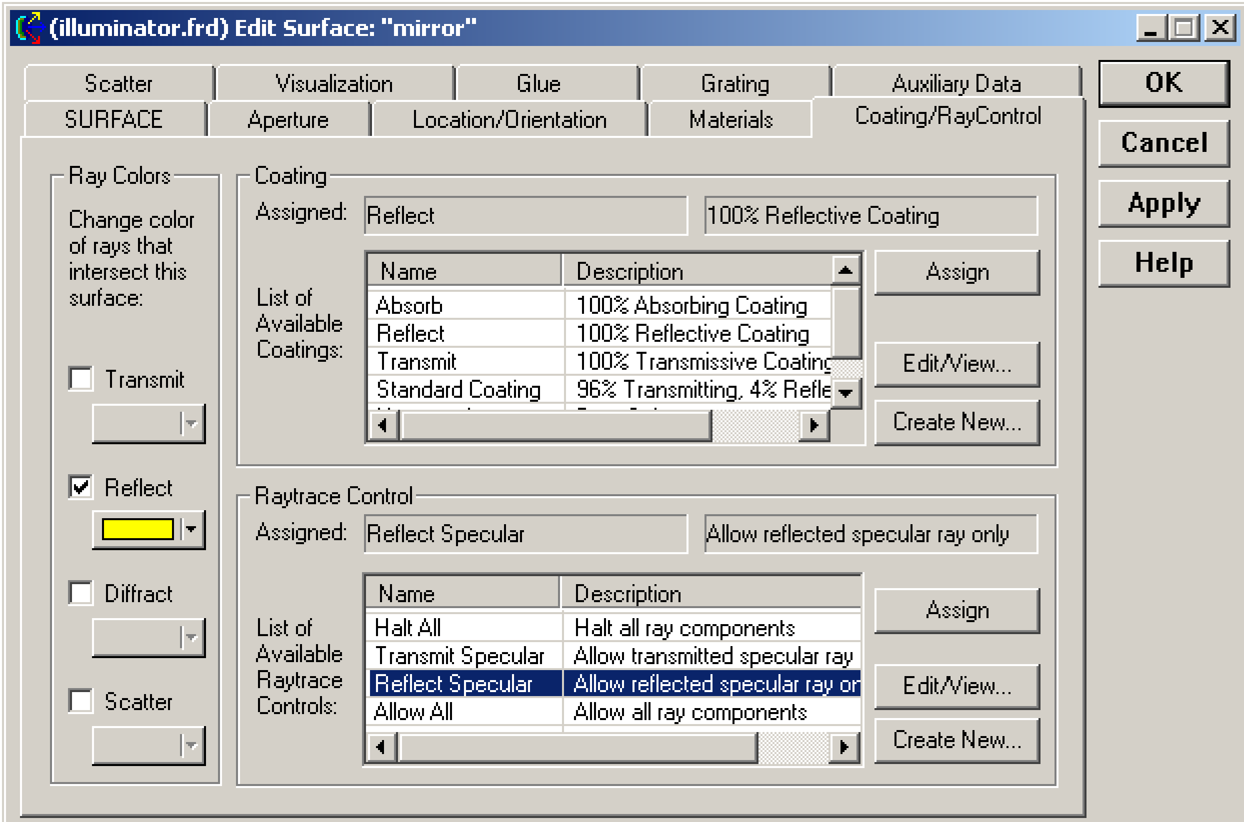
How Do I Get There?

Default Raytrace Controls – Reflect Specular

The dialog can be reached with a right click on the Reflect Specular control under the Raytrace Properties folder.

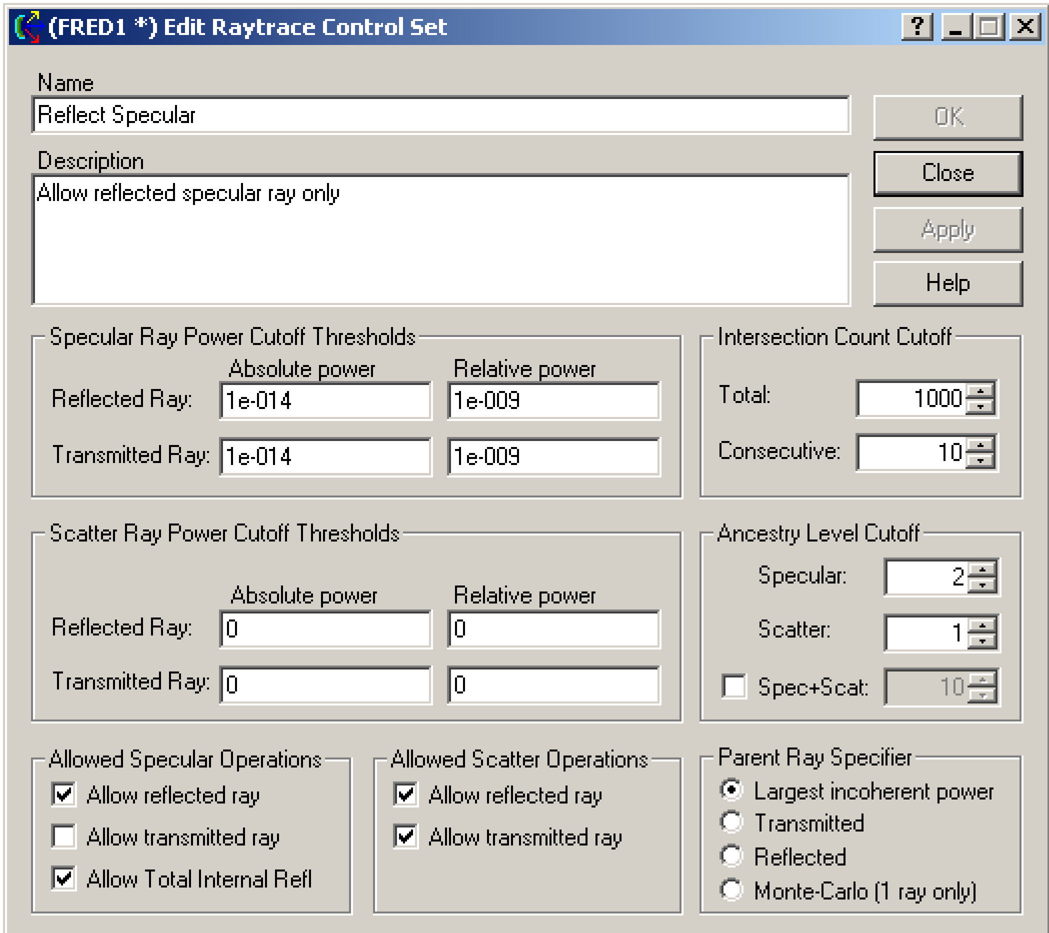


The Dialog can also be reached using the Edit/View button under the Coating/Raytrace Control tab in the Edit/View Surface or Create a New Surface Dialogs.



Dialog Box and Controls

Default Raytrace Controls – Reflect Specular



Control	Inputs	Defaults
Name	Name of the Raytrace Control.	Reflect Specular
Description	Alpha-numeric description of the Raytrace Control.	Allow reflected specular ray only
Specular Ray Power Cutoff Thresholds		
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	1e-009
Scatter Ray Power Cutoff Thresholds		

Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	0
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	0
Intersection Count Cutoff		
Total	This value sets the maximum number of surface intersections for each ray.	1000
Consecutive	This value sets the number of consecutive intersections each ray can have with a single surface.	10
Ancestry Level Cutoff		
Specular	This value sets the maximum number of Specular generations that can be split.	2
Scatter	This value sets the maximum number of Scatter generations that can be split.	1
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)
Allowed Specular Operations		
Allow reflected ray	Check this box to allow propagation of the reflected ray component.	Checked
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Unchecked
Allow Total Internal Reflection	Check this box to allow propagation a ray that undergoes Total Internal Reflection.	Checked
Allowed Scatter Operations		
Allow reflected ray	Check this box to allow propagation of the reflected scatter component.	Checked
Allow transmitted ray	Check this box to allow propagation of the transmitted scatter component.	Checked
Parent Ray Specifier		
Largest incoherent power	Check this radio button to allow FRED to determine the Parent ray following a surface intersection.	Selected
Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected

Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
OK	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

See Also….

Default Raytrace Controls – Reflect Specular

For a detailed explanation of Raytrace Controls, select the following link

Raytrace Controls

To view the remaining default Raytrace Control settings select the following links

Halt All

Transmit Specular

Allow All

Default Raytrace Controls – Transmit Specular

Description

How Do I Get There?

Dialog box and Controls

See Also…

Description

Default Raytrace Controls – Transmit Specular

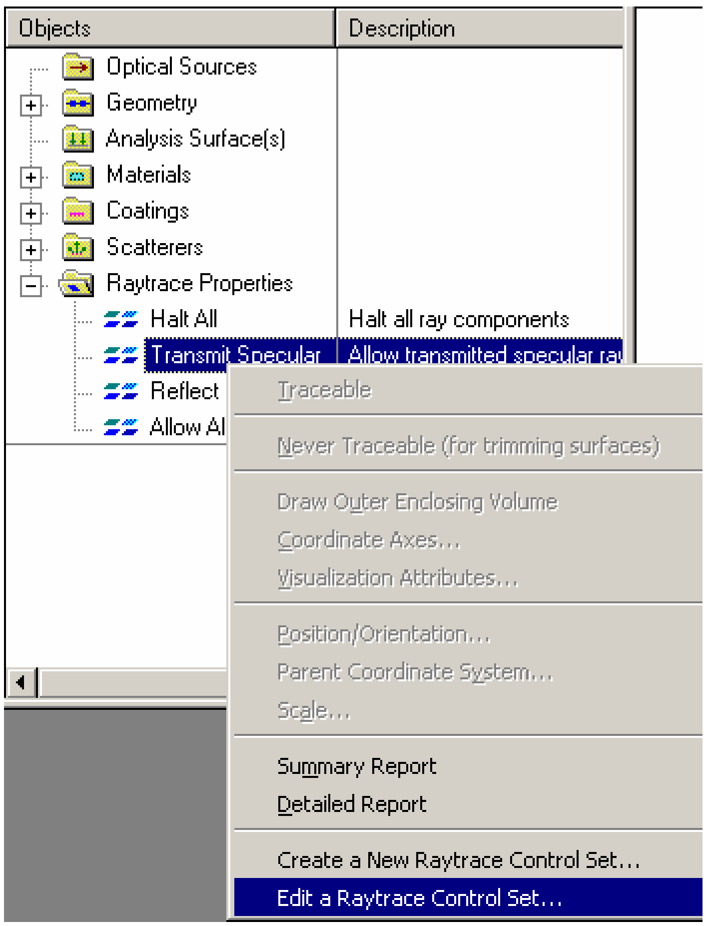
The Transmit Specular raytrace control allows only transmitted rays to propagate if the transmitted flux (power) exceeds the specified thresholds. This control does not allow Total Internal Reflection.

WARNING Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is required.

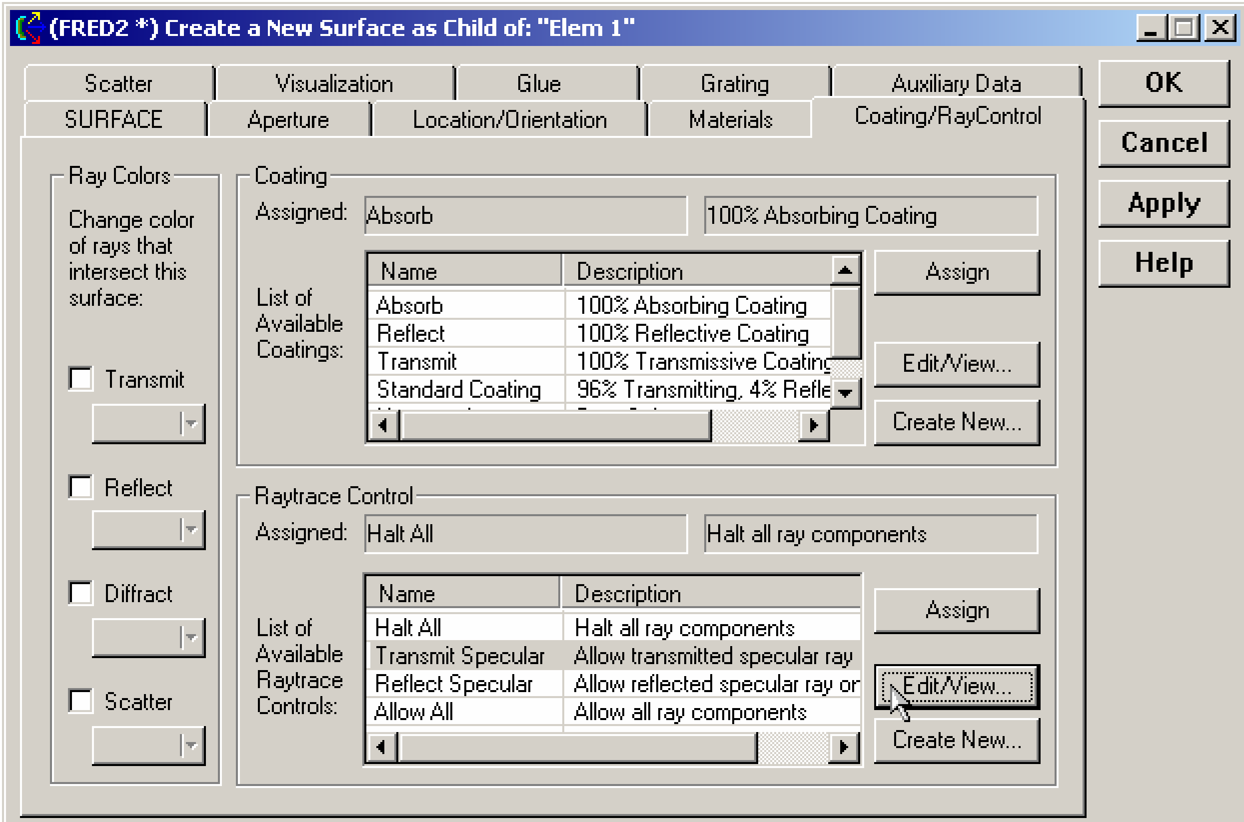
How Do I Get There?

Default Raytrace Controls – Transmit Specular

The dialog can be reached either by a right click on the Transmit All control under the Raytrace Properties folder...

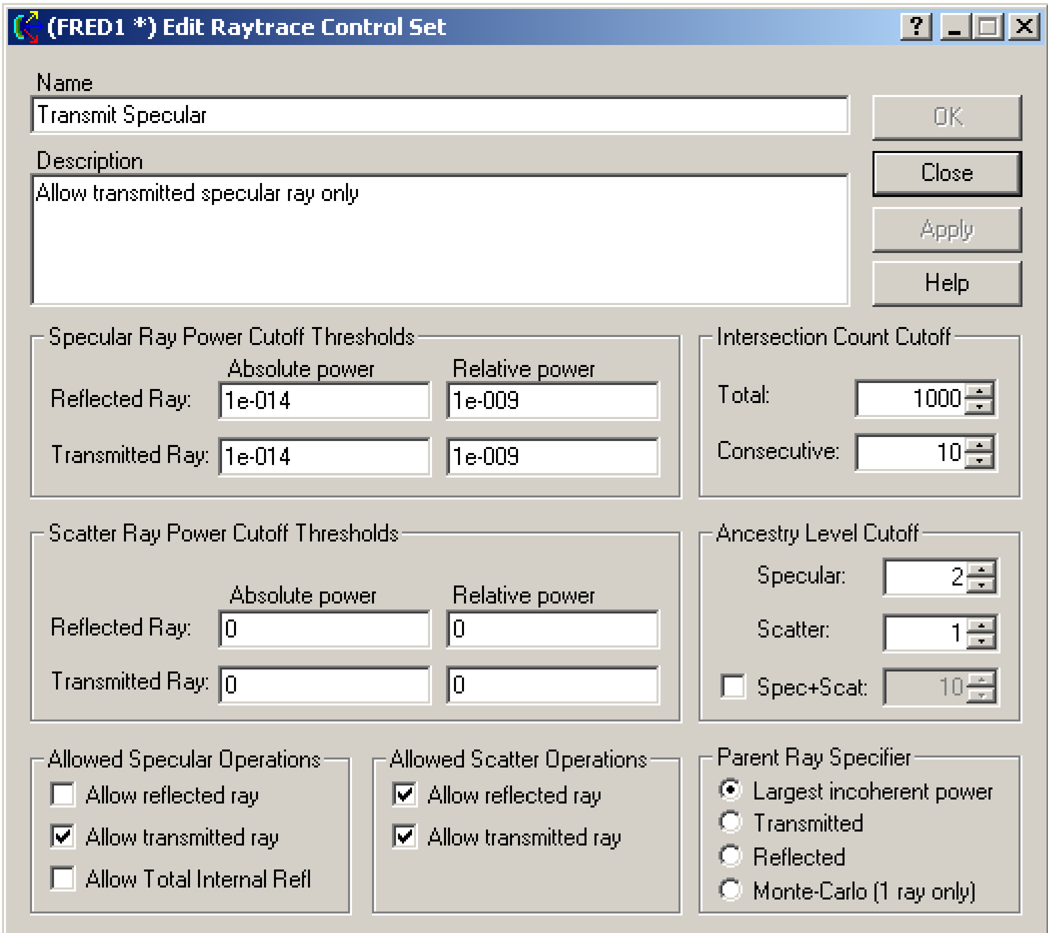


... or by using the Edit/View button under the Coating/Raytrace Control tab in the Edit/View Surface or Create a New Surface Dialogs.



Dialog Box and Controls

Default Raytrace Controls – Transmit Specular



Control	Inputs	Defaults
Name	Name of the Raytrace Control.	Transmit Specular
Description	Alpha-numeric description of the Raytrace Control.	Allow transmitted specular ray only
Specular Ray Power Cutoff Thresholds		
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	1e-009

Scatter Ray Power Cutoff Thresholds		
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	0
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	0
Intersection Count Cutoff		
Total	This value sets the maximum number of surface intersections for each ray.	1000
Consecutive	This value sets the number of consecutive intersections each ray can have with a single surface.	10
Ancestry Level Cutoff		
Specular	This value sets the maximum number of Specular generations that can be split.	2
Scatter	This value sets the maximum number of Scatter generations that can be split.	1
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)
Allowed Specular Operations		
Allow reflected ray	Check this box to allow propagation of the reflected ray component.	Unchecked
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Checked
Allow Total Internal Reflection	Check this box to allow propagation a ray that undergoes Total Internal Reflection.	Unchecked
Allowed Scatter Operations		
Allow reflected ray	Check this box to allow propagation of the reflected scatter component.	Checked
Allow transmitted ray	Check this box to allow propagation of the transmitted scatter component.	Checked
Parent Ray Specifier		
Largest incoherent power	Check this radio button to allow FRED to determine the Parent ray following a surface intersection.	Selected

Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected
Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
OK	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

See Also….
Default Raytrace Controls – Transmit Specular

For a detailed explanation of Raytrace Controls, select the following link
Raytrace Controls
To view the remaining default Raytrace Control settings select the following links
Halt All
Reflect Specular
Allow All

Chapter 12 - New Coatings and Materials Digitization Tool

Description

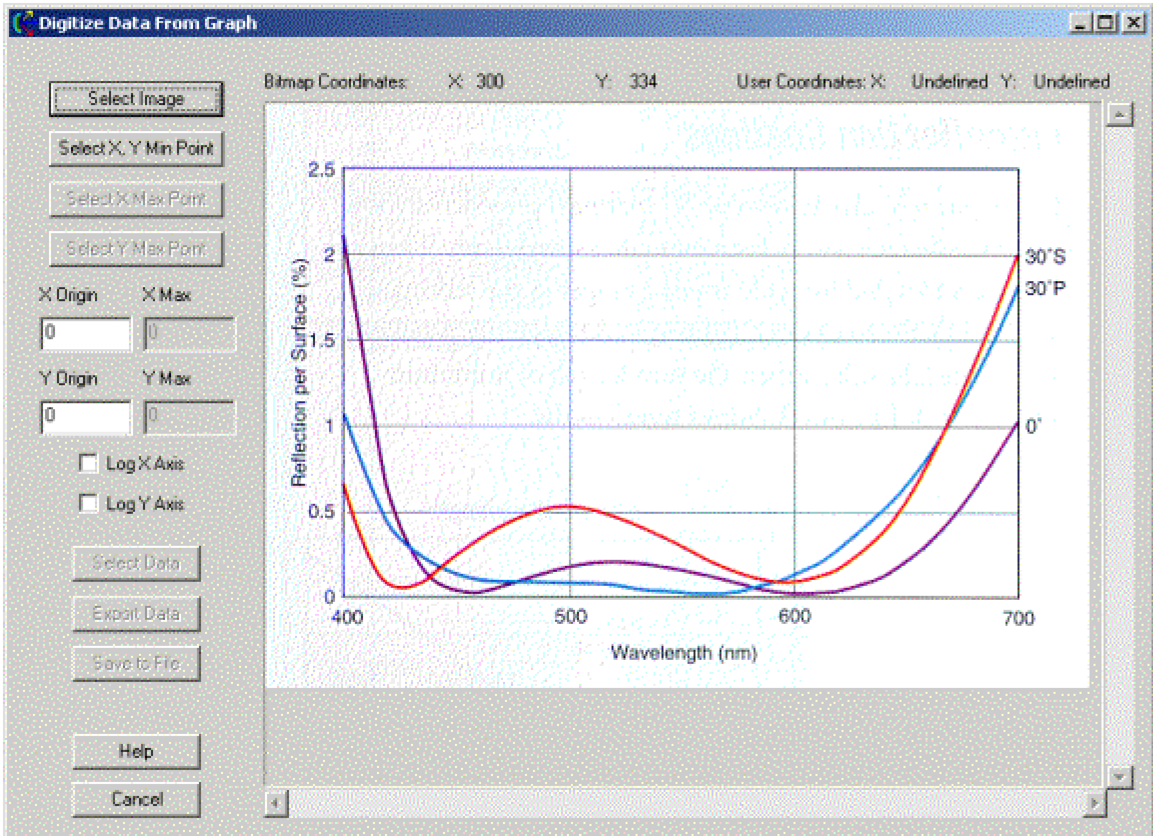
New Coatings and Materials Digitization Tool

The Digitization Tool (or Digitizer) is a tool unique to FRED in the optical engineering software market. This tool allows the user to digitize data points from a graph, plot, lens drawing, etc in an image file. The user can import an image file in a number of different image file formats including BMP bitmap, PC Paintbrush, JPEG, Targa, or TIFF image file. The user then uses the mouse to identify the graph origin, the X-axis scale, and the Y-axis scale. The user can then acquire data from the image by using the mouse to point and click on the image.

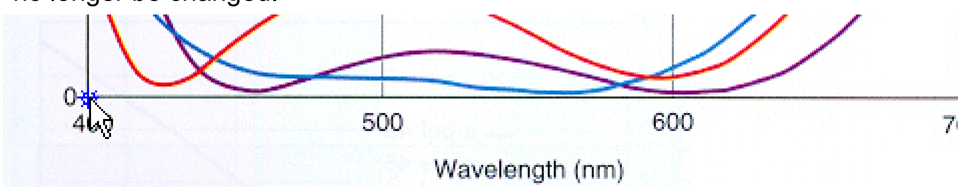
These data points are then exported as different types of data, depending on how the Digitization Tool is started. For example, you can call the Digitizer from the Sampled Materials Edit dialog and display a graph of refractive indices versus wavelength. The data you select is then interpreted as wavelength-refractive index pairs.

Follow this process for digitizing New Coating or New Material data from an image file:

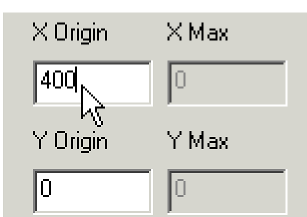
a) The option to digitize data is available in the Sampled Coating and Generalized Coating option in the New Coating dialog and the Sampled Material option in the New Material dialog. To access this tool, right mouse click in the sampled data area and select the appropriate Digitize data option in the right mouse click pop-up menu.
b) Press the Select Image button and select the image file to digitize. The graph image will be displayed in the Digitization Tool Dialog. In the example below, a reflectivity graph for a single layer anti-reflection (AR) coating is being digitized.



a) Press the Select X,Y Min Point button and then left mouse click on the point where the X and Y axes cross. The point clicked on with the mouse will be marked with this symbol: ⌖. The X Y minimum point selection can be changed as long as the Select X Max Point button is not pushed, once the Select X Max Point button has been pushed, this point can no longer be changed.

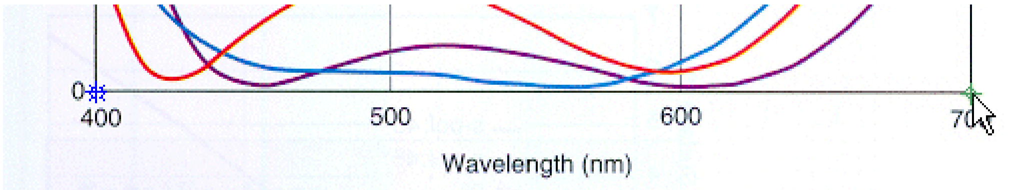


1. Enter the graph or plot coordinates where the X and Y axes cross, in this example the axes cross at X = 400 and Y = 0.

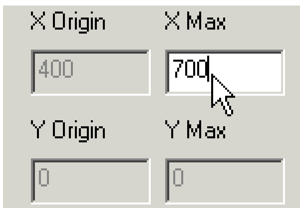


2. Press the Select X Max Point button and then left mouse click on the max coordinate on the X axis. This point will be marked with this symbol: ✛. Note that the point does not have to be the max value on the X axis, it just needs to be a point that can be numerically identified on the graph. The X maximum point selection can be changed as long as the

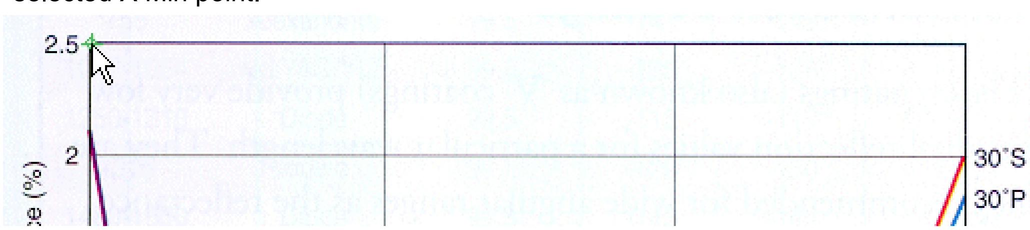
Select Y Max Point button is not pushed, once the Select Y Max Point button has been pushed, this point can no longer be changed.



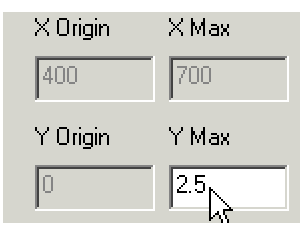
- Enter the graph coordinate for the point selected on the X-axis. In this example the selected X value is 700.



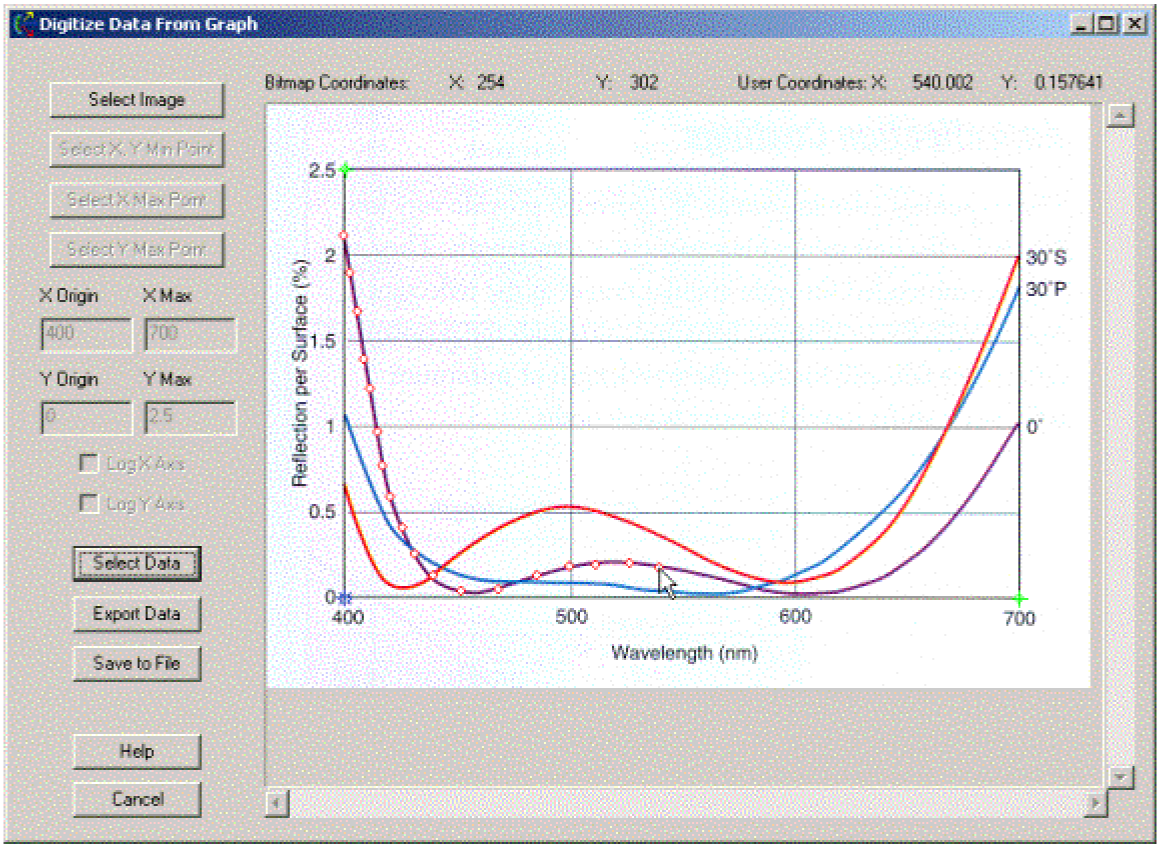
- Press the Select Y Max Point button and then left mouse click on the max coordinate on the Y axis. This point will be marked with this symbol: . Note that the point does not have to be the max value on the Y axis, it just needs to be a point that can be numerically identified on the graph. The Y maximum point selection can be changed as long as the Select Data button is not pushed, once the Select Data button has been pushed, this point can no longer be changed. This point should be located above the previously selected X Min point.



- Enter the graph coordinates for the point selected on the Y-axis. In this example, the selected Y value is 2.5.



- Press the Select Data button and start acquiring data by left mouse clicking on the appropriate data points in the graph. Each selected point will be marked with this symbol: . The data points will not be sorted prior to loading them into the New Coating dialog so select the data points in ascending or descending wavelength order.

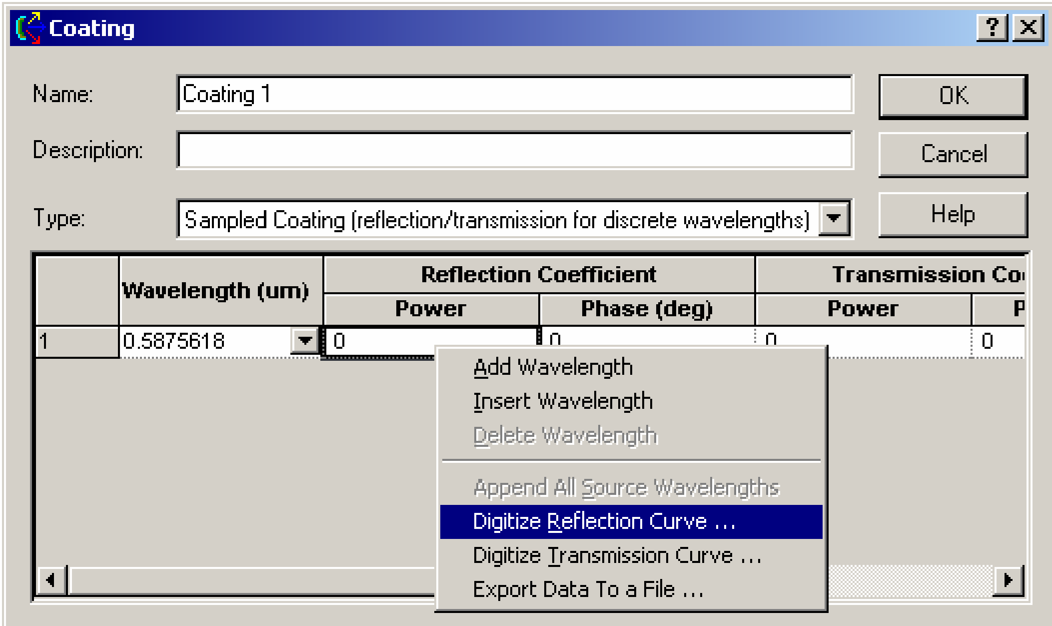


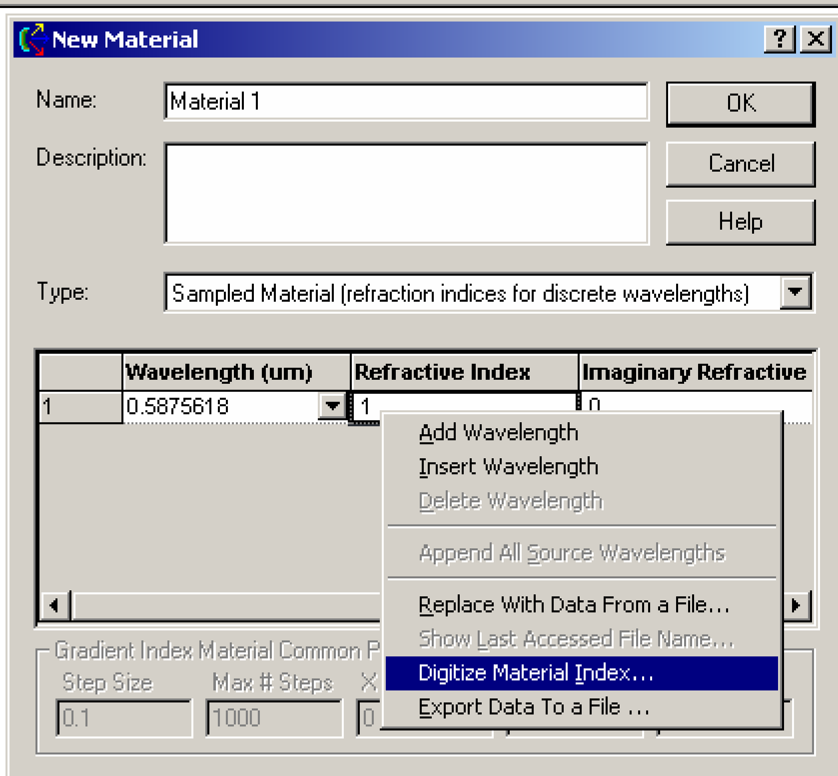
- In addition, the current image pixel and graph coordinates are listed at the top of the window.
- If you would like to save the acquired data to a ASCII text file press the Save To File button.
- After acquiring the data by selecting points on the graph, the data can be loaded into the into the dialog which generated the Digitizer by pressing the Export Data button. This will close the Digitizer and load the acquired data into the previous dialog.

How do I get there?

New Coatings and Materials Digitization Tool

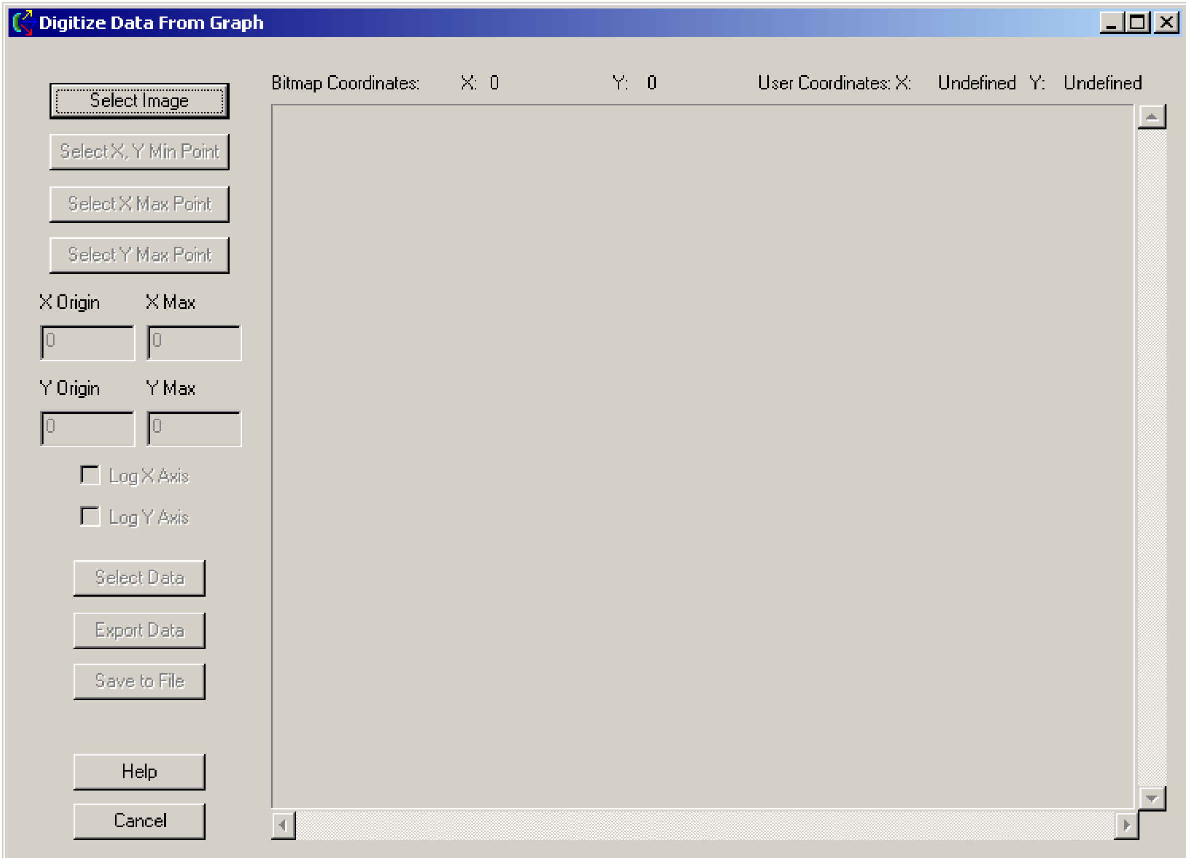
The Digitizer is available as a right mouse click pop-up menu option for entering sampled data into the New Materials and New Coatings dialogs.





Dialog Box and Controls

New Coatings and Materials Digitization Tool



Control	Inputs	Defaults
Select Image	Allows selection of image file (*.bmp only).	
Select X, Y Min Point	Sets the origin of the X- and Y-axes on the image.	
Select X Max Point	Sets the maximum point on the X scale.	
Select Y Max Point	Sets the maximum point on the Y scale.	
X Origin	Sets the value of the origin point on the X scale.	0
Y Origin	Sets the value of the origin point on the Y scale.	0
X Max	Sets the value of the max point on the X scale.	0
Y Max	Sets the value of the max point on the Y scale.	0
Log X Axis	Defines the X-axis as a logarithmic axis. Values for the X Origin and X Max are limited to positive, nonzero values.	Unchecked
Log Y Axis	Defines the Y-axis as a logarithmic axis. Values for the Y Origin and Y Max are limited to positive, nonzero values.	Unchecked

Image Coordinates	Specifies the location of the cursor in bitmap coordinates, relative to the point X=0, Y=0 at the upper left corner of the image.	(0, 0) is at the upper left corner
User Coordinates	Specifies the location of the cursor in the coordinate system you define. Shown as undefined until Data Selection Mode chosen.	Undefined
Image	Displays the image selected for Digitization.	
Select Data	Toggles Data Selection Mode if all requisite parameters have been specified correctly.	
Export Data	Exports data selected to the dialog that brought up the Digitization Tool (for example, the sampled materials edit dialog).	
Save to File	Saves selected data in a text file in x, y format, one point per line.	
Help	Brings up this help article.	
Cancel	Dismisses the dialog without exporting any data to the coating or material.	

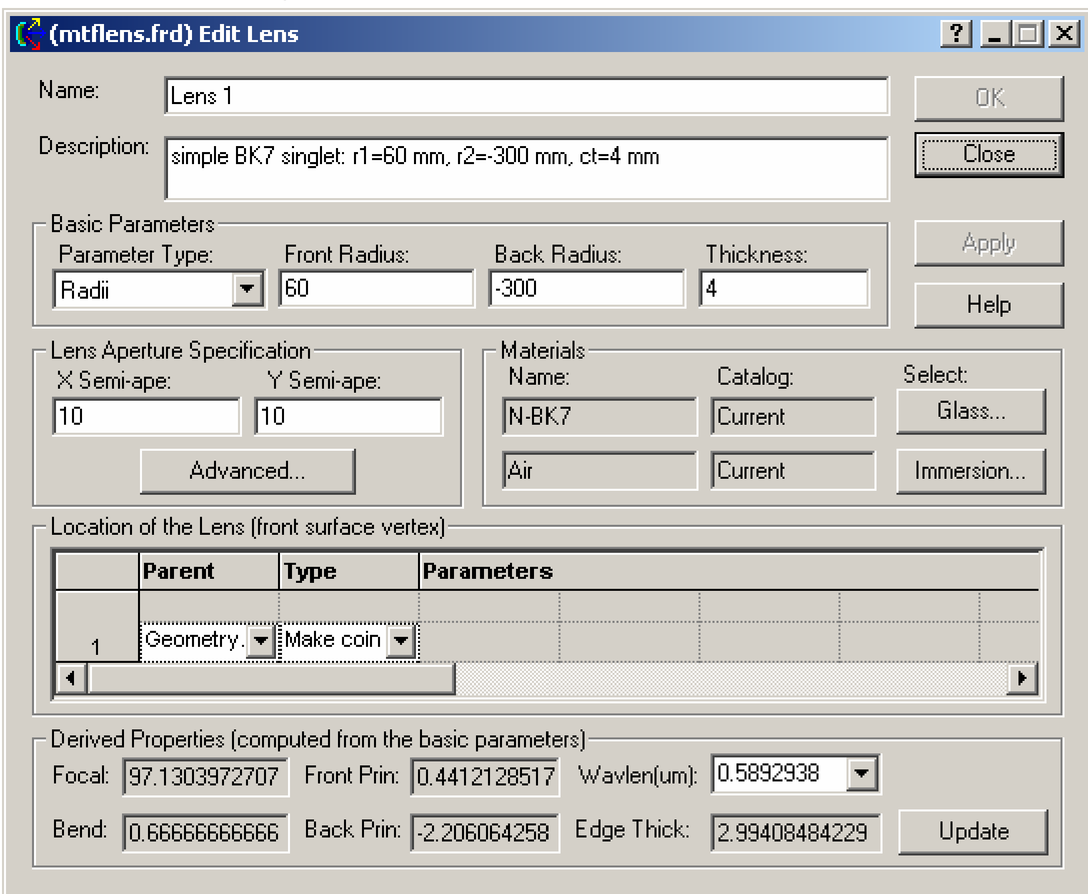
Chapter 13 - The Modulation Transfer Function Calculation in FRED

Description - The Modulation Transfer Function Calculation in FRED

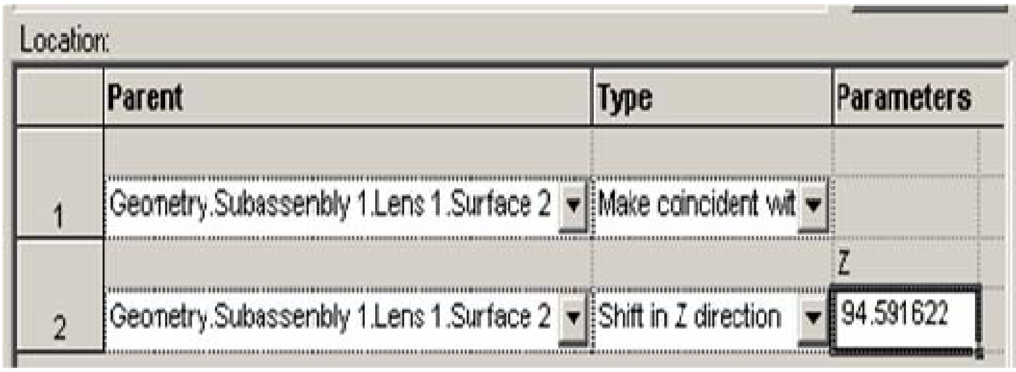
FRED can calculate the Modulation Transfer Function (MTF) for a given system. This help article explains how to do so.

Building The System - The Modulation Transfer Function Calculation in FRED

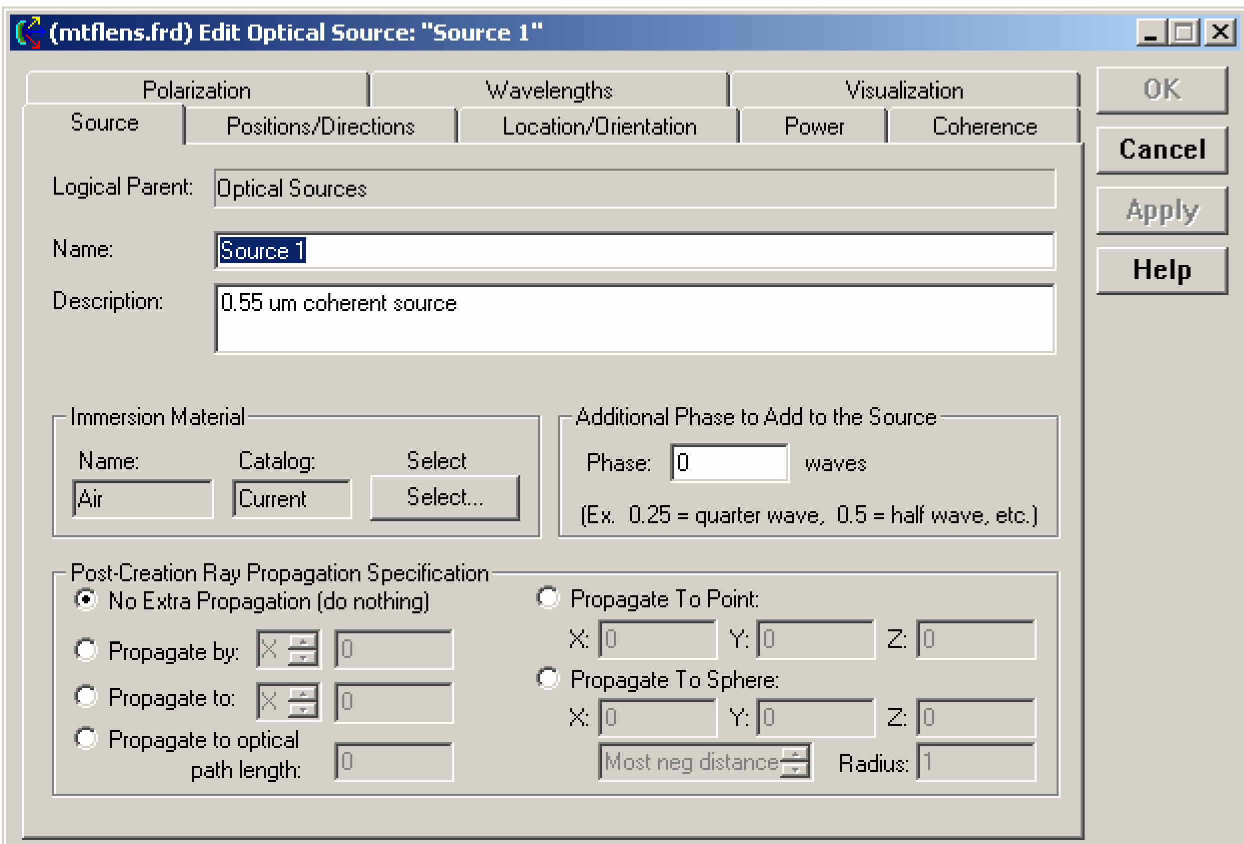
The system we will use for this article is a simple lens, focusing a source's light onto an analysis surface attached to a geometric surface. The lens is a simple biconvex BK7 singlet, with parameters r1=60 mm, r2=-300 mm, ct=4 mm, x semi-aperture=10, y semi-aperture=10. The lens has its image plane located at the paraxial focus.

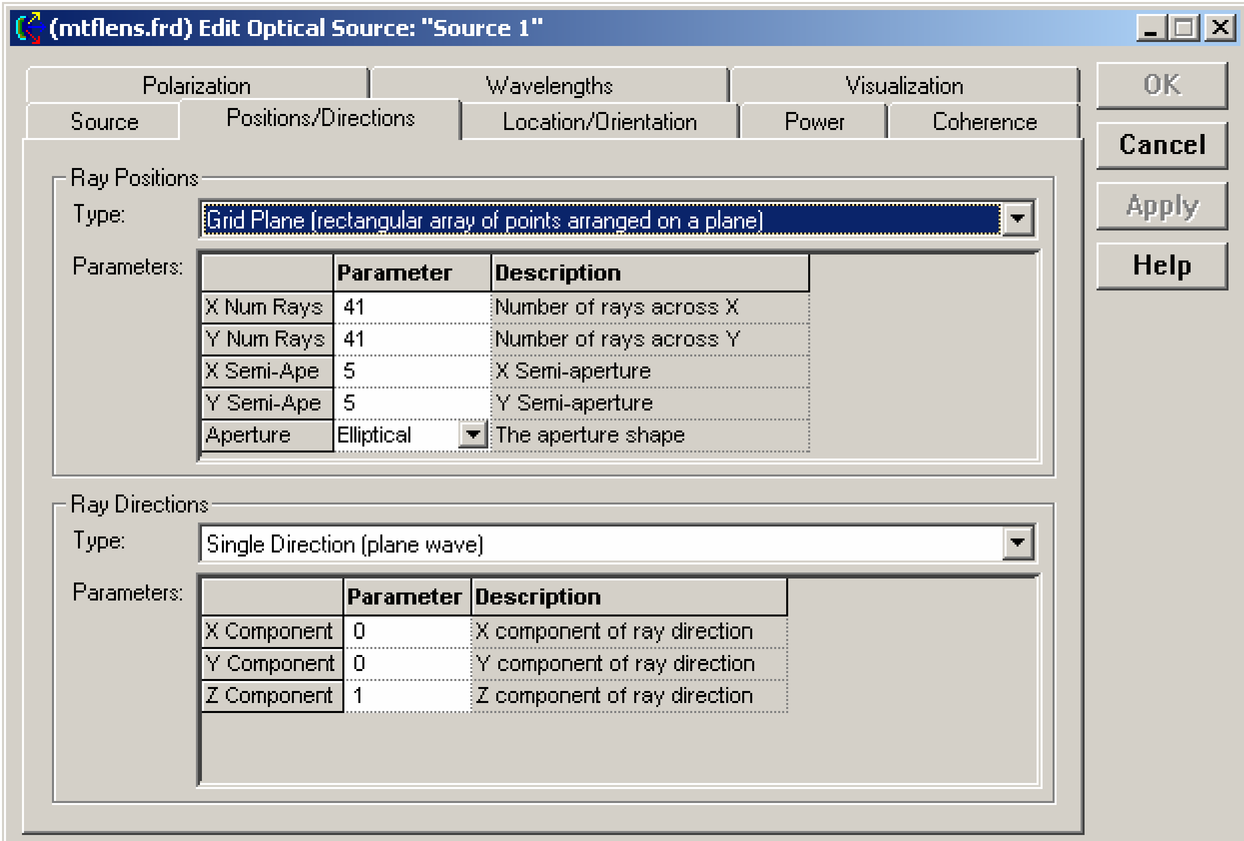


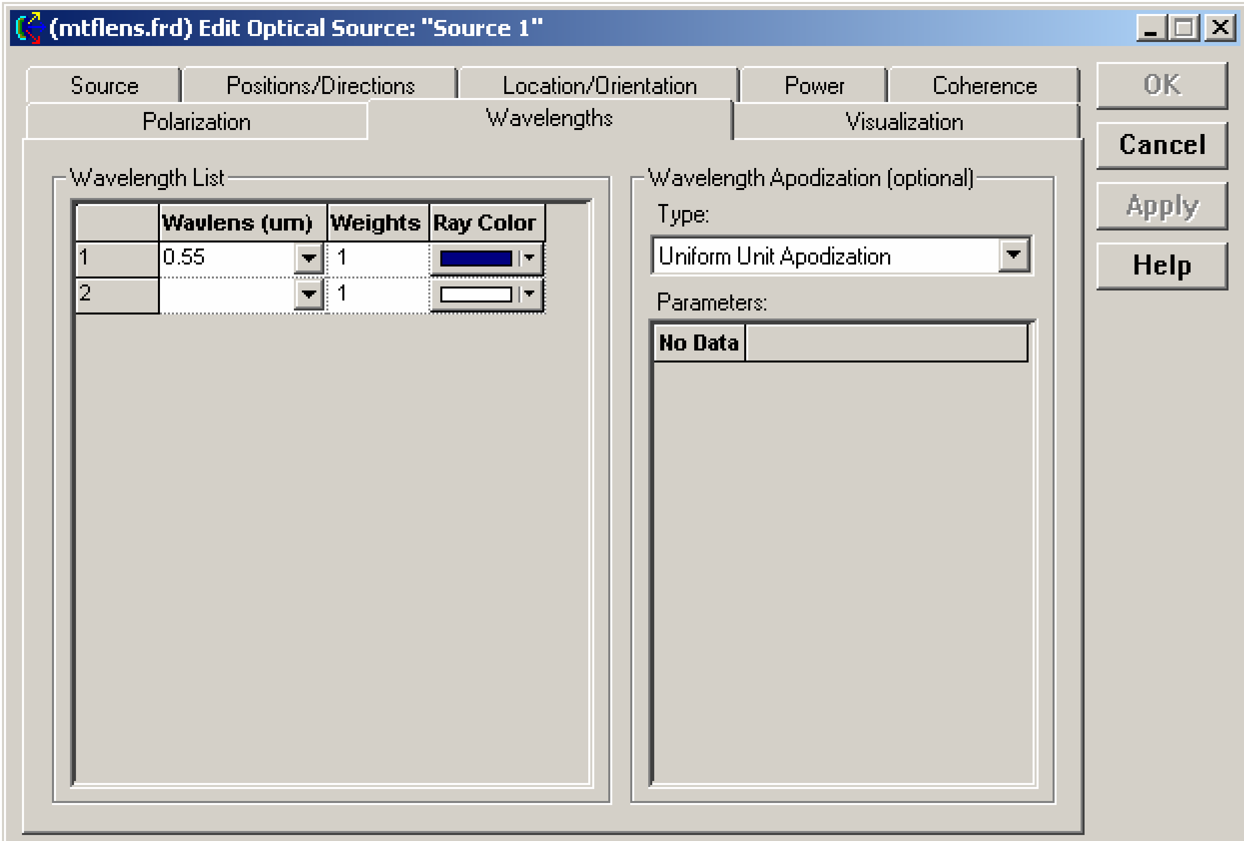
The geometric surface where the rays focus is a simple plane whose location specification is coincident with the second surface of the lens and shifted in the Z direction 94.591622 mm.

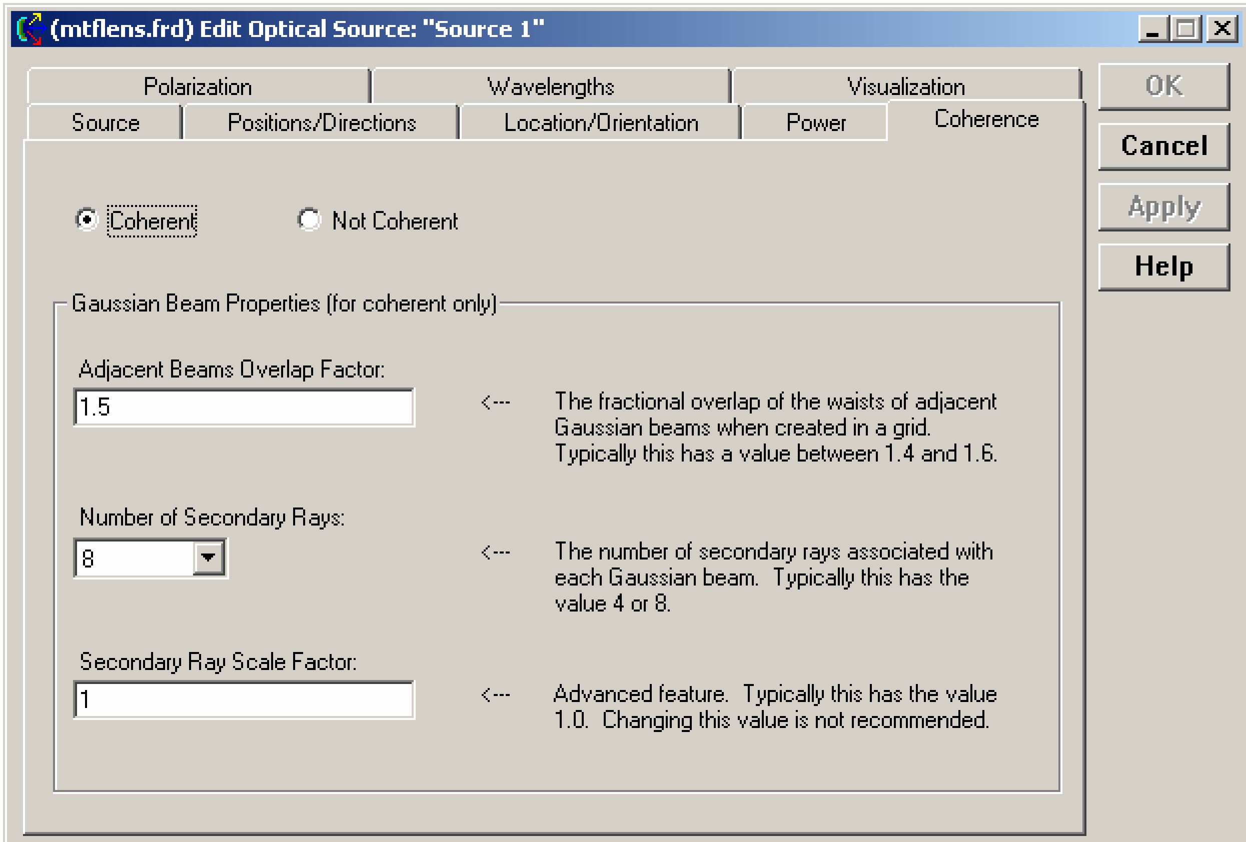


The source is a 41 x 41 grid of coherent rays pointed in a single, planar direction, with wavelength 0.55 µm, and unit power.




(mtflens.frd) Edit Optical Source: "Source 1"
Polarization
Wavelengths
Visualization
Source
Positions/Directions
Location/Orientation
Power
Coherence
OK
Cancel
Apply
Help
Ray Positions
Type:
Grid Plane (rectangular array of points arranged on a plane)
Parameters:
Parameter
Description
X Num Rays
41
Number of rays across X
Y Num Rays
41
Number of rays across Y
X Semi-Ape
5
X Semi-aperture
Y Semi-Ape
5
Y Semi-aperture
Aperture
Elliptical
The aperture shape
Ray Directions
Type:
Single Direction (plane wave)
Parameters:
Parameter
Description
X Component
0
X component of ray direction
Y Component
0
Y component of ray direction
Z Component
1
Z component of ray direction


(mtflens.frd) Edit Optical Source: "Source 1"
Source
Positions/Directions
Location/Orientation
Power
Coherence
Polarization
Wavelengths
Visualization
OK
Cancel
Apply
Help
Wavelength List
Wavlens (um)
Weights
Ray Color
1
0.55
1
2
1
Wavelength Apodization (optional)
Type:
Uniform Unit Apodization
Parameters:
No Data



Analysis - The Modulation Transfer Function Calculation in FRED

The point spread function for this system with

Log (Normal PSF)

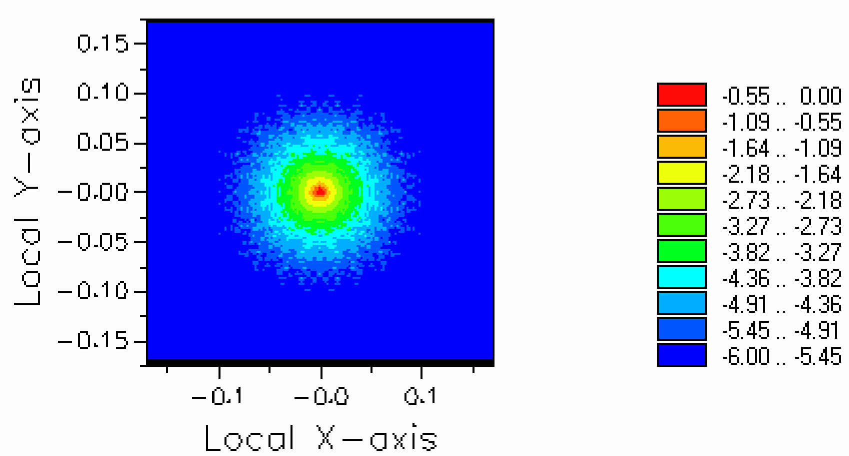
λ = 0.55 mm

0.32 waves 3rd order spherical

EPD = 10 mm

f/# = 9.68

Gives this point spread function:



The point spread function for this system with

Log (Normal PSF)

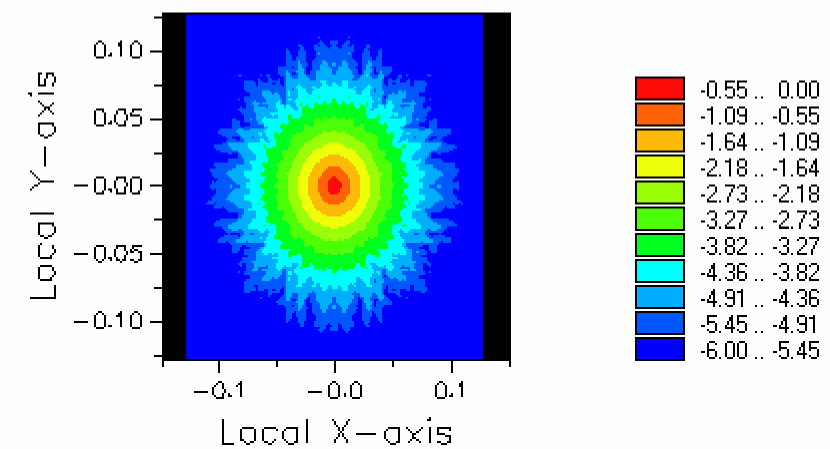
λ = 0.55 mm

1 wave 3rd order spherical

EPD = 13.31 mm

f/# = 7.27

Gives this point spread function:



Setting Up The Calculation - The Modulation Transfer Function Calculation in FRED

In order to fully sample the spatial frequency out to the lens cutoff, the minimum half width of the analysis plane must be at least the following (I, F, D in lens units):

$$w_{\min} = \frac{N_x^2 \lambda F}{4 N_f D} = \frac{N_x^2}{4 N_f} \cdot \lambda (f/\#)$$

In this equation the variables are defined as follows:

- N_x == number of pixels in the analysis plane for the irradiance spread function (PSF)
- w == half width of the analysis plane for the irradiance spread function (PSF)
- Δ_x == pixel size in lens units = 2w/Nx
- N_f == number of pixels in the transform grid;
  - a. the transform grid must have 2n x 2n pixels (i.e. ...16, 32 , 64, 128, 256, 512, ...)
  - b. FRED automatically sizes the transform grid so that it is 2n x 2n. Its size is the smallest grid for which Nf is greater than or equal to Nx
    - if N_x = 127, then FRED makes N_f = 128
    - if N_x = 128, then FRED makes N_f = 128
    - if N_x = 129, then FRED makes N_f = 256
- Δf == pixel size in 1/lens units = 1/(Nf*Dx)
- λ == wavelength in lens units
- F == focal length
- D == entrance pupil diameter

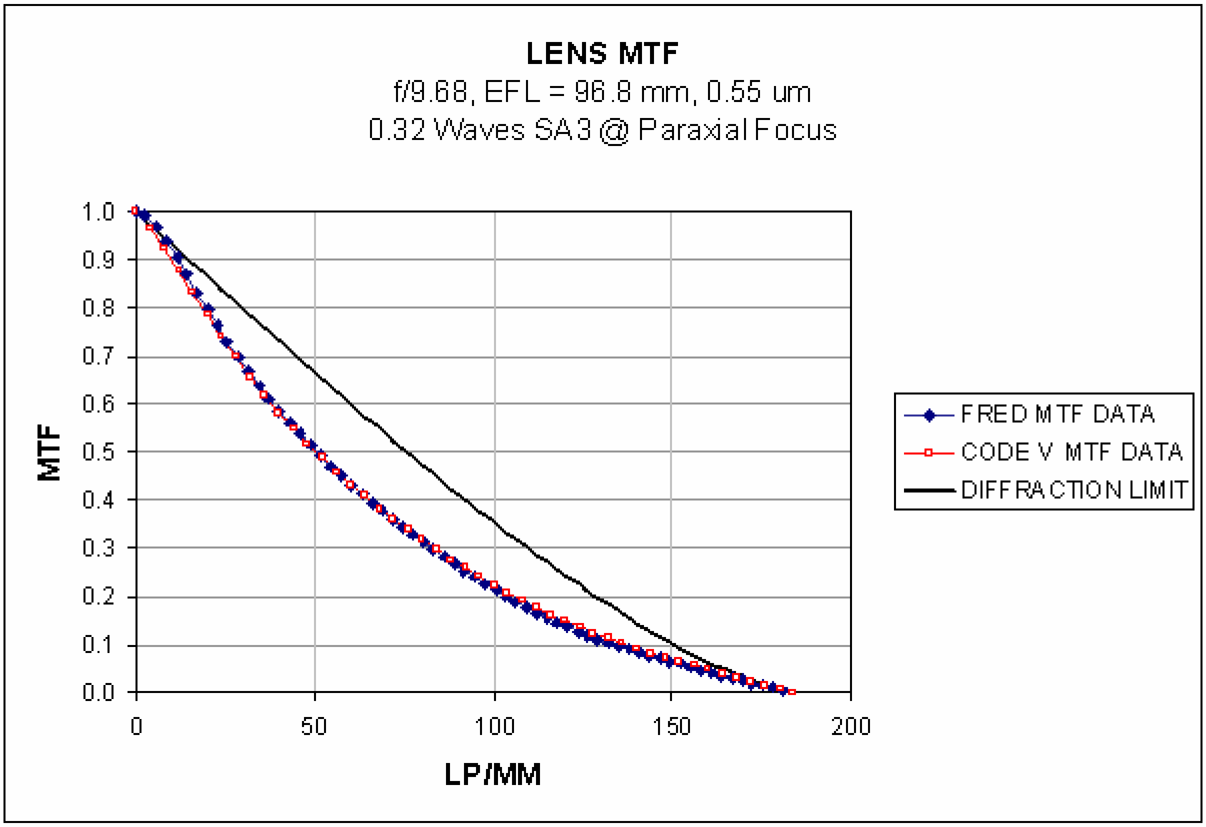
Comparison - The Modulation Transfer Function Calculation in FRED

For the following graph,

Lens EPD = 10 mm

Cutoff frequency = 184 lp/mm

Image plane grid: 128x128 pixels, 0.348 mm x 0.348 mm full width in X and Y

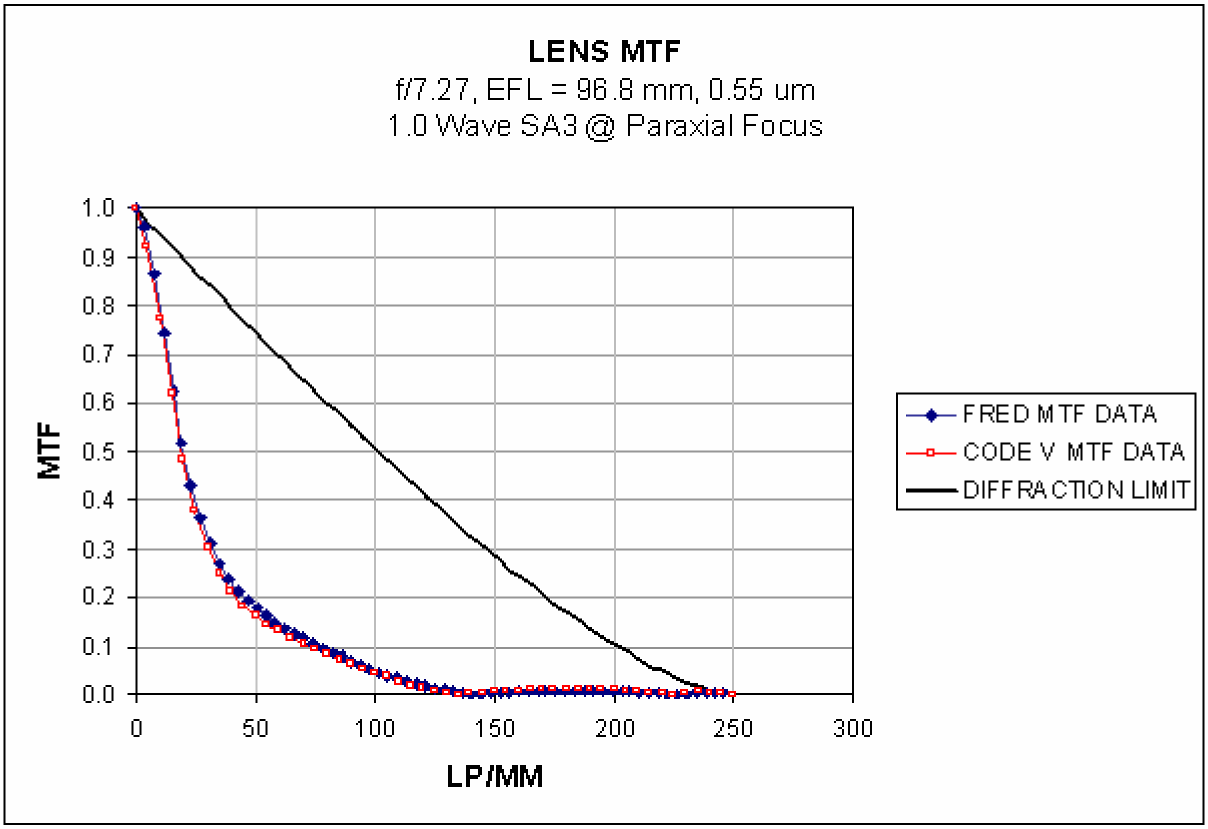


For the following graph,

Lens EPD = 13.31 mm

Cutoff frequency = 250 lp/mm

Image plane grid: 128x128 pixels, 0.256 mm x 0.256 mm full width in X and Y


LENS MTF
f/7.27, EFL = 96.8 mm, 0.55 um
1.0 Wave SA3 @ Paraxial Focus
MTF
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
LP/MM
FRED MTF DATA
CODE V MTF DATA
DIFFRACTION LIMIT

Chapter 14 - Chart Axes Labels Dialog

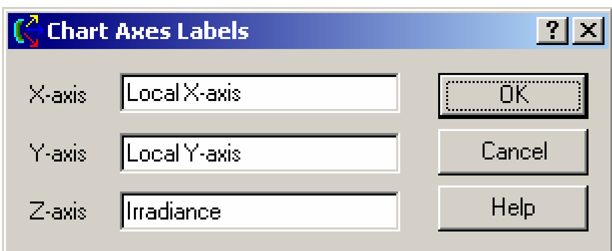
Description - Chart Axes Labels Dialog

This dialog sets the label text for the axes of a 3-D plot.

How Do I Get There? - Chart Axes Labels Dialog

From a 3-D plot, right-click and choose “Axes Labels...”.

Dialog Box and Controls - Chart Axes Labels Dialog



Control	*Inputs / Description*	*Defaults*
X-axis	Displays the label applied to the X axis	Local X-axis
Y-axis	Displays the label applied to the Y axis	Local Y-axis
Z-axis	Displays the label applied to the Z axis	(Analysis dependent)
OK	Applies the changes and dismisses the dialog	
Cancel	Discards the changes and dismisses the dialog	
Help	Displays this help article	

Application Notes - Chart Axes Labels Dialog

This dialog is modal and not resizable.

See Also.... - Chart Axes Labels Dialog

Plot Color Dialog

Adjust Image Brightness

Description - Adjust Image Brightness

How Do I Get There? - Adjust Image Brightness

There are three different ways to execute this command:

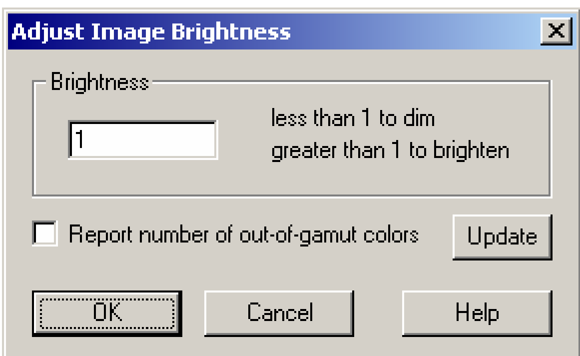
Menu

Keyboard Accelerator

Toolbar Button

Include Images

Dialog Box and Controls - Adjust Image Brightness



Control	*Inputs / Description*	*Defaults*

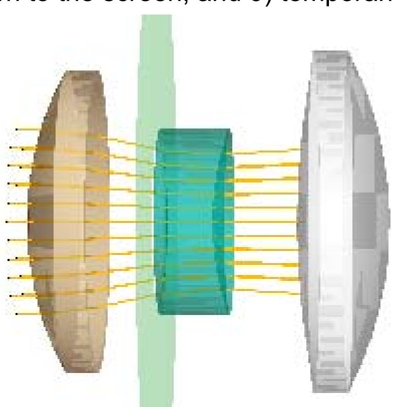
Application Notes - Adjust Image Brightness

Chapter 15 - Advanced Raytrace

Description

Advanced Raytrace

The Advanced Raytrace is a user-customized raytrace and is the most flexible of all raytrace methods. The user has the option to 1) choose sequential, non-sequential or specific paths to be traced, 2) specify the number of intersections to be traced, 3) start and/or stop rays on specified surfaces, 4) prevent or allow reflect/transmit operations, 5) create and trace source rays or simply trace existing rays, 6) select which rays are to be traced, 7) save path and history information pertaining to the current raytrace, 8) control which traced rays are drawn to the screen, and 9) temporarily supress scattering and summary printout.

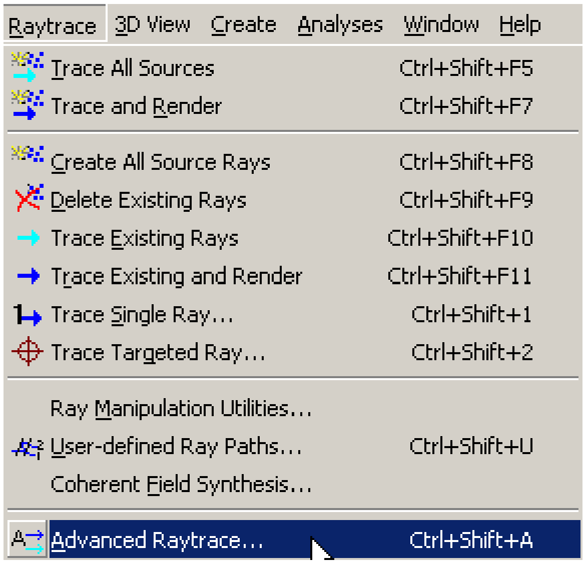


How Do I Get There?

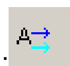
Advanced Raytrace

There are three different ways to execute this command:

1. Select Advanced Trace in the Raytrace Menu,

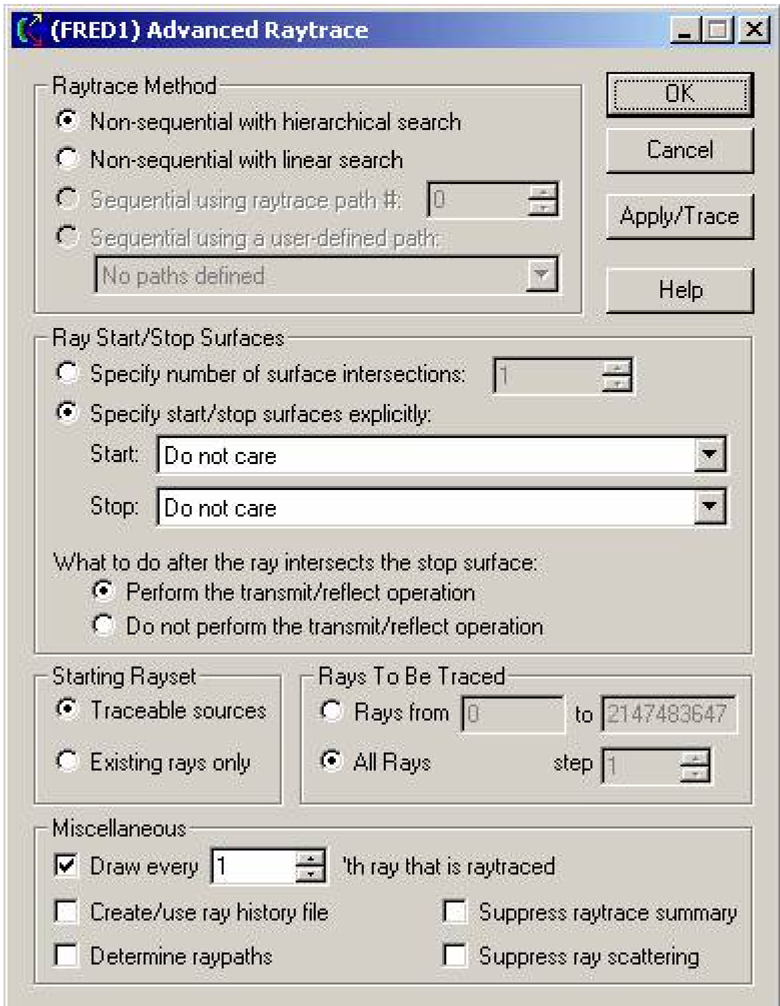


2. or press the keyboard accelerator keys: Ctrl+Shift+A,

3. or press the toolbar button:  .

Dialog Box and Controls

Advanced Raytrace



Control	Description	Defaults
Raytrace Method		
Non-sequential with hierarchical search	Default ray-tracing mode. See application notes below for an explanation of the search process.	Selected
Non-sequential with linear search	See application notes below for an explanation of the search process.	Not selected
Sequential raytrace using raytrace path #	If selected, rays will only be traced for selected user-defined path.	Not selected
Sequential using a user-defined path:	Opens a pop-up menu showing the user defined paths.	No paths defined
Ray Start/Stop Surfaces		
Specify number of surface intersections:	Number of intersections before raytrace terminates.	1

Specify start/stop surfaces explicitly:	Specifies at which surfaces the raytrace will start and stop.	Start: Do not care Stop: Do not care
What to do after the ray intersects the stop surface:	Determines if the ray will transmit, reflect, or do nothing after it encounters the stop surface.	Perform the transmit/reflect operation
Starting Rayset		
Traceable sources	Trace all sources.	Selected
Existing rays only	Trace only existing rays.	Not selected
Rays To Be Traced		
Rays from	Rays numbers (inclusive)	All active rays
All rays	Use all rays.	All active sources
Miscellaneous		
Draw every	Determines if the rays will be rendered when traced.	Render
Create/use ray history file	Generates history file for later use.	Unchecked
Determine paths	Add each path traced to the list of paths as the paths are found.	Unchecked
Suppress raytrace summary	Do not print raytrace summary to output window.	Unchecked
Suppress ray scattering	Temporarily turns off all scattering for this trace.	Unchecked
OK	Trace rays and close dialog box.	
Cancel	Discard tracing anymore rays and close dialog box.	
Apply / Trace	Trace rays with current selections and keep dialog open.	
Help	Access this Help page.	

Application Notes

Advanced Raytrace

- The Advanced Raytrace uses the same buffer as all other trace options with the exception of the single raytrace, which has its own temporary buffer. Therefore, the raytrace results from an Advanced Trace are available to the analysis planes, spot diagrams, and spread functions.

- Upon completion of a raytrace, *FRED* prints a Raytrace Summary to the Output Window. The user is encouraged to examine this print-out for timing information and as a diagnostic tool.

RAYTRACE SUMMARY:				(ghost.frd)	
				07/30/07 10:16:29	
81		Num rays at start			
1566		Num rays at end			
1566		Num rays traced			
4936		Num ray-surface intersections			
0.319 sec		Elapsed ray trace time			
0.28125		Total ray trace CPU time (seconds)			
0.882280		Ratio of Cpu time to elapsed time			
4912.536		Rays traced per elapsed second			
4912.536		Rays processed per elapsed second			
15484.21		Intersections per elapsed second			
2		Num processors/cores detected			
1		Num threads used during the raytrace			
No		Ray buffer interlaced during trace			

- The Trace Advanced command has the following options:

1. Trace using one of the following three methods:
2. Hierarchical surface search algorithm,
3. Linear surface search,
4. Or trace a previously set user defined ray path. Note that the ray paths are defined with User Defined Ray Paths command.
5. Trace the existing ray set using one of the three methods above.
6. Trace all new rays using one of the three methods above. This option deletes the existing ray set and creates a new ray set from the currently traceable sources.
7. Render the rays during the trace.

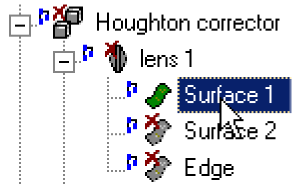
The user-defined ray path can pause the rays at any surface in the path with the ray path ray controls. The rays can then be continued on the path by selecting the Trace Existing Rays option in the Advanced Trace dialog and pressing the apply button in the dialog box. If after the rays have hit a paused surface the "Delete existing rays and recreate all sources" option is used, then the rays will be traced from the source(s) to the same paused surface. It will appear as if nothing has changed.

Note	If the rays have been traced along a sequential or mixed sequential and non-sequential path with a pause in the path, then the rays can be traced beyond the surface marked with a pause in the path by selecting "Existing Rays Only" in the Advanced Trace dialog and pressing Apply (or OK).

1. The linear raytrace search algorithm systematically checks every traceable surface node to determine if the ray interests the bounding surface. If the ray intersects the bounding surface, then the algorithm checks to see if the ray intersects the surface. After the algorithm has determined all the surfaces that the ray intersects, the closest

surface is chosen as the next surface intersection. The process then repeats. This algorithm does not consider and non-surface nodes.

Warning: It is possible in the scripting language to have a traceable surface node that is a child of a non-traceable parent node. The linear raytrace search algorithm will trace the surface 1 in the example shown below. Because the hierarchical raytrace search algorithm ignores any nodes under a non-traceable node, this algorithm will not trace the surface 1 in the example shown above.



The hierarchical raytrace search algorithm searched the FRED geometry nodes starting with a parent node and then working down through the children, grandchildren, etc. until the all progeny nodes have been searched. At each node (parent, child, grandchild, etc.), the algorithm first checks to see if the node is traceable. If the node is not traceable, then skips that node and all of its children and grandchildren. If the node is traceable, then it checks to see if the ray intersects the bounding box for that node. If the ray intersects the bounding box, then the algorithm checks to see if the node is a surface. If the node is a surface, then the algorithm checks to see if the ray intersects the surface. If the node is not a surface, and it has child nodes then it systematically follows the same process for the child nodes. This process continues until all of the nodes under a parent node have been checked. Then the algorithm moves on to the next parent node. After the algorithm has determined all the surfaces that the ray intersects, the closest surface is chosen as the next surface intersection. The process then repeats.

1. *FRED* and *FRED Turbo*

The multi-core usage feature is active at the time of a raytrace unless:

1. the user invokes a “Trace and Render” or “Trace Existing and Render”
2. the Advanced Raytrace “Determine raypaths” check-box is checked,
3. the Advanced Raytrace “Create/use ray history file” check-box is checked.

See Also….

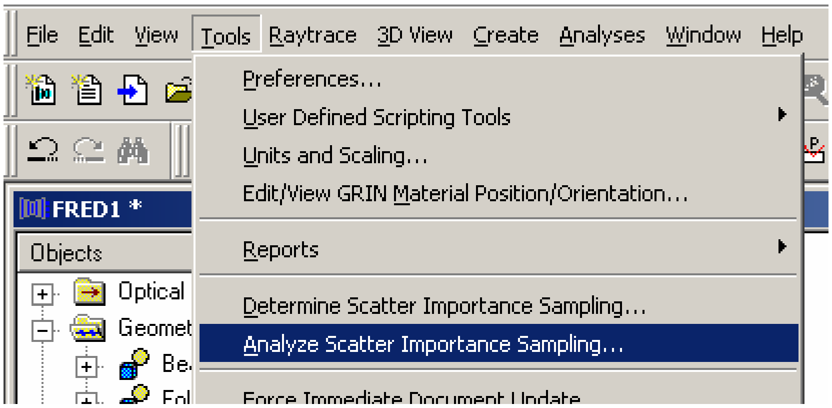
Advanced Raytrace

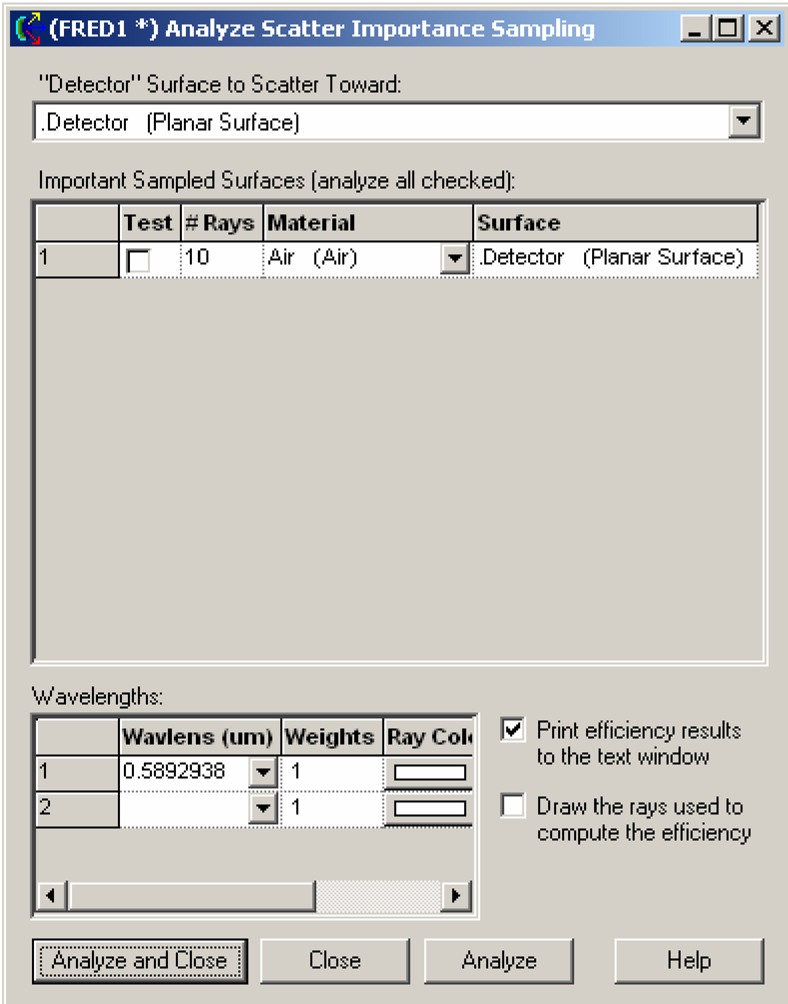
Trace and Render
Trace All Sources
Trace Existing Rays
Trace Existing and Render
Trace Single Ray
Delete Existing Rays
Create All Source Rays
User Defined Ray Paths
User Defined Ray Paths

Analyze Scatter Importance Sampling Dialog

How Do I Get There? - Analyze Scatter Importance Sampling Dialog

After a Scatter Direction has been assigned to a surface, select the Tools menu, then select "Analyze Scatter Importance Sampling...".





Control	Inputs / Description	Defaults
"Detector" Surface to Scatter Toward	Identifies which surface will be used to perform the scatter analysis.	The first surface found in the tree that has a Scatter Direction assigned.
Important Sampled Surfaces (analyze all checked):	Contains the list of surfaces that have importance samplings assigned.	
Wavelengths:	Lists the wavelengths assigned to the importance sampling.	One wavelength (0.5892938 um) with weight 1 and white color

Print efficiency results to the text window	When checked, prints the results in the output window.	Checked
Draw the rays used to compute the efficiency	When checked, draws the rays used in the calculation in the Visualization Window.	Unchecked
Analyze and Close	Performs an analysis and closes the dialog.	
Close	Closes the dialog without performing an analysis.	
Analyze	Performs an analysis and does not close the dialog.	
Help	Displays this help article.	

Application Notes - Analyze Scatter Importance Sampling Dialog

This dialog is both resizable and modeless.

See Also…. - Analyze Scatter Importance Sampling Dialog

Auto-Compute Scatter Importance Sampling Dialog

Chapter 16 – Importance Sampling and how to Auto-Compute Scatter Importance Sampling

Importance Sampling

Description

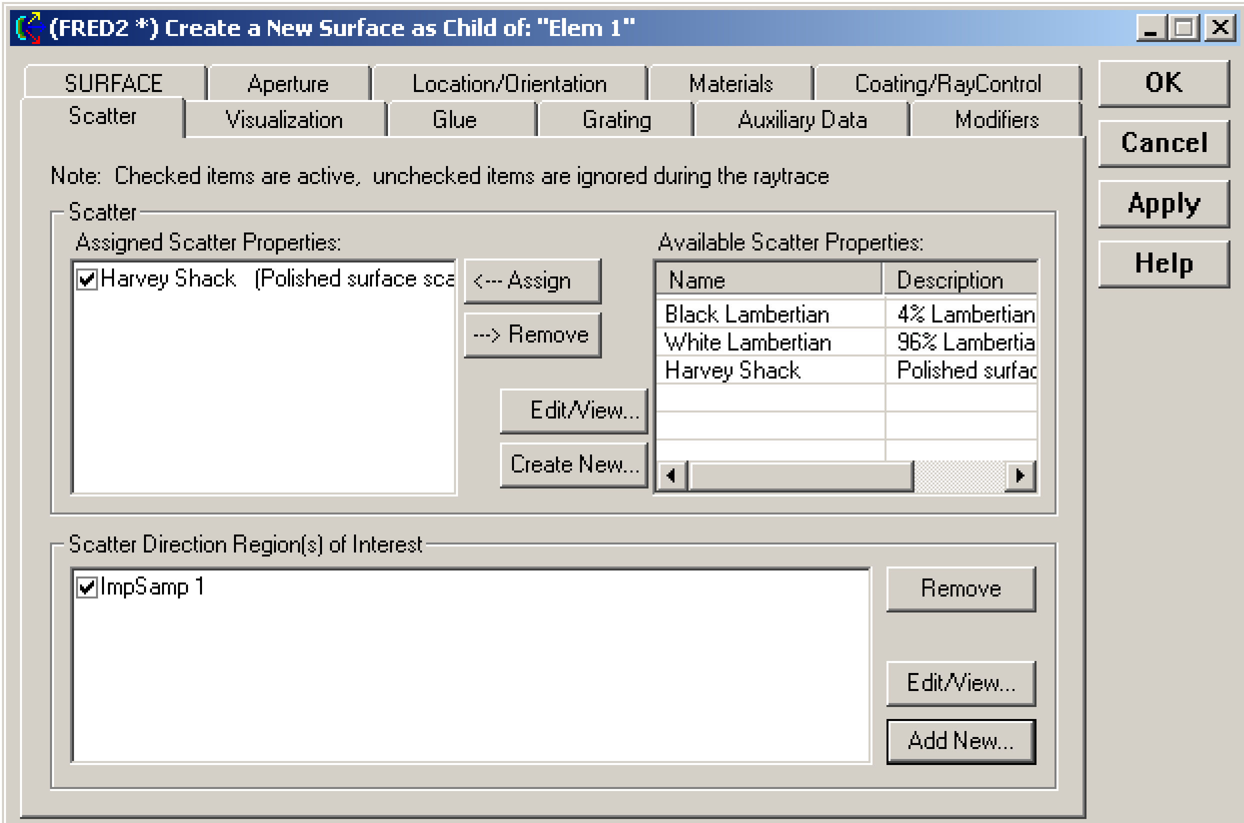
Importance Sampling

Importance Sampling defines a direction or region of interest towards which scattered rays are allowed to propagate. This method significantly increases the efficiency of the raytracing task. FRED handles the radiometry such that the proper amount of power is scattered into the given solid angle according to the specified scatter model.

How Do I Get There?

Importance Sampling

An Importance Sampling is specified as a *Scatter Direction Region(s) of Interest* entry on the Scatter Tab of any Surface entity.

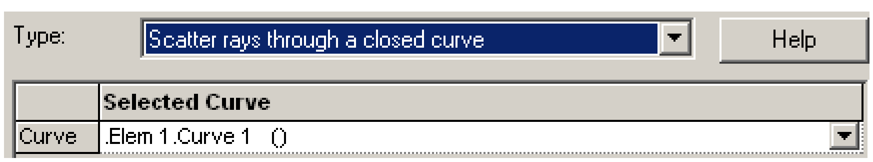


Dialog Box and Controls

Importance Sampling

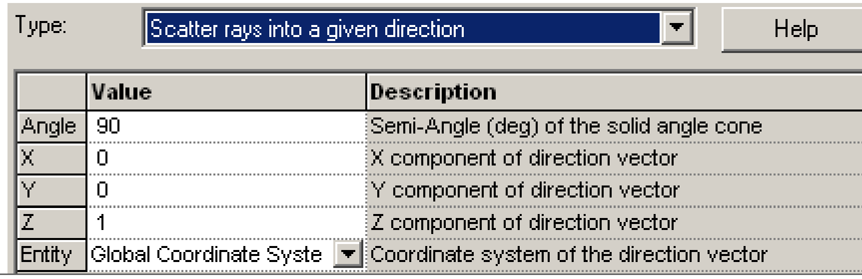
The following Importance Sampling Types are available:

Through a closed curve



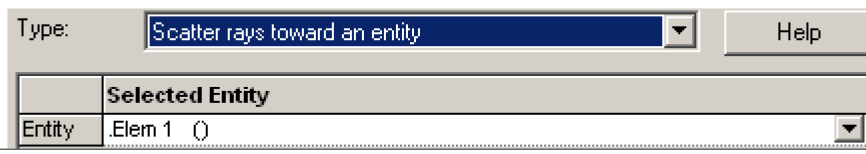
Control	*Inputs / Description*	*Defaults*
Curve	An existing closed curve through which rays are to be aimed.	First available curve

In a given direction



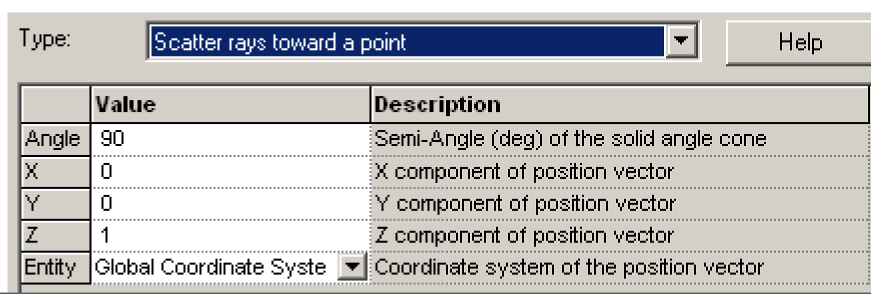
Control	***Inputs / Description***	***Defaults***
Angle	Semi-angle (deg) of a cone centered about the Direction vector.	90
X Y Z	Direction vector.	0,0,1
Entity	Coordinate system in which the XYZ vector is specified.	Global Coordinate System

Towards an entity



Control	***Inputs / Description***	***Defaults***
Entity	Entity towards which rays are to be scattered.	First entity in list

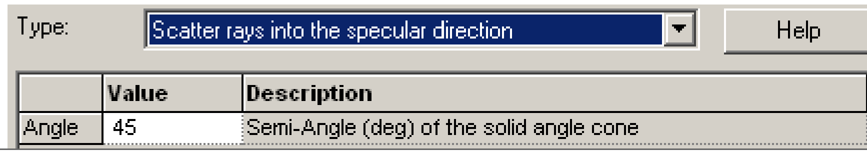
Towards a point



Control	***Inputs / Description***	***Defaults***
Angle	Semi-angle (deg) of a cone centered about the Position vector.	90
X Y Z	X,Y,Z position of point to scatter towards.	0,0,1

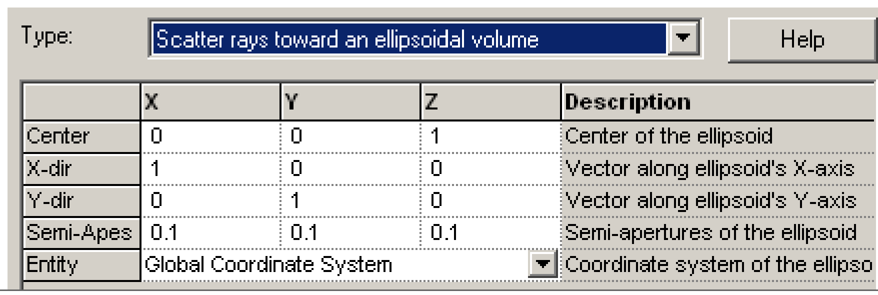
Entity	Coordinate system in which the XYZ vector is specified.	Global Coordinate System

Into the specular direction



Control	Inputs / Description	Defaults
Angle	Semi-angle of solid angle cone centered on the specular direction.	45

Towards an ellipsoidal volume



Control	Inputs / Description	Defaults
Center	Center location of ellipsoid.	0,0,1
X-dir	Vector direction specifying ellipsoid's X-axis	1,0,0
Y-dir	Vector direction specifying ellipsoid's Y-axis	0,1,0
Semi-Apes	Ellipsoid semi-dimensions in X, Y & Z.	0.1, 0.1, 0.1
Entity	Coordinate system in which the ellipsoid is specified.	Global Coordinate System

Application Notes

Importance Sampling

- Assignment of a scatter model MUST be accompanied by the specification of at least one Importance Sampling Region of Interest.

- Multiple Importance Sampling specifications can be assigned to any given surface.

- Each Importance Sampling specification is applied to every Scatter model assigned.

- New As of version 6.100, surfaces are now created with a default scatter importance sampling into the hemisphere. The user can now quickly add useful scattering to a surface by simply assigning the desired scatter model to the surface without bothering to explicitly assign an importance specification. Keep in mind that the default importance sampling is a general one that scatters into the whole hemisphere and is not optimized for efficiently generating scatter ray directions specific to any particular geometry.

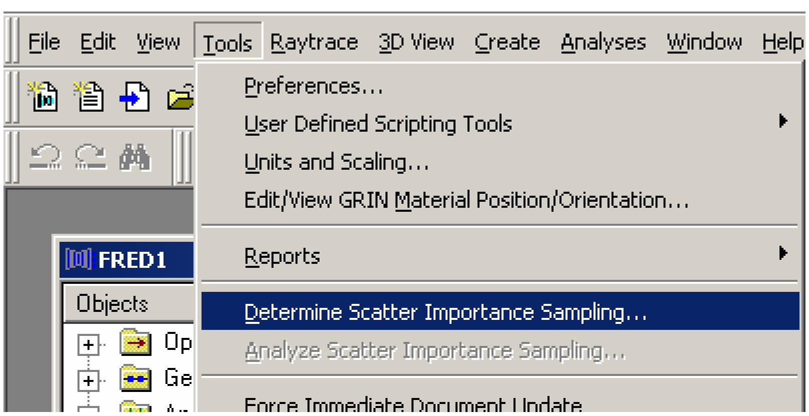
See Also….
Importance Sampling

Determine Importance Sampling
Analyze Importance Sampling

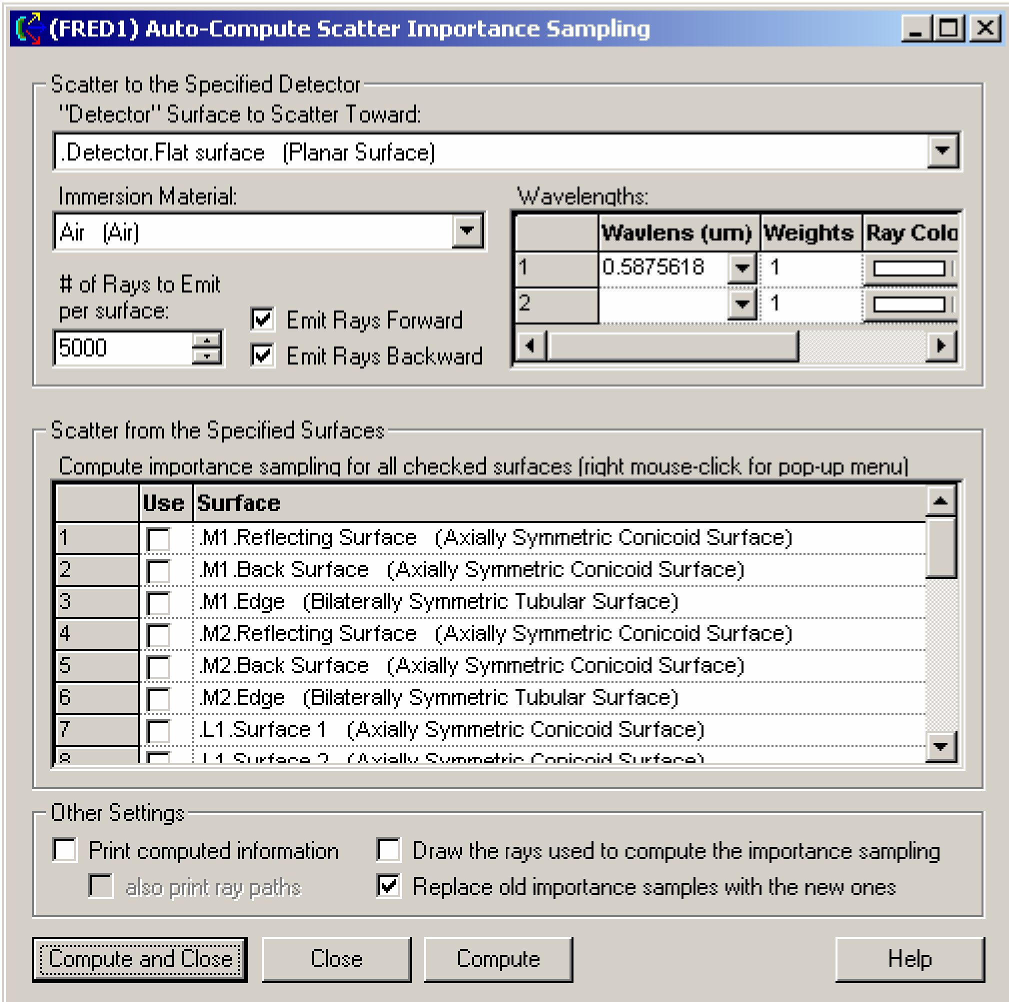
Auto-Compute Scatter Importance Sampling

How Do I Get There? - Auto-Compute Scatter Importance Sampling Dialog

On the Tools menu, then select "Determine Scatter Importance Sampling...".



Dialog Box and Controls - Auto-Compute Scatter Importance Sampling Dialog



Control	Inputs / Description	Defaults
"Detector" Surface to Scatter Toward:		The first surface found in the tree that has a Scatter Direction assigned.
Immersion Material:		Air
# of Rays to Emit per surface:		5000
Emit Rays Forward		Checked
Emit Rays Backward		Checked
Wavelengths:		0.5892938
Scatter from the Specified Surfaces		None Selected

Print Computed Information		
also print ray paths		
Draw the rays used to compute the importance sampling		
Replace old importance samples with the new ones		
Compute and Close	Closes the dialog and computes the Scatter Importance Sampling.	
Close	Closes the dialog and does not compute the Scatter Importance Sampling.	
Compute	Computes the Scatter Importance Sampling and does not close the dialog.	
Help	Displays this help article	

Application Notes - Auto-Compute Scatter Importance Sampling Dialog

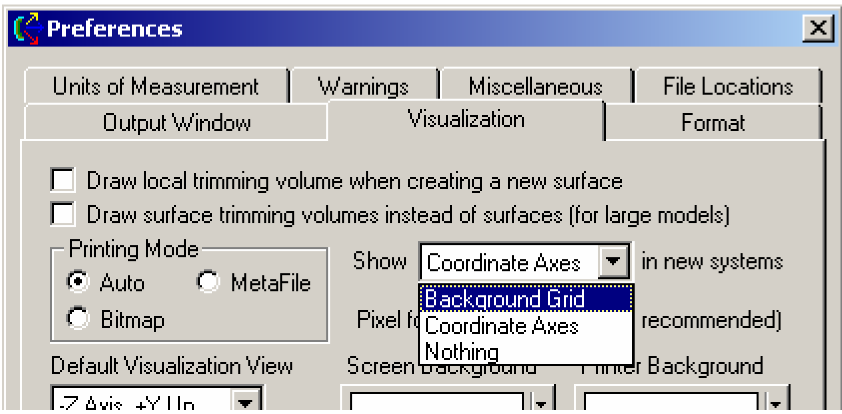
This dialog is both resizable and modeless.

See Also…. - Auto-Compute Scatter Importance Sampling Dialog

Chapter 17 - Background Grid Dialog

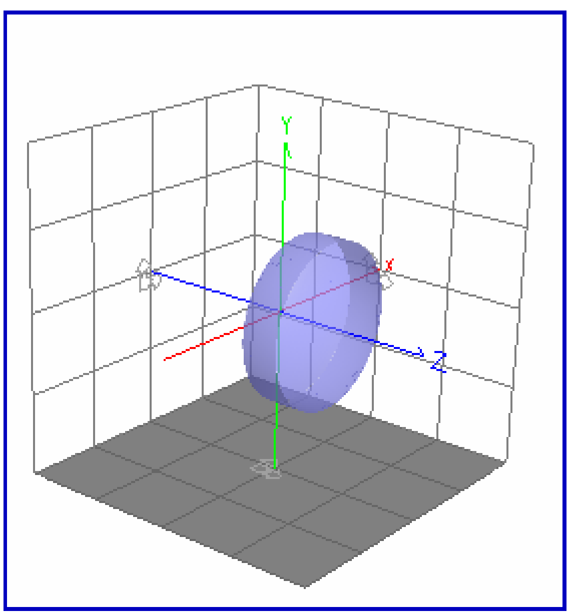
Description - Background Grid Dialog

This command brings up the dialog that allows you to draw and change the Background Grid. Whether a new FRED document opens with a Background grid or not can be set in the preferences. The Background Grid can be added to Visualization window at any time.

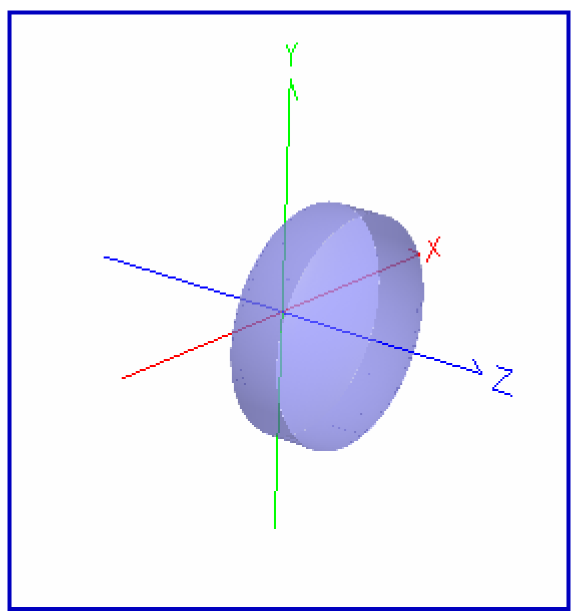


Visualization (example) - Background Grid Dialog

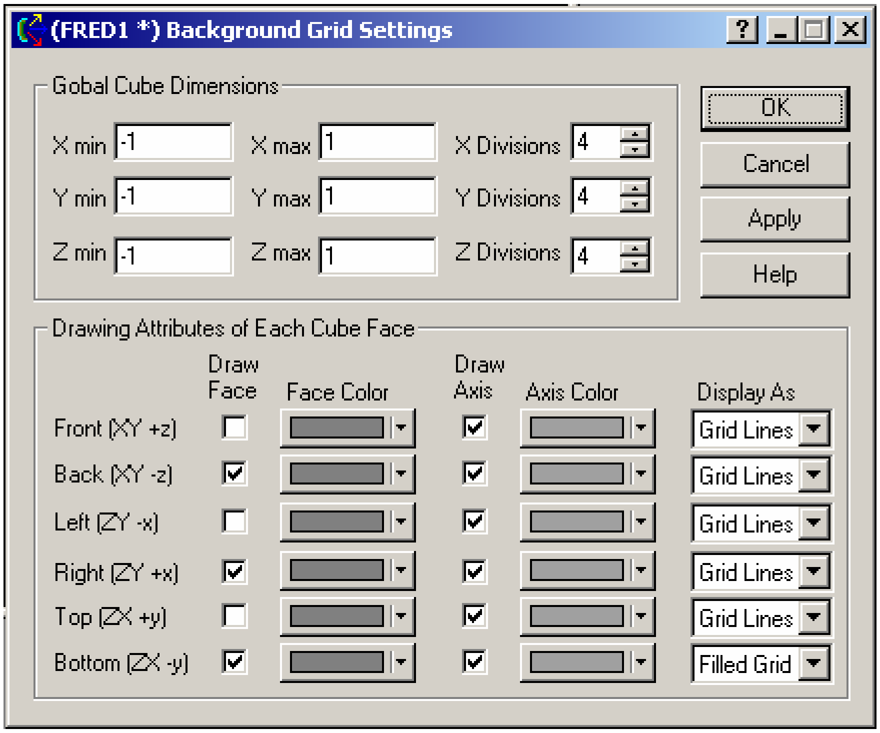
An example of with and without the Background Grid is shown below. The Background Grid dialog settings for the Background Grid are shown below. Note that the coordinate axes are included for reference and are not part of the background grid dialog.



Background Grid



No Background Grid

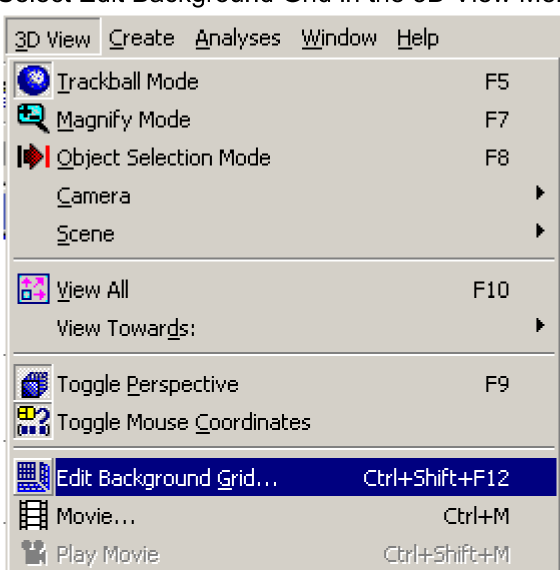


Background Grid settings for the example shown above.

How Do I Get There? - Background Grid Dialog

There are three different ways to execute this command:

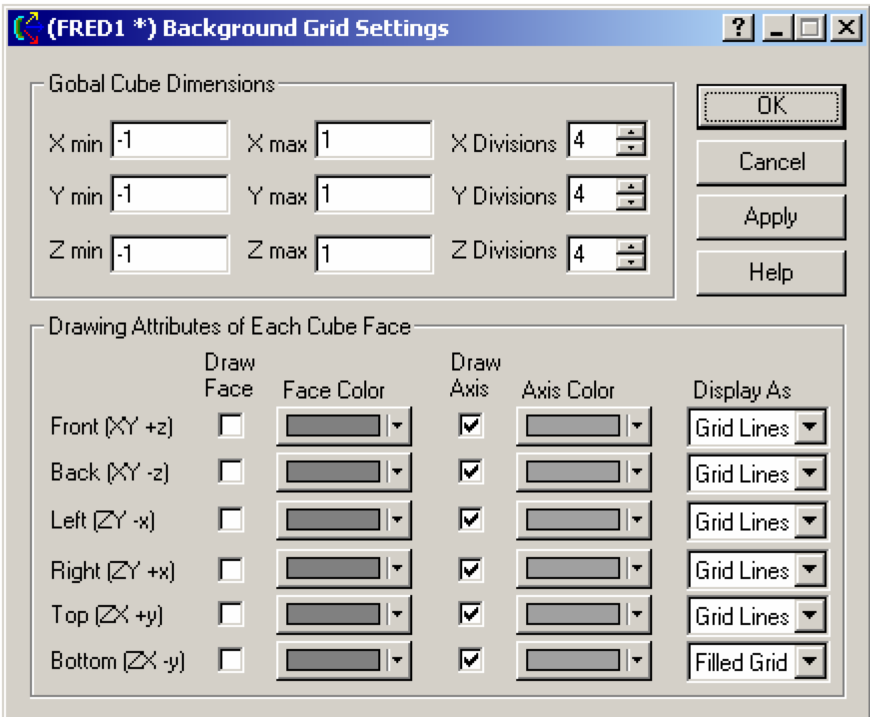
1. Select Edit Background Grid in the 3D View Menu,



2. or press the keyboard accelerator keys: Ctrl+Shift+F12,

3. or press the toolbar button: 

Dialog Box and Controls - Background Grid Dialog



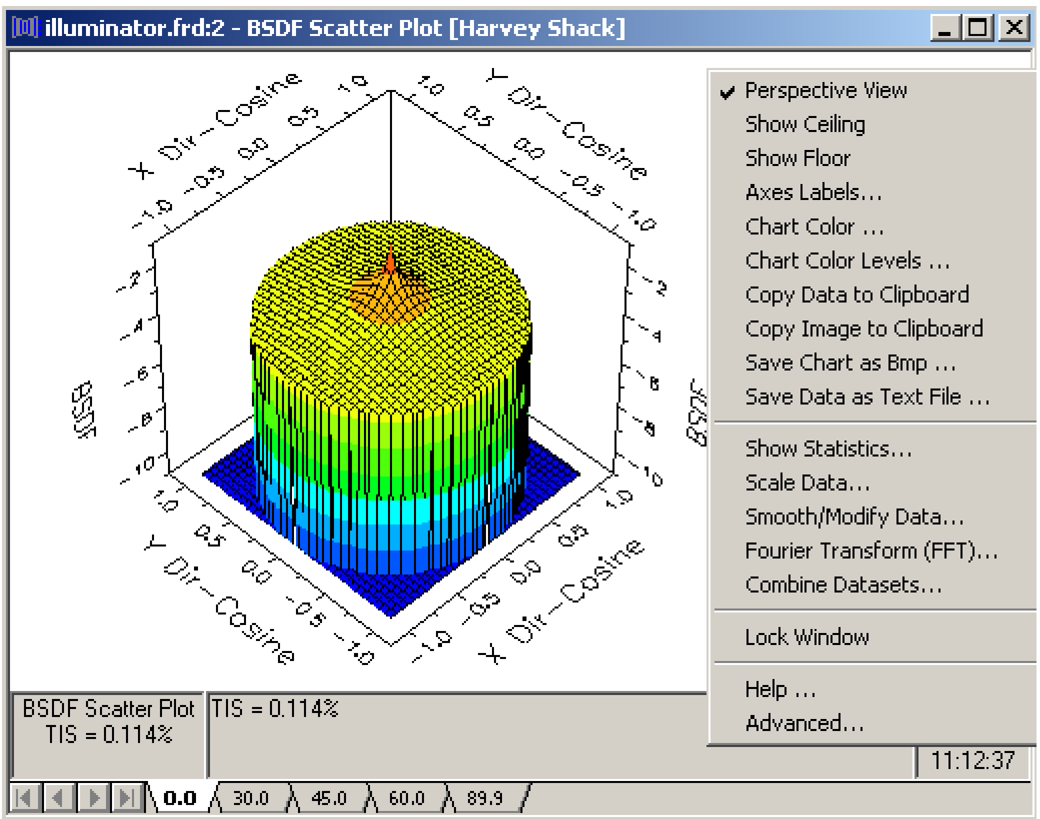
Control	Inputs	Defaults
Global Cube Dimensions, X min, Max	Lists the minimum and maximum extent of the background grid on the X axis	-1, 1
Global Cube Dimensions, Y min and max	Lists the minimum and maximum extent of the background grid on the Y axis	-1, 1
Global Cube Dimensions, Z min and max	Lists the minimum and maximum extent of the background grid on the Z axis	-1, 1
Global Cube Dimensions, X Divisions	Lists the number of divisions in the X direction of the background grid	4
Global Cube Dimensions, Y Divisions	Lists the number of divisions in the Y direction of the background grid	4
Global Cube Dimensions, Z Divisions	Lists the number of divisions in the Z direction of the background grid	4
Drawing Attributes of Each Cube Face, Face	When checked, the cube face listed to the left will be drawn (can be set in the preferences)	Unchecked
Drawing Attributes of Each Cube Face, Face Color	Selects the color of the given grid face	Dark gray
Drawing Attributes of Each Cube Face, Axis	When checked, draws the axis labels for the face listed to the left. Overridden by the Face checkbox	Checked
Drawing Attributes of Each Cube Face, Axis Color	Selects the color of the axis labels	Light gray
Drawing Attributes of Each Cube Face, Display As	Selects the drawing style for the background grid faces. Options are Filled Grid, Grid Lines, and Grid Points.	Grid lines
OK	Changes the Background Grid, dismisses the dialog.	
Cancel	Dismisses the dialog without changing the Background Grid.	
Help	Brings up this help article.	
Apply	Changes the Background Grid and does not dismiss the dialog.	

Chapter 18 - BSDF 3D Plot Setup Dialog

Description - BSDF 3D Plot Setup Dialog

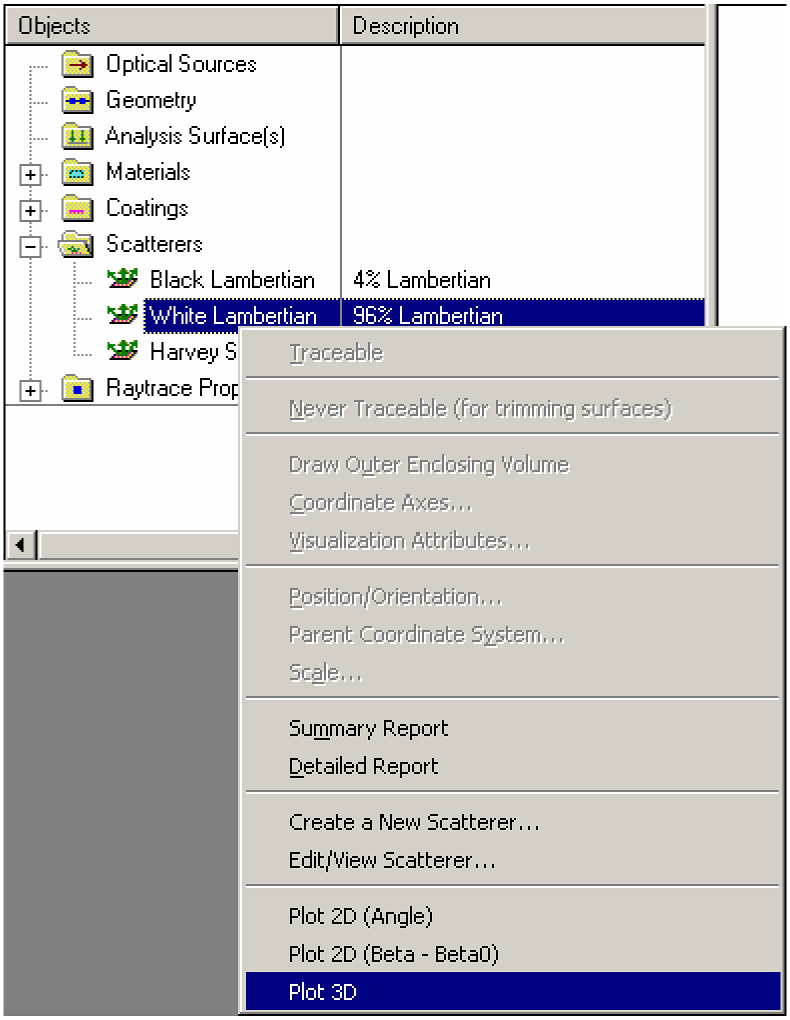
Provides a 3D plot of an existing scatter model at selected angles of incidence.

Visualization (example) - BSDF 3D Plot Setup Dialog

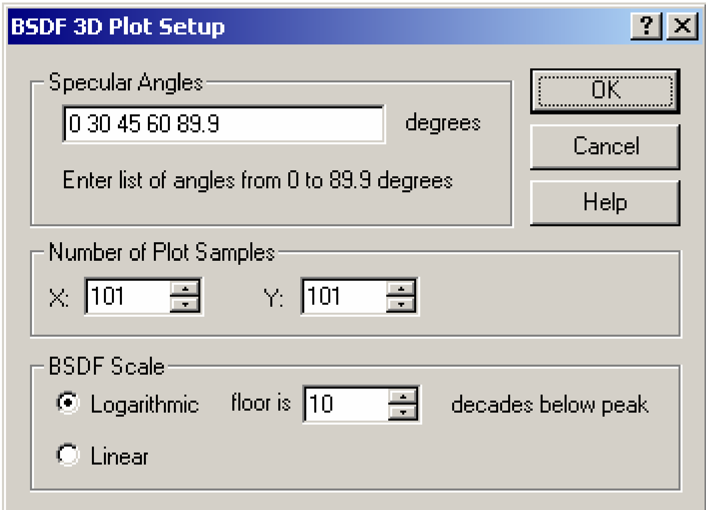


How Do I Get There? - BSDF 3D Plot Setup Dialog

Right-click on the scatter model you want to create a plot for and choose "Plot 3D".



Dialog Box and Controls - BSDF 3D Plot Setup Dialog



Control	***Inputs***	***Defaults***
Specular Angles	List incident angles for which scatter data is plotted. Entered in ascending order.	0, 30, 45, 60, 89.9
Number of Plot Samples		
X, Y	Number of evenly spaced angular samples used to evaluate scatter model for plotting.	101, 101
BSDF Scale		
Logarithmic	Display BSDF values as logarithmic.	Selected
Linear	Display BSDF values as linear.	Not selected
Floor is	Minimum value displayed below peak in decades.	10
OK	Accept plot settings and close dialog box.	
Cancel	Discard plot settings and close dialog box.	
Help	Access this Help page.	

Application Notes - BSDF 3D Plot Setup Dialog

See Also.... - BSDF 3D Plot Setup Dialog

Plot 2D

Chapter 19 - Insert Lens from Catalog

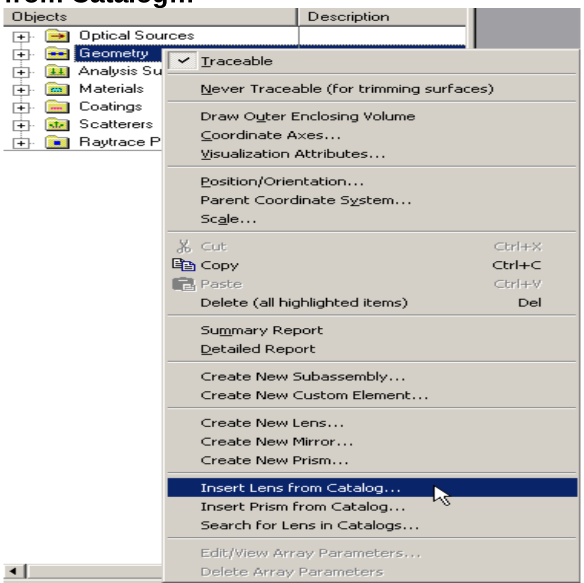
Description - Insert Lens from Catalog

This dialog allows the selection and entry of a lens into your system from a vendor catalog. The lens is inserted with the location and orientation specified in the dialog.

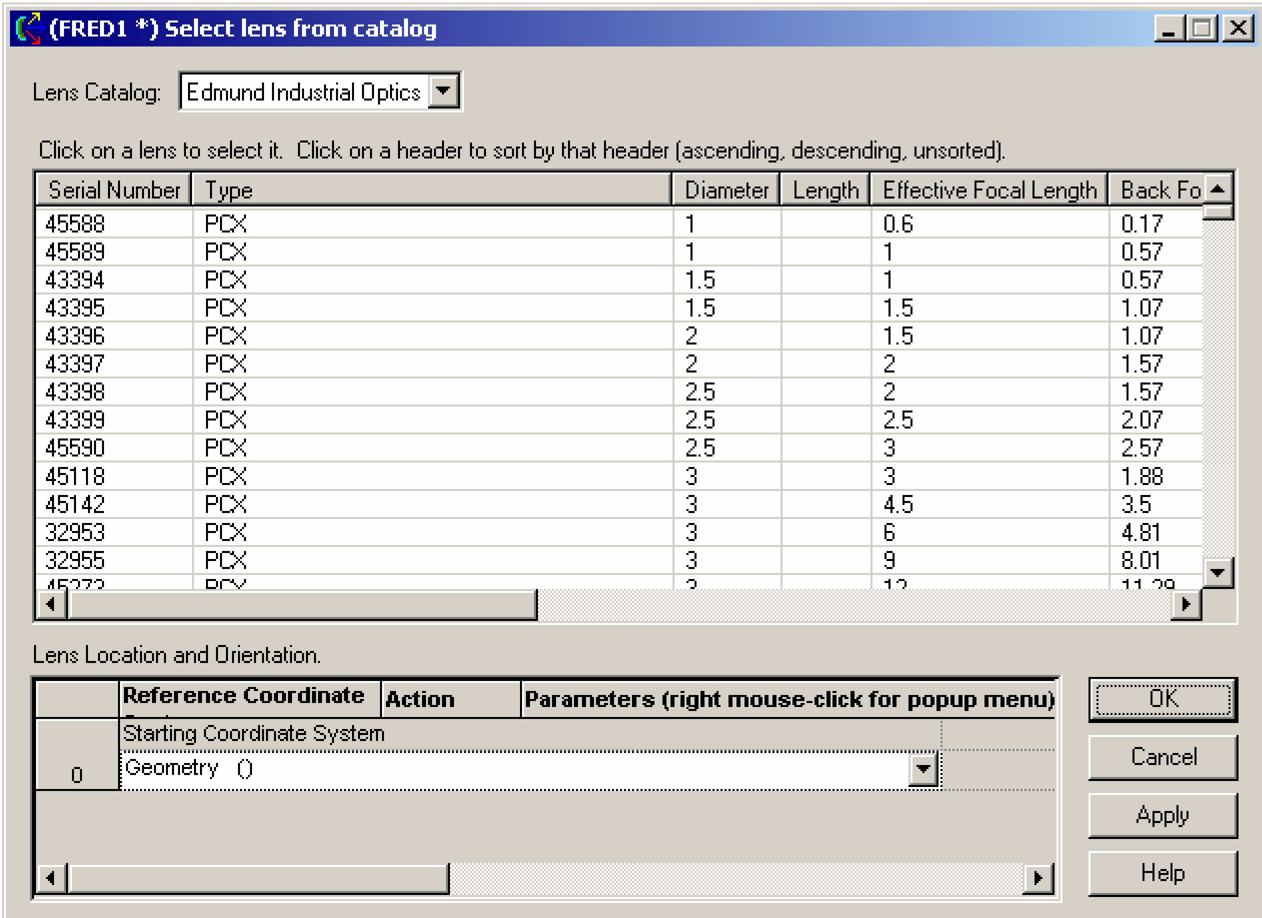
Note	FRED inserts the lens using the units provided by the vendor. Currently, in all cases, the units are millimeters. If this is not the unit of measure for your system, the lens is scaled by the appropriate factor for your system. For example, if your system uses centimeters and you import a singlet whose semi-aperture measures 10 mm by 10 mm, the Edit Lens dialog will show the singlet as having a 1.0 cm by 1.0 cm semi-aperture.

How Do I Get There? - Insert Lens from Catalog

To execute this command, right click on the **Geometry** folder and choose **Insert Lens from Catalog…**



Dialog Box and Controls - Insert Lens from Catalog



Control	Inputs	Defaults
Lens Catalog	Shows selected vendor catalog.	Edmund Industrial Optics
Lens List	Shows lenses available from vendor selected in the Lens Catalog list.	Edmund Industrial Optics lenses
Lens Location and Orientation	Shows Location and Orientation modifiers that will apply to lens when placed in the FRED document.	Parent = Geometry Type = Make coincident with another coordinate system
OK	Insert Catalog lens and close dialog box.	

Cancel	Close dialog without inserting Catalog lens.	
Apply	Inserts Catalog lens and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Insert Lens from Catalog

- This dialog is modeless, so you can have this window open while working on other things in your system.
- You may bring up more than one of these dialogs for a single system at a time.

See Also… - Insert Lens from Catalog

Select Prism from Catalog

Chapter 20 - Insert Prism from Catalog

Description - Insert Prism from Catalog

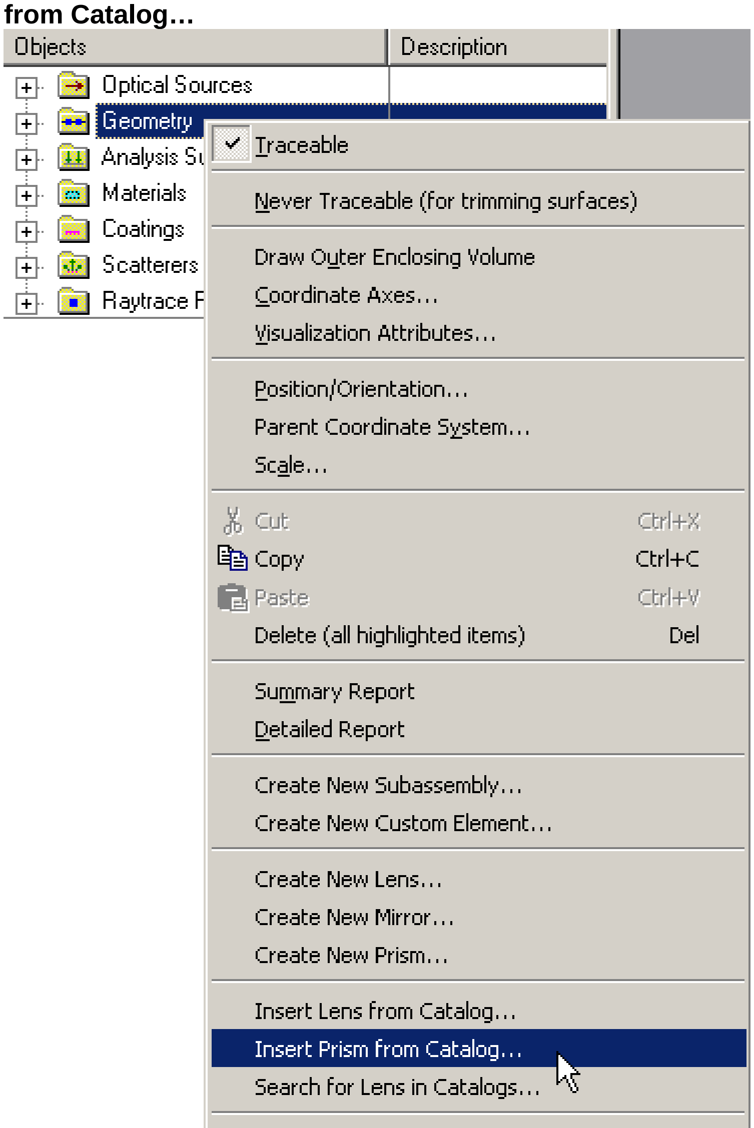
This dialog allows the selection and entry of a prism into your system from a vendor catalog. The prism is inserted with the location and orientation specified in the dialog.

Note FRED inserts the prism using the units provided by the vendor. Currently, in all cases, the units are millimeters. If this is not the unit of measure for your system, the prism is scaled by the appropriate factor for your system.

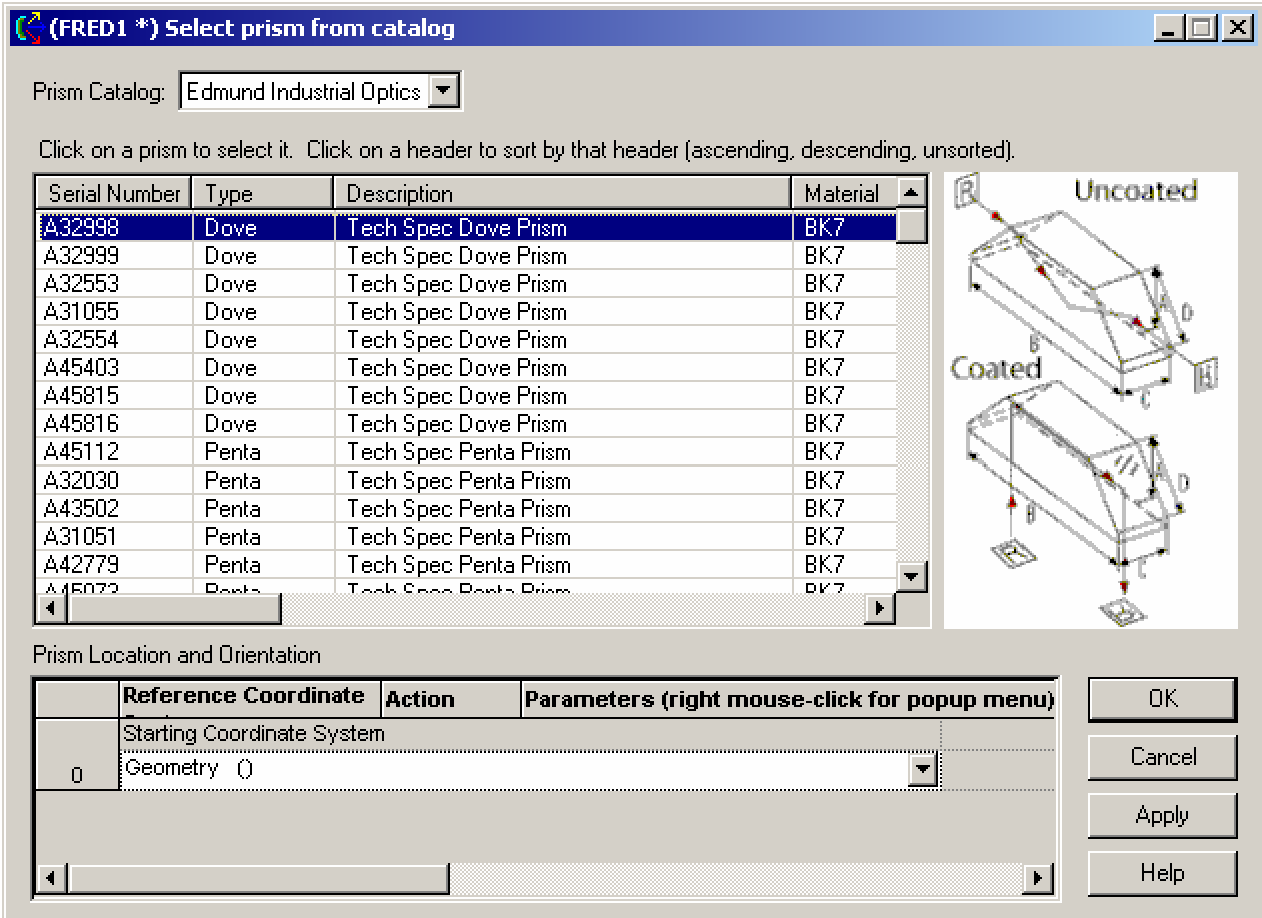
For example, if your system uses centimeters and you import a right-angle prism whose input face measures 10 mm by 10 mm, the Edit Prism dialog will show the prism as having a 1.0 cm by 1.0 cm input face.

How Do I Get There? - Insert Prism from Catalog

To execute this command, right click on the **Geometry** folder and choose **Insert Prism from Catalog…**



Dialog Box and Controls - Insert Prism from Catalog



Control	*Inputs*	*Defaults*
Prism Catalog	Shows the vendor whose catalog is listed in the Prism List.	Edmund Industrial Optics
Prism List	Shows the prisms available from the vendor selected in the Prism Catalog list.	Edmund Industrial Optics prisms
Prism Diagram	Shows a diagram of the prism, listing various dimensions specified in the Prism List.	Click on a prism to see its dimensions
Prism Location and Orientation	Shows the Location and Orientation Modifiers that will apply to the prism when it is placed in the FRED document.	Parent = Geometry Type = Make coincident with another coordinate system

OK	Inserts prism and close dialog box.	
Cancel	Discard prism and close dialog box.	
Apply	Inserts prism and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Insert Prism from Catalog

- This dialog is modeless, so you can have this window open while working on other things in your system.
- You may bring up more than one of these dialogs for a single system at a time.

See Also…. - Insert Prism from Catalog

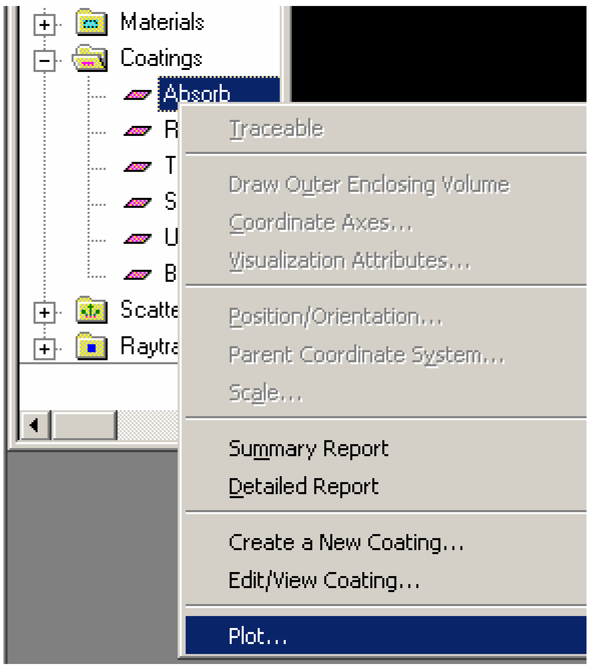
Select Lens from Catalog

Chapter 21 - Coating Plot Setup Dialog

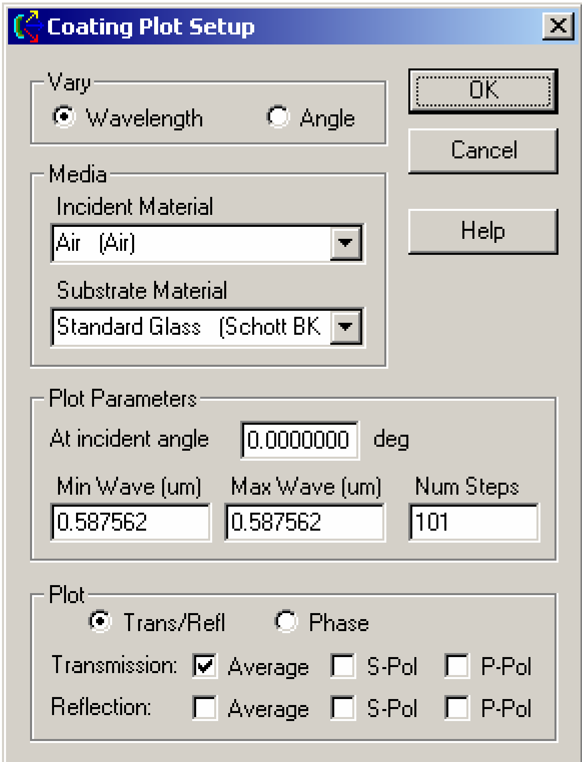
Description - Coating Plot Setup Dialog

How Do I Get There? - Coating Plot Setup Dialog

Right click on a coating and choose "Plot...".



Dialog Box and Controls - Coating Plot Setup Dialog



Control	***Inputs / Description***	***Defaults***
Wavelength		Selected
Angle		Not Selected
Incident Material		Air
Substrate Material		Standard Glass (Schott BK7)
Incident Angle		
Minimum Wavelength		
Maximum Wavelength		
Number of Steps		
Transmit/Reflect		Selected
Phase		Not Selected
Average Transmission		Checked
S-Pol Transmission		Unchecked

P-Pol Transmission		Unchecked
Average Reflection		Unchecked
S-Pol Reflection		Unchecked
P-Pol Reflection		Unchecked
OK	Closes the dialog and draws the plot	
Cancel	Closes the dialog and does not draw the plot	
Help	Displays this help article	

Application Notes - Coating Plot Setup Dialog

This dialog is modal and not resizable.

See Also.... - Coating Plot Setup Dialog

Chapter 22 - Changing *FRED's* Plots, Axes, and Visualization Attributes

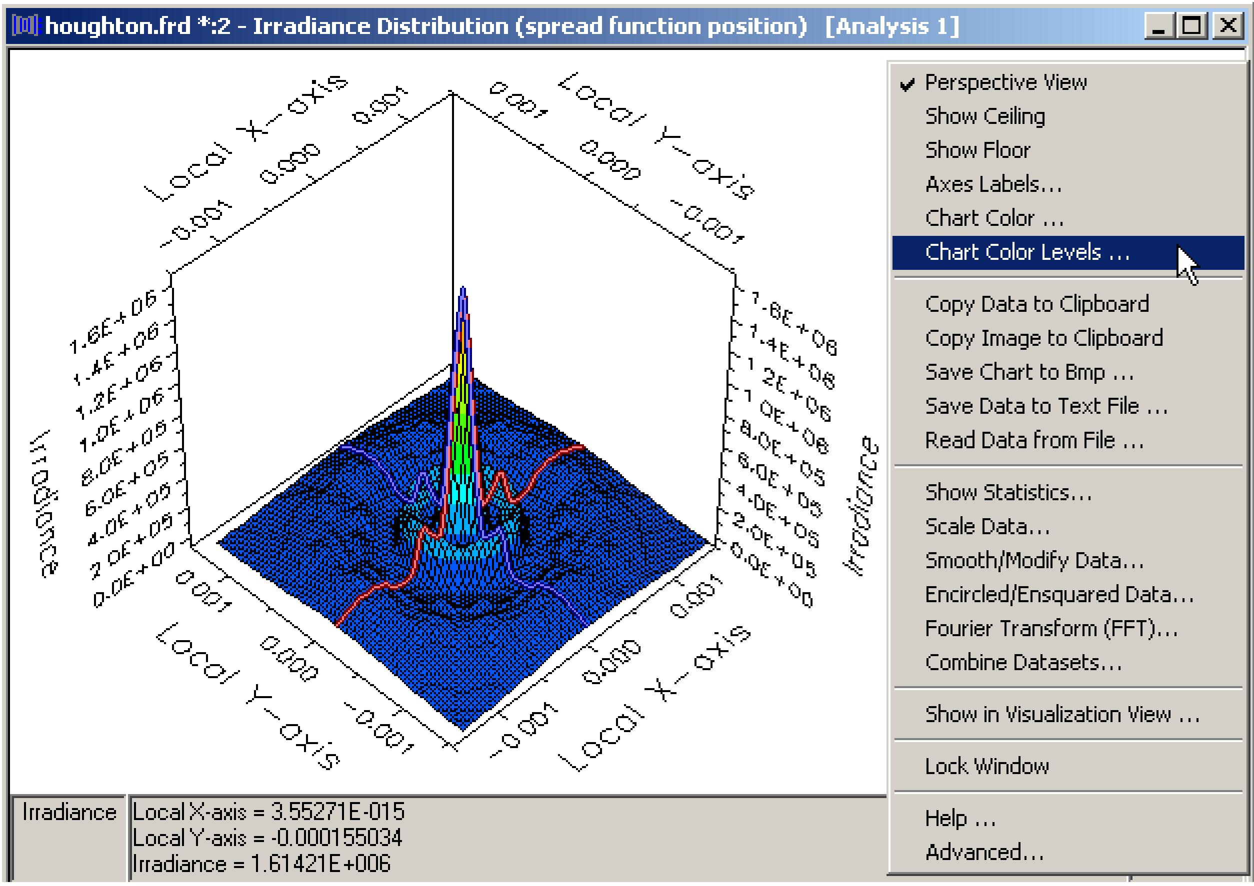
Plot Color Levels

Description
Plot Color Levels Dialog

The Plot Color Levels Dialog allows you to select the style and number of levels for the color scale of 3-D plots. These styles are specified in .sty files, located by default in <FRED Installation Directory>\Resources\Charts. Each chart type has its own default style, which is what is loaded into the chart when it is brought up for the first time. FRED will automatically adjust the number of levels and range of each level when you press the OK button.

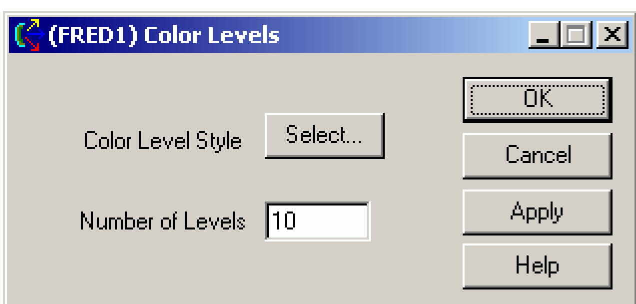
How Do I Get There?
Plot Color Levels Dialog

From a 3-D plot, right-click and choose "Chart Color Levels"



Dialog Box and Controls

Plot Color Levels Dialog



Control	***Inputs***	***Defaults***
Color Level Style	Selects the chart style definition file.	
Number of Levels	A number from 1 to 100	10

OK	Accept Color Level changes and close dialog box.	
Cancel	Discard Color Level changes and close dialog box.	
Apply	Apply Color Level changes and keep dialog box open.	
Help	Access this Help page.	

Color Similarity

Description - Color Similarity

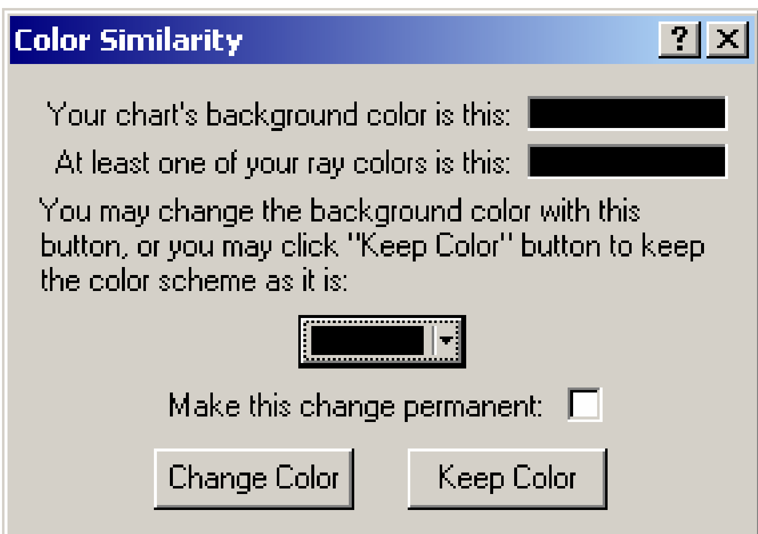
How Do I Get There? - Color Similarity

There are three different ways to execute this command:

2. Menu
3. Keyboard Accelerator
4. Toolbar Button

Include Images

Dialog Box and Controls - Color Similarity



Control	Inputs / Description	Defaults

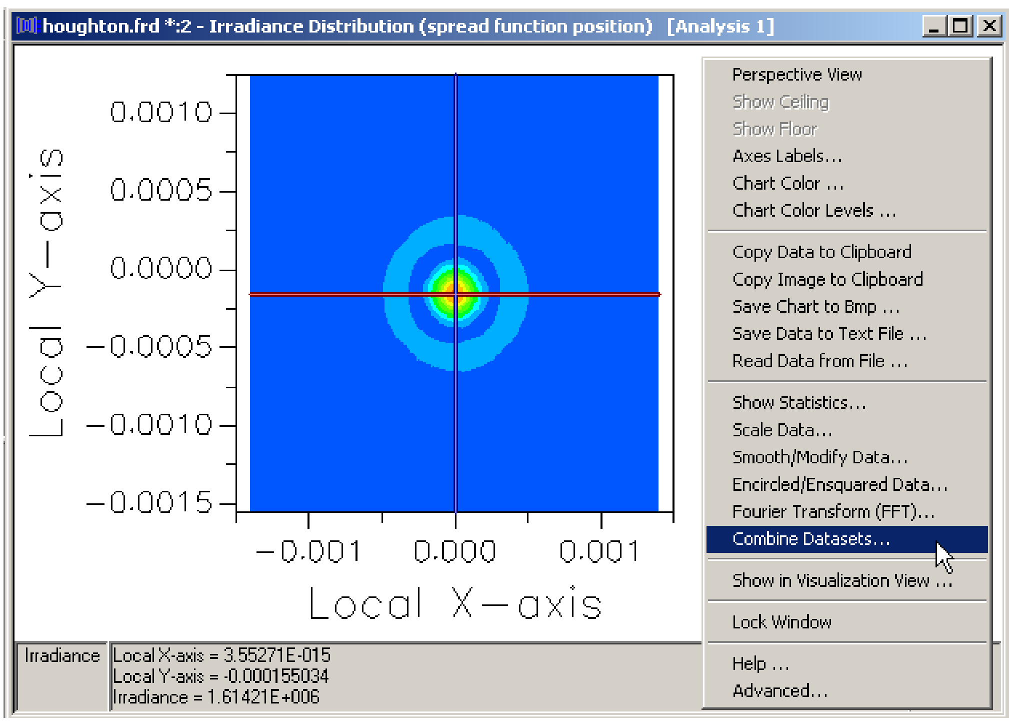
Application Notes - Color Similarity

See Also…. - Color Similarity

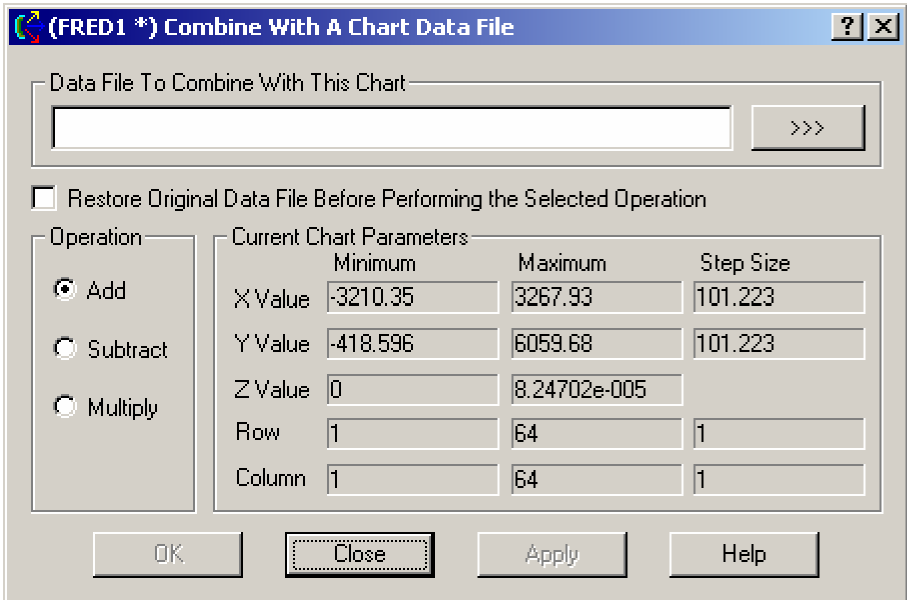
Combine Datasets

This command, available in the right mouse click pop-up menu, brings up the Combine Datasets dialog box. This dialog provides an environment where the current dataset can be combined with saved datasets with the same number of grid points in X and Y, the same grid spacing, and the same analysis plane size.

Warning	Once a combination has been applied to the dataset, there is no trivial way to recover the original dataset without recalculating the spread function from the filtered rays.



Irradiance spread function contour



The Combine Datasets dialog

The Combine Date dialog is broken up into four sections: the file to combine with this dataset, restore original data set, the operation, and current chart parameters.

Control	Inputs	Defaults
Data File To Combine With This Chart	File name of a previously saved data file with the same grid size, grid location, and grid spacing as the current dataset.	Blank
>>>	Equivalent to Open or Browse. Brings up an Open File dialog.	
Restore Original Data File Before Performing the Selected Operation	If checked, the original dataset will be restored prior to performing the next combining operation.	Unchecked
Operation		
Add	Adds the two data sets pixel by pixel.	Selected
Subtract	Subtracts the two data sets pixel by pixel.	Not Selected
Multiply	Multiplies the two data sets pixel by pixel.	Not Selected
Current Chart Parameters		
X,Y Value, Min/Max	The current dataset min and max values in the X,Y direction. This is set by the analysis plane parameters.	

X,Y Value, Step Size	The step size between grid points in the X,Y direction. This is set by the analysis plane parameters.	
Z Value, Min and Max	The min and max Z values in the current dataset.	
Row: Min/Max	The number of pixels in the "X" direction.	
Row: Step Size	Always 1	
Column: Min/Max	The number of pixels in the "Y" direction.	
Column: Step Size	Always 1	
OK	Accept indicated combinations and close dialog box.	
Close	Closes the dialog without any further combinations but does not cancel already applied combinations.	
Apply	Apply indicated combinations and keep dialog box open.	
Help	Access this Help page.	

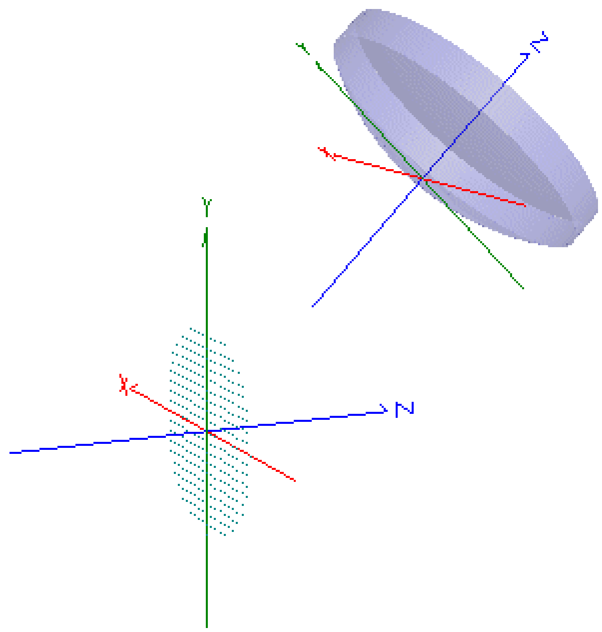
Coordinate Axes...

Description - Coordinate Axes...

The Coordinate Axes visualization dialog is accessed via the right mouse click context menu. It is functionally identical to the Coordinate Axes control found under the Visualization tab on the Surface dialog.

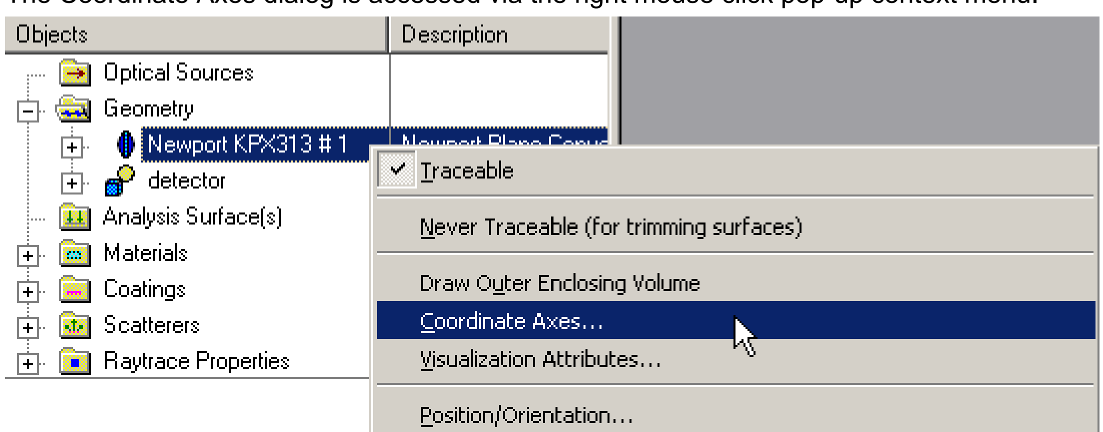
Visualization (example) - Coordinate Axes...

The following image shows Coordinate axes rendering for a source and at tilted and decentered catalog lens.

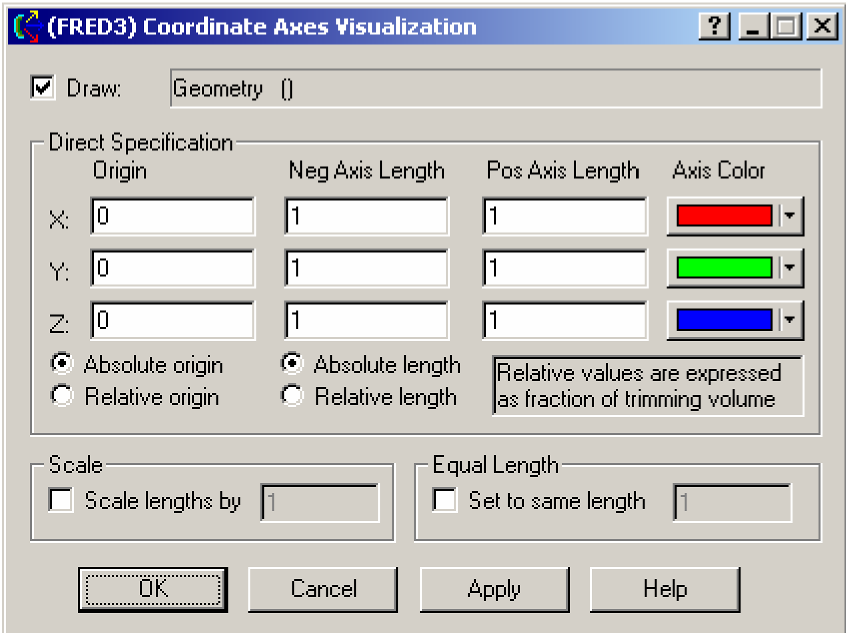


How Do I Get There? - Coordinate Axes...

The Coordinate Axes dialog is accessed via the right mouse click pop-up context menu.



Dialog Box and Controls - Coordinate Axes...



Control	***Inputs***	***Defaults***
Draw	Check this box to render the coordinate axes for the displayed node.	Unchecked
Direct Specification		
Origin	Enter the X, Y, and Z offsets of the coordinate axes from the local origin.	(0,0,0) absolute origin
Neg Axis Length	Enter the absolute or relative X, Y, and Z negative axes lengths.	(1.2,1.2,1.2) rel length
Pos Axis Length	Enter the absolute or relative X, Y, and Z positive axes lengths.	(1.2,1.2,1.2) rel length
Axis color	Change the axis color using the standard Windows color palette.	X=Red Y=Green Z=Blue
Absolute origin	Select this option to orient the coordinate axes relative to the local origin of the displayed node.	Selected
Relative origin	Select this option to orient the coordinate axes relative to the origin of the local (surfaces only) or global bounding volume.	Not selected
Absolute Length	Select this option to fix the axis lengths in system units.	Selected

Relative Length	Select this option to size the axes lengths based on the local (surfaces only) or global bounding volume.	Not selected
Scale		
Scale lengths by	Scale axes lengths.	Unchecked (1)
Equal Length		
Set to same length	Make all axes of same length.	Unchecked (1)
OK	Accept Coordinate Axes Visualization changes and close dialog box.	
Cancel	Discard Coordinate Axes Visualization changes and close dialog box.	
Apply	Apply Coordinate Axes Visualization changes and keep dialog box open.	
Help	Access this Help page.	

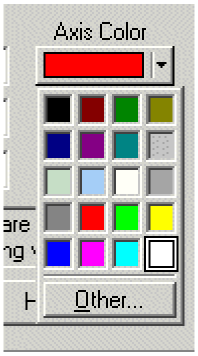
Application Notes - Coordinate Axes...

- The default settings for the dialog are to draw the coordinate axes at the local origin of the selected node with axis lengths that are scaled relative to the size of the bounding volume. If the bounding volume is not symmetric in three dimensions, the axes are rendered with different lengths.
- Selecting the relative position option is useful if the bounding volume is not centered at the local origin.
  - Only surfaces have a local bounding volume that may be both shifted and rotated
  - All other entities have a global bounding volume that may be decentered, but is never rotated
  - FRED always shows the local or global bounding volume in the Visualization window whenever a node is selected.
- Coordinate axes can be rendered for any Optical Sources, Geometry, or Analysis Surface(s) node.

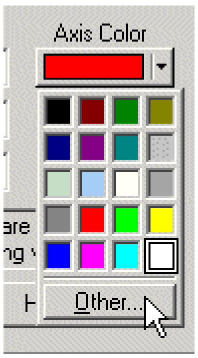
Examples - Coordinate Axes...

Example 1 – Change the rendered color

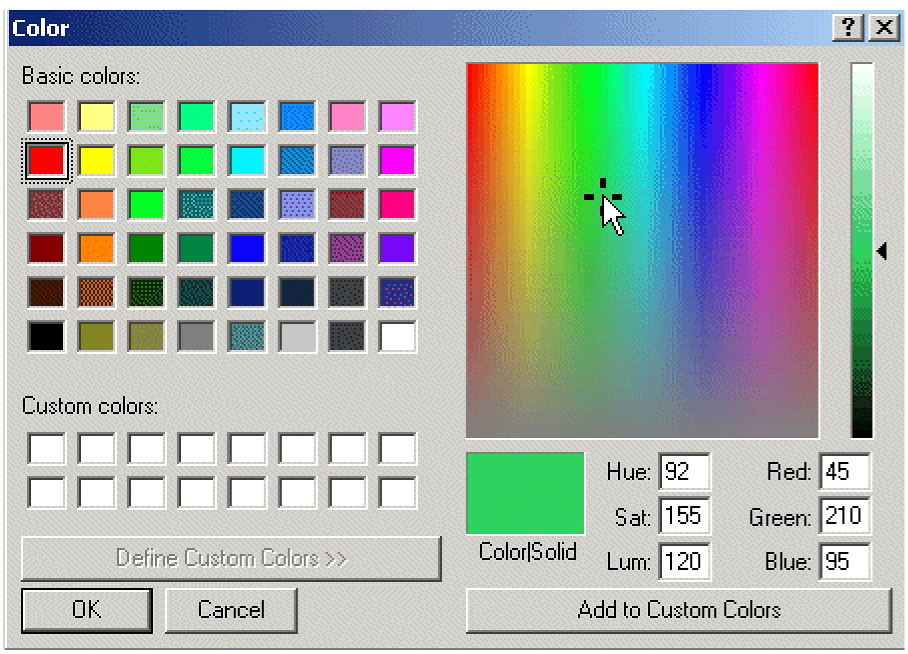
The axis rendering colors are edited via a standard Windows color palette, as shown in the following example. Any one of the displayed colors can be selected.



To expand the list of available colors, left mouse click on the ‘Other…’ button.



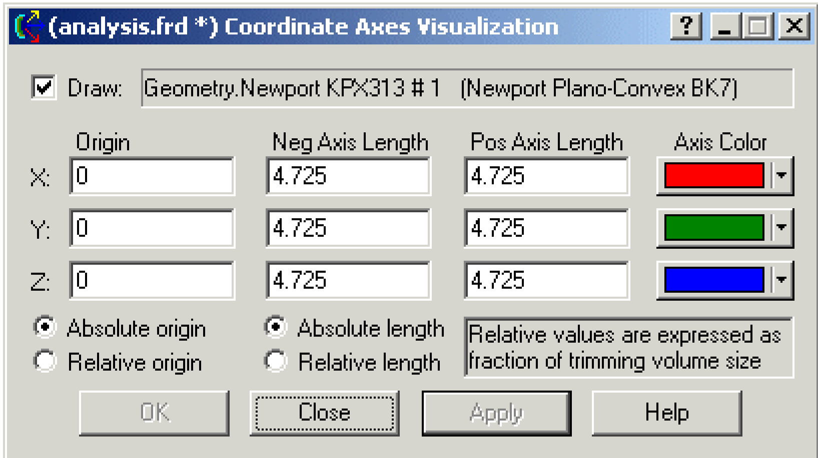
Now choose a color from the Windows palette and ‘Add to Custom Colors’ to save it, if so desired. Left mouse click on the OK or Cancel buttons to close the dialog. Note that the list of available colors may differ from that shown in the figure if a different color resolution is being used.

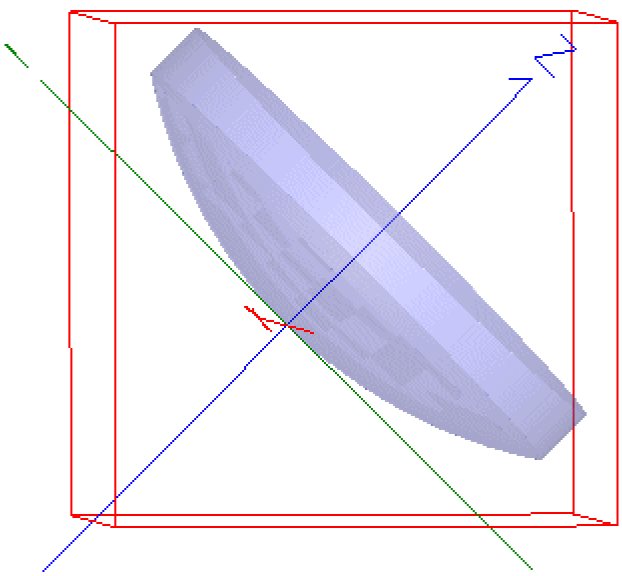


<u>Example 2 – The difference between absolute and relative coordinate axis origins</u>

Absolute coordinate origin:

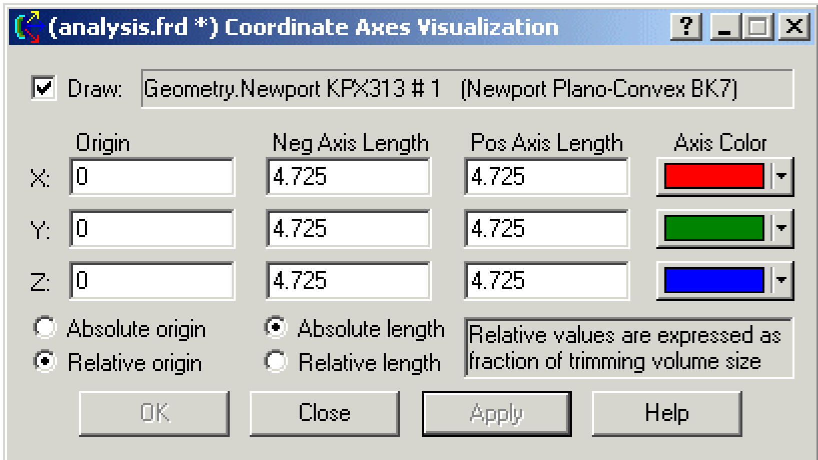
The coordinate axes are coincident with the local origin of the lens entity. The global bounding volume is shown.

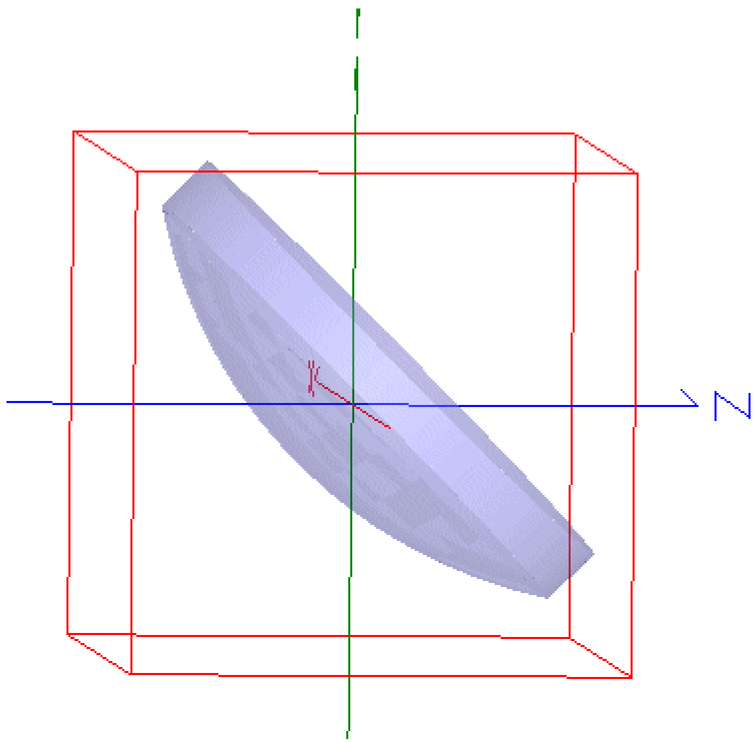




Relative coordinate origin:

The coordinate axes are coincident with the local origin of the global bounding volume for the lens. The global bounding volume is shown.


(analysis.frd *) Coordinate Axes Visualization
Draw:
Geometry.Newport KPX313 # 1 (Newport Plano-Convex BK7)
Origin
Neg Axis Length
Pos Axis Length
Axis Color
X:
0
4.725
4.725
Y:
0
4.725
4.725
Z:
0
4.725
4.725
Absolute origin
Relative origin
Absolute length
Relative length
Relative values are expressed as fraction of trimming volume size
OK
Close
Apply
Help


Z

See Also…. - Coordinate Axes…

Help for other options available from the right click pop-up menu is available by selecting the appropriate links.

- Traceable
- Sequential Raytrace
- Draw Global Enclosing Volume
- Coordinate Axes…
- Visualization Attributes…
- Position/Orientation…
- Parent Coordinate System…
- Scale…
- Summary Report
- Detailed Report

Curve Visualization Tab

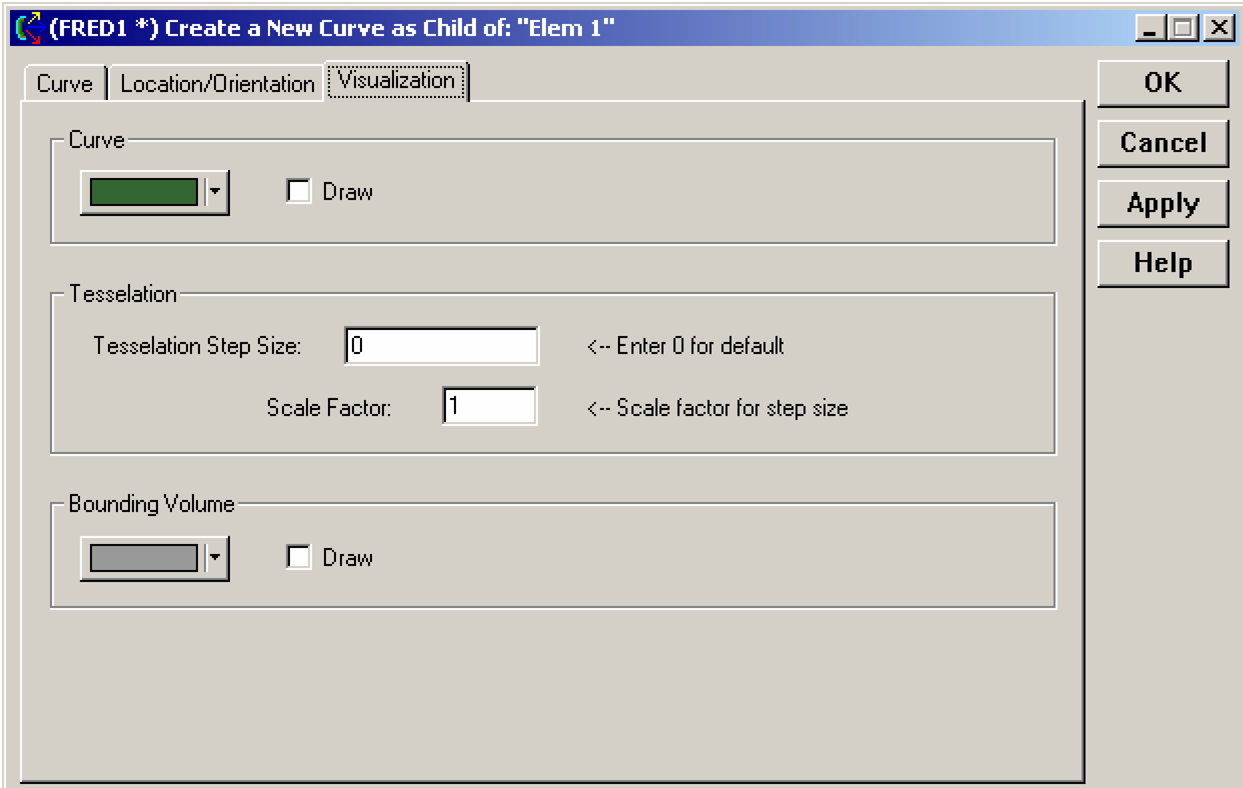
Description - Curve Visualization Tab

This property tab allows you to modify the visualization attributes of the curve.

How Do I Get There? - Curve Visualization Tab

Bring up the Curve dialog by right clicking on a custom element, lens, mirror, or prism, then choose "Create New Curve...", or right click on an existing curve. Click the Visualization tab.

Dialog Box and Controls - Curve Visualization Tab



Control	*Inputs / Description*	*Defaults*
Curve Color	Determines the color of the curve	**Green**
Draw Curve Checkbox	Draws the curve when checked	Unchecked
Tessellation Step Size	Determines the granularity of the curve when drawn. A value of zero sets the granularity to a heuristically determined default value.	0
Scale Factor	Scales the tessellation by the specified amount	1
Bounding Volume Color	Determines the color of the bounding box	**Gray**
Draw Bounding Volume Checkbox	Draws a box around the curve when checked	Unchecked
OK	Applies the changes and dismisses the dialog	
Cancel	Does not apply changes and dismisses the dialog	
Apply	Applies the changes and keeps the dialog visible	
Help	Displays this help article	

Application Notes - Curve Visualization Tab

This property tab is both modeless and resizable.

See Also…. - Curve Visualization Tab

Curve Tab

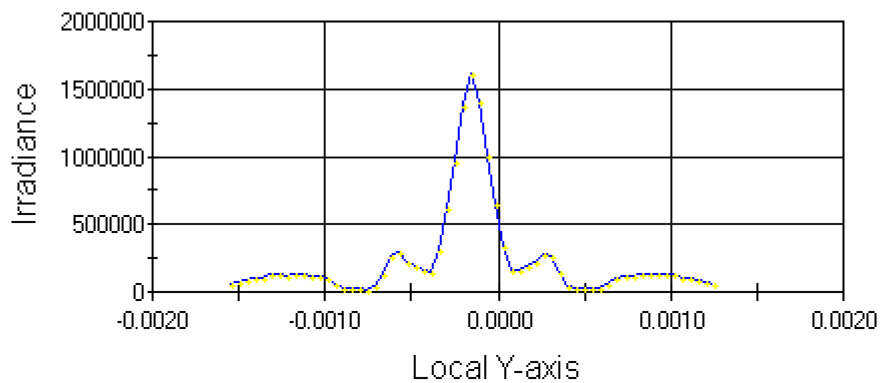
Location/Orientation Tab

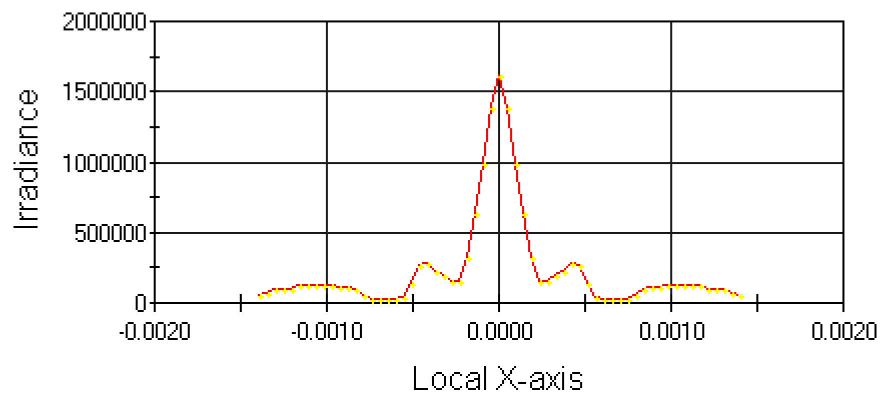
Charts Profile View

Description

Profile View

Displays profiles or slices through data sets when plotting intensity or irradiance calculations.



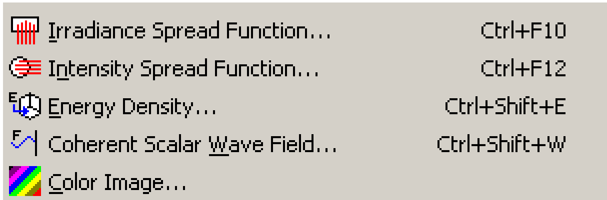


How Do I Get There?

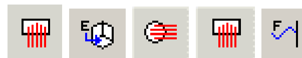
Profile View

There are three different ways to execute this command:

1. Select any of the functions below from the Analysis Menu:



2. Press any of the keyboard accelerator keys: Ctrl+F10, Ctrl+F12, Ctrl+Shift+E, Ctrl+Shift+W.

3. Press any of the toolbar buttons: 

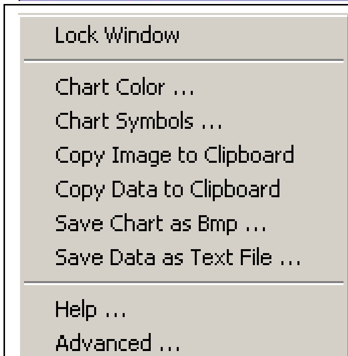
Dialog Box and Controls

Profile View

No dialog box is available with this function.

Application Notes

Profile View

	Lock Window Chart Color ... Chart Symbols ... Copy Image to Clipboard ... Copy Data to Clipboard ... Save Chart as Bmp ... Save Data as Text File ... Help ... Advanced ...

Examples

Profile View

See Also….

Profile View

Chapter 23 - Decompose Wavefront

Decompose Wavefront

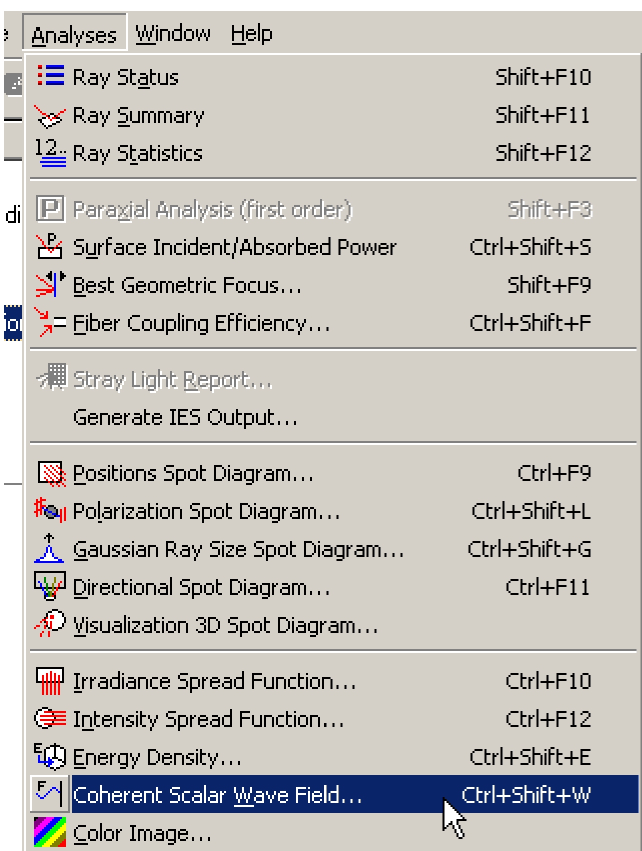
Description - Decompose Wavefront

Performs a Zernike decomposition from the computed wavefront data. The user can specify the number of Zernike terms for the fit as well as subtract out the first 6 terms.

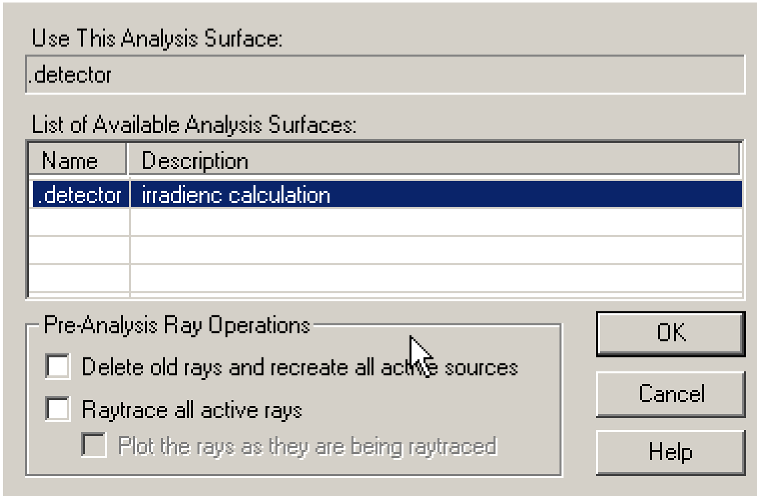
How Do I Get There? - Decompose Wavefront

Decomposition of the wavefront into Zernike coefficients requires four steps:

1.

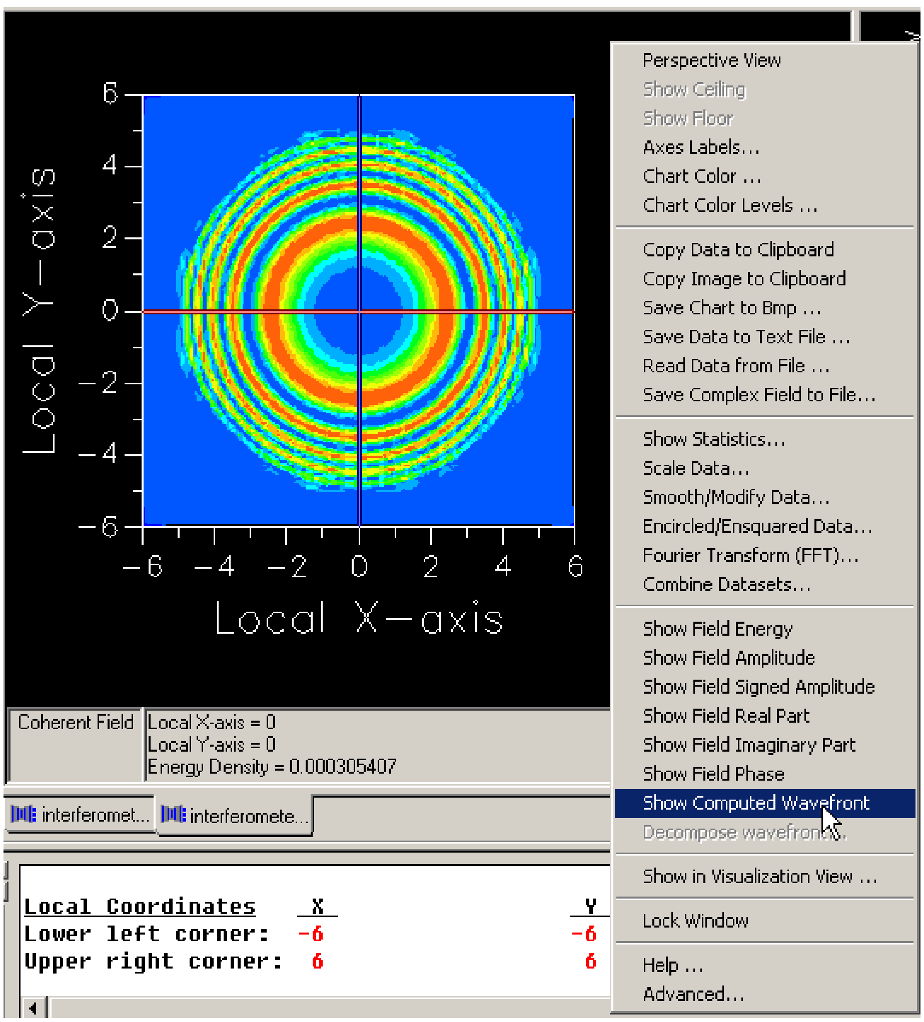


2.



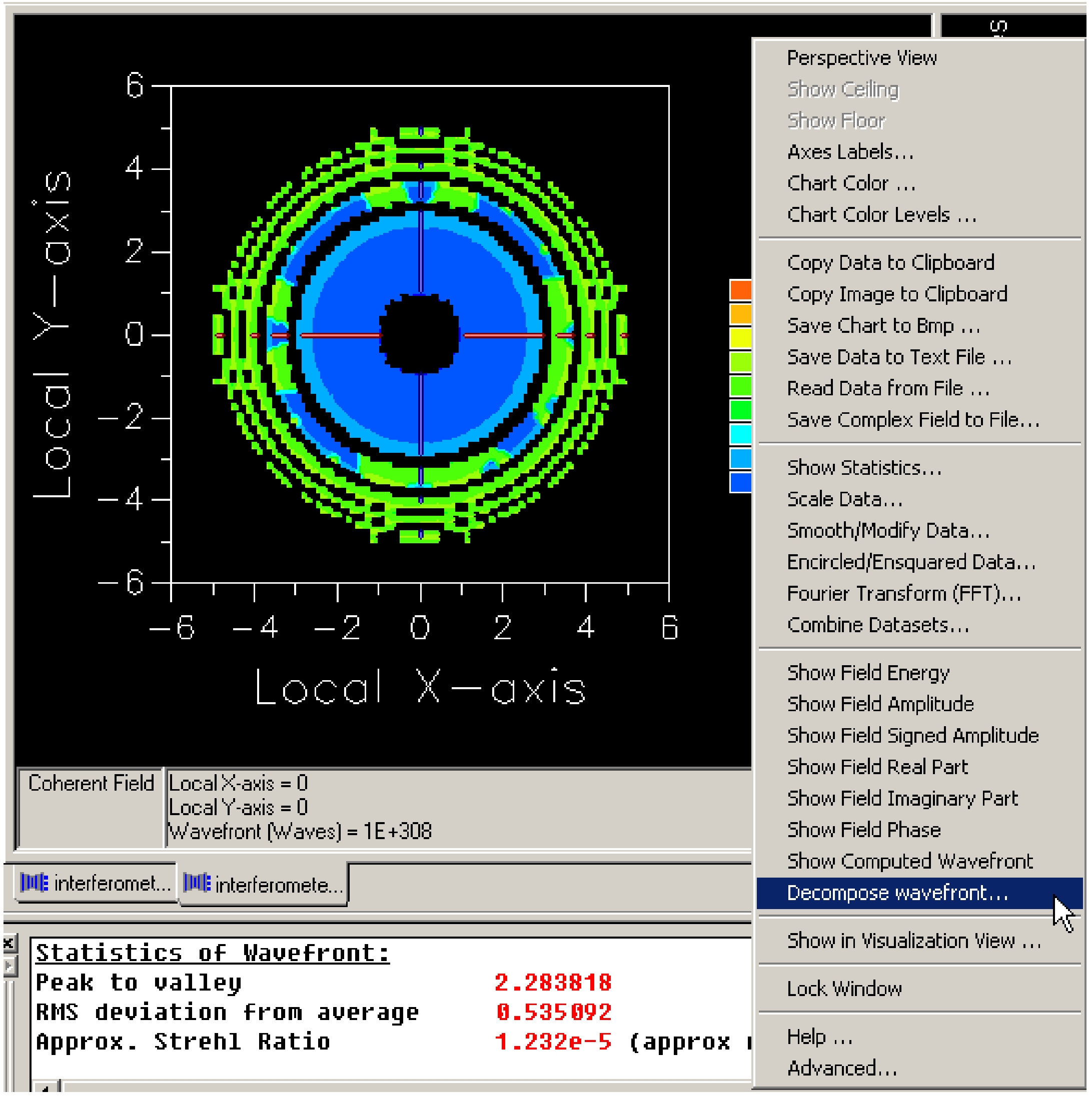
Use This Analysis Surface:
.detector
List of Available Analysis Surfaces:
Name
Description
.detector
irradienc calculation
Pre-Analysis Ray Operations
Delete old rays and recreate all active sources
Raytrace all active rays
Plot the rays as they are being raytraced
OK
Cancel
Help

3.

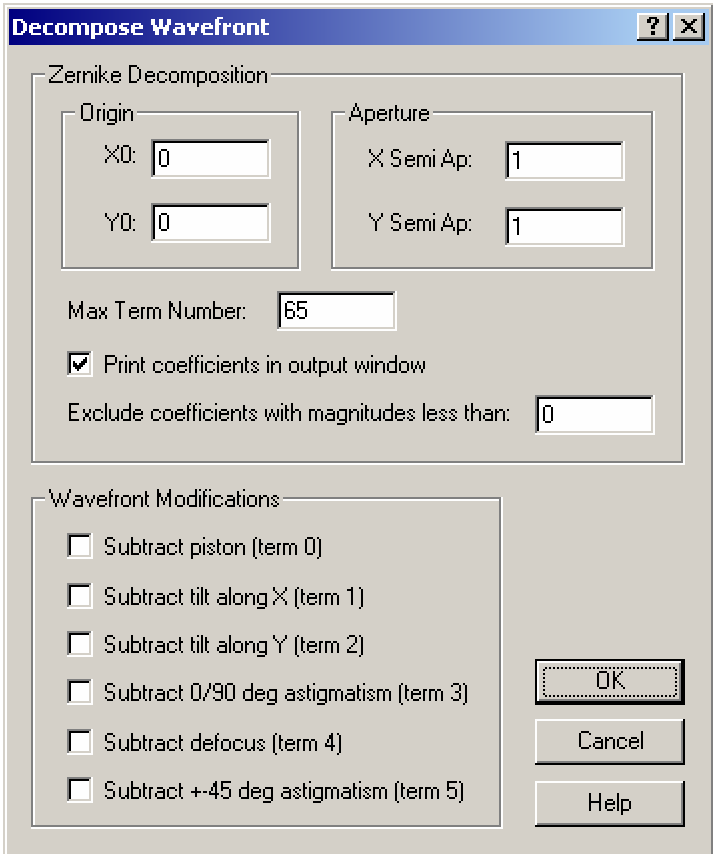


Local Y−axis
Local X−axis
Coherent Field
Local X-axis = 0
Local Y-axis = 0
Energy Density = 0.000305407
interferomet...
interferomete...
Local Coordinates X Y
Lower left corner: -6 -6
Upper right corner: 6 6
Perspective View
Show Ceiling
Show Floor
Axes Labels...
Chart Color ...
Chart Color Levels ...
Copy Data to Clipboard
Copy Image to Clipboard
Save Chart to Bmp ...
Save Data to Text File ...
Read Data from File ...
Save Complex Field to File...
Show Statistics...
Scale Data...
Smooth/Modify Data...
Encircled/Ensquared Data...
Fourier Transform (FFT)...
Combine Datasets...
Show Field Energy
Show Field Amplitude
Show Field Signed Amplitude
Show Field Real Part
Show Field Imaginary Part
Show Field Phase
Show Computed Wavefront
Decompose wavefront...
Show in Visualization View ...
Lock Window
Help ...
Advanced...

4.



Dialog Box and Controls - Decompose Wavefront



Control	Inputs / Description	Defaults
Zernike Decomposition		
Origin	X,Y origin of Zernike.	0,0
Aperture	X,Y semi-aperture of Zernike.	1,1
Max Term Number	Maximum number of Zernike terms to include.	65
Print coefficients	Prints coefficients to output window.	Checked
Exclude coefficients	Exclude coefficients with magnitude less than user-defined value.	0
Wavefront Modifications		
Subtract piston	Subtract tilt (term 0) from Decomposed Wavefront.	Unchecked
Subtract tilt along X	Subtract X-tilt (term 1) from Decomposed Wavefront.	Unchecked
Subtract tilt along Y	Subtract Y-tilt (term 2) from Decomposed Wavefront.	Unchecked
Subtract 0/90 deg astigmatism	Subtract astigmatism (term 3) from Decomposed Wavefront.	Unchecked

Subtract defocus	Subtract defocus (term 4) from Decomposed Wavefront.	Unchecked
Subtract +/- 45 deg astigmatism	Subtract astigmatism (term 5) from Decomposed Wavefront.	Unchecked
OK	Accept Wavefront Modifications and close dialog box.	
Cancel	Discard Wavefront Modifications and close dialog box.	
Help	Access this Help page.	

Application Notes - Decompose Wavefront

See Also - Decompose Wavefront

Chapter 24 - *FRED* Turbo

FRED **Turbo** takes advantage of the high performance capabilities of today's multi-cpu systems containing more than 2 cores. Our new **Turbo** edition dramatically increases ray trace speed by breaking up the raytracing task across multiple CPUs without user intervention. *FRED* **Turbo** has been tested on AMD Opteron, Intel Xeon, and Duo-Core CPU technologies. Typical benchmark results show an average ray trace speed increase of 3x for a two CPU Opteron Dual Core system (4 cores) over a single CPU. Some types of simulations which benefit from **Turbo** are tolerancing, Point Source Transmittance (PST), illumination systems requiring millions of rays to check for uniformity, non-sequential ghost analysis and thermal imaging problems.

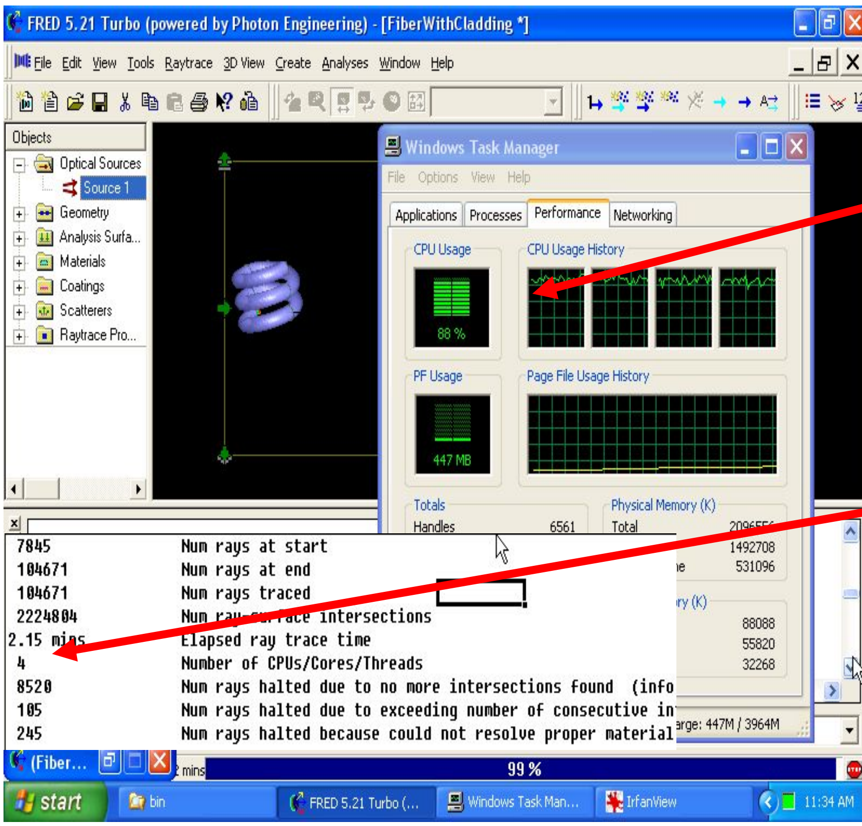


Figure 1 (left) - shows *FRED* *Turbo* running a simulation on a two CPU AMD Opteron system with Dual Core 2.0 GHz CPUs. All 4 of the CPUs are running with over 80% efficiency for an overall 88% average efficiency as reported by the Windows Task Manager. Using 4 CPUs speeds up the ray trace

Example Turbo results

Type of System Traced with large ray bundle	Number or Rays Traced	Single Threaded Mode – Speedy (1 CPU) HP xw9300 series	Multi-Threaded Mode-Speedy (4 CPUs) HP xw9300 series	Speed Increase
Enclosed Tube multiple geometry types	54316	85.6 secs	26 secs	3.29
LED Lightpipe Example	45000	35.2 secs	15.7 secs	2.24
Elliptical Reflector	486245	54.9 secs	14.5 secs	3.79
Classical Cassegrain	224576	12 secs	4.53 secs	2.65

Chapter 25 – Miscellaneous Topics using *FRED*

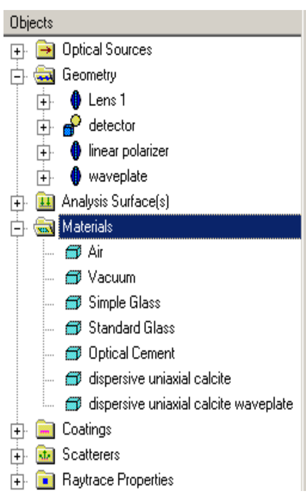
Color Separation by Polarization

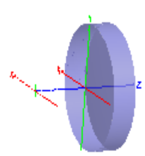
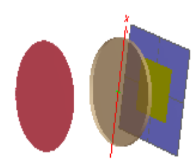
Description - Color Separation by Polarization

This example illustrates the spatial separation of color resulting from passage through birefringent optical elements. Polarized white light is incident upon a simple lens made from calcite, a uniaxial crystal. The converging bundle continues through a waveplate and a polarizing element and is captured on a screen. The Color Image feature in FRED is used to display the spatially distributed spectra.

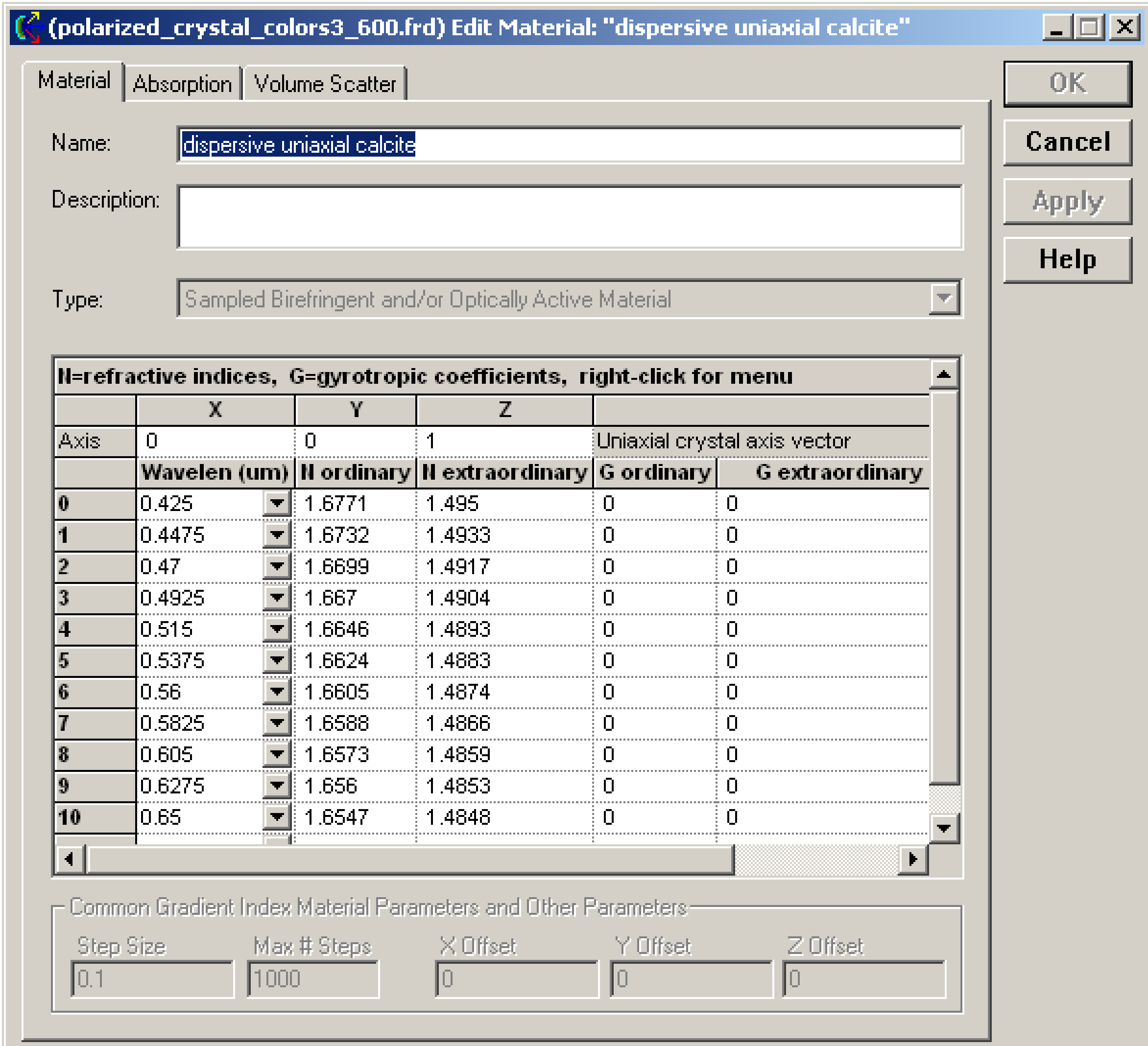
Example - Color Separation by Polarization

Start by setting up the geometry. Included here are a plano-convex calcite lens followed by a calcite waveplate, a linear polarizer and a collection plane.

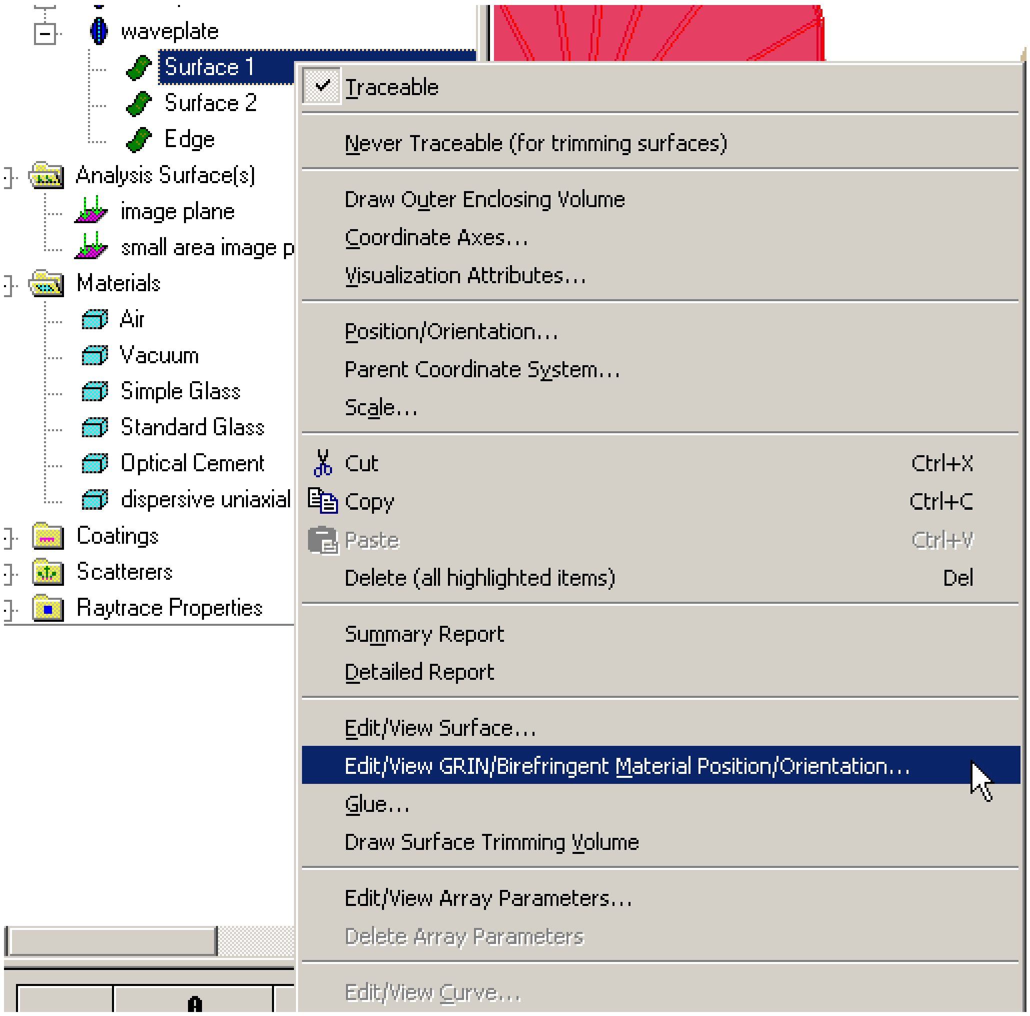


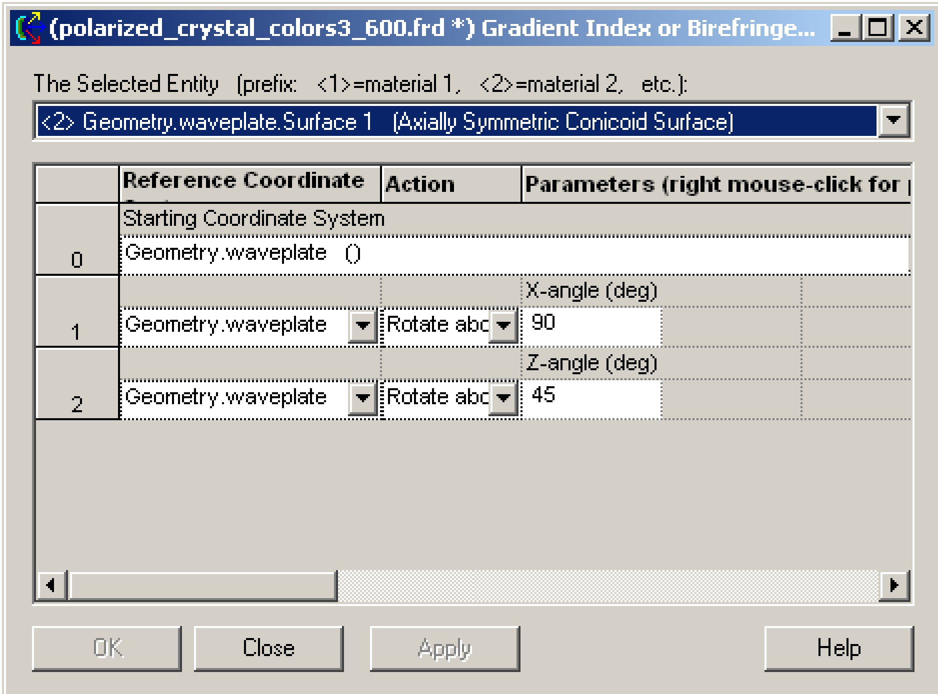



Even though there are two orientations of calcite in this model, only one calcite material need be created. The material orientation defined for the lens has its fast axis along global-z:

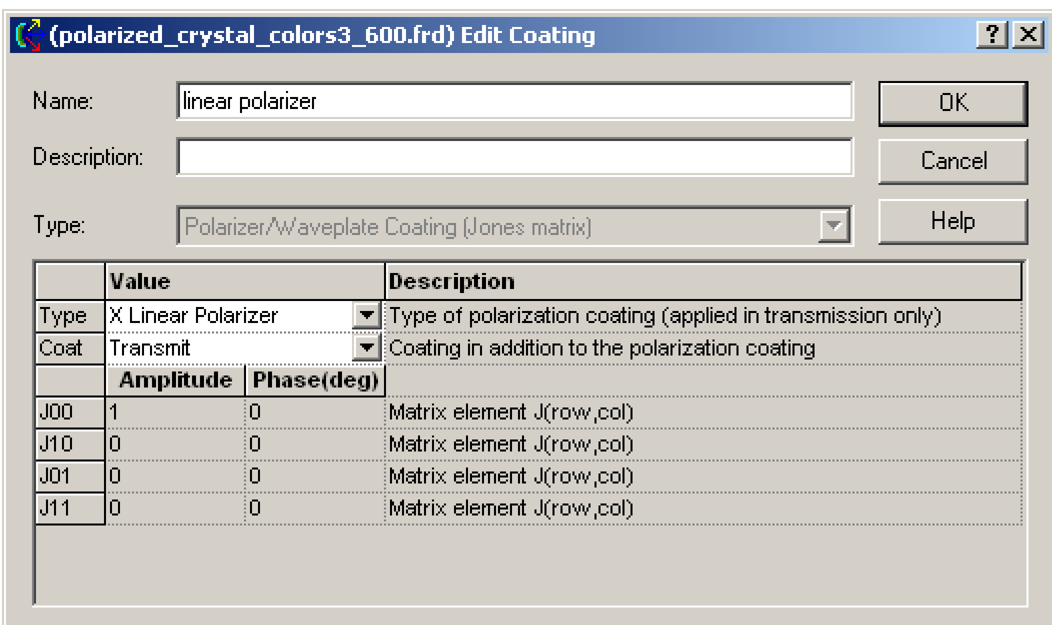


The calcite waveplate material is oriented with its fast axis bisecting the global +x & +y directions. The same birefringent material definition used for the lens can also be used for the waveplate by applying a coordinate transformation to the waveplate surfaces through the "Edit/View GRIN/Birefringent Position/Orientation" dialog:


waveplate
Surface 1
Surface 2
Edge
Analysis Surface(s)
image plane
small area image p
Materials
Air
Vacuum
Simple Glass
Standard Glass
Optical Cement
dispersive uniaxial
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes…
Visualization Attributes…
Position/Orientation…
Parent Coordinate System…
Scale…
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Surface…
Edit/View GRIN/Birefringent Material Position/Orientation…
Glue…
Draw Surface Trimming Volume
Edit/View Array Parameters…
Delete Array Parameters
Edit/View Curve…

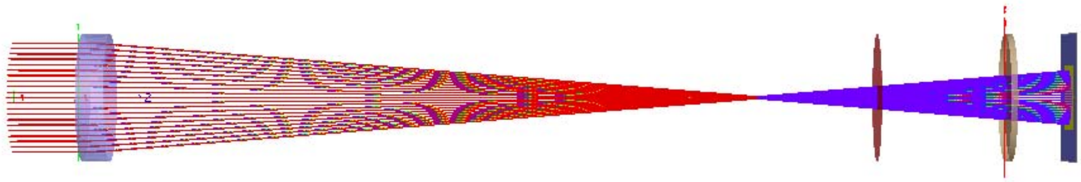


The polarizer has a coating that passes only light polarized along the global x-direction:

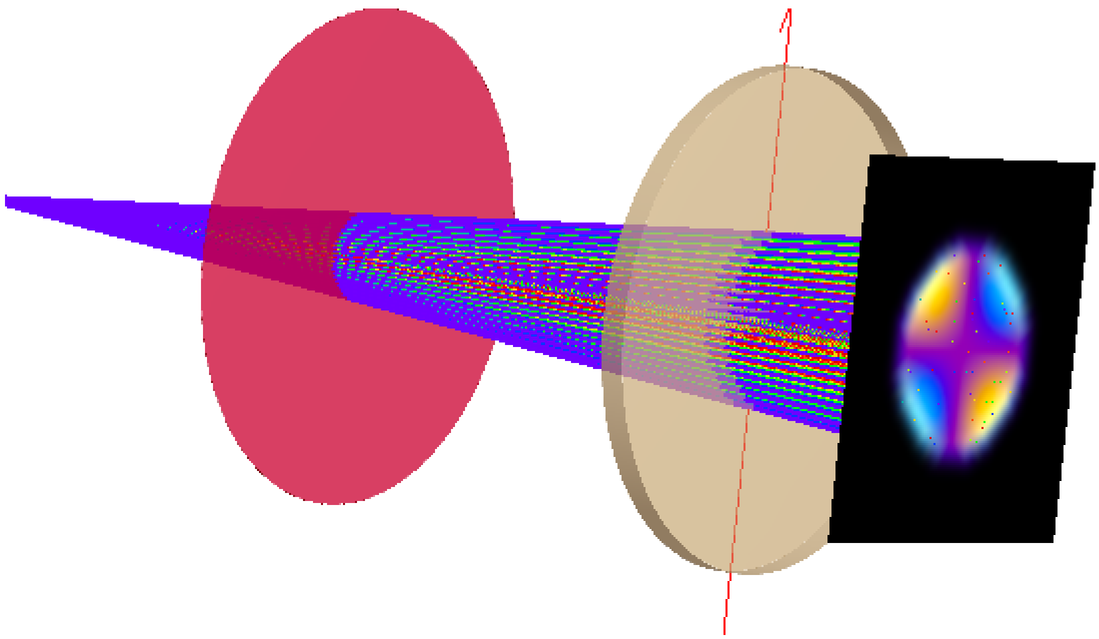


The source is a coherent, collimated bundle polarized along the global y-direction. The "Synthesize a Color" feature was used to create and weight a range of evenly spaced wavelengths simulating the color "white".

Upon tracing the source



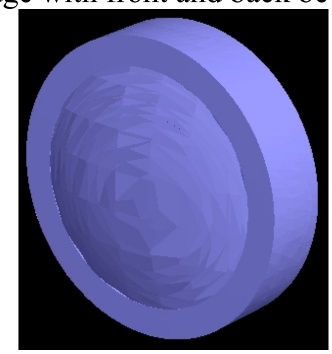
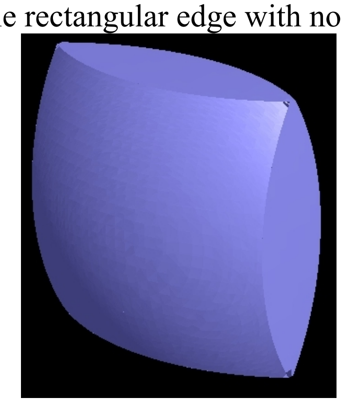
and evaluating the rays on the detector using the Color Image feature, the image has the following appearance. This view is obtained by invoking the "Show in Visualization View.." option in the Chart Viewer and setting the detector Visualization Attribute *Opacity* to "Invisible".



Advanced Aperture Dialog

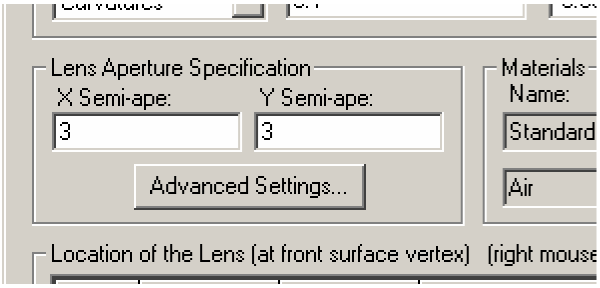
Description - Advanced Aperture Dialog

This dialog allows you to define advanced edge types for lenses and mirrors. There are four types of edge that can be defined for a lens or mirror.

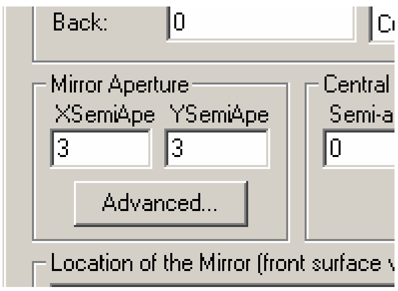
Edge with front and back bevels 	Simple circular edge with no bevels 
No edge 	Simple rectangular edge with no bevels 

How Do I Get There? - Advanced Aperture Dialog

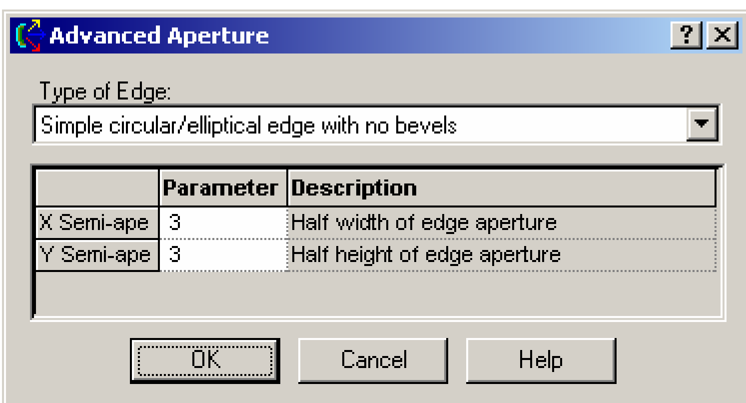
From the Edit/Create New Lens dialog, press the "Advanced Settings..." button in the Lens Aperture Specification area.



This dialog is also available on the Edit/Create New Mirror dialog, in the Mirror Aperture area. Click the "Advanced..." button.



Dialog Box and Controls - Advanced Aperture Dialog



Control	***Inputs / Description***	***Defaults***
Type of Edge:	Displays what type of edge will be placed on the object.	Simple circular/elliptical edge with no bevels
Parameters	Displays the parameters of the edge type.	X Semi-ape = 0.5 Y Semi-ape = 0.5
OK	Applies the changes to the aperture and closes the dialog.	
Cancel	Closes the dialog without applying changes to the aperture.	

Help	Displays this help article.	

Application Notes - Advanced Aperture Dialog

This dialog is resizable and modal. It must be closed before other work can be done.

See Also…. - -Advanced Aperture Dialog

Edit/Create New Mirror Dialog

Edit/Create New Lens Dialog

Encircled/Ensquared Values Dialog

How Do I Get There? - Encircled/Ensquared Values Dialog

There are three different ways to execute this command:

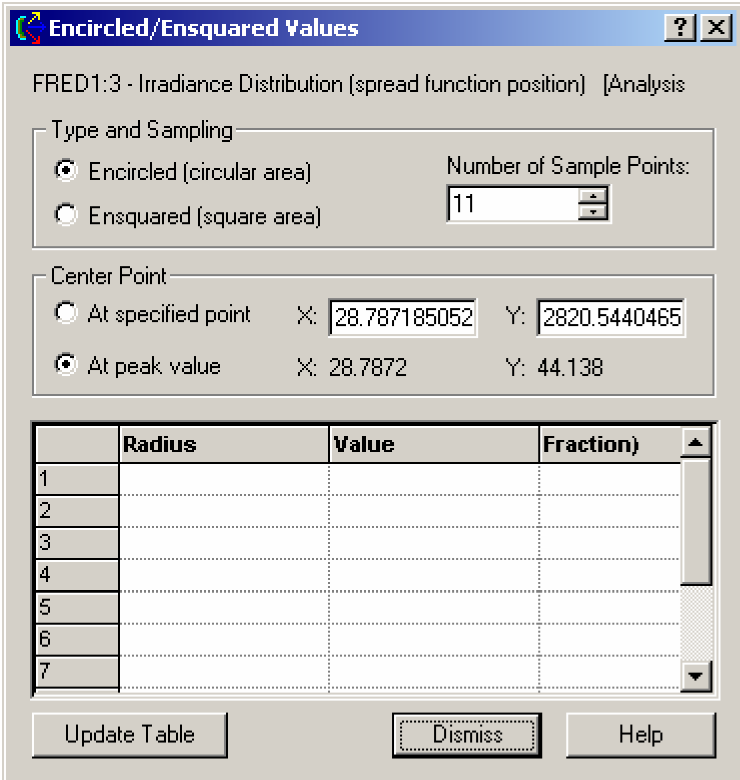
Menu

Keyboard Accelerator

Toolbar Button

Include Images

Dialog Box and Controls - Encircled/Ensquared Values Dialog



Control	***Inputs / Description***	***Defaults***

Application Notes - Encircled/Ensquared Values Dialog

See Also…. - Encircled/Ensquared Values Dialog

Entity Array Dialog

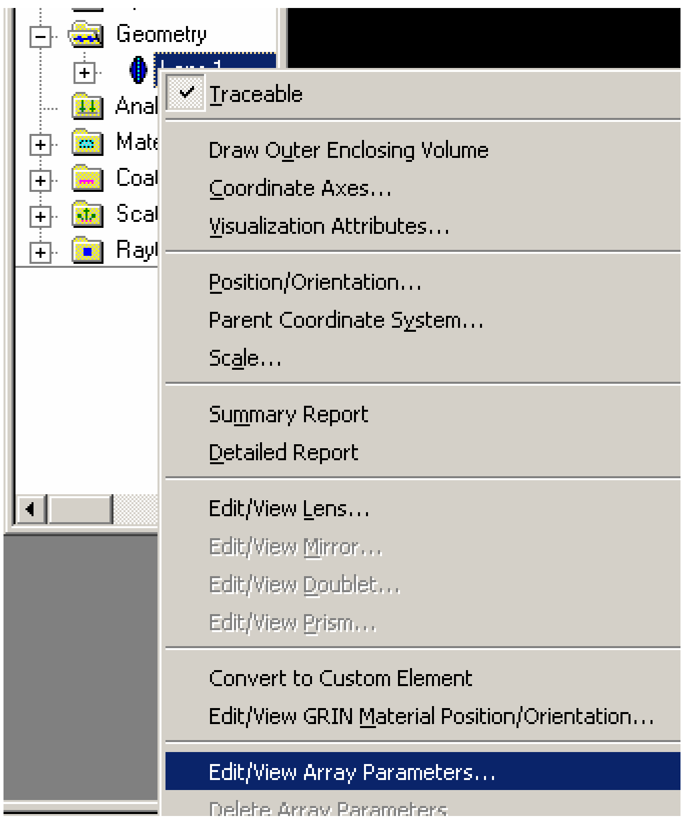
Description - Entity Array Dialog

This dialog allows you to set up a planar array of entity types in the FRED system. It replicates a particular type (a lens, for example) across an array whose size and drawing specification is defined in the dialog.

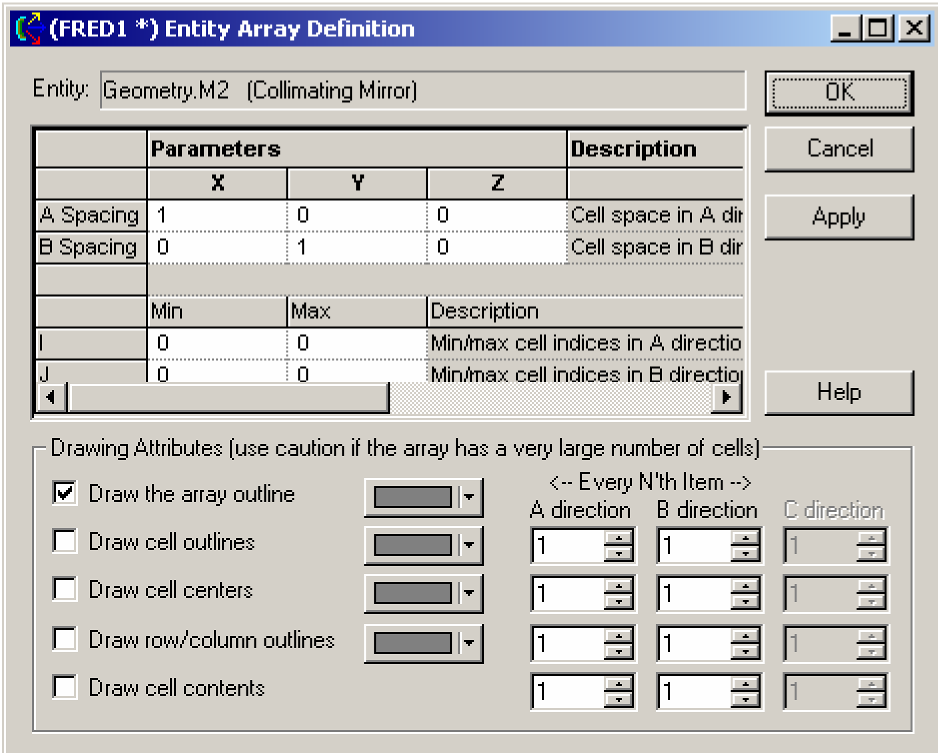
For the purposes of this article, an array of default lenses will be used.

How Do I Get There? - Entity Array Dialog

Right click on a geometry object and choose "Edit/View Array Parameters..."



Dialog Box and Controls - Entity Array Dialog



Control	Inputs / Description	Defaults
Entity	Identifies the entity which will become an array of objects	The name of the entity you right-clicked on
Parameters	Allows you to specify the size and orientation of the array	See Below
Draw the array outline	Draws a box around all the elements of the array	Checked
Draw cell outlines	Draws a box around the individual array cells	Unchecked
Draw cell centers	Draws a dot at the center of each array cell	Unchecked
Draw row/column outlines	Draws a box around a row and/or column	Unchecked
Draw cell contents	Draws the element in an array cell	Unchecked
Array Outline Color	Specifies the color of the array bounding box	Gray
Cell Outline Color	Specifies the color of the cell bounding box	Gray

Cell Center Color	Specifies the color of the center of a cell	Gray
Row/Column Outline Color	Specifies the color of the row/column bounding box	Gray
Every N'th Item: A Direction, cell outlines	Specifies how many items in the A direction will have their cell outlines drawn	1
Every N'th Item: B Direction, cell outlines	Specifies how many items in the B direction will have their cell outlines drawn	1
Every N'th Item: C Direction, cell outlines	Specifies how many items in the C direction will have their cell outlines drawn	Disabled
Every N'th Item: A Direction, cell centers	Specifies how many items in the A direction will have their cell centers drawn	1
Every N'th Item: B Direction, cell centers	Specifies how many items in the B direction will have their cell centers drawn	1
Every N'th Item: C Direction, cell centers	Specifies how many items in the C direction will have their cell centers drawn	Disabled
Every N'th Item: A Direction, row/col outlines	Specifies how many rows or columns in the A direction will have their outlines drawn	1
Every N'th Item: B Direction, row/col outlines	Specifies how many rows or columns in the B direction will have their outlines drawn	1
Every N'th Item: C Direction, row/col outlines	Specifies how many rows or columns in the C direction will have their outlines drawn	Disabled
Every N'th Item: A Direction, cell contents	Specifies how many items in the A direction will have their cell contents drawn	1
Every N'th Item: B Direction, cell contents	Specifies how many items in the B direction will have their cell contents drawn	1
Every N'th Item: C Direction, cell contents	Specifies how many items in the C direction will have their cell contents drawn	Disabled
OK	Applies the changes and dismisses the dialog	

Cancel	Dismisses the dialog and does not apply changes	
Apply	Applies the changes and does not dismiss the dialog	
Help	Displays this help article	

Application Notes - Entity Array Dialog

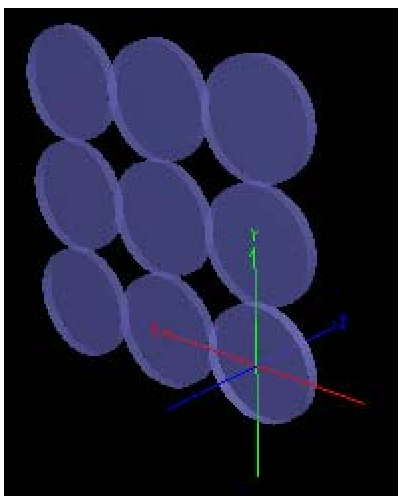
This dialog is modeless and resizable. It does not need to be dismissed before other work can be done on the FRED system.

The array is identified in the Tree View by a single entity with an array icon next to it, like this: 

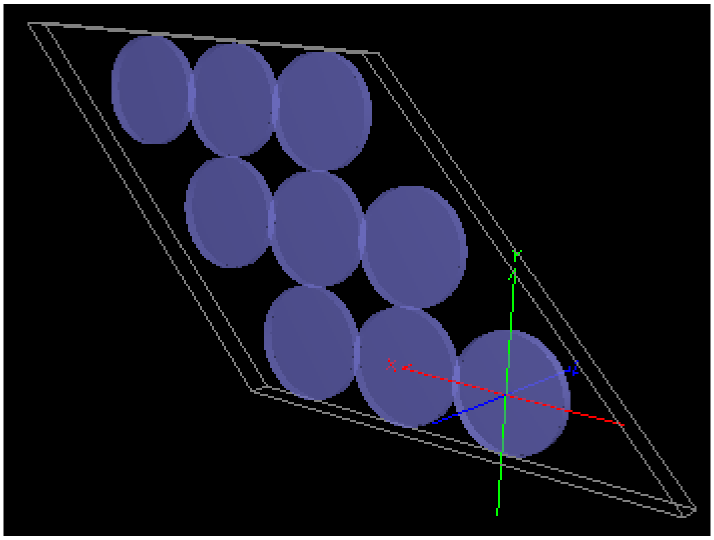
. Editing the entity will edit the parameters for all the entities in the array.

Parameters - Entity Array Dialog

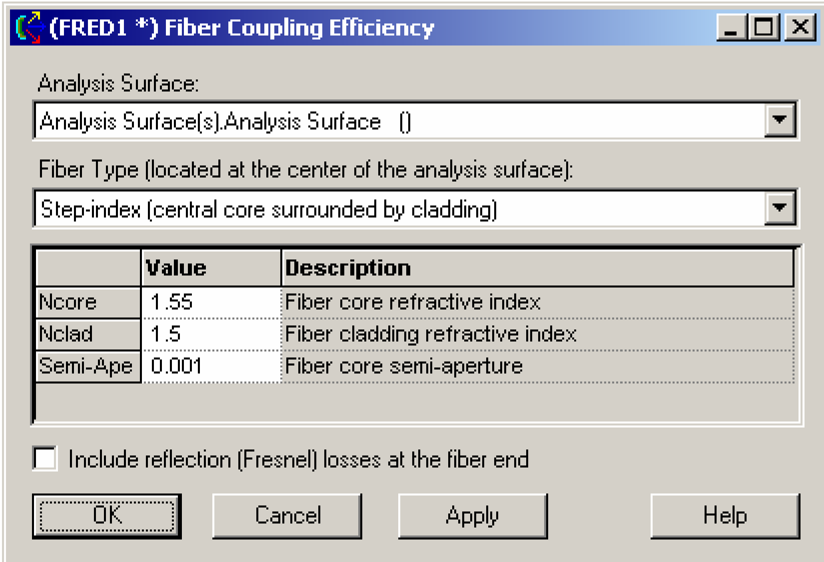
An A Spacing vector of (1, 0, 0) with a B Spacing vector of (0, 1, 0), an I value of (0, 2) and a J value of (0, 2) drawing all the cell contents produces an array like this:



An A Spacing vector of (1, 0, 0) with a B Spacing vector of (1, 1, 0), an I value of (0, 2) and a J value of (0, 2) drawing all the cell contents and the array outline produces an array like this:



Dialog Box and Controls - Fiber Coupling Efficiency Dialog



Control	***Inputs / Description***	***Defaults***
Analysis Surface	Lists all the analysis surfaces in the FRED system.	The first Analysis Surface found in the system
Fiber Type	Lists the type of fiber available for the calculation	Step-index
Fiber Type Options	Lists the options for the selected fiber type	Ncore = 1.55 Nclad = 1.5 Semi-Ape = 0.001
Include reflection (Fresnel) losses at the fiber end	When checked, calculates Fresnel losses at the end of the fiber	Unchecked
OK	Performs the efficiency analysis and closes the dialog	
Cancel	Does not perform the efficiency analysis but closes the dialog	
Apply	Performs the efficiency analysis and does not close the dialog	
Help	Displays this help article	

Application Notes - Fiber Coupling Efficiency Dialog

This dialog is resizable and modeless.

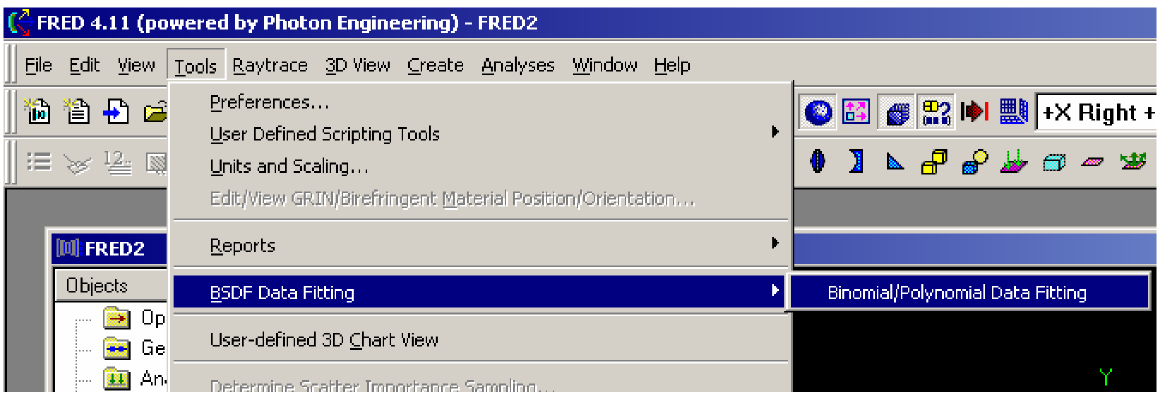
See Also…. - Fiber Coupling Efficiency Dialog

Best Geometric Focus

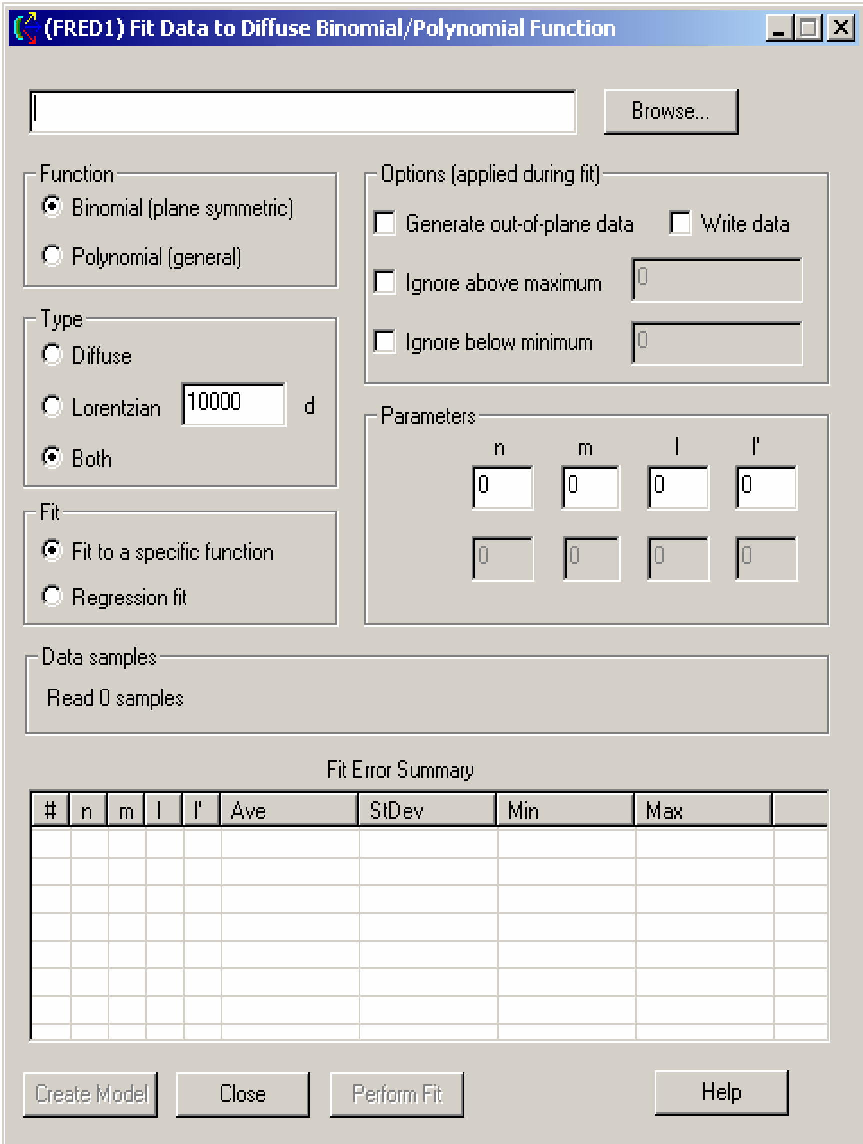
Fit Data To Diffuse Binomial/Polynomial Function Dialog

How Do I Get There? - Fit Data To Diffuse Binomial/Polynomial Function

From the Tools menu, choose "BSDF Data Fitting", then "Binomial/Polynomial Data Fitting".



Dialog Box and Controls - Fit Data To Diffuse Binomial/Polynomial Function



Control	***Inputs / Description***	***Defaults***
Path Box		
Browse		
Binomial Function		Selected
Polynomial Function		Unselected
Generate out-of-plane data		Unchecked

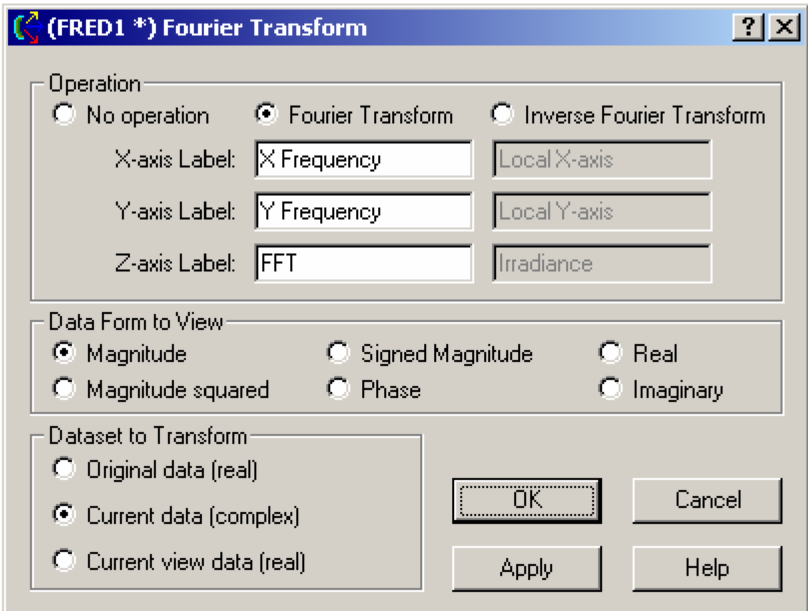
Ignore above maximum		Unchecked
Ignore above minimum		Unchecked
Diffuse		Unselected
Lorentzian		Unselected
Both		Selected
Fit to a specific binomial		Selected
Regression fit		Unselected
n		0
m		0
l		0
l'		0
Data Samples		
Fit Error Summary		
Create Model		
Close	Dismisses the dialog	
Perform Fit		
Help	Displays this help article	

Application Notes - Fit Data To Diffuse Binomial/Polynomial Function Dialog

This dialog is modeless and resizable. It remembers both its size and position when it is closed. It can remain open while other work is done and updates itself to reflect changes.

Fourier Transform Analysis

This command, available in the right mouse click pop-up menu, brings up the Combine Datasets dialog box. This dialog provides an environment where the current dataset can be combined with saved datasets with the same number of grid points in X and Y, the same grid spacing, and the same analysis plane size.



Control	Function	Defaults
Operation		
No operation	No operation	Not Selected
Fourier Transform	Perform Fourier Transform	Selected
Inverse Fourier Transform	Perform Inverse Fourier Transform	Not Selected
X-axis Label:	Specifies label to be placed on the X-axis	X Frequency
Y-axis Label:	Specifies label to be placed on the Y-axis	Y Frequency
Z-axis Label:	Specifies label to be placed on the Z-axis	FFT

Data Form to View		
Magnitude	Displays $\|z\|$ ($z=x+iy$)	Selected
Magnitude Squared	Displays $\|z\|^2$	Not Selected
Signed Magnitude	Displays signed $\|z\|$	Not Selected
Phase	Displays atan(y/x)	Not Selected
Real	Displays x	Not Selected
Imaginary	Displays y	Not Selected
Dataset to Transform		
Original data (real)	Transforms original dataset	Not Selected
Current data (complex)	Transforms complex dataset	Selected
Current view data (real)	Transforms real part of dataset	Not Selected
OK	Perform Fast Fourier Transform and close dialog box.	
Cancel	Close dialog box without performing Fast Fourier Transform.	
Apply	Perform Fast Fourier Transform and keep dialog box open.	
Help	Access this Help page	

Function Test Dialog

Description - Dialog name/function

How Do I Get There? - Dialog name/function

There are three different ways to execute this command:

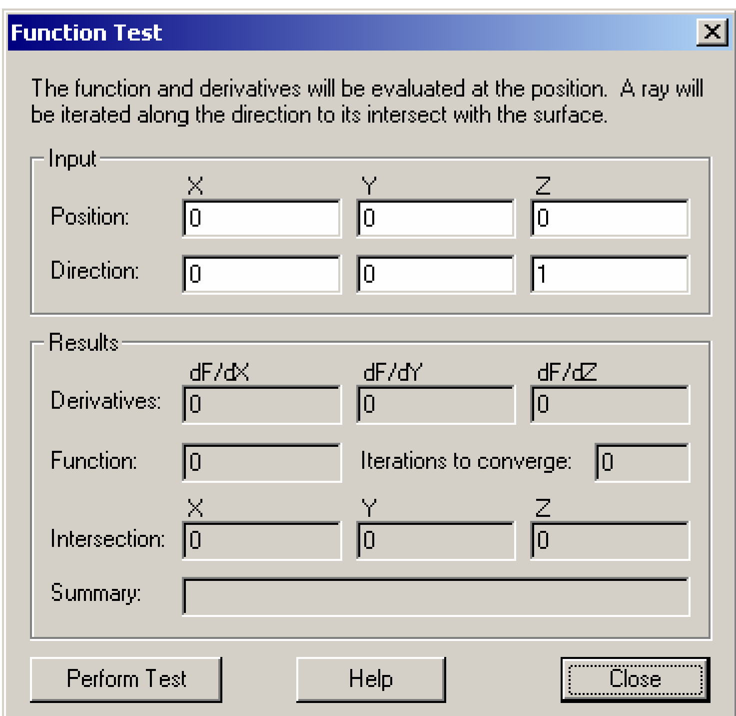
Menu

Keyboard Accelerator

Toolbar Button

Include Images

Dialog Box and Controls - Dialog name/function



Control	*Inputs / Description*	*Defaults*

Application Notes - Dialog name/function

See Also…. - Dialog name/function

Generate IES Output Dialog

Description - Generate IES Output Dialog

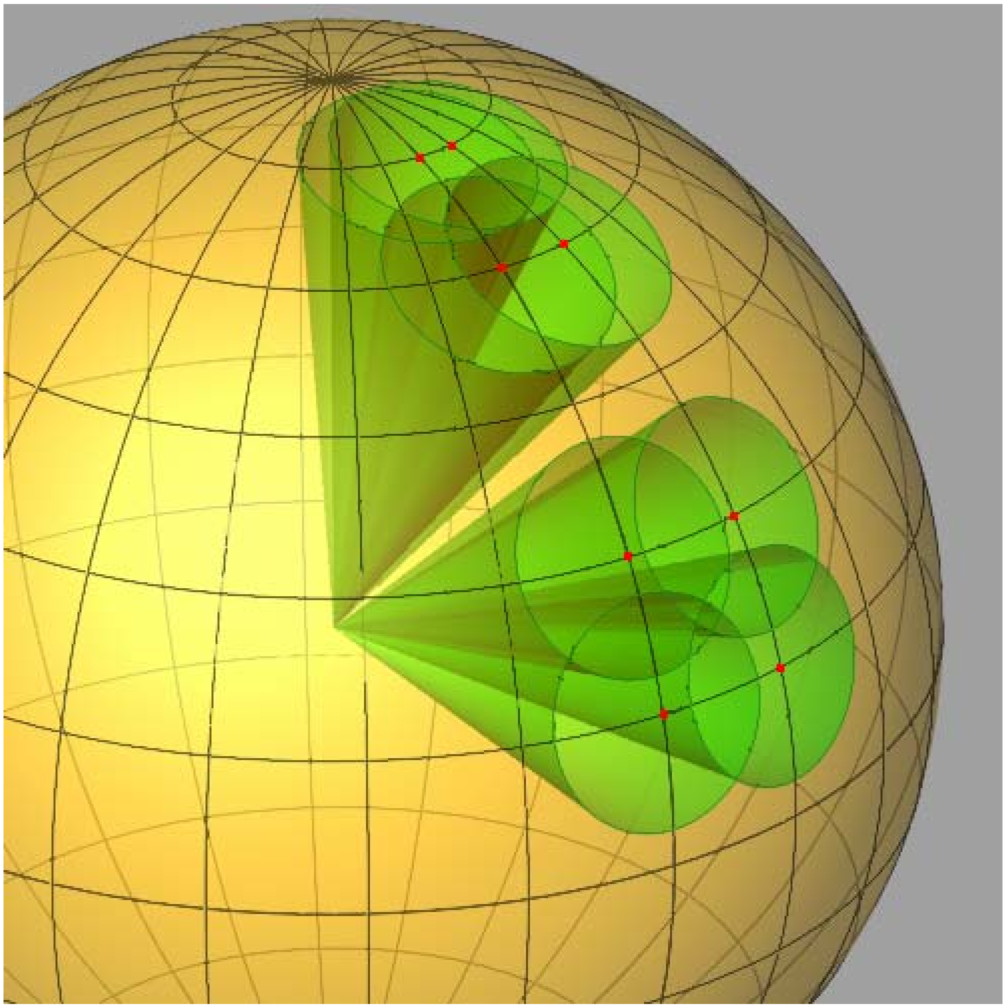
This dialog generates IES output. The intensity is calculated at directions on a polar grid according to the specified photometry type and written to a file in ANSI/IESNA LM-63-2002 format.

Calculation Details - Generate IES Output Dialog

The intensity calculation at a given direction is performed by binning rays with propagation directions within the specified cone half-angle of that given direction. The total flux collected along a direction is then divided by the solid angle that the acceptance cone subtends to give the intensity in that direction. One advantage of this approach is that each direction bin subtends the same solid angle, potentially giving more even statistics than an approach where the bin size varies with direction (e.g., polar grid bins).

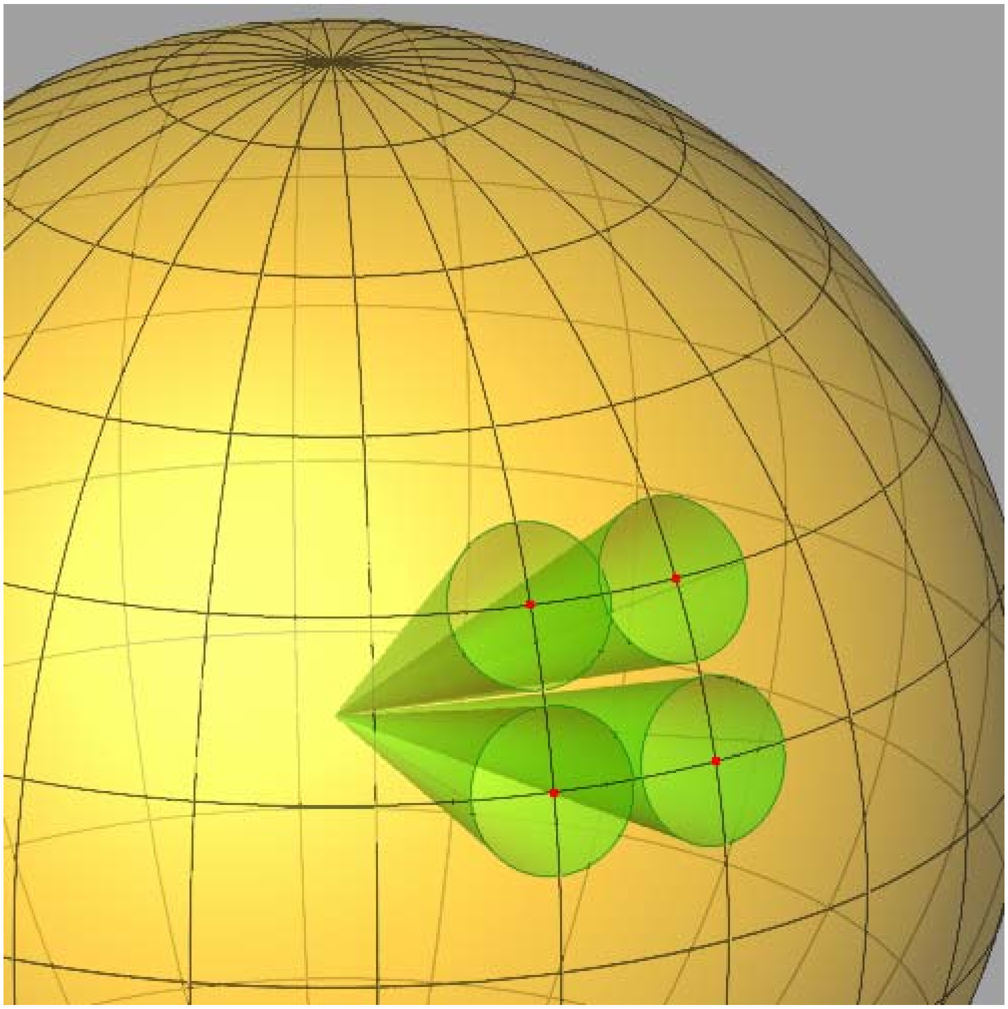
If the cone half-angle is large enough acceptance cones for adjacent polar direction samples can overlap. This will result in some rays being collected in more than one direction bin. The intensity calculation will still be correct, but the adjacent intensity values will not be fully independent of each other. By default, the cone size is chosen to be just large enough to ensure overlap of adjacent polar directions at the equator. While such a cone size guarantees that all rays (within the specified angular range) will be binned, it also produces a substantial overlap for directions near the poles.

To help illustrate this, this figure



shows the direction sphere with corresponding acceptance cones for the directions marked with red dots. Note that for adjacent polar directions near the equator the overlap is much smaller than for the same size cones near the pole. The net effect is that adjacent intensities near the poles will vary less than those near the equator.

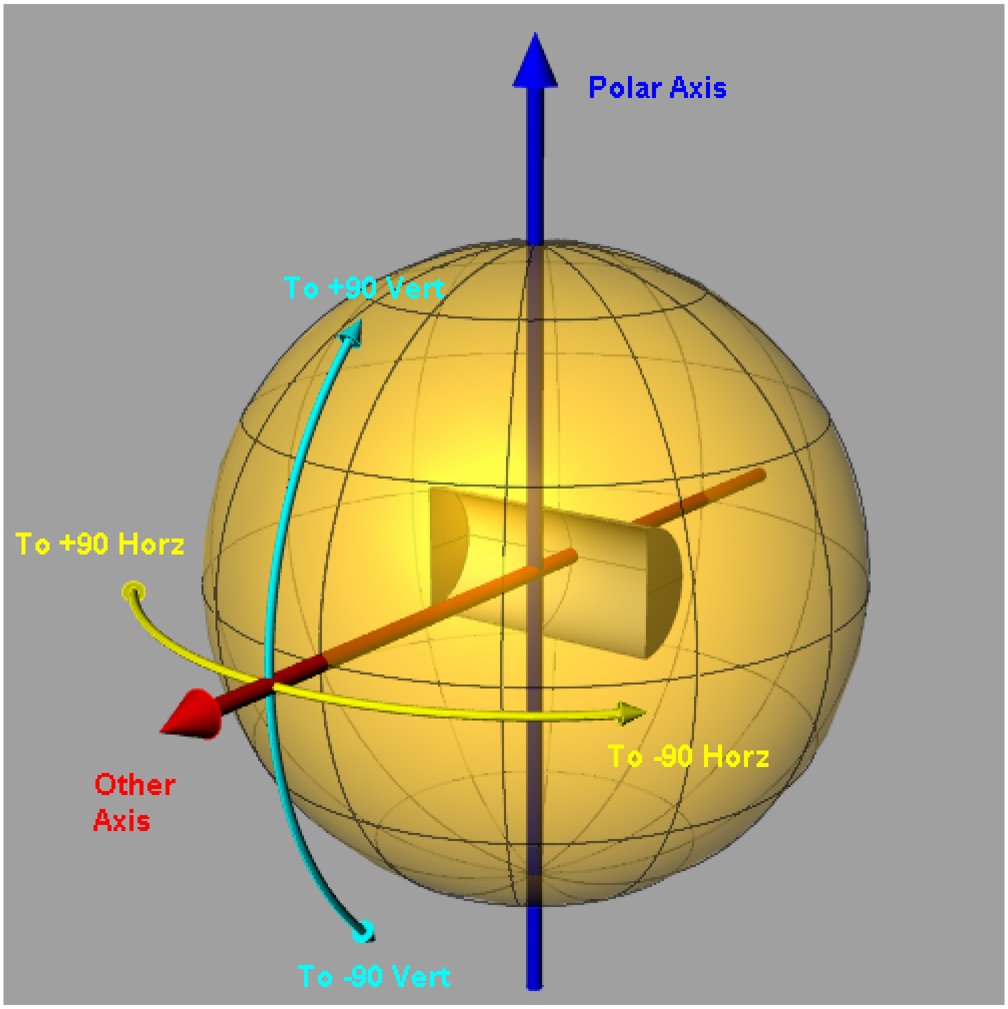
The cone half-angle can be set so that some adjacent directions do not overlap. This figure

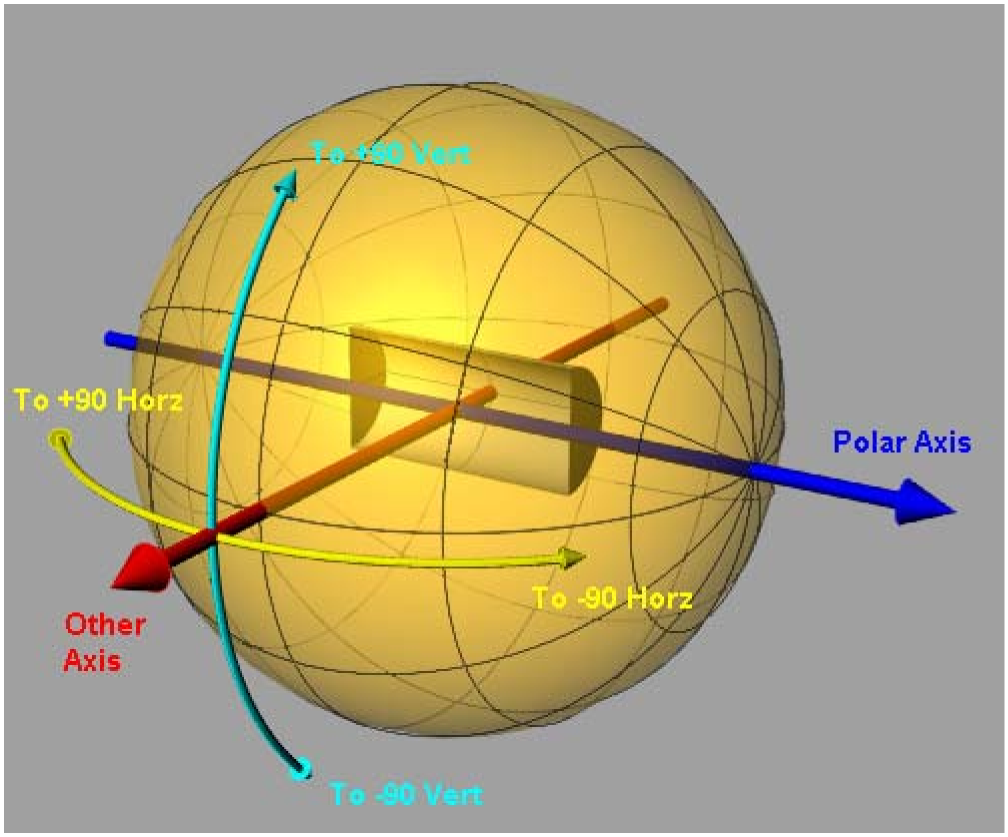


illustrates the situation. The intensities calculated for non-overlapping directions will be entirely independent. Rays with directions outside of all cones will simply not contribute to the calculation, and consequently the total number of rays binned may be less than the total within the angular range being calculated.

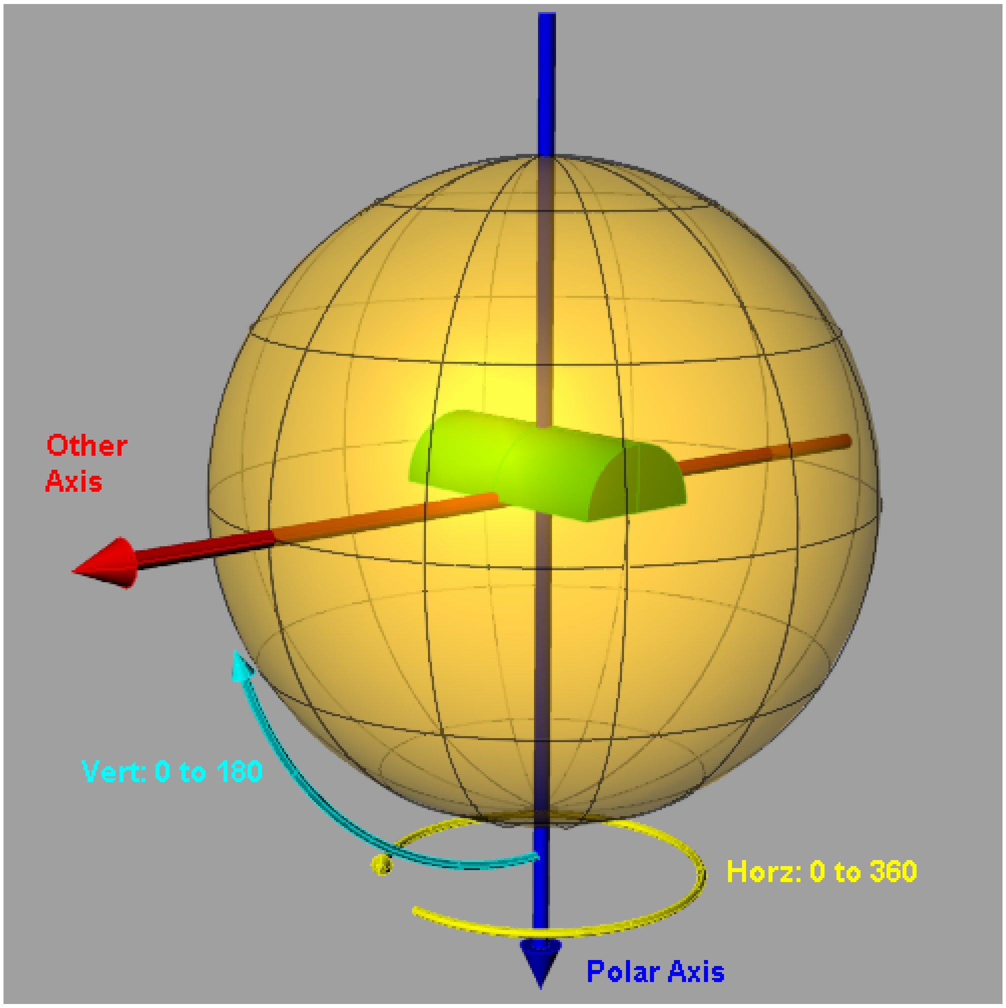
Photometry Types - Generate IES Output Dialog

These figures illustrate how angles are defined for the different photometry types.


Polar Axis
To +90 Vert
To +90 Horz
To -90 Horz
Other
Axis
To -90 Vert
IES Type A


To +90 Vert
To +90 Horz
Polar Axis
To -90 Horz
Other
Axis
To -90 Vert

IES Type B

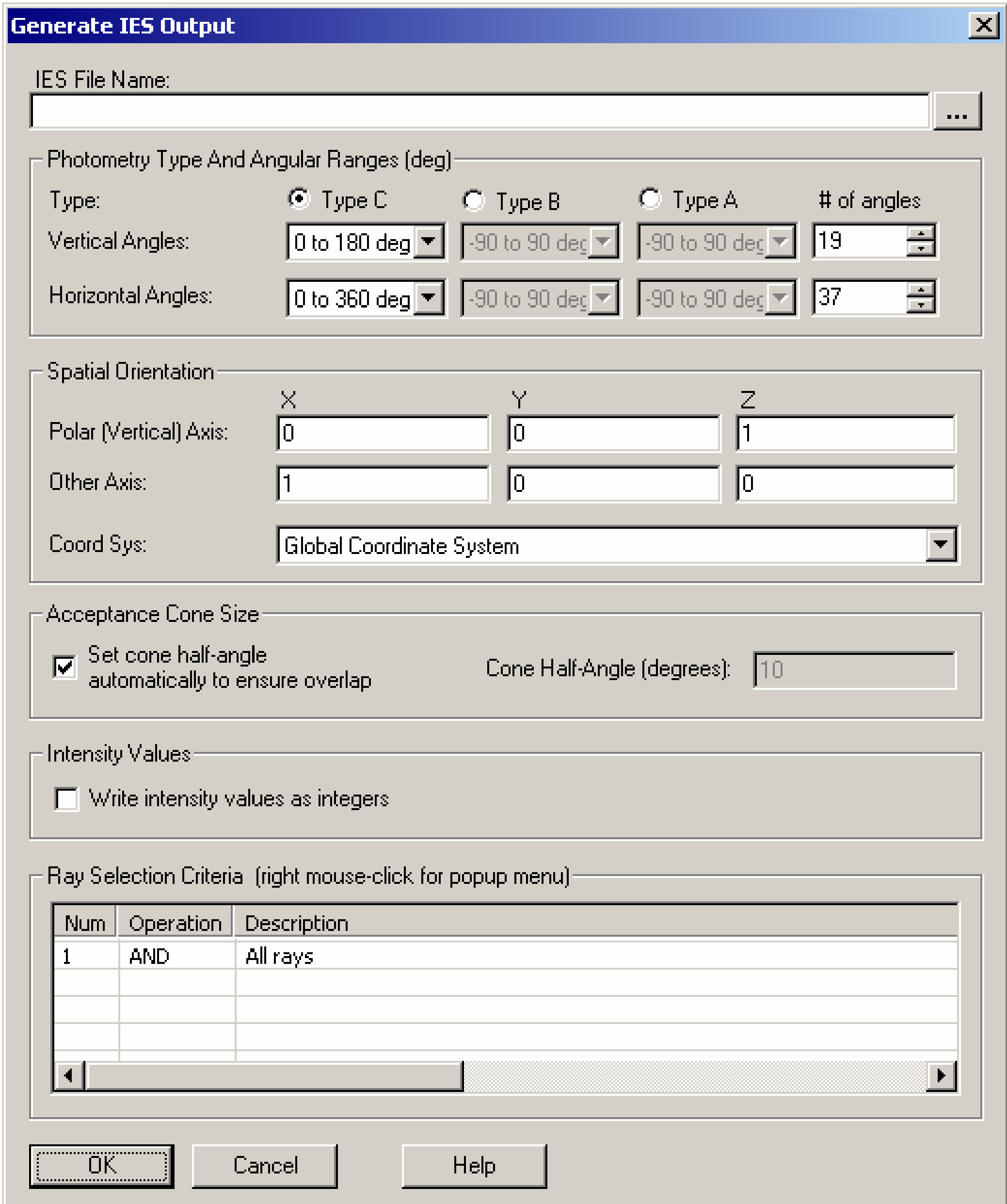


IES Type C

How Do I Get There? - Generate IES Output Dialog

This dialog requires a raytrace to have been performed. There are three different ways to execute this command:

2. On the Analyses Menu, select "Generate IES Output..."
3. Click the IES Output toolbar button
4. Use the keyboard shortcut



Control	***Inputs / Description***	***Defaults***
IES File Name	Name of IES output file. Type the filename directly or press the '...' button to select a filename by browsing with the file dialog.	Blank
Photometry Type	Specifies the IES photometry type to use, as illustrated above.	Type C
Vertical Angles	Specifies the angular range in the vertical direction.	0 to 180 degrees

Horizontal Angles	Specifies the angular range in the horizontal direction.	0 to 360 degrees
# of angles	Specifies the number of angles at which to calculate the intensity. Note that some programs that read IES data require a sample at (0H,0V). To satisfy this requirement, specify an odd number of angles when using an angular range that doesn't end at (0H,0V).	19 vertical, 37 horizontal
Polar Axis	Specifies the axis to use as the pole. Depending on the photometry type, this can be either the vertical or horizontal axis. See figures above for more information.	(0, 0, 1)
Other Axis	Specifies the 'Other Axis' used to define the polar coordinate system. The meaning of this axis varies with photometry type, see figures above. If the axis entered is not perpendicular to the polar axis it will be used to calculate one that is. An error message will be reported if the 'Other Axis' is parallel to the polar axis.	(1, 0, 0)
Coord Sys	The coordinate system in which the polar and other axis are specified.	Global Coordinate System
Set cone half-angle automatically to ensure overlap	If checked, the cone half-angle will be automatically set to ensure overlap of cones for adjacent sample directions at the equator. This guarantees all rays in the requested angle range will be binned at least once.	Checked
Write intensity values as integers	If checked, the calculated intensities are rounded to the nearest integer when written to the IES file. This should be checked if the IES file is destined for use with software that requires integer intensities.	Unchecked
Cone Half-Angle	Specifies the size of the acceptance cone used for calculating intensity at each sample direction. See the discussion above for more information on this quantity's meaning.	10
Ray Selection Criteria	Defines the rays included in the output.	All rays
OK	Closes the dialog and outputs the file	
Cancel	Closes the dialog without outputting the file	
Help	Displays this help article	

References - Generate IES Output Dialog

The ANSI/IESNA LM-63-2002 format is defined in "IESNA Standard File Format for the Electronic Transfer of Photometric Data and Related Information", LM-63-02, ISBN # 0-87995-178-8 (distributed by http://www.techstreet.com/).

Information on the coordinate systems used for the various photometry types can be found in "Goniophotometer Types and Photometric Coordinates", LM-75-01, ISBN # 0-87995-180-X (distributed by http://www.techstreet.com/).

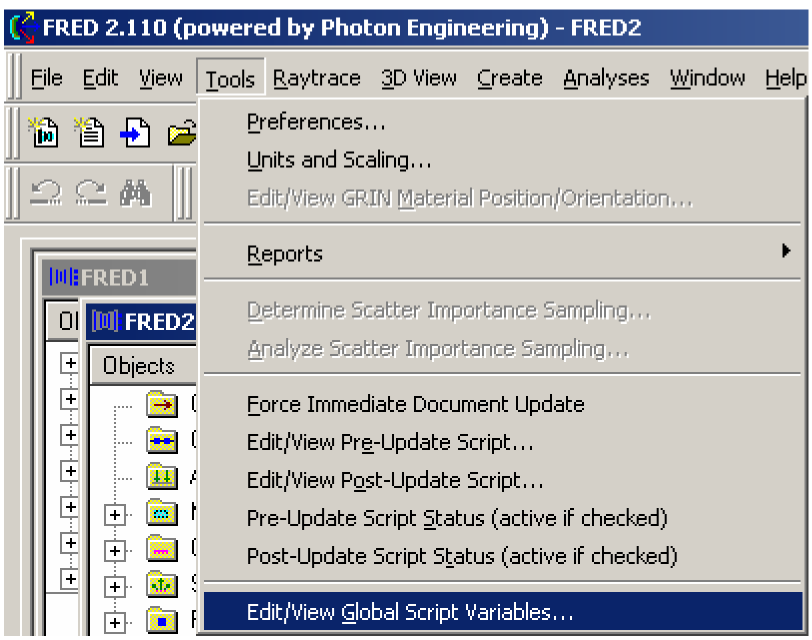
Global Script Variables Dialog

Description - Global Script Variables Dialog

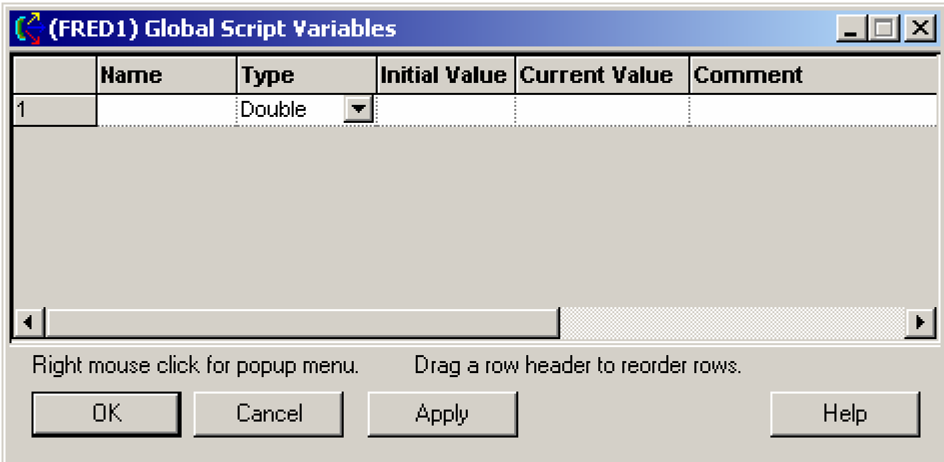
This dialog allows you to enter variables that can be referenced by multiple scripts associated with a particular document. These variables are stored in a FRED document.

How Do I Get There? - Global Script Variables Dialog

With a FRED document open, open the Tools menu and choose "Edit/View Global Script Variables...".



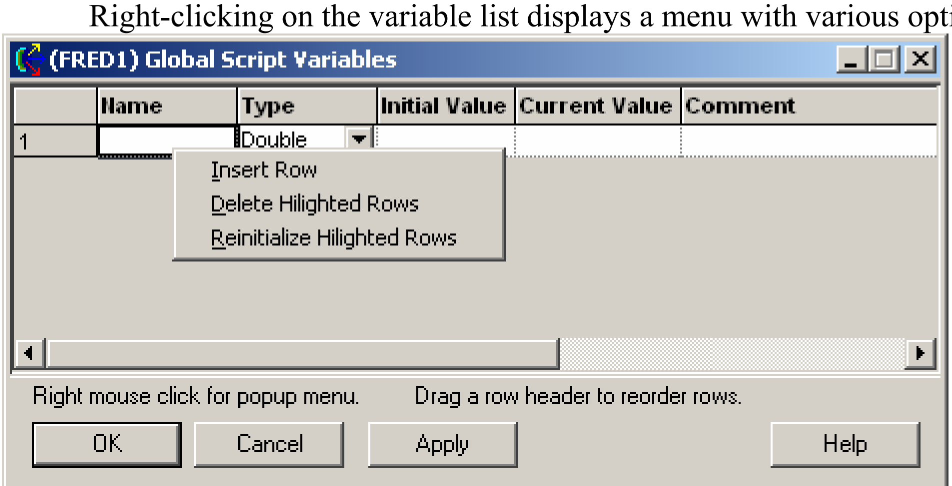
Dialog Box and Controls - Global Script Variables Dialog



Control	***Inputs / Description***	***Defaults***
Variable listing	Lists the name, type, initial & current values of the variables, as well as any comment associated with the variable.	Empty listing
OK	Closes the dialog and applies the changes.	
Cancel	Closes the dialog and does not apply the changes.	
Apply	Applies the changes and does not close the dialog.	
Help	Displays this help article.	

Application Notes - Global Script Variables Dialog

Right-clicking on the variable list displays a menu with various options.



"Insert Row" inserts a row before the item you clicked on.

"Delete Hilighted Rows" deletes the row (or rows, if you selected more than one) you clicked on.

"Reinitialize Hilighted Rows" changes the Current Value of the highlighted rows to the Initial Value for each variable.

To select multiple rows, click in one row and drag across the consecutive rows you want to delete.

You can reorganize the listing of variables by clicking on the row number (on the left of the variable list) and dragging it up or down to another place in the listing.

See Also…. - Global Script Variables Dialog

Tools Menu Commands

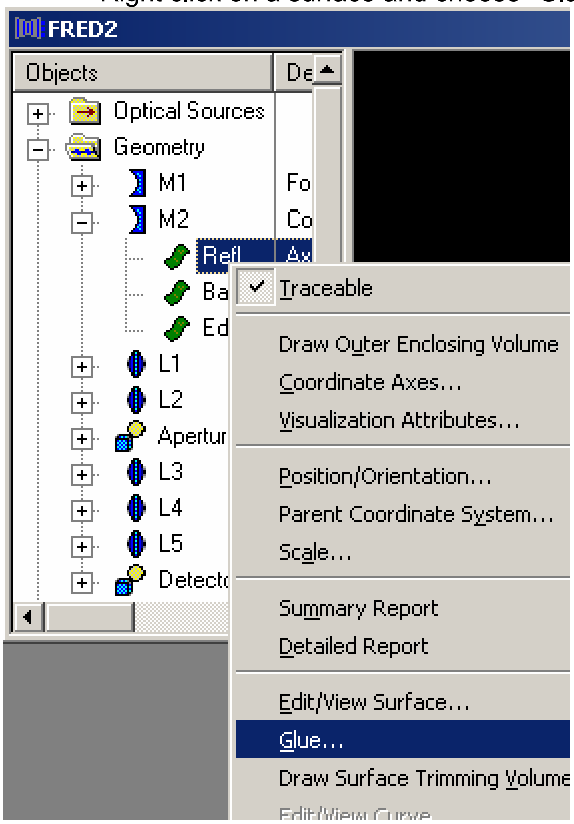
Glue Surface(s) Dialog

Description - Glue Surface(s) Dialog

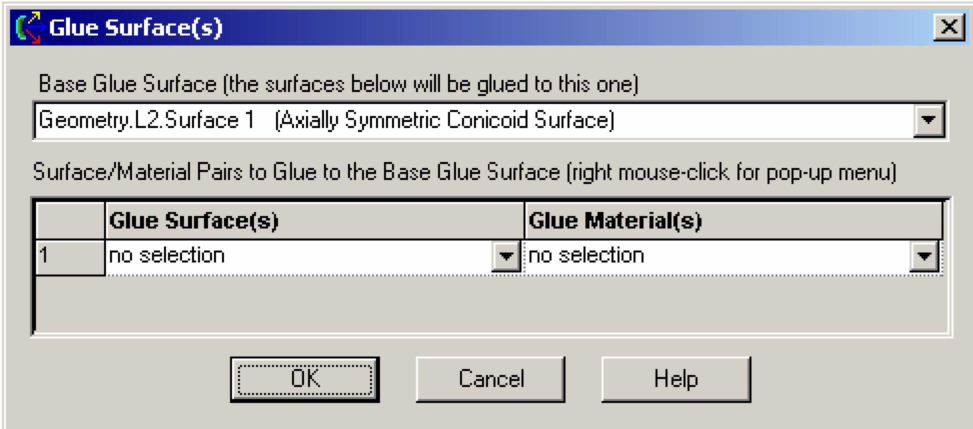
This dialog allows you to glue one surface to another.

How Do I Get There? - Glue Surface(s) Dialog

Right click on a surface and choose "Glue..."



Dialog Box and Controls - Glue Surface(s) Dialog



Control	***Inputs / Description***	***Defaults***
Base Glue Surface	Identifies which surface to which others will be glued.	The surface you clicked on to display the dialog
Surface/Material Pairs to Glue to the Base Glue Surface	Identifies the surface that will be glued to the base surface and the material used as the glue.	no selection/no selection
OK	Applies the changes and dismisses the dialog.	
Cancel	Does not apply the changes but dismisses the dialog.	
Help	Displays this help article.	

Application Notes - Glue Surface(s) Dialog

This dialog is modal and resizable.

See Also…. - Glue Surface(s) Dialog

Applying Glue

Trace Targeted Ray dialog

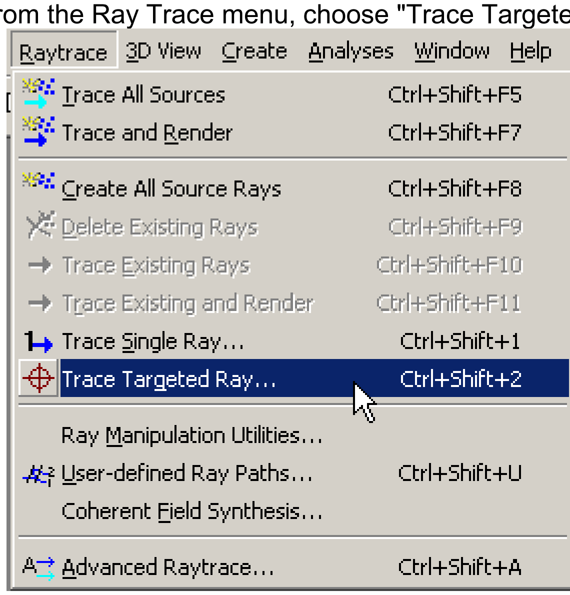
Description - Trace Targeted Ray dialog

FRED allows you to specify a raytrace that targets a particular surface in the system.

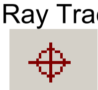
How Do I Get There? - Trace Targeted Ray dialog

There are three ways to access this dialog:

- From the Ray Trace menu, choose "Trace Targeted Ray":

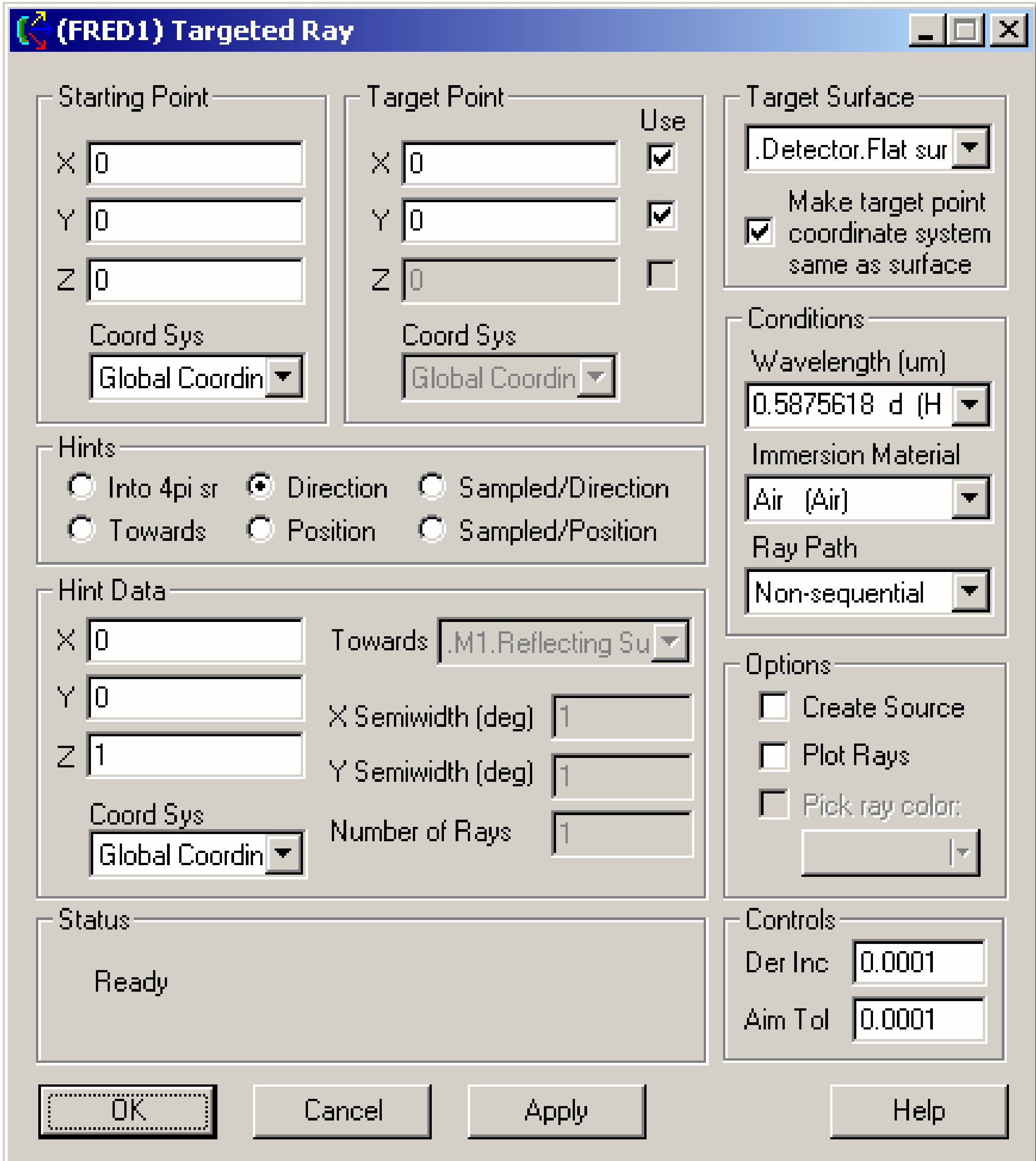


- On the Ray Trace toolbar, press the "Trace Targeted Ray" button:



- Use the keyboard accelerator Ctrl+Shift+2.

Dialog Box and Controls - Trace Targeted Ray dialog



Control	***Description***	***Defaults***
Starting Point		
X, Y, Z	Defines the coordinates of the starting point of the ray.	0
Coordinate System	Defines which coordinate system to use for the starting point of the ray.	Global Coordinate System

Target Point		
X, Y, Z	Defines the coordinates of the aim point of the ray	0
Coordinate System	Defines which coordinate system to use for the aim point of the ray.	Global Coordinate System
Target Surface		
Surface List	Choose from dropdown menu of existing surfaces.	
Make target point coordinate system same as surface	Places target point and surface coordinate systems coincident.	Checked
Conditions		
Wavelength	Defines the wavelength to use for the ray.	0.5892938
Immersion Material	Defines the material the ray will sit in when it begins tracing.	Air
Ray Path	Select any valid path from dropdown menu.	Non-sequential
Hints		
Into 4pi sr		Not selected
Towards	Trace ray towards any valid surface.	Not selected
Direction	Trace ray in specified direction.	Selected
Position	Trace ray to specified position.	Not selected
Sampled/Direction		Not selected
Sampled/Position		Not selected
Hint Data		
X, Y, Z	Coordinates of end point.	X, Y: 0 Z: 1
Towards	Dropdown list of valid surfaces.	First valid surface
X, Y Semiwidth (deg)	Solid angle	0
Number of Rays	Rays to trace.	1
Coord Sys	Specify ray in this coordinate system.	Global
Options		
Create Source		Unchecked

Plot Rays	Plot rays during trace.	Unchecked
Pick Ray Color	Select color of rays.	Unchecked
Status		
Status	Indicates status of iterated trace.	Ready
Controls		
Der Inc	Derivative increment used in iteration.	0.0001
Aim Tol	Aim Tolerance used in iteration.	0.0001
OK	Trace Targeted Ray and close dialog box.	
Cancel	Discard Targeted Ray and close dialog box.	
Apply	Trace Targeted Ray and keep dialog box open.	
Help	Access this Help page.	

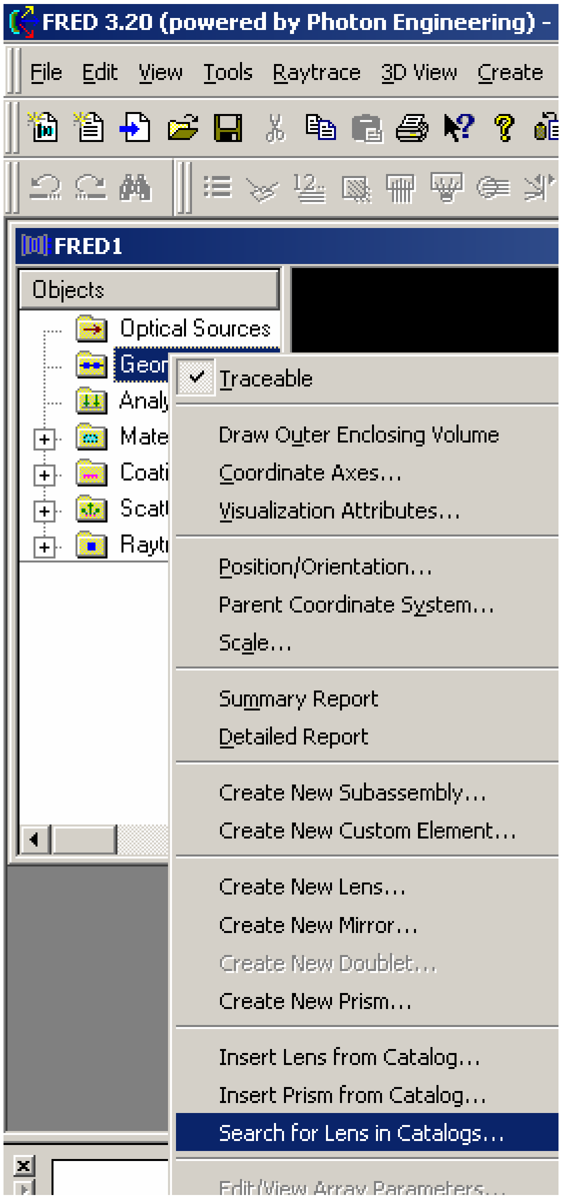
Search Vendor Catalogs Dialog

Description - Search Vendor Catalogs Dialog

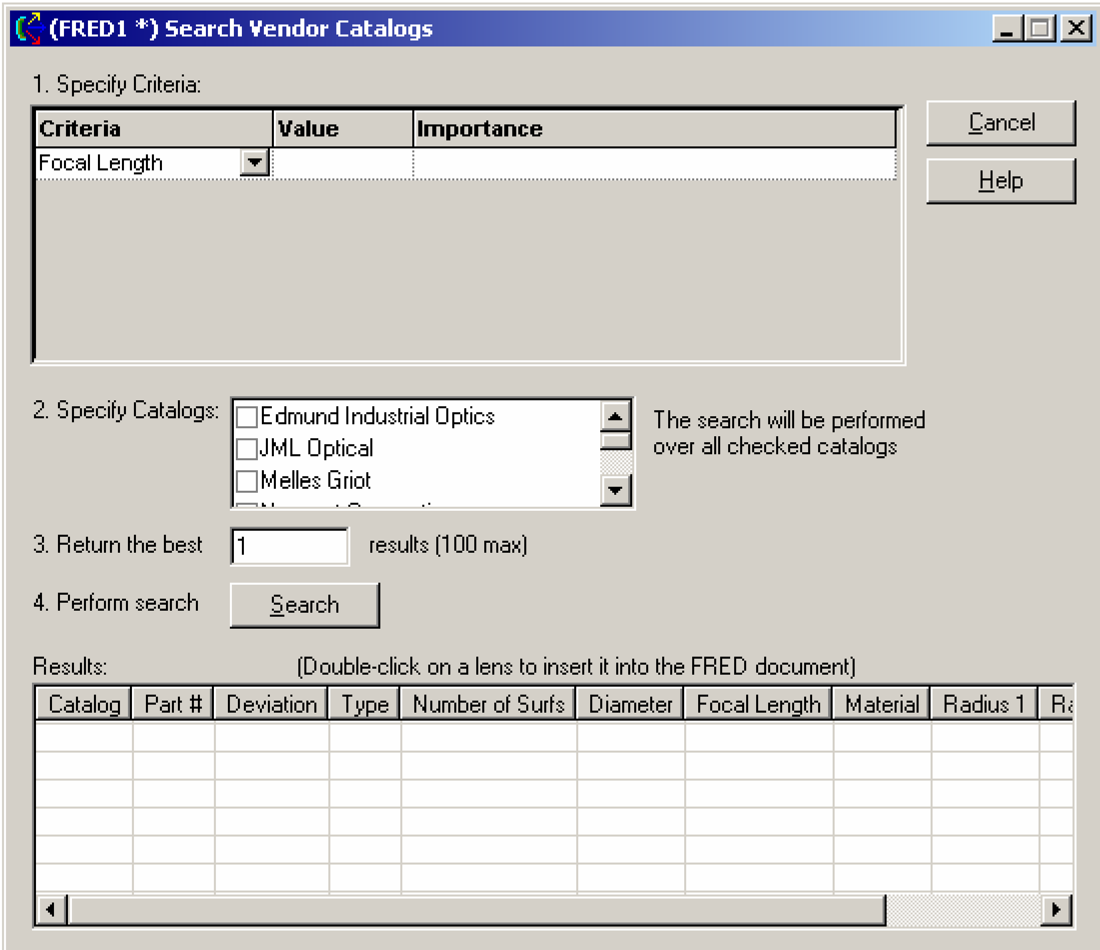
This dialog allows you to search the lens catalogs for items that match various parameters.

How Do I Get There? - Search Vendor Catalogs Dialog

From the Tree view of a FRED document, right click on the Geometry folder and choose "Search for Lens in Catalogs..."


FRED 3.20 (powered by Photon Engineering) -
File Edit View Tools Raytrace 3D View Create
FRED1
Objects
Optical Sources
Traceable
Draw Outer Enclosing Volume
Coordinate Axes…
Visualization Attributes…
Position/Orientation…
Parent Coordinate System…
Scale…
Summary Report
Detailed Report
Create New Subassembly…
Create New Custom Element…
Create New Lens…
Create New Mirror…
Create New Doublet…
Create New Prism…
Insert Lens from Catalog…
Insert Prism from Catalog…
Search for Lens in Catalogs…

Dialog Box and Controls - Search Vendor Catalogs Dialog

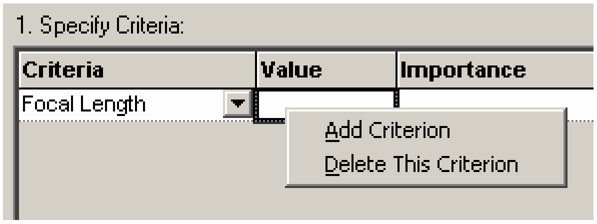


Control	*Inputs / Description*	*Defaults*
Criteria List	Identifies which criteria will be used to define the ideal lens. Each criterion consists of a value to measure, the value desired, and the importance attached.	Focal Length, no value, no importance
Specify Catalogs	Identifies which catalogs will be searched	none checked
Number of results	Specifies how many lenses will be displayed from the results	1
Search	Performs the catalog search	
Results	Displays the list of entries that matched and result's values for the various criteria. Limited to 100 results.	empty
Cancel	Closes the dialog	
Help	Displays this help article	

Application Notes - Search Vendor Catalogs Dialog

This dialog is modeless and resizable.

Search criteria can be added via a right-click in the criteria list.



Criteria can always be added, but there is a minimum of one. You can delete all but the last criteria.

There are seven criteria you can specify: Focal Length, Diameter, Thickness, Radius 1, Radius 2, Material, and Number of Surfaces. The value for Importance must be positive. The Value cell must be filled in, but certain values will produce invalid results. For example, entering a string for Focal Length will not produce the correct results.

At least one catalog must be selected. If not, a message box appears.

The results are sorted according to their similarity to the "perfect" lens, that is, the lens described by the criteria.

Examples - Search Vendor Catalogs Dialog

Entering 1 for Focal Length with an Importance of 100 and 2 for Diameter with an Importance of 90, searching the Edmund catalog, displaying 1 result gives

See Also…. - Search Vendor Catalogs Dialog

Catalog Lens Dialog

Catalog Prism Dialog

Create/Edit Lens

- Description
- How Do I Get There?
- Dialog Box and Controls
- Application Notes
- See Also…

Description

Create/Edit Lens

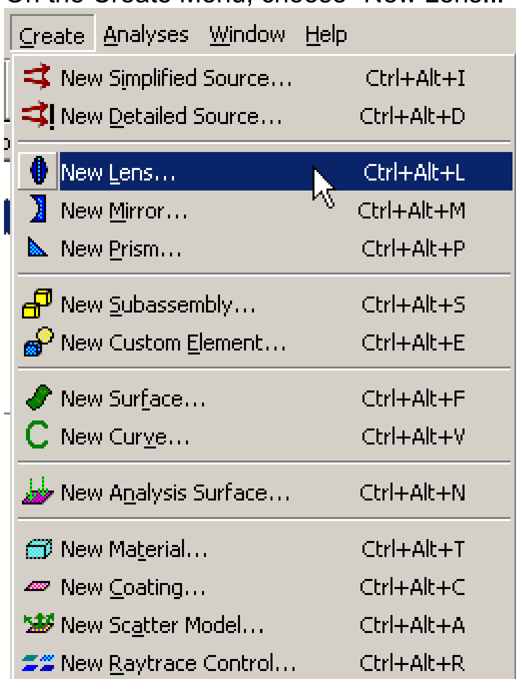
This dialog allows you to edit and create new singlet lenses in your FRED optical system.

How Do I Get There?

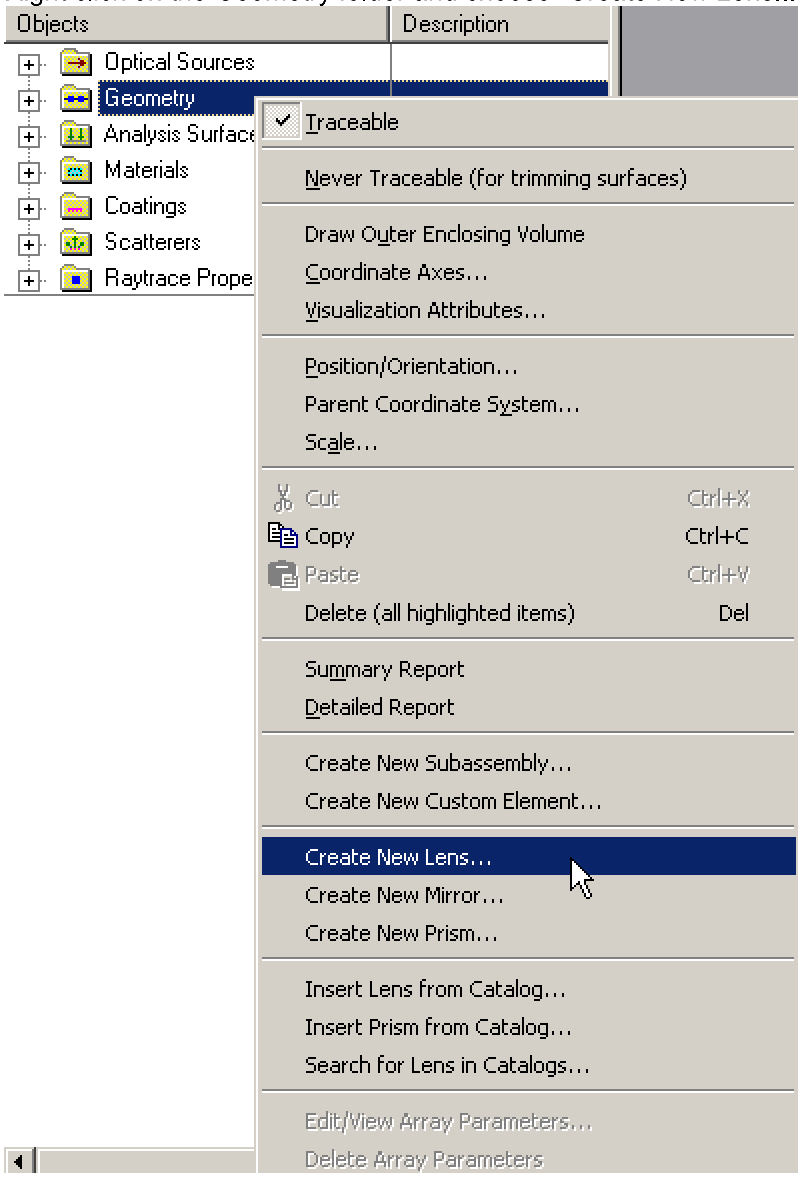
Create/Edit Lens

There are four different ways to execute this command:

2. On the Create Menu, choose "New Lens..."



3. Right click on the Geometry folder and choose "Create New Lens...".



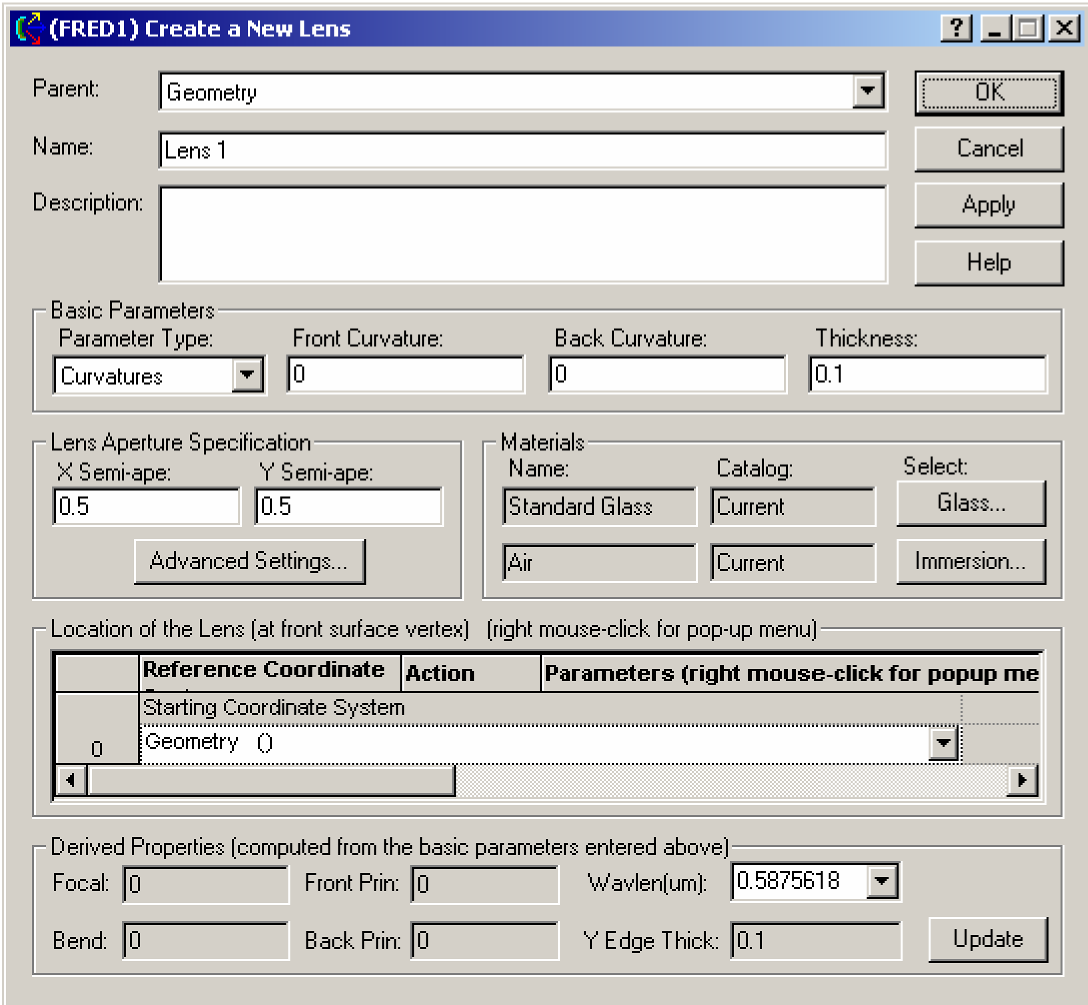
4. Use the keyboard accelerator Ctrl+Alt+L.

5. On the Create toolbar, press the Create Lens button.

Right clicking on an existing lens in the tree and choosing "Edit/View Lens..." will also display the dialog, but will apply the changes made to the lens you selected, instead of making a new lens.

Dialog Box and Controls

Create/Edit Lens



Control	Inputs / Description	Defaults
Parent	Identifies the Geometric Parent of the Lens. This control is grayed out when a lens is being edited and available when a lens is being created.	Geometry unless created under Subassembly.
Name	Displays the name of the Lens.	Lens 1
Description	Displays the description of the Lens (optional).	blank
Basic Parameters		
Parameter Type	Chooses between *Radii*, *Curvatures*, and *Focal Length/Bending Parameter* for expressing front and back surface shape.	Curvatures (set in Preferences)
Front …	Displays the Front Radius, Front Curvature, or Focal Length, depending on the Parameter Type selected.	0

Back …	Displays the Back Radius, Back Curvature, or Bending Parameter, depending on the Parameter Type selected.	0
Thickness	Displays the value of the lens center thickness.	0.1
Lens Aperture Specification		
X/Y Semi-aperture	Displays the value of the semi-aperture in the X direction.	0.5, 0.5
Advanced Settings	Advanced aperture specifications including edge bevels details.	
Materials		
Glass Name	Displays the name of the material used for the lens.	Standard Glass
Immersion Name	Displays the name of the material that surrounds the lens.	Air
Glass Catalog	Displays the catalog that contains the lens material.	Current
Immersion Catalog	Displays the catalog that contains the immersion material.	Current
Select Glass	Selects lens material.	
Select Immersion	Immerse the lens in this material.	
Location of the Lens		
Table	Displays the Location/Orientation specification for the lens.	Geometry ()
Derived Properties		
Focal	Displays the focal length of the lens at the selected wavelength.	0
Bend	Displays the bending parameter of the lens at the selected wavelength.	0
Front Prin	Displays the location of the front principal plane location of the lens at the selected wavelength.	0
Back Prin	Displays the back principal plane location of the lens at the selected wavelength.	0
Wavelength (um)	Wavelength used to calculate the derived properties.	0.5892938

Y Edge Thick	Calculated Edge Thickness in the Y direction at the selected wavelength.	0.1
Update	Updates the derived properties display boxes.	
OK	Create a new Lens and close dialog box.	
Cancel	Discard new Lens and close dialog box.	
Apply	Apply new Lens changes and keep dialog box open.	
Help	Access this help page.	

Application Notes

Create/Edit Lens

This dialog is modeless and resizable.

See Also….

Create/Edit Lens

Create/Edit Mirror
Create/Edit Prism

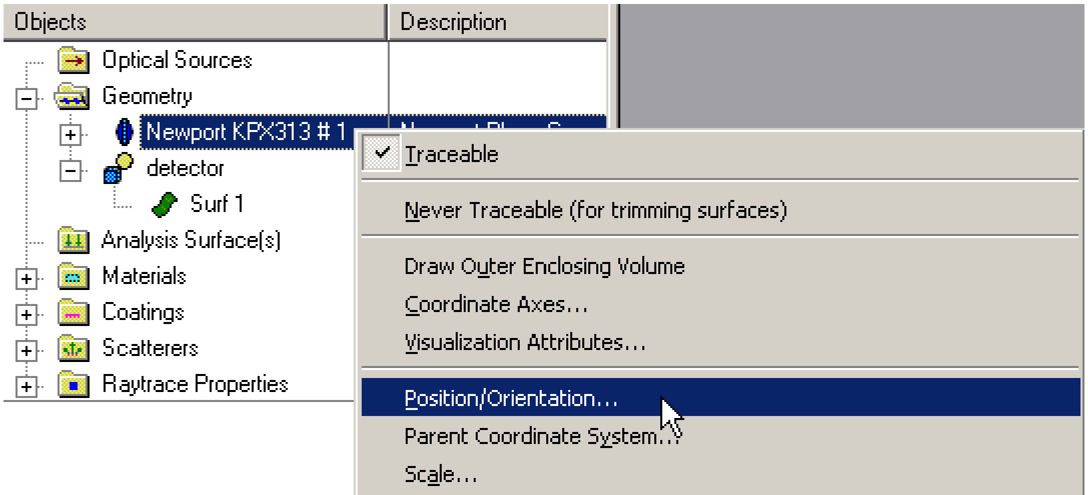
Position/Orientation...

Description - Position/Orientation...

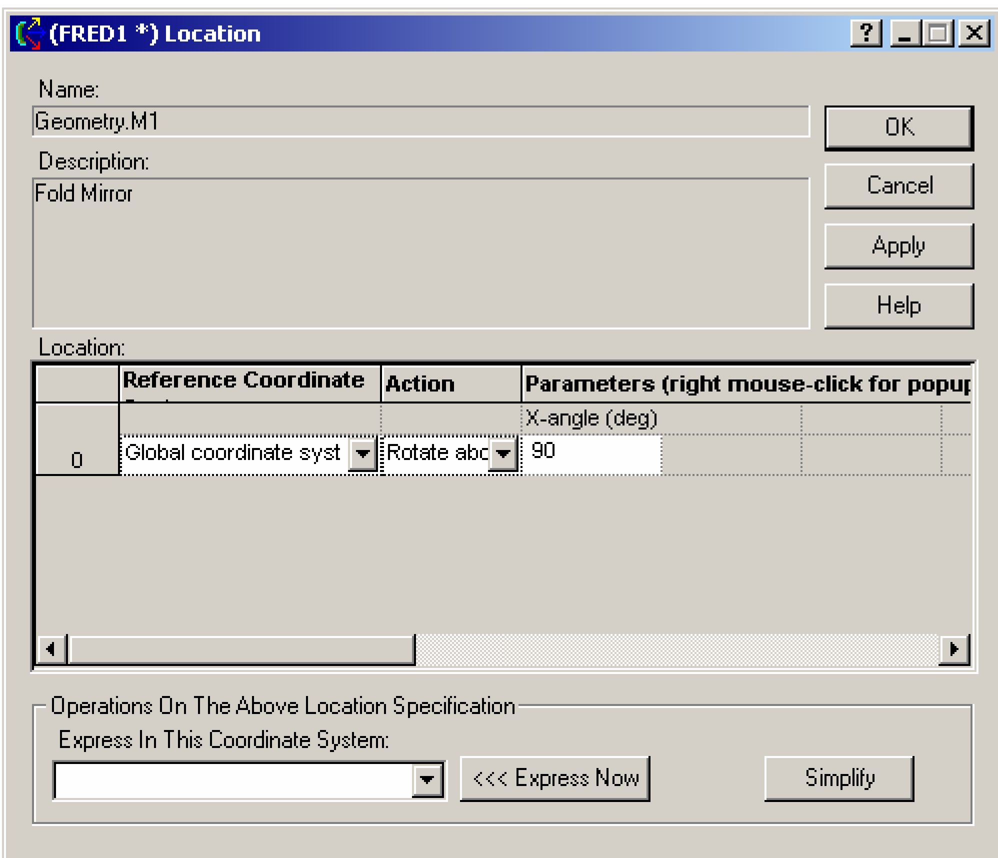
The Position/Orientation dialog is accessed via the right mouse click context menu. It allows the user to view and edit the location of the selected node. Further, the position and orientation of the selected node can be expressed in the coordinate system of any other node and applied. This latter feature distinguishes this dialog from the Position/Orientation tab associated with surfaces, curves, and sources.

How Do I Get There? - Position/Orientation...

The Position/Orientation dialog is accessed via the right mouse click pop-up context menu.



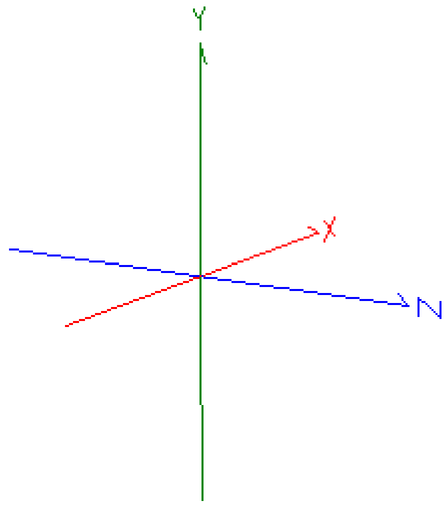
Dialog Box and Controls - Position/Orientation...



Control	Inputs	Defaults
Name:	None.	Name of the selected node.
Description:	None.	Shows the Description associated with the selected node.
Location		
Parent or Reference Coordinate System	Select the base coordinate system in which the transformation is to be applied.	Logical Parent Node
Action	Select the transformation operation.	Re-parent the coordinate system (make coincident).
Parameters	Enter shifts and rotations.	blank
Operations on the Above Location Specification		
Express in This Coordinate System	Select a new coordinate system in which to display the current location.	Global coordinate system
Express Now	Expresses the entity location in the selected coordinate system.	
Simplify	Reduces the list of coordinate system transformations to its most efficient form.	
OK	Accept Location changes and close dialog box.	
Cancel	Discard Location changes and close dialog box.	
Apply	Apply Location changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Position/Orientation...

- FRED operates in a right-handed coordinate system, as shown below.



- Positive rotations about the X axis rotate Y to Z
- Positive rotations about the Y axis rotate Z to X
- Positive rotations about the Z axis rotate X to Y

- Changing the Position/Orientation of a node changes the location of all other nodes that are referenced to it either directly or indirectly.
- The Re-parent command has 2 effects:
  - The selected node is moved to be coincident with the Parent Coordinate System
  - An association (link) is created between the selected node and the Parent Coordinate System so that any transformations applied to the Parent Coordinate System are applied to the selected node as well.
  - In the absence of a Re-parent command, the node is referenced to the global coordinate system.
  - By default, every new entity is Re-parented to the coordinate system of its logical parent. For example, the parent coordinate system for a new Lens is the Subassembly in which it was created. Likewise, the parent coordinate system of all of the lens surfaces is that of the new Lens node. The Lens node is linked to the Subassembly. The lens surfaces are linked directly to the Lens, and indirectly to the Subassembly.
  - The link formed is not two-way: coordinate transformations on the Parent will affect the Child, but coordinate transformations of the Child will not affect the Parent.

NOTE	It is strongly recommended that the Re-parent command be the first command issued in the coordinate transformation list as this command negates the operation of any that preceded it.

- The coordinate transformations are applied in the order that they are entered. Order of entry is important: a shift and then rotation may not have the same effect as a rotation and then a shift.
- Coordinate transformations are always applied relative to the Reference or Parent Coordinate System.

- The Parent Coordinate System for multiple transformations need not be the same.
- The 'Express Now…' and 'Simplify' buttons

Examples - Position/Orientation…

The following examples list all of the currently available coordinate transformations and a brief description of the parameter settings for each.

Re-parent the Coordinate System (make coincident)

Action
Re-parent the coordinate system (make coincident)

This action makes the selected node coincident with the Parent Coordinate System (not shown) and links the two together.

-

Place at specific coordinate

Action	Parameters		
	X-pos	Y-pos	Z-pos
Place at specific coordinate	0	0	0

Moves the local origin of the selected node to the X, Y, and Z positions in the Parent Coordinate system.

Shift

Action	Parameters
	X
Shift in X direction	0

Action	Parameters
	Y
Shift in Y direction	0

Action	Parameters
	Z
Shift in Z direction	0

Action	Parameters		
	X	Y	Z
Shift	0	0	0

Shift the local coordinate system of the selected node by X, Y, and/or Z in the Parent Coordinate System. This transformation is additive: consecutive rows of Shift X 2 and Shift X 2 will move the object 4 units. In the absence of any tilts or rotations, the order of entry is not important.

Simple rotations

Action	Parameters
	X-angle (deg)
Rotate about X-axis	0

Action	Parameters
	Y-angle (deg)
Rotate about Y-axis	0

Action	Parameters
	Z-angle (deg)
Rotate about Z-axis	0

Rotate the local coordinate system of the selected node about the origin of the X, Y, and/or Z axes of the Parent Coordinate System. The order of entry is important.

Compound Rotations

Action	Parameters				
	X-angle (deg)	Y-angle (deg)	Z-angle (deg)	Order	Euler rotations
Rotate about X, Y, and Z axes	0	0	0	XYZ order (XYZ order / ZYX order)	Euler angles

Rotate the local coordinate system of the selected node about the origin of the X, Y, and/or Z axes of the Parent Coordinate System. Choose the order of rotation (default is X, then Y, then Z). If the Euler angles box is open, then the rotations are all relative to coordinate axes of the Parent Coordinate System, which remain stationary. If the Euler angles box is checked, the second and third rotations are relative to the rotated coordinate axes of the previous operation(s). The latter transformation is typical of that used in optical design software.

Rotate about a distant point

Action	Parameters		
	X-angle (deg)	Y-axis pos	Z-axis pos
Rotate about X-axis through a point in the Y-Z plane	0	0	0

Action	Parameters		
	Y-angle (deg)	Z-axis pos	X-axis pos
Rotate about Y-axis through a point in the Z-X plane	0	0	0

Action	Parameters		
	Z-angle (deg)	X-axis pos	Y-axis pos
Rotate about Z-axis through a point in the X-Y plane	0	0	0

Rotate the local coordinate system of the selected node about a shifted point in the Parent Coordinate System. This action results in a tilt and a decenter for non-zero position entries. The order of entry is important.

Rotate about an axis through the origin

Action	Parameters			
	Angle (deg)	X-dir	Y-dir	Z-dir
Rotate about an axis through the origin	0	0	0	1

Rotate the local coordinate system of the selected node about a new axis passing through the origin of the Parent Coordinate System. The new axis is specified by its direction cosines. FRED normalizes the sum X-dir^2 + Y-dir^2 + Z-dir^2 to unity. The default orientation of the new axis is coincident with the Z-axis of the Parent Coordinate System.

Rotate about an arbitrary axis

Action	Parameters						
	Angle (deg)	X-pos1	Y-pos1	Z-pos1	X-pos2	Y-pos2	Z-pos2
Rotate about an arbitrary axis	0	0	0	0	0	0	1

Rotate the local coordinate system of the selected node about a new axis that is coincident with the line connecting the points (X-pos1, Y-pos1, Z-pos1) and (X-pos2, Y-pos2, Z-pos2). The X, Y, and Z positions are referenced to the Parent Coordinate System. The default orientation of the new axis is coincident with the Z-axis of the Parent Coordinate System.

Rotate one direction to another

Location:

	Parent Coordinate System	Action	Parameters		
			X-dir1	Y-dir1	Z-dir1
1	Global coordinate system	Rotate one direction to another	0	0	1

…

X-dir2	Y-dir2	Z-dir2	X-pos	Y-pos	Z-pos	Preserve nex	X-dir3	Y-dir3	Z-dir3
0	0	1	0	0	0	☑ Preserve	0	1	0

…

Applies to the selected node the coordinate transformation that sweeps from one direction to another. The start and end directions are specified as direction cosines in the Parent coordinate system. The position entries specify the center of rotation. The Preserve setting is used to determine and to preserve the orientation of the new position vector, so that, for example, the YZ plane is the same in the original and rotated positions.

General Rotation Matrix

Action	Parameters											
	R00	R01	R02	R10	R11	R12	R20	R21	R22	X	Y	Z
General matrix	1	0	0	0	1	0	0	0	1	0	0	0

Rotate the local coordinate system of the selected node relative to the Parent Coordinate System using a general rotation matrix and (X, Y, Z) decenter. The entries for the rotation matrix are shown below. The first column contains the (x,y,z) projections of the new X' axis onto the coordinate axes of the Parent Coordinate System. The second and third columns have similar projections for the new Y' and Z' coordinate axes.

$$R = \begin{bmatrix} R00 & R01 & R02 \\ R10 & R11 & R12 \\ R20 & R21 & R22 \end{bmatrix} = \begin{bmatrix} \begin{pmatrix} X_i' \\ X_j' \\ X_k' \end{pmatrix} \begin{pmatrix} Y_i' \\ Y_j' \\ Y_k' \end{pmatrix} \begin{pmatrix} Z_i' \\ Z_j' \\ Z_k' \end{pmatrix} \end{bmatrix}$$

FRED does not check to verify that the entries are ortho-normal. This transformation should only be used as a last resort and if the correct input data is readily available. The rotation matrix is applied first, the decenter second.

See Also…. - Position/Orientation…

Help for other options available from the right click pop-up menu is available by selecting the appropriate links.

Traceable

Draw Global Enclosing Volume

Coordinate Axes…

Visualization Attributes…

Position/Orientation…

Parent Coordinate System…

Scale…

Summary Report

Detailed Report

New Material Dialog

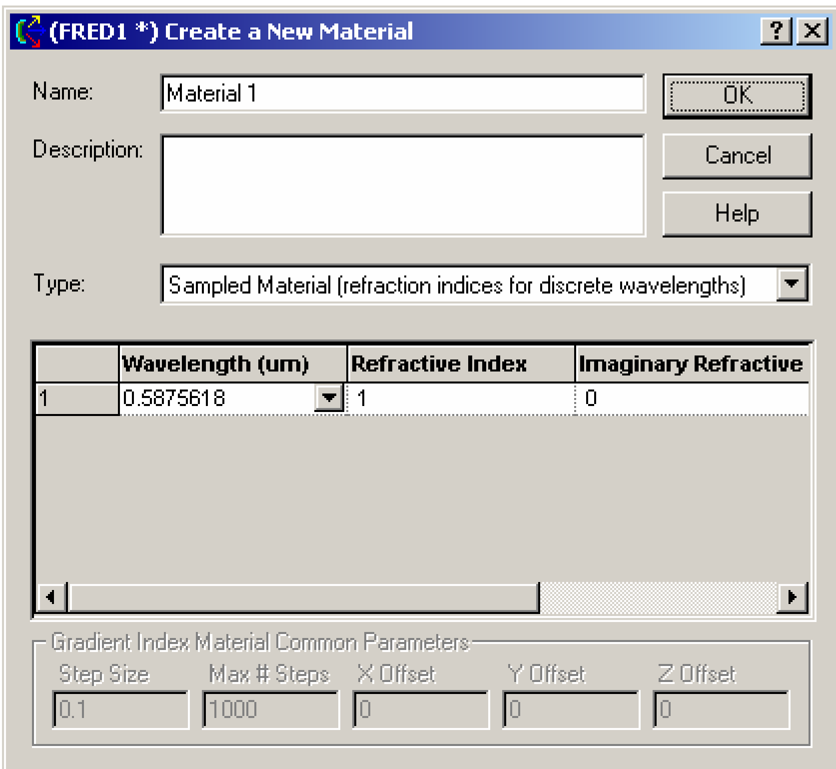
How Do I Get There? - New Material Dialog

There are three different ways to execute this command:

3. Menu
4. Keyboard Accelerator
5. Toolbar Button

Include Images

Dialog Box and Controls - New Material Dialog

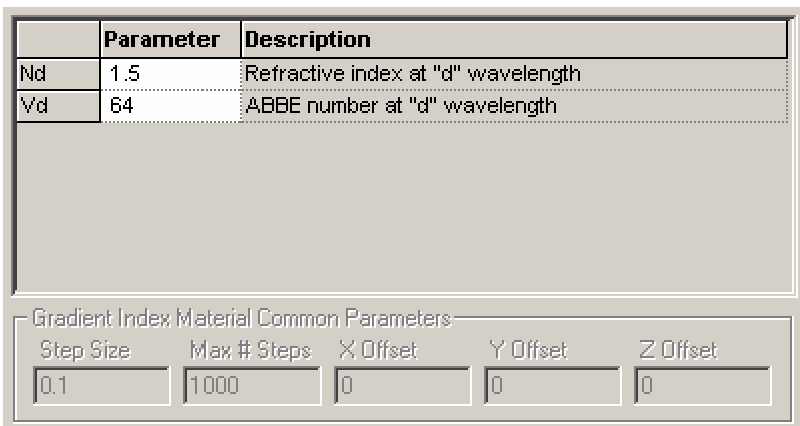


Control	Inputs / Description	Defaults
Name	Shows the name of the material	Material 1
Description	Shows the description of the material	empty
Type	Shows the selected type of the material.	Sampled Material
Parameters	Shows the data needed to define the material.	

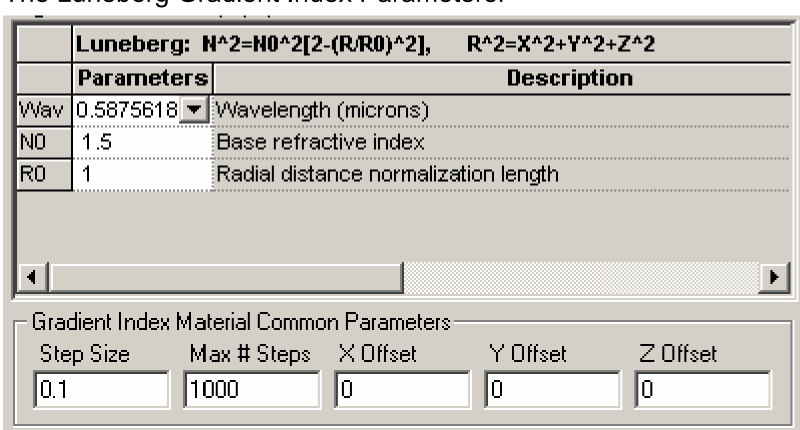
Step Size	Indicates the size of the step in the gradient	0.1
Max # Steps	Indicates the number of steps in the gradient	1000
X Offset		0
Y Offset		0
Z Offset		0
OK	Applies the changes and dismisses the dialog	
Cancel	Dismisses the dialog without changing the material	
Help	Displays this help article	

The Parameters box changes to display the correct fields for the selected material type. The Sampled Material type is shown above, the other types are shown below.

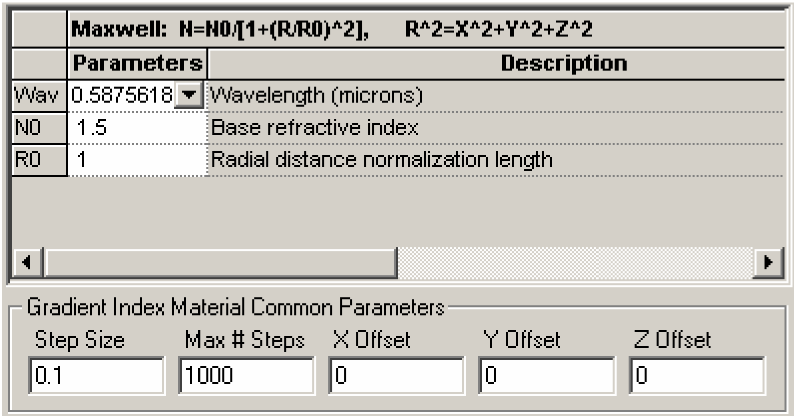
The Model Material Parameters:



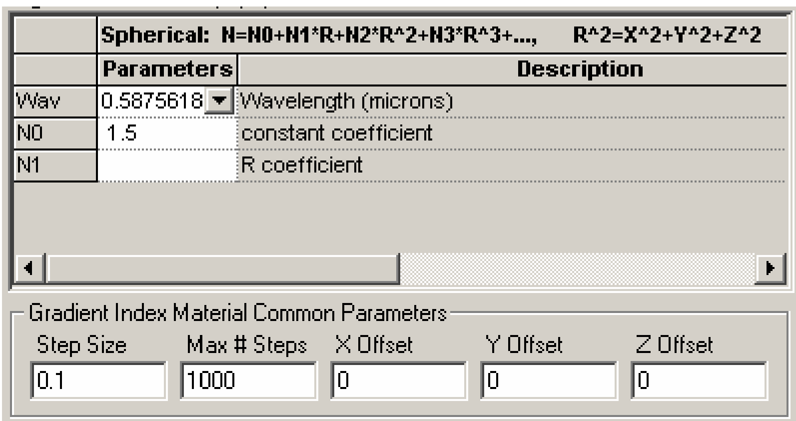
The Luneberg Gradient Index Parameters:



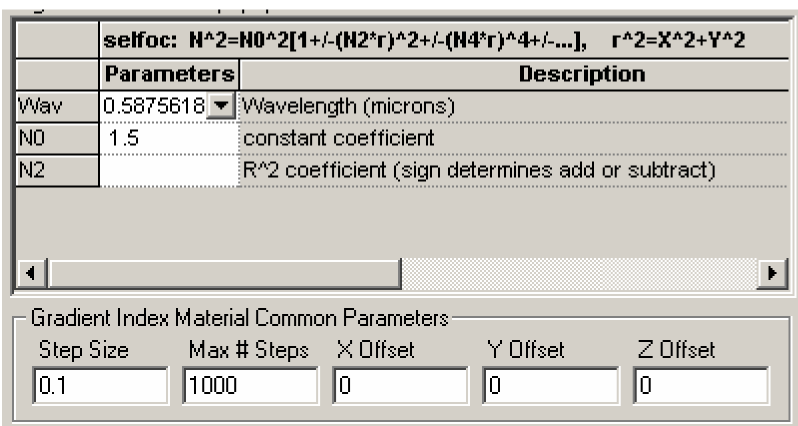
The Maxwell Gradient Index Parameters:



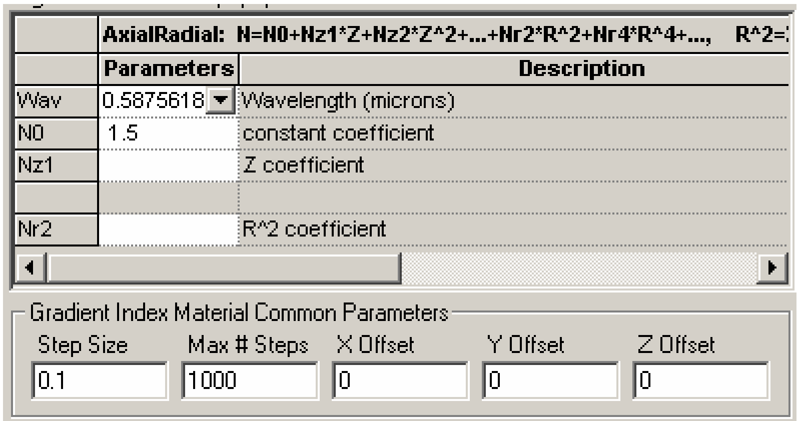
The Spherical Gradient Index Parameters:



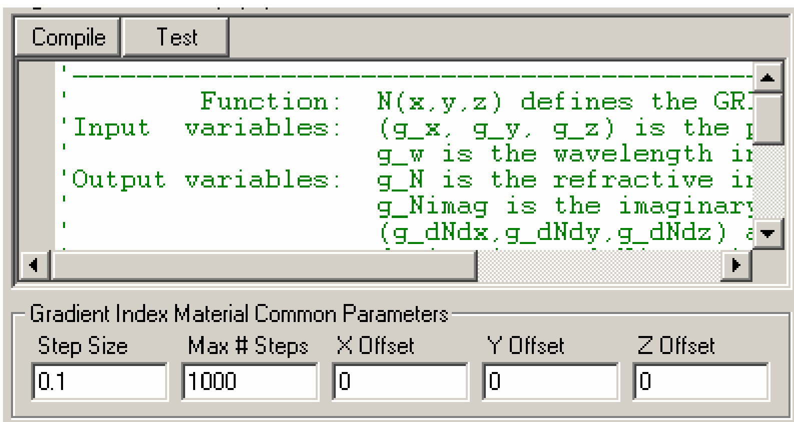
The selfoc Gradient Index Parameters:



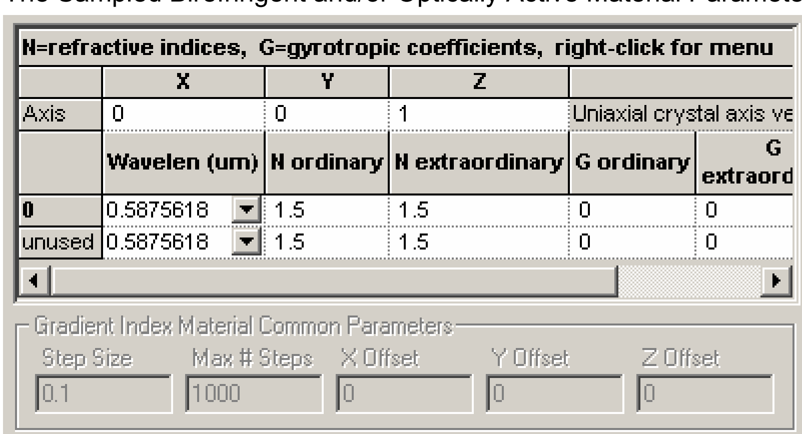
The Axial/Radial Gradient Index Parameters:



The Script Gradient Index Material Parameters:



The Sampled Birefringent and/or Optically Active Material Parameters:



Application Notes- New Material Dialog

See Also…. - New Material Dialog

Axial/Radial Gradient Index Material

Luneberg Gradient Index Material

Maxwell Gradient Index Material

Model Material

Sampled Birefringent Material

Sampled Material

Script Gradient Index Material

Selfoc Gradient Index Material

Spherical Gradient Index Material

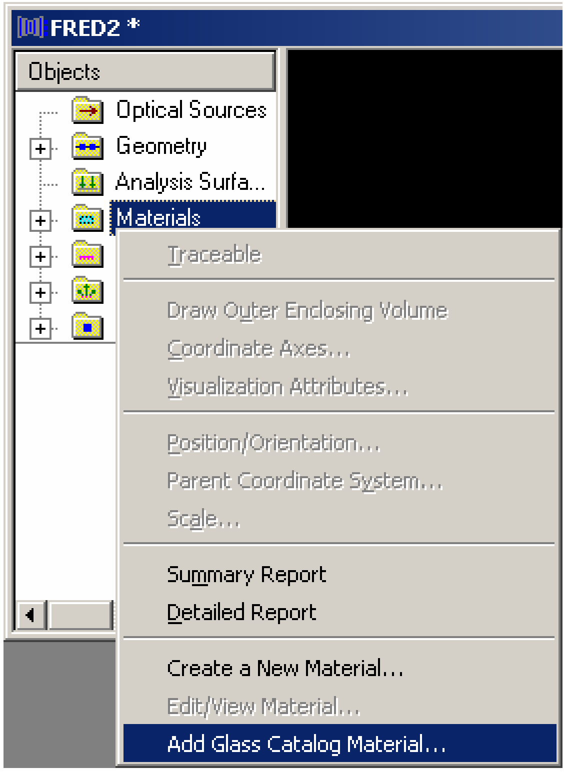
Material Listing/Selection Dialog

Description - Material Listing/Selection Dialog

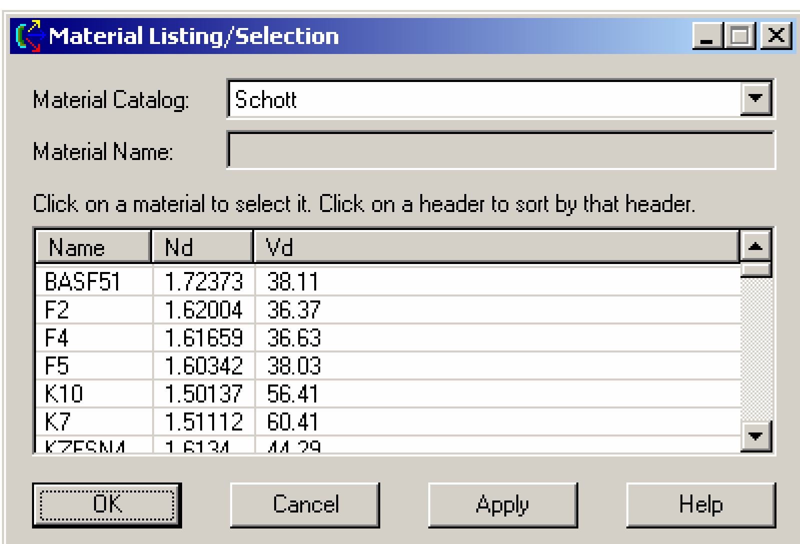
This dialog allows you to add a material from a vendor catalog to the active FRED document.

How Do I Get There? - Material Listing/Selection Dialog

From the Tree View, right click on the Materials folder and choose "Add Glass Catalog Material...":



Dialog Box and Controls - Material Listing/Selection Dialog



Control	Inputs / Description	Defaults
Material Catalog	Displays the catalog that is currently listed in the Material List.	Schott
Material Name	Displays the name of the Material selected from the list.	
Material List	Displays the materials found in the currently selected catalog.	
OK	Adds the material to the FRED document and closes the dialog.	
Cancel	Closes the dialog without adding a material to the FRED document.	
Apply	Adds the material to the FRED document and does not close the dialog.	
Help	Displays this help article.	

Application Notes - Material Listing/Selection Dialog

This dialog is modal and resizable.

See Also…. - Material Listing/Selection Dialog

New Material Dialog

New Mirror

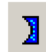
- Description
- How Do I Get There?
- Dialog Box and Controls
- Application Notes
- See Also…

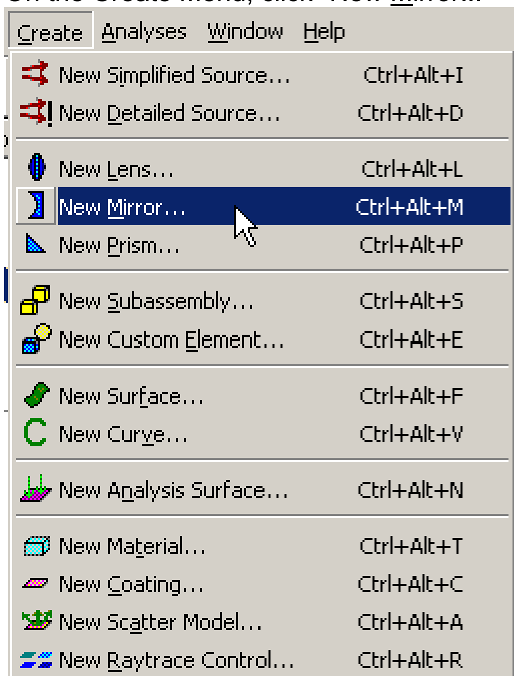
Description
New Mirror

This command displays a dialog that allows you to create a new mirror in the FRED optical system.

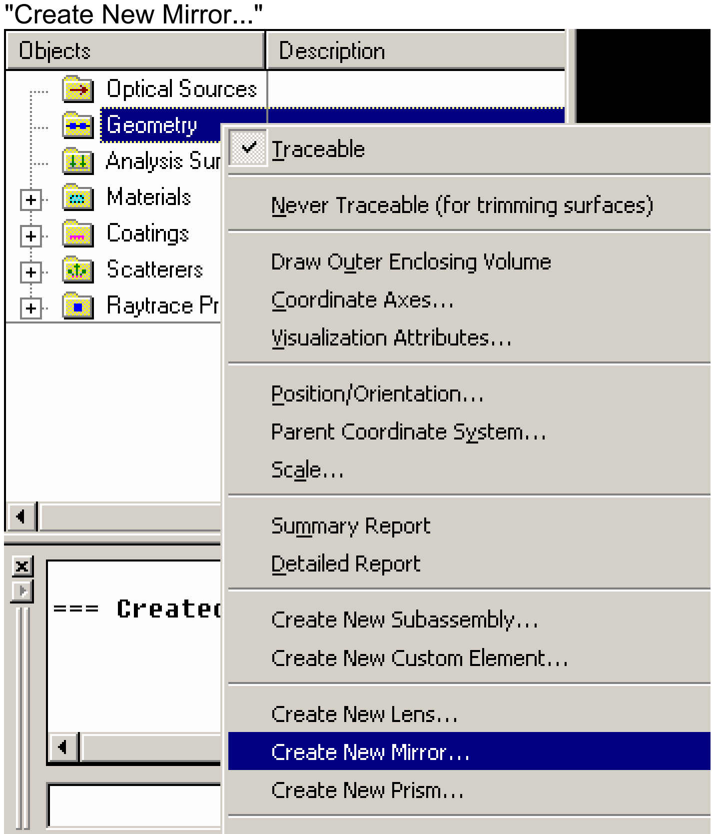
How Do I Get There?
New Mirror

There are four ways to access this command:

- On the Create Toolbar, click this button: 
- On the Create Menu, click "New Mirror..."



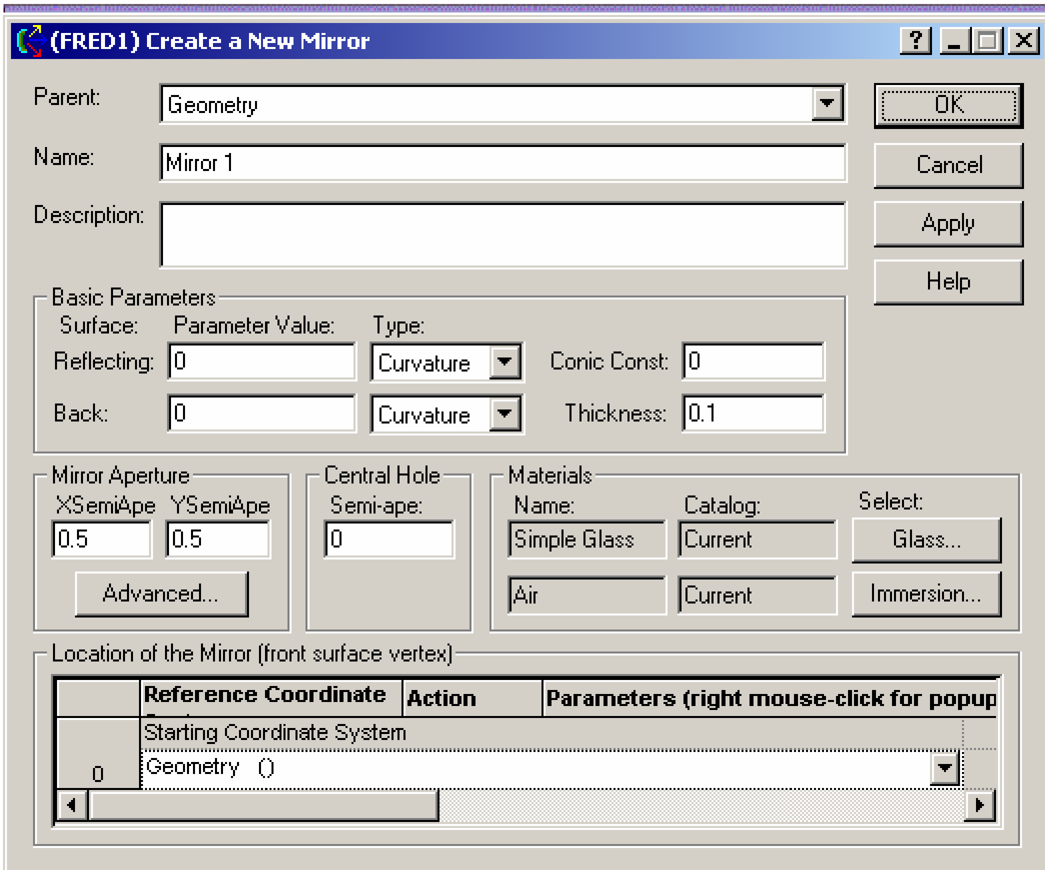
- On the Geometry folder or a Subassembly in the Tree View, right-click and choose "Create New Mirror..."



- Use they keyboard shortcut Ctrl+Alt+M.

Dialog Box and Controls

New Mirror



Control	Inputs	Defaults
Parent:	Displays the name of the tree object that will be the parent of the new mirror.	Geometry folder is the parent unless created under Subassembly.
Name:	Displays the name of the mirror.	Mirror *n*
Description:	Informative description of the mirror.	Empty String
Basic Parameters		
Reflecting Surface, Parameter Value	Defines the value for the reflecting (front) surface parameter.	0
Reflecting	Sets *Radius*, *Curvature*, or	Curvature

Surface, Type	*Focal Length* as surface specification for reflecting (front) surface.	(set in Preferences)
Back Surface, Parameter Value	Sets *Radius*, *Curvature*, or *Focal Length* as surface specification for back surface parameter.	0
Back Surface, Type	Defines the type of parameter for the back surface. Can be Radius, Curvature, or Focal Length.	Curvature (set in Preferences)
Conic Const:	Defines the mirror conic constant.	0
Thickness:	Defines the mirror center thickness.	0.1
Mirror Aperture		
X/Y SemiApe	Defines the mirror semi-aperture in the X/Y direction.	0.5, 0.5
Advanced	Advanced aperture specifications including edge bevels details.	
Central Hole		
Semi-Ape	Specifies semi-aperture of central hole in the mirror.	0
Materials		
Glass Name	Displays name of mirror substrate material.	Simple Glass
Glass Catalog	Displays catalog name that holds mirror substrate material.	Current
Glass	Displays a Material selection dialog.	
Immersion Name	Displays the name of material the mirror is immersed in.	Air
Immersion Catalog	Displays catalog name that holds immersion material.	Current
Immersion	Displays immersion material selection dialog.	
Location of the Mirror (front surface vertex)		
Table	Specifies mirror Location and Orientation.	Starting Coordinate System: Geometry
OK	Create a new Mirror and close dialog box.	

Cancel	Discard new Mirror and close dialog box.	
Apply	Apply new Mirror changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes

New Mirror

This dialog is resizable and modeless, so you can do other work in FRED without dismissing the dialog.

See Also….

New Mirror

Create/Edit Lens
Create/Edit Prism

Chapter 26 – FRED Menu Commands

File - Menu commands

The File menu offers the following commands:

New, FRED Type	Creates a new optical layout
New, Script Type	Creates a new script
Import	Imports a Code V, OSLO, ZEMAX, or IGES file by creating a FRED file with the defined surfaces.
Export	Exports an IGES or STEP file
Save 3D View as JPEG	Exports the Visualization 3-D View as a JPEG image.
Open	Opens an existing document, either an optical layout or a macro type
Close	Closes an opened document.
Save	Saves an opened document using the same file name.
Save As	Saves an opened document to a specified file name.
Exit	Exits FRED.
Open From Recent Documents List	Lists the four most recent documents opened.
Print Active View	Prints a document.
Print Setup	Selects a printer and printer connection.
Print Output Window...	Prints the current contents of the output window.
Output Window Print Setup	Displays the output window on the screen as it would appear printed.
Print Preview	Displays the document on the screen as it would appear printed.

File - New document commands

Description
How Do I Get There?

Description - New document commands

Use this command to create a new optical system document or a new script document. You can open an existing document with the Open command.

How Do I Get There? - New document commands

There are four ways to execute this command:

- On the file toolbar, click this button to create a new optical document:

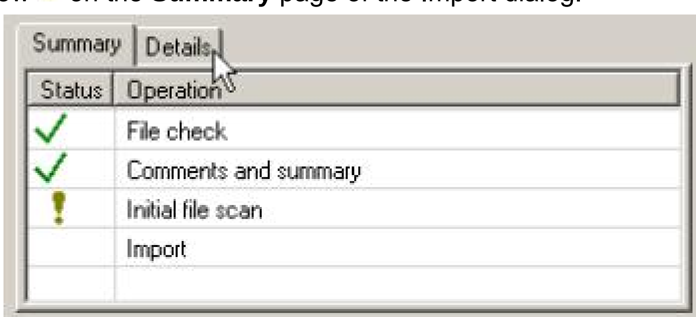
  Click this button to create a new script document:
- Use the Ctrl+N keyboard shortcut to generate a new optical document.
  Use the Ctrl+Shift+N keyboard shortcut to generate a new script document.
- On the command line, type "newsys" to generate a new optical document.
- On the File menu, select New, then "Fred Type" or "Script Type".

File - Import Dialog

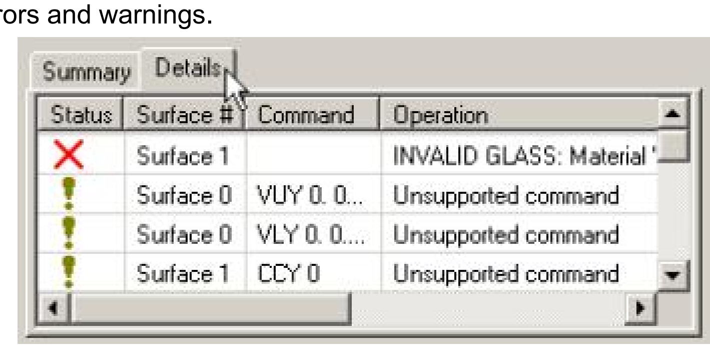
Description - File Import Dialog

FRED can read a variety of files and translate them directly into the native FRED format. This is accomplished through the File Importation Dialog, which is located on the File menu. This command takes a Code V, OSLO, ZEMAX, or IGES formatted file and creates a FRED file, displaying any errors that occur during the import. process.

If there are any errors during the importing process, FRED will notify the user with a yellow ! on the **Summary** page of the Import dialog.



The errors are listed on the **Details** page of the dialog. Click on the **Details** tab to see the errors and warnings.

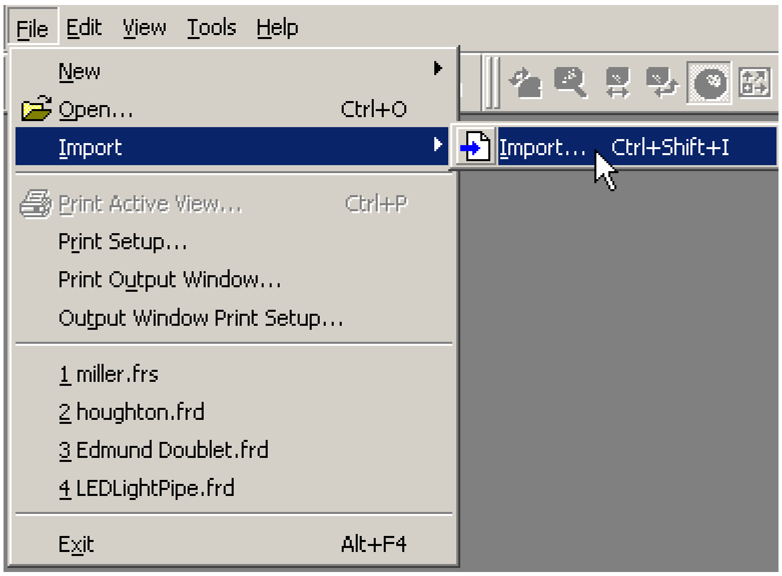


FRED supports many of the object or entity types defined in the IGES standard. FRED internally models these IGES objects exactly as they are defined in the standard instead of approximating the IGES objects with a FRED object. A list of the IGES objects supported by FRED can be used to understand the **Import** dialog **Details** report.

How Do I Get There? - File Import Dialog

There are three different ways to execute this command:

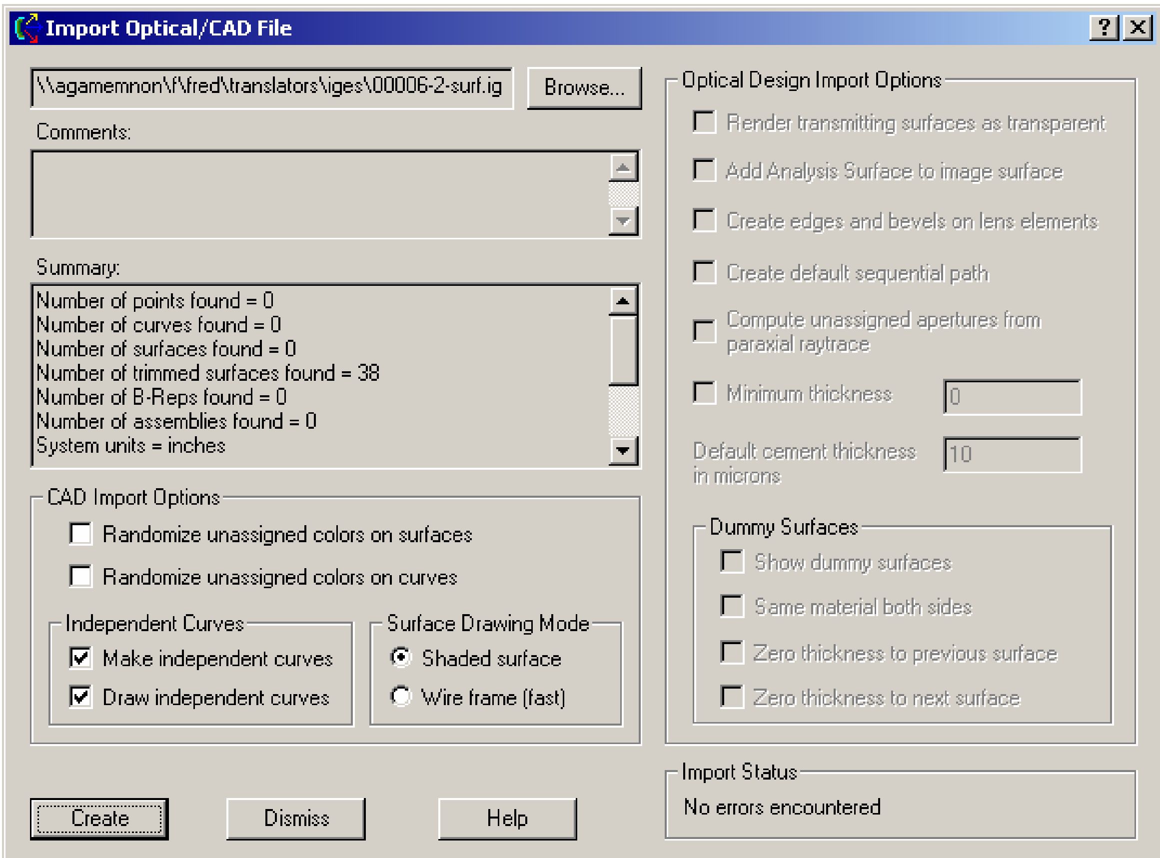
1. Select **Import** in the **File** menu:



2. Press the keyboard accelerator keys: Ctrl+Shift+I (the letter "i" and not the number "1" or the letter "L")

3. Press the toolbar button: 

This dialog is preceded by a file open dialog that asks you which file to import. When you select the file and click the Open button, this dialog appears. Although the data is read in when the file is selected, the elements are not created in a FRED file until you click the Create button on this dialog. FRED behaves this way so as to alert you to any possible errors that occurred before the system is created as a FRED file.



Control	Description	Defaults
File Location	Displays the filename of the file that is being imported.	Name of the file to import
…	Allows selection of a different file to import.	
Comments:	Displays the comments found in the file being imported.	
Summary:	Displays a summary of the file being imported.	
CAD Import Options		

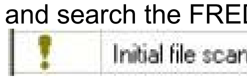
Randomize unassigned colors on surfaces	Allow FRED to choose surface colors.	Unchecked
Randomize unassigned colors on curves	Allow FRED to choose curve colors.	Unchecked
Make independent curves	Translate all curves as independent curves.	Checked
Draw independent curves	Draw independent curves in 3D window.	Checked
Surface Drawing Mode		
Shaded surface/ Wireframe	Renders surfaces as Shaded or Wireframe (fast render).	Shaded
Optical Design Import Options		
Render transmitting surfaces as transparent	Display transparent surfaces as transparent in 3D.	Checked
Add Analysis Surface to image surface	Adds an analysis plane to the last surface listed in the Code V, OSLO, or ZEMAX file. This checkbox is grayed out when importing IGES files.	Unchecked
Create edges and bevels on lens elements	Add edges and bevels to lens elements.	Checked
Create default sequential path	Store sequential path as path data.	Checked
Compute unassigned apertures from paraxial raytrace	Assign apertures based upon paraxial raytrace for unassigned apertures.	Unchecked
Minimum thickness	Force all thickness to be equal to value.	0
Default cement thickness in microns	Choose default cement thickness.	10
Dummy Surfaces		
Show dummy surfaces	Import dummy surfaces.	Unchecked
Same material both sides	Dummy surfaces have same material both sides.	Unchecked
Zero thickness to previous surface	Add no thickness to previous dummy surface.	Unchecked

Zero thickness to next surface	Add no thickness to next dummy surface.	Unchecked
Import Status		
Import Status	Displays status of import operation.	
Create	Populates a new FRED file with the elements and surfaces from the imported file.	
Dismiss	Discards dialog box and does not import any elements (if the Create button has not been pushed).	
Help	Access this Help page.	

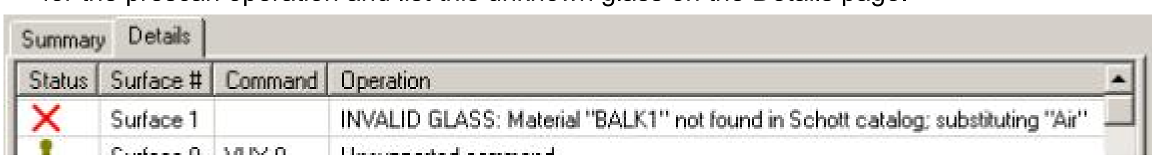
Application Notes - File Import Dialog

This dialog is modal, which means it must be dismissed before any further work on the system can be done.

Examples - File Import Dialog

If, for example, we import a Code V file called LensFile.seq, which had a material called "BALK1" for surface 1. FRED would import the CodeV LensFile.seq file and search the FRED catalogs for "BALK1". If it is not found, FRED would display a yellow "!", 

, for the prescan operation and list this unknown glass on the Details page.



Errors in Importing

The FRED File Import Tool will intercept errors in importing surface types, materials, and coatings, as well as others. These errors fall into four main categories:

Material Errors: Errors occurring because of undefined or unknown materials. Errors of this type include:

UNCERTAIN CATALOG errors occur when FRED cannot determine the catalog a material came from. This error is common with ZEMAX files.

UNDEFINED GLASS errors occur when a material is not defined, whether in a vendor catalog or a user catalog

INVALID GLASS errors occur when a given material is not found in the catalog it is supposed to be in

Surface Errors: Errors occurring because of a surface type that FRED does not support. Errors of this type include:

UNSUPPORTED SURFACE errors occur when a file being imported has a surface that FRED does not know how to interpret.

Coating Errors: Errors occurring because of undefined or unknown coatings. Errors of this type include:

UNDEFINED COATING errors occur when a coating is not defined in FRED

Program-specific Errors: Errors occurring because of commands not supported by FRED. Errors of this type include any command that does not have a similar command in the FRED optical engineering system.

See Also…. - File Import Dialog

New Fred Document

Open

File – Import - Aperture Import Dialog

Description - The Aperture Import Dialog

When FRED imports a file from Code V, OSLO, or ZEMAX, it can automatically determine when a surface doesn't have aperture data specified. It then asks you for the necessary data using the Aperture Import Dialog.

How Do I Get There? - The Aperture Import Dialog

This dialog appears during a file import operation if FRED cannot determine the aperture of a given surface. It will appear automatically if the file being imported has any surface that has no aperture specification. There is no menu option that brings up this dialog.

Dialog Box and Controls - The Aperture Import Dialog

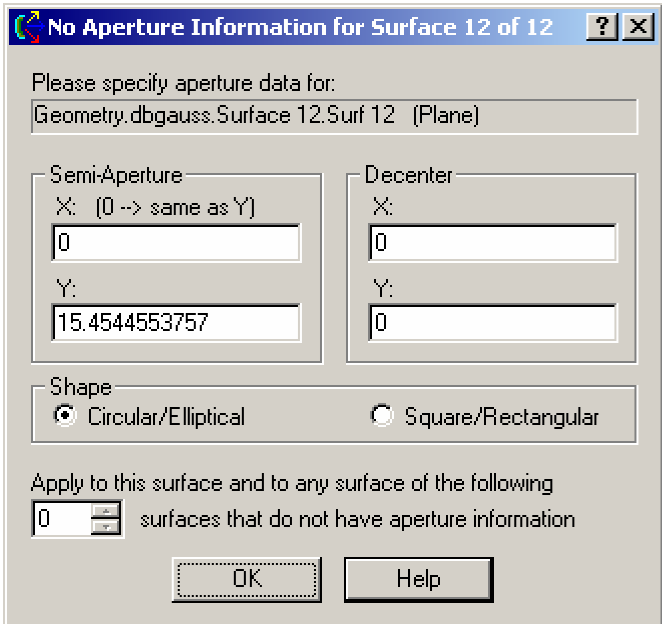


Figure 1: *The Aperture Import Dialog*

Control	Inputs	Defaults
Please specify aperture data for:	Lists the name of the surface that requires additional aperture data.	
Semi-Aperture		
X	Surface X semi-aperture value. If 0, then the X semi-aperture is set to the same value as the Y semi-aperture.	0
Y	Surface Y semi-aperture value.	Y semi-aperture of the previous surface
Decenter		
X	X direction offset value.	0
Y	Y direction offset value.	0
Shape		
Circular/Elliptical	Selects an elliptical aperture shape.	Selected
Square/ Rectangular	Selects a rectangular aperture shape.	Not Selected
Apply to this surface……	The number of surfaces to apply this data to if FRED cannot determine the aperture automatically.	0

OK	Apply aperture data and close dialog box.	
Help	Access this Help page.	

Application Notes - The Aperture Import Dialog

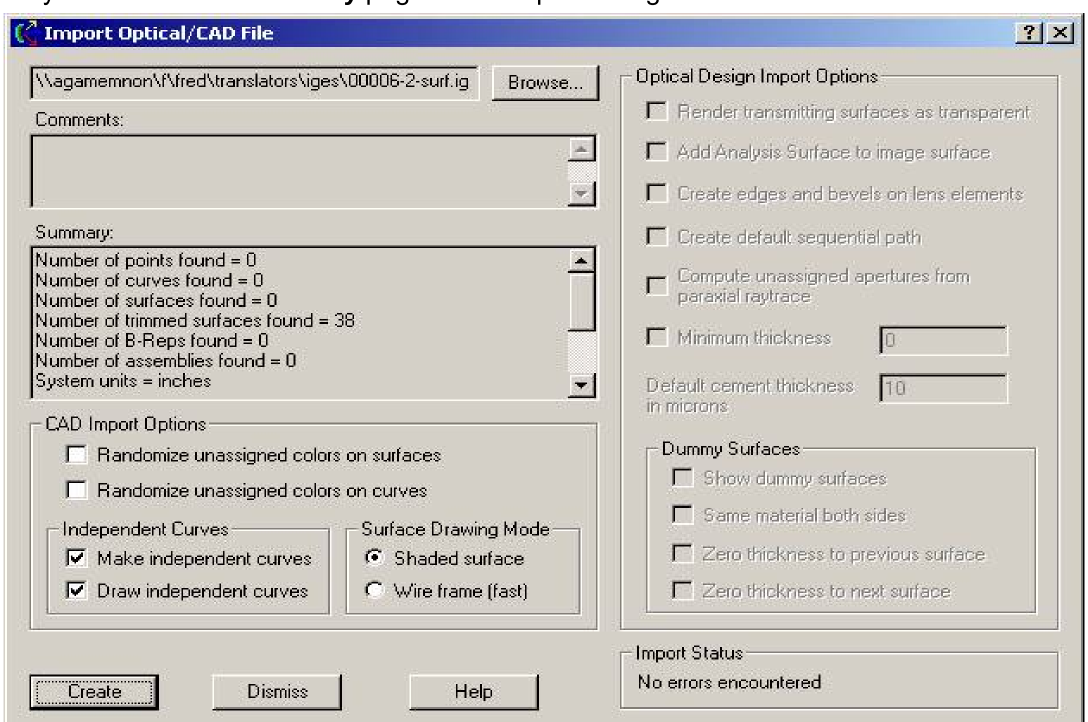
- This is a modal dialog, which means that you must push the OK button in order to continue with the file import.
- The Y semi-aperture is determined from the last surface whose y semi-aperture was determined. For example, if a system has surfaces 1, 2, and 3, and the aperture for surface 1 is specified but surface 2 is not, FRED will ask you what the aperture information should be for surface 2 based on the data for surface 1. It will then ask you for the data for surface 3, using the data from surface 2.

See Also…. - The Aperture Import Dialog

File - Importation Dialog

FRED can read a variety of files and translate them directly into the native FRED format. This is accomplished through the File Importation Dialog, which is located on the File menu. This command takes a Code V, OSLO, ZEMAX, or IGES formatted file and creates a FRED file, displaying any errors that occur during the import. process.

If there are any errors during the importing process, FRED will notify the user with a yellow  on the **Summary** page of the Import dialog.



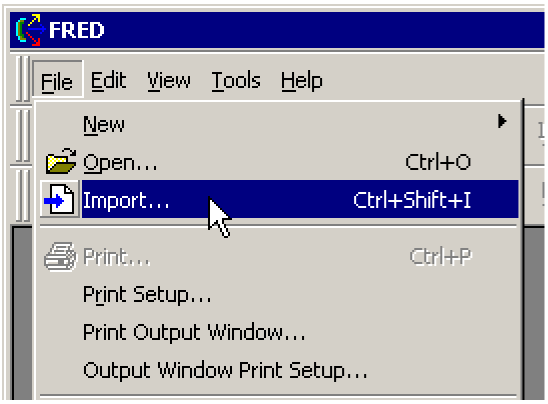
The errors are listed in the Output Window.

FRED supports many of the object or entity types defined in the IGES standard.   FRED internally models these IGES objects exactly as they are defined in the standard instead of approximating the IGES objects with a FRED object. A list of the IGES objects supported by FRED can be used to understand the **Import** dialog **Details** report.

How Do I Get There? - The File Importation Dialog

There are three different ways to execute this command:

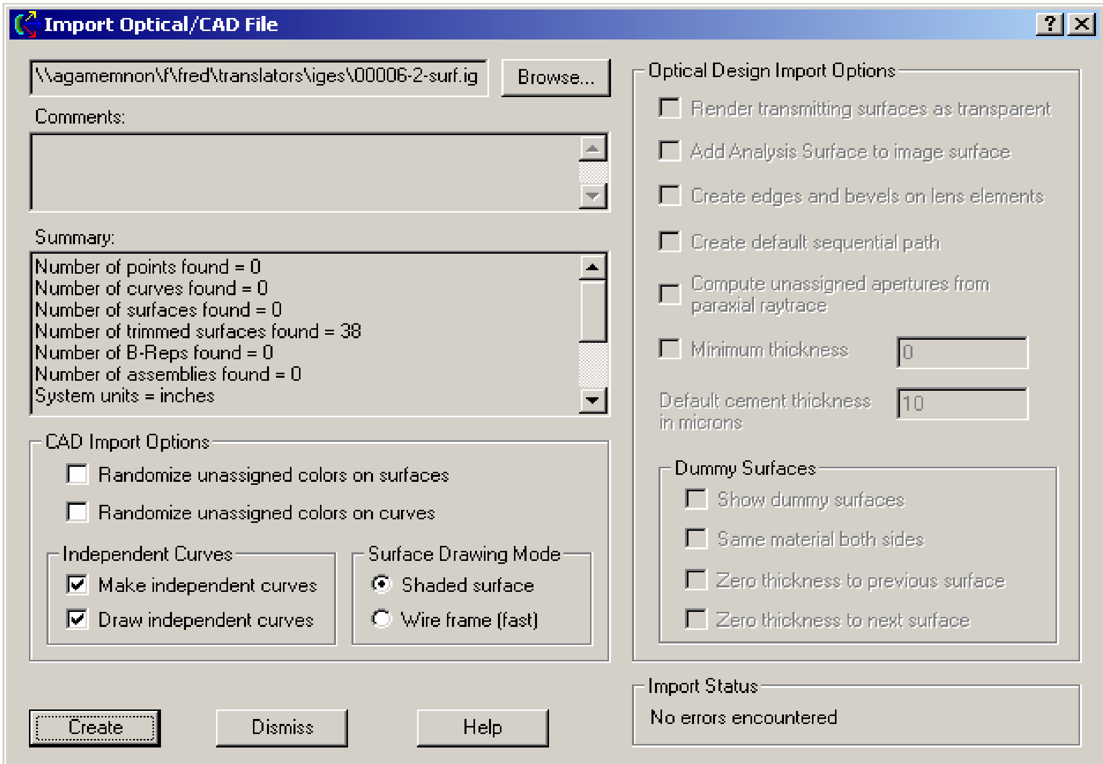
1. Select **Import** in the **File** menu:



2. Press the keyboard accelerator keys: Ctrl+Shift+I (the letter "i" and not the number "1" or the letter "L")
3. Press the toolbar button:

Dialog Box and Controls - The File Importation Dialog

This dialog is preceded by a file open dialog that asks you which file to import. When you select the file and click the Open button, this dialog appears. Although the data is read in when the file is selected, the elements are not created in a FRED file until you click the Create button on this dialog. FRED behaves this way so as to alert you to any possible errors that occurred before the system is created as a FRED file.



Control	***Description***	***Defaults***
File Location	Displays the filename of the file that is being imported	The name of the file you want to import
Browse Button	Allows you to select a different file to import	
Comments:	Displays the comments found in the file being imported	
Summary:	Displays a summary of the file being imported	
Summary Tab	Shows the status of each of the four steps of the import process. Can have one of 4 icons: blue triangle (currently executing), green check (all is well), yellow exclamation (recoverable error occurred), or red X (serious problem occurred).	
Details Tab	Gives details of each of the steps shown on the Summary Tab including any errors, unrecognized commands, missing materials, etc.	
Write messages to output window		

Render transmitting surfaces as transparent		
Randomize unassigned colors		
Add Analysis Surface to image surface	Adds an analysis plane to the last surface listed in the Code V, OSLO, or ZEMAX file. This checkbox is grayed out when importing IGES files.	
Create edges and bevels on lens elements		
Create default sequential path		
Show dummy surfaces		
Compute unassigned apertures from paraxial raytrace		
Minimum thickness		0
Default cement thickness in microns		10
Create	Populates a new FRED file with the elements and surfaces from the imported file	
Dismiss	Dismisses the dialog and does not import any elements (if the Create button has not been pushed).	
Help	Displays this help article	

Application Notes - The File Importation Dialog

This dialog is modal, which means it must be dismissed before any further work on the system can be done.

Examples - The File Importation Dialog

If, for example, we import a Code V file called LensFile.seq, which had a material called "BALK1" for surface 1. FRED would import the CodeV LensFile.seq file and search the FRED catalogs for “BALK1”. If it is not found, FRED would display a yellow “!”, for the prescan operation and list this unknown glass in the Output Window.

Errors in Importing

The FRED File Import Tool will intercept errors in importing surface types, materials, and coatings, as well as others. These errors fall into four main categories:

Material Errors: Errors occurring because of undefined or unknown materials. Errors of this type include:

UNCERTAIN CATALOG errors occur when FRED cannot determine the catalog a material came from. This error is common with ZEMAX files.

UNDEFINED GLASS errors occur when a material is not defined, whether in a vendor catalog or a user catalog

INVALID GLASS errors occur when a given material is not found in the catalog it is supposed to be in

Surface Errors: Errors occurring because of a surface type that FRED does not support. Errors of this type include:

UNSUPPORTED SURFACE errors occur when a file being imported has a surface that FRED does not know how to interpret.

Coating Errors: Errors occurring because of undefined or unknown coatings. Errors of this type include:

UNDEFINED COATING errors occur when a coating is not defined in FRED

Program-specific Errors: Errors occurring because of commands not supported by FRED. Errors of this type include any command that does not have a similar command in the FRED optical engineering system.

File – Import - ASAP Import Units Dialog

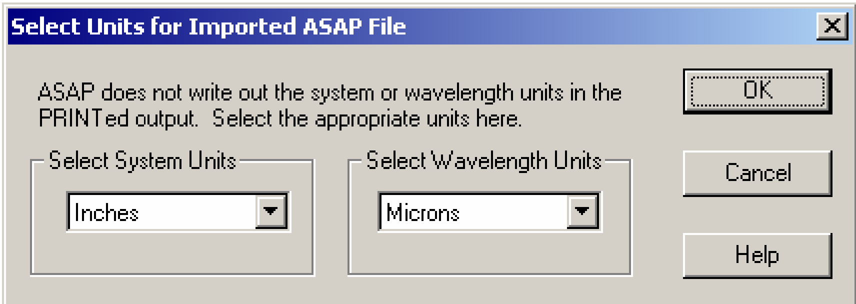
Description - ASAP Import Units Dialog

This dialog asks for the units of measurement for data contained in the ASAP file that is to be imported to FRED.

How Do I Get There? - ASAP Import Units Dialog

This dialog appears when you attempt to import an ASAP text file.

Dialog Box and Controls - ASAP Import Units Dialog



Control	*Inputs / Description*	*Defaults*
Select System Units	Determines geometry dimensional units.	Inches
Select Wavelength Units	Determines wavelengths units.	Microns
OK	Accept the units selections to the imported file and close dialog box.	
Cancel	Discard units selections and close dialog box.	
Help	Access this Help page.	

Application Notes - ASAP Import Units Dialog

When the OK button is clicked, the units are passed into the FRED Import Dialog.

See Also - ASAP Import Units Dialog

FRED Import Dialog

File - Export

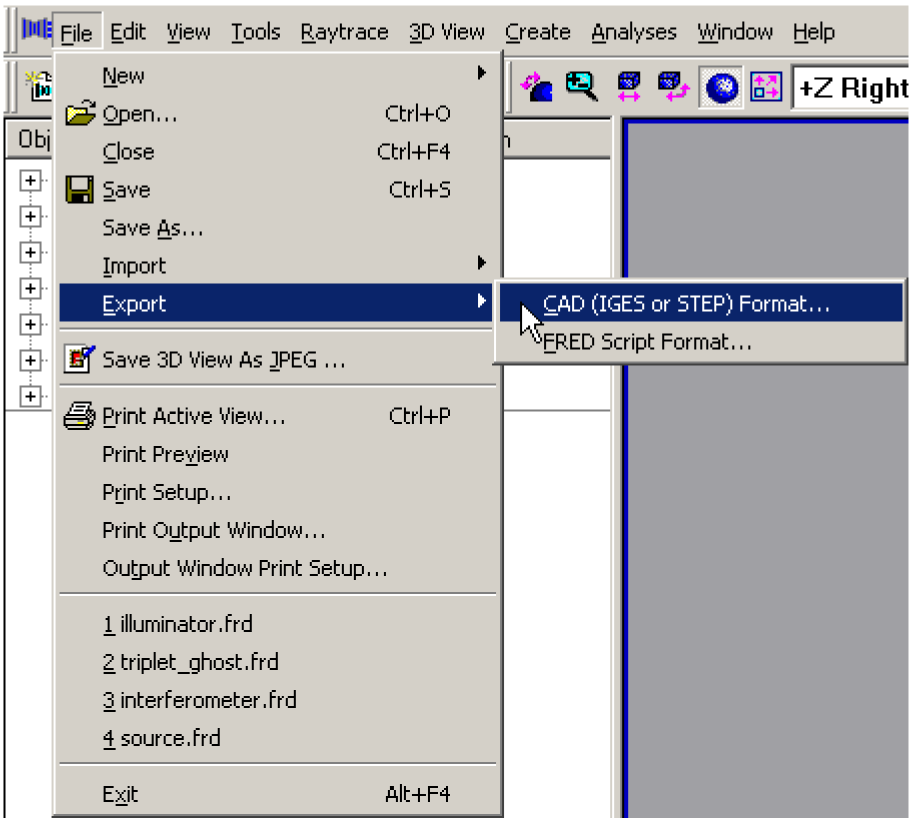
Description
How Do I Get There?
Dialog Box and Controls
Application Notes
See Also...

Description - File Export

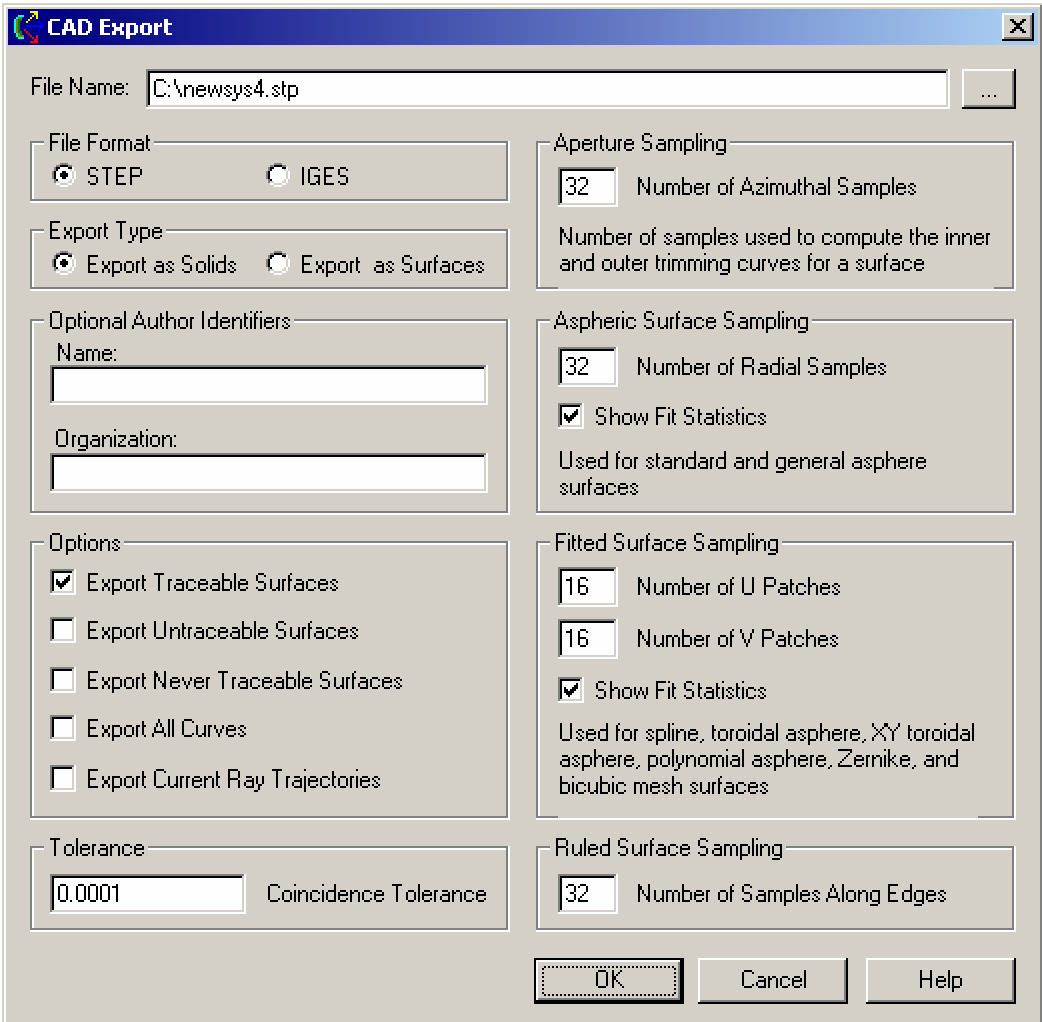
Exports FRED geometry in IGES or STEP format.

How Do I Get There? - File Export

From the File menu, select Export>CAD(IGES or STEP) Format……



Dialog Box and Controls - File Export



Control	Inputs / Description	Defaults
File Name	Name of file to export.	FRED file name
File Format	Choose STEP or IGES.	STEP
Export Type	Export as Solids or Surfaces.	Solids
Optional Author Identifiers	User input: Name and Organization	blank
Options		
Export	Select an export option: *Traceable* *Untraceable* *Never Traceable* *All Curves* *Current Ray Trajectories*	Traceable
Tolerance		

Coincidence Tolerance	Tolerance for which points/curves/surfaces are considered coincident.	0.0001
Aperture Sampling		
Azimuthal Samples	Number of samples used to compute the inner and outer trimming curves for a surface.	32
Aspheric Surface Sampling		
Radial Samples	Number of radial samples used to compute the inner and outer trimming curves for a surface.	32
Show fit statistics	Print fit statistics to output window.	Checked
Fitted Surface Sampling		
Number of Patches	Number of U V patches.	16, 16
Show fit statistics	Print fit statistics to output window.	Checked
Ruled Surface Sampling		
Number of Samples	Samples along Edges	32
OK	Accept CAD Export settings and close dialog box.	
Cancel	Discard changes and close dialog box.	
Help	Access this Help page.	

Application Notes - File Export

See Also - File Export

File Import

File - Save 3D View as JPEG command

Description
How Do I Get There?
See Also...

Description - Save 3D View as JPEG command

Use this command to save the Visualization view as a JPEG image. When you select this command, FRED brings up a standard Windows File Save As dialog. Navigate the file system to the directory where you want to save the image, then type in a file name and click the "Save" button.

How Do I Get There? - Save 3D View as JPEG command

There are two different ways to execute this command:

- From the File menu, choose "Save 3D View as JPEG...".
- On the File Toolbar, press this button: 

See Als - Save 3D View as JPEG command

Save Command
Active View Copy

File - Open command

Description
How Do I Get There?
See Also...

Description - Open command (File menu)

Use this command to open an existing document file. You cannot open multiple documents at once. Use the Window menu to switch among the multiple open documents. See Window 1, 2, ... command.

When you select this command, FRED brings up a standard Windows File Open dialog, listing the FRED files in the currently selected directory. Navigate the file system to the directory that holds your file, then select it and press the Open button.

How Do I Get There? - Open command (File menu)

There are four different ways to execute this command:

1. Select **Open** in the **File** menu:

2. Press the keyboard accelerator keys: Ctrl+O
3. Press the toolbar button: 
4. Type "open *filename*" on the input line, where *filename* is a valid, existing FRED file. If the file is already open a duplicate is not opened.

See Also - Open command (File menu)

File New Command
Window 1, 2 … Command

File - Close command

Description
How Do I Get There?

Description - Close command

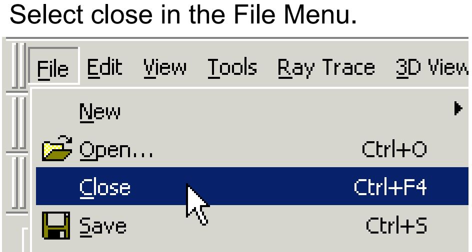
Use this command to close the active document without saving the document. If you close a document without saving, you lose all changes made since the last time you saved it.

Note:	We recommend that you save your changes often.

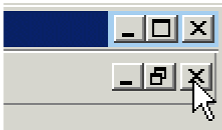
How Do I Get There? - Close command

There are three ways to close the active document:

1. Select close in the File Menu.



2. Using the accelerator keys, Ctrl+F4
3. Closing the active window by left mouse clicking on the  icon in the upper right-hand corner.



> Note: If there are multiple windows open for the same optical system, you are not prompted to save changes to the system until you close the last window that relates to that system. It does not matter which window is the last window.

File - Save command

[Description](#)
[How Do I Get There?](#)
[Dialog box and Controls](#)
[See Also...](#)

Description - Save command

Use this command to save the active document with a name in a directory. When you save a document for the first time, FRED displays the Save As dialog box so you can name your document. If you want to change the name and directory of an existing document before you save it, choose the Save As command.

Note or Tip When dealing with multiple windows that describe the same optical system (i.e. the optical layout and various analysis plots), you are not prompted to save changes to the system until you close the last window that relates to that system. For instance, say you have cassegrain.frd open, along with a Ray Positions Plot and a Ray Irradiance Distribution Plot. If you close the Ray Positions Plot and the optical layout window, FRED will not ask you to save the changes you have made. It will only ask you to save the changes when you close the Ray Irradiance Distribution Plot. To return to the Tree View + OpenGL View, select the Window->New Window menu.

(We recommend that you save your changes often, regardless of what windows you have open, and that you close the optical layout last. This is because after closing the optical layout, you cannot reopen it unless you close all windows relating to that system and reopen the file.

How Do I Get There? - Save command

There are three ways to access this command:

1. On the File Toolbar, click this button: 
2. Use the keyboard shortcut Ctrl+S.
3. On the File menu, select "Save".

Dialog Box and Controls - Save command

This command brings up a standard Windows Save dialog box.

See Also - Save command

New FRED Document
Open

File - Save As command

Description
How Do I Get There?
Dialog box and Controls
See Also...

Description - Save As command

Use this command to save and name the active document. FRED displays the Save As dialog box so you can give your document a new name. To save a document with its existing name and directory, use the Save command.

How Do I Get There? - Save As command

From the **File** menu, choose **Save As…**.

Dialog Box and Controls - Save As command

This command displays a standard Windows Save As dialog box.

See Also - Save As command

New FRED Document
Open
Save

File - Save As dialog box

[Description](#)
[How Do I Get There?](#)

Description - File Save As dialog box

FRED allows you to save the currently open file as a copy with a different file name. When you chose this menu option, FRED displays a standard Windows Save As dialog. Enter the location and name of the copy you want to save and choose **Save**.

How Do I Get There? - File Save As dialog box

From the File menu, choose "Save As…" There is no keyboard shortcut or toolbar button for this command.

File - Exit command

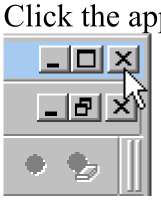
[Description](#)
[How Do I Get There?](#)

Description - Exit command

Use this command to end your FRED session. You can also use the Close command on the application Control menu. FRED prompts you to save documents with unsaved changes.

How Do I Get There? - Exit command

There are three ways to execute this command.
Click the application's Close button in the upper right corner.



Use the keyboard shortcut Alt+F4.
Type "exit" on the input line.

File - Print Active View...

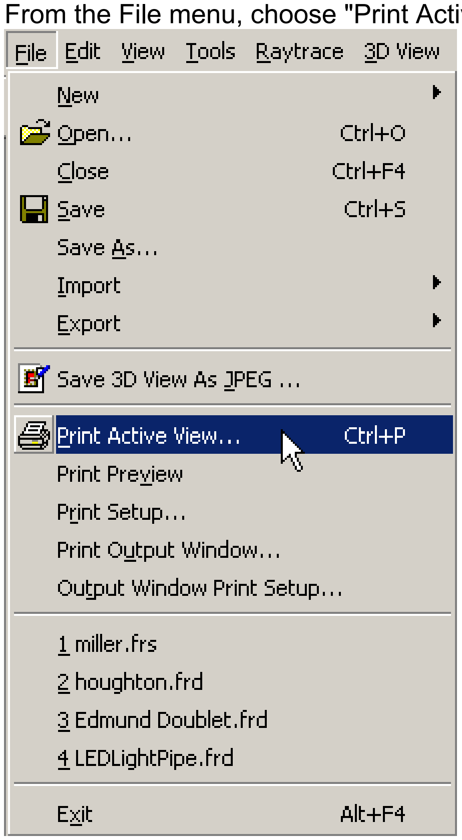
Description - Print dialog box

Use this command to print the active view in the current optical layout (or script, as the case may be). This command presents a standard Windows print dialog box, where you may specify the range of pages to be printed, the number of copies, the destination printer, and other printer setup options.

How Do I Get There? - Print dialog box

There are three ways to execute this command:

3. From the File menu, choose "Print Active View..."



4. From the File Toolbar, press the Print button:

5. Press Ctrl+P on the keyboard.

Dialog Box and Controls - Print dialog box

This command brings up a standard Windows Print dialog. This dialog will vary from system to system, based on the Windows version and the printer used.

Application Notes - Print dialog box

When the OK button is pushed, the window that is printed is the active window. If, for example, you last clicked in the Visualization window, that window will be printed. If you last clicked in the Tree View, the Tree View will be printed.

File - Print Preview command

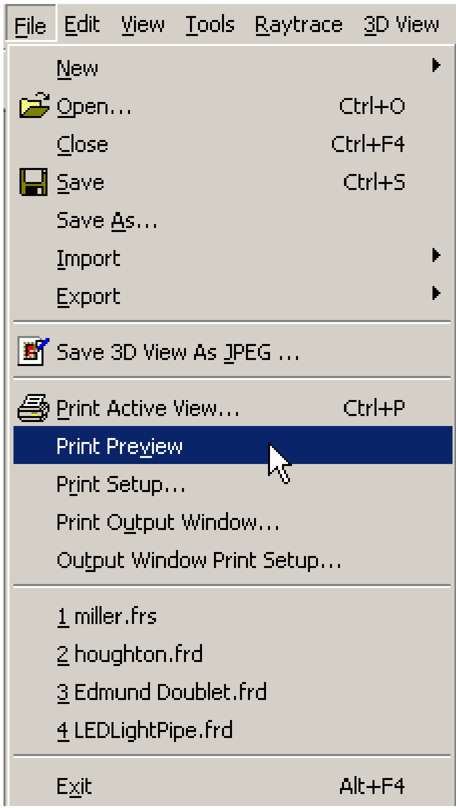
Description
How Do I Get There?

Description - Print Preview command

Use this command to display the active document, as it would appear when printed. When you choose this command, the main window will be replaced with a print preview window in which one or two pages will be displayed in their printed format. The print preview toolbar offers you options to view either one or two pages at a time; move back and forth through the document; zoom in and out of pages; and initiate a print job.

How Do I Get There? - Print Preview command

From the **File** Menu, choose **Print Preview**.



File - Print Setup command

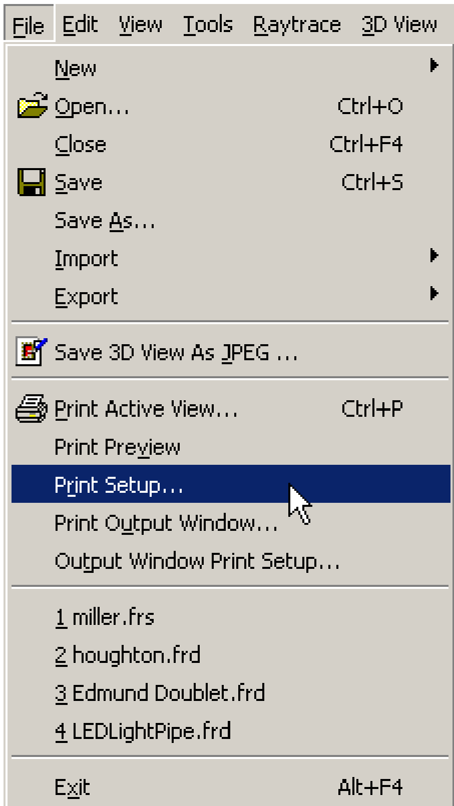
Description
How Do I Get There?

Description - Print Setup command

This command allows you to change the general settings for your printer. Specifically, it allows you to change which printer you use, the paper orientation, the paper size, and the paper source.

How Do I Get There? - Print Setup command

From the **File** menu, choose **Print Setup...**.



Dialog Box and Controls - Print Setup command

This command displays a Windows standard print setup dialog box.

File - Print Output Window command

Description
How Do I Get There?

Description - Print Output Window command

Use this command to select a printer and a printer connection. This command presents a Print Setup dialog box, where you specify the printer and its connection. After clicking OK, it sends a print job to the printer consisting of whatever is in the output grid. There are certain rules it follows that you should be aware of.

How Do I Get There? - Print Output Window command

If there is not something highlighted in the Output Window:
FRED checks to see if the Print Selection option was chosen in the Print Setup dialog box.

This option is grouped with the Print All pages option and the Print Range of pages option. If it was not selected, it prints the entire grid or the range of pages selected. If it was selected, it prints the grid, beginning with the first visible row in the Output Window and ending after one page.

If there is something selected in the Output Window:
FRED prints only what is selected, even if you choose the Print All option.

There are three ways to access this command:

- On the File Toolbar, click this button: 
- On the File menu, choose "Print Output Window".
- Use the Keyboard shortcut Ctrl+Shift+P.

File - Output Window Print Setup

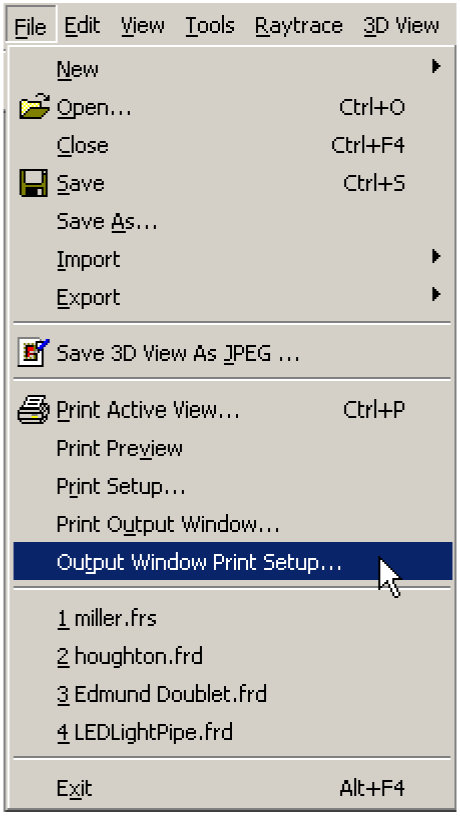
Description
How Do I Get There?
Dialog box and Controls
Application Notes
See Also...

Description - Output Window Print Setup

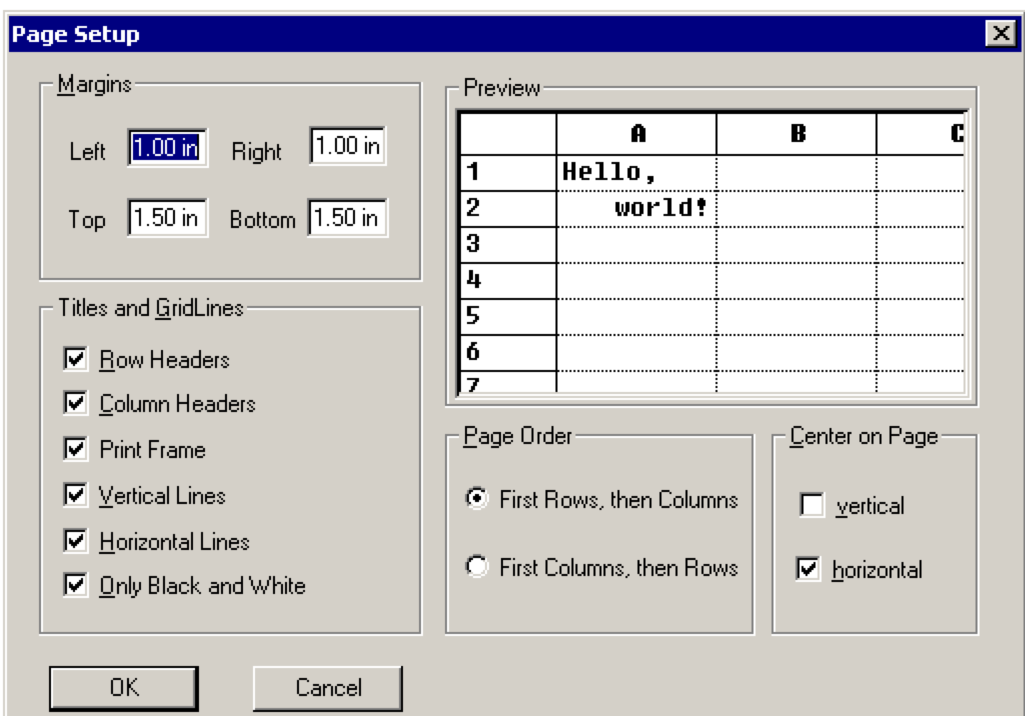
This will bring up a dialog where you can change several printing options for the output window. There is a simple preview window in this dialog that allows you to see the effect of the changes you make. These options are not saved between FRED sessions.

How Do I Get There? - Output Window Print Setup

From the **File** menu, choose **Output Window Print Setup…**. There is no keyboard shortcut or toolbar button for this command.



Dialog Box and Controls - Output Window Print Setup



Control	Inputs	Defaults
Margins Left	Displays the amount of margin to allow on the left side of the page.	1.00 in
Margins Right	Displays the amount of margin to allow on the right side of the page.	1.00 in
Margins Top	Displays the amount of margin to allow at the top of the page.	1.50 in
Margins Bottom	Displays the amount of margin to allow at the bottom of the page.	1.50 in
Row Headers	Tells FRED to print the column of row numbers at the left of the Output Window.	Checked
Column Headers	Tells FRED to print the row of column letters at the top of the Output Window.	Checked
Print Frame	Prints a frame around the output window on the printed page.	Checked
Vertical Lines	Prints the vertical lines separating the columns.	Checked
Horizontal Lines	Prints the horizontal lines separating the rows.	Checked
Only Black and White	Ignores color in the output window when printing.	Checked
First Rows, then Columns	Determines the collating order of the print job. See Application Notes for details.	Set
First Columns, then Rows	Determines the collating order of the print job. See Application Notes for details.	Not Set
Center on Page vertical	Centers the printing vertically on the page.	Unchecked
Center on Page horizontal	Centers the printing horizontally on the page.	Checked
Preview	Shows how the Output Window will look printed.	
OK	Saves changes and dismisses the dialog	
Cancel	Ignores changes and dismisses the dialog	

Application Notes - Output Window Print Setup

- This is a modal dialog, which means that the dialog must be dismissed in order to return to the document(s).

- When collating pages, FRED checks the state of the Page Order option to determine which sequence to print the pages in. For example, suppose your Output Window has A-R columns and 60 rows and a page can hold 5 columns and 20 rows. If the Page Order option is set to “First Rows, then Columns”, FRED will print columns A-E and rows 1-20 on the first page, then print columns A-E and rows 21-40 on the second page, then columns A-E and rows 41-60. It will then move to columns F-J, and proceed in the same manner.

  If the Page Order option is set to “First Columns, then Rows”, FRED will print columns A-E and rows 1-20 on the first page, then print columns F-J and rows 21-40 on the second page. It will continue in the same manner until it prints the entire print job.

See Also - Output Window Print Setup

Print Output Window

File - Print Preview command

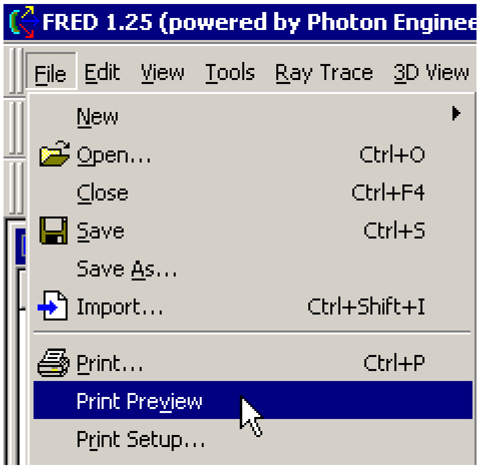
Description
How Do I Get There?

Description - Print Preview command

Use this command to display the active document, as it would appear when printed. When you choose this command, the main window will be replaced with a print preview window in which one or two pages will be displayed in their printed format. The print preview toolbar offers you options to view either one or two pages at a time; move back and forth through the document; zoom in and out of pages; and initiate a print job.

How Do I Get There?
Print Preview command

From the **File** Menu, choose **Print Preview**.

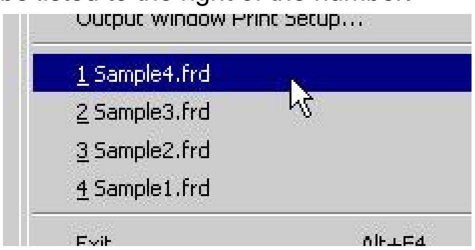


File - 1, 2, 3, 4 command

[Description](#)
[How Do I Get There?](#)

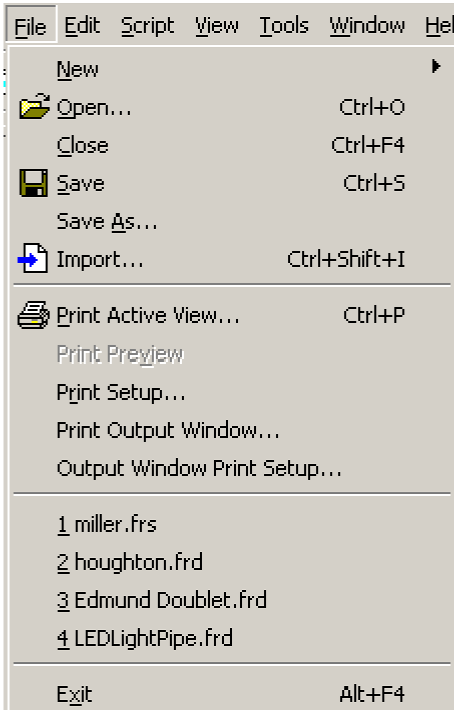
Description - 1, 2, 3, 4 command (File menu)

FRED allows you to rapidly open a recently used file. To do this, you select from the numbers and filenames listed at the bottom of the File menu to open the last four documents you closed. Choose the number that corresponds with the document you want to open, which will be listed to the right of the number.



How Do I Get There? - 1, 2, 3, 4 command (File menu)

From the File menu, press the 1, 2, 3, or 4 key, corresponding to the file you want to open.



Edit - Menu commands

The Edit menu offers the following commands:

Undo	Reverses the previous action
Redo	Performs the previous action again
Cut	Cuts the currently selected object onto the clipboard
Copy	Copies the currently selected object onto the clipboard
Paste	Pastes the current object on the clipboard into the currently selected position
Select All	Available only when a Script window is active. Selects all the text in the window.
Find	Available only when a Script window is active. Displays the find text dialog.
Find Next	Available only when a Script window is active. Finds the next instance of the string being searched for.
Replace	Available only when a Script window is active. Displays the replace text dialog.
Output Window Cut	Cuts the data that is selected in the Output Window and places it on the clipboard
Output Window	Copies the data that is selected in the Output Window and places it on

Copy	the clipboard
Output Window Paste	Pastes the data that is on the clipboard into the selected area in the Output Window
Active View Copy	Copies the current view as a bitmap to the Windows Clipboard
General File Comment	Edits the comment for the currently active file.

Edit - Undo command

Description
How Do I Get There?

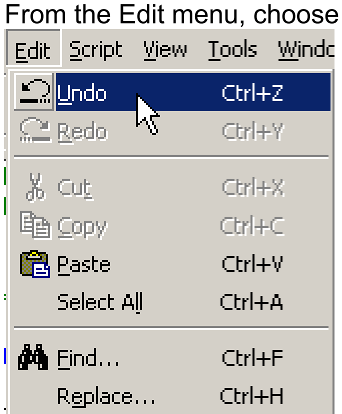
Description - Undo command

This command reverses the most recently taken action. For example, if you typed something, executing the Undo command will remove the typed text. This command is only available when a Script is being edited.

How Do I Get There? - Undo command

There are two ways to execute this command:

- From the Edit menu, choose "Undo".



- Use the keyboard shortcut Ctrl+Z.

Edit - Redo command

Description

Description - Redo command

This command is not implemented yet.

Edit - Cut command

Description
How Do I Get There?

Description - Cut command (Edit menu)

Use this command to remove the currently selected data from the document and put it on the clipboard. This command is unavailable if there is no data currently selected.

In general, anything that can be selected can be cut. This includes text, numbers, Tree objects, and multiple selections of these things.

How Do I Get There? - Cut command (Edit menu)

There are three ways to access this command:

- On the Edit Toolbar press this button: 
- Use the Keyboard Shortcut Ctrl+X.
- From the Edit menu, choose "Cut".

Edit - Copy command

Description
How Do I Get There?

Description - Copy command

Use this command to copy selected data onto the clipboard. This command is unavailable if there is no data currently selected. Copying data to the clipboard replaces the contents previously stored there.

In general, anything that can be selected can be copied. This includes text, numbers, Tree objects, and multiple selections of these things.

How Do I Get There? - Copy command

There are three ways to execute this command:

From the File toolbar, press this button: 
Use the keyboard shortcut CTRL+C
From the Edit menu, select "Copy".

Edit - Paste command

Description
How Do I Get There?

Description - Paste command (Edit menu)

Use this command to insert a copy of the clipboard contents at the insertion point. This command is unavailable if the clipboard is empty.

If something is selected and the Paste command is given, the selected item will be replaced with the item from the clipboard.

How Do I Get There? - Paste command (Edit menu)

There are three ways to execute this command:

- From the File toolbar, press this button: 
- Use the keyboard shortcut Ctrl+V
- From the Edit menu, select "Paste".

Edit - Select All command

Description
How Do I Get There?

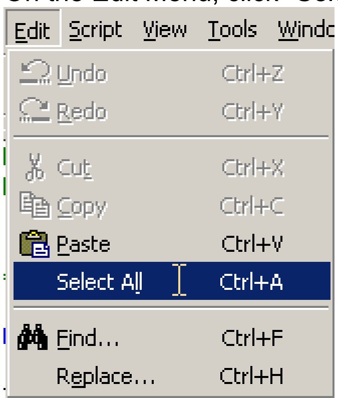
Description - Select All command

This command selects all the text in a FRED Script. This command is only available when a Script document is active and when there is text to select.

How Do I Get There? - Select All command

There are two ways to access this command:

- On the Edit Menu, click "Select All"



- Use they keyboard shortcut Ctrl+A.

Edit - Output Window Cut Command

Description

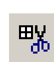
How Do I Get There?

Description - Output Window: Cut Command

This command takes the current selection in the text output window and cuts it to the Windows clipboard. The selected area remains selected. If nothing is selected, nothing gets cut.

How Do I Get There? - Output Window: Cut Command

There are three ways to execute this command:

- From the Output Window toolbar, press this button: 
- Use the Ctrl+Shift+X keyboard shortcut.
- From the edit menu, select "Output Window Cut".

Edit - Paste Output Window Command

Description

How Do I Get There?

Description - Output Window: Paste Command

This command takes the current Windows clipboard contents and pastes them into the selected text Output Window area. If nothing is selected, nothing gets pasted.

How Do I Get There? -Output Window: Paste Command

There are three ways to execute this command:

- From the Output Window toolbar, press this button: 
- Use the Ctrl+Shift+V keyboard shortcut.
- From the edit menu, select "Output Window Paste".

View - Menu Commands

The View menu offers the following commands:

Toolbars	Brings up the toolbars dialog for selecting the buttons to display
Status Bar	Displays the application status bar at the bottom, showing lock key status and mouse coordinates.
Output Window -> View	Toggles displaying the Output Window
Output Window -> Cells	Displays the Output Window as a spreadsheet (with grid boxes) or a regular sheet (no grid boxes)
Output Window -> Clear Contents	Deletes any text in the output Window
Calculator	Brings up a calculator that can be attached to the perimeter of the document

Toolbars

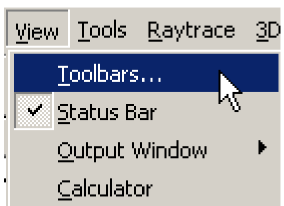
Description
How Do I Get There?
Dialog box and Controls

Description
Toolbars

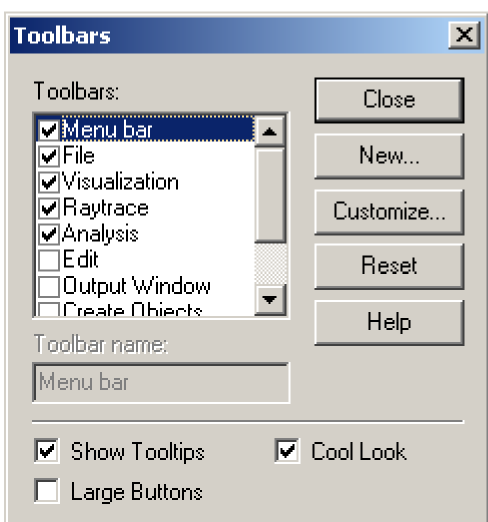
This dialog displays the various toolbars available in FRED and enables customization of the Toolbar Buttons.

How Do I Get There?
Toolbars

From the **View** menu, select **Toolbars**.



Dialog Box and Controls
Toolbars



Toolbars	List of Toolbars
Toolbar Name	Selected toolbar.
Show Tooltips	Show tooltips on hover.
Cool Look	Change button style.

Large Buttons	Use Large buttons
Close	Close and accept changes.
New	Add new toolbar.
Customize	Customize existing toolbar.
Reset	Reset toolbars to default.
Help	Access this Help page.

View - Output Window Cells

Description

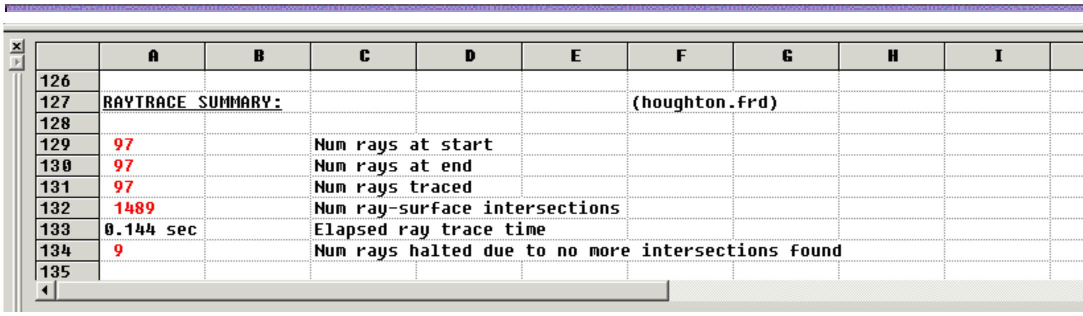
Output Window Cells

The Output Window is a spreadsheet with rows and columns with two viewing options: 1) spreadsheet style with cell borders, row numbers, and column letters or 2) text file option with no cell borders, no row numbers, and no column letters. The user can toggle between the two viewing options with this command. Note, in both cases the Output Window is still a spreadsheet.

Note	The colors of the text, numbers, and formulas in the Output Window can be set to difference colors in the Format page of the Preferences.

Visualization (example)

Output Window Cells

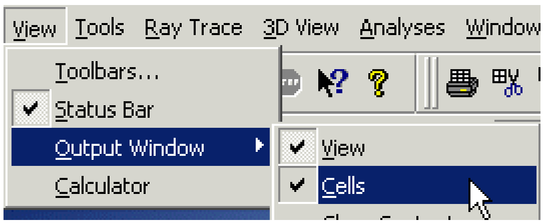


	A	B	C	D	E	F	G	H	I
126									
127	RAYTRACE SUMMARY:					(houghton.frd)			
128									
129	97		Num rays at start						
130	97		Num rays at end						
131	97		Num rays traced						
132	1489		Num ray-surface intersections						
133	0.144 sec		Elapsed ray trace time						
134	9		Num rays halted due to no more intersections found						
135									

How Do I Get There?
Output Window Cells

There are two different ways to execute this command:

To view the output window cells, select Output Window in the View Menu and toggle the Cells option.



View - Calculator

Description

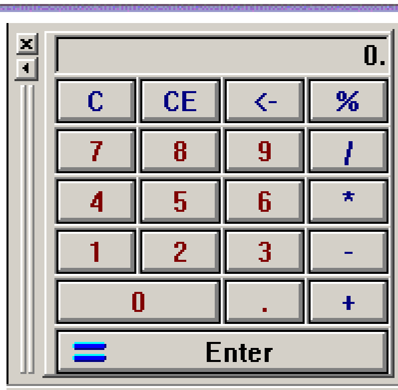
Visualization (example)

How Do I Get There?

Description
Calculator

FRED has a basic calculator that provides for simple arithmetic. This calculator is designed as part of the toolbars, so it can be detached to float freely, or attached to anywhere on the perimeter of FRED.

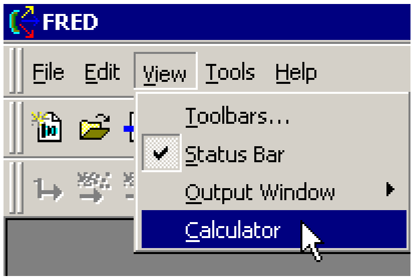
Visualization (example)
Calculator



The calculator enabled.

How Do I Get There?
Calculator

From the **View** menu, select **Calculator**.



Tools - Menu commands

The Tools menu offers the following commands:

Preferences	Displays the dialog that lets you set the options available in FRED.
User Defined Scripting Tools	Links to the specified scriptsthey can be run by choosing the matching menu item.
Units and Scaling	Displays the dialog that scales an optical system and modifies the system units.
Edit/View GRIN Material Position/Orientation	Displays the dialog that scales an optical system and modifies the system units.
Reports -> Document Summary	Displays in the output window a summary of all the items in the system
Reports -> Document Detail	Displays in the output window a detailed listing of all the items in the system
Reports -> Entity Reference Coordinates	Displays in the output window coordinates of all entities in selected coordinate system.
Reports -> Current Ray Set Summary	Displays in the output window a summary of all the rays in the ray buffer
Reports -> Ray Detail	Displays in the output window a detailed report of a specified ray from the ray buffer
Reports -> Raytrace Paths	Displays a spreadsheet containing all raytrace paths.
Reports -> Stray Light Report	Displays a customizable stray light report documenting specular and scatter paths.
Determine Scatter Importance Sampling	Automatically determines Importance Sampling for specified components.
Analyze Scatter Importance Sampling	Evaluates efficiency of Importance Sampling assignments.
Force Immediate Document Update	Forces an immediate update of your FRED document.
Edit/View Pre-Update Script	Edits a Pre-Update script.
Edit/View Post-Update Script	Edits a Post-Update script.
Pre-Update Script Status (active if checked)	Sets status of Pre-Update script.
Post-Update Script Status (active if checked)	Sets status of Post-Update script.
Edit/View Global Script Variables	Displays a dialog box containing Global Script Variable assignments.

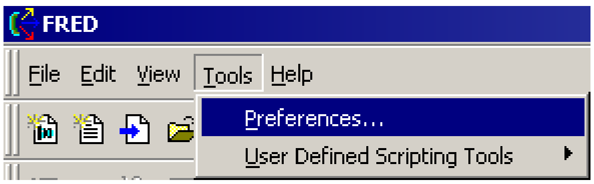
Tools - Format Options Page

Description - The Format Options Page

This help article describes the options in FRED that affect the macro editor.

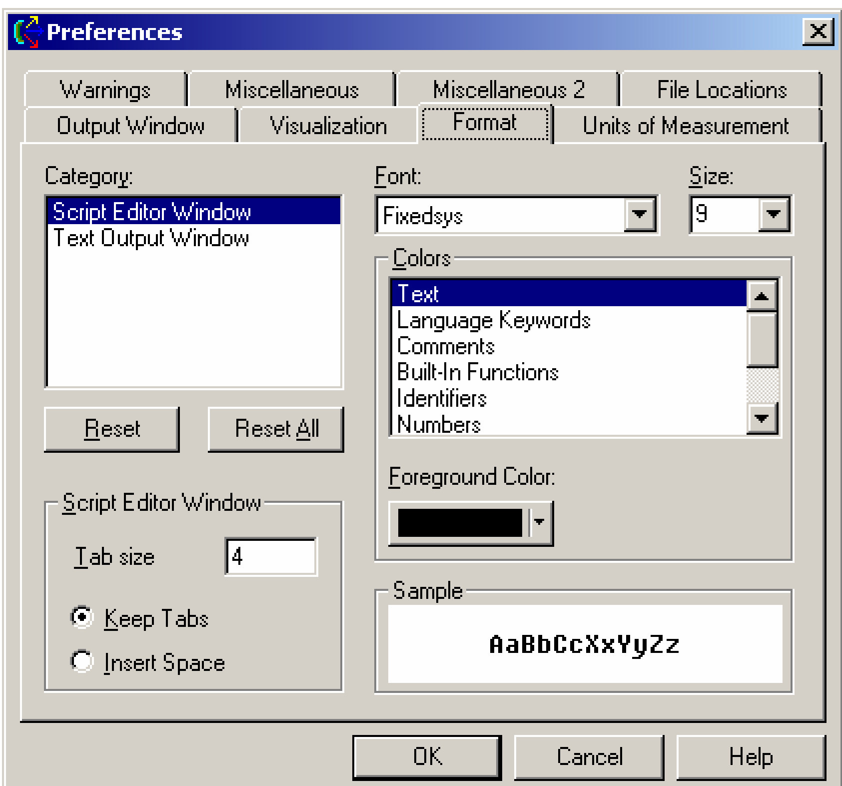
How Do I Get There? - The Format Options Page

From the **Tools** menu, choose **Preferences**, then click on the **Format** tab.



Dialog Box and Controls - The Format Options Page

This dialog gives a listing of the settings that can be set for displaying text in FRED.



Control	*Inputs/Description*	*Defaults*
Category	Lists the various categories that can have their text customized.	Script Editor

		Window
Reset Button	Resets the selected item listed in the Colors list to its default.	
Reset All Button	Resets all items in the Colors list to their default.	
Tab Size	Selects how large a tab is in the macro editor.	4
Keep Tabs	In the macro editor, selecting this option inserts actual tab characters when you press the tab button.	Selected
Insert Space	In the macro editor, selecting this option inserts space characters when you press the tab button, instead of tabs.	Not selected
Font	Sets the font of the text item selected in the Category list.	Fixedsys
Size	Sets the font size of the text item selected in the Category list.	9
Colors	Gives a listing of the various items in a Category that can be colored.	Text
Foreground	Sets the foreground color for the item selected in the Colors listing.	Automatic
OK	Accept changes and close dialog box.	
Cancel	Discard changes and close dialog box.	
Help	Access this Help Page.	

See Also…. - The Format Options Page

Preferences Dialog

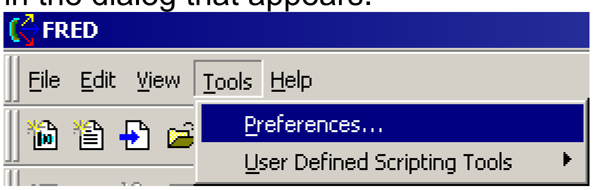
Tools – Preferences - Miscellaneous Options Page

Description - The Miscellaneous Options Page -

This help article describes the general options that can be set in FRED.

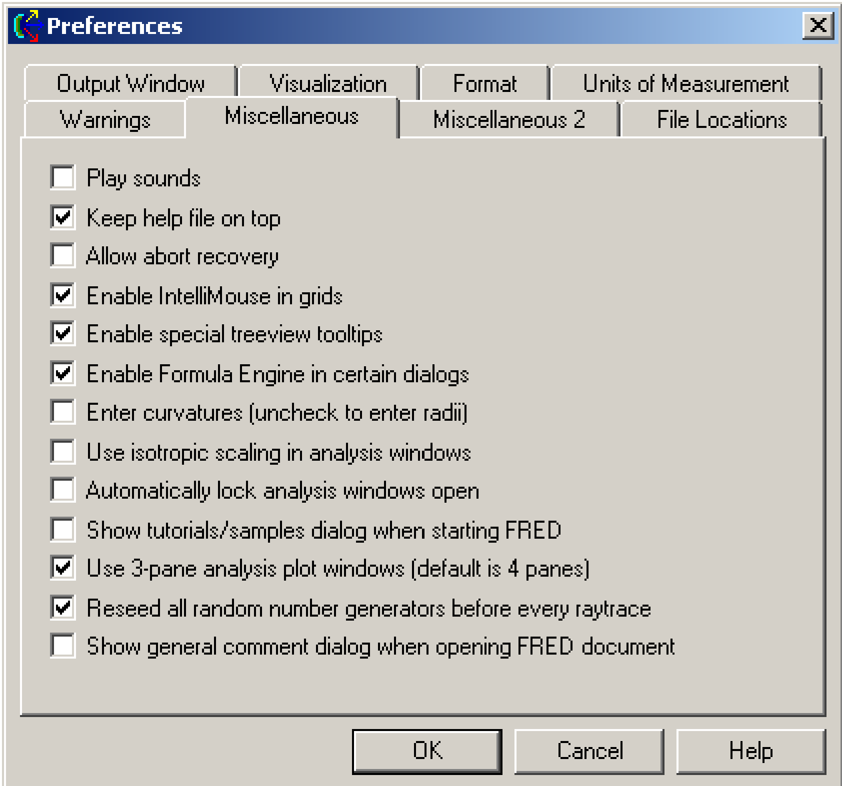
How Do I Get There? - The Miscellaneous Options Page

From the "Tools" menu, choose "Preferences". Click on the "Miscellaneous" tab in the dialog that appears.



Dialog Box and Controls - The Miscellaneous Options Page

This dialog gives a listing of the general settings in FRED.



Control	***Inputs / Description***	***Default Value***
Play Sounds	Enables sounds to be played for various events throughout FRED.	Unchecked
Keep help file on top	When checked, keeps the help file on top of all other windows.	Checked
Allow abort recovery	Enables abort recovery from FRED Undo files.	Unchecked
Enable IntelliMouse in grids	Avoids driver conflicts with some mouse manufacturers.	Unchecked
Enable special treeview tooltips	When checked, displays supplemental tree node information in tool tips.	Checked
Enable Formula Engine in dialogs	Allows entry of formulas in dialogs that have grids.	Checked
Enter Curvatures (uncheck to enter radii)	Checking this option causes FRED to prompt for entry of the curvature of an object (1/radius) whenever appropriate. Unchecking this box causes FRED to ask for the radius.	Checked

Use isotropic scaling in analysis windows	Sets isotropic scaling in Analysis windows	Checked
Automatically lock analysis windows open	When an analysis window is opened, this option will keep it open by default when the ray set is deleted.	Unchecked
Show tutorials/samples dialog when starting FRED	When checked, displays the Tutorials and Samples Dialog when FRED starts up. Useful for beginning users.	Unchecked (Full) Checked (Demo)
Use 3-pane analysis plot windows (default is 4 panes)	Sets number of windows in Chart Viewer plots.	Unchecked
Reseed all random number generators before every raytrace	Reinitializes the random number generators when performing a raytrace.	Unchecked
Show general comment dialog when opening FRED document	When checked, displays the comment for a file when the file is opened.	Unchecked
OK	Accept Miscellaneous changes and close dialog box.	
Cancel	Discard Miscellaneous changes and close dialog box.	
Help	Access this Help page.	

See Also - The Miscellaneous Options Page

Preferences Dialog

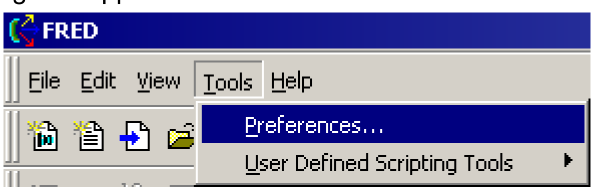
Tools – Preferences - The Miscellaneous 2 Options Page

Description - The Miscellaneous 2 Options Page

This help article describes the general options that can be set in FRED.

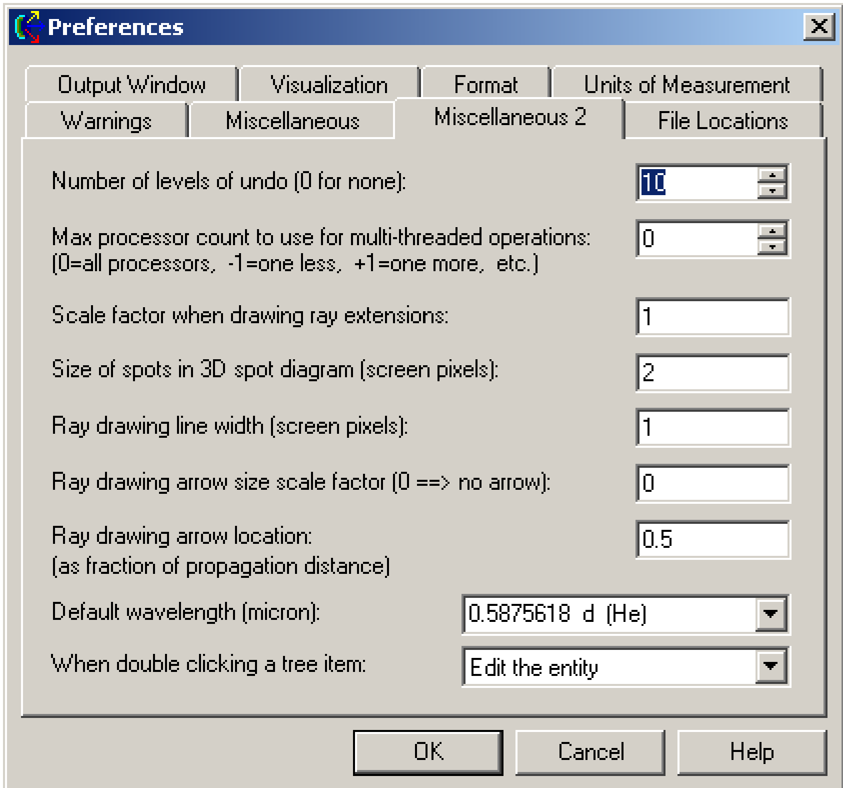
How Do I Get There? - The Miscellaneous 2 Options Page

From the "Tools" menu, choose "Preferences". Click on the "Miscellaneous 2" tab in the dialog that appears.



Dialog Box and Controls - The Miscellaneous 2 Options Page

This dialog gives a listing of the general settings in FRED.



Control	***Inputs / Description***	***Default Value***
Number of levels of undo:	Defines the number of actions that can be undone when working with FRED.	1
Max processor count	Specifies the number of processors FRED will use in raytracing. Set to zero to use all available processors.	1
Scale factor when drawing ray extensions	Determines the amount of dash to draw when a ray misses geometry and heads into infinity during a raytrace. To turn off drawing missed rays, set this value to 0.	1
Size of spots in 3D spot diagram:	Sets the default size in pixels of the ray spots in spot diagrams.	2
Ray drawing line width	Line draw width in pixels.	1
Ray drawing arrow size scale factor	Scales size of ray arrow (0 for no arrow).	0
Ray drawing arrow location	Sets location of arrow along ray draw line (as a fraction of ray propagation distance).	0.5
Default wavelength	Default wavelength for new FRED files.	0.5875618

(micron):		d (He)
When double clicking a tree item:	Defines the action to take when double clicking on a tree object. Possible options: expand the object, edit the object, edit the object's position.	Edit the entity
OK	Accept Miscellaneous 2 changes and close dialog box.	
Cancel	Discard Miscellaneous 2 changes and close dialog box.	
Help	Access this Help page.	

See Also - The Miscellaneous 2 Options Page

Preferences Dialog
Miscellaneous Options

Tools – Preferences - Output Window Preferences Tab

Description

Output Window Preferences Tab

The Output Window is a spreadsheet with rows and columns. This command sets the number of columns and the number of rows in the output window.

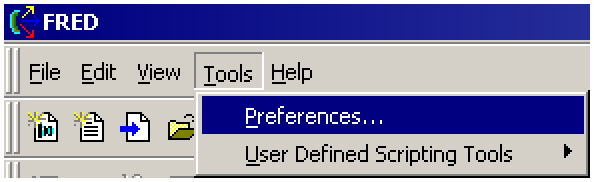
The Output Window spreadsheet can be toggled between a spreadsheet style presentation with cell borders, row numbers, and column letters and a text file style of presentation without cell borders, row numbers, and column letters using the Cells command. In either case, the output window is still a spreadsheet.

Note	The colors of the text, numbers, and formulas in the Output Window can be set to difference colors in the Format Tab of the Preferences.

How Do I Get There?

Output Window Preferences Tab

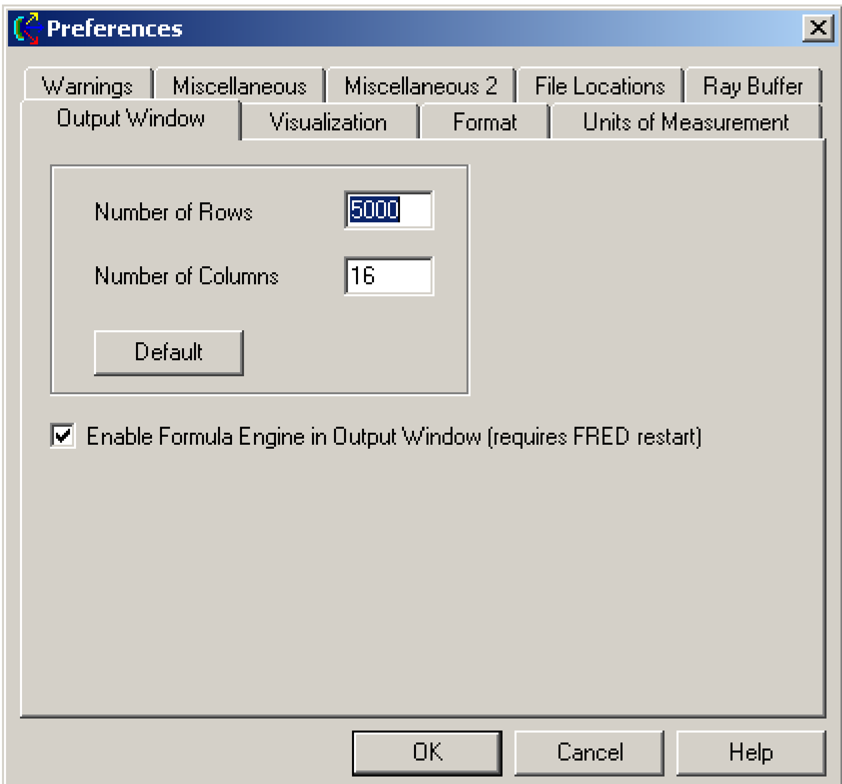
From the "Tools" Menu, Select "Preferences". The Output Window tab appears first.



Dialog Box and Controls

Output Window Preferences Tab

This preference dialog allows you to change the number of rows and columns in the output window.



Control	***Inputs***	***Defaults***
Number of Rows	Specifies the number of rows to show in the Output Window.	256
Number of Columns	Specifies the number of columns to show in the Output Window.	16
Default button	Sets the number of rows & columns to 256x16.	

Enable Formula Engine in Output Window (requires FRED restart)	Allows formulae to be entered in the individual cells of the output window, when checked.	Unchecked
OK	Accept Output Window changes and close dialog box.	
Cancel	Discard Output Window changes and close dialog box.	
Help	Access this Help page.	

See Also….
Output Window Preferences Tab

Preferences Dialog

Tools – Preferences - Units of Measurement Tab

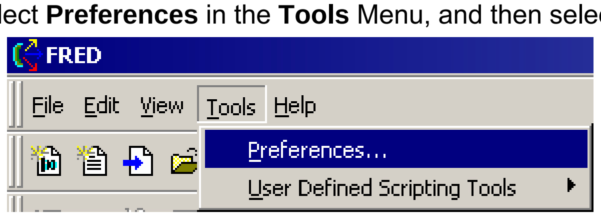
Description
How Do I Get There?
Dialog box and Controls
See Also…

Description
Units of Measurement Tab

This preferences page allows you to set the units of measurement for new systems. Changes made on this page apply to new systems. To change the units of an existing FRED document, select "Units and Scaling …" from the Tools menu.

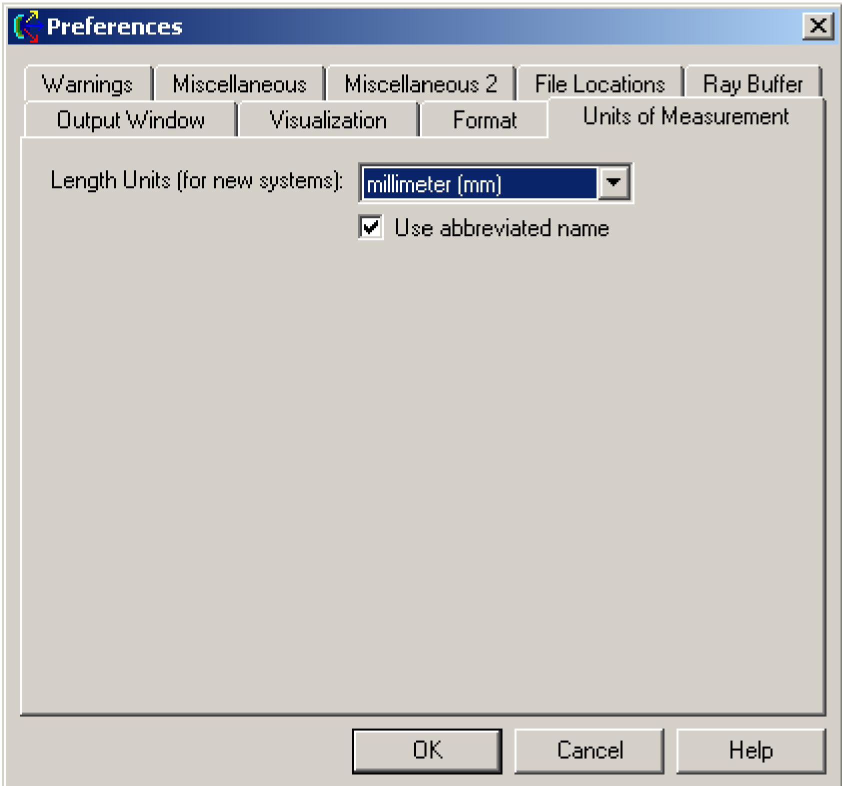
How Do I Get There?
Units of Measurement Tab

Select **Preferences** in the **Tools** Menu, and then select the **Units of Measurement** tab.



Dialog Box and Controls

Units of Measurement Tab



Control	***Inputs***	***Defaults***
Units List	Listing of all possible units of measurement	Millimeters
Use abbreviated name	Checked or Unchecked	Checked
OK	Accept Output Window changes and close dialog box.	
Cancel	Discard Output Window changes and close dialog box.	
Help	Access this Help page.	

See Also….

Units of Measurement Tab

[Preferences Dialog](#)

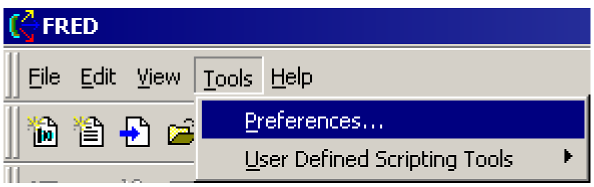
Tools – Preferences - Visualization Options Tab

Description
Visualization Options Tab

This help article describes the options that can be set for the Visualization window.

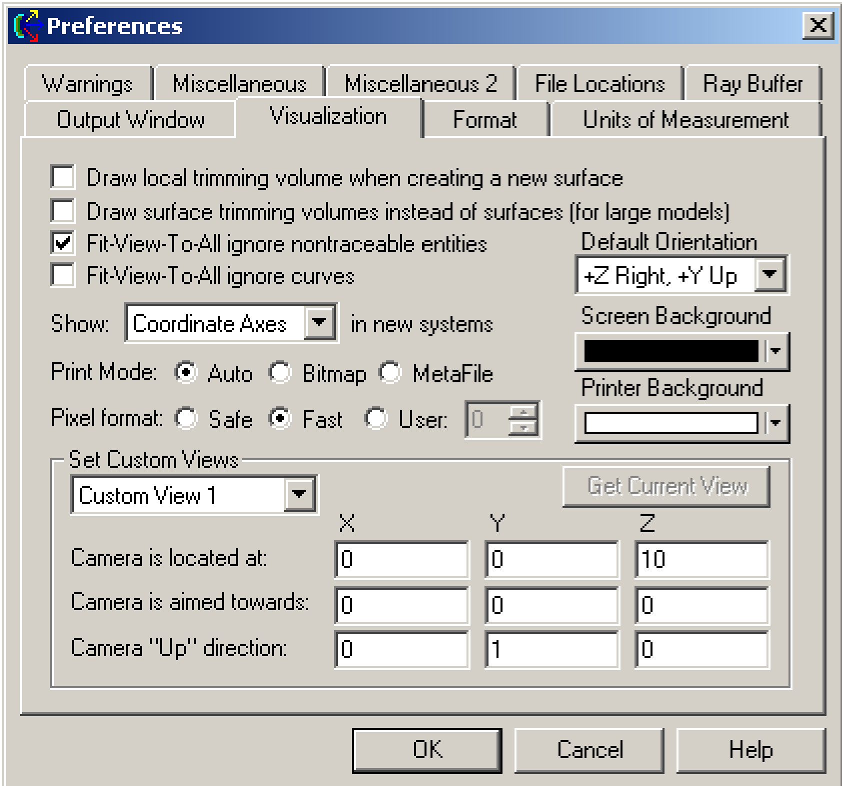
How Do I Get There?
Visualization Options Tab

From the **Tools** menu, select **Preferences**, then click on the **Visualization** tab.



Dialog Box and Controls
Visualization Options Tab

This dialog gives a listing of the Visualization options that can be set in FRED.



Control	Function	Default
Draw local trimming volume when creating a new surface	Enables drawing the local trimming volume box around new surfaces when they are created.	Unchecked
Draw surface trimming volumes instead of surfaces	Enables drawing the surface trimming volume box around surfaces. For use with large models.	Unchecked
Fit-View-To-All ignore nontraceable entities	Ignore nontraceable entities when sizing to Fit-View-To-All.	Unchecked
Fit-View-To-All ignore curves	Ignore curves when sizing to Fit-View-To-All.	Unchecked
Show ... in new systems	Sets what is shown when a new FRED document is created.	Coordinate Axes
Print Mode	Auto, Bitmap or Metafile	Auto
Pixel format	Determines rendering mode FRED will use when it draws the system in the Visualization Window.	Fast
Default Orientation	Specifies which view of the system is the default when a file is opened or created. (1st entry sets out-of-page axis direction)	-Z Axis, +Y up
Screen Background	Select color of the background when viewing the optical system in FRED.	Automatic

Printer Background	Select the color of the background when printing the optical system. Warns if there is too much of a particular component in the chosen color (which could result in wasting ink).	White
Set Custom Views		
Custom View 1, 2, 3	Displays the settings for Custom View in the text boxes shown below.	Selected
Camera is located at: (X,Y,Z)	Sets (X,Y,Z) coordinates of camera location for selected Custom View.	0, 0, 10
Camera is aimed at: (X,Y,Z)	Sets (X,Y,Z) coordinates for camera aim point for selected Custom View.	0, 0, 0
"Up" relative to camera: (X,Y,Z)	Sets (X,Y,Z) direction cosines of camera orientation for selected Custom View.	0, 1, 0
Get Current View	Get camera location, aim & up direction for current view.	
OK	Accept Visualization changes and close dialog box.	
Cancel	Discard Visualization changes and close dialog box.	
Help	Access this Help page.	

See Also….
Visualization Options Tab

Preferences Dialog

Tools – Preferences - Warnings Options Tab

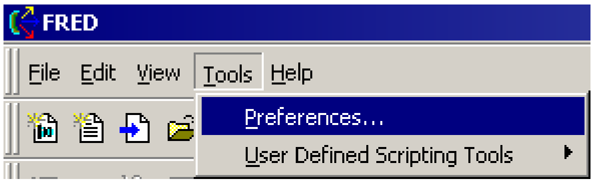
Description
How Do I Get There?
Dialog box and Controls
See Also…

Description
Warnings Options Tab

This help article describes the options in FRED that affect the macro editor.

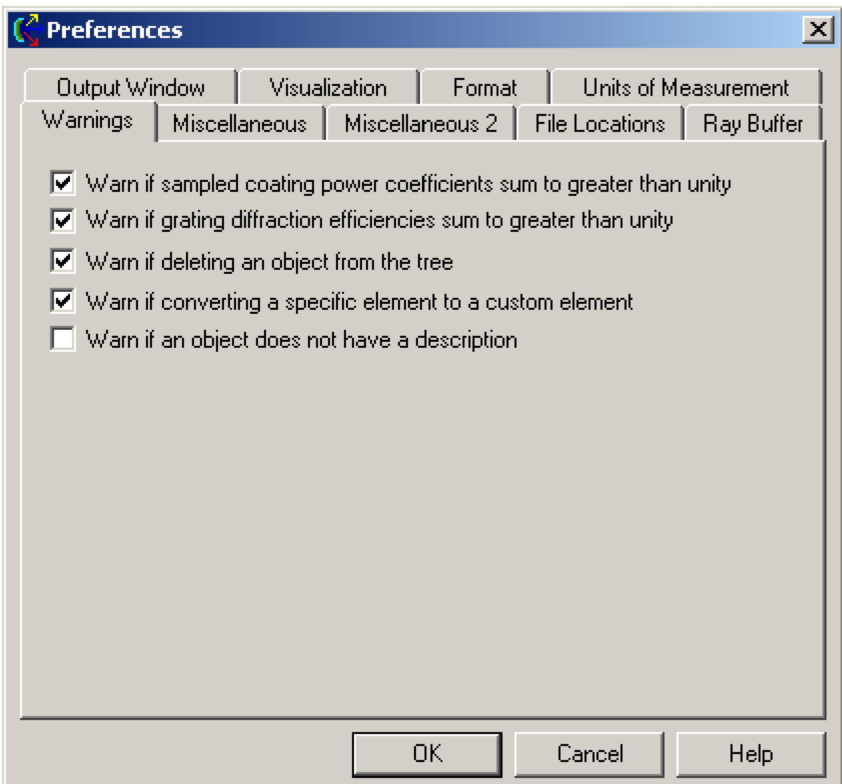
How Do I Get There?
Warnings Options Tab

From the Tools menu, choose Preferences. Click on the "Warnings" tab on the dialog that appears.



Dialog Box and Controls
Warnings Options Tab

This dialog gives a listing of the settings that can be set for displaying text in FRED.



Control	Inputs	Defaults
Warn if sampled coating power coefficients sum to greater	When checked, warns if the sum of power coefficients is greater than 1.	Checked

than unity		
Warn if grating diffraction efficiencies sum to greater than unity	When checked, warns if the sum of diffraction efficiencies is greater than 1.	Checked
Warn if deleting an object from the tree	When checked, asks confirmation on attempt to delete an object from the tree.	Checked
Warn if converting specific element to custom element	When checked, warns if action taken that can convert a specific element, such as a lens, mirror, or prism, to a custom element. These actions include adding or deleting curves and surfaces.	Checked
Warn if an object does not have description	When checked, warns if the object currently being created has an empty description.	Unchecked
OK	Accept Warnings changes and close dialog box.	
Cancel	Discard Warnings changes and close dialog box.	
Help	Access this Help page.	

See Also….

Warnings Options Tab

Preferences Dialog

3D View - Menu commands

The 3-D View menu offers the following commands:

Trackball Mode	Switches the program into Trackball Mode (the default mode upon creating a new optical layout).
Magnify Mode	Switches the program into Magnify Mode
Object Selection	Allows selection of objects in the Visualization window by clicking on them with the mouse
Toggle Perspective	Switches between orthographic (layout or right-angle view) and perspective (real life view) mode
View All	Zooms out to view the entire system
Edit Background Grid...	Displays a dialog for editing properties of the background grid
Mouse Coordinates	Displays the mouse coordinates in the status bar at the bottom of the window
Movie...	Displays a dialog for creating a movie of the system
Camera->Orbit Camera	Orbits the camera about a point in the system
Camera->Translate Camera	Moves the camera from its current position to a new position
Camera->Rotate Camera	Rotates the camera about its current point in the system
Scene->Translate Scene	Moves the scene from its current position to a new position
Scene->Rotate Scene	Rotates the scene about the camera's location in the system
View Towards:	Behaves the same way as the drop down menu on the toolbar: allows selection of a view towards one of the 6 axes directions, 3 saved custom views, or a specified view

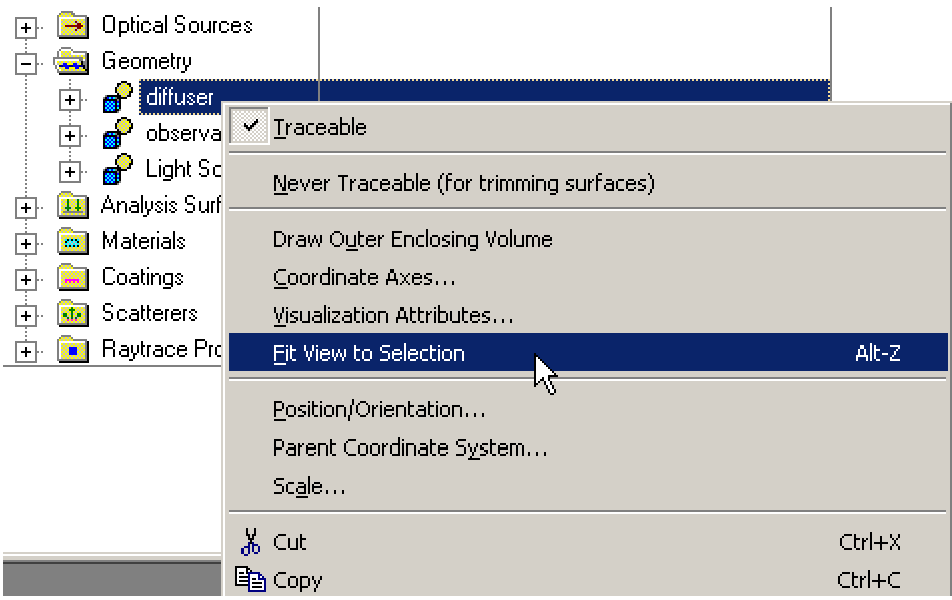
See **NEW** navigation features here: Navigating FRED's 3D View

Trackball Mode	Switches the program into Trackball Mode (the default mode upon creating a new optical layout).
Magnify Mode	Switches the program into Magnify Mode
Object Selection	Allows you to select objects in the Visualization window by clicking on them with the mouse
Toggle Perspective	Switches between orthographic (layout or right-angle view) and perspective (real life view) mode

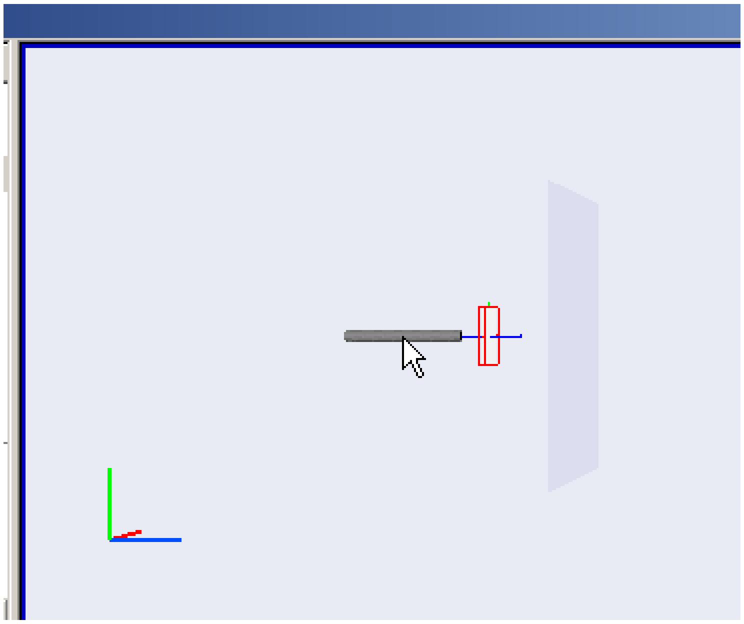
View All	Zooms out to view the entire system
Edit Background Grid...	Displays a dialog that allows you to edit the properties of the background grid
Mouse Coordinates	Displays the mouse coordinates in the status bar at the bottom of the window
Movie...	Displays a dialog that allows you to create a movie of the system
Camera->Orbit Camera	Orbits the camera about a point in the system
Camera->Translate Camera	Moves the camera from its current position to a new position
Camera->Rotate Camera	Rotates the camera about its current point in the system
Scene->Translate Scene	Moves the scene from its current position to a new position
Scene->Rotate Scene	Rotates the scene about the camera's location in the system
View Towards:	Behaves the same way as the drop down menu on the toolbar: allows you to select a view towards one of the 6 axes directions, 3 saved custom views, or a specified view

There are new mouse operations in the 3D View. These features are available without regard to the view's mode, and are loosely similar to how SolidWorks behaves.

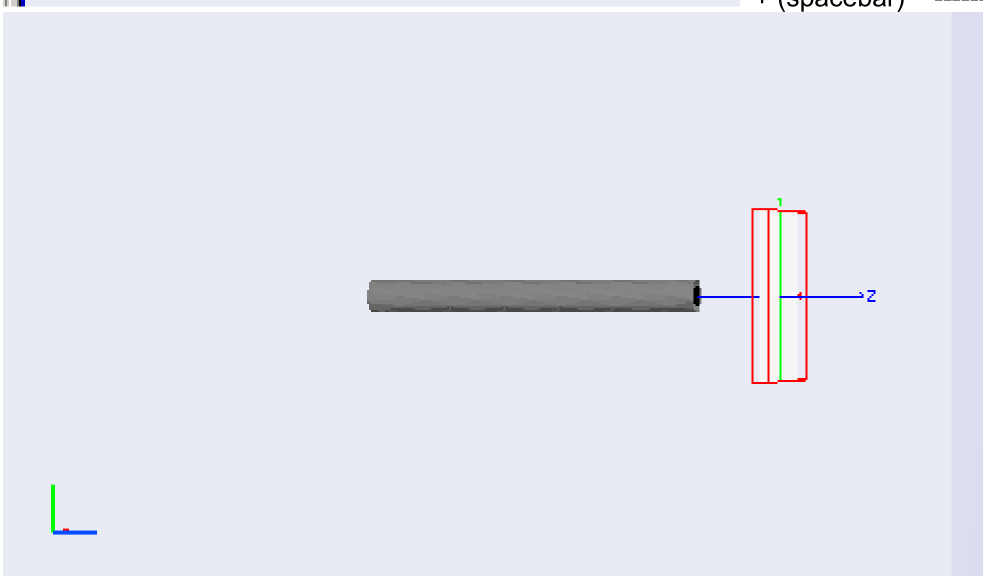
- Holding down middle mouse button (wheel) and dragging now rotates scene.
- Holding down control and middle mouse button pans/translates the scene.
- Holding down shift and middle mouse button zooms the scene about screen center as mouse is dragged vertically.
- Mouse wheel zoom now zooms about the mouse point.
- The visualization view can now be zoomed to fit the current selection(s) in the tree view by choosing "Fit view to selection" on the popup menu or by pressing Alt-Z. The rotation center will also be changed to match the center of the new view.



- The visualization view can be zoomed to fit the entity that's under the mouse by pressing the space bar (when the visualization view has focus). The rotation center will also be changed to match the center of the new view.



+ (spacebar) ----------->>



3D View - Trackball mode

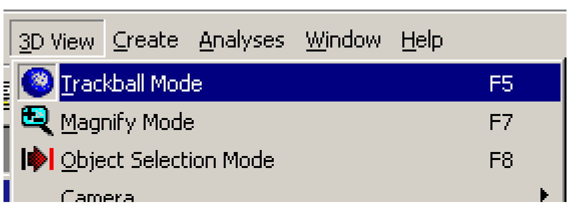
Description - Trackball mode

Allows the contents of the Visualization window to be rotated about a point. The default center of rotation is the global origin. The rotation point can be changed to the center of the trimming volume of any surface in the Visualization Window by holding the <CTRL> key down and left mouse clicking on the surface. When this done, the surface will momentarily change colors indicating that its trimming volume is now the center of rotation. To change back to the global origin, <CTRL>+left mouse click on the background in the Visualization window. When this is done, the Visualization window background will momentarily turn green.

How Do I Get There? - Trackball mode

There are three different ways to execute this command:

1. Select Trackball Mode in the 3D View Menu,



2. or press the keyboard accelerator keys: F5,
3. or press the toolbar button: 

Application Notes - Trackball mode

None.

Examples - Trackball mode

None.

See Also -Trackball mode

None.

3D View - Magnify Mode

Description - Magnify Mode

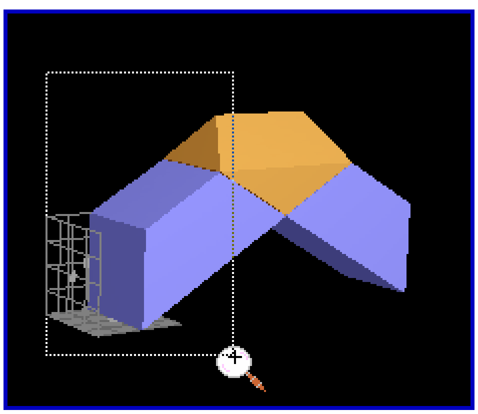
This command toggles on and off the Magnification Mode. In the magnification mode the cursor changes to a magnifying glass, . If the Shift key is pressed, then the mode changes to demagnification and the magnification pointer changes to a minus sign, . The magnification pointer can be used in two modes: simple point and click or dragging a selection rectangle of the area to be magnified.

The point and click method will employ a magnification of 200% (2X) and a demagnification of 50% (0.5X). The point and click method will also center the coordinates of the magnification pointer in the Visualization window when it was clicked.

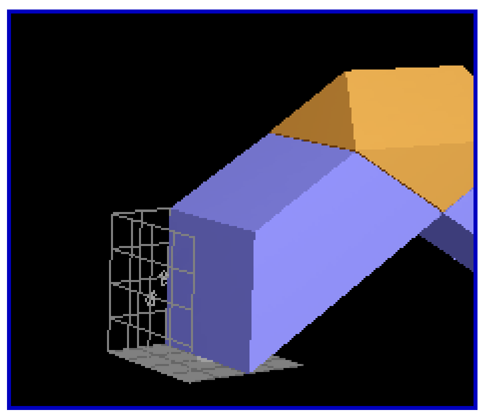
Dragging the selection rectangle over an area will take the long axis of the selected area and fit that into the visualization window.

Visualization (example) - Magnify Mode

This figure shows an example of magnification in the Visualization Window by dragging a selection rectangle over the objects.



Before magnification

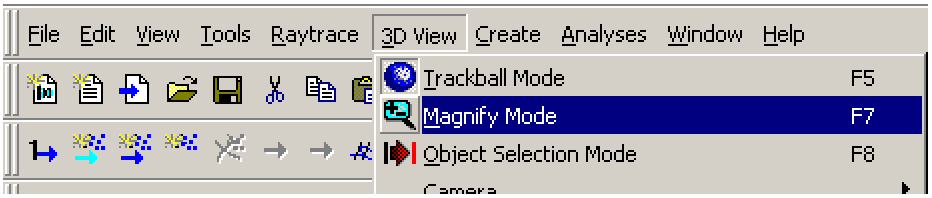


After magnification

How Do I Get There? - Magnify Mode

There are three different ways to execute this command:

1. Select Magnification Mode in the 3D View Menu,



2. or press the keyboard accelerator keys: F7,

3D View - Object Selection

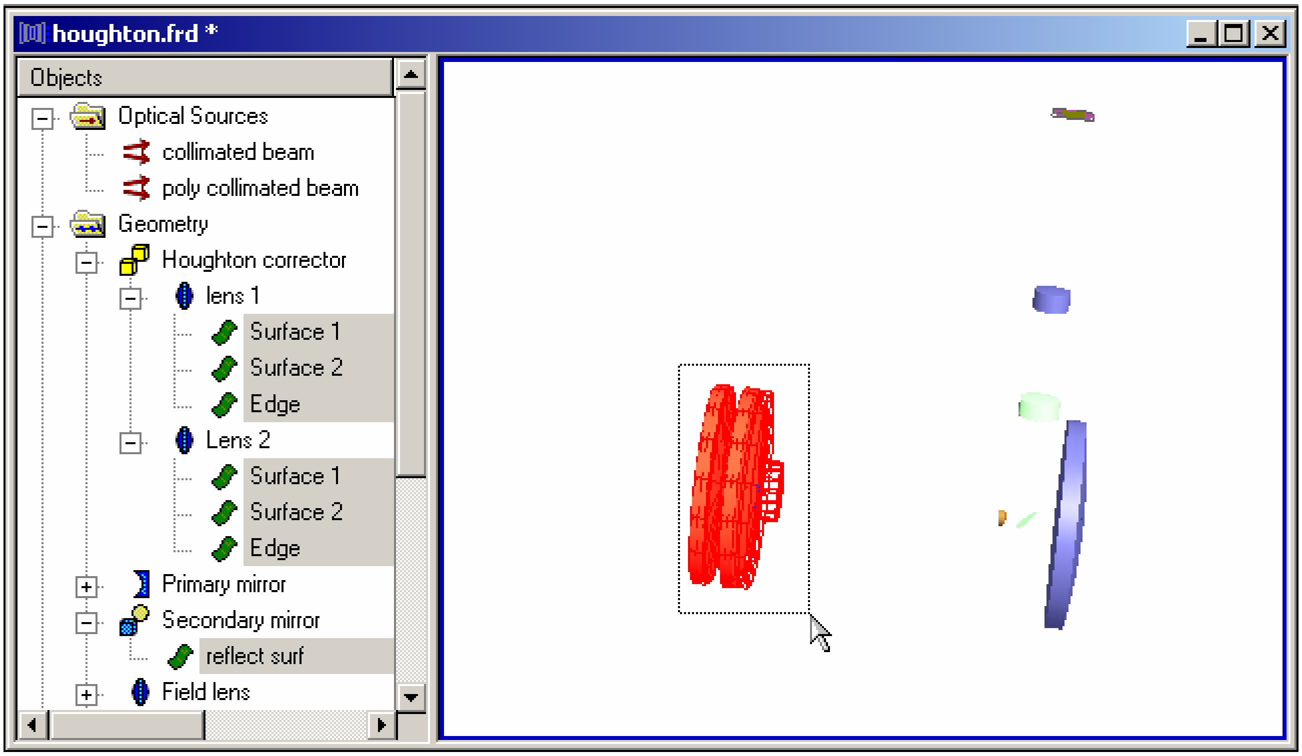
Description
Visualization (example)
How Do I Get There?
Application Notes
Examples
See Also…

Description - Object Selection

This command toggles on and off the ability to select individual objects in the Visualization Window with the mouse. The objects can be selected with a left mouse click while pointing at the object or with by dragging a selection rectangle over the objects. Once selected, the objects will be highlighted in both the Visualization Window and the Tree View. The selected objects can then be operated on with any command that handles multiple objects, i.e. visualization attributes, traceability, gluing, etc. You can select many objects at once as well as one by one. This is equivalent to selecting the objects in Tree View only in the Tree View the user must use the <CTRL> with the left mouse button to make multiple selections.

Visualization (example) - Object Selection

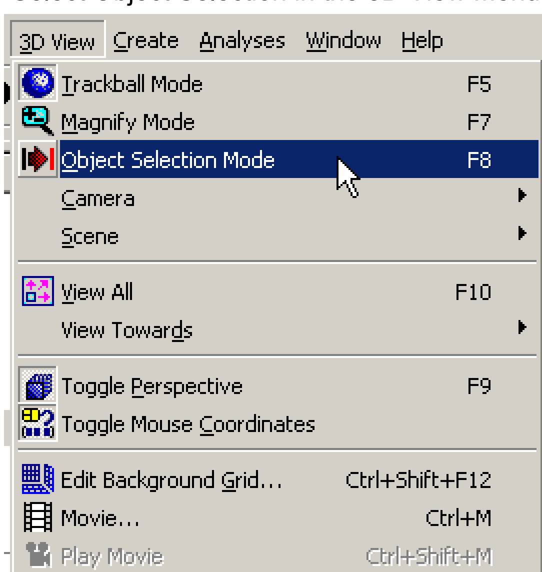
This figure shows an example of multiple object selection in the Visualization Window by dragging a selection rectangle over the objects. Note that the selected objects are highlighted in the Tree View.



How Do I Get There? - Object Selection

There are three different ways to execute this command:

1. Select Object Selection in the 3D View Menu,



2. or press the keyboard accelerator keys: F8,
3. or press the toolbar button: 

Application Notes - Object Selection

None.

Examples - Object Selection

None.

See Also - Object Selection

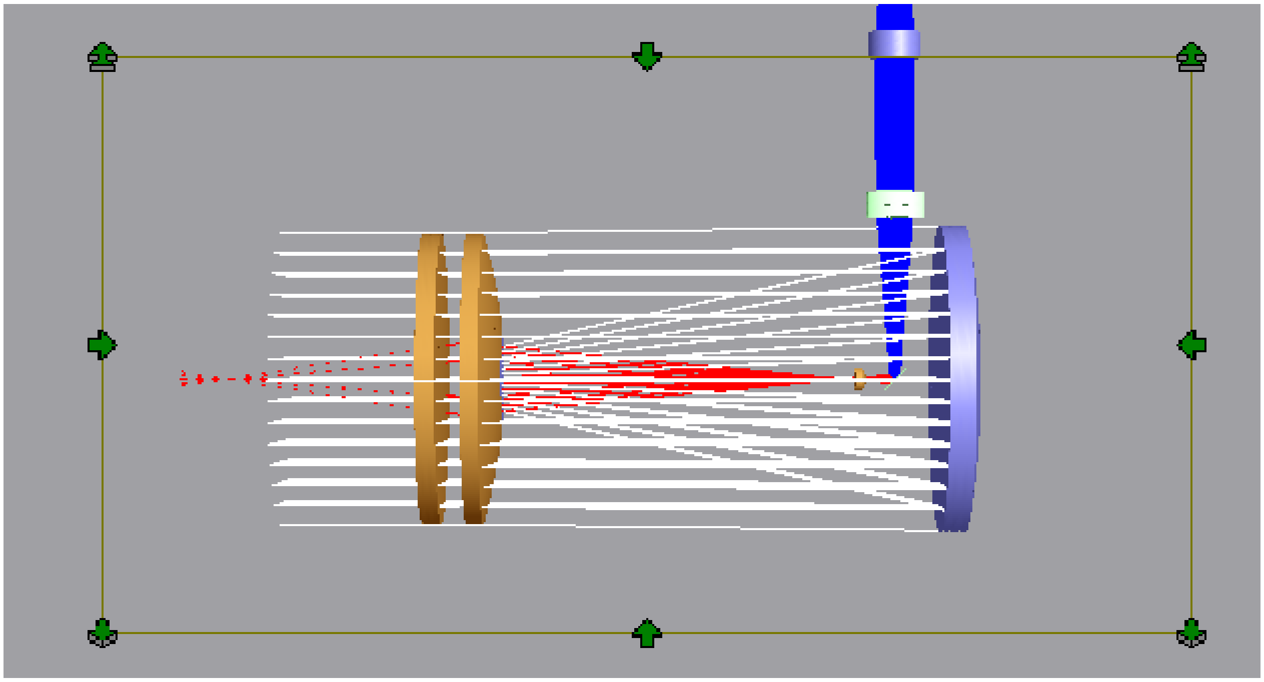
None

3D View – Scene - Translate Scene

Description - Translate Scene

This command allows the scene in the visualization window to be translated interactively with the mouse.

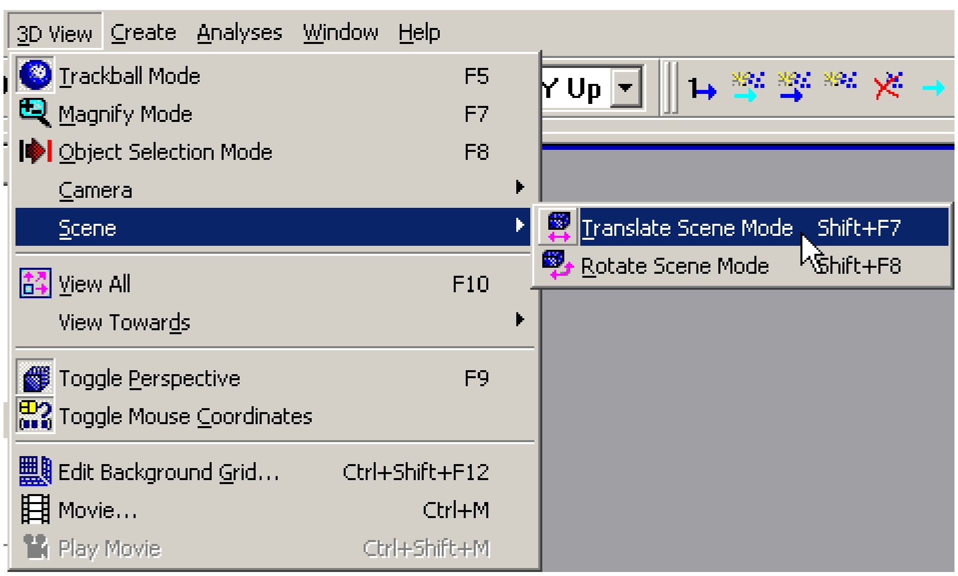
Visualization (example) - Translate Scene



How Do I Get There? - Translate Scene

There are three different ways to execute this command:

1. Select Scene and then Translate Scene in the 3D View Menu,



2. or press the keyboard accelerator keys: Shift+F7,
3. or press the toolbar button: 

Application Notes - Translate Scene

None.

Examples - Translate Scene

None.

See Also - Translate Scene

None.

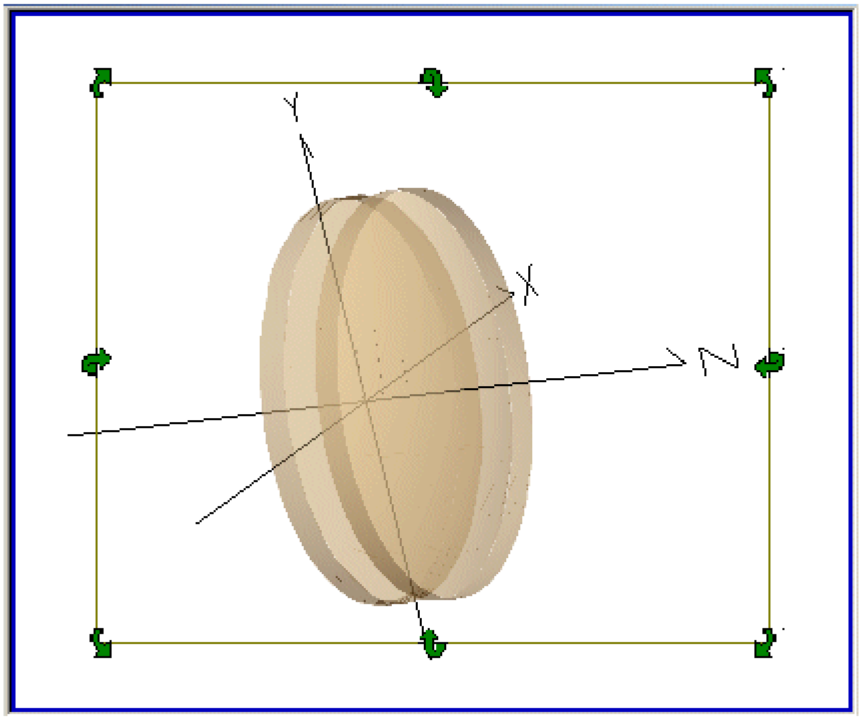
3D View – Scene - Rotate Scene

- Description
- Visualization (example)
- How Do I Get There?
- Application Notes
- Examples
- See Also…

Description - Rotate Scene

This command allows the scene in the visualization window to be rotated interactively with the mouse.

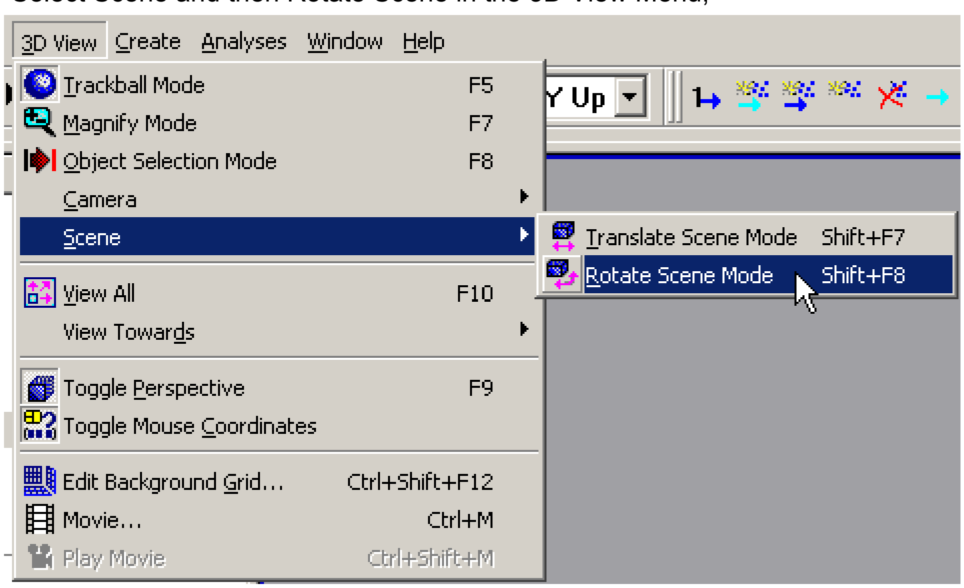
Visualization (example) - Rotate Scene



How Do I Get There? - Rotate Scene

There are three different ways to execute this command:

1. Select Scene and then Rotate Scene in the 3D View Menu,



2. or press the keyboard accelerator keys: Shift+F8,
3. or press the toolbar button: 

Application Notes - Rotate Scene

None.

Examples - Rotate Scene

None.

See Also - Rotate Scene

None.

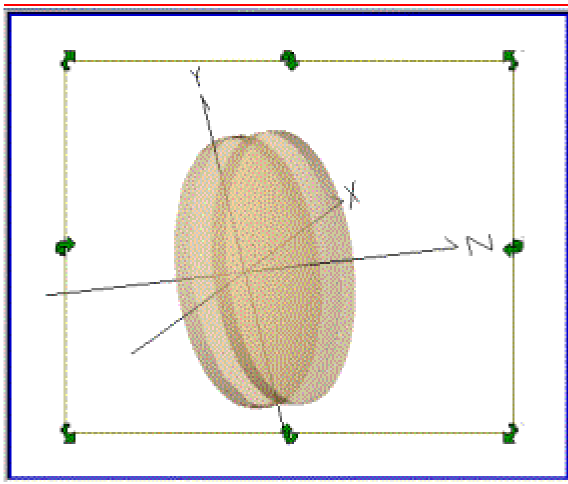
3D View – Camera - Rotate Camera

Description - Rotate Camera

This command allows the Camera's view of the visualization window to be rotated interactively with the mouse.

Note: The motion relative of the visualization view to the mouse motion is the opposite of the scene rotation because you are moving the camera instead of the scene.

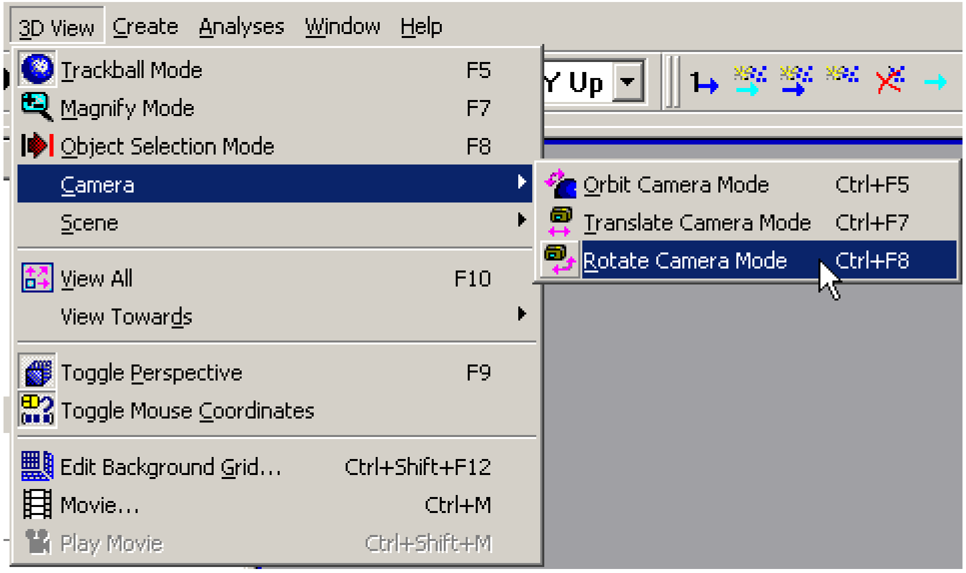
Visualization (example) - Rotate Camera



How Do I Get There? - Rotate Camera

There are three different ways to execute this command:

1. Select Camera and then Rotate Camera in the 3D View Menu,



2. or press the keyboard accelerator keys: Ctrl+F8,

3. or press the toolbar button: 

Application Notes - Rotate Camera

None.

Examples - Rotate Camera

None.

See Also - Rotate Camera

None.

3D View – View All

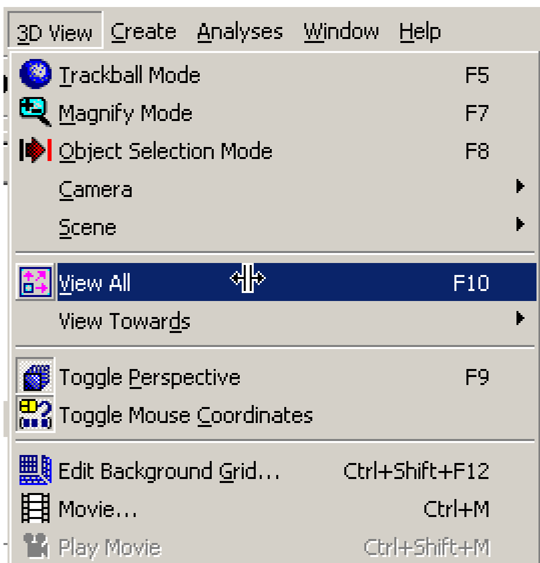
Description - View All

This command will adjust the zoom of the visualization window so that all of the objects are rendered in the view. This command actually keys off the geometry parent node's outer trimming volume, so even if some objects are flagged as not traceable this command will adjust the zoom to view them even though they will not be rendered.

How Do I Get There? - View All

There are three different ways to execute this command:

1. Select View All in the 3D View Menu,



2. or press the keyboard accelerator keys: F10,
3. or press the toolbar button: 

See Also - View All

3D View – View Towards

Description - View Towards

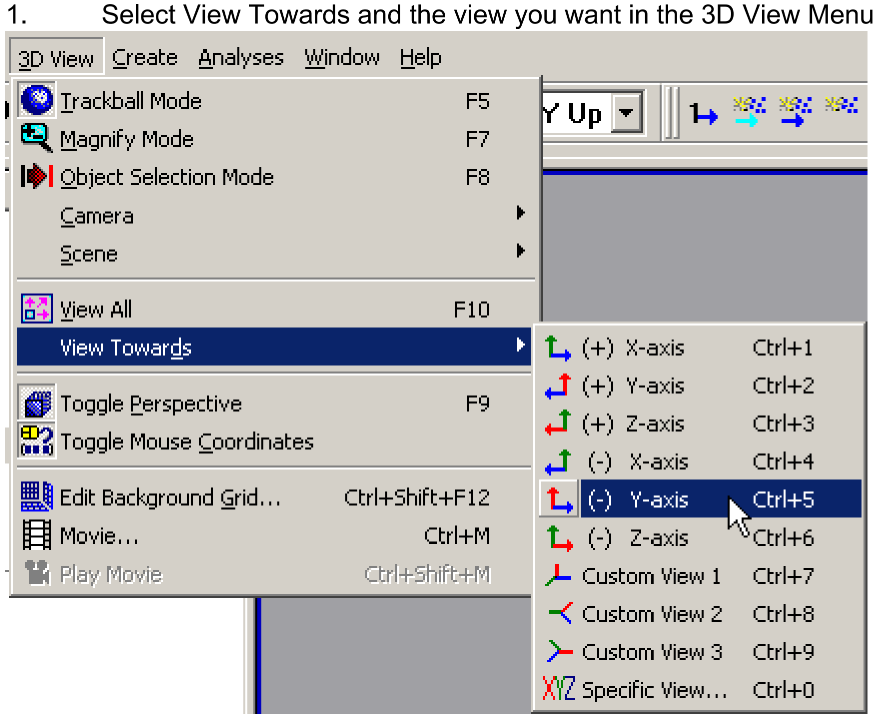
This command allows you to switch the camera view of the Visualization window to look towards one of ten directions.

1. Six predefined directions: the plus and minus X, Y, and Z axes views.
2. Three custom views set in the Visualization preferences.
3. One custom view that can be set in the Camera Configuration dialog.

How Do I Get There? - View Towards

There are two different ways to execute this command:

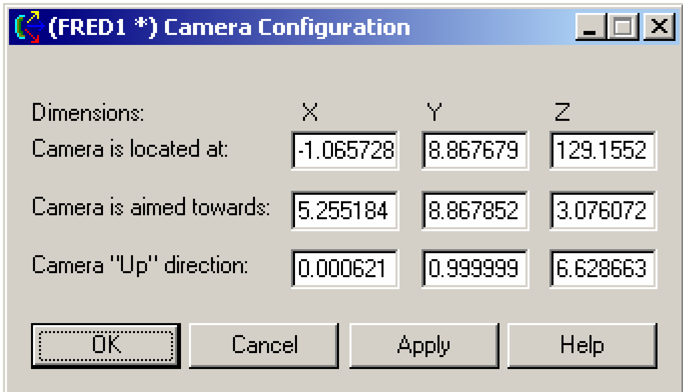
1. Select View Towards and the view you want in the 3D View Menu,



2. Press the keyboard accelerator keys: Ctrl+0 thru Ctrl+9

Dialog Box and Controls - View Towards

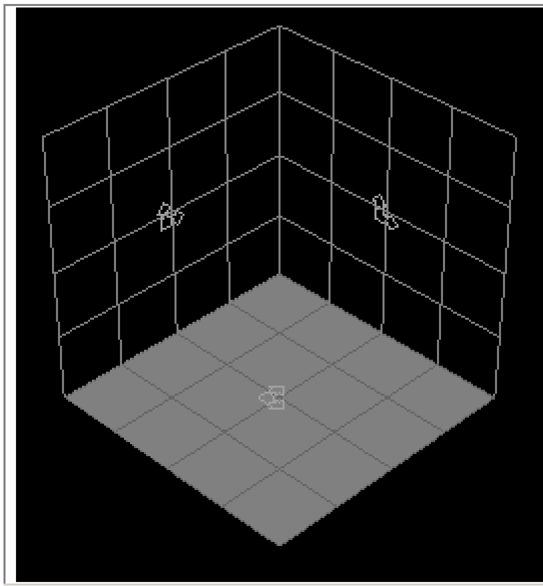
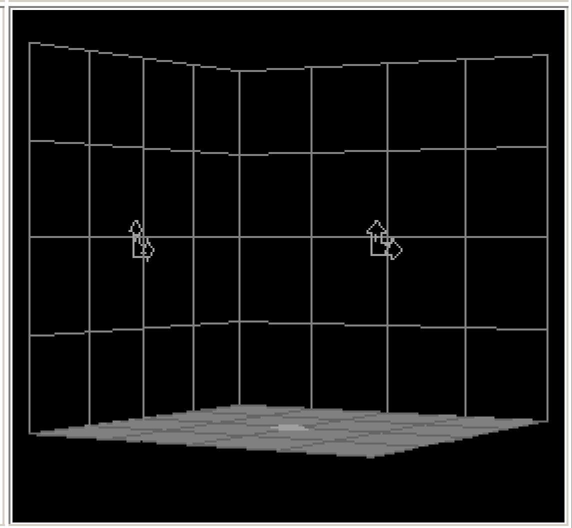
Selecting Specific View … or pressing <CTRL>+0 will open the Camera Configuration dialog, which allows you to position the camera anywhere in space.



Control	***Inputs***	***Defaults***
Camera is located at:	Specifies the (X,Y,Z) position of the camera (in the global coordinate system).	0, 0, 9.82
Camera is aimed towards:	Specifies the point towards which the camera is aimed (in the global coordinate system).	0, 0, 0
Camera "Up" direction:	Specifies the direction in which the top of the camera is pointed. Cannot be same as aim direction.	0, 1, 0
OK	Accept Camera Configuration and close dialog box.	
Cancel	Discard Camera Configuration changes and close dialog box.	
Apply	Apply Camera Configuration changes and keep dialog box open.	
Help	Access this Help page.	

Examples - View Towards

Listed below are some common camera positions that may be useful.

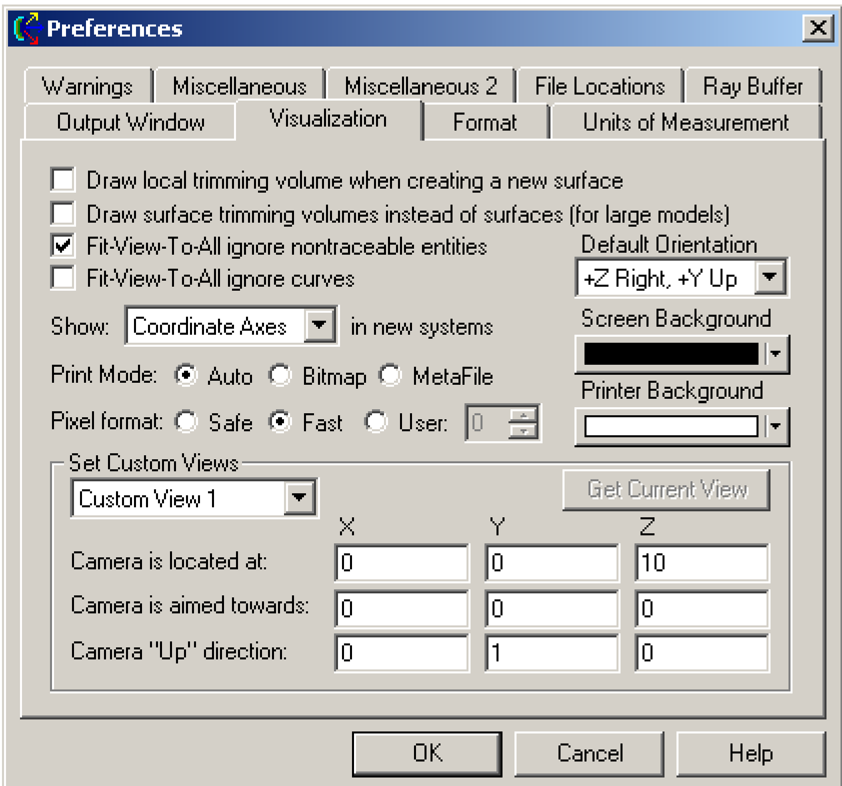
Camera Position/Orientation	*Description*	*Picture*
Location = {-7, 7, 7}; Aim Point = {0, 0, 0}; Up Direction = {0, 1, 0}	Elevated in y and spaced away in X and Z, looking towards the global origin	
Location = {-8.75, 0, 5.25}; Aim Point = {0, 0, 0}; Up Direction = {0, 1, 0}	Low, rotated view: begin at +X-axis view and rotate about the vertical (Y) axis	

See Also…. - View Towards

3D View - Background Grid Dialog

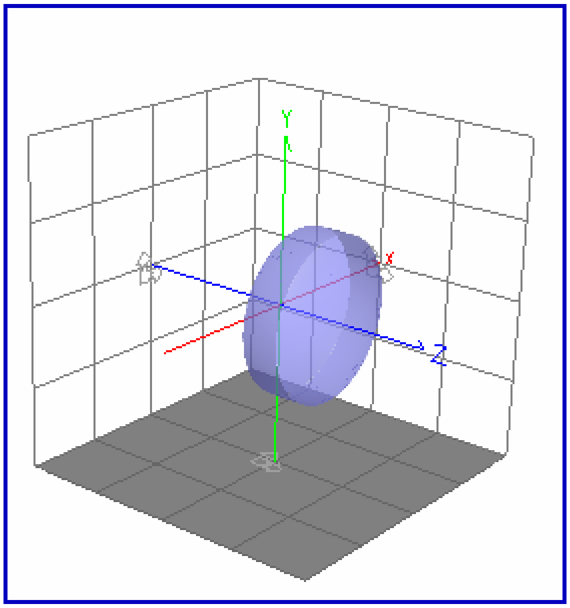
Description
Background Grid Dialog

This command brings up the dialog that allows you to draw and change the Background Grid. Whether a new FRED document opens with a Background grid or not can be set in the preferences. The Background Grid can be added to Visualization window at any time.

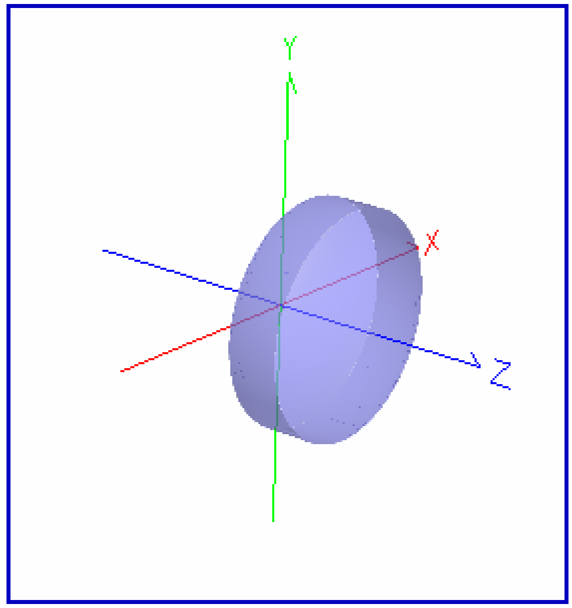


Visualization (example)
Background Grid Dialog

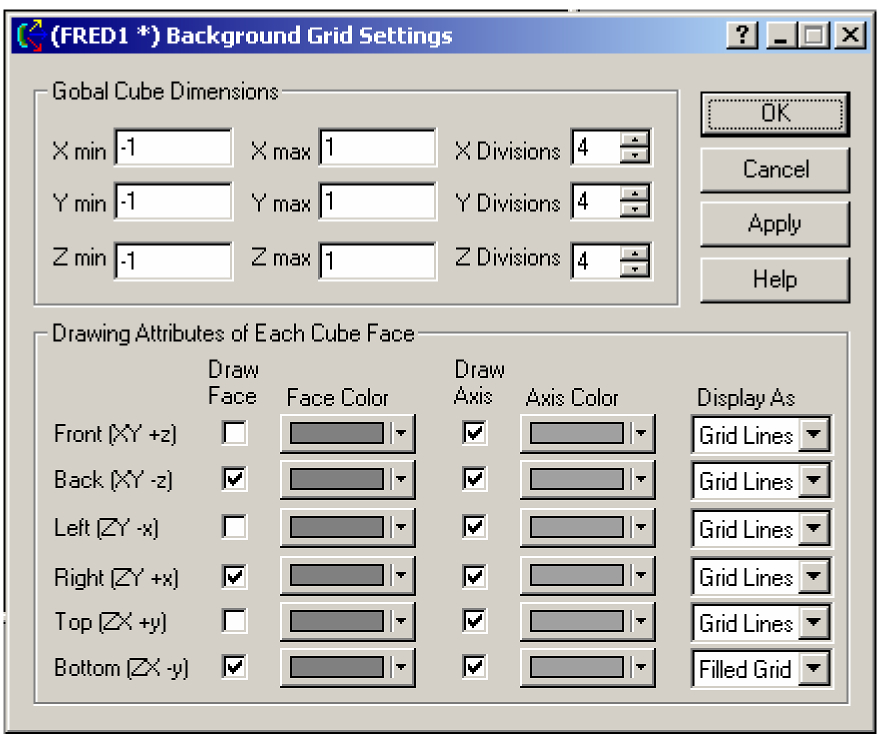
An example of with and without the Background Grid is shown below. The Background Grid dialog settings for the Background Grid are shown below. Note that the coordinate axes are included for reference and are not part of the background grid dialog.



Background Grid



No Background Grid



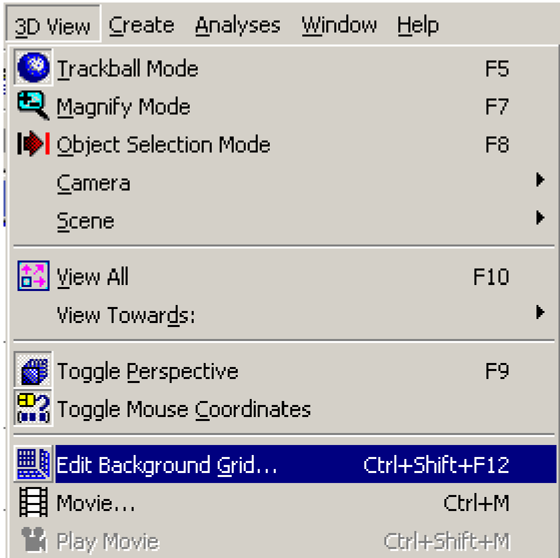
Background Grid settings for the example shown above.

How Do I Get There?

Background Grid Dialog

There are three different ways to execute this command:

1. Select Edit Background Grid in the 3D View Menu,

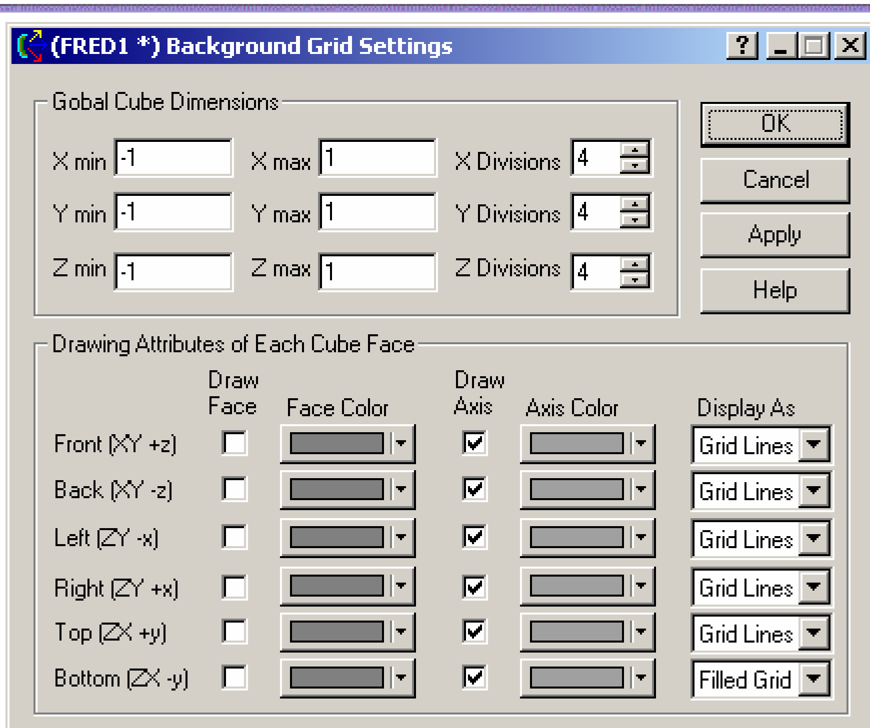


2. or press the keyboard accelerator keys: Ctrl+Shift+F12,

3. or press the toolbar button: 

Dialog Box and Controls

Background Grid Dialog



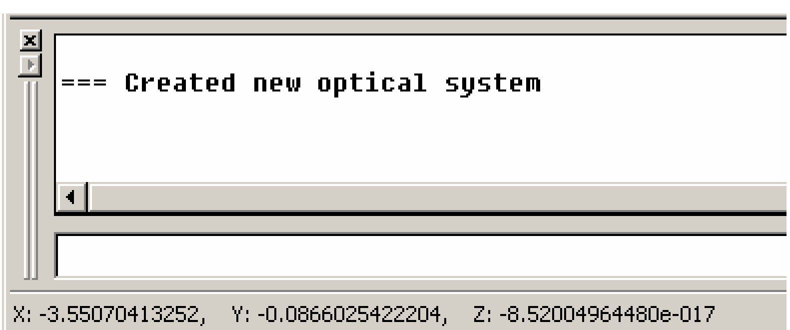
Control	Inputs	Defaults
Global Cube Dimensions		
X/Y/Z min and max	Lists the minimum and maximum extent of the background grid on the X axis.	-1, 1
X/Y/Z Divisions	Lists the number of divisions in the X direction of the background grid.	4
Drawing Attributes of Each Cube Face		
Face	When checked, the cube face listed to the left will be drawn (can be set in the preferences).	Unchecked
Face Color	Selects the color of the given grid face.	Dark gray
Axis	When checked, draws the axis labels for the face listed to the left. Overridden by the Face checkbox.	Checked
Axis Color	Selects the color of the axis labels.	Light gray
Display As	Selects the drawing style for the background grid faces. Options are Filled Grid, Grid Lines, and Grid Points.	Grid lines
OK	Accept Background Grid Settings changes and close dialog box.	
Cancel	Discard Background Grid Settings changes and close dialog box.	
Apply	Apply Background Grid Settings changes and keep dialog box open.	
Help	Access this Help page.	

3D View – Toggle Mouse Coordinates

Description
How Do I Get There?

Description - Mouse Coordinates

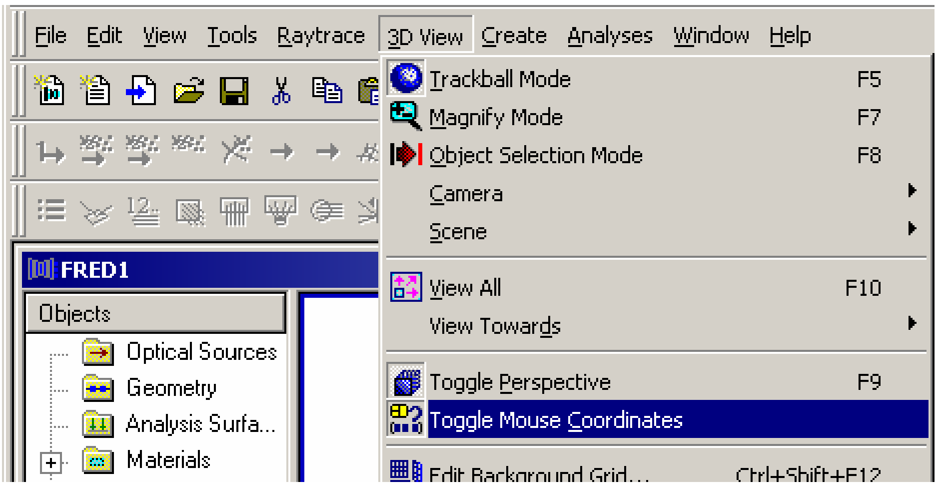
This command enables or disables the mouse coordinates from being shown on the status bar.



How Do I Get There? - Mouse Coordinates

There are two different ways to execute this command:

1. Select "Toggle Mouse Coordinates" in the 3D View Menu,

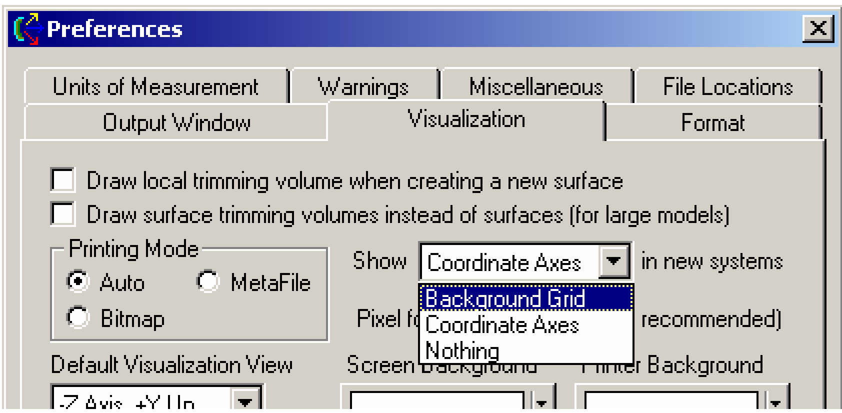


2. or press the toolbar button:  (Since this button is not available by default, you will have to customize the toolbar to see this button.),

3D View – Edit Background Grid Dialog

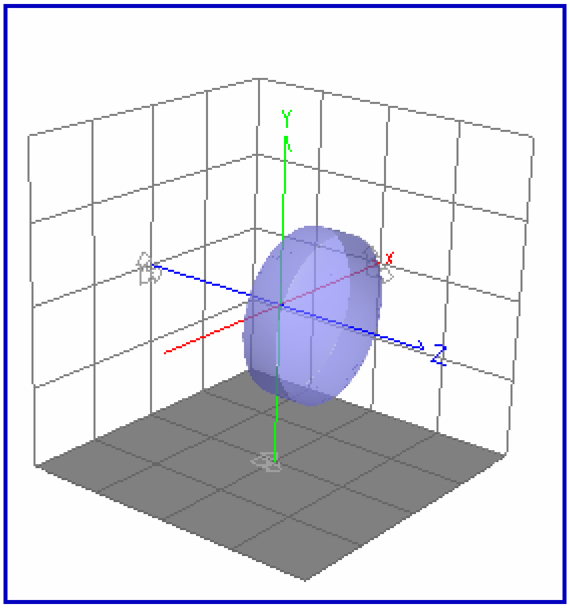
Description - Background Grid Dialog

This command brings up the dialog that allows you to draw and change the Background Grid. Whether a new FRED document opens with a Background grid or not can be set in the preferences. The Background Grid can be added to Visualization window at any time.

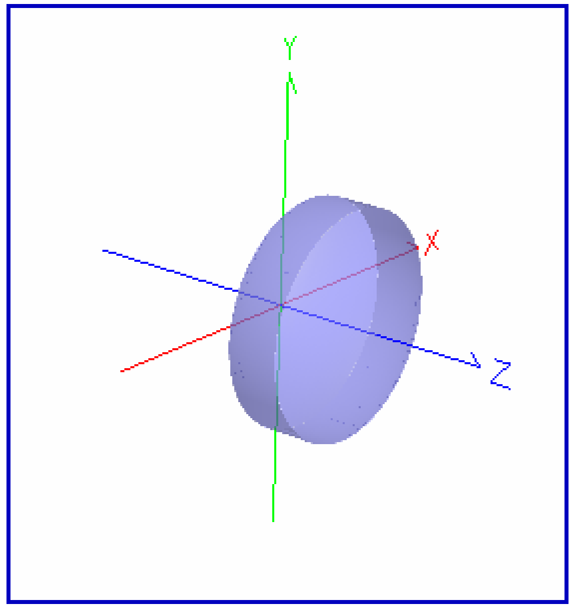


Visualization (example) - Background Grid Dialog

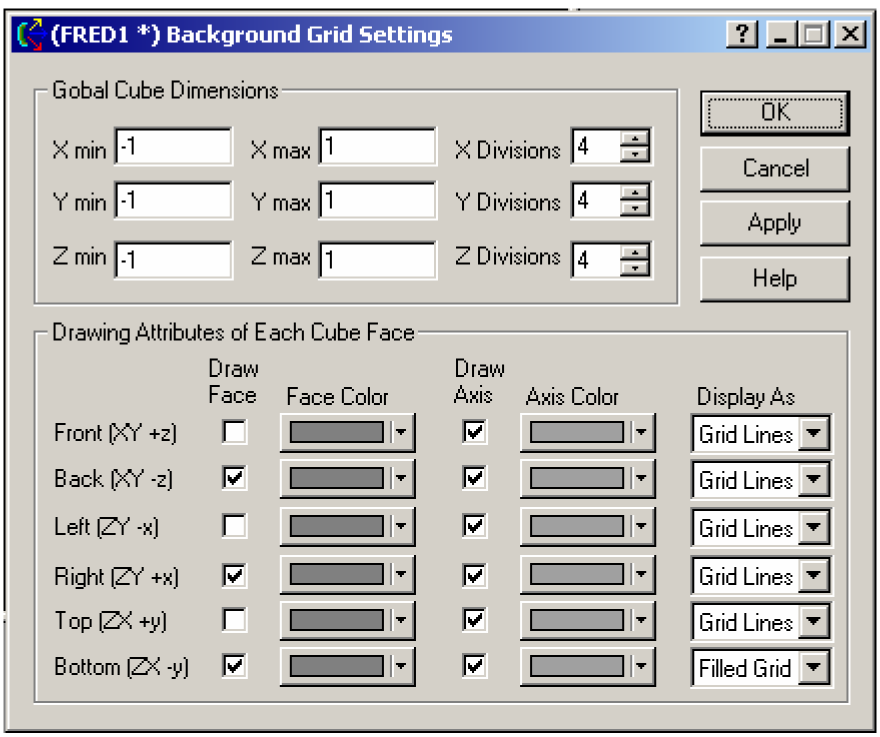
An example of with and without the Background Grid is shown below. The Background Grid dialog settings for the Background Grid are shown below. Note that the coordinate axes are included for reference and are not part of the background grid dialog.



Background Grid



No Background Grid

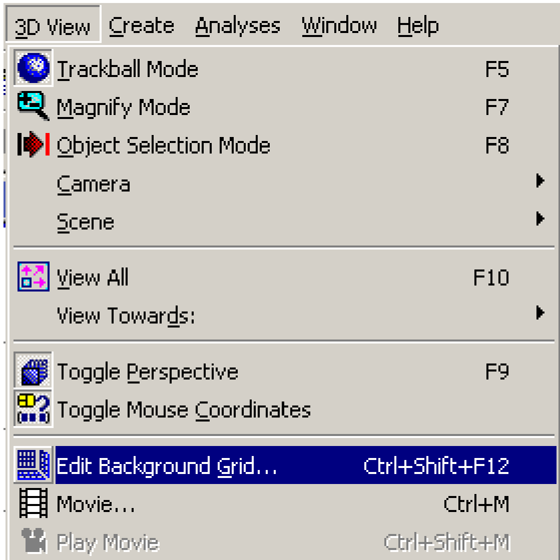


Background Grid settings for the example shown above.

How Do I Get There? - Background Grid Dialog

There are three different ways to execute this command:

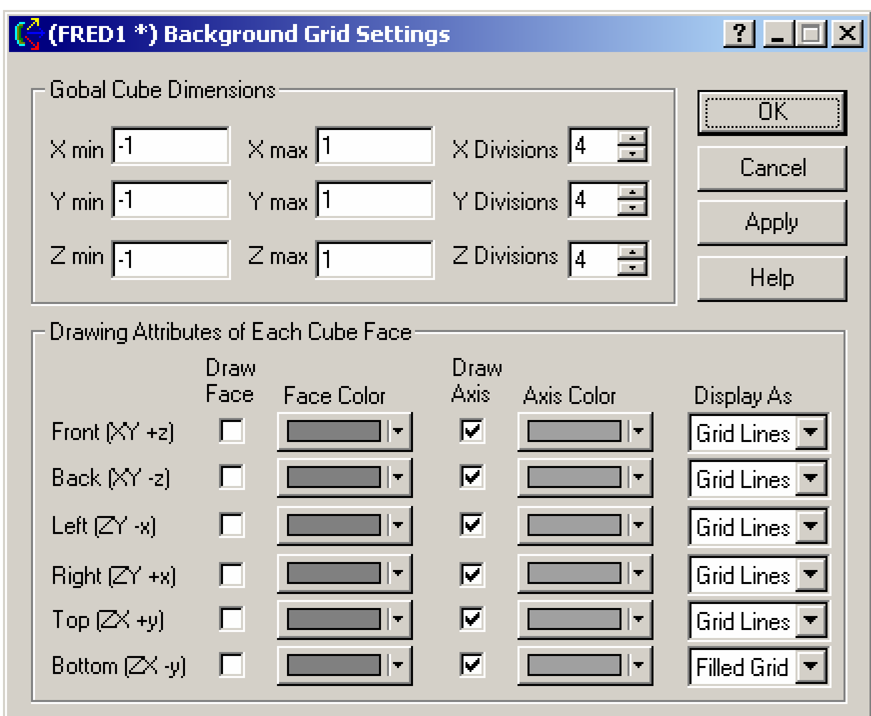
1. Select Edit Background Grid in the 3D View Menu,



2. or press the keyboard accelerator keys: Ctrl+Shift+F12,

3. or press the toolbar button: 

Dialog Box and Controls - Background Grid Dialog



Control	*Inputs*	*Defaults*
Global Cube Dimensions		

X/Y/Z min and max	Lists the minimum and maximum extent of the background grid on the X axis.	-1, 1
X/Y/Z Divisions	Lists the number of divisions in the X direction of the background grid.	4
Drawing Attributes of Each Cube Face		
Face	When checked, the cube face listed to the left will be drawn (can be set in the preferences).	Unchecked
Face Color	Selects the color of the given grid face.	Dark gray
Axis	When checked, draws the axis labels for the face listed to the left. Overridden by the Face checkbox.	Checked
Axis Color	Selects the color of the axis labels.	Light gray
Display As	Selects the drawing style for the background grid faces. Options are Filled Grid, Grid Lines, and Grid Points.	Grid lines
OK	Accept Background Grid Settings changes and close dialog box.	
Cancel	Discard Background Grid Settings changes and close dialog box.	
Apply	Apply Background Grid Settings changes and keep dialog box open.	
Help	Access this Help page.	

3D View - The FRED Movie Dialog

Description

The FRED Movie Dialog

The Movie feature in FRED allows you to create a sequence of Visualization frames that, when played, fly the camera through the optical system. There can be one movie per file.

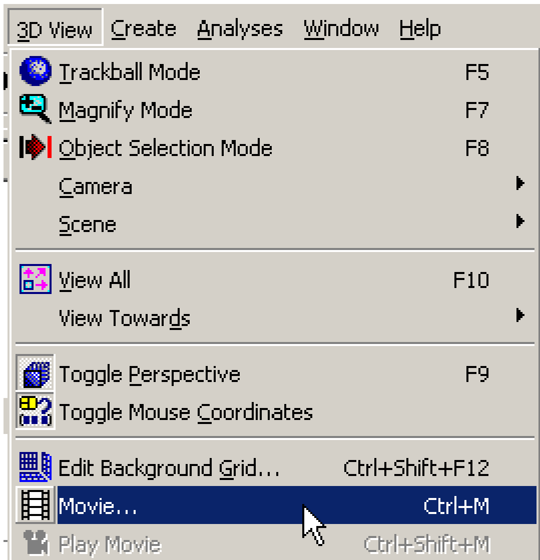
Note that this dialog is modeless, so you can both play the movie and have the dialog open at the same time. Each frame has 3 vectors, a delay, and an interpolation count. The three vectors describe the location and orientation of the camera for that frame. The delay, measured in milliseconds, shows how long the frame will last. The interpolation count tells how many steps there are in a given frame. For instance, if a given frame has a 60 ms time with an interpolation count of 4, then the camera will fly between the two orientations (the one for that frame and the one for the next), stopping at the 3 points between the two frame start points. The fourth point is the start point for the next frame.

Additional frames / entries can be appended, inserted, or deleted via a right mouse click pop-up menu.

How Do I Get There?
The FRED Movie Dialog

There are three different ways to execute this command:

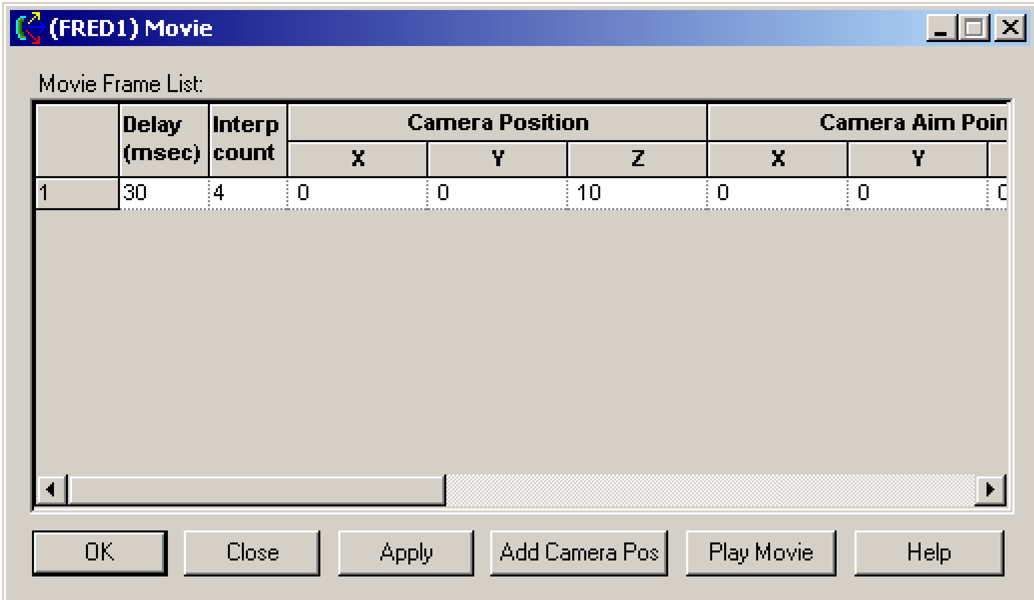
1. Select Movie in the 3D View Menu,



2. or press the keyboard accelerator keys: Ctrl+M,

3. or press the toolbar button:  (Since this button is not available by default, you will have to customize the toolbar to see this button.),

Dialog Box and Controls
The FRED Movie Dialog



Control	***Inputs***	***Defaults***
Movie Frame List		
Delay (msec)	Controls how long the frame will be displayed.	30
Interp Count	Controls how many steps in the frame between the current camera position and the camera position in the next frame.	4
Camera Position	Camera position in the global coordinate system.	0, 0, 10
Camera Aim Point	Camera aim point in the global coordinate system.	0, 0, 0
Camera “Up” Direction	Camera “up” direction relative to the global coordinate system.	0, 1, 0
Comment	A comment of any length may be entered here.	Blank
OK	Save the movie in the FRED document and close dialog box.	
Close	Close dialog box without saving the changes to the FRED document.	
Add Camera Pos	Insert additional camera positions.	
Apply	Save Movie Frame List changes to the FRED dialog but keep dialog box open.	

Play Movie	Play the movie.	
Help	Access this Help page.	

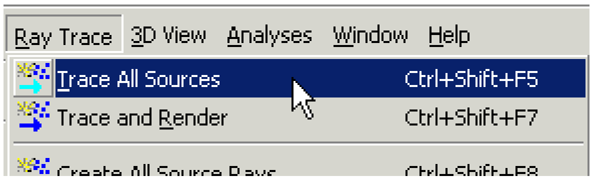
Raytrace - Trace All Sources

This command deletes all the existing rays, creates new rays at all the traceable sources, and then traces all the created rays. It does not render the rays in the visualization window.

How Do I Get There? - Trace All Sources

There are three ways to execute this command:

1. Select Trace All Sources in the Ray Trace Menu,



2. or press the keyboard accelerator keys: Ctrl+Shift+F5,
3. or press the toolbar button:

Raytrace - Trace Existing and Render

[Description](#)
[How Do I Get There?](#)
[Application Notes](#)
[See Also…](#)

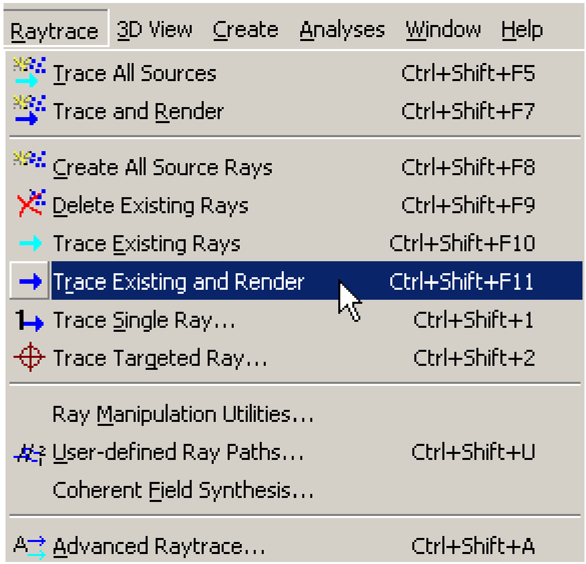
Description
Trace Existing and Render

Traces all rays and renders them in the Visualization window. This command is unavailable until the rays have been created with the Create Sources command.

How Do I Get There?
Trace Existing and Render

There are three different ways to execute this command:

1. Select Trace Existing Ray in the Ray Trace Menu



2. Press the keyboard accelerator keys: Ctrl+Shift+F11

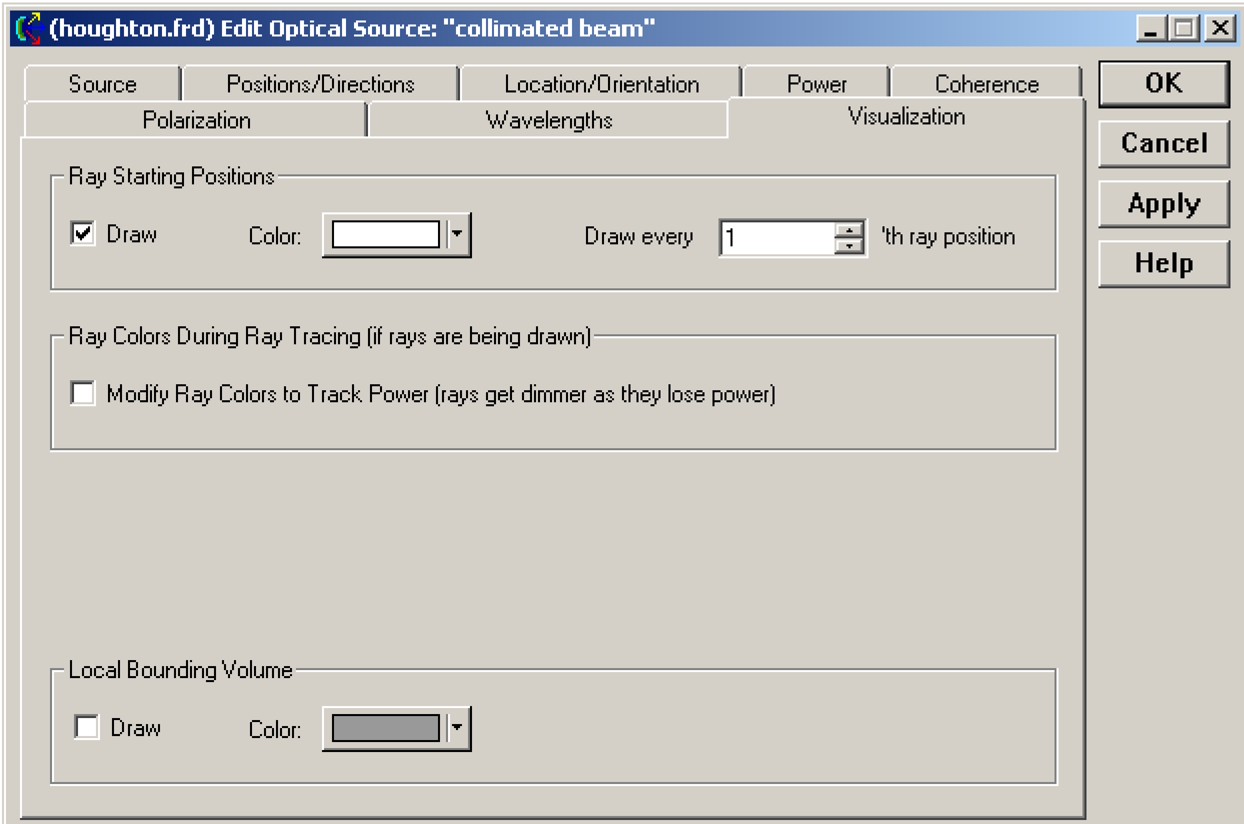
3. Press the toolbar button: 

Application Notes

Trace Existing and Render

- Manipulating the system view (i.e., pan or rotate) in the Visualization window while the rays are being rendered can lead to spurious effects, particularly if a large number of rays have been selected. For best results, wait to change the view until the raytrace has completed, as indicated by the status bar at the bottom of the FRED program window.

- The number of rendered rays can be different than the number of rays defined by the source. Go to the Source dialog, select the Visualization tab, and enter the number of sources rays per rendered ray:



- If a source contains multiple wavelengths, FRED automatically creates and renders the number of rays specified in the Positions/Directions tab for each wavelength.

- The color of the rendered rays is specified under the Wavelengths tab of the Source dialog. The rendered color can be calculated to approximately match the wavelength. It may be different from the color of the ray starting positions (which is useful if multiple wavelengths have been assigned to a single source).

- Ray colors can also be modified during the raytrace. They can be made dimmer (i.e., blacker) as they lose power. They can also be made to change color after intersecting a surface.

FRED and ***FRED*** ***Turbo***

The multi-core usage feature is active at the time of a raytrace unless:

- the user invokes a “Trace and Render” or “Trace Existing and Render”
- the Advanced Raytrace “Determine raypaths” check-box is checked,
- the Advanced Raytrace “Create/use ray history file” check-box is checked.

See Also….

Trace Existing and Render

Trace and Render
Trace All Sources
Trace Existing Rays
Trace Single Ray
Delete Existing Rays
Create All Source Rays

Raytrace - Create Sources

Description
How Do I Get There?
Application Notes
See Also…

Description

Create Sources

Creates the rays for all traceable optical sources. After the rays are created, their starting points will be shown in the visualization window if it is turned on, but this command does not execute the raytrace.

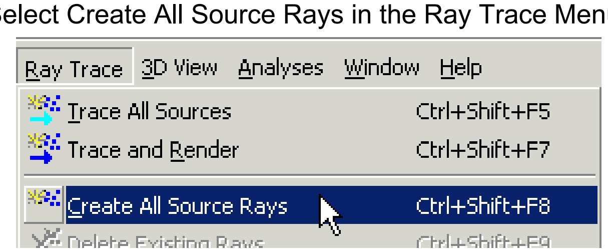
> Note: If there are rays in the system prior to issuing this command, they are deleted before new rays are created.

How Do I Get There?

Create Sources

There are three ways to execute this command:

1. Select Create All Source Rays in the Ray Trace Menu,



2. or press the keyboard accelerator keys: Ctrl+Shift+F8,
3. or press the toolbar button: .

Application Notes

Create Sources

All analysis options can be exercised on any and all of the currently traceable sources prior to execution of the raytrace. Graphical displays of the intensity and irradiance properties of a source can be created by first attaching an Analysis Plane to the source of interest and then generating either a spot diagram or spread function.

See Also…

Create Sources

Trace and Render
Trace All Sources
Trace Existing Rays
Trace Existing and Render
Trace Single Ray
Delete Existing Rays

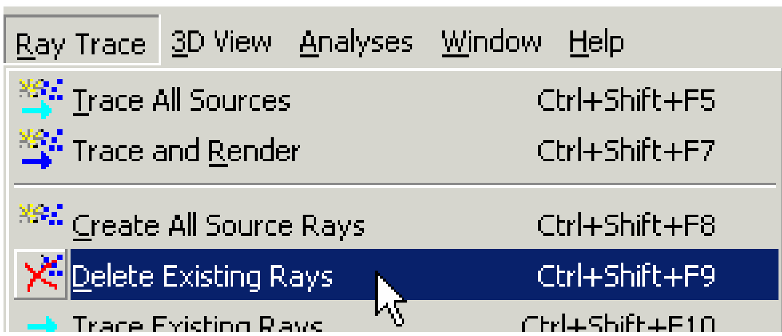
Raytrace - Delete All Rays

Deletes all rays that are in the ray buffer. Does not delete the sources of those rays.

How Do I Get There? - Delete All Rays

There are three ways to execute this command:

1. Select Trace All Sources in the Ray Trace Menu,



2. or press the keyboard accelerator keys: Ctrl+Shift+F9,
3. or press the toolbar button: .

Application Notes - Delete All Rays

All rays are deleted. As a result, all associated ray information, such as ray summary data, is lost. Further, unless they are locked, all open analysis windows (spot diagrams or spread functions) associated with the model are closed.

If no rays have been created, generating a spot diagram or spread function will automatically prompt the user for 'Pre-Analysis Ray Operations' that include recreating all active sources and executing the raytrace.

Raytrace - Trace Existing Rays

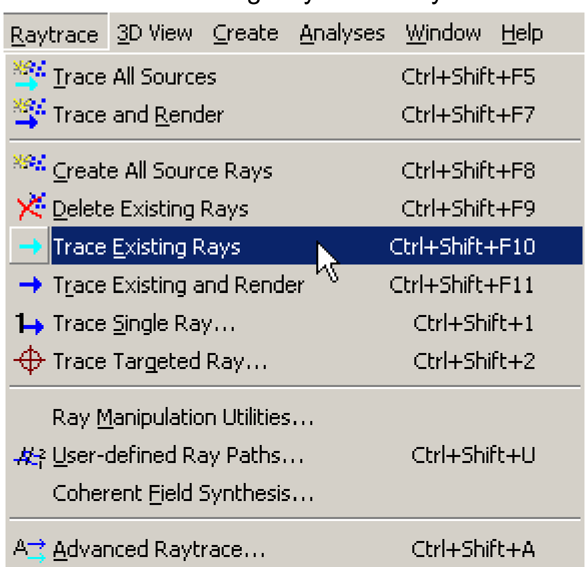
Description
Trace Existing Rays

Traces, but does not render, rays in the ray buffer. This command is unavailable until the rays have been created with the Create Sources command.

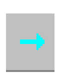
How Do I Get There?
Trace Existing Rays

There are three different ways to execute this command:

1. Select Trace Existing Ray in the Ray Trace Menu



2. Press the keyboard accelerator keys: Ctrl+Shift+F10

3. Press the toolbar button: 

Application Notes
Trace Existing Rays

FRED and ***FRED Turbo***

The multi-core usage feature is active at the time of a raytrace unless:

- the user invokes a “Trace and Render” or “Trace Existing and Render”

- the Advanced Raytrace “Determine raypaths” check-box is checked,
- the Advanced Raytrace “Create/use ray history file” check-box is checked.

Examples
Trace Existing Rays

See Also….
Trace Existing Rays

Trace and Render
Trace All Sources
Trace Existing and Render
Trace Single Ray
Delete Existing Rays
Create All Source Rays

Raytrace - Trace and Render

Description
How Do I Get There?
Application Notes
See Also…

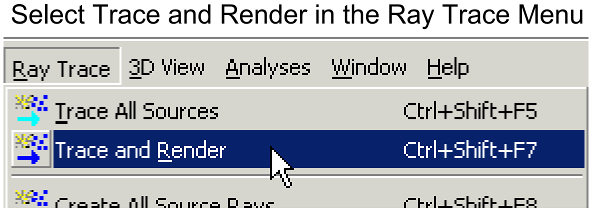
Description
Trace and Render

This command creates all sources, traces their rays, and renders the rays in the Visualization window.

How Do I Get There?
Trace and Render

There are three different ways to execute this command:

1. Select Trace and Render in the Ray Trace Menu

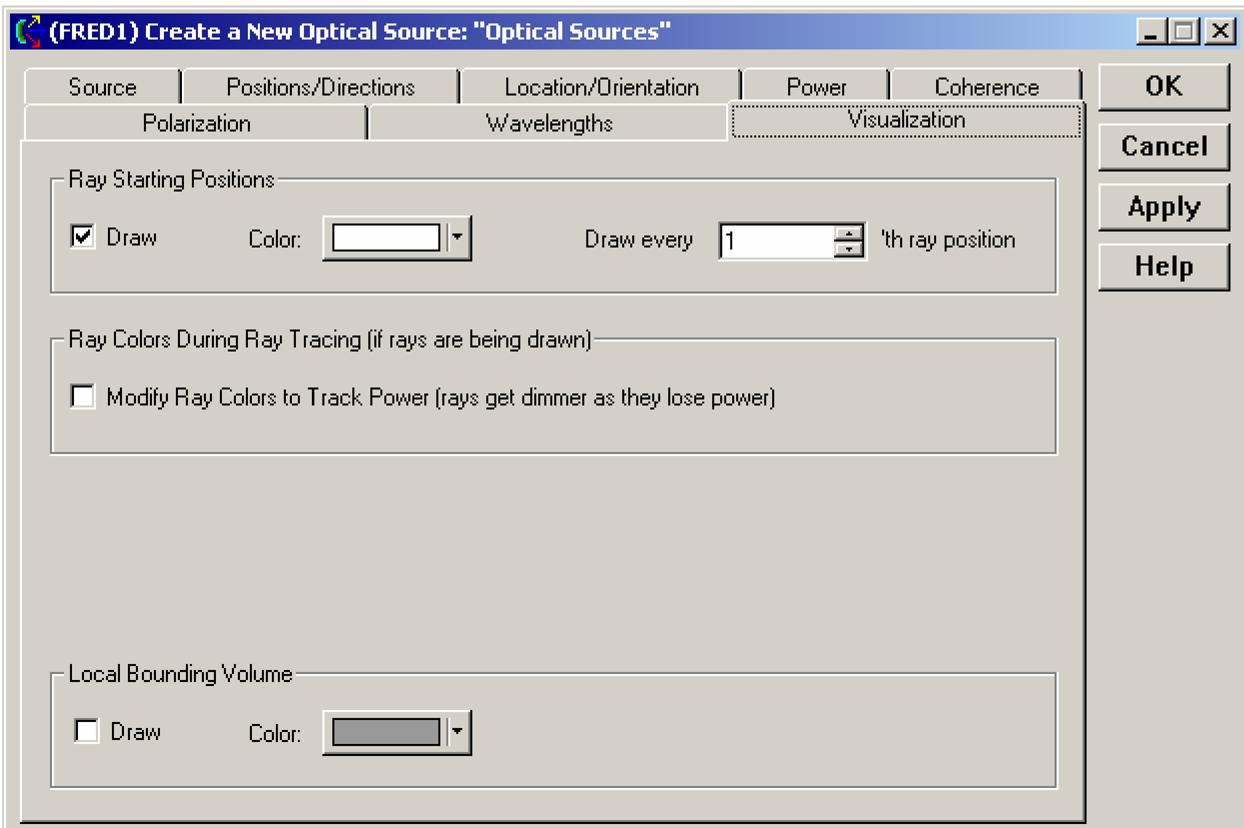


2. Press the keyboard accelerator keys: Ctrl+Shift+F7

3. Press the toolbar button: 

- Manipulating the system view (i.e., pan or rotate) in the Visualization window while the rays are being rendered can lead to spurious effects, particularly if a large number of rays have been selected. For best results, wait to change the view until the raytrace has completed, as indicated by the status bar at the bottom of the FRED program window.

- The number of rendered rays can be different than the number of rays defined by the source. Go to the Source dialog, select the Visualization tab, and enter the number of sources rays per rendered ray:



- If a source contains multiple wavelengths, FRED automatically creates and renders the number of rays specified in the Positions/Directions tab for each wavelength.

- The color of the rendered rays is specified under the Wavelengths tab of the Source dialog. The rendered color can be calculated to approximately match the wavelength. It may be different from the color of the ray starting positions (which is useful if multiple wavelengths have been assigned to a single source).

- Ray colors can also be modified during the raytrace. They can be made dimmer (i.e., blacker) as they lose power. They can also be made to change color after intersecting a surface.

- ***FRED*** and ***FRED*** *Turbo*

The multi-core usage feature is active at the time of a raytrace unless:

- the user invokes a "Trace and Render" or "Trace Existing and Render"
- the Advanced Raytrace "Determine raypaths" check-box is checked,
- the Advanced Raytrace "Create/use ray history file" check-box is checked.

See Also….

Trace and Render

Trace All Sources
Trace Existing Rays
Trace Existing and Render
Trace Single Ray
Delete Existing Rays
Create All Source Rays

Raytrace - Coherent Scalar Field Synthesis

Description

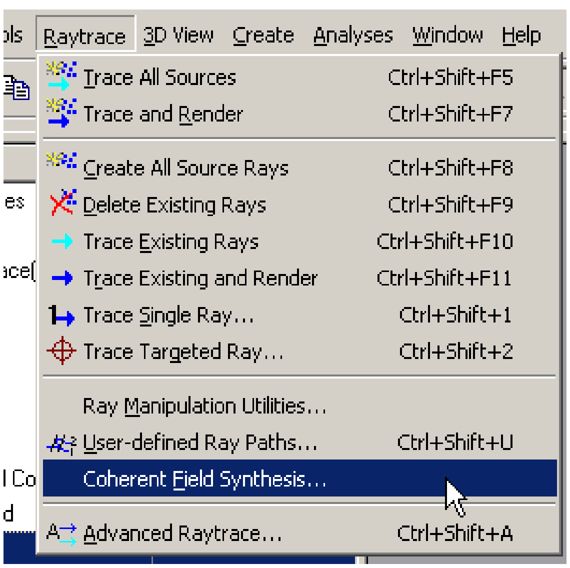
Coherent Scalar Field Synthesis

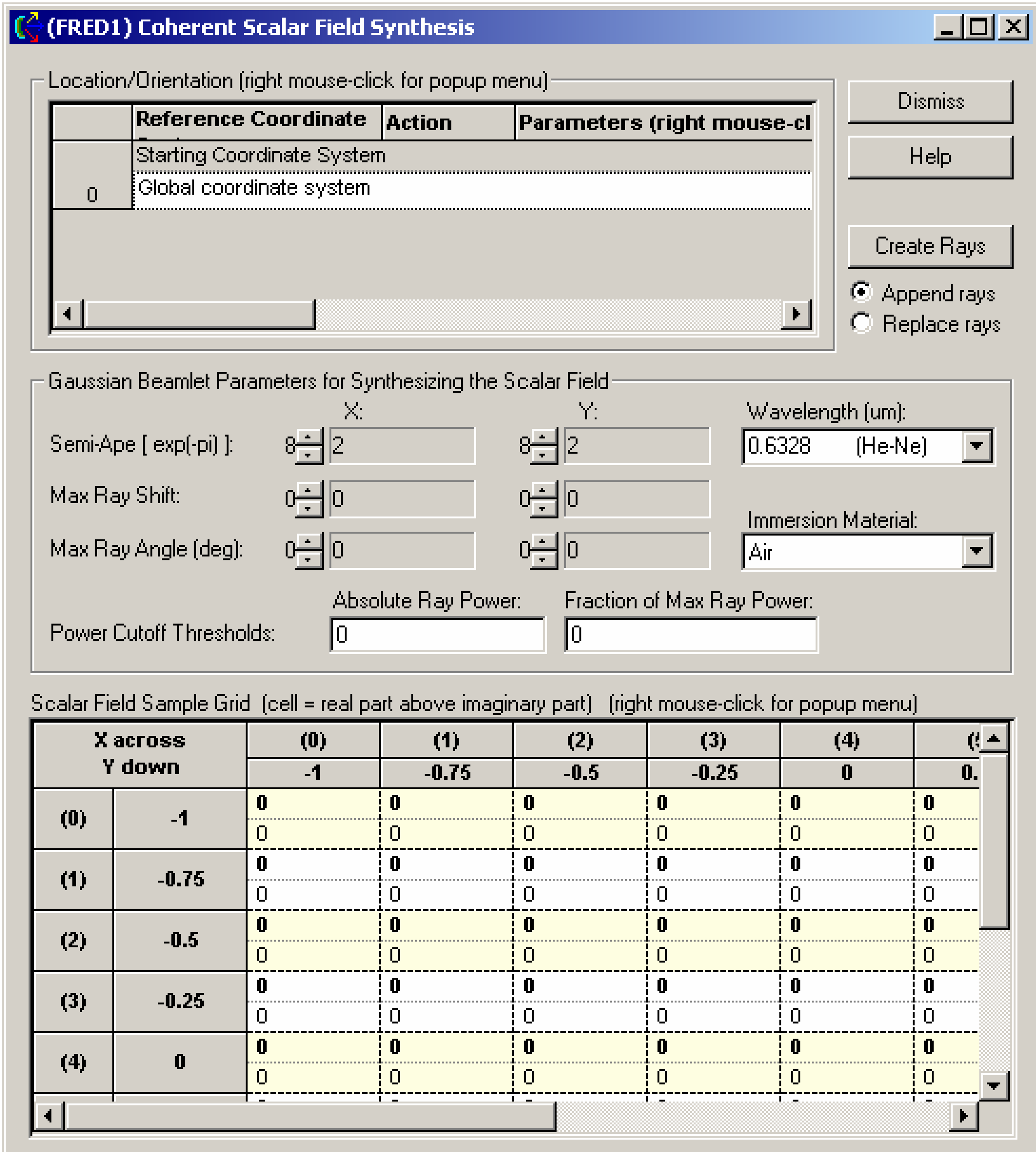
This dialog creates a new coherent rayset based upon a Gabor synthesis of a user-calculated complex field. The field is synthesized from a collection from a collection of Gaussian beamlets whose amplitude, phase and directional distribution are determined by the the field characteristics as well as the area and spatial resolution over which the original field was calculated.

How Do I Get There?

Coherent Scalar Field Synthesis

Coherent Field Synthesis is activated from the Raytrace Menu by choosing "Coherent Field Synthesis..."





Control	*Inputs / Description*	*Defaults*
Location/Orientation		
Location/Orientation	Set coordinate system & Location/Orientation of new rayset.	Global/None
Gaussian Beamlet Parameters		
Semi-Ape ($e^{-\pi}$ HW)	Halfwidth of individual Gaussian beamlets.	2,2

Max Ray Shift	Number of extra beams supplied for smoothing.	0,0
Max Ray Angle	Maximum ray angle (in degrees) measured from plane normal direction.	0,0
Wavelength (um)	Source wavelength	0.6328 um (He-Ne)
Immersion material	Rays are immersed in this material.	Air
Power Cutoff Threshold	Specify Absolute Ray Power & Fraction of Max Ray Power. Discard rays with powers below these thresholds.	0,0
Scalar Field Sample Grid		
Cell	Holds real and imaginary values at each field point.	0,0
Right-click Cell	Field edit options: *Set Size* *Read from File* *Write to File* *Modify Field Values*	
Create Rays	Create coherent rays from input data.	
Append/Replace Rays	Append to current rayset or Replace current rayset.	Append
Dismiss	Dismiss dialog box.	
Help	Access this Help page.	

Application Notes
Coherent Scalar Field Synthesis

The general approach behind Coherent Field Synthesis is the creation of a coherent rayset that, when coherently summed, yields a desired coherent scalar field. The rayset consists of a collection of coherent Gaussian beamlets each having the same size. The spatial distribution of this collection is a rectilinear array which may span the spatial size of the scalar field or emanate from a central location. The angular distribution is rectilinear array in direction cosine space which may span a predetermined angular size. That is, at each spatial location there is a number of rays all pointing in different directions.

The coherent field to be synthesized can be entered directly in the dialog box data area or read from a text file. FRED can create a text file representation of a coherent field after calculating the Coherent Scalar Wave Field by accessing the 'Save Complex Field to File' option from the popup menu in the Chart Viewer. The Analysis Surface used in calculating the Coherent Scalar Wave Field specifies the sampling of the scalar field to be synthesized. The Coherent Field Synthesis dialog is used to specify the Gaussian beamlet size "L" (defined as the exp(-□) amplitude point), the wavelength □, and the refractive index "n" of immersion material. Once this information is specified, the spatial and angular array spacings are automatically determined. The spatial array spacing is equal to the beamlet size, L. The angular spacing in direction cosine space is given by □/(n*L). The user has control over how far out to create rays in the spatial dimensions, and how far out to create rays in the direction dimensions.

In practice it is often difficult to specify the proper field sampling, beamlet size, spatial limit, and angular limits in order to create a rayset that accurately synthesizes the given field. The user must often try many different combinations of parameters before arriving at a satisfactory result. However, there are some general rules that can be used to guide this process.

- Never assume that the computed rayset gives an accurate synthesis of the field without verification. In this regard, it is recommended that a coherent field analysis be done and compared this with the original field.
- The more densely sampled the original scalar field the better. Sparse sampling can lead to inaccuracy regardless of how the user-specified parameters are set.
- In general, the more rays created, the more accurate the result will be.
- With regard to the ray size "L", bigger is better. The algorithm computes faster for bigger rays. The algorithm is also numerically more accurate for bigger rays. In fact, small rays can be inaccurate by a very large amount.
- Wider angular ranges are better than smaller ranges. When possible, however, limit the angular range of the rayset to the acceptance cone of the receiving optical system.
- You can extend spatial range to one position bigger than extent of the field using the L parameter. Occasionally, you may need a slightly bigger range to accurately model field edge effects.
- The total number of spatial ray positions is the main factor in determining how long the calculation will take. The more ray positions, the longer the time it will take. The effect of more ray directions is less important.
- Smoother fields can be synthesized with less rays than fields with sharp discontinuities.
- The angular divergence of individual beamlets is inversely proportional to the beamlet size. Smaller beamlets spread more rapidly than big beamlets as they propagate.

See Also….
Coherent Scalar Field Synthesis

Modify Scalar Field Values

Set Scalar Field Array Size

[1] *Gabor representation and aperture theory*, P.D. Einziger, S. Raz, and M Shapira, J. Opt. Soc. Am. A/Vol. 3, No. 4/ April 1986, p.508

Raytrace – Coherent Scalar Field Synthesis - Sizing the Scalar Wave Field

Description

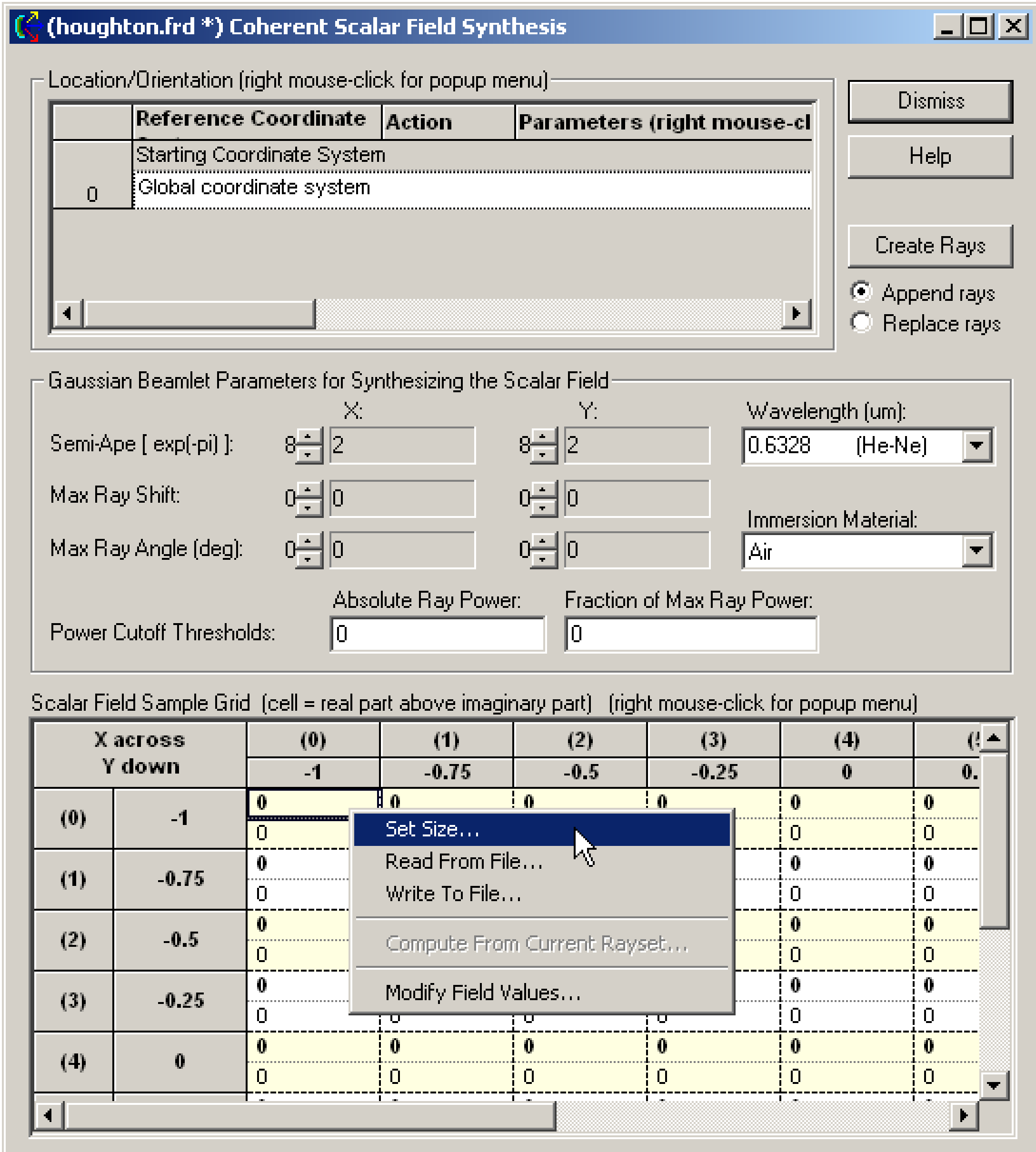
Sizing the Scalar WaveField

Alters the number of rows and columns in the Scalar Field sample grid.

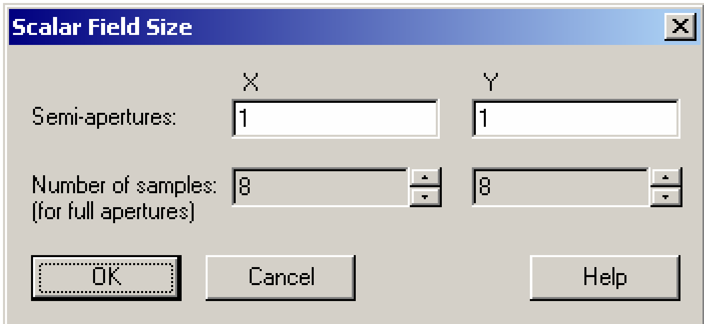
How Do I Get There?

Sizing the Scalar WaveField and Amplitude/Phase Mask

Set the Scalar Field size by right-clicking in a data value cell.


(houghton.frd *) Coherent Scalar Field Synthesis
Location/Orientation (right mouse-click for popup menu)
Reference Coordinate
Action
Parameters (right mouse-cl
Starting Coordinate System
Global coordinate system
Dismiss
Help
Create Rays
Append rays
Replace rays
Gaussian Beamlet Parameters for Synthesizing the Scalar Field
Semi-Ape [exp(-pi)]:
Max Ray Shift:
Max Ray Angle (deg):
Wavelength (um):
0.6328 (He-Ne)
Immersion Material:
Air
Absolute Ray Power:
Fraction of Max Ray Power:
Power Cutoff Thresholds:
Scalar Field Sample Grid (cell = real part above imaginary part) (right mouse-click for popup menu)
X across
Y down
Set Size...
Read From File...
Write To File...
Compute From Current Rayset...
Modify Field Values...

Dialog Box and Controls
Sizing the Scalar WaveField



Control	Inputs / Description	Defaults
Semi-apertures	Set semi-aperture widths.	1,1
Number of samples	Set sampling over full aperture.	(8,8) (5,5)
OK	Accept aperture settings and close dialog box.	
Cancel	Discard aperture changes and close dialog box.	
Help	Access this Help page.	

Application Notes
Sizing the Scalar WaveField

See Also….
Sizing the Scalar WaveField

Coherent Scalar Field Synthesis
Scalar Field Modify

Raytrace – Coherent Scalar Field Synthesis -Modifying Scalar Field Values

Description

Scalar Field Modify Values

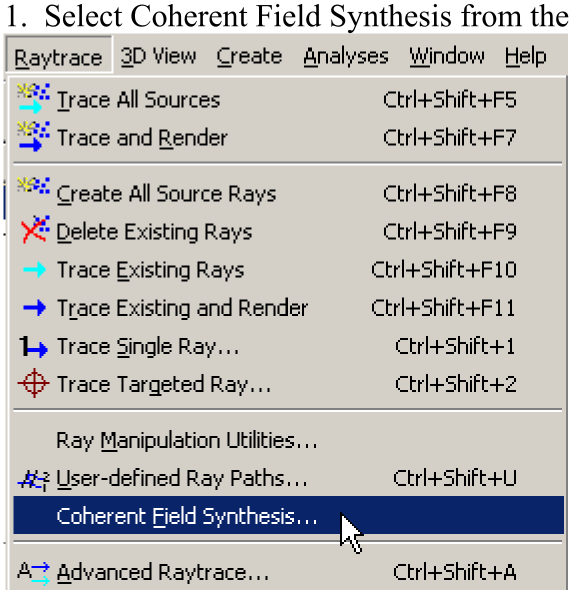
Specifies a subsection of the field data and modifies amplitude or phase values.

How Do I Get There?

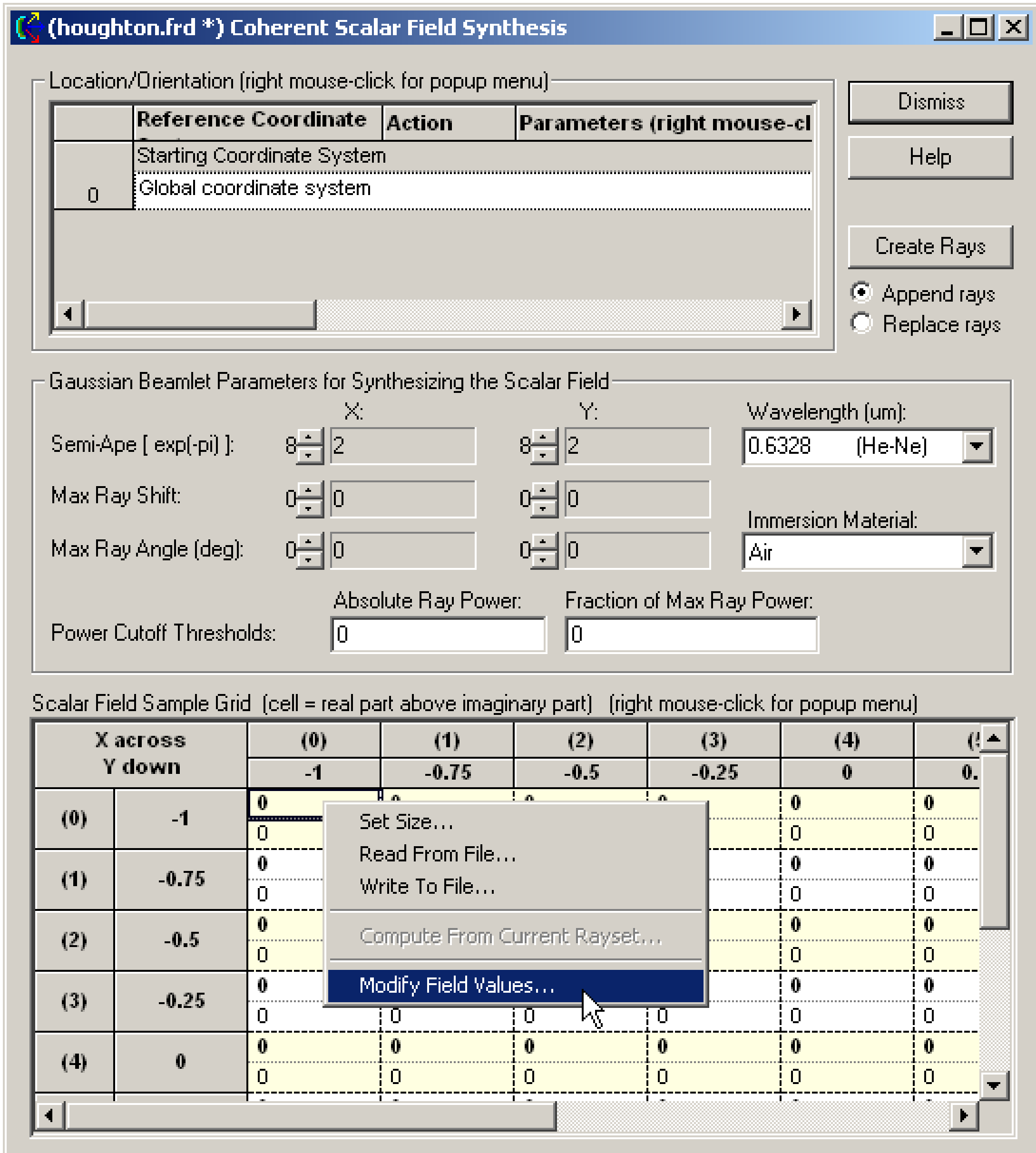
Scalar Field Modify Values

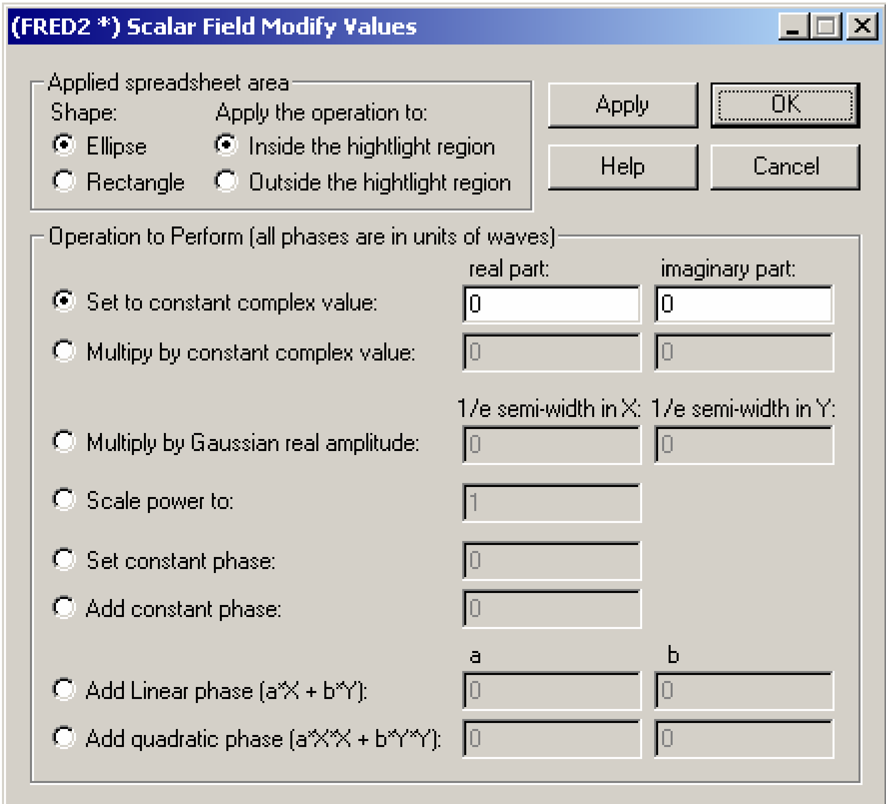
Modification of the Scalar Field values is accessed through the Coherent Field Synthesis dialog:

1. Select Coherent Field Synthesis from the Raytrace Menu,



2. Right-click in the data values area.


(houghton.frd *) Coherent Scalar Field Synthesis
Location/Orientation (right mouse-click for popup menu)
Reference Coordinate
Action
Parameters (right mouse-cl
Starting Coordinate System
0
Global coordinate system
Dismiss
Help
Create Rays
Append rays
Replace rays
Gaussian Beamlet Parameters for Synthesizing the Scalar Field
X:
Y:
Wavelength (um):
Semi-Ape [exp(-pi)]:
0.6328 (He-Ne)
Max Ray Shift:
Immersion Material:
Max Ray Angle (deg):
Air
Absolute Ray Power:
Fraction of Max Ray Power:
Power Cutoff Thresholds:
Scalar Field Sample Grid (cell = real part above imaginary part) (right mouse-click for popup menu)
X across
Y down
Set Size…
Read From File…
Write To File…
Compute From Current Rayset…
Modify Field Values…



Control	***Inputs / Description***	***Defaults***
Applied spreadsheet area		
Shape	Choose Ellipse or Rectangle	Ellipse
Apply the operation to	Inside or outside region	Inside
Operation to Perform		
Set to constant complex value	Set field to constant complex value.	0,0
Multiply by constant complex value	Multiply field by constant complex value.	0,0
Multiply by Gaussian real amplitude	Multiply field by Gaussian real amplitude.	0,0
Scale power to	Scale power of field.	1
Set constant phase	Set constant phase for field.	0
Add constant phase	Add constant phase to field.	0

Add Linear phase	Add a linear phase to the field. (a*X + b*Y)	0,0
Add quadratic phase	Add a quadratic phase to the field. ($a*X^2 + b*Y^2$)	0,0
OK	Accept modifications and close dialog box.	
Cancel	Discard modifications and close dialog box.	
Apply	Apply modifications and keep dialog box open.	
Help	Access this Help page.	

Application Notes

Scalar Field Modify Values

See Also….

Scalar Field Modify Values

Coherent Scalar Field Synthesis

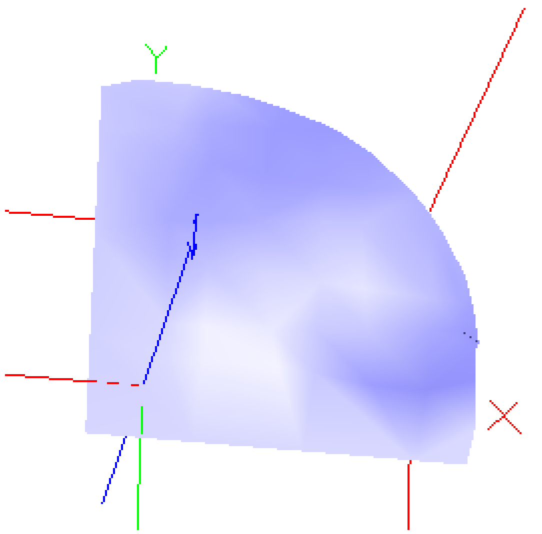
Sizing the Scalar Field

Create – New Surface - Bicubic Mesh Surface

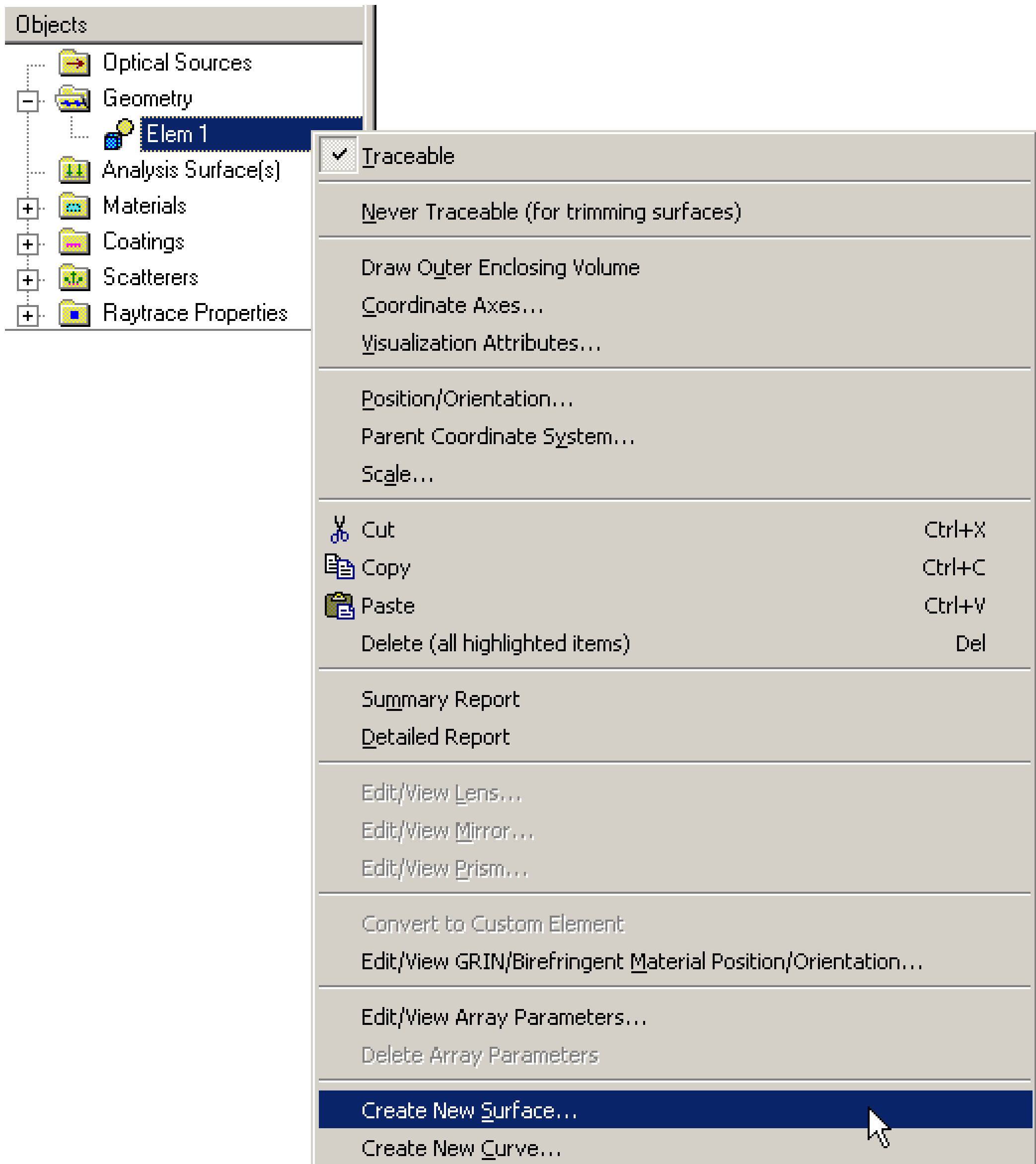
Description
How Do I Get There?
Dialog Box and Controls
Application Notes
See Also…

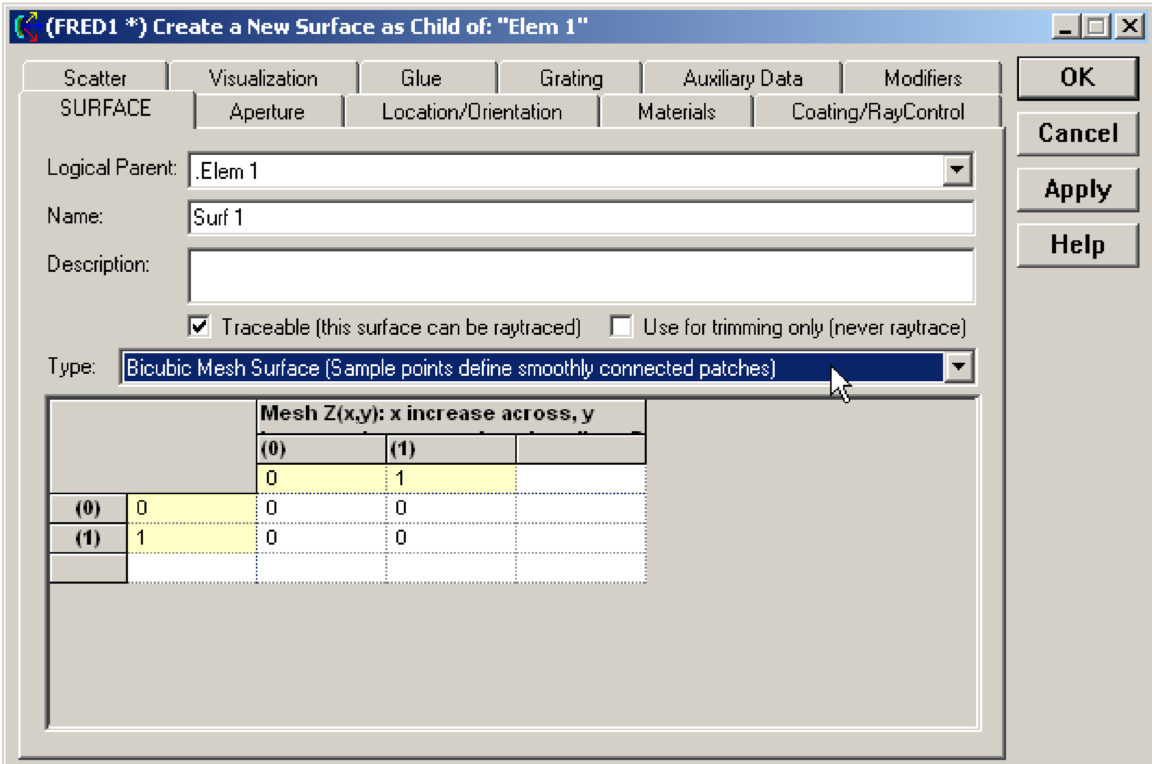
Description - Surface - Bicubic Mesh Surface

Creates a Bicubic Mesh surface from tabular data. Data points represent Z-values for evenly spaced X,Y.



How Do I Get There? - Surface - Bicubic Mesh Surface


Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...



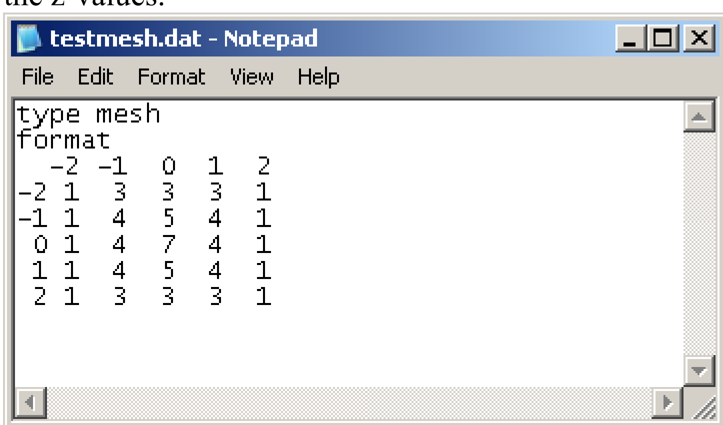
Control	Inputs / Description	Defaults
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Bicubic Mesh Surface
Mesh Z(x,y)		
Data Table	User input data or read from file.	
OK	Accept Bicubic Mesh Surface surface and close dialog box.	

Cancel	Discard Bicubic Mesh Surface surface and close dialog box.	
Apply	Create Bicubic Mesh Surface surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Bicubic Mesh Surface

- The Bicubic Mesh Surface is a sagable surface. A "sagable" surface is defined as single-valued in z.

- A sample of the text file format for user-defined bicubic mesh data is shown here. This file should have a *.dat extension. The first line must have the entry *type mesh* while the second line has only the word *format*. The first row of data contains x-values while the first column contains y-values. The remaining data are the z-values.

1. 

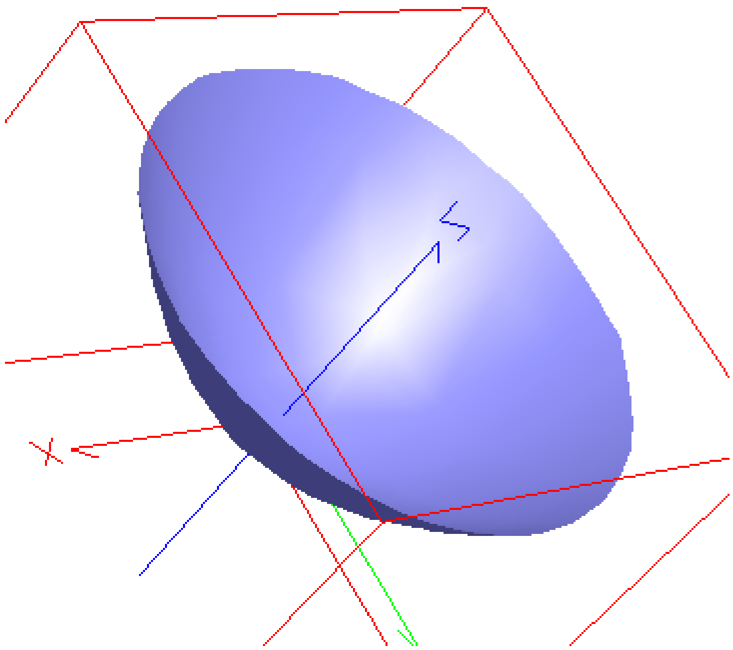

```
type mesh
format
   -2  -1   0   1   2
-2  1   3   3   3   1
-1  1   4   5   4   1
 0  1   4   7   4   1
 1  1   4   5   4   1
 2  1   3   3   3   1
```

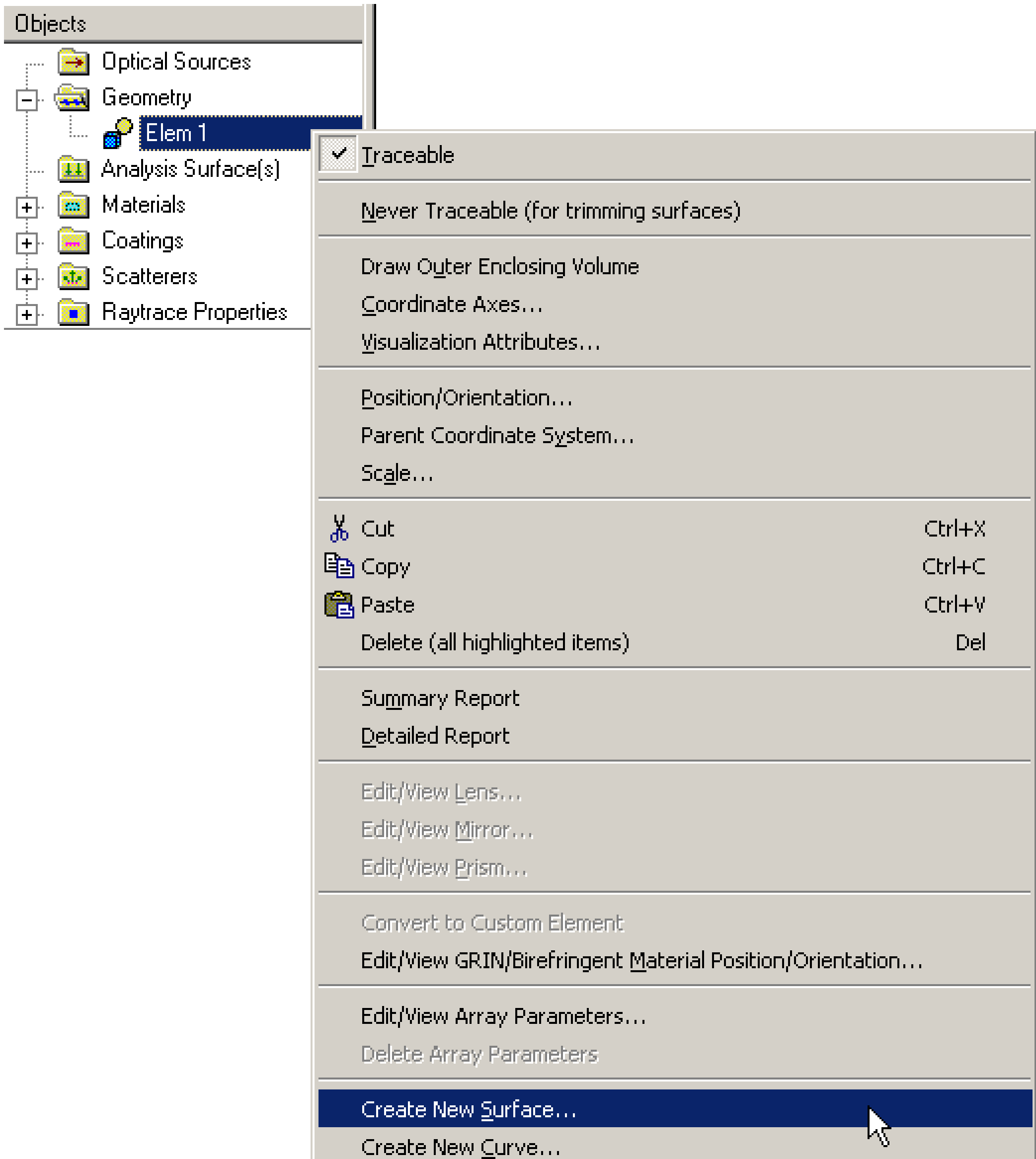
See Also - Surface - Bicubic Mesh Surface

Create – New Surface - Conicoid

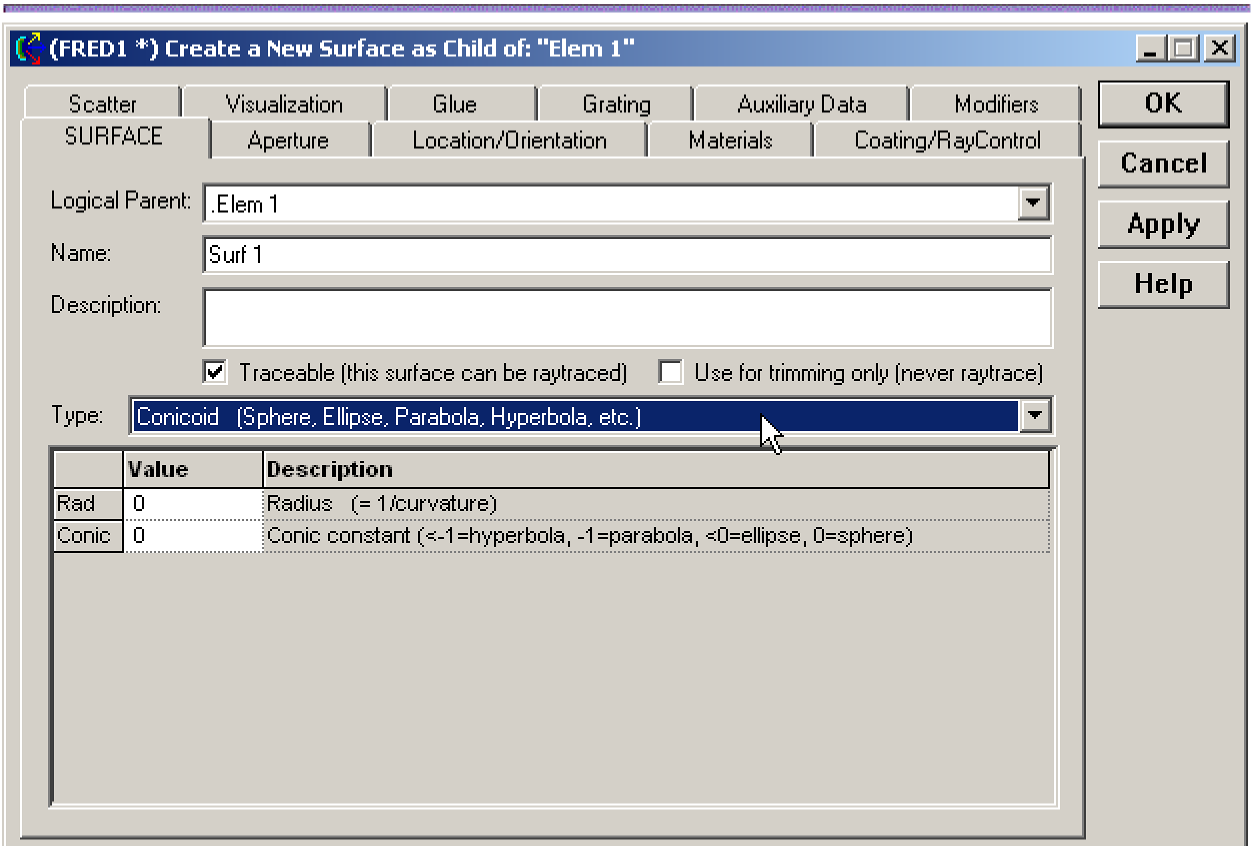
Description - Surface - Conicoid

Creates a conicoid surface with a default aperture, material, coating, raytrace control, location, etc. The default location is at the origin.




Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Conicoid



Control	Inputs / Description	Defaults
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Conicoid
Rad	Radius of curvature.	0
Conic	Conic constant.	0
OK	Accept Conicoid surface and close dialog box.	
Cancel	Discard Conicoid surface and close dialog box.	

Apply	Create Conicoid surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Conicoid

1 The conicoid and conic focii are only closed surfaces in FRED. They can be used to construct spheres and ellipsoids. The conicoid can also be used to create open surfaces such as hyperbolas and parabolas.

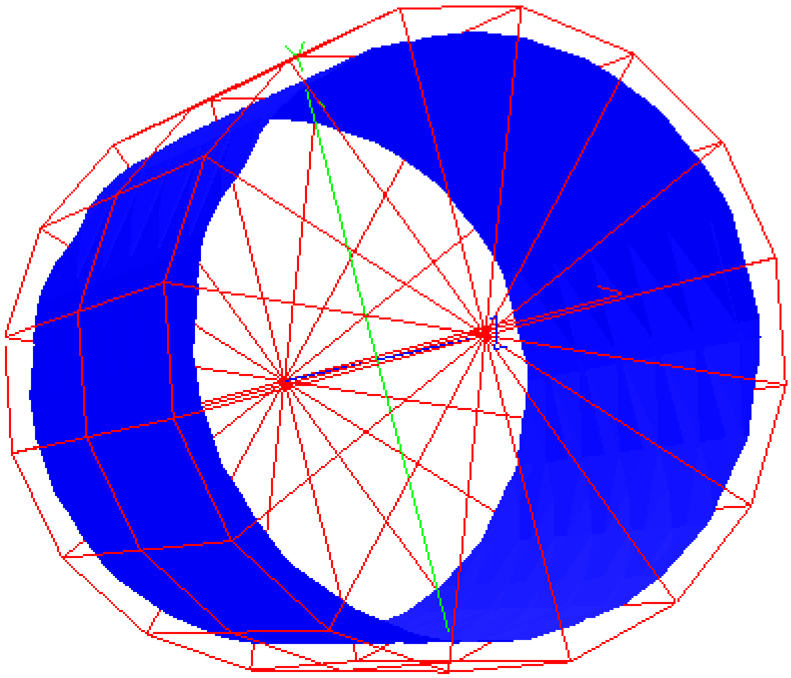
2. The conicoid is a "non-sagable" surface. Therefore, it cannot be used as a defroming surface. A "Sagable" surface is defined as a single-valued in z.

See Also…. - Surface - Conicoid

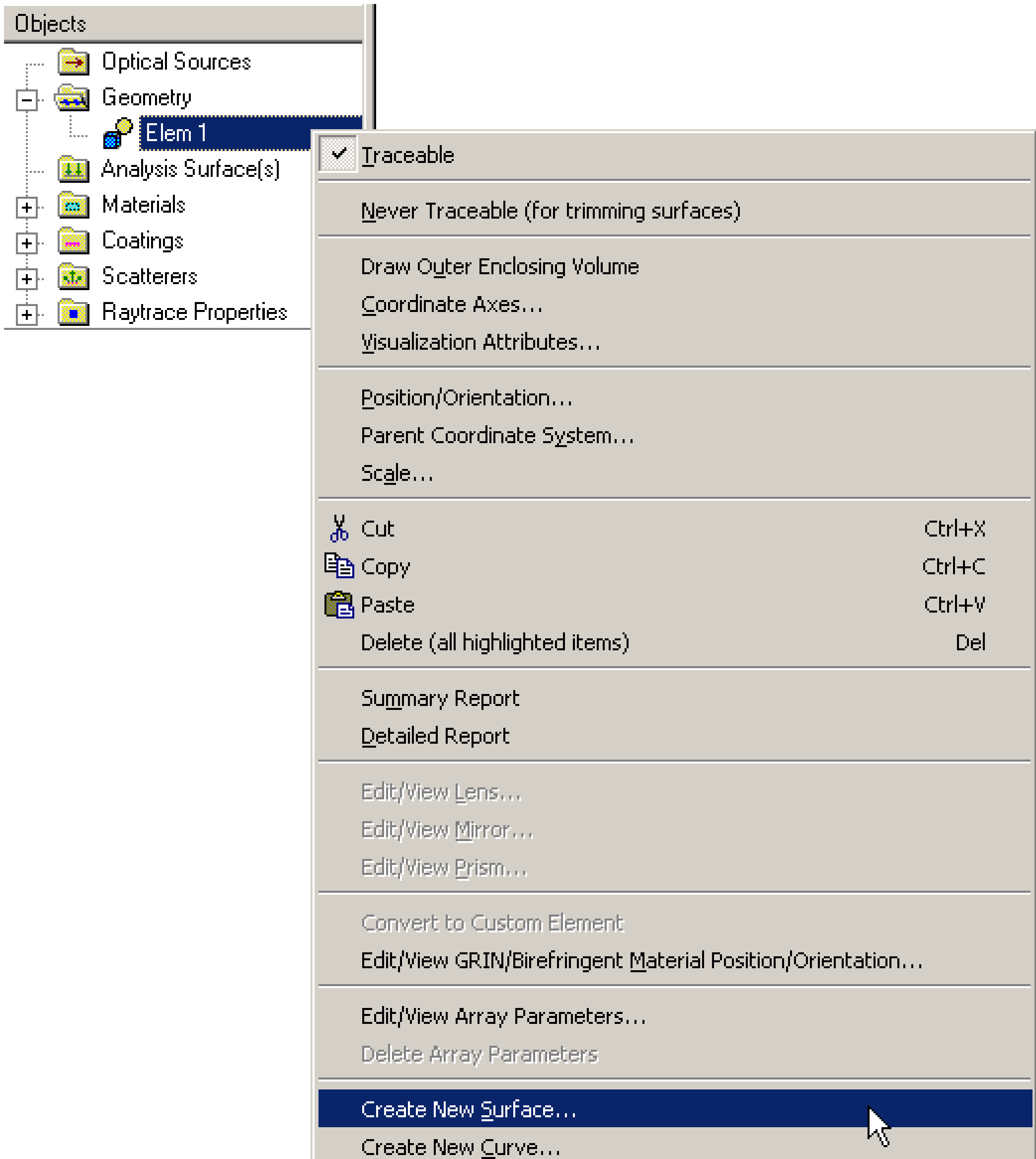
Create - New Surface - Cylinder

Description - Surface - Cylinder

Creates a cylindrical or tubular surface.



[How Do I Get There? - Surface - Cylinder]


Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
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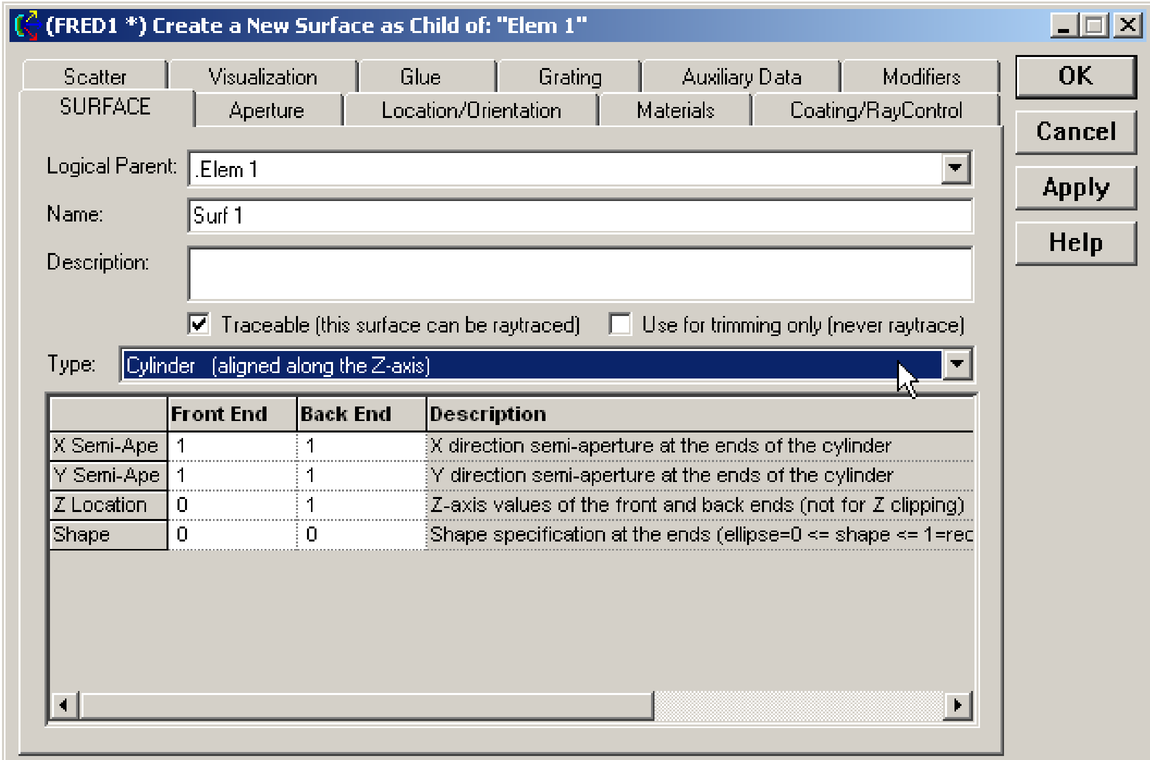
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Cylinder



Control	Inputs / Description	Defaults
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Cylinder
X/Y semi-Ape	Semi-aperture at cylinder ends.	0
Z Location	Starting and ending location of cylinder.	0
Shape	Specifies shape at ends of cylinder (ellipse=0 <= shape <= 1=rectangle)	0
OK	Accept cylinder surface and close dialog box.	
Cancel	Discard cylinder surface and close dialog box.	

Apply	Create cylinder surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Cylinder

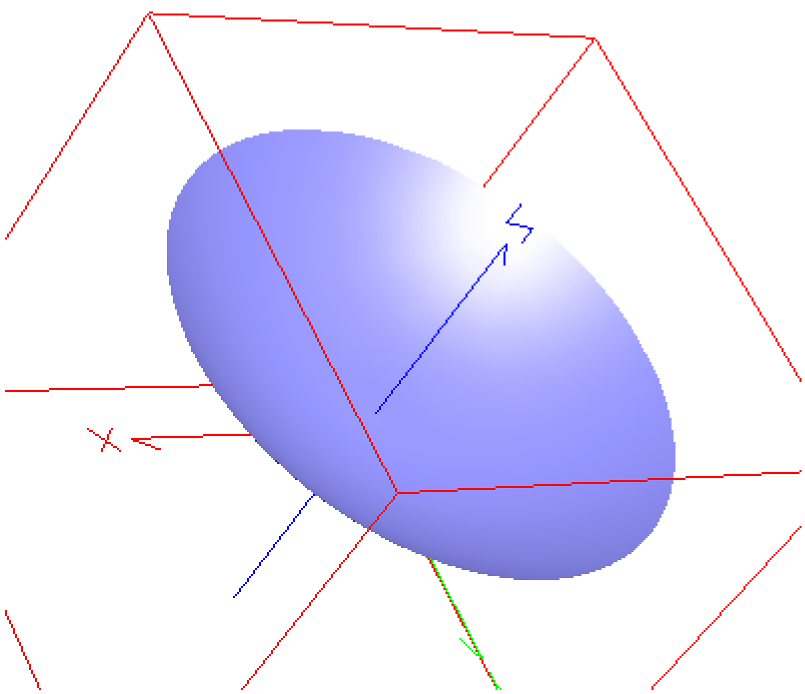
1. The Cylinder is a sagable surface.

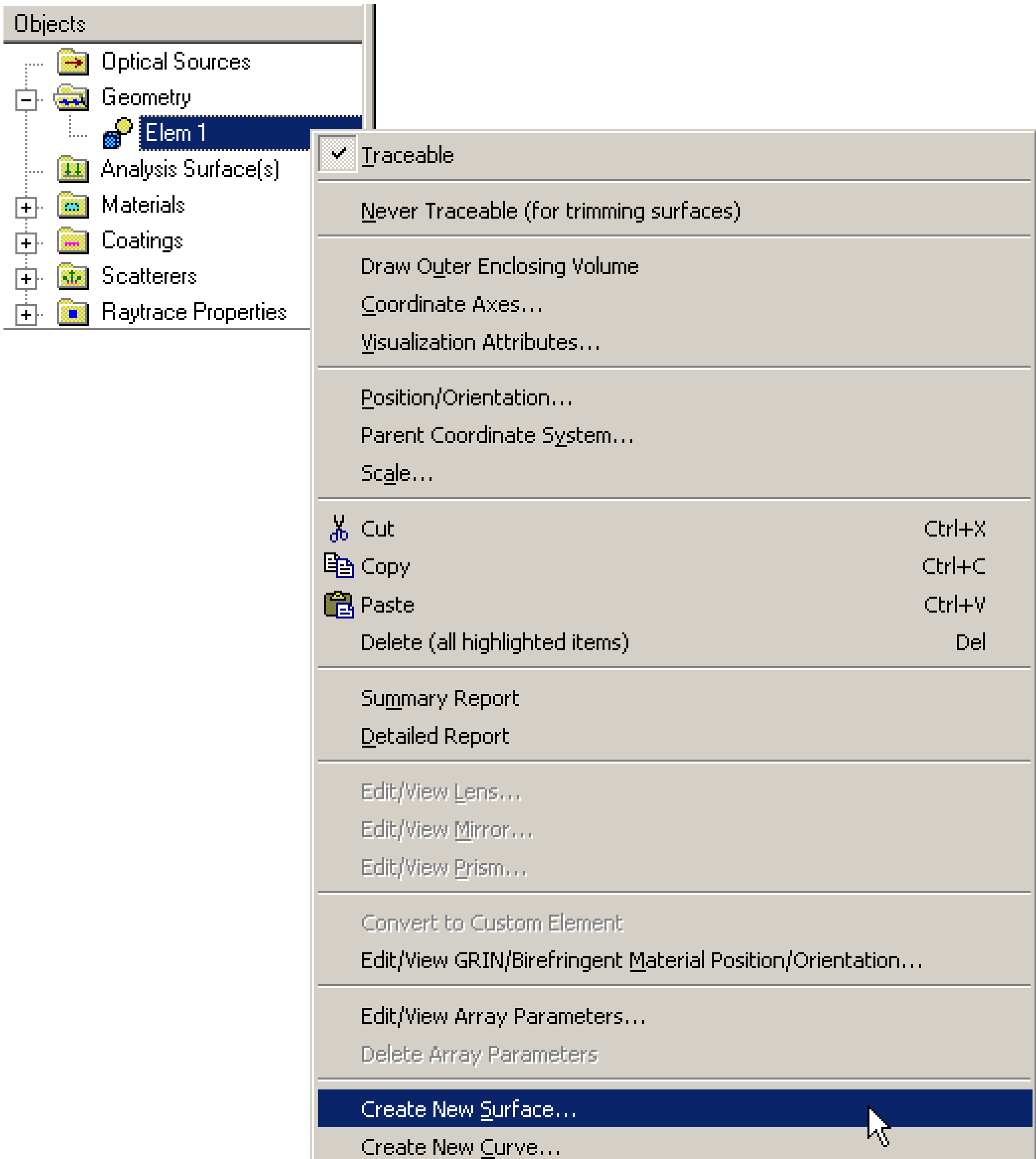
See Also…. - Surface - Cylinder

Create – New Surface - General Asphere

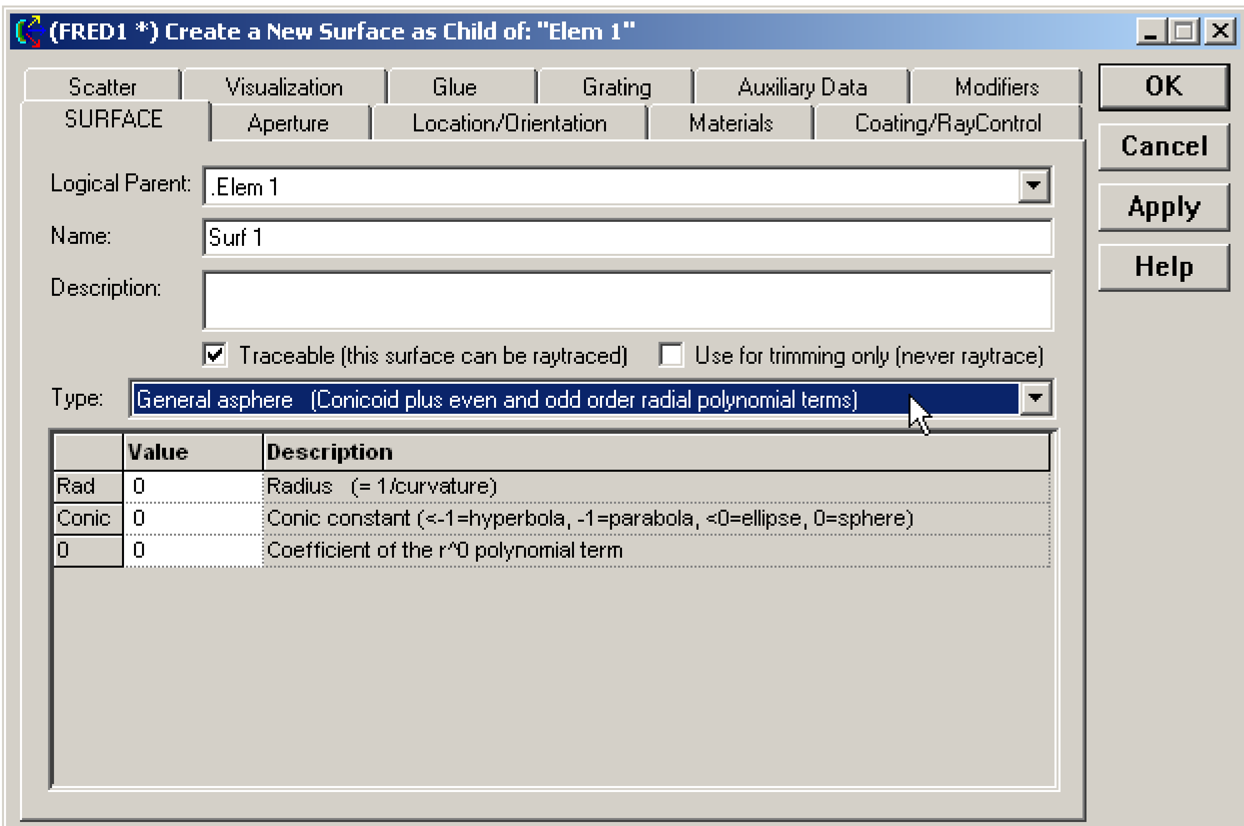
Description - Surface - General Asphere

Creates an aspheric surface with both odd and even terms.




Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - General Asphere



Control	*Inputs / Description*	*Defaults*
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	General Asphere
Rad	Radius of curvature.	0
Conic	Conic constant.	0
r^n	all order aspheric terms	0

OK	Accept general asphere surface and close dialog box.	
Cancel	Discard general asphere surface and close dialog box.	
Apply	Create general asphere surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - General Asphere

1. The function form of the general asphere is given by

$$f(r,z) = z - \frac{cv \cdot r^2}{1 + \sqrt{1 - (1 + conic) \cdot (cv \cdot r)^2}} - \sum_i even_i \cdot r^{2i} - \sum_j odd_j \cdot r^{2j+1} = 0$$

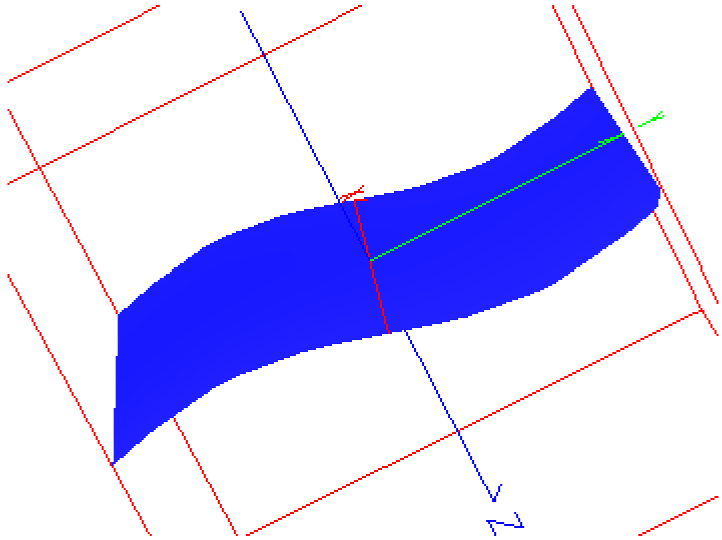
2. The general asphere is a sagable surface.

See Also…. - Surface - General Asphere

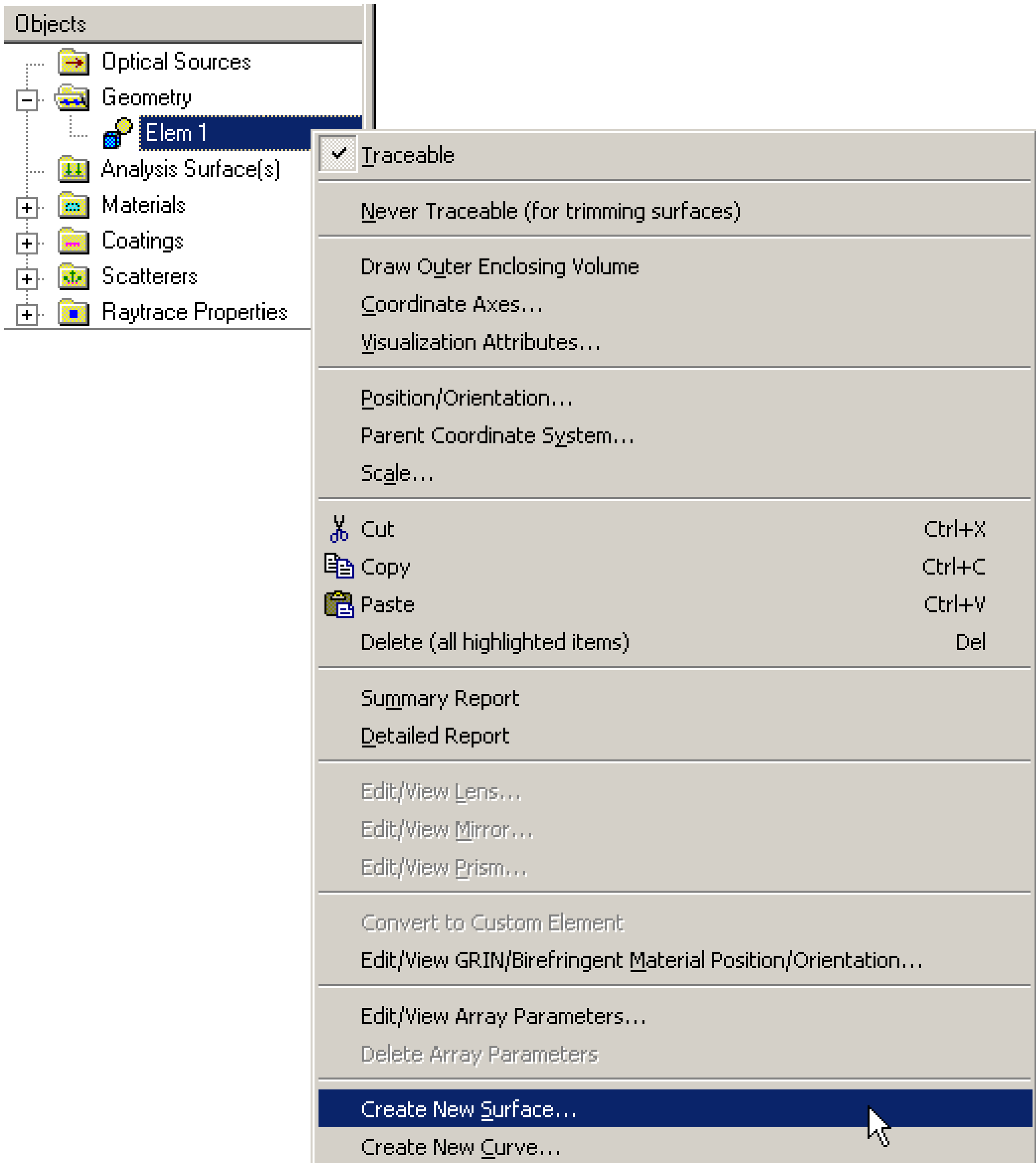
Create - New Surface - Implicit Script Surface

Description - Surface - Implicit Script Surface

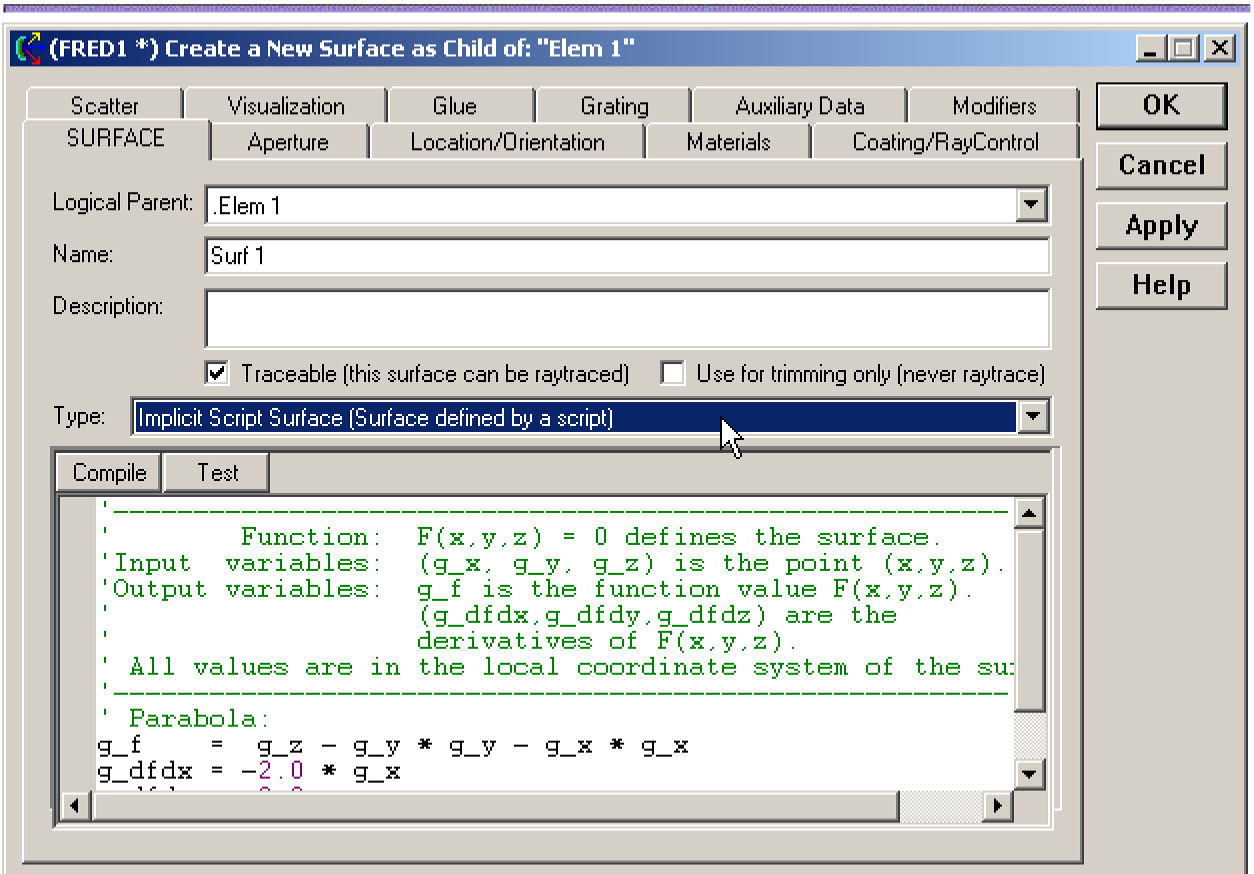
Creates a Implicit Script surface from functional form defined in script. FRED supplies the x,y,z coordinates. The user supplies FRED with the functional form of the surface as f(x,y,z)=0.



How Do I Get There? - Surface - Implicit Script Surface


Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Implicit Script Surface



Control	***Inputs / Description***	***Defaults***
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	Blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Implicit Script Surface
Mesh Z(x,y)		
Data Table	User input data or read from file.	

OK	Accept Implicit Script Surface surface and close dialog box.	
Cancel	Discard Implicit Script Surface surface and close dialog box.	
Apply	Create Implicit Script Surface surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Implicit Script Surface

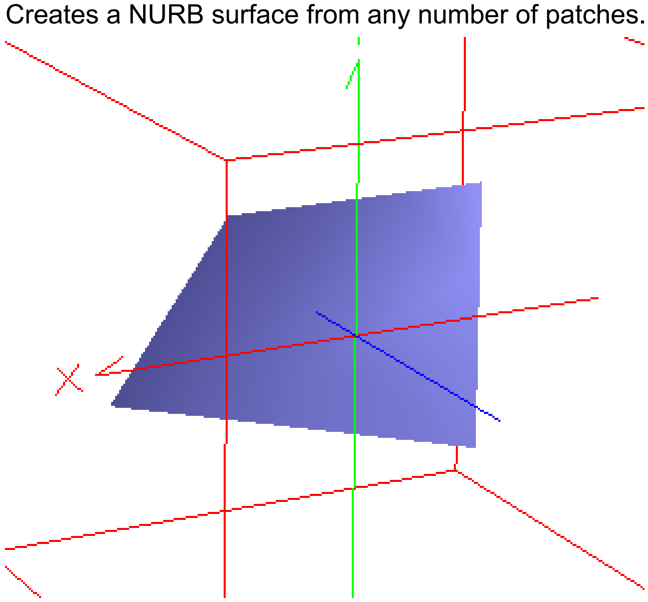
1. The Implicit Script Surface is a sagable surface.

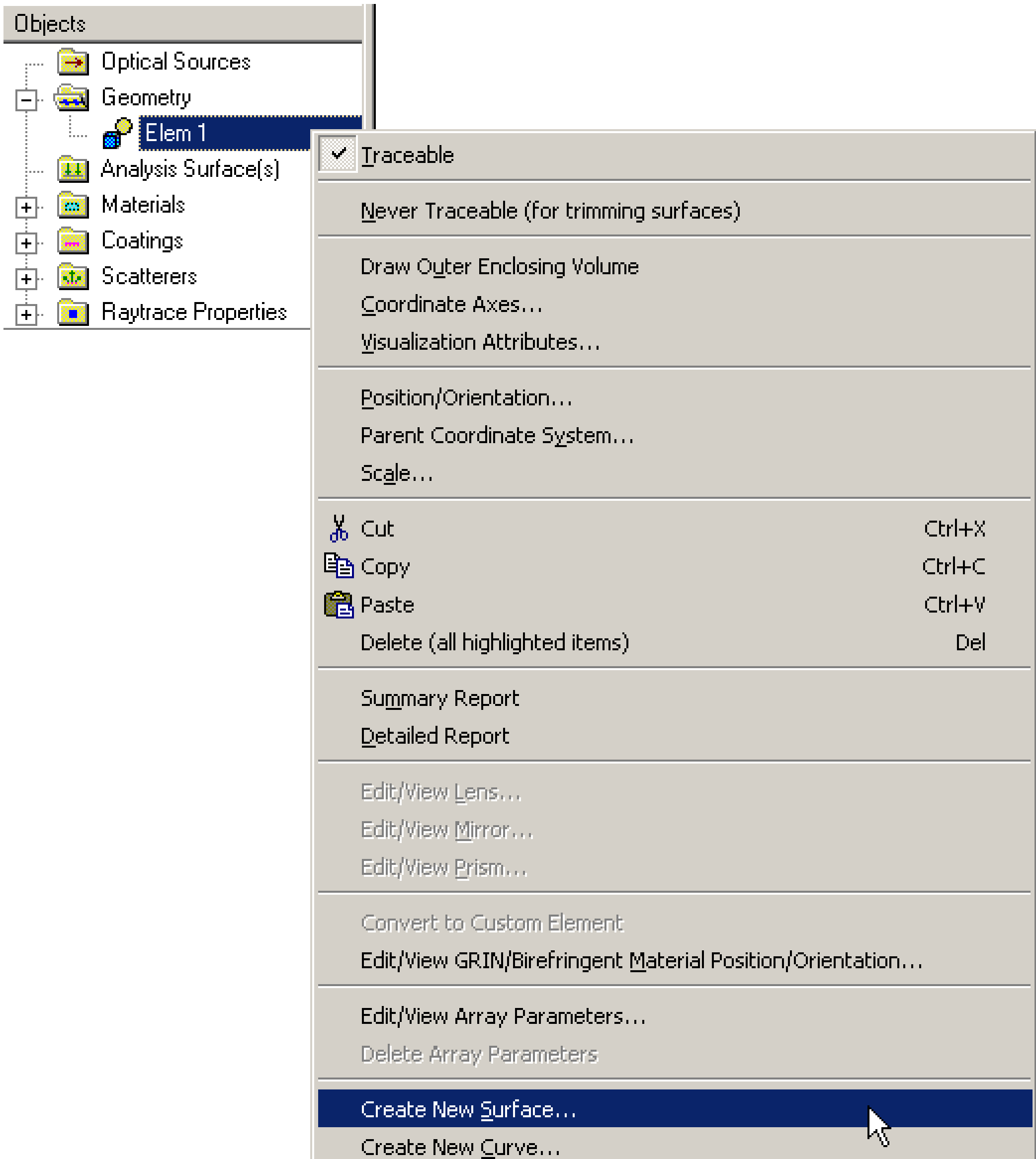
See Also…. - Surface - Implicit Script Surface

Create – New Surface - NURB

Description - Surface - NURB

Creates a NURB surface from any number of patches..




Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
Copy Ctrl+C
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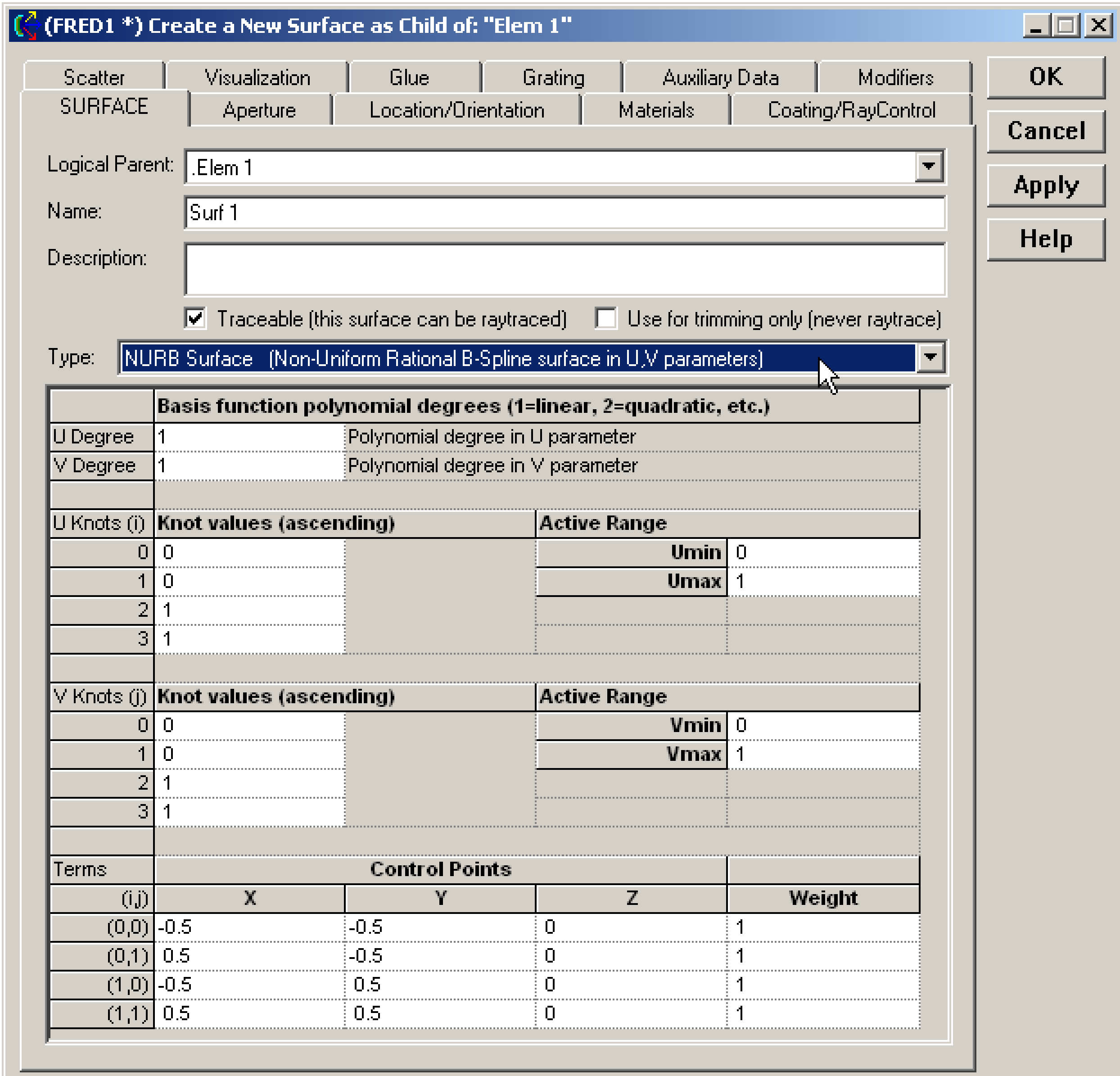
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...



Control	*Inputs / Description*	*Defaults*
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked

Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	NURB
UV Degree	Polynomial degree	blank
UV knots (Value/Range)	Knot values and Active Range.	0-360
Control Points/weights	XYZ control points and their associated weights.	X(0,0) Y(0,0) Z(0,1)
OK	Accept NURB surface and close dialog box.	
Cancel	Discard NURB surface and close dialog box.	
Apply	Create NURB surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - NURB

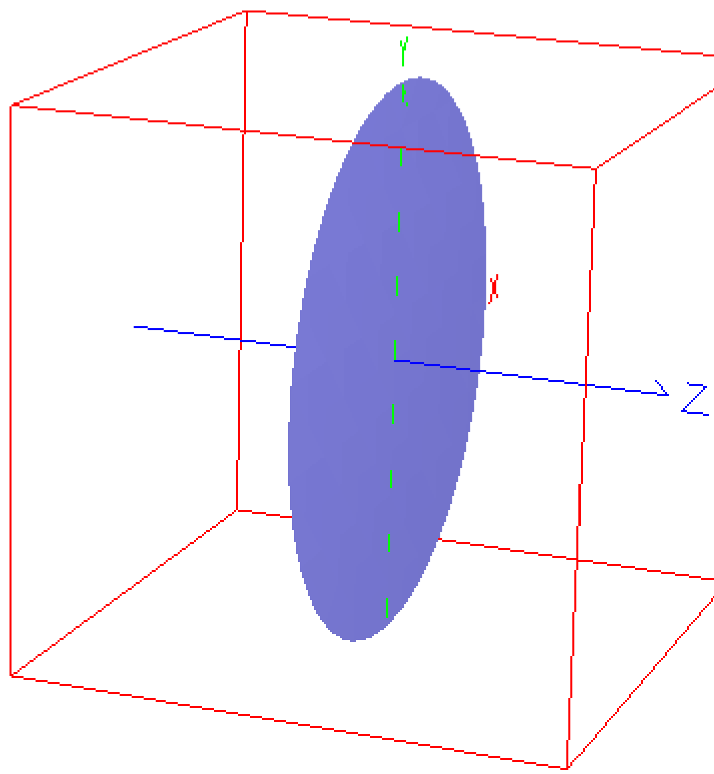
1. The NURB is a sagable surface.

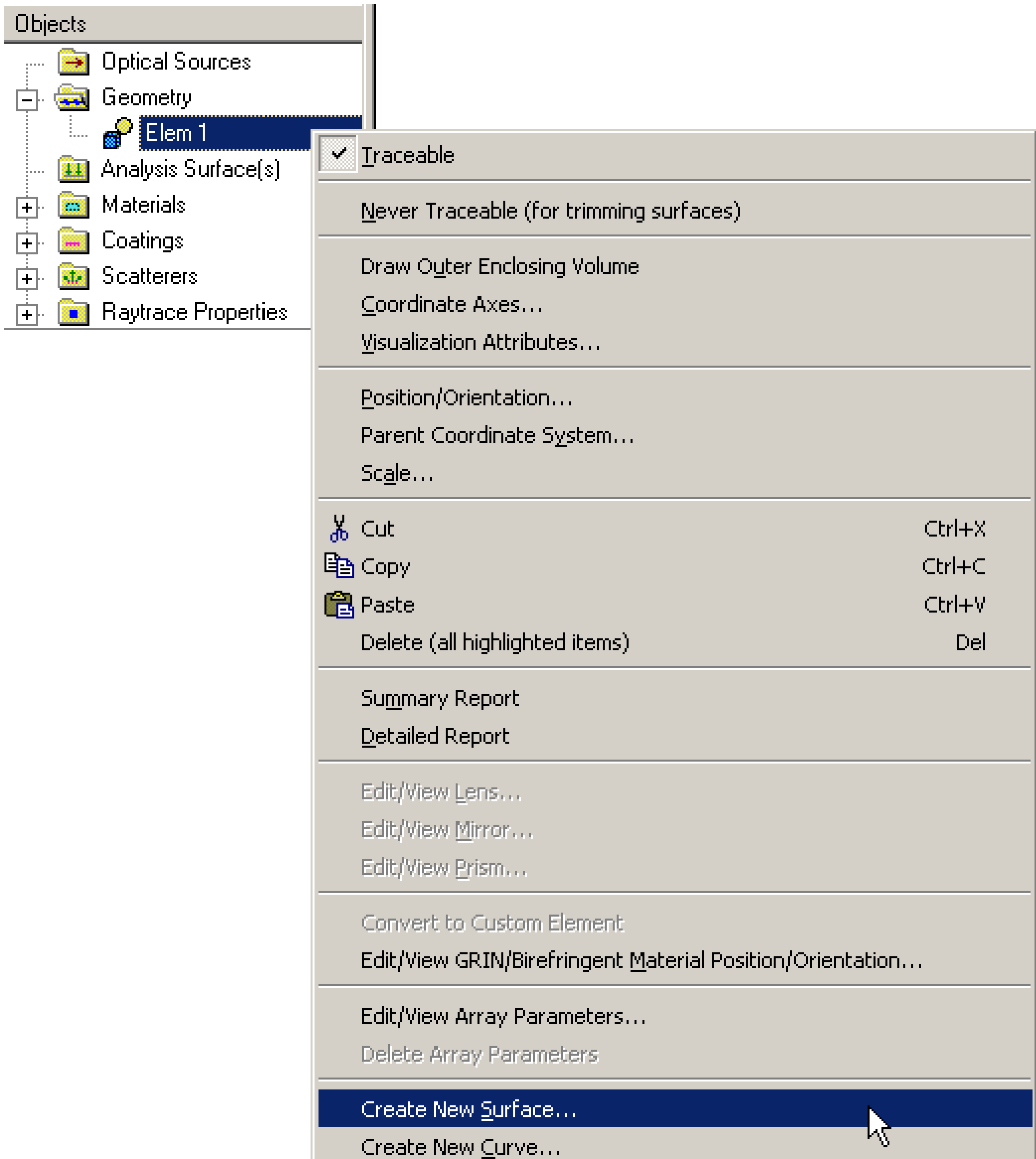
See Also…. - Surface - NURB

Create - New Surface - Plane

Description - Surface - Plane

Creates a planar surface with a default aperture, material, coating, raytrace control, location, etc. The default location/orientation is at the origin in the xy-plane.




Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
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Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
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Delete (all highlighted items) Del
Summary Report
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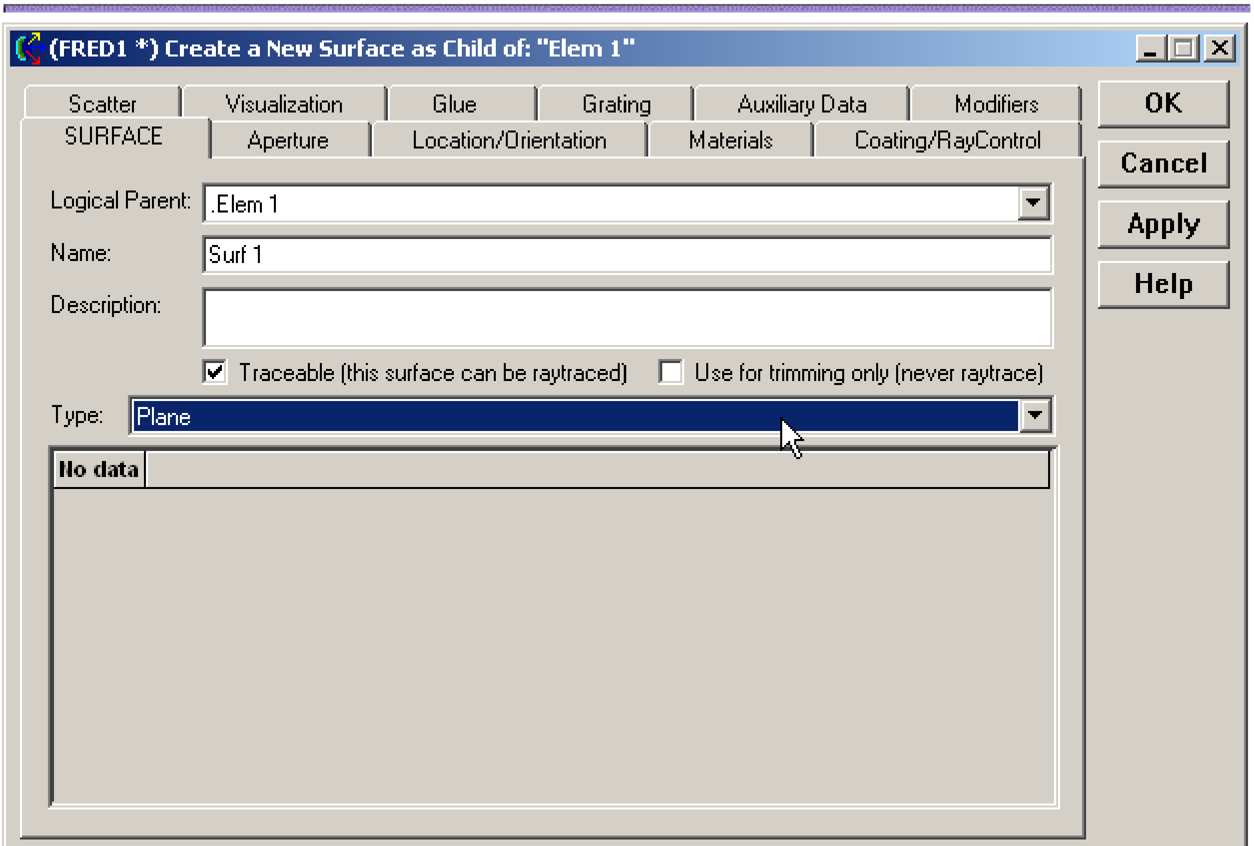
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Plane



Control	*Inputs / Description*	*Defaults*
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Plane
OK	Accept Plane surface and close dialog box.	
Cancel	Discard Plane surface and close dialog box.	

Apply	Create Plane surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Plane

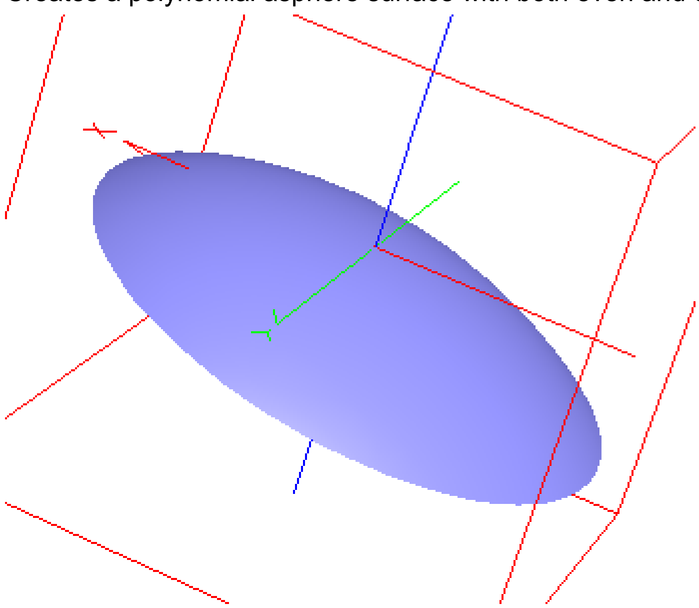
1. The Plane is a "Sagable" surface.

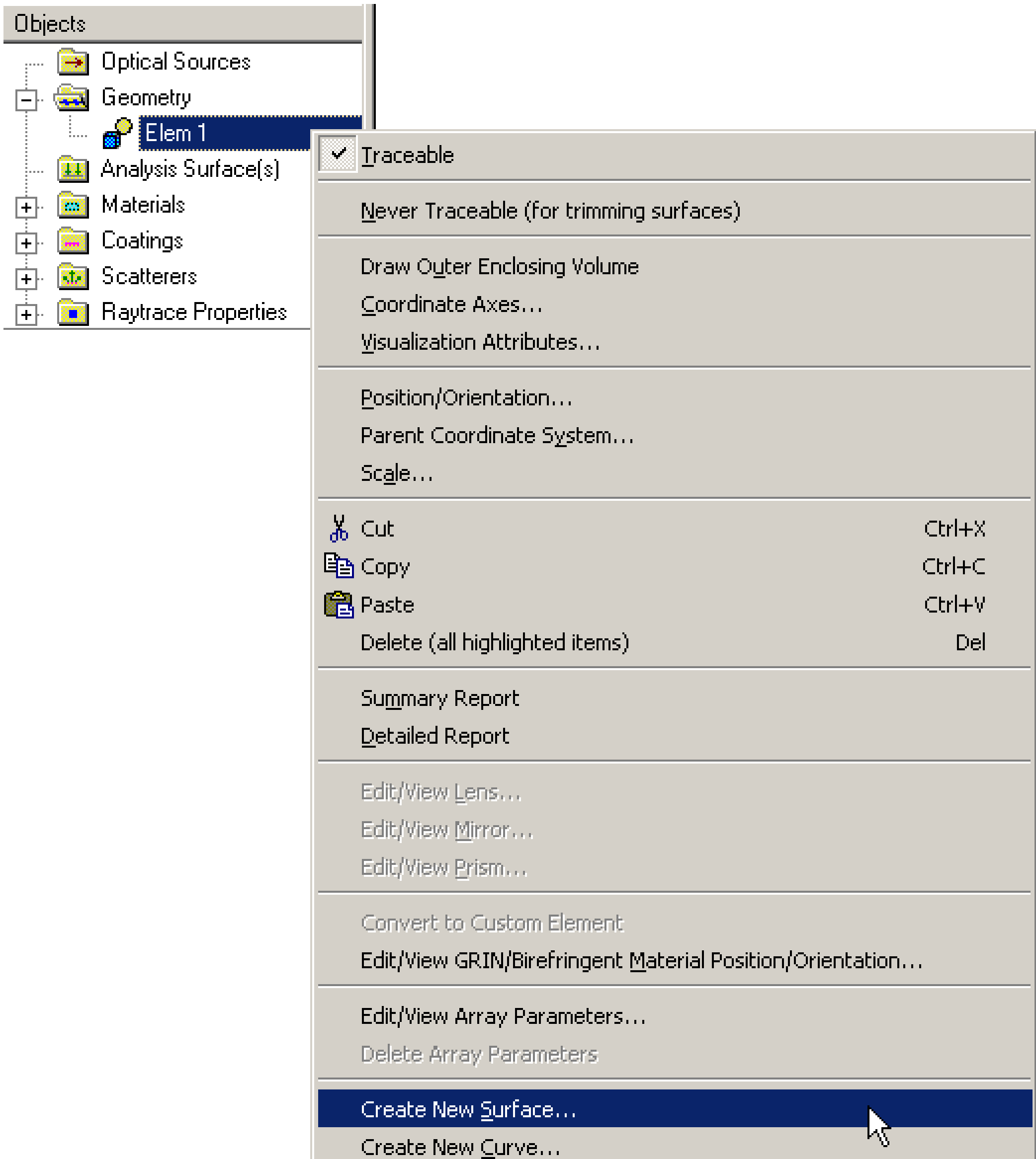
See Also.... - Surface - Plane

Create - New Surface - Polynomial Asphere Surface

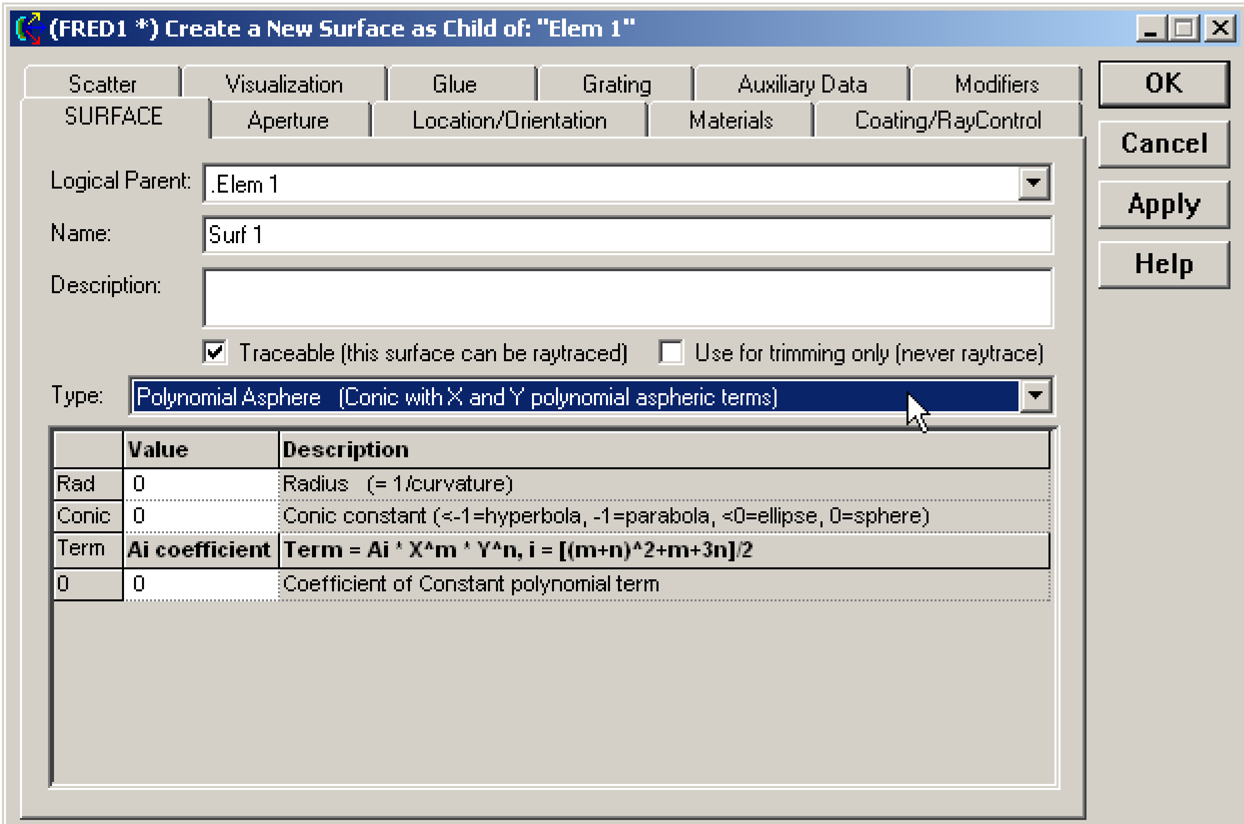
Description - Surface - Polynomial Asphere Surface

Creates a polynomial asphere surface with both even and odd order terms.




Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Polynomial Asphere Surface



Control	*Inputs / Description*	*Defaults*
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Polynomial Surface
Rad	Radius of curvature.	0
Conic	Conic constant.	0
A_i coefficients	Aspheric term coefficients.	0

OK	Accept Polynomial Asphere Surface surface and close dialog box.	
Cancel	Discard Polynomial Asphere Surface surface and close dialog box.	
Apply	Create Polynomial Asphere Surface surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Polynomial Asphere Surface

1. The function form of the Polynomial Asphere Surface is given by

$$f(x,y,z) = z - \frac{cv \cdot r^2}{1 + \sqrt{1 - (1 + conic) \cdot (cv \cdot r)^2}} - \sum_i \sum_j A_{ij} \cdot x^{i-j} \cdot y^j$$

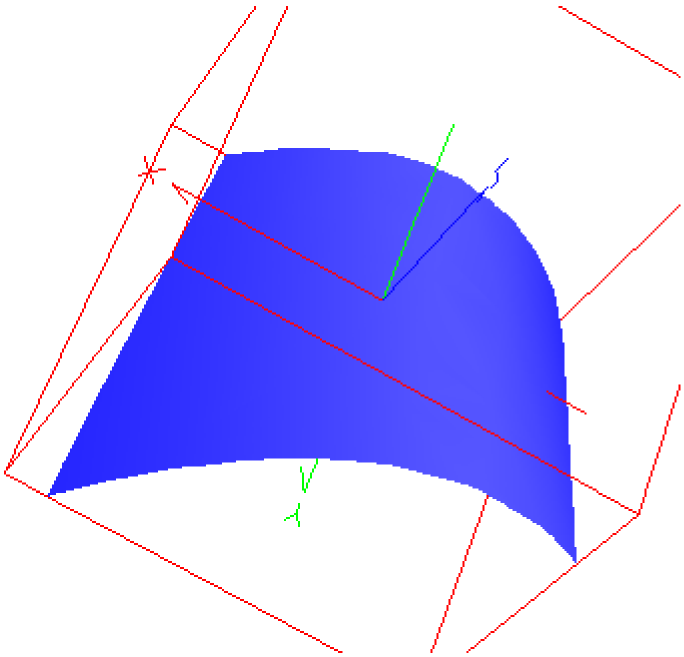
2. The Polynomial Apshere Surface is a sagable surface.

See Also…. - Surface - Polynomial Asphere Surface

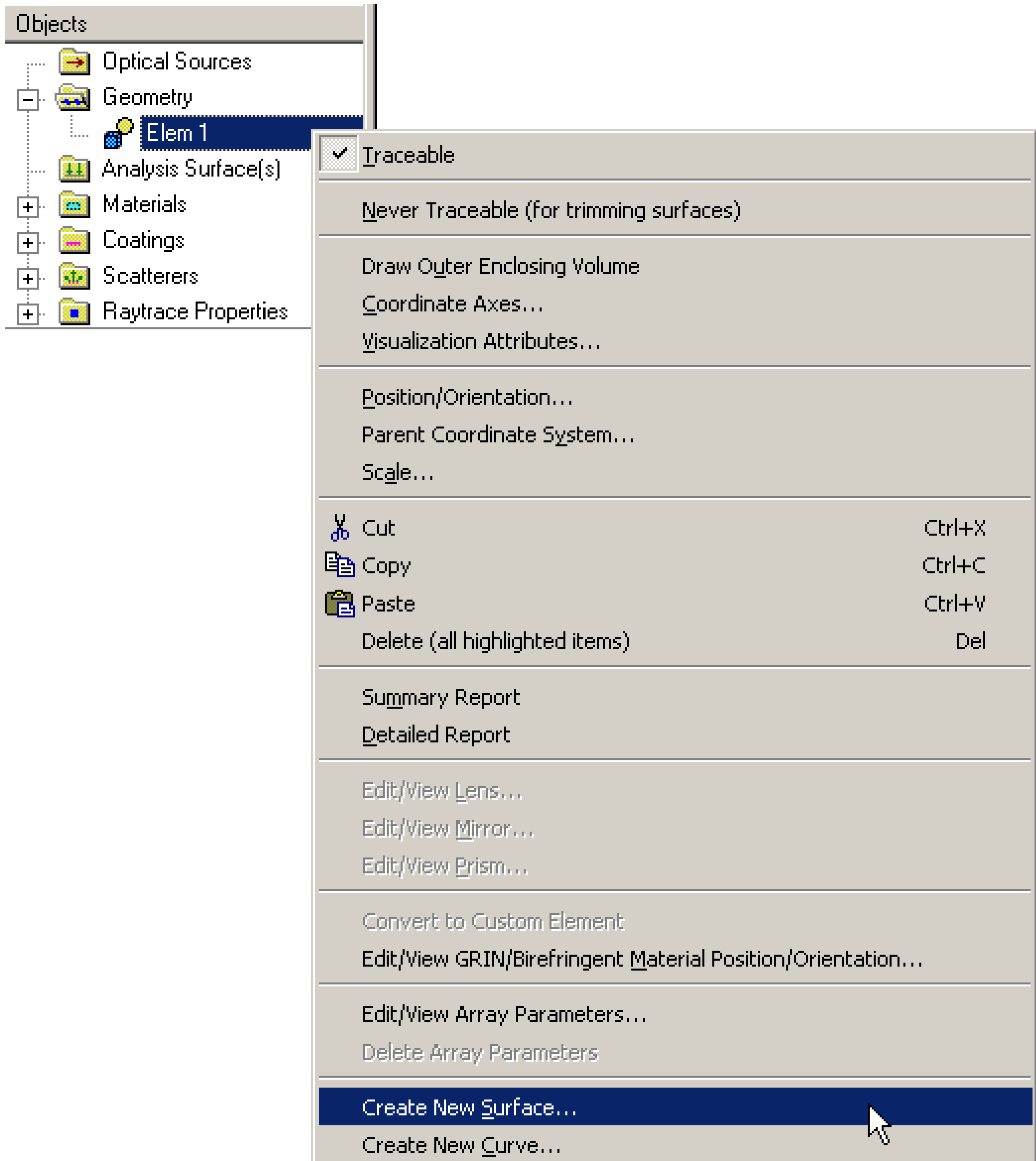
Create – New Surface - Polynomial Surface

Description - Surface - Polynomial Surface

Creates a polynomial surface with both even, odd and cross terms.



How Do I Get There? - Surface - Polynomial Surface


Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
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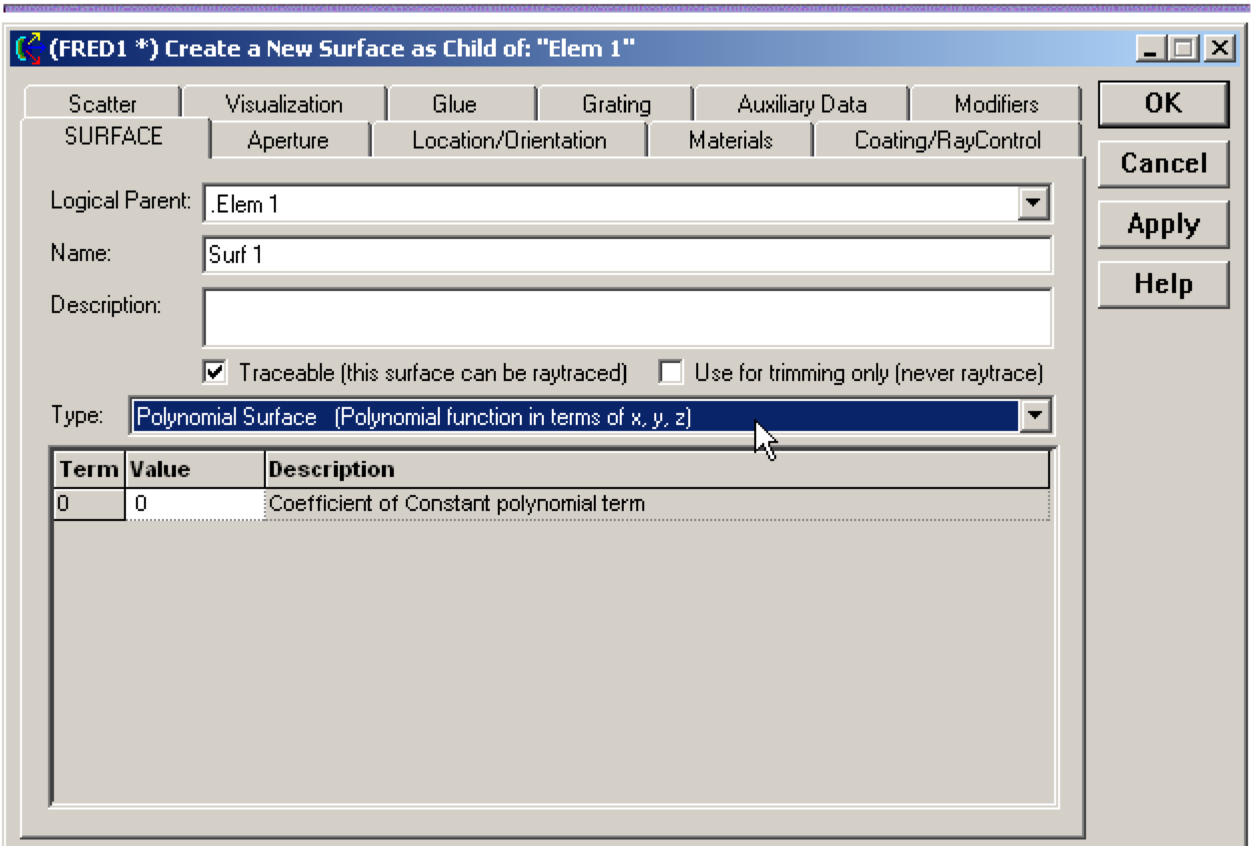
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Polynomial Surface



Control	Inputs / Description	Defaults
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Polynomial Surface
Coefficients	Polynomial coefficients of all order.	0
OK	Accept Polynomial Surface surface and close dialog box.	

Cancel	Discard Polynomial Surface surface and close dialog box.	
Apply	Create Polynomial Surface surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Polynomial Surface

1. The function form of the Polynomial Surface is given by

$$f(x,y,z)=\sum_{i=0}^{n}\sum_{j=0}^{i}\sum_{k=0}^{j}A_{ijk}\cdot X^{i-j}\cdot Y^{j-k}Z^{k}$$

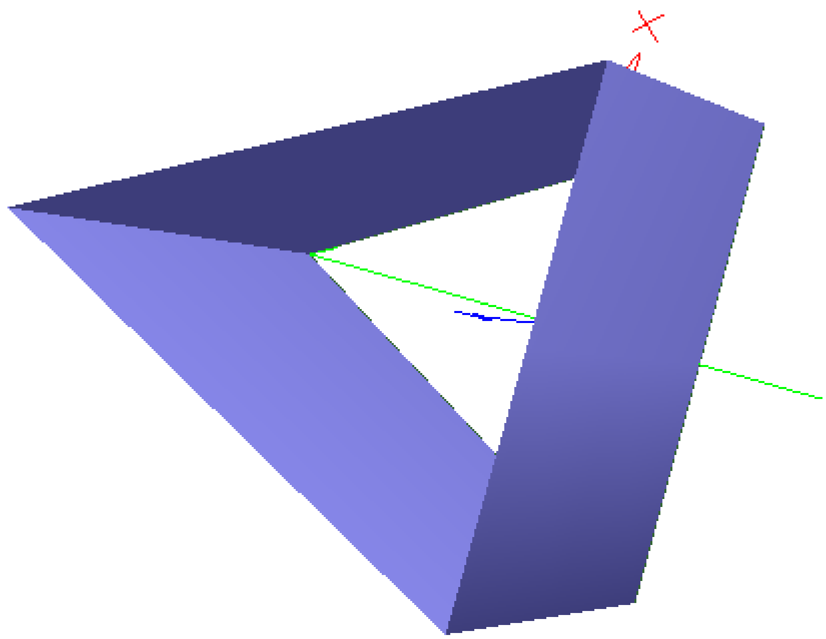
2. The Polynomial Surface is a sagable surface.

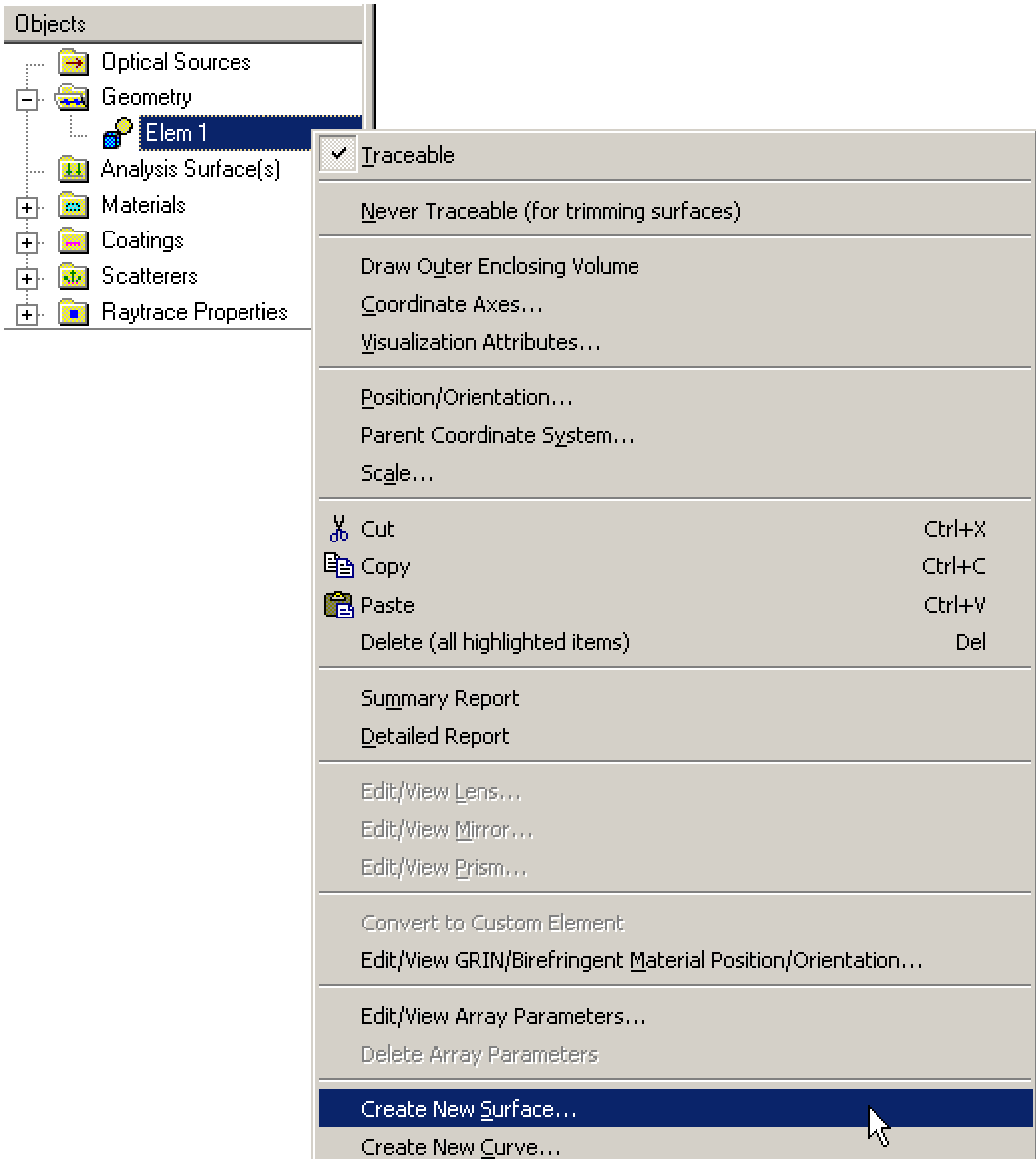
See Also…. - Surface - Polynomial Surface

Create - New Surface - Ruled Surface

Description - Surface - Ruled Surface

Creates a ruled surface by connecting two curves. This is a more general extrusion method.




Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
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Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
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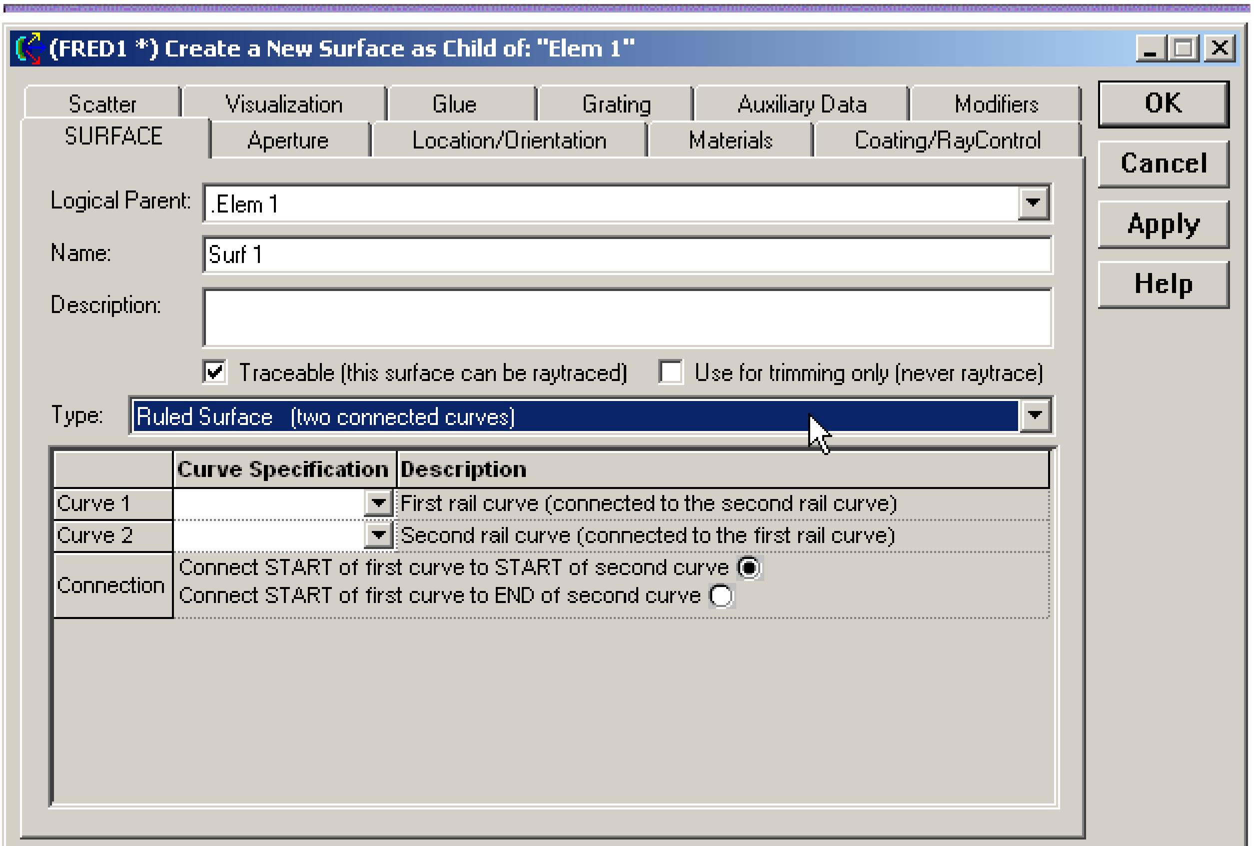
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Ruled Surface



Control	*Inputs / Description*	*Defaults*
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Ruled Surface
Curve 1,2	Specifies curves to connect.	blank
Connection	Connect start of 1st curve to Start/End of 2nd curve.	START

OK	Accept Ruled Surface surface and close dialog box.	
Cancel	Discard Ruled Surface surface and close dialog box.	
Apply	Create Ruled Surface surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Ruled Surface

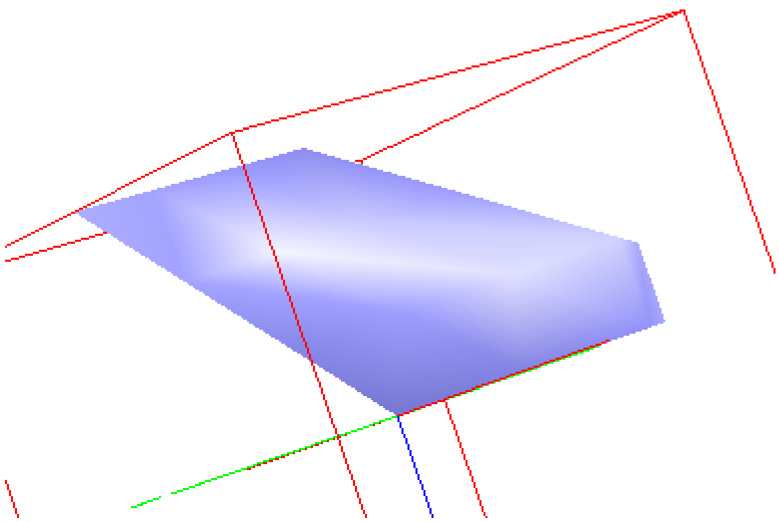
1. The Ruled Surface is a sagable surface.

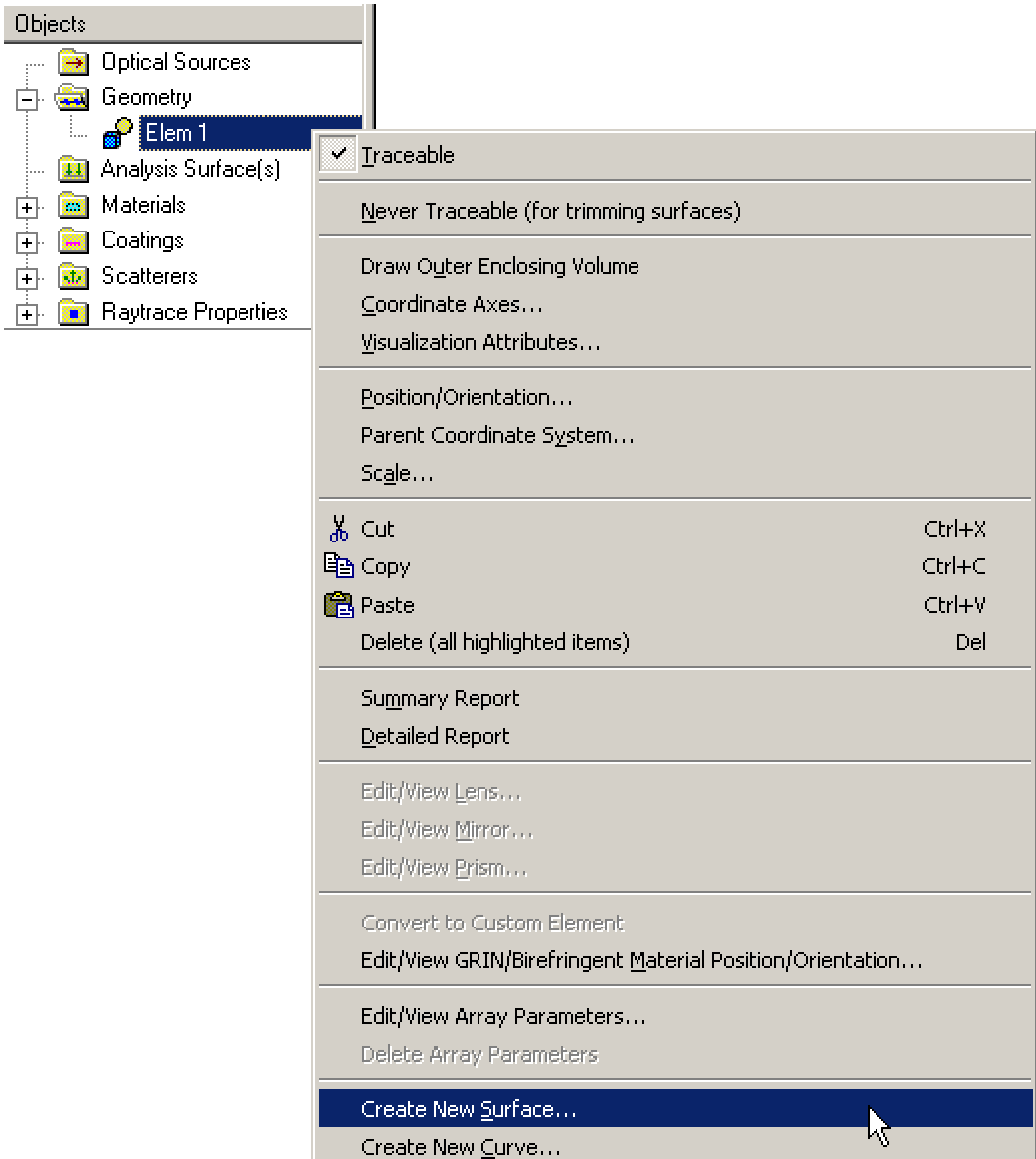
See Also…. - Surface - Ruled Surface

Create - New Surface - Spline

Description - Surface - Spline

Creates a Spline surface using piecewise parametric polynomials.




Objects
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Elem 1
Analysis Surface(s)
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Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
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Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
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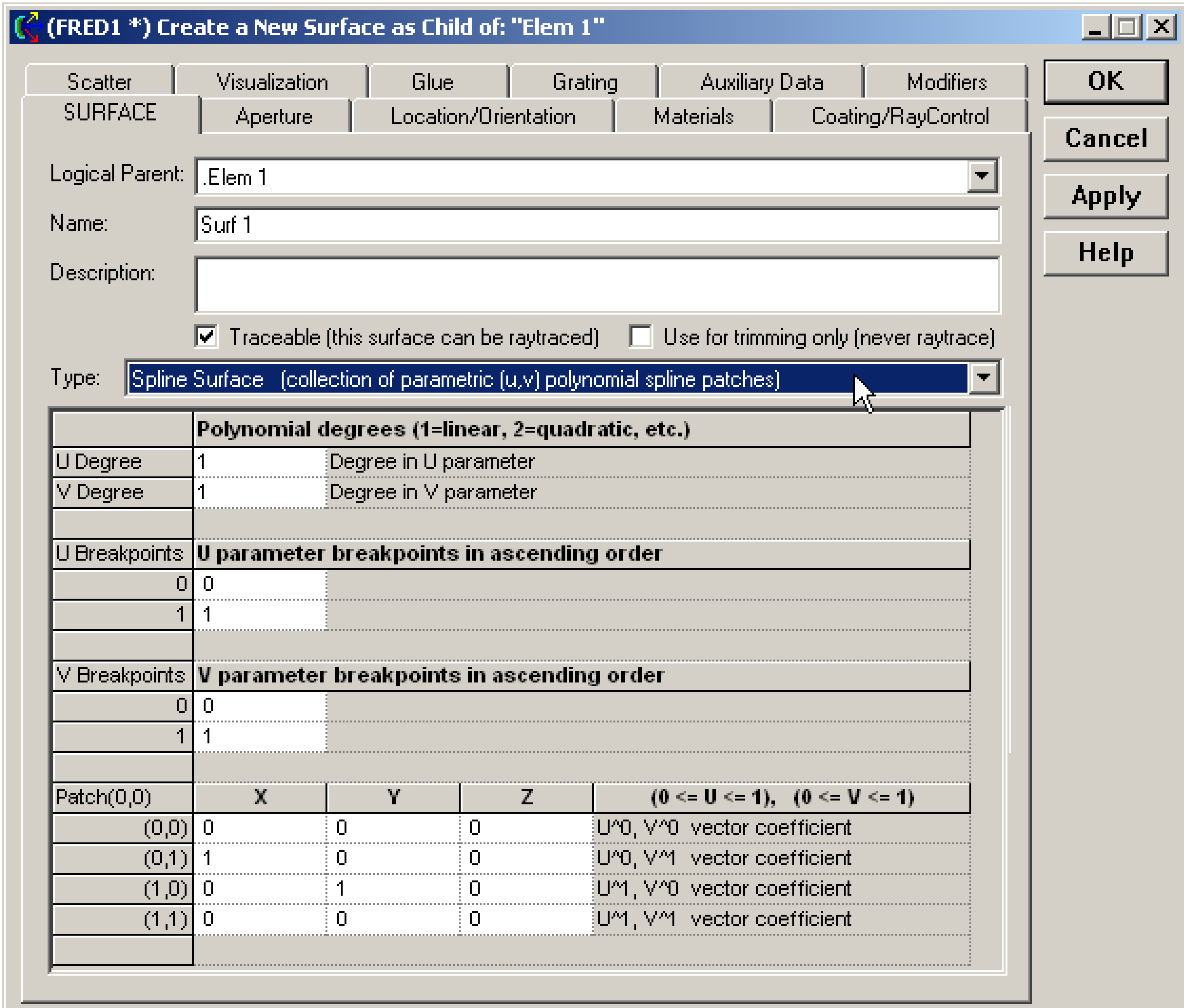
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Spline



Control	Inputs / Description	Defaults
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Spline
UV Degree	Polynomial degree	1,1

UV Breakpoints	Breakpoints	(0,1) (0,1)
Patch	Patch specifications	X(0,1)=Y(1,0)=1, all others zero
OK	Accept Spline surface and close dialog box.	
Cancel	Discard Spline surface and close dialog box.	
Apply	Create Spline surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Spline

1. The functional form of a spline is given by

$$\vec{\mathbf{P}}(s,t) = \sum_{k=0}^{K}\sum_{l=0}^{L}\vec{\mathbf{C}}_{kl}s^l t^k$$

where the $\mathbf{C}_{kl}$ are for the (i,j) patch and s, t are determined by

$$Tu(i) \le u < Tu(i+1), \quad i = 0,....M-1, \quad \text{then} \quad s = u - Tu(i)$$

$$Tv(j) \le v < Tv(j+1), \quad j = 0,....N-1, \quad \text{then} \quad t = v - Tv(j)$$

U, V are related to u, v by :

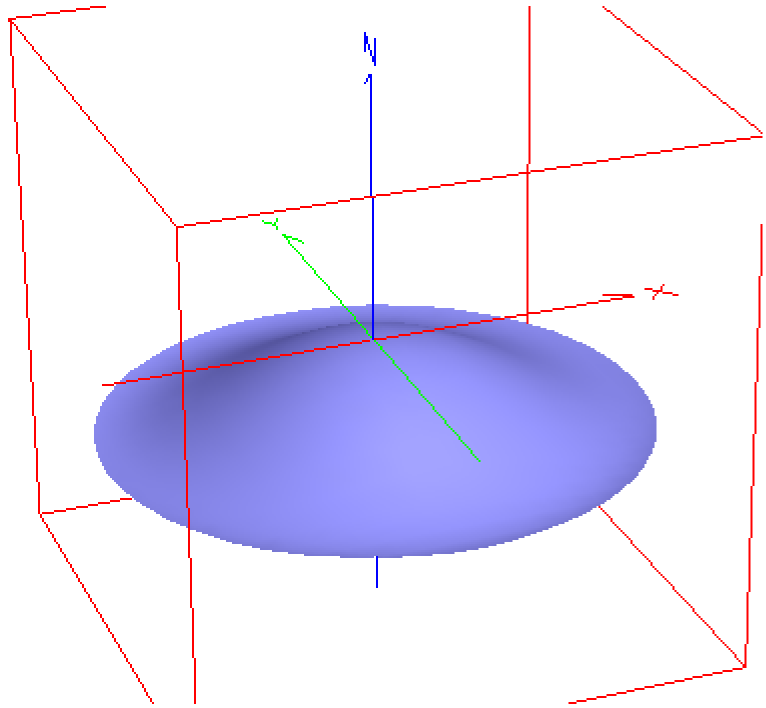
$$U = \frac{u - Tu(0)}{Tu(M) - Tu(0)} \quad \text{and} \quad V = \frac{v - Tv(0)}{Tv(N) - Tv(0)}$$

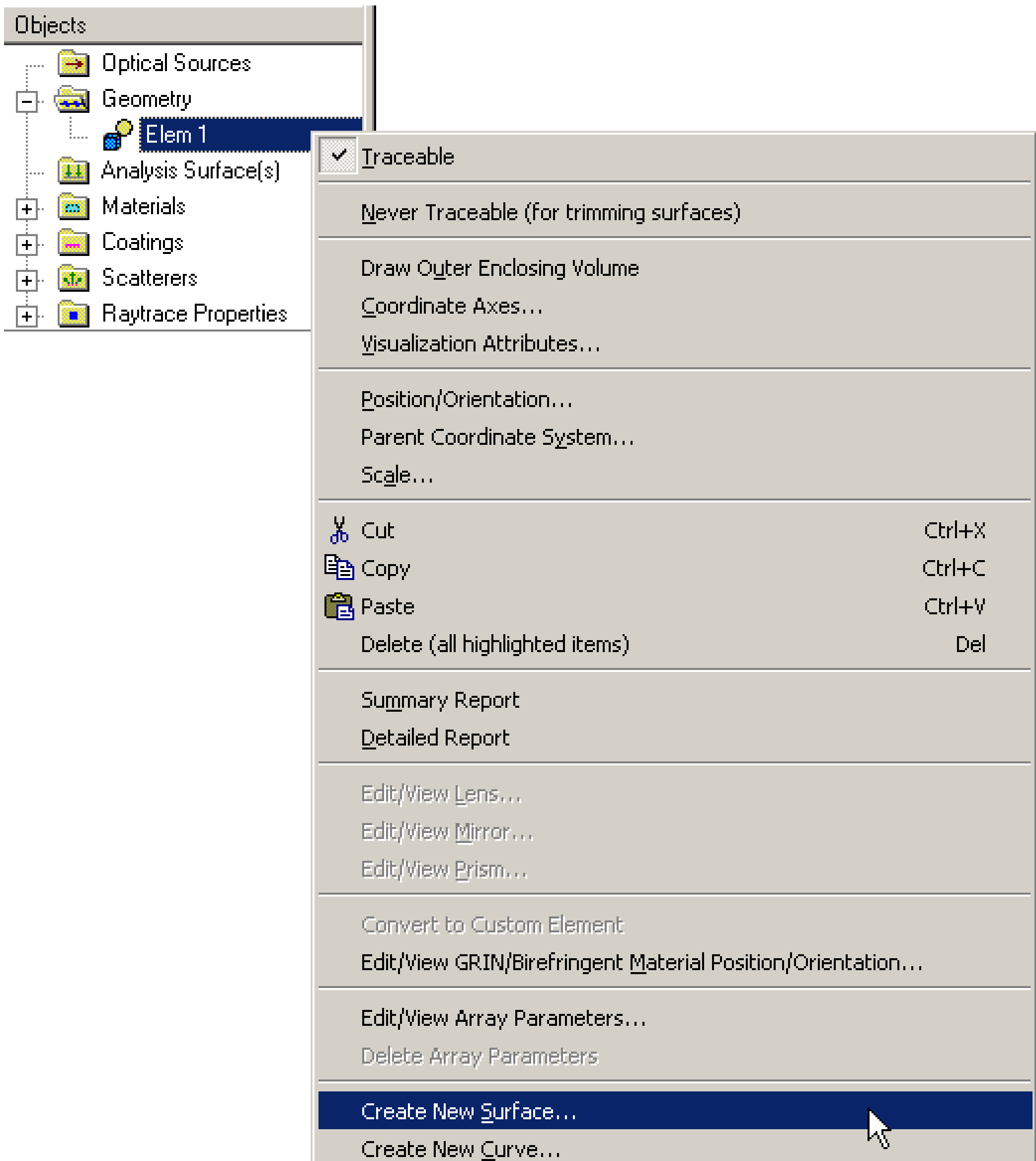
2. The Spline is a sagable surface.

See Also…. - Surface - Spline

Description - Surface - Standard Asphere

Creates an aspheric surface with only even terms.




Objects
Optical Sources
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Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
Visualization Attributes...
Position/Orientation...
Parent Coordinate System...
Scale...
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Summary Report
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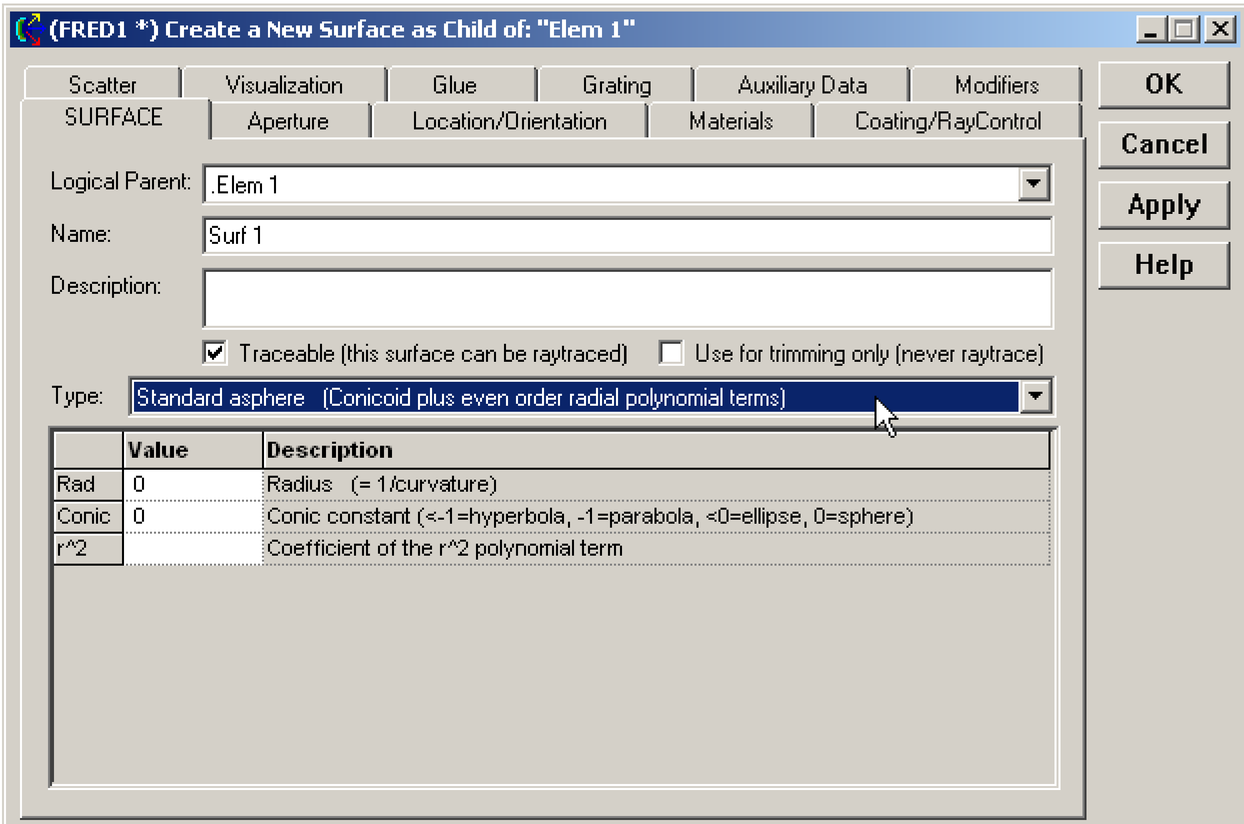
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Standard Asphere



Control	*Inputs / Description*	*Defaults*
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Standard Asphere
Rad	Radius of curvature.	0
Conic	Conic constant.	0
r^2. r^4, r^6...........	Even order aspheric terms	0

OK	Accept Standard asphere surface and close dialog box.	
Cancel	Discard Standard asphere surface and close dialog box.	
Apply	Create Standard asphere surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Standard Asphere

1. The function form of the Standard asphere is given by

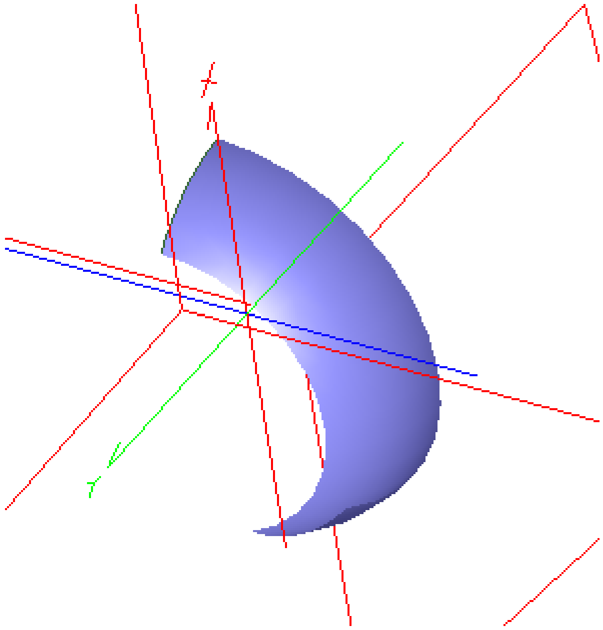
$$f(r,z) = z - \frac{cv \cdot r^2}{1 + \sqrt{1 - (1 + conic) \cdot (cv \cdot r)^2}} - \sum_{n=0} A_n \cdot r^{2n} = 0$$

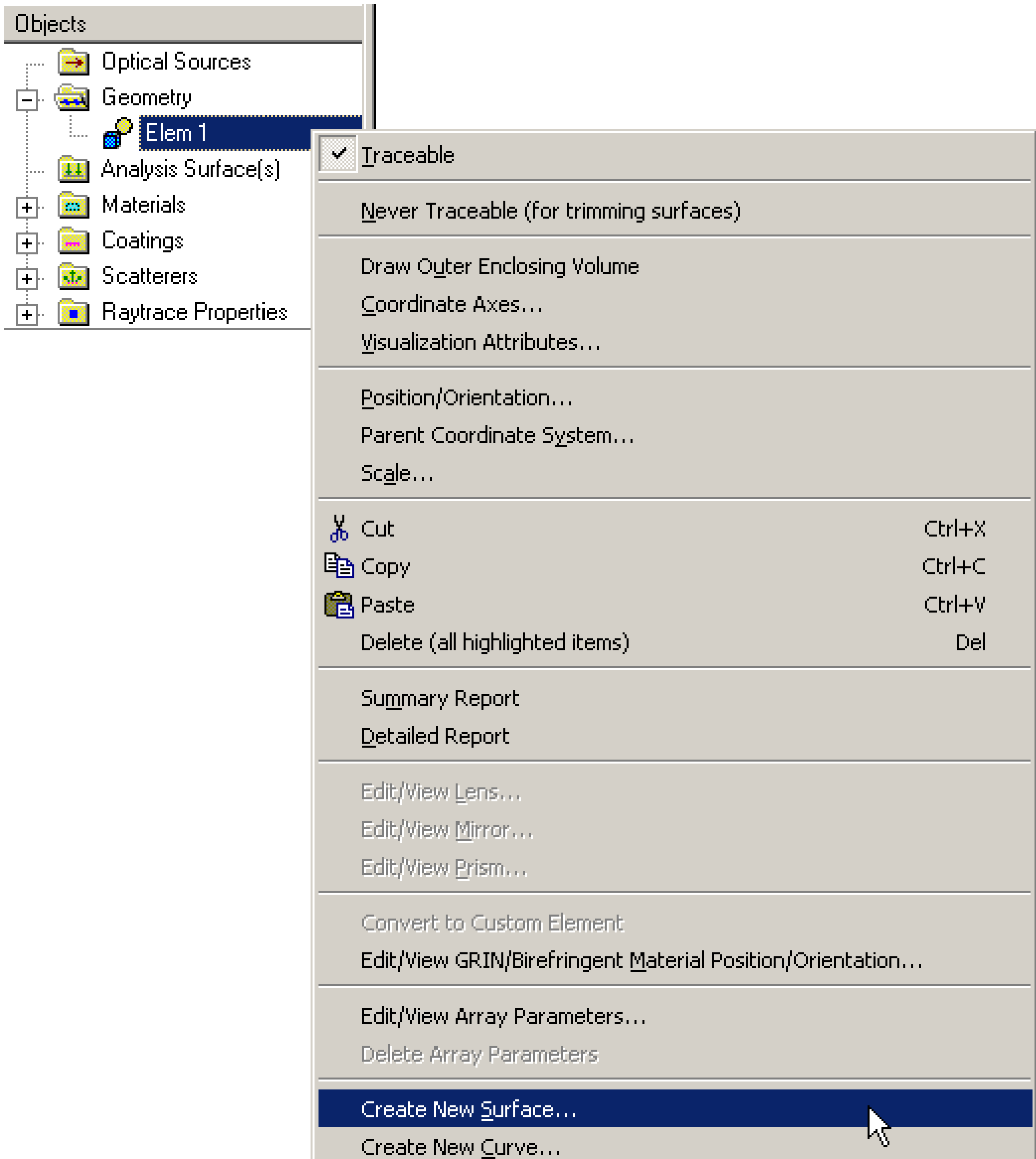
2. The Standard asphere is a sagable surface.

See Also…. - Surface - Standard Asphere

Description - Surface - Surface of Revolution

Creates a Surface of Revolution by sweeping a curve about an axis.




Objects
Optical Sources
Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes...
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Summary Report
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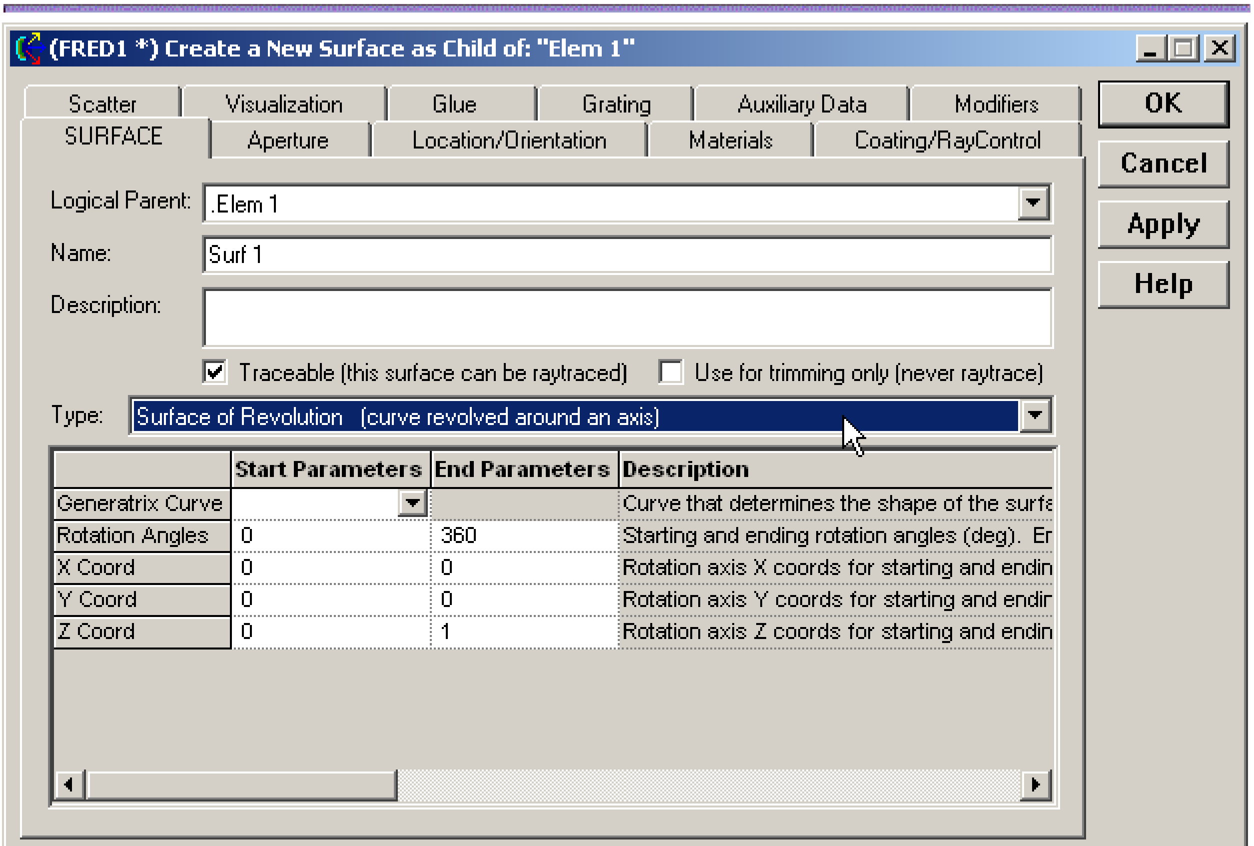
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Surface of Revolution



Control	***Inputs / Description***	***Defaults***
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Surface of Revolution
Generatrix Curve	Specifies curve to sweep	blank
Rotation angle	Angle to sweep curve through.	0-360
Connection	XYZ start/End points of vector to sweep around.	X(0,0) Y(0,0) Z(0,1)

OK	Accept Surface of Revolution surface and close dialog box.	
Cancel	Discard Surface of Revolution surface and close dialog box.	
Apply	Create Surface of Revolution surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Surface of Revolution

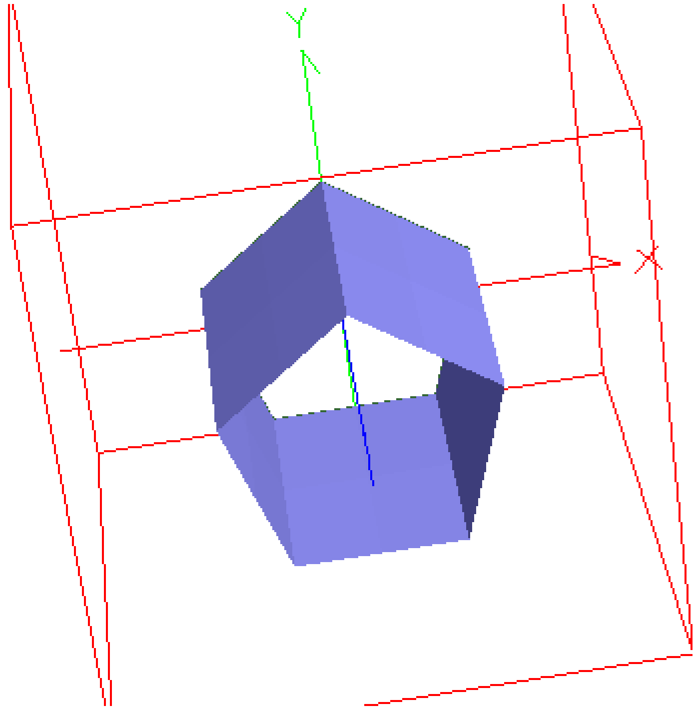
1. The Surface of Revolution is a sagable surface.

See Also…. - Surface - Surface of Revolution

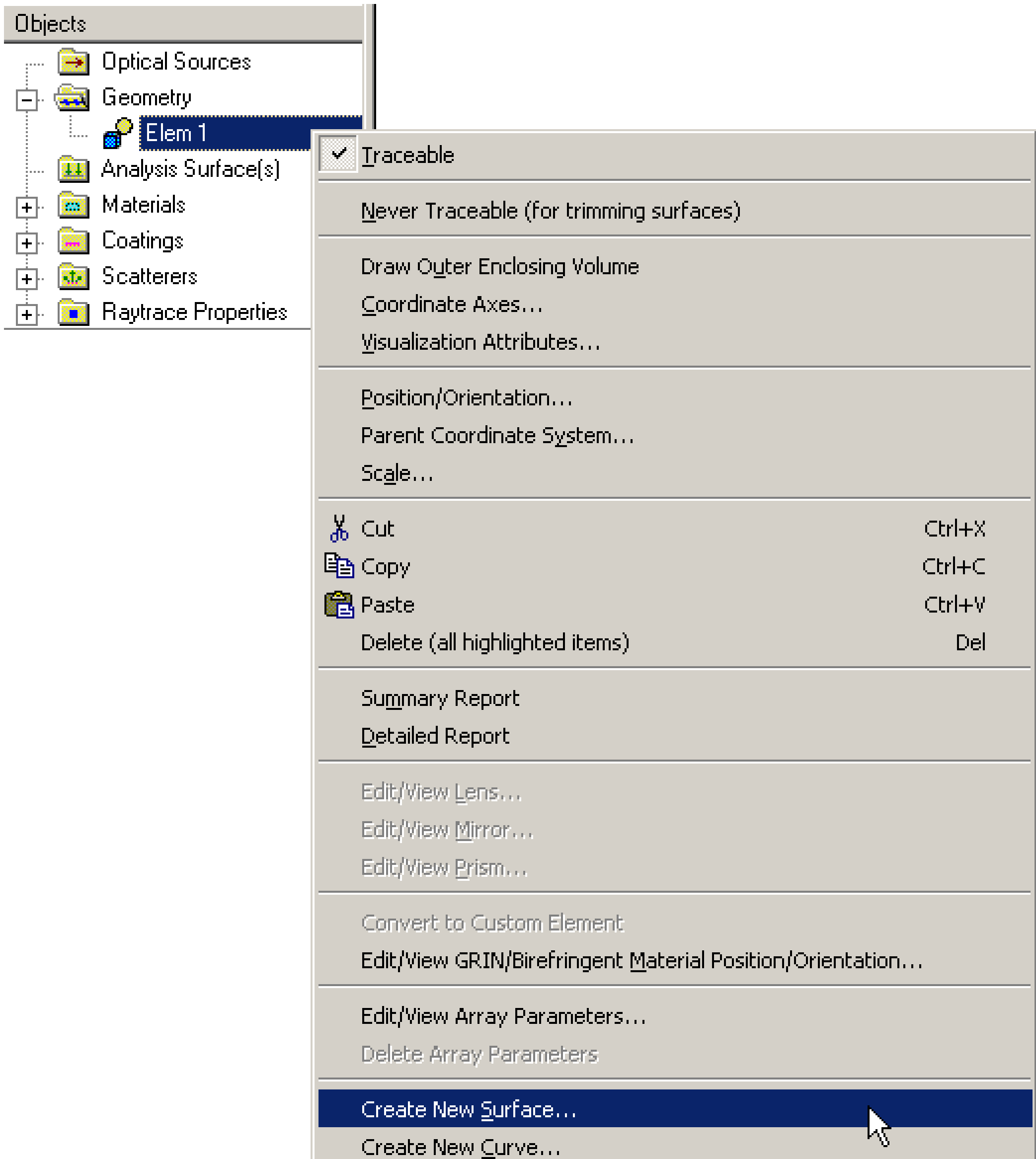
Create – New Surface - Tabulated Cylinder

Description - Surface - Tabulated Cylinder

Creates a tabulated cylinder by extruding a curve entity.



How Do I Get There? - Surface - Tabulated Cylinder


Objects
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Draw Outer Enclosing Volume
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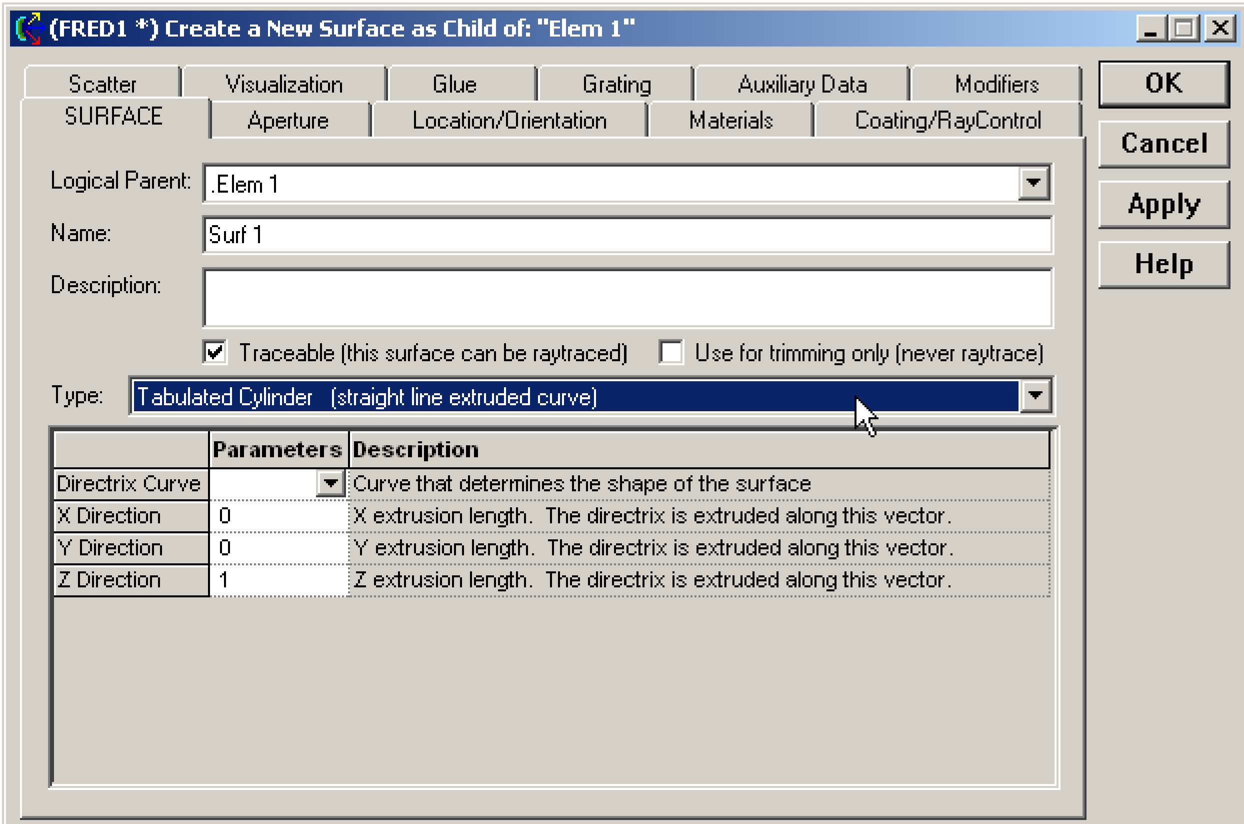
Summary Report
Detailed Report
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Tabulated Cylinder



Control	Inputs / Description	Defaults
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Tabulated Cylinder
Directrix curve	Curve used for extrusion.	first existing curve
X/Y/Z Direction	Direction/length to extrude	X=0,Y=0,Z=3

OK	Accept Tabulated Cylinder surface and close dialog box.	
Cancel	Discard Tabulated Cylinder surface and close dialog box.	
Apply	Create Tabulated Cylinder surface and keep dialog box open.	
Help	Access this Help page.	

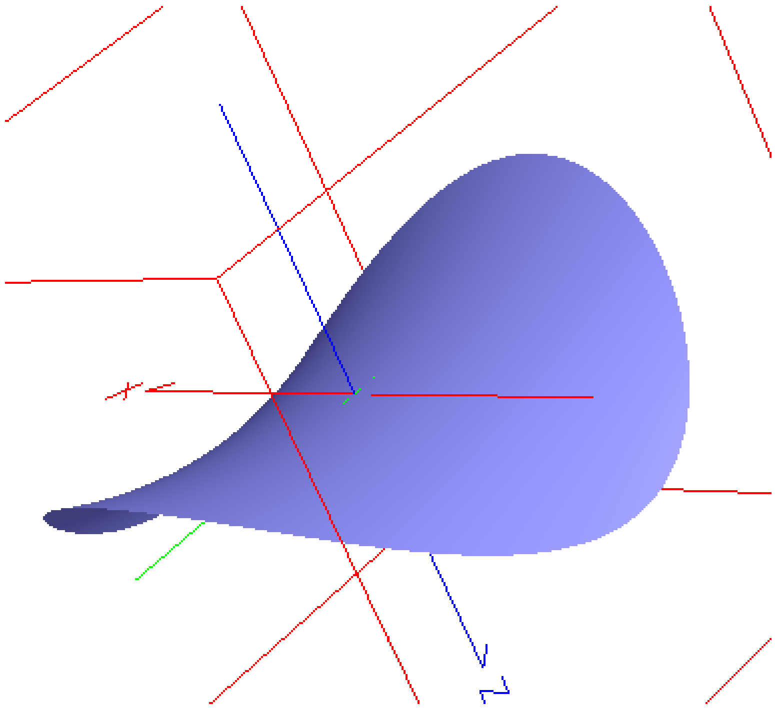
Application Notes - Surface - Tabulated Cylinder

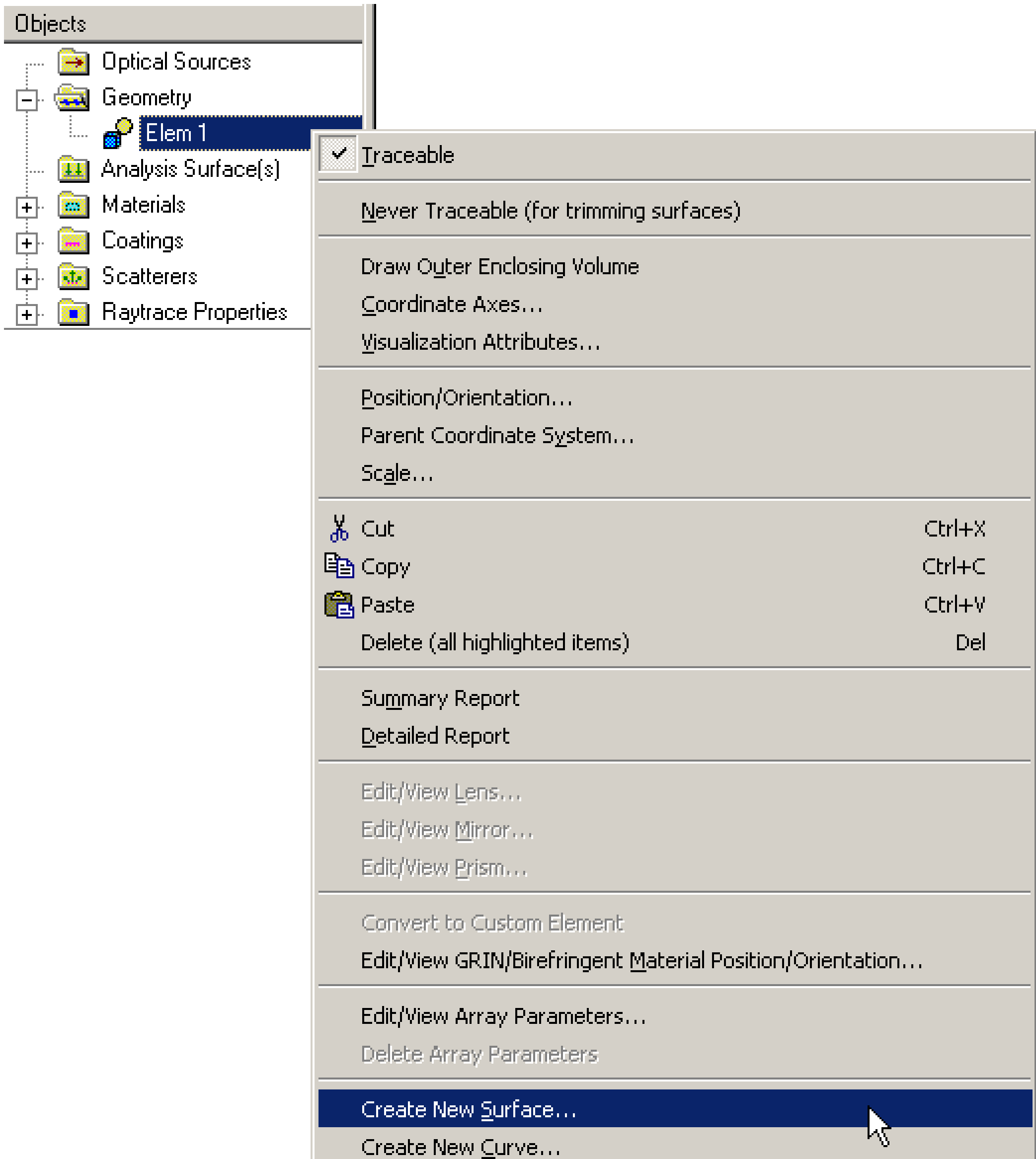
1. The Tabulated Cylinder is a "non-sagable" surface. Therefore, it cannot be used as a deforming surface.

See Also…. - Surface - Tabulated Cylinder

Description - Surface - Toroidal Asphere

Creates a toroidal aspheric surface with only even order terms.

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Draw Outer Enclosing Volume
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Summary Report
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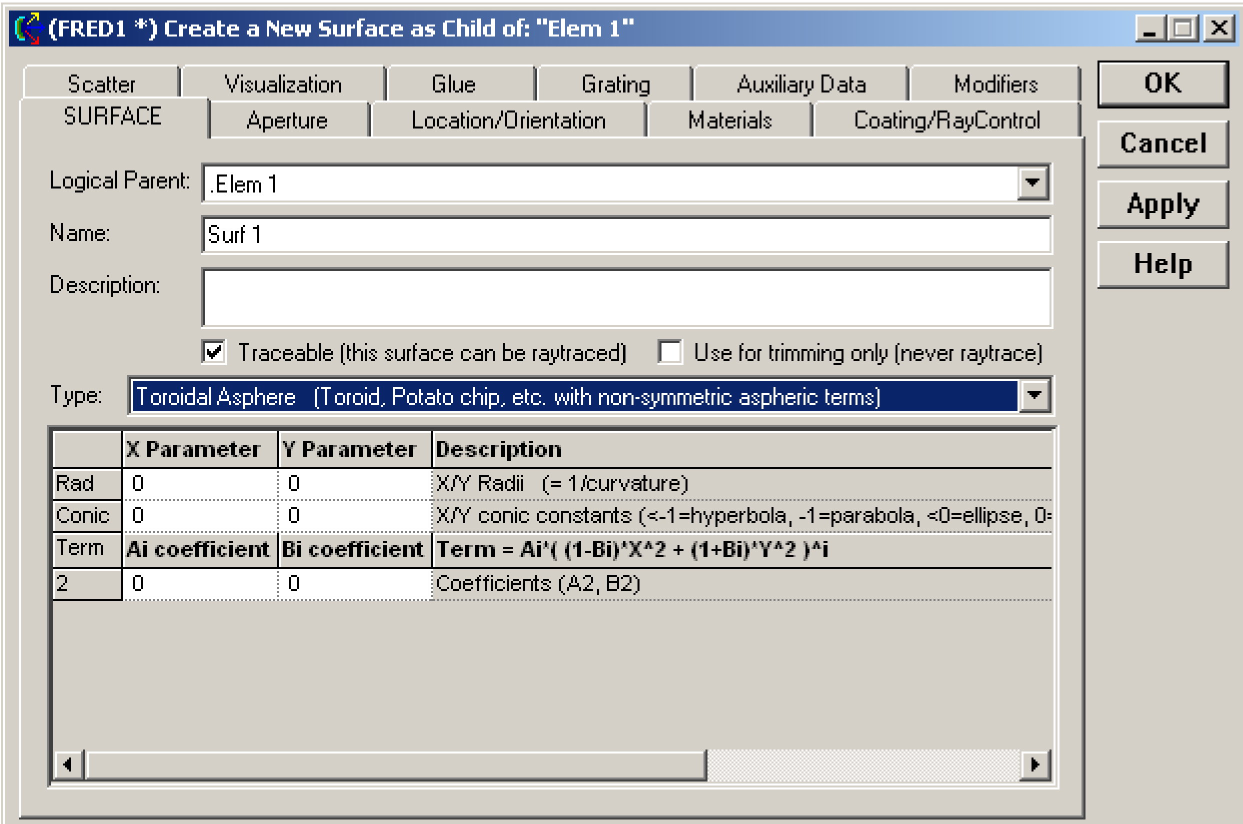
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Toroidal Asphere



Control	*Inputs / Description*	*Defaults*
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Toroidal Asphere
Rad	X & Y radii of curvature.	0
Conic	X & Y Conic constants.	0
A_i, B_i coefficients	X & Y aspheric term coefficients.	0

OK	Accept Toroidal asphere surface and close dialog box.	
Cancel	Discard Toroidal asphere surface and close dialog box.	
Apply	Create Toroidal asphere surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Toroidal Asphere

1. The function form of the Toroidal asphere is given by

$$f(x,y,z) = z - \frac{C_x \cdot x^2 + C_y \cdot y^2}{1 + \sqrt{1 - (1+K_x)\cdot(C_x \cdot x)^2 - (1+K_y)\cdot(C_y \cdot y)^2}} - \sum_i A_i((1-B_i)\cdot x^2 + (1+B_i)\cdot y^2)^i$$

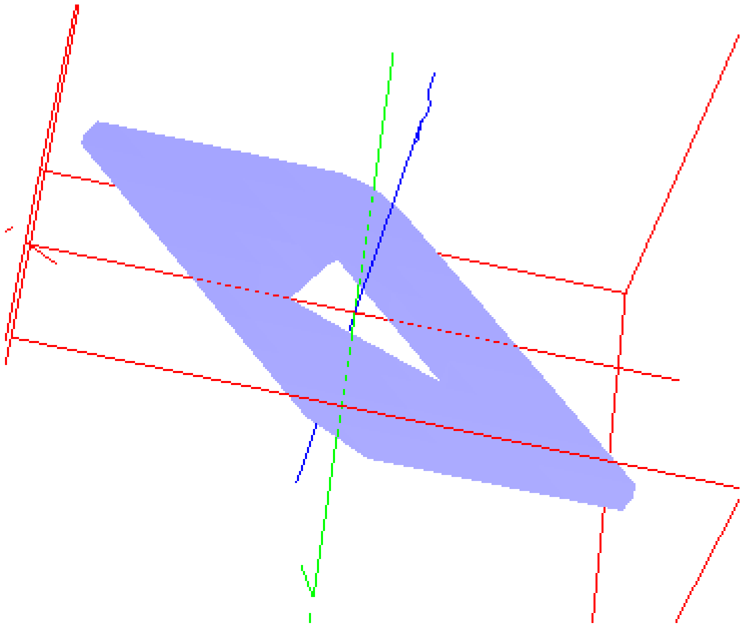
2. The Toroidal asphere is a sagable surface.

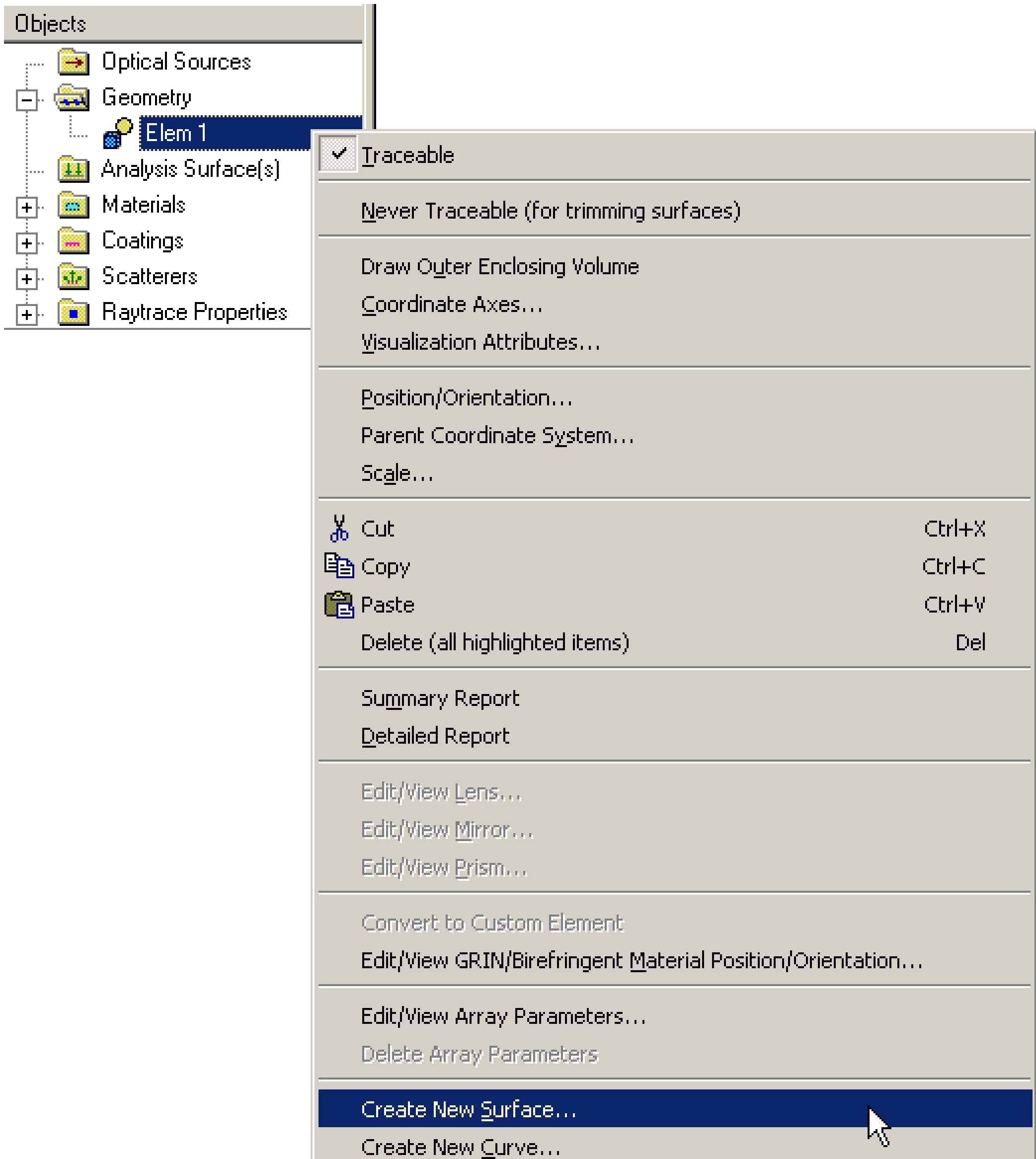
See Also…. - Surface - Toroidal Asphere

Create – New Surface - Trimmed Parametric

Description - Surface - Trimmed Parametric

Creates a Trimmed Parametric surface.

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Raytrace Properties
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Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
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Parent Coordinate System...
Scale...
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Summary Report
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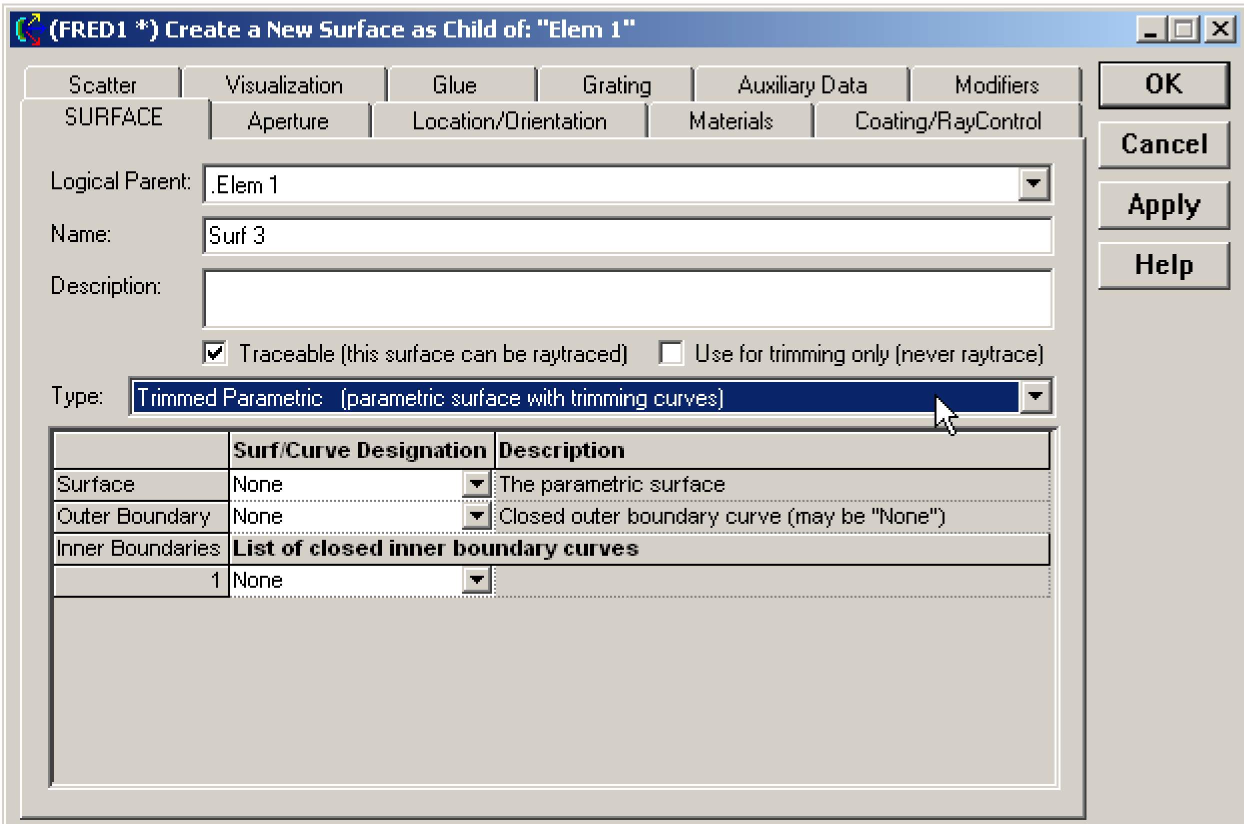
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Trimmed Parametric



Control	Inputs / Description	Defaults
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Trimmed Parametric
Surface	Parametric surface to be trimmed.	None
Outer Boundary	Curve used to trim outer boundary.	None
Inner Boundary	Curve or curves used to trim inner boundary.	None

OK	Accept Trimmed Parametric surface and close dialog box.	
Cancel	Discard Trimmed Parametric surface and close dialog box.	
Apply	Create Trimmed Parametric surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Trimmed Parametric

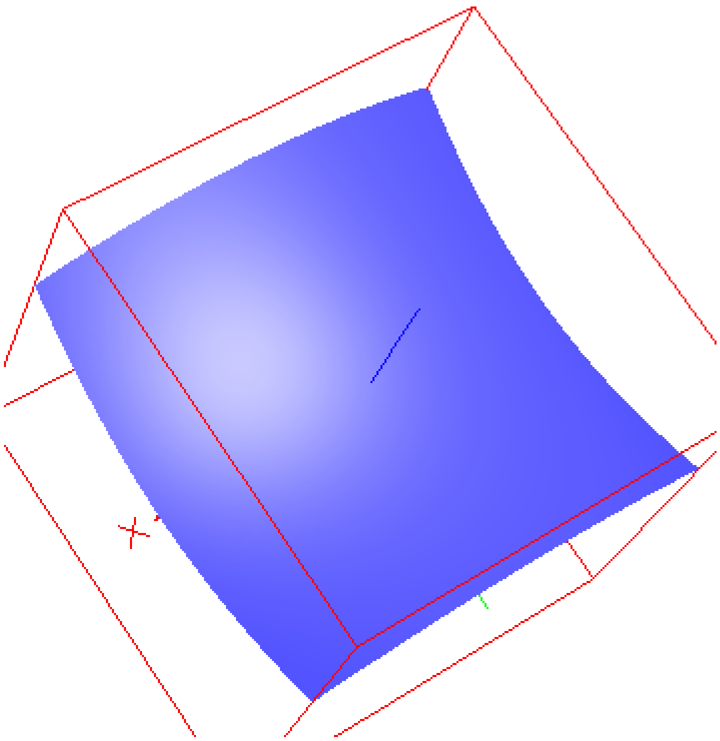
1. The Trimmed Parametric is a sagable surface.

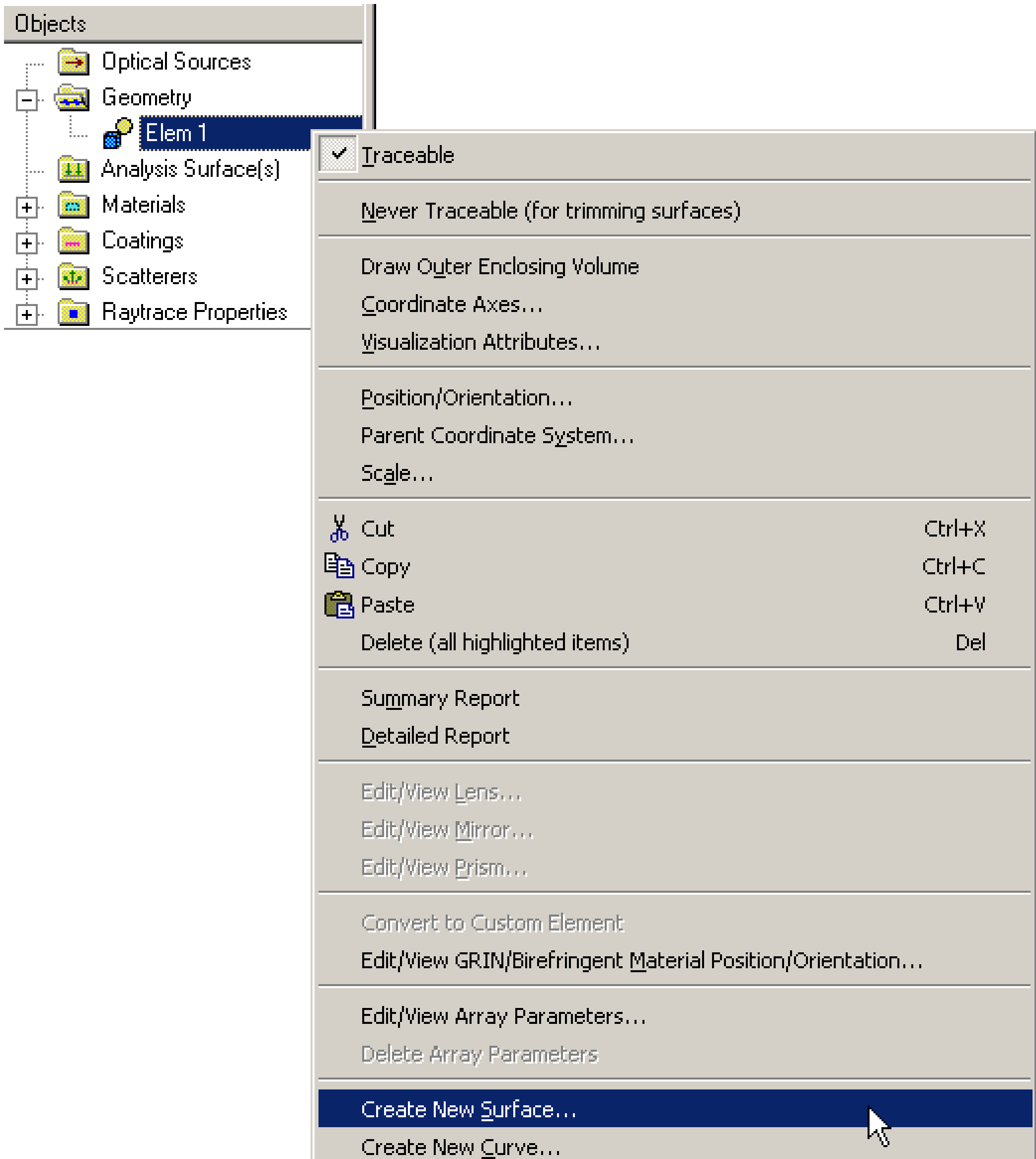
See Also…. - Surface - Trimmed Parametric

Create – New Surface - XY Toroidal Asphere

Description - Surface - XYToroidal Asphere

Creates an X or Y toroidal aspheric surface with both even and odd order terms.




Objects
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Analysis Surface(s)
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Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
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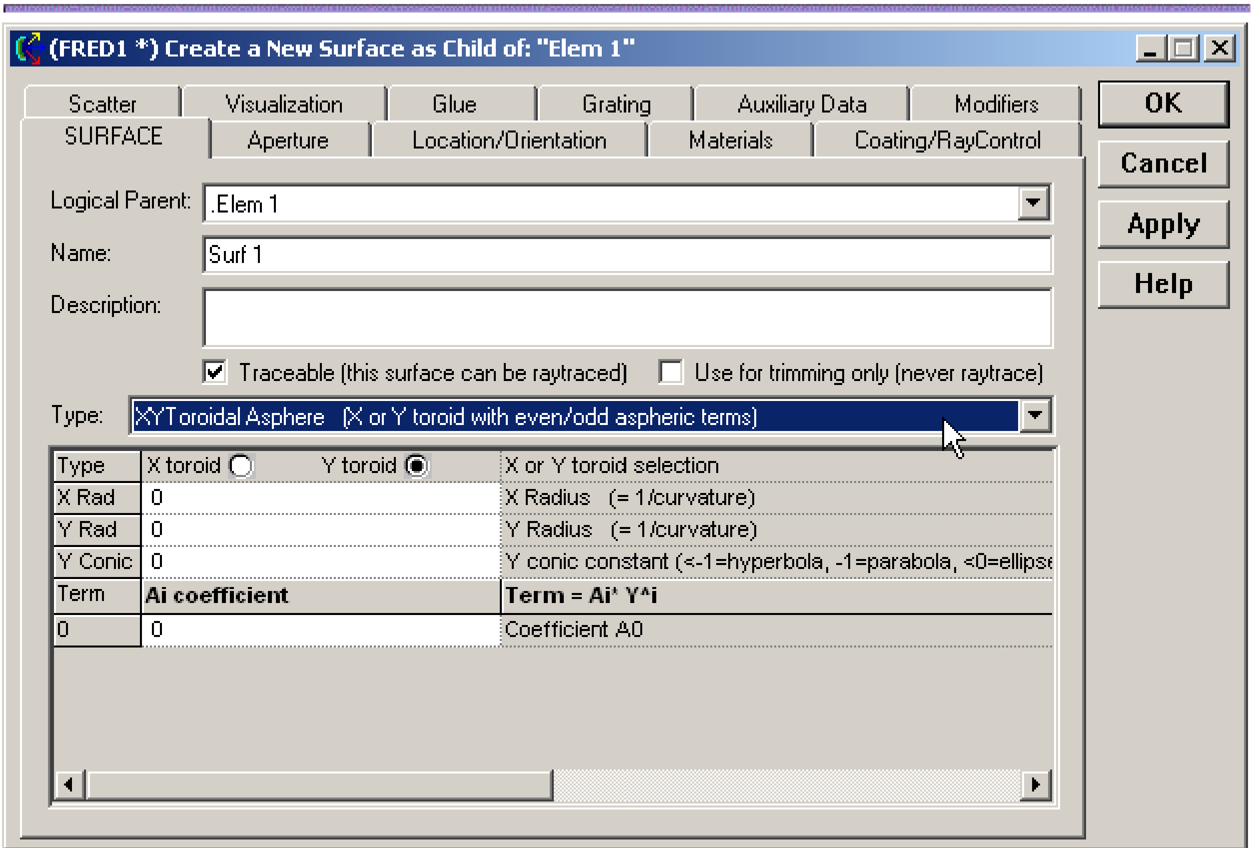
Edit/View Lens...
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - XYToroidal Asphere



Control	Inputs / Description	Defaults
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	XYToroidal Asphere
Toroid Type	Choose an X- or Y-toroid.	Y toroid
X,Y Rad	X & Y radii of curvature.	0
X,Y Conic	X or Y Conic constants.	0
A_i coefficients	Aspheric term coefficients.	0

OK	Accept Toroidal asphere surface and close dialog box.	
Cancel	Discard Toroidal asphere surface and close dialog box.	
Apply	Create Toroidal asphere surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surfce - XYToroidal Asphere

1. The function form of the XYToroidal asphere is given by

$$f(x,y,z) = z - \frac{(C_x \cdot (x^2 - G^2) + 2G)}{1 + \sqrt{1 - C_x(C_x(x^2 - G^2) + 2G)}}$$

where

$$G = \frac{C_y \cdot y^2}{1 + \sqrt{1 - (1 + K_y) \cdot (C \cdot y)^2}} + \sum_i A_i \cdot y^i$$

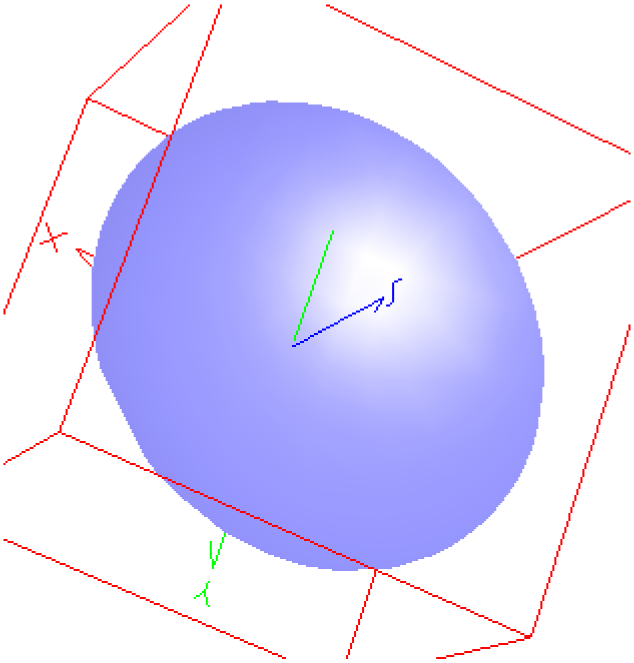
2. The XYToroidal asphere is a sagable surface.

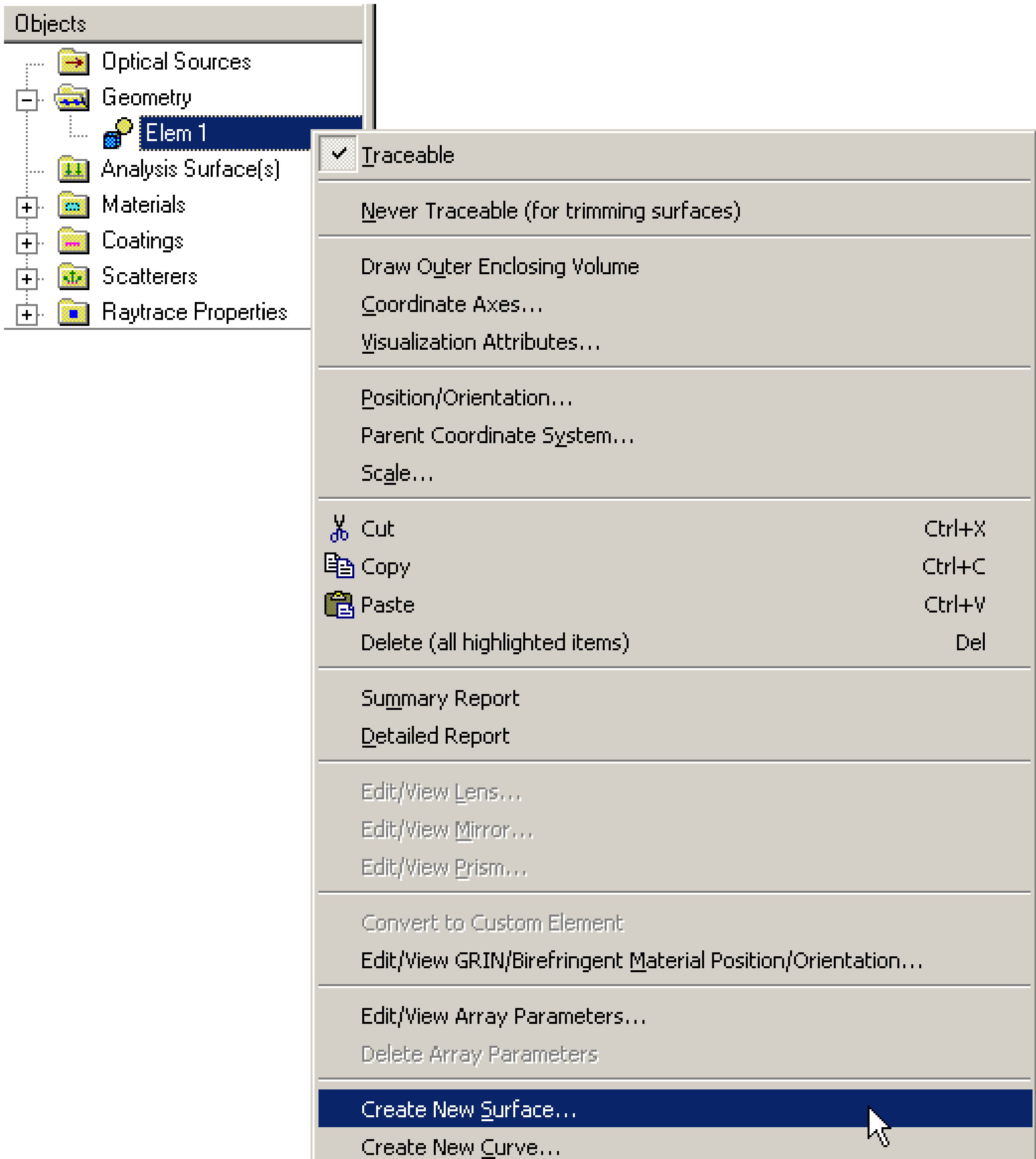
See Also…. - Surface - XYToroidal Asphere

Create – New Surface - Zernike Surface

Description - Surface - Zernike Surface

Creates a Zernike surface.




Objects
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Geometry
Elem 1
Analysis Surface(s)
Materials
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
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Position/Orientation...
Parent Coordinate System...
Scale...
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Delete (all highlighted items) Del
Summary Report
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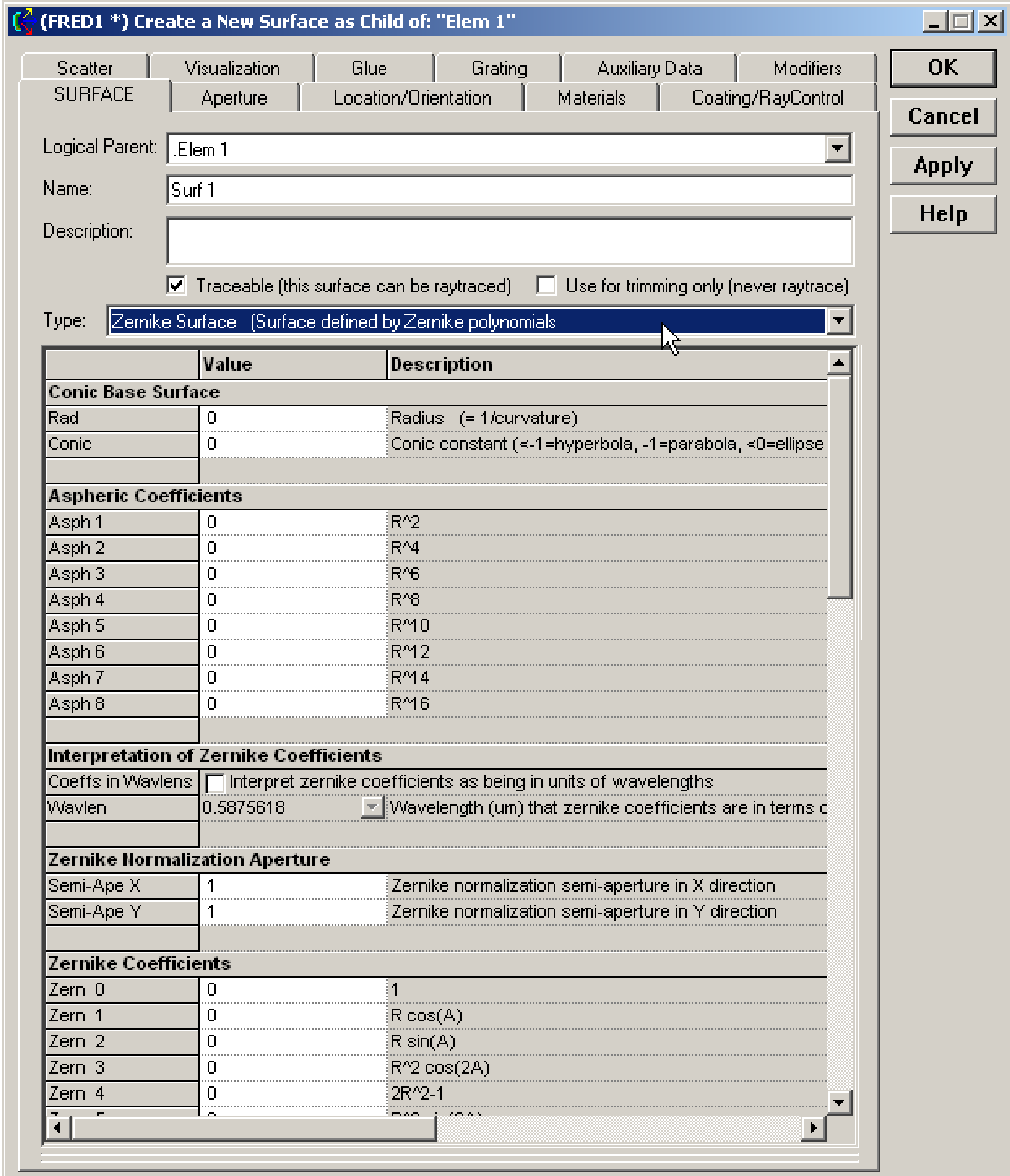
Edit/View Mirror...
Edit/View Prism...
Convert to Custom Element
Edit/View GRIN/Birefringent Material Position/Orientation...
Edit/View Array Parameters...
Delete Array Parameters
Create New Surface...
Create New Curve...

Dialog Box and Controls - Surface - Zernike Surface



Control	Inputs / Description	Defaults
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Type	Surface type.	Zernike Surface
Conic Base Surface		
Rad	Radius of curvature for base surface.	0
Conic	Base surface conic constant.	0
Aspheric Coefficients		
Asph n	Even order aspheric coefficients.	0
Interpretation of Zernike Coefficients		
Coeffs in Wavelen	Interpret the Zernike coefficients in waves. If unchecked, use system units.	Unchecked
Wavelen	Wavelength for coefficient interpretation.	0.5875618
Zernike Normalization Aperture		
SemiApe X/Y	Normalization Aperture (Standard Zernike coefficients are normalized to a unit semi-aperture).	1,1
Zernike Coefficients		
Zern n	Coefficient values in waves or system units.	0
OK	Accept Zernike Surface surface and close dialog box.	
Cancel	Discard Zernike Surface surface and close dialog box.	
Apply	Create Zernike Surface surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Zernike Surface

1. The Zernike Surface is a sagable surface.

See Also…. - Surface - Zernike Surface

Create – New Curve - Introduction to Curves

FRED has a number of curve-based surface types: the **Tabulated Cylinder**, the Ruled Surface, and the **Surface of Revolution**. These surfaces allow for a great deal of flexibility to generate complicated surface geometries, but have some simple rules and limitations that do not apply to more conventional surface functions.

First among these is that a curved-based surface cannot be used to trim another surface. This is because the surfaces are generated as parametric functions, and, as such, do not have an easily identifiable positive and negative side. In other words, the +Z direction of the local surface normal, which is used to establish rules for trimming, is ambiguous. However, these surfaces are bounded and can be trimmed by function-based surface types.

Second, at least some portion of the generating curve must be located inside the bounding volume of the surface. Only that portion of the curve inside the bounding volume will be created. Putting both the curve and the surface in the same coordinate system most easily satisfies this requirement.

Curves may be used to create surfaces, not volumes. For example, a rod lens that uses a surface of revolution to create the cylinder must also include separate surfaces for each end to close the volume. Failure to do so may result in ray failures because FRED may propagate a ray that sees a change in the refractive index as it exits the volume occupied by the cylinder without intersecting a surface. Without a surface intersection, FRED cannot refract the ray.

Types of Curves - Introduction to Curves

FRED has number of simple curve types. In general, each curve is defined parametrically over an interval from [0,1]. The starting point is always at *u* = 0. Likewise, the ending point is at *u* = 1. Curves alone are not traceable.

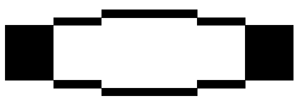
A brief description of each curve type follows.

Line segment - This is the simplest curve type. It is defined as the line connecting the point $(x, y, z)_{start}$ with the point $(x, y, z)_{end}$.

Circular arc – As the name implies, this is a simple circular arc. By default, it is defined in the local XY plane. It is centered at (x_0, y_0) and has a radius *r*. The start and end points for the arc are given by the start angle and the sweep angle, respectively. These are polar angles are measured in degrees, counter-clockwise from the X-axis (□ = 0). Both the start and sweep angles can be between 0 and 360 degrees.

$$\frac{(x-x_0)^2}{a^2}+\frac{(y-y_0)^2}{b^2}=1$$

Conic arc – The conic arc is a more general form of the circular arc. It is used primarily for IGES™ import. It is defined by the equation



The function f(x,y) is a second-degree curve if both A and C are not 0. The curve is a parabola if the product AC = 0. The curve is an ellipse if the product AC > 0. It is a circle if A=C. The curve is a hyperbola if the product AC < 0. The B coefficient represents a rotation of the coordinate axes. If B = 0, the curves are not rotated about the local x- and y-axes. The D and E coefficients represent coordinate shifts.

User inputs include the desired coefficients and the range of values over which the curve is defined: x_{start}, y_{start} and x_{end}, y_{end}. These points do not have to lie on the curve. Rather they define the polar angle subtended by the curve, analogous to the convention used for the circular arc. The starting angle is simply

$$-2A\cdot x_0$$

Likewise, the ending angle is

$$\frac{D^2}{4A}+\frac{E^2}{4C}-1$$

Parabola

A parabola in y has the form Ey = Ax^2 + Bxy + Dx + F. For any such parabola, the coefficients A and E cannot be zero and the C coefficient must be zero. The B and D coefficients rotate and shift the curve, respectively. The coefficient F is a constant offset that moves the curve up and down along the y-axis.

Ellipse

An ellipse centered at the point (x_0, y_0) has the form

$$a = \frac{r}{1+k}$$

where a and b are the semi-major and semi-minor axis lengths, respectively. The coefficient values A..F can be found by equating the two forms. To create an ellipse in which both *a* and *b* are known and is not rotated in the XY-plane, the conversion to the curve coefficients is found in Table 1.

Table 1 Coefficient Conversion for an Ellipse

Curve Coefficient	Value
A	$\frac{D^2}{4A} + \frac{E^2}{4C} - 1$
B	0
C	$\frac{1}{b^2}$
D	$-2A \cdot x_0$
E	$-2C \cdot y_0$
F	$\frac{D^2}{4A} + \frac{E^2}{4C} - 1$

If the conic constant *k* and the radius of curvature *r* are known, then *a* and *b* can be computed using the following relationships (-1 < *k* ≤ 0).

$$a = \frac{r}{1+k}$$

$$b = a \cdot \sqrt{1+k}$$

Hyperbola

A hyperbola centered at the point (x_0, y_0) has the form

$$\frac{(x-x_0)^2}{a^2} - \frac{(y-y_0)^2}{b^2} = 1$$

which describes a curve that intersects the x-axis (A > 0, C < 0). If the signs are reversed (A < 0, C > 0) the curve intersects the y-axis. The terms *a* and *b* do not have the same geometric significance for a hyperbola as they do for an ellipse and are not used except to calculate the asymptotes of the curve

$$y - y_0 = \pm\frac{a}{b}(x - x_0)$$

When A > 0 both x_{start} and x_{end} should be greater than zero. Further, y_{start} and y_{end} should be chosen so that the start and ending angles are between the asymptote lines. When A < 0, choose y_{start} and y_{end} greater than zero and x_{start} and x_{end} to be between the asymptote lines. Following these rules will help avoid unexpected results arising from creating multiple branches of the curve.

The curve coefficients for the hyperbola are analogous to those of the ellipse except A and C have opposite signs. Table 2 shows a similar coefficient conversion based on knowledge of *a* and *b*.

Table 2 Coefficient Conversion for a Hyperbola (A>0)

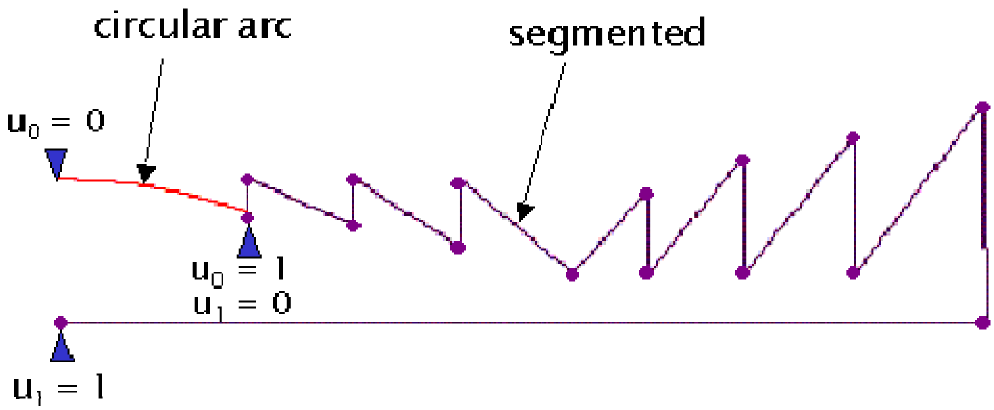
Curve Coefficient	Value
A	$\frac{1}{a^2}$
B	0
C	$-\frac{1}{b^2}$
D	$-2A \cdot x_0$
E	$-2C\ y_0$
F	$\frac{D^2}{4A} - \frac{E^2}{4C} - 1$

<u>*Segmented*</u> - A segmented curve is simply a collection of points in (x, y, z) connected by straight lines. It is not necessary for the curve to be closed and FRED will not automatically close the surface. To close the surface, simply enter the same coordinates for the last point as were entered for the first. A right mouse click in the active cell area in the dialogue box allows for row addition or deletion.

<u>*Composite Curve*</u> – A composite curve is two or more curves joined in the following fashion,

start end, start end, .., start end

The start point ($u_k = 0$) of each subsequent curve is coincident with the end point ($u_{k-1} = 1$) of the previous curve. When 2 or more curves are joined, the parameterization is renormalized so that the curve starts at $u_{composite} = 0$ and ends at $u_{composite} = 1$. The curves do not need to be the same type. Multiple composite curves can be joined as well. The following figure shows a circular arc joined with a series of line segments.



If the segments are not properly positioned, FRED issues an error message. A common error is to have the parameterization reversed so that FRED is trying to connect the start point of one curve to the start point of a different curve, which is an invalid operation. It is often useful (but not required) to define the curves in that same coordinate system. The composite curve should also be located in the proper coordinate system as well. After creating the composite curve, it is recommended that each component curve be placed in the coordinate system of the composite. This way, the composite curve can be repositioned anywhere in the system and the component curves will automatically follow.

Any curve used to create the composite can be edited. Changes are reflected automatically. The rules governing the endpoint connections must still be obeyed. If a composite curve is copied, FRED automatically creates a duplicate set of the generating curves.

Other curve types

FRED also has a number of special curve types that are used primarily to import IGES™ files and lenses from CODE V™, OSLO™, and ZEMAX™. These surface types are: *NURB* (Non-Uniform Rational B-spline), *Spline* (polynomial segments), and *Aperture Curve Collection*. FRED automatically creates the fit coefficients for the NURB and Spline curves during a CAD system import. The user is not required to enter points manually. The Aperture Collection Curve is used to create complex or segmented apertures on a single surface (instead of creating multiple copies of the same surface). These curves must be closed and are used only to establish trimming boundaries in the aperture settings for the surface. Aperture curves will be created automatically during a lens file import. The user can also create and apply them manually.

Create - New Analysis Surface

Description
How Do I Get There?
Dialog Box and Controls

Description
New Analysis Surface

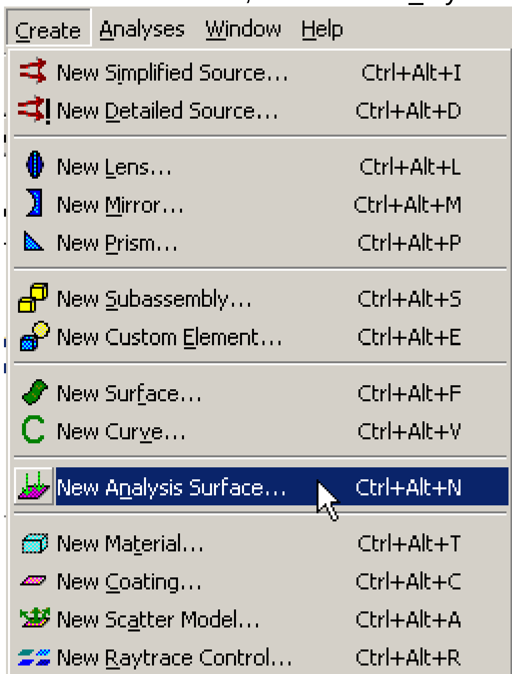
This command displays a dialog that allows you to create a new Analysis Surface in the FRED optical system.

How Do I Get There?
New Analysis Surface

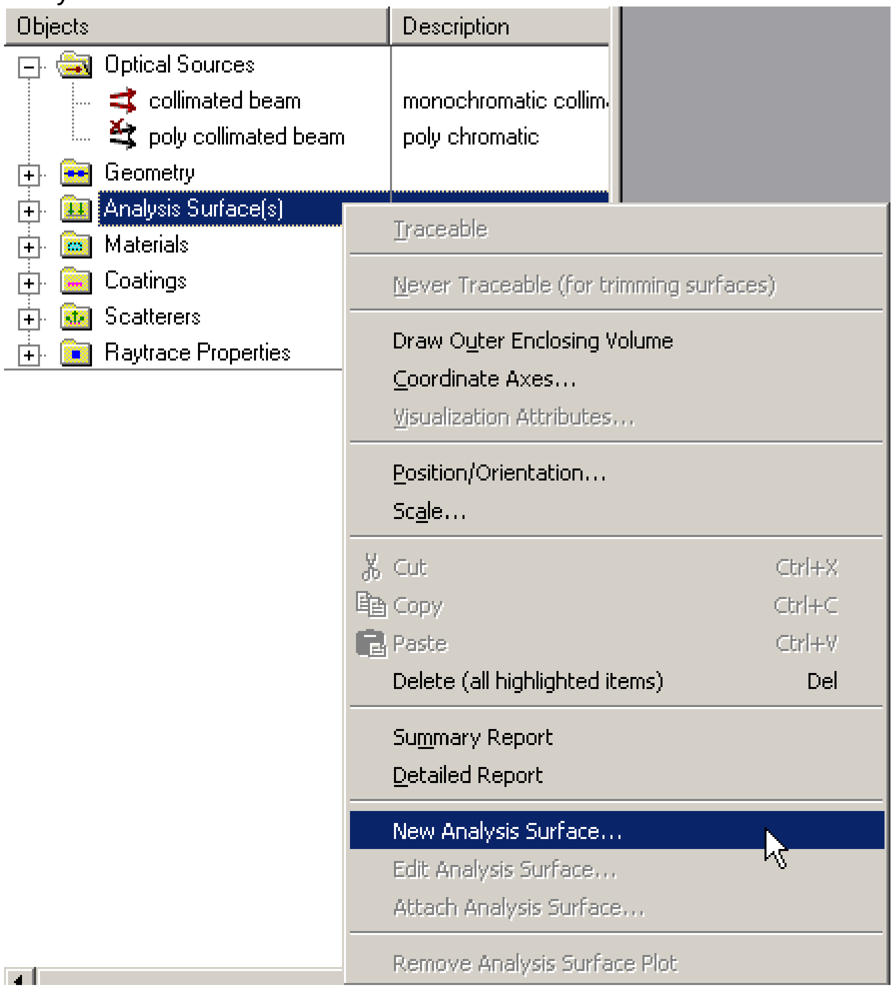
There are four ways to access this command:

1. On the Create Toolbar, click this button: 

2. On the Create Menu, click "New Analysis Surface…"

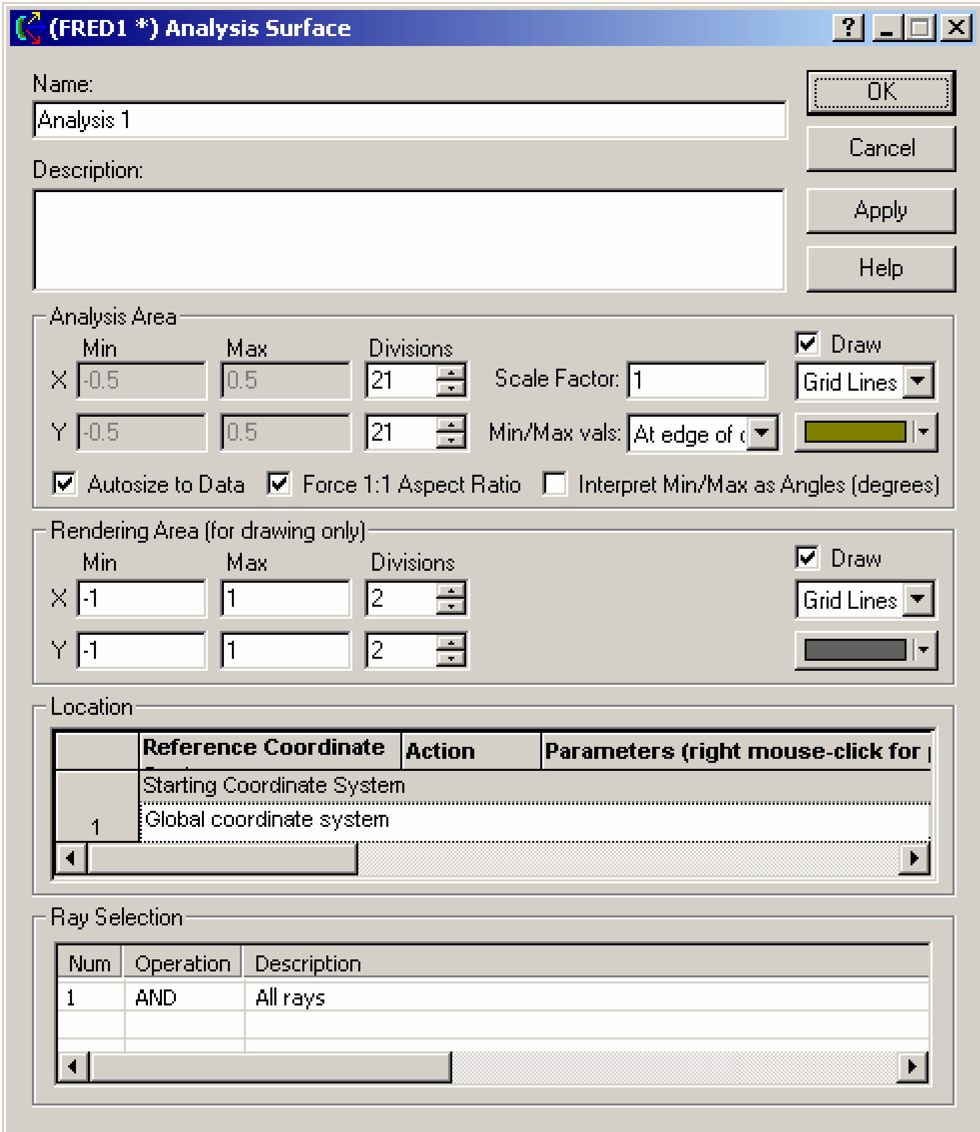


3. On the Analysis Surfaces folder in the Tree View, right-click and choose "New Analysis Surface…"



4. Use they keyboard shortcut Ctrl+Alt+N.

Dialog Box and Controls
New Analysis Surface



Control	Inputs	Defaults
Name	Enter the name of the plane here	Analysis *n*
Description	Enter a description here that is shown in Tree View	Blank
Analysis Area		
Autosize to Data	Use ray data to autosize window.	Checked
X, Y Min	Minimum X,Y coordinates of window.	-0.5, -0.5

X, Y Max	Maximum X,Y coordinates of window.	0.5, 0.5
X, Y Divisions	Number of window divisions.	21, 21
Scale Factor	Scale window size.	1
Force 1:1 Aspect Ratio	Force isotropic window.	Checked
Interpret Min/Max as Angles (deg)	For use with directional analysis.	Unchecked
Draw	Draw window in 3D View.	Checked
Draw as…	Window display method: *Filled Grid* *Grid Lines* *Grid Points*	Grid Lines
Drawing Color	Grid color	Copper
Rendering Area		
X, Y Min	Minimum X,Y coordinates of render area.	-1, -1
X, Y Max	Maximum X,Y coordinates of render area.	1, 1
X, Y Divisions	Number of divisions in render area.	2, 2
Draw	Draw render area in 3D View.	Checked
Draw as…	Render display method: *Filled Grid* *Grid Lines* *Grid Points*	Grid Lines
Drawing Color	Rendering color	Gray
Location		
Table	Shows a list of the Location Modifiers that define the location and orientation of the plane in the	Global Coordinate System

	system	
Ray Selection		
Table	Rays included for analysis.	AND, All rays
OK	Create a new Analysis Plane and close dialog box.	
Cancel	Discard the Analysis Plane and close dialog box.	
Apply	Create/Apply changes to Analysis Plane and keep dialog box open.	
Help	Access this Help page.	

Create - New Material

Description

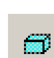
New Material

This command displays a dialog that allows you to create a new material in the FRED optical system.

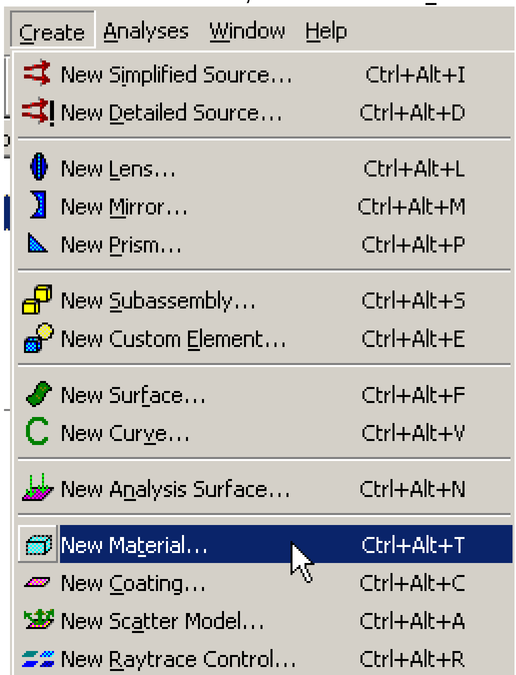
How Do I Get There?

New Material

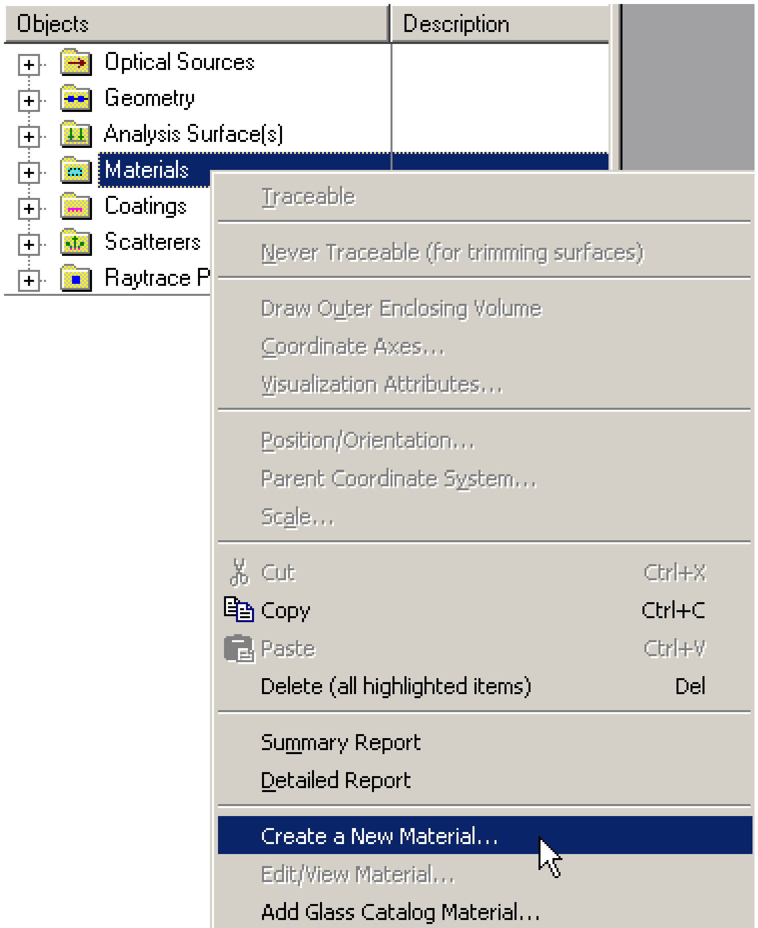
There are four ways to access this command:

1. On the Create Toolbar, click this button: 

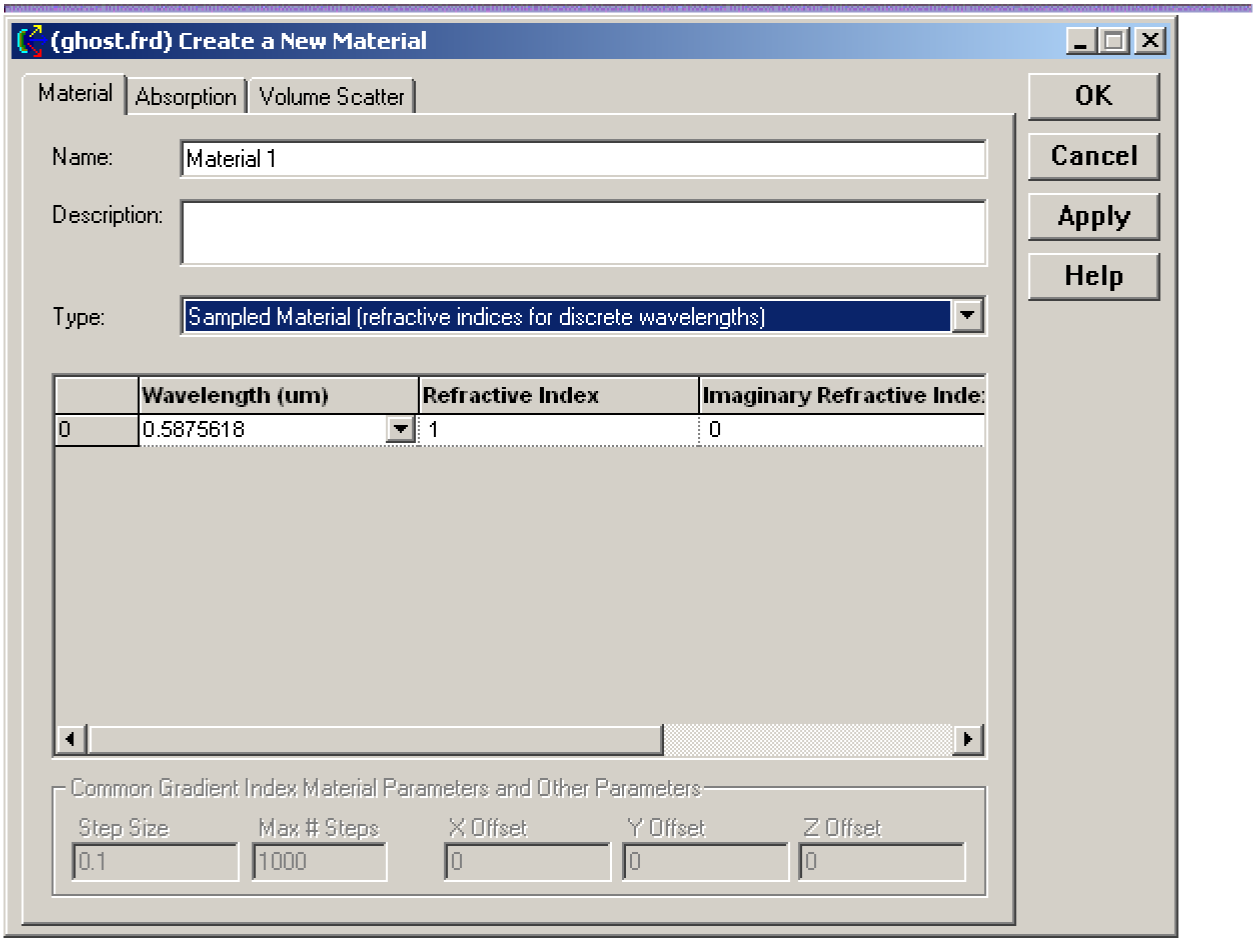
2. On the Create Menu, click "New Material…"



3. On the Materials folder in the Tree View, right-click and choose "Create a New Material…"



4. Use they keyboard shortcut Ctrl+Alt+T.



Control	***Inputs***	***Defaults***
Name:	Displays the name of the new material	Material *n*
Description:	Displays the description of the new material	Empty String
Type:	Displays the type of new material. Options are: *Sampled Material (refraction indices for discrete wave* *Model Material (Refraction Index and Abbe number)*	Sampled Material
Parameters	Displays the data necessary to define the material type	Varies
OK	Create a new material and close dialog box.	
Cancel	Discard new material and close dialog box.	
Help	Access this Help page.	

Create - New Coating

Description

New Coating

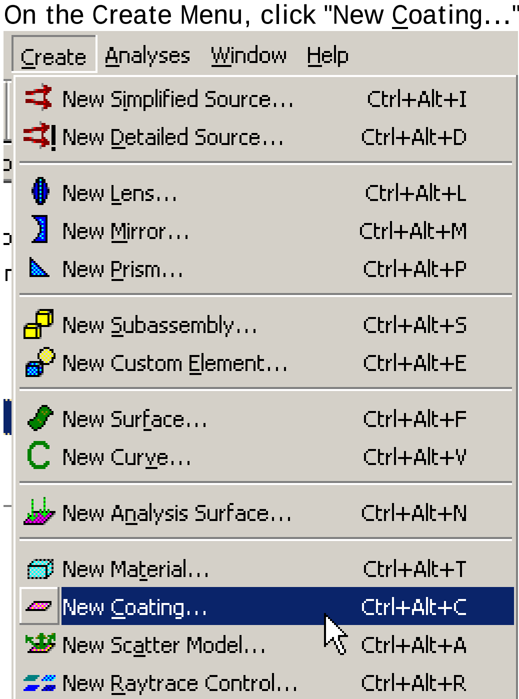
This command displays a dialog that allows you to create a new coating in the FRED optical system.

How Do I Get There?

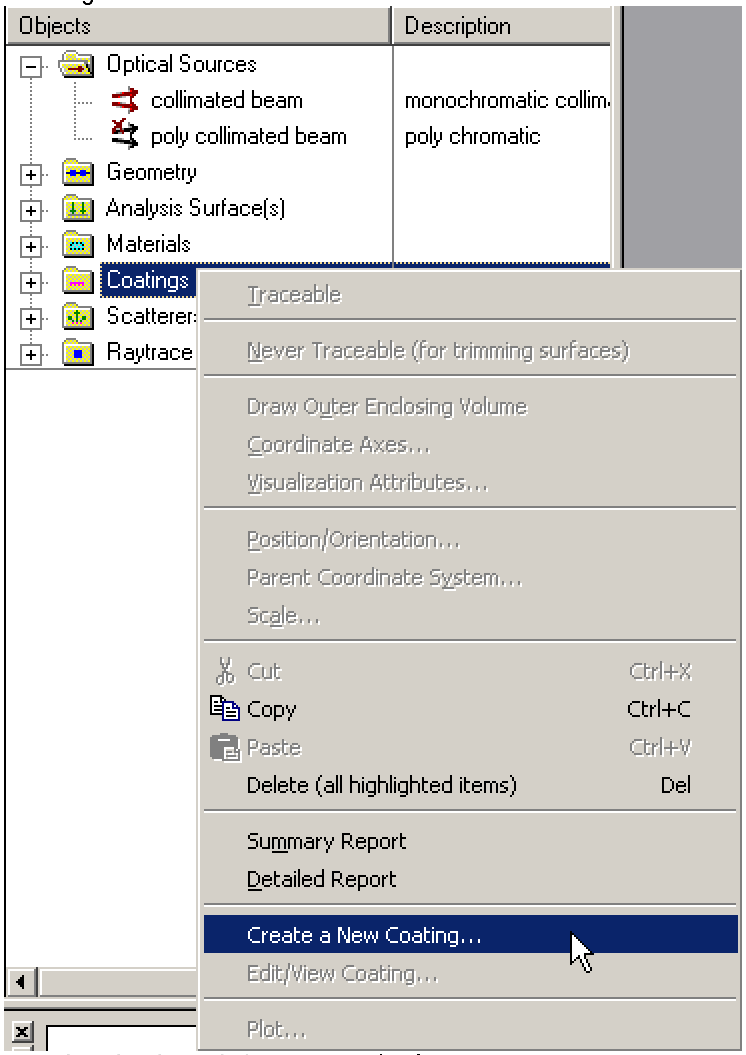
New Coating

There are four ways to access this command:

1. On the Create Toolbar, click this button:
2. On the Create Menu, click "New Coating…"



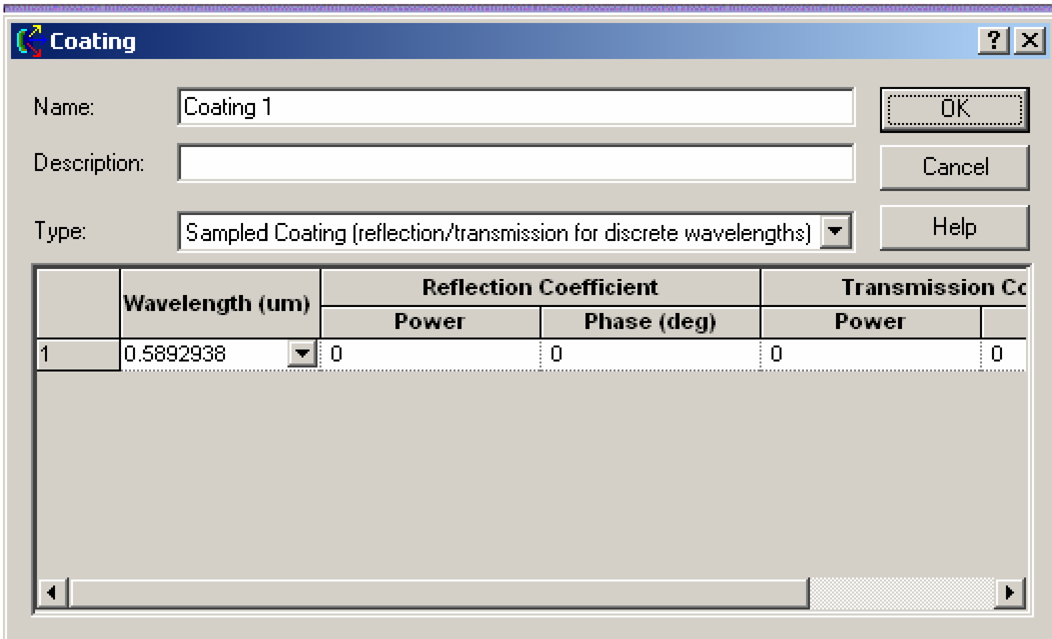
3. On the Coatings folder in the Tree View, right-click and choose "Create a New Coating..."



4. Use they keyboard shortcut Ctrl+Alt+C.

Dialog Box and Controls

New Coating



Control	Inputs	Defaults
Name:	The name of the new coating	Coating *n*
Description:	The description of the new coating	Empty String
Type:	Type of coating to be created. Can be one of the following: *Sampled Coating (reflection/transmission for discrete wavelengths)* *Uncoated (bare surface with no coating)* *Thin Film Layered Coating* *General Sampled Coating (table of reflection/transmission coefficients)* *Polarizer/Waveplate Coating (Jones matrix)*	Sampled Coating
Parameters	Lists the parameters needed for the different types of coating available.	Varies
OK	Create a new coating and close dialog box.	
Cancel	Discard coating and close dialog box.	
Help	Access this Help page.	

Create - New Scatter Model

Description

New Scatter Model

This command displays a dialog that allows you to create a new scatter model in the FRED optical system.

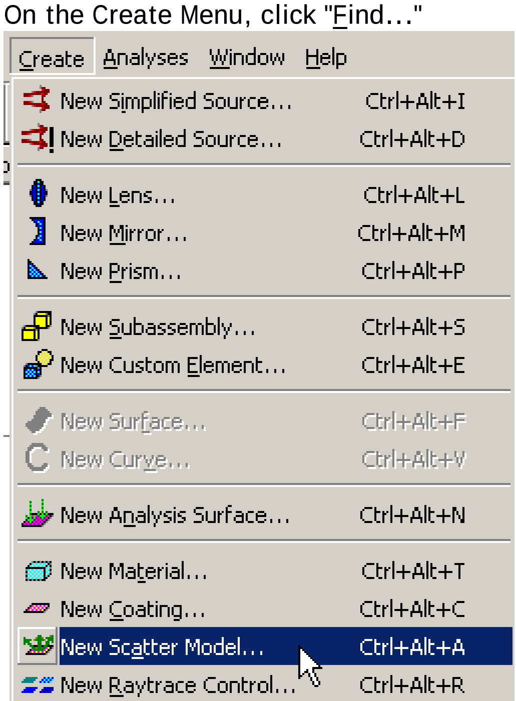
How Do I Get There?

New Scatter Model

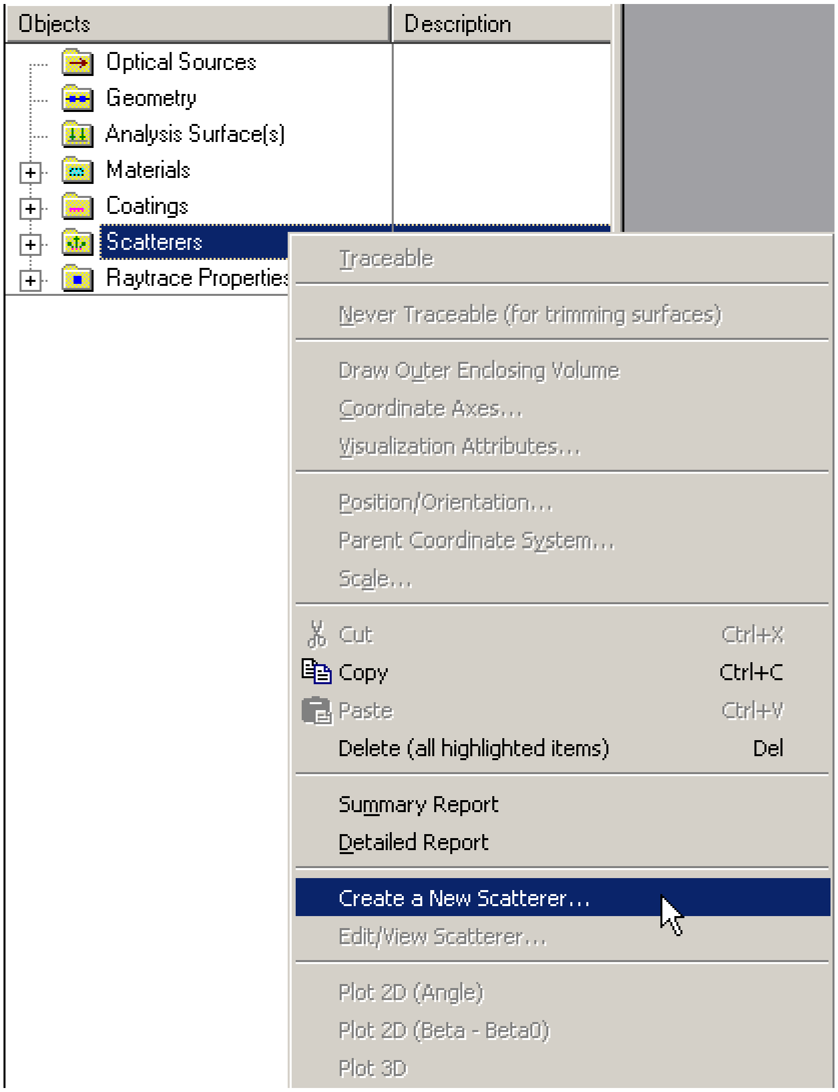
There are four ways to access this command:

1. On the Create Toolbar, click this button: 

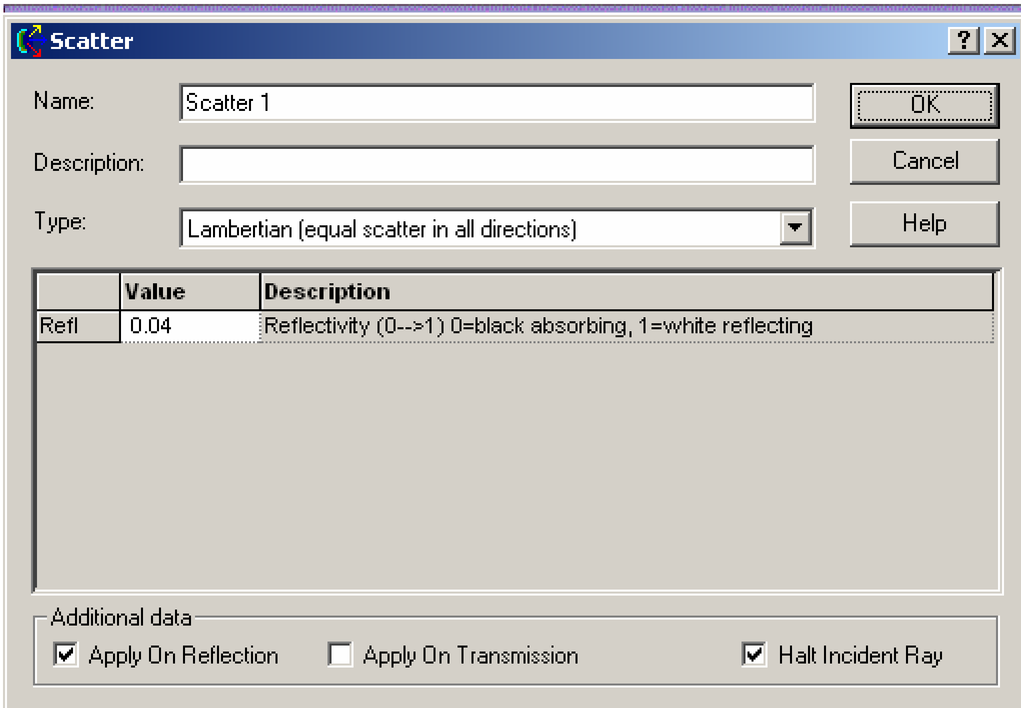
2. On the Create Menu, click "Find…"



3. On the Scatterers folder in the Tree View, right-click and choose "Create a New Scatterer…"



4. Use they keyboard shortcut Ctrl+Alt+A.



Control	Inputs	Defaults
Name	Name of scatter type.	Scatter *n*
Description	Description of scatter type.	blank
Type	Type of scatter model to be created. Options are: *Lambertian (equal scatter in all directions)* *Harvey-Shack (polished surface scatter)* *ABg scatter (polished surface scatter)* *Phong scatter (Cos^n from specular)* *Flat Black Paint* *Surface Particle (Mie) Scatter* *Diffuse Polynomial*	Lambertian
Parameter Field	Displays parameters of selected scatter model.	Varies
Additional data		
Apply on Reflection	When checked, applies the scatter properties when a ray is reflected.	Checked
Apply on Transmission	When checked, applies the scatter properties when a ray is transmitted.	Unchecked
Halt Incident Ray	When checked, will generate an incident ray in the ray buffer but will not trace it.	Checked
OK	Create or modify a scatter model and close dialog box.	

Cancel	Discard scatter model or modifications and close dialog box.	
Help	Access this Help page.	

See Also….
New Scatter Model

General Information on Scatter Models

Create - New Raytrace Control

Description
New Raytrace Control

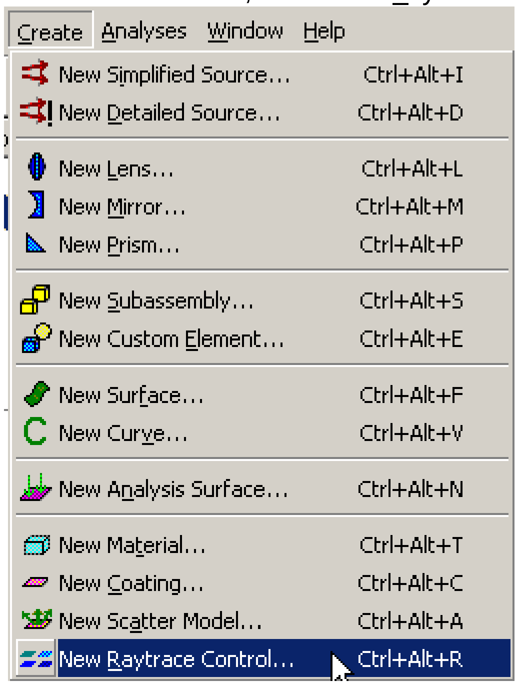
This command displays a dialog that allows you to create a new Raytrace Control in the FRED optical model.

How Do I Get There?
New Raytrace Control

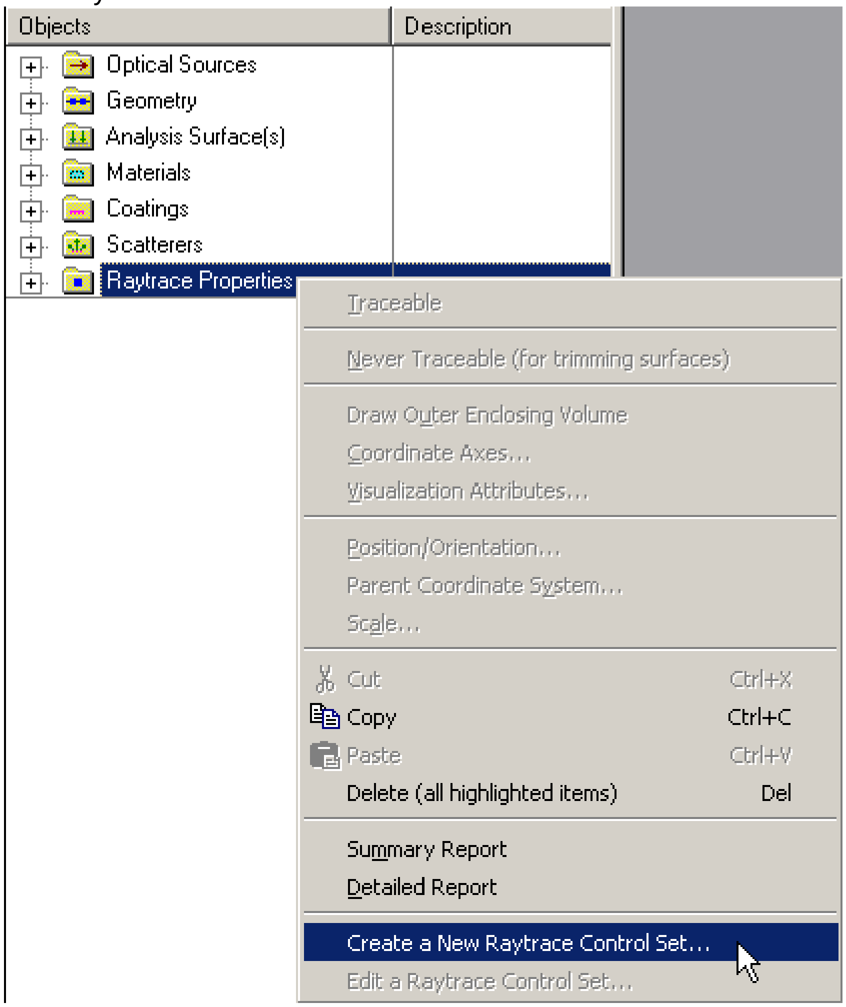
There are four ways to access this command:

1. On the Create Toolbar, click this button: 

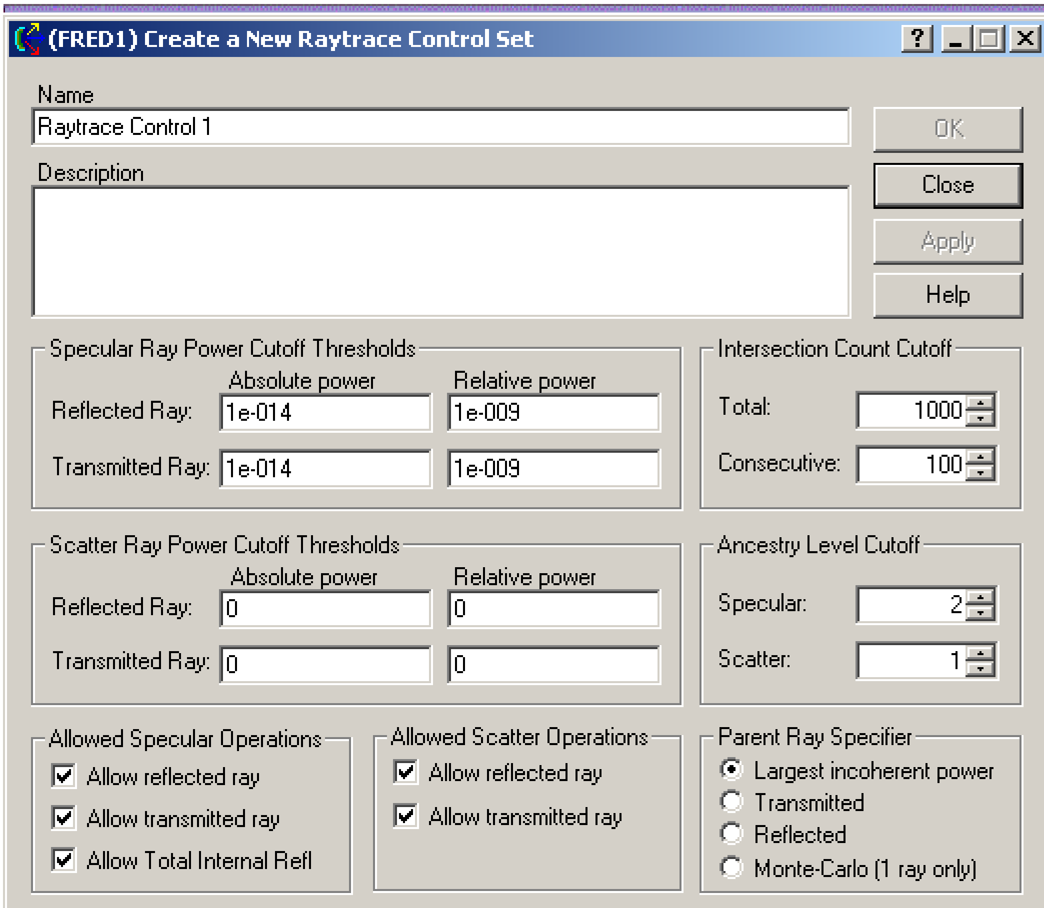
2. On the Create Menu, click "New Raytrace Control…"



3. On the Raytrace Properties folder in the Tree View, right-click and choose "Create a New Raytrace Control Set…"



4. Use they keyboard shortcut Ctrl+Alt+R.



Control	*Inputs*	*Defaults*
Name	The name of the Raytrace Control	Raytrace Control *n*
Description	The description of the Raytrace Control	blank
	Specular Ray Power Cutoff Threshold	
Reflected Ray-Abs/Rel Power	Controls specular reflected ray cutoff.	1e-014, 1e-009
Transmitted Ray-Abs/Rel Power	Controls specular transmitted ray cutoff.	1e-014, 1e-009
	Scattered Ray Power Cutoff Threshold	
Reflected Ray-Abs/Rel Power	Controls scattered reflected ray cutoff.	0, 0

Transmitted Ray-Abs/Rel Power	Controls scattered transmitted ray cutoff.	0, 0
Intersection Count Cutoff		
Total	Total number of allowed ray intersections.	1000
Consecutive	Number of consecutive ray intersections with single object.	100
Ancestry Level Cutoff		
Specular	Number of specular splits.	2
Scatter	Number of times a parent ray can scatter.	1
Allowed Specular Operations		
Reflected ray	Allow reflection.	Checked
Transmitted ray	Allow transmission.	Checked
Total Internal Reflection	Allow TIR.	Checked
Allowed Scatter Operations		
Reflected ray	Allow scatter in reflection.	Checked
Transmitted ray	Allow scatter in transmission.	Checked
Parent Ray Specifier		
Largest incoherent power	Largest power direction determines parent.	Selected
Transmitted	Transmitted ray is parent.	Not selected
Reflected	Reflected ray is parent.	Not selected
Monte-Carlo (1 ray only)	Statistically chooses the transmitted, reflected or scattered ray	Not selected
OK	Create a raytrace control or apply changes and close dialog box.	
Close	Discard a raytrace control or applied changes and close dialog box.	
Apply	Apply raytrace control changes and keep dialog box open.	
Help	Access this Help page.	

Analyses - Ray Status

Description

Ray Status

The Ray Status command outputs the status of all the rays in the system in the Output Window. The Ray Status output is very useful for diagnosing a FRED document with errors.

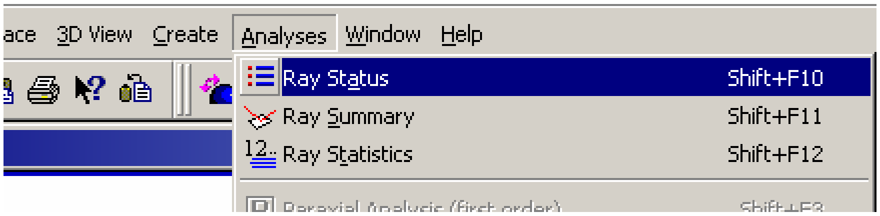
	A	B	C	D	E	F	G	H
88	RAY STATUS SUMMARY:					(houghton.frd)		
89								
90	97	total rays created						
91	97	active (traceable)						
92	0	inactive (not traceable)						
93	0	polarized						
94	97	coherent						
95	0	scatter						
96	88	stopped by the surface's raytrace control specification						
97	0	fell below absolute transmitted power threshold						
98	0	fell below absolute reflected power threshold						
99	0	fell below relative transmitted power threshold						
100	0	fell below relative reflected threshold						
101	0	could not resolve material ambiguity						
102	0	could not resolve transmitted glue material ambiguity						
103	0	could not resolve reflected glue material ambiguity						
104	0	exceeded total intersection count						
105	0	exceeded consecutive intersection count						
106	0	exceeded specular ancestry threshold						
107	0	exceeded scatter ancestry threshold						
108	0	had coherent secondary ray errors						
109	0	are evanescent						
110	0	are halted because total internal reflection not allowed						
111	0	acquired a bad position						
112	0	acquired a bad direction						
113	0	exceeded allowed number of steps in an inhomogenuous material						
114								
115								

How Do I Get There?

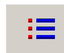
Ray Status

There are three different ways to execute this command:

1. Select Ray Status in the Analysis Menu



2. Press the keyboard accelerator keys: Shift+F10

3. Press the toolbar button: 

Application Notes

Ray Status

None.

See Also….

Ray Status

Ray Statistics
Ray Summary

Analyses - Ray Summary

Description
How Do I Get There?
Application Notes
Examples
See Also…

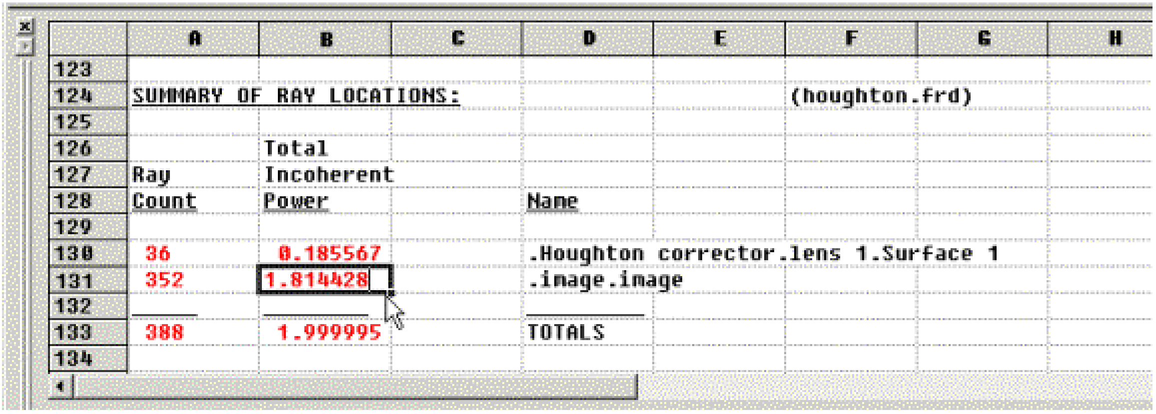
Description

Ray Summary

The Ray Summary command produces a count of the rays and their total incoherent power for all the rays associated with traceable objects (sources and surfaces marked Traceable) in the FRED document. Rays associated with untraceable objects are omitted from the Ray Summary. The ray's associated surface is named using the hierarchy naming convention.

The data stored with a ray includes its present location, power, direction, and associated surface or source. A ray is associated with the last surface that it intersected. If a ray has not been traced or it did not intersect a surface, then it is associated with the source that defined the ray. Unless the ray position is otherwise altered after a ray trace, the ray's location will be at the intersection it made last surface it intersected or on the ray's source if it did not intersect a surface or was not traced.

The Ray Summary is printed in the output window.



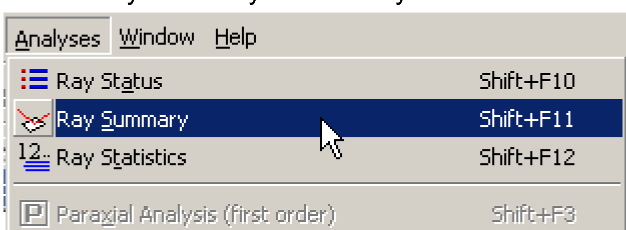
An example of the Ray Summary.

How Do I Get There?

Ray Summary

There are four different ways to execute this command:

1. Select Ray Summary in the Analysis Menu



2. Press the keyboard accelerator keys: Shift+F11
3. Press the toolbar button: 

Application Notes

Ray Summary

None.

See Also….

Ray Summary

Ray Statistics

Ray Status

Analyses - Ray Statistics

Description

How Do I Get There?

Description

Ray Statistics

The Ray Statistics command outputs the statistical average, standard deviation, minimum, and maximum of the position and direction coordinates in relation to the global coordinate system for rays associated with traceable objects in the FRED document. The output is printed in the output window.

	A	B	C	D	E	F	G	H	I	J	K	L	M
72													
73	RAY STATISTICS:					(houghton.frd)							
74													
75		X AVG	Y AVG	Z AVG	X STD	Y STD	Z STD	X MIN	X MAX	Y MIN	Y MAX	Z MIN	Z MAX
76													
77	.Houghton corrector.lens 1.Surface 1					Tot Pwr=	0.092783		Avg Pwr=	0.010309		Ray Cnt=	9
78	Pos	8.41e-17	7.47e-17	-0.002228	0.558117	0.558117	0.001117	-0.684036	0.684036	-0.684036	0.684036	-0.003346	0
79	Dir	-1.63e-17	-1.86e-17	-0.993377	0.081207	0.081207	0.003311	-0.099531	0.099531	-0.099531	0.099531	-1	-0.990065
80													
81	.image.image					Tot Pwr=	0.907216		Avg Pwr=	0.010309		Ray Cnt=	88
82	Pos	-1.04e-16	20.7	16.12386	0.000724	0	0.000724	-0.001291	0.001291	20.7	20.7	16.12257	16.12515
83	Dir	-2.15e-17	0.998129	-2.285e-5	0.043222	0.000875	0.043222	-0.074390	0.074390	0.996802	0.999551	-0.074413	0.074367
84													
85	Tot Pwr=	1			Tot Rays=	97							
86													

The Ray Statistics for Houghton example are shown.

Note that the minimum and maximum position values for the X, Y, and Z axes define a box around all the rays associated with a given FRED traceable object.

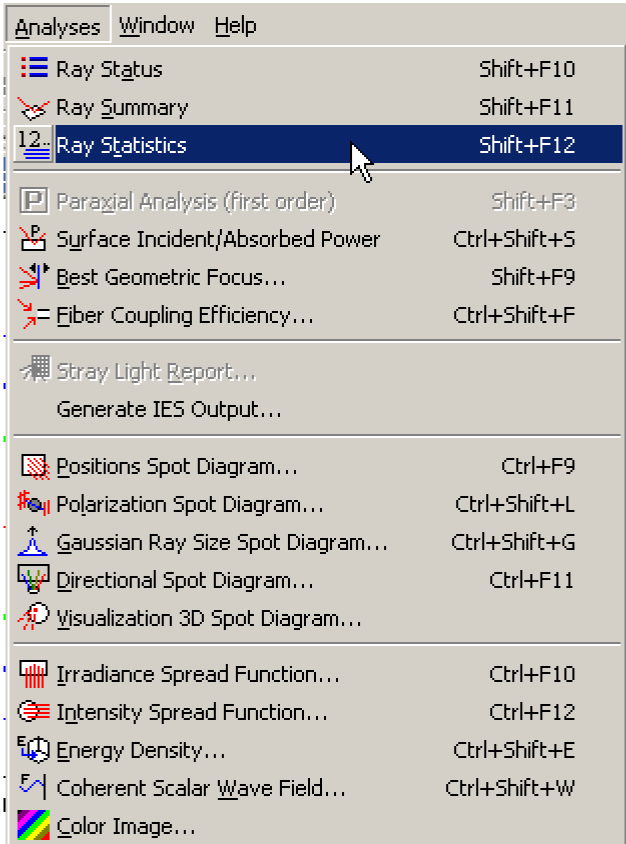
This command is essentially an expanded version of Ray Summary, since it also prints out the ray count and total power.

How Do I Get There?

Ray Statistics

There are three different ways to execute this command:

1. Select Ray Statistics in the Analysis Menu



2. Press the keyboard accelerator keys: Shift+F12

3. Press the toolbar button: 

See Also...

Ray Statistcs

[Ray Summary](#)
[Ray Status](#)

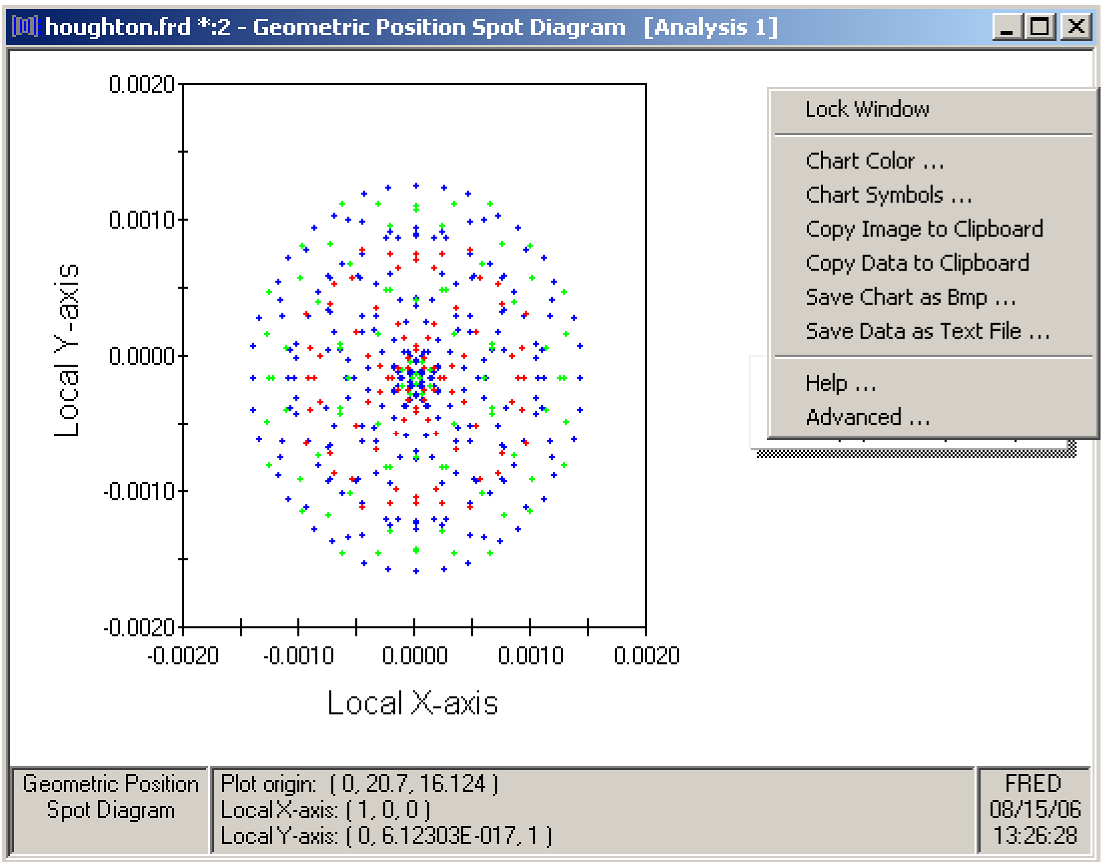
Analyses - Position Spot Diagram

[Description](#)
[How Do I Get There?](#)
[Dialog box and Controls](#)
[Application Notes](#)
[Examples](#)

Description

Position Spot Diagram

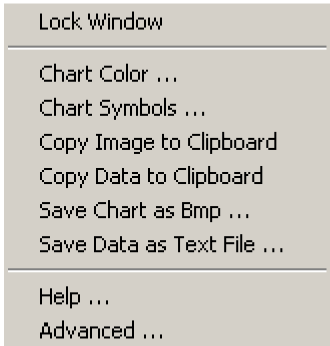
This command generates a ray position spot diagram based on the rays filtered by the user selected analysis plane. The axes of the position spot diagram represent the local X and Y axes of the analysis plane regardless of where the rays are positioned. For example, the analysis plane can attached to one object and filter/select rays from multiple objects. In that case, the ray positions on the spot diagram will be referenced to the analysis plane origin and not the surfaces or sources where the rays current are positioned.



Position Spot Diagram from the image plane of the Houghton sample

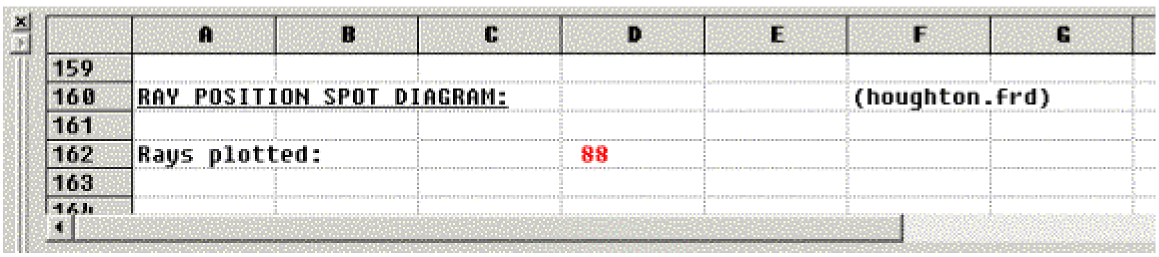
Note	The default operation of the spot diagrams and spread plot views in FRED is that they are deleted when a new raytrace is done. A plot view can be locked so it is not deleted when the rays are deleted via a right mouse click pop-up menu.

The following commands are available via a right mouse click pop-up menu.



Lock Window
Chart Color …
Chart Symbols …
Copy Image to Clipboard …
Copy Data to Clipboard …
Save Chart as Bmp …
Save Data as Text File …
Help …
Advanced…

In addition to the graphical ray position plot, textual information about the number of filtered rays is listed in the output window.



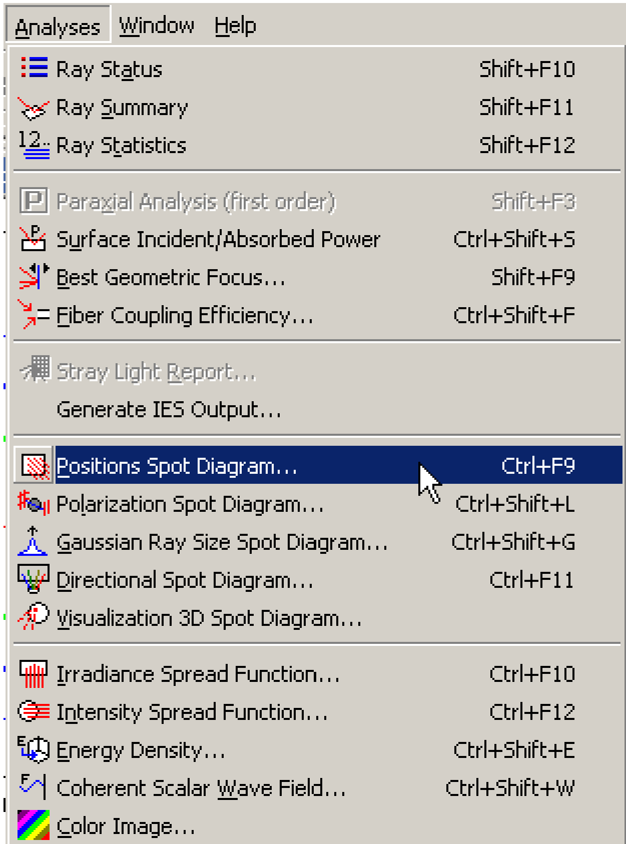
Position spot diagram plot information is printed in the output window

How Do I Get There?

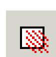
Position Spot Diagram

There are three different ways to execute this command:

1. Select Position Spot Diagram in the Analysis Menu

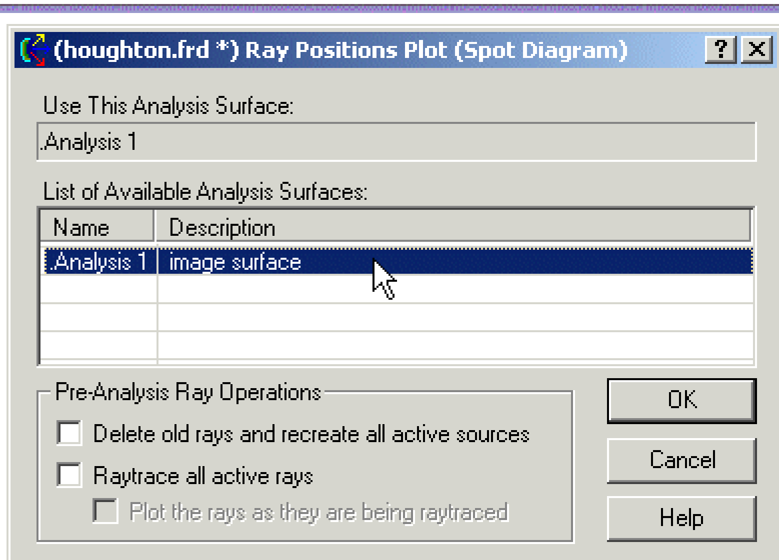


2. Press the keyboard accelerator keys: Ctrl+F9

3. Press the toolbar button: 

Dialog Box and Controls

Position Spot Diagram

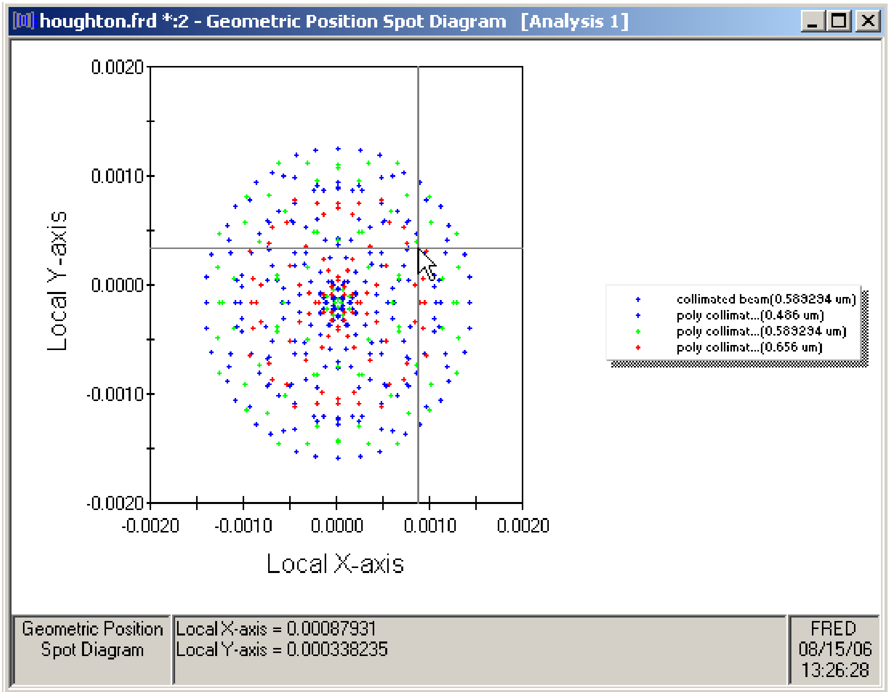


Control	Inputs	Defaults
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	Highlighted Analysis Surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First valid Analysis Surface
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Unchecked
OK	Plot Spot Diagram and close dialog box.	
Cancel	Discard Spot Diagram and close dialog box.	
Help	Access this Help page.	

Application Notes

Position Spot Diagram

Chart crosshairs are available by holding the left mouse button down inside the plot. The plot value under the cursor is reported at the bottom of the chart in both direction cosines and angles (both relative to the local analysis plane X and Y axes).



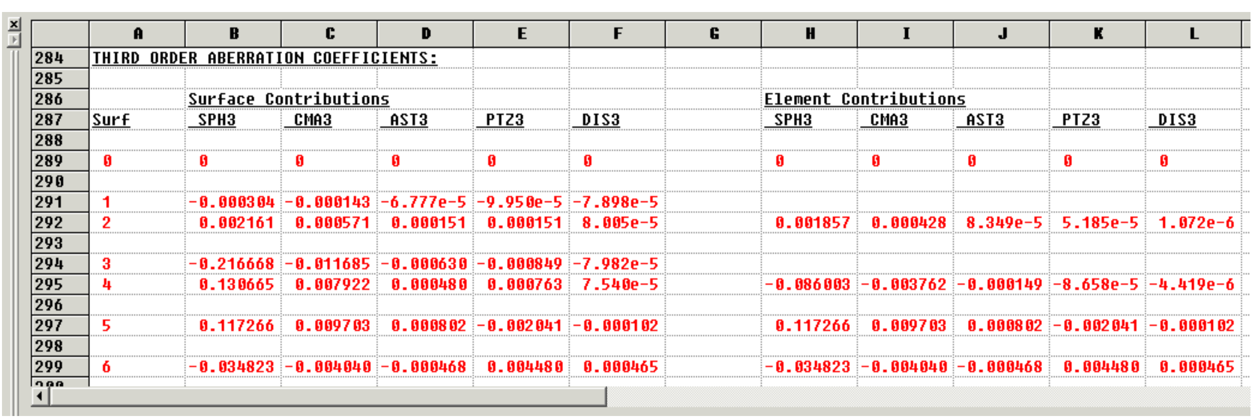
An example of crosshairs

See Also…

Position Spot Diagram

Direction Spot Diagram

Analyses – Paraxial Analysis - Third Order

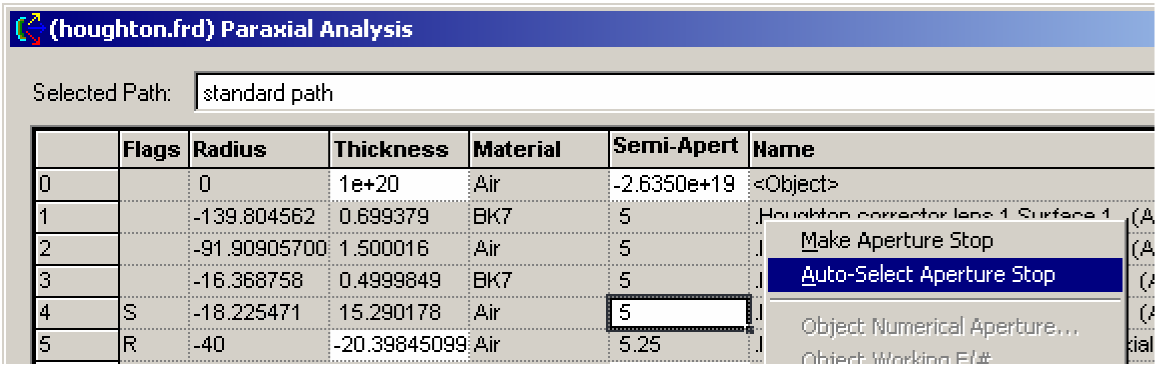


	A	B	C	D	E	F	G	H	I	J	K	L
284	THIRD ORDER ABERRATION COEFFICIENTS:											
285												
286		Surface Contributions						Element Contributions				
287	Surf	SPH3	CMA3	AST3	PTZ3	DIS3		SPH3	CMA3	AST3	PTZ3	DIS3
288												
289	0	0	0	0	0	0		0	0	0	0	0
290												
291	1	-0.000304	-0.000143	-6.777e-5	-9.950e-5	-7.898e-5						
292	2	0.002161	0.000571	0.000151	0.000151	8.005e-5		0.001857	0.000428	8.349e-5	5.185e-5	1.072e-6
293												
294	3	-0.216668	-0.011685	-0.000630	-0.000849	-7.982e-5						
295	4	0.130665	0.007922	0.000480	0.000763	7.540e-5		-0.086003	-0.003762	-0.000149	-8.658e-5	-4.419e-6
296												
297	5	0.117266	0.009703	0.000802	-0.002041	-0.000102		0.117266	0.009703	0.000802	-0.002041	-0.000102
298												
299	6	-0.034823	-0.004040	-0.000468	0.004480	0.000465		-0.034823	-0.004040	-0.000468	0.004480	0.000465

Auto Select Aperture Stop

This command selects the limiting surface aperture from the selected ray path and makes it the stop surface for the paraxial ray trace calculations done in the Paraxial Analysis dialog box. The surface selected is likely to change depending the on the other settings in the Paraxial Analysis dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.

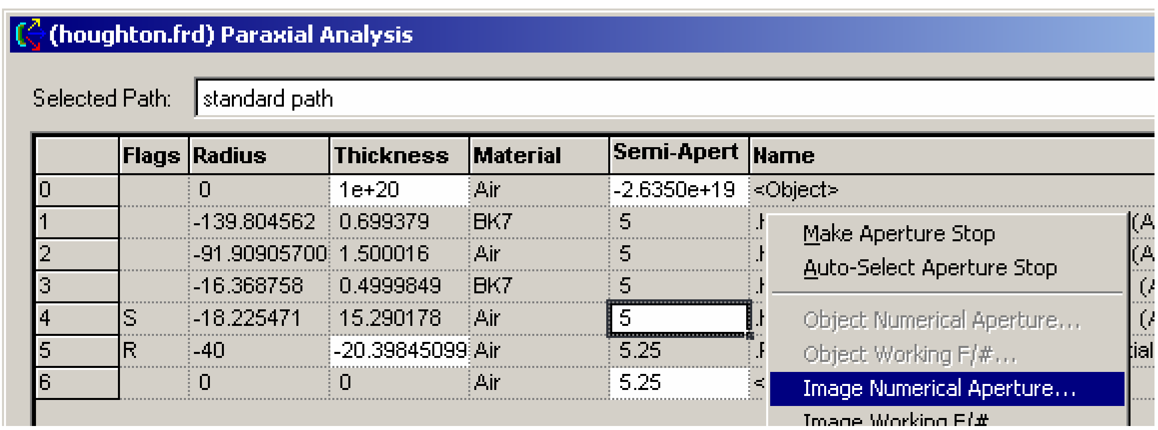


The Auto Select Aperture Stop command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box

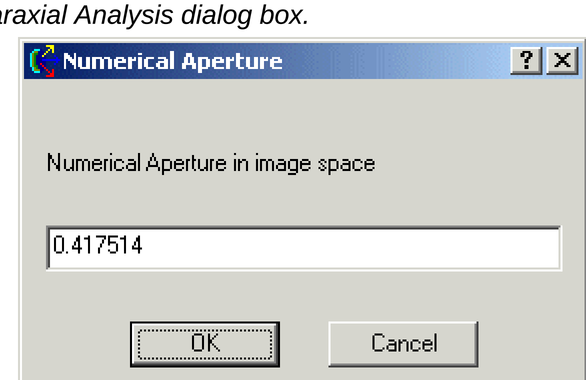
Image Numerical Aperture

This command sets the stop surface semi-aperture to meet the image space numerical aperture entered into the Image Space Numerical Aperture dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.



The Image Numerical Aperture command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

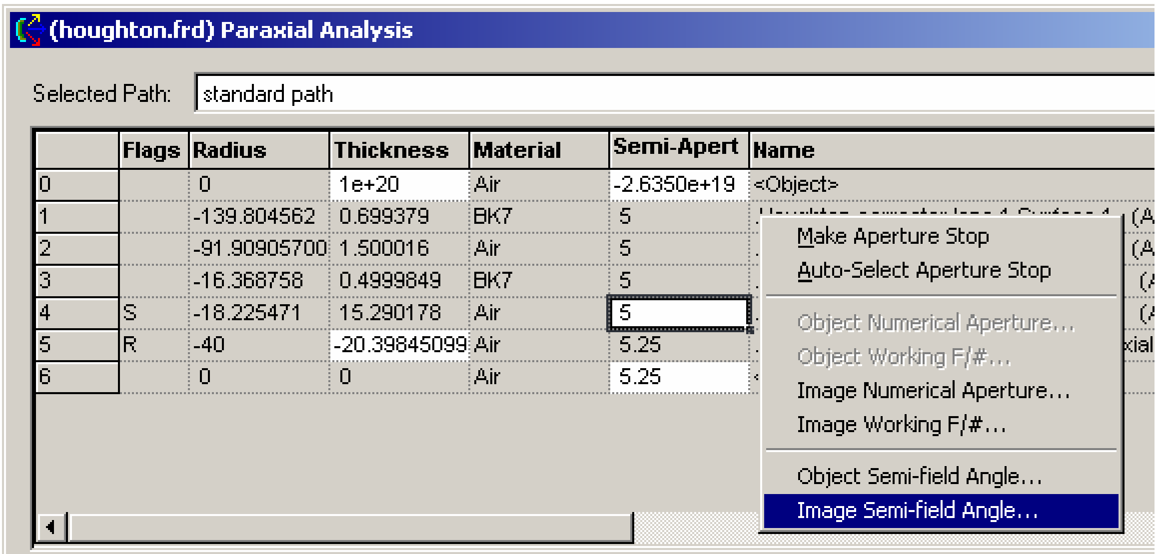


The Image Space Numerical Aperture dialog box

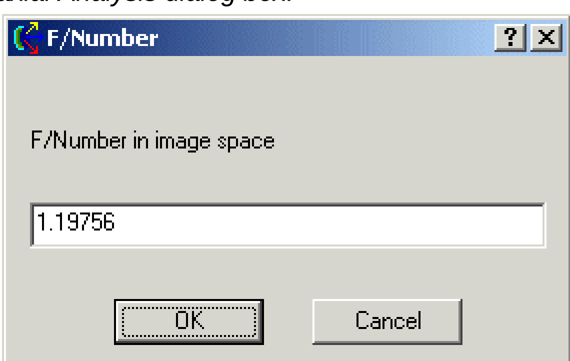
Image Semi-Field Angle

This command sets the object and image semi-apertures (object and image heights) to meet the Image semi-field angle entered by the user in the Image Semi-Field Angle dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.



The Image Semi-Field Angle command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

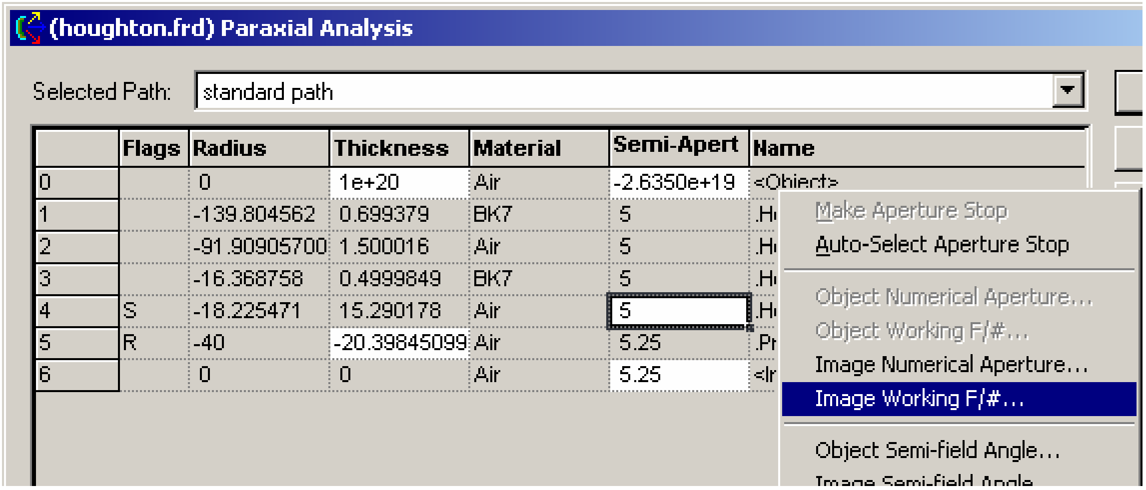


The Image Semi-Field Angle dialog box

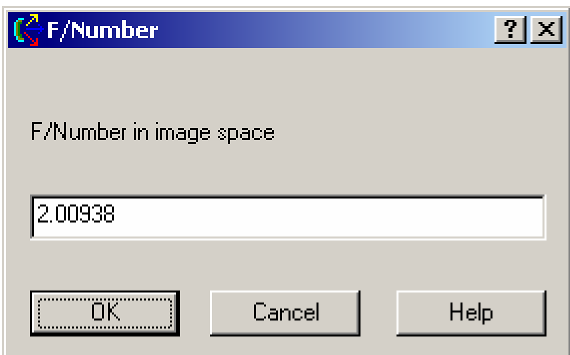
Image Working F/#...

This command sets the stop surface semi-aperture using paraxial calculations to meet the Image space working F/# entered into the Image Working F/# dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.



The Image Working F/# command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

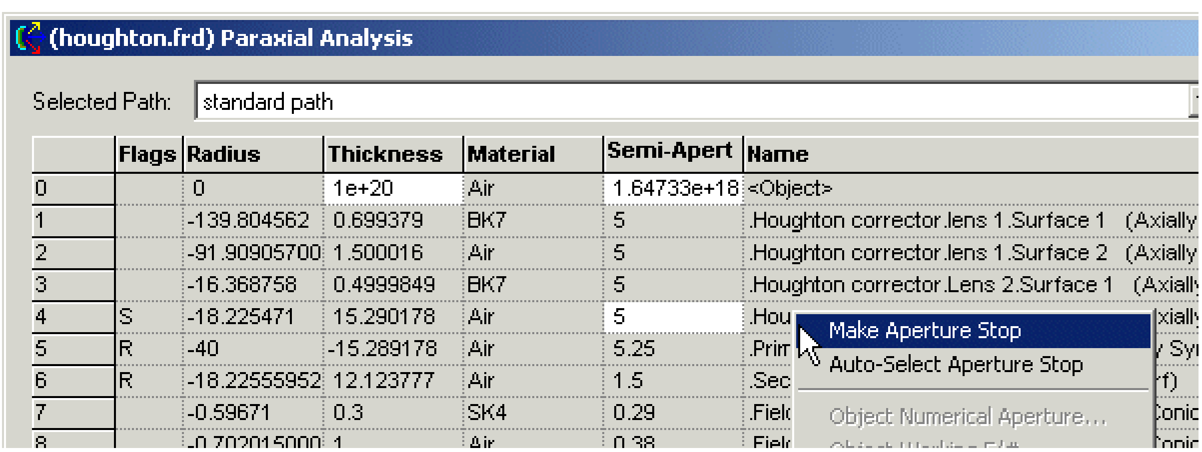


The Image Working F/# dialog box

Make Aperture Stop

This command makes the surface under the cursor the stop surface for the paraxial ray trace calculations done in the Paraxial Analysis dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.

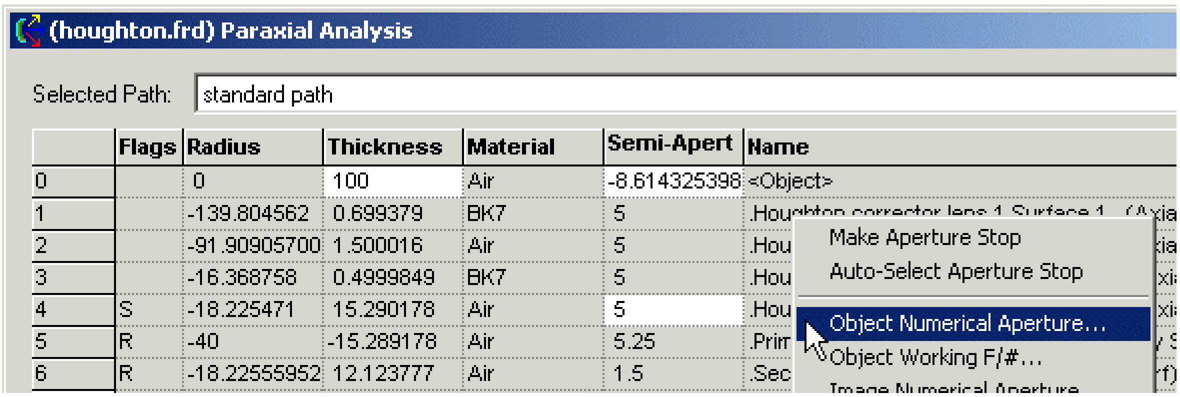


The Make Aperture Stop command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

Object Numerical Aperture

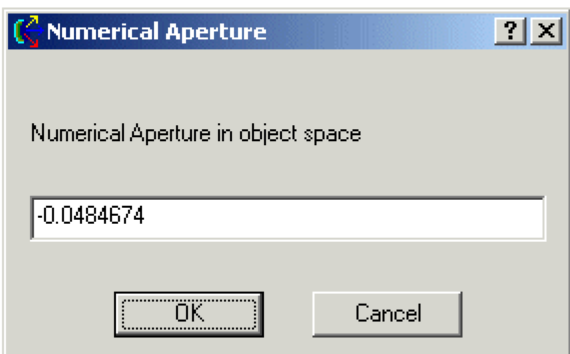
This command sets the stop surface semi-aperture to meet the object space numerical aperture entered into the Object Space Numerical Aperture dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.



	Flags	Radius	Thickness	Material	Semi-Apert	Name
0		0	100	Air	-8.614325398	<Object>
1		-139.804562	0.699379	BK7	5	Hou
2		-91.90905700	1.500016	Air	5	Hou
3		-16.368758	0.4999849	BK7	5	Hou
4	S	-18.225471	15.290178	Air	5	Hou
5	R	-40	-15.289178	Air	5.25	Prim
6	R	-18.22555952	12.123777	Air	1.5	Sec

The Object Numerical Aperture command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

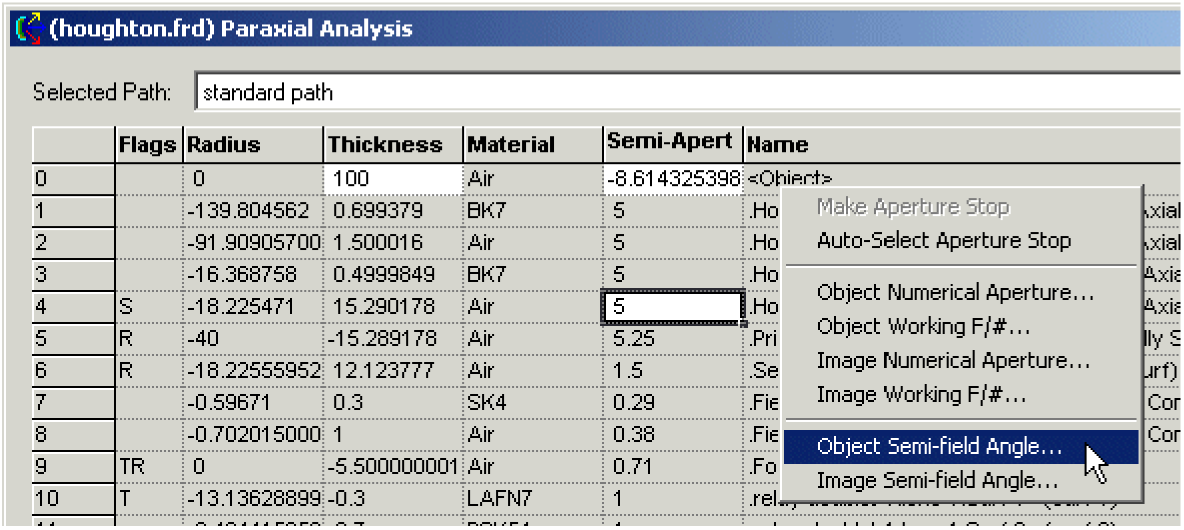


The Object Space Numerical Aperture dialog box

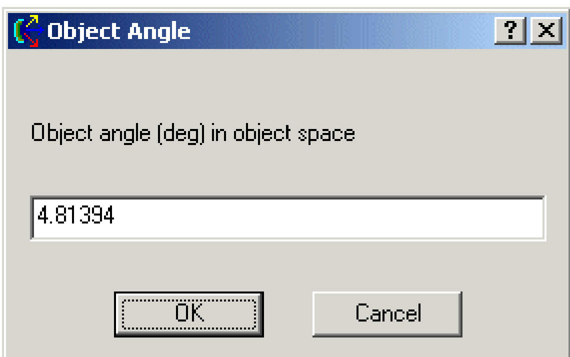
Object Semi-Field Angle

This command sets the object and image semi-apertures (object and image heights) to meet the object semi-field angle entered by the user in the Object Semi-Field Angle dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.



The Object Semi-Field Angle command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

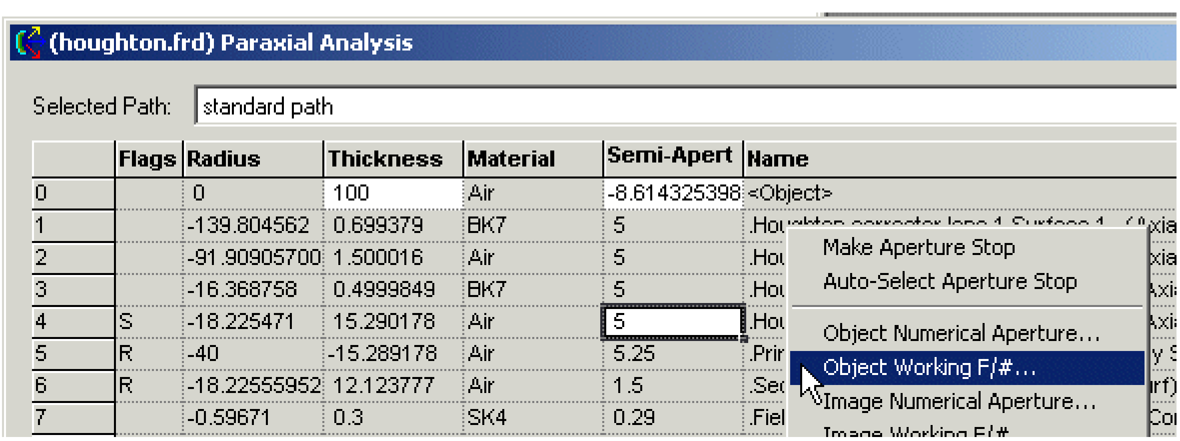


The Object Semi-Field Angle dialog box

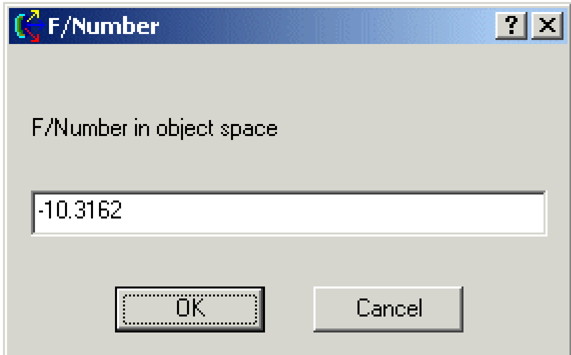
Object Working F/#...

This command sets the stop surface semi-aperture using paraxial calculations to meet the object space working F/# entered into the Object Working F/# dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.



The Object Working F/# command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

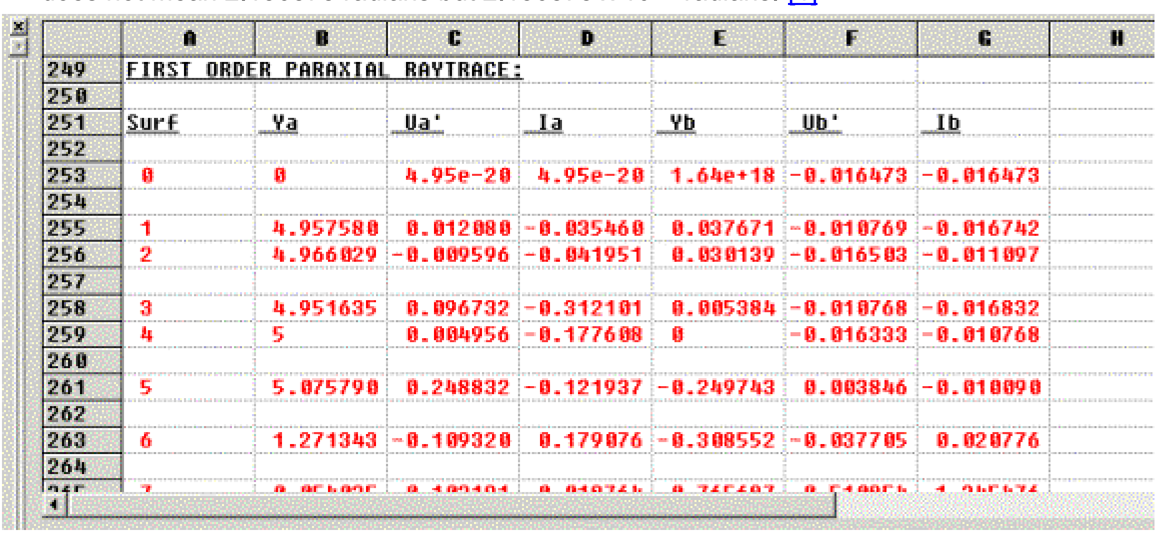


The Object Working F/# dialog box

Paraxial Trace

The Paraxial Trace command lists the paraxial Y height, the paraxial ray angle relative to the optical axis, and the paraxial angle of incidence with the surface for the chief ray and marginal ray. The marginal ray information has the "a" subscript and the chief ray information has the "b" subscript.

It is important to note that these are paraxial quantities. By calling them paraxial, we are assuming that the rays have been raytraced in a tiny "pencil" of rays around the optical axis. The rays in this tiny pencil have infinitesimal Y heights and angles. In this limit small angles we can assume that U=sin(u), U=tan(u), and 1=cos(u) where u is in radians. "Since these infinitesimal values have finite relative magnitudes, we may use any finite numbers to represent paraxial quantities, but we must remember to assume that each number is to be multiplied by a very small factor such as 10^{-50}, so that a paraxial angle written as 2.156878 does not mean 2.156878 radians but 2.156878 x 10^{-50} radians."[1]



	A	B	C	D	E	F	G	H
249	FIRST ORDER PARAXIAL RAYTRACE:							
250								
251	Surf	Ya	Ua'	Ia	Yb	Ub'	Ib	
252								
253	0	0	4.95e-20	4.95e-20	1.64e+18	-0.016473	-0.016473	
254								
255	1	4.957580	0.012080	-0.035460	0.037671	-0.010769	-0.016742	
256	2	4.966029	-0.009596	-0.041951	0.030139	-0.016503	-0.011097	
257								
258	3	4.951635	0.096732	-0.312101	0.005384	-0.010768	-0.016832	
259	4	5	0.004956	-0.177608	0	-0.016333	-0.010768	
260								
261	5	5.075790	0.248832	-0.121937	-0.249743	0.003846	-0.010090	
262								
263	6	1.271343	-0.109320	0.179076	-0.308552	-0.037705	0.020776	
264								
[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

[1] Kingslake, Rudolf, *Lens Design Fundamentals*, San Diego, Academic Press, 1978

```
FIRST ORDER SYSTEM DATA:

SYSTEM DATA
          Effective Focal Length:        -19.92334
          Magnification:                 -1.99e-19
          Overall Lens Length:            17.98955
          Object-To-Image Length:         1e+20
          Lagrange Invariant:             1.306371
          Petzval Curvature:             -0.050850
OBJECT/IMAGE CONJUGATE DATA
          Object Angle (deg):             14.76242
          Image Angle (deg):             -3.520842
          Object Height:                 -2.63e+19
          Image Height:                   5.25
          Object Dist:                   -1e+20
          Image Dist:                    -20.39845
OBJECT/IMAGE SPACE BEAM DATA
          Object Numerical Aperture:     -4.95e-20
          Image Numerical Aperture:       0.248832
          Object Working F/#:            -1.00e+19
          Image Working F/#:              2.009383
          Object F/#:                    -2.009383
          Image F/#:                     -0.469177
ENTRANCE/EXIT PUPIL DATA
          Entrance Pupil Semi-Ape:        4.957577
          Exit Pupil Semi-Ape:            21.23222
          Entrance Pupil Dist:            2.286793
          Exit Pupil Dist:                64.92889
CARDINAL POINT DATA
          Front Principal Pt Dist:        17.55817
          Rear Principal Pt Dist:        -0.475105
          Front Nodal Pt Dist:           -22.28851
          Rear Nodal Pt Dist:            -0.475105
          Front Focal Pt Dist:           -2.365170
          Rear Focal Pt Dist:            -20.39845

Object space distances are measured from surface 1
Image  space distances are measured from surface 5
```

Construction

FIRST ORDER CONSTRUCTION DATA:

Surf	Rd	Th	N	Conic	A4
0	infinity	1e+20	1	0	0
1	-139.8045	0.699379	1.516800	0	0
2	-91.90905	1.500016	1	0	0
3	-16.36875	0.499984	1.516800	0	0
4	-18.22547	15.29017	1	0	0
5	-40	-20.39845	-1	0	0
6	infinity	0			

Analyses - Surface Incident/Absorbed Power

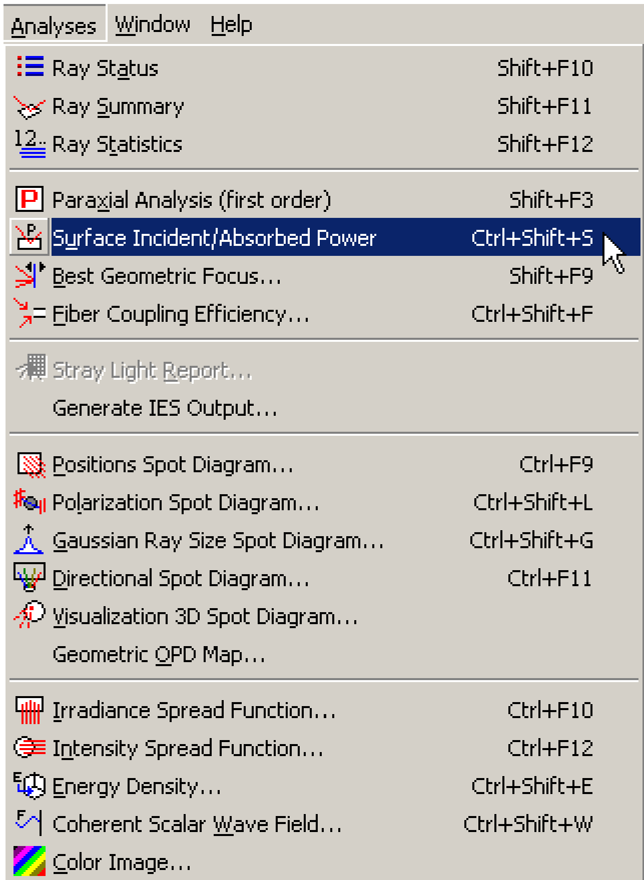
Description - Surface Incident/Absorbed Power

Writes tabulated surface data to the Output Window. The listing includes incident power, absorbed power and number of rays broken out into specular and scatter categories.

How Do I Get There? - Surface Incident/Absorbed Power

There are three different ways to execute this command:

1. Menu



2. Keyboard Accelerator - Ctrl+Shift+S

3. Toolbar Button 

Dialog Box and Controls - Surface Incident/Absorbed Power

No dialog box appears with this feature.

Application Notes - Surface Incident/Absorbed Power

Sample ouptut from Surface Incident/Absorbed Powers:

INCIDENT/ABSORBED SURFACE INCOHERENT POWERS:					(ghost.frd)				
(from most recent raytrace)									
Total # of Rays Incident	Absorbed Total Power	Incident Total Power	Incident Specular Level 0	Specular Level 1	Specular Level 2	Incident Scatter Level 0	Scatter Level 1	Scatter Level 2	Surface
418	1.31e-17	1.013960	1	0.013957	2.825e-6	1.013960	0	0	.triplet.Lens 1-2.Surface 1
650	0	1.008640	0.997272	0.011324	4.339e-5	1.008640	0	0	.triplet.Lens 1-2.Surface 2
8	0.000261	0.000261	0	0.000261	0	0.000261	0	0	.triplet.Lens 1-2.Bevel 2
128	0.000167	0.000167	0	0.000130	3.713e-5	0.000167	0	0	.triplet.Surface 3.Surf 3
701	5.57e-17	1.004440	0.994588	0.009798	5.400e-5	1.004440	0	0	.triplet.Lens 4-5.Surface 4
779	0	1.001987	0.991848	0.010040	9.769e-5	1.001987	0	0	.triplet.Lens 4-5.Surface 5
220	0.001800	0.001800	0	0.001653	0.000147	0.001800	0	0	.triplet.Lens 4-5.Edge
24	0.001260	0.001260	0	0.001260	0	0.001260	0	0	.triplet.Lens 4-5.Bevel 1
696	1.87e-17	0.994281	0.989147	0.005056	7.761e-5	0.994281	0	0	.triplet.Lens 6-7.Surface 6
696	1.39e-18	0.984239	0.984125	0	0.000114	0.984239	0	0	.triplet.Lens 6-7.Surface 7
24	3.315e-6	3.315e-6	0	0	3.315e-6	3.315e-6	0	0	.triplet.Lens 6-7.Bevel 1
592	0.979148	0.979148	0.979068	0	7.966e-5	0.979148	0	0	.triplet.Surface 8.Surf 8

See Also - Surface Incident/Absorbed Power

Analyses - Fiber Coupling Efficiency Dialog

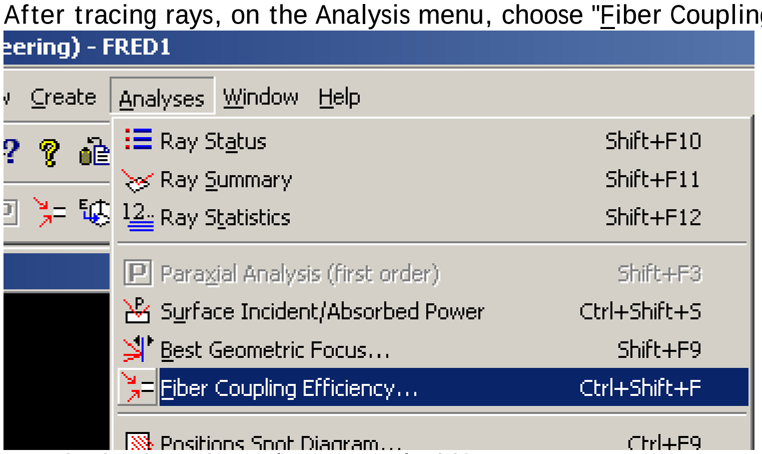
Description - Fiber Coupling Efficiency Dialog

This dialog allows you to calculate the fiber coupling efficiency for a system given data about the fiber.

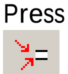
How Do I Get There? - Fiber Coupling Efficiency Dialog

There are three different ways to execute this command:

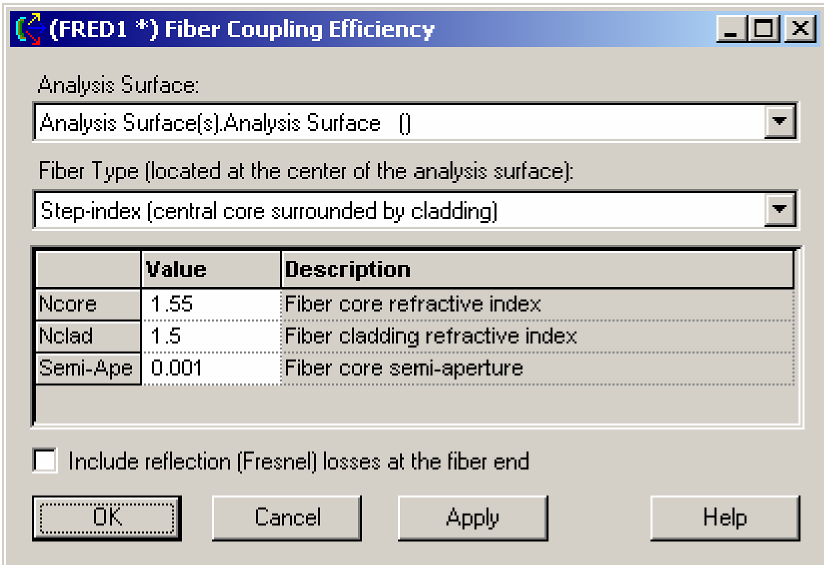
1. After tracing rays, on the Analysis menu, choose "Fiber Coupling Efficiency…"



2. Use the keyboard accelerator Ctrl+Shift+F
3. Press the Fiber Coupling toolbar button



Dialog Box and Controls - Fiber Coupling Efficiency Dialog



Control	Inputs / Description	Defaults
Analysis Surface	List all analysis surfaces in the FRED system.	The first Analysis Surface found in the system
Fiber Type	List the type of fiber available for the calculation. Options are: *Step-index* *Gaussian fundamental mode*	Step-index
Fiber Type Options	List the options for the selected fiber type.	Ncore = 1.55 Nclad = 1.5 Semi-Ape = 0.001
Include reflection (Fresnel) losses at the fiber end	Calculate Fresnel losses at the end of the fiber.	Unchecked
OK	Perform efficiency analysis and close dialog box.	
Cancel	Discard efficiency analysis and close dialog box.	
Apply	Perform efficiency analysis and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Fiber Coupling Efficiency Dialog

This dialog is resizable and modeless.

See Also -Fiber Coupling Efficiency Dialog

Best Geometric Focus

Analyses - Stray Light Path Report

Description

Stray Light Path Report Dialog

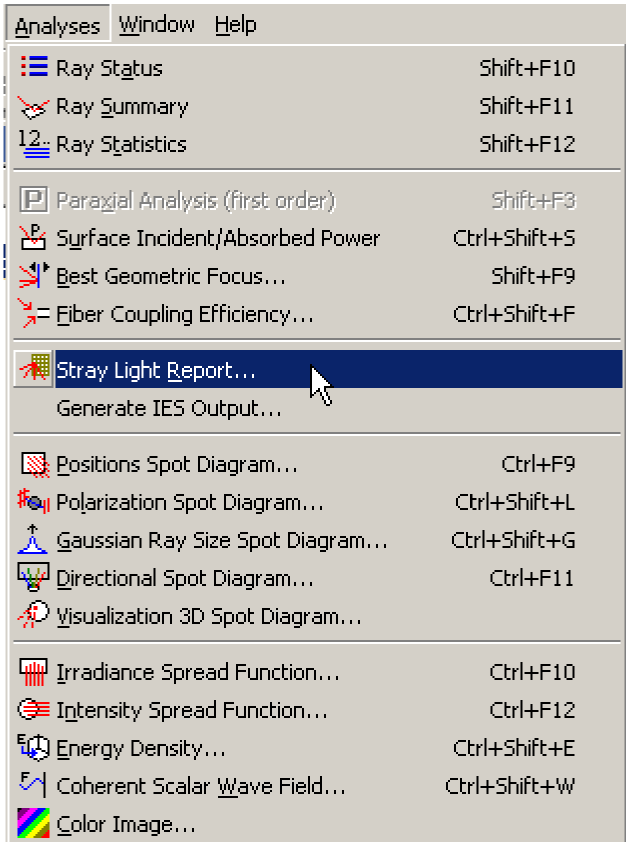
Provides a customized report of stray light paths included number of rays, power and scattering surfaces.

How Do I Get There?

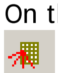
Stray Light Path Report Dialog

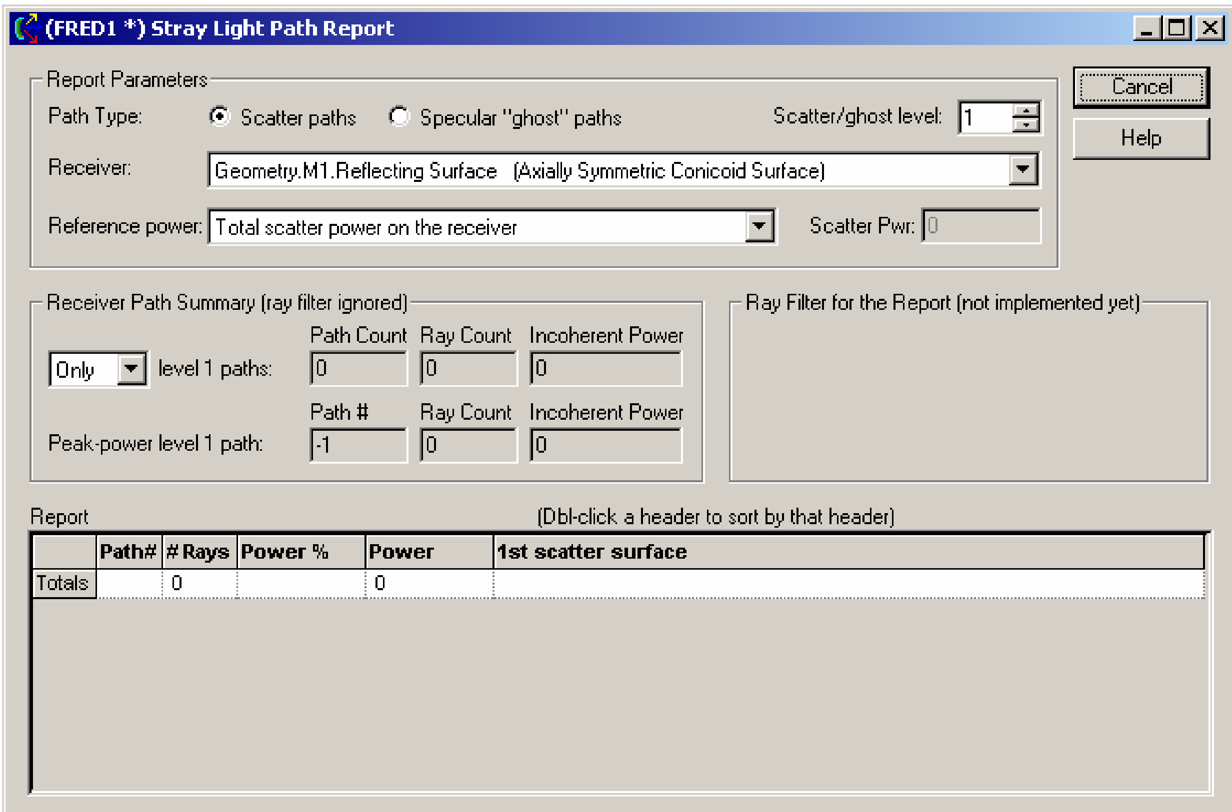
This command requires an Advanced Ray Trace with the “Determine ray paths” option enabled. There are two different ways to execute this command.

1. From the Analyses menu, choose "Stray Light Report...":



2. On the Analyses Toolbar, press the Stray Light Report Button:





Control	***Inputs / Description***	***Defaults***
Report Parameters		
Path Type:	Choose Scatter paths *or* Specular "ghost" paths.	Scatter Path
Scatter/ghost level	Number of generations	1
Receiver	Any valid surface	First surface in list
Reference Power	Set reference power to which path powers are compared.	Total scatter power on receiver
Scatter Power	User-defined power.	Grey
Receiver Path Summary		
Only/Thru level 1 paths	Path selection filter.	Only
Path Count	Number of paths.	0
Ray Count	Number of rays in all considered paths.	0

Incoherent Power	Total power in all considered paths.	0
Peak power level *n* path: Path #	Path number with largest power.	-1
Peak power level *n* path: Ray Count	Number of rays in path with largest power.	0
Peak power level *n* path: Incoherent Power	Power in path with largest power.	0
Report	Tabulated Path data.	empty
Cancel	Cancel Straylight Report and close dialog box.	
Help	Access this Help page.	

Application Notes

Stray Light Path Report Dialog

This dialog is resizable and modeless. It requires that at least one ray path be defined in order for the dialog to be displayed.

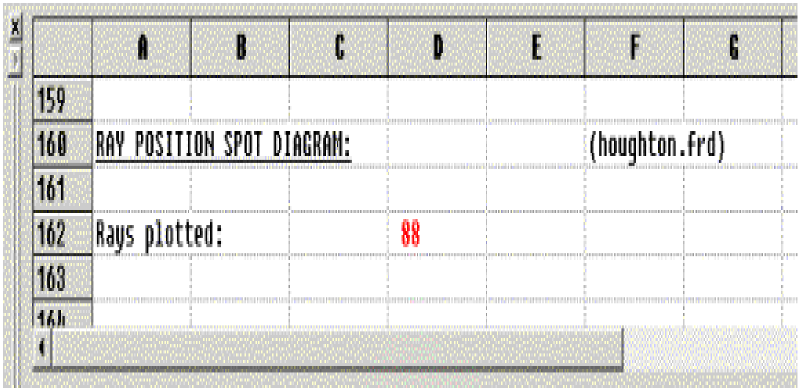
See Also….

Stray Light Path Report Dialog

Advanced Raytrace Dialog

Analyses - Position Spot Diagram

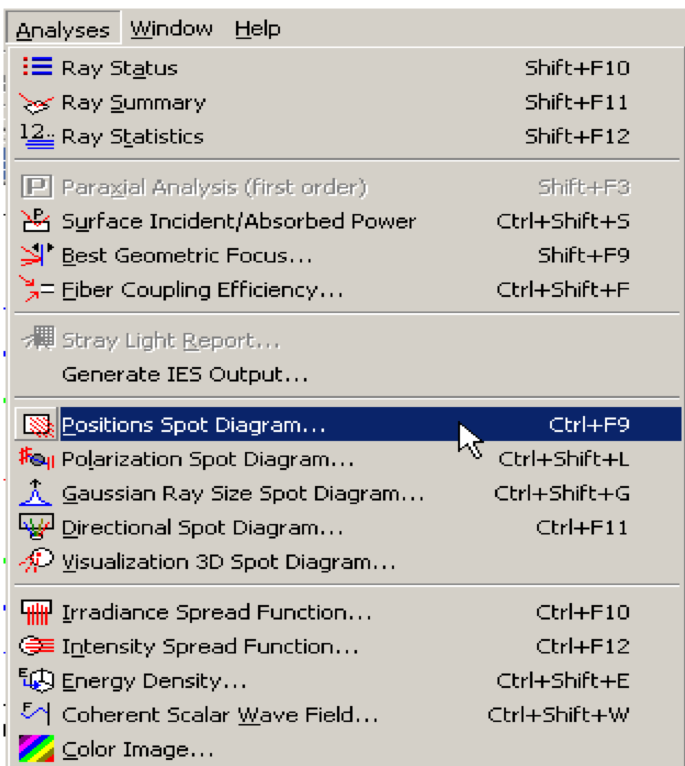
This command generates a ray position spot diagram based on the rays filtered by the user selected analysis plane. The axes of the position spot diagram represent the local X and Y axes of the analysis plane regardless of where the rays are positioned. For example, the analysis plane can attached to one object and filter/select rays from multiple objects. In that case, the ray positions on the spot diagram will be referenced to the analysis plane origin and not the surfaces or sources where the rays current are positioned.



Position Spot Diagram from the image plane of the Houghton sample

Note	The default operation of the spot diagrams and spread plot views in FRED is that they are deleted when a new raytrace is done. A plot view can be locked so it is not deleted when the rays are deleted via a right mouse click pop-up menu.

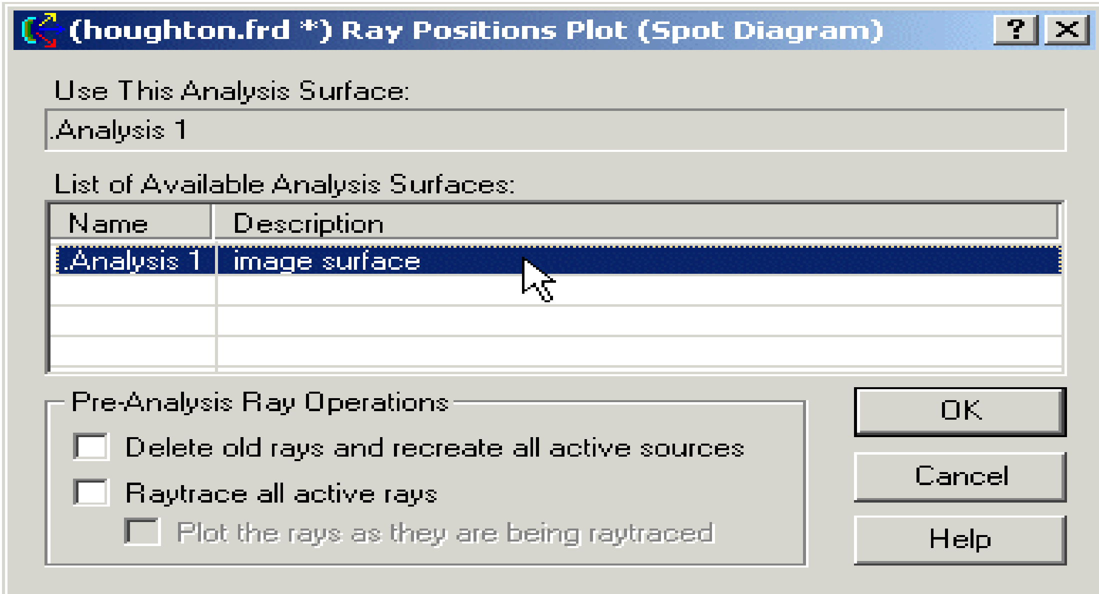
The following commands are available via a right mouse click pop-up menu.



Lock Window

Advanced…

In addition to the graphical ray position plot, textual information about the number of filtered rays is listed in the output window.

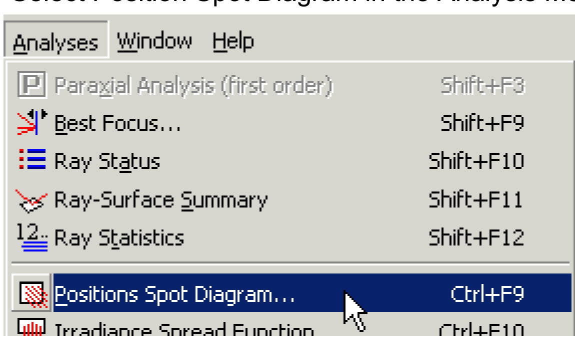


Position spot diagram plot information is printed in the output window

How Do I Get There? - Position Spot Diagram

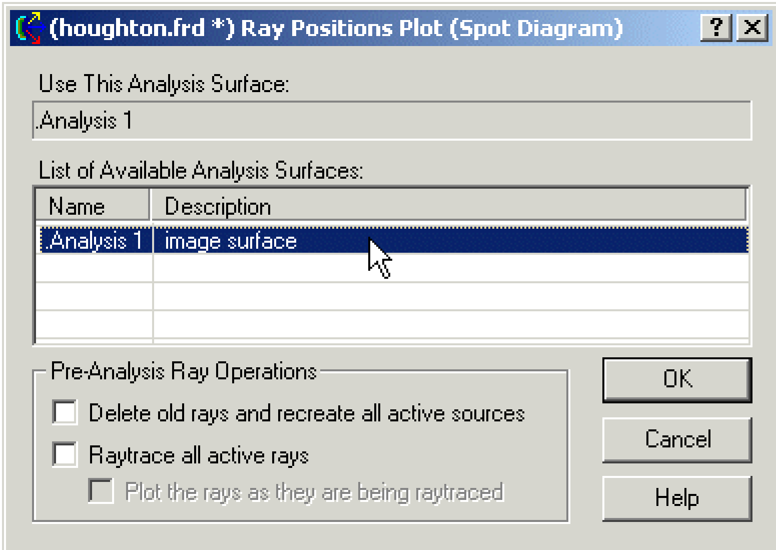
There are three different ways to execute this command:

1. Select Position Spot Diagram in the Analysis Menu



2. Press the keyboard accelerator keys: Ctrl+F9
3. Press the toolbar button:

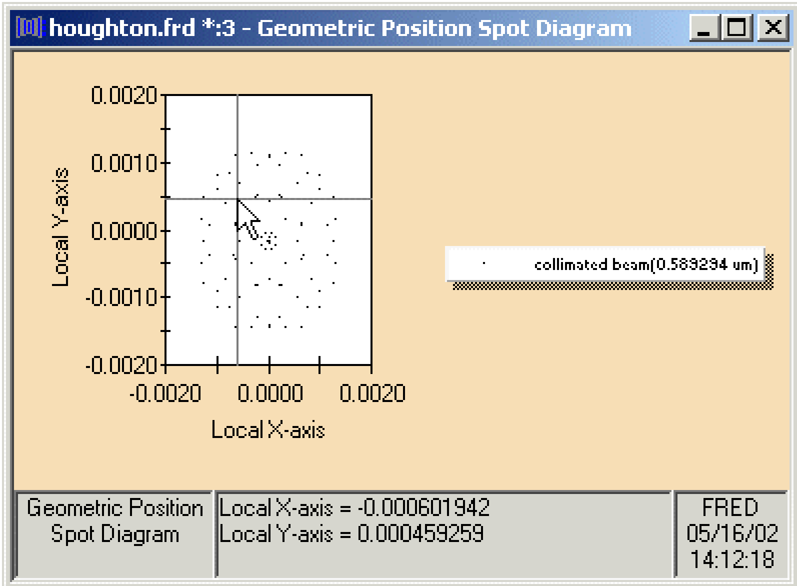
Dialog Box and Controls - Position Spot Diagram



<u>*Control*</u>	<u>*Inputs*</u>	<u>*Defaults*</u>
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	
OK		
Cancel		
Help		

Application Notes - Position Spot Diagram

Chart crosshairs are available by holding the left mouse button down inside the plot. The plot value under the cursor is reported at the bottom of the chart in both direction cosines and angles (both relative to the local analysis plane X and Y axes).



An example of crosshairs

Examples - Position Spot Diagram

Analyses - Polarization Spot Diagram

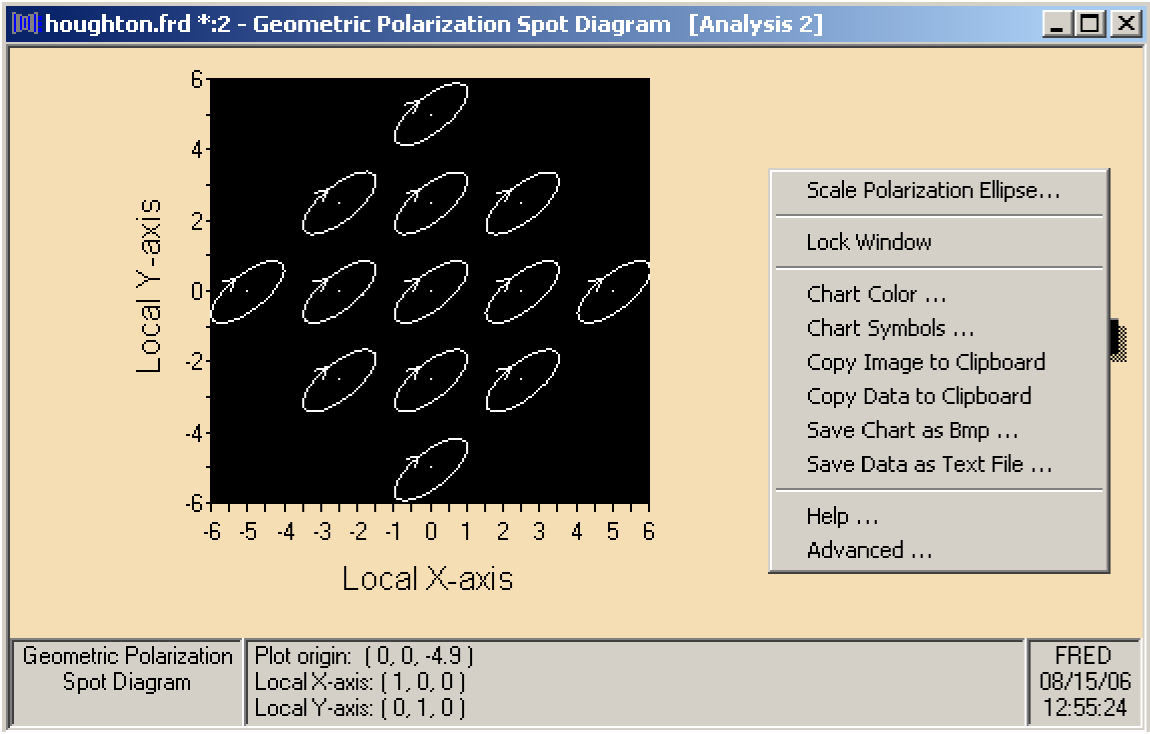
Description
How Do I Get There?
Dialog box and Controls
Application Notes
See Also…

Description

Polarization Spot Diagram

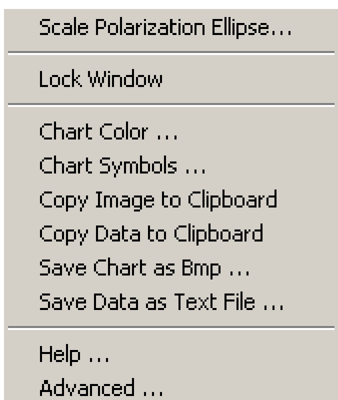
The Polarization Spot Diagram command generates a 2D polarization state plot of the rays filtered by the analysis plane selected by the user. The polarization ellipses can be scaled via the right mouse click menu.

Note	The spot diagram windows are deleted if anything in the FRED document is altered unless the spot diagram windows have been locked.



Polarization Spot Diagram

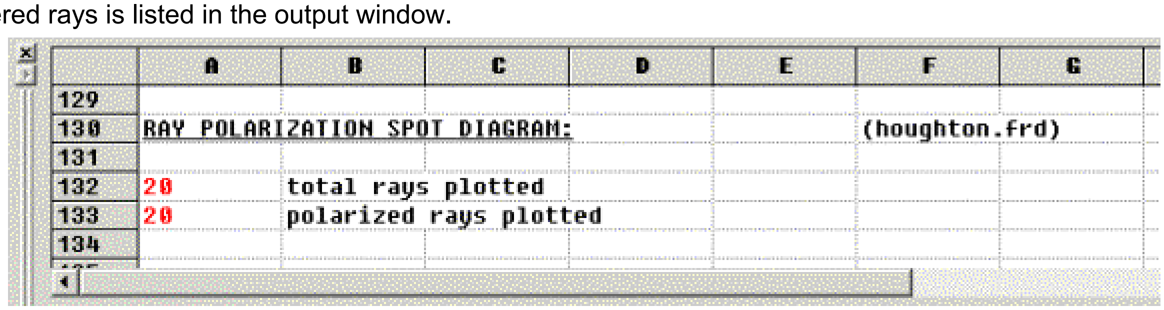
The following commands are available via a right mouse click pop-up menu.



Scale Polarization Ellipse
Lock Window
Chart Color …
Chart Symbols …
Copy Image to Clipboard …
Copy Data to Clipboard …
Save Chart to Bmp …
Save Data as Text File …
Help …
Advanced…

Right mouse click menu options

In addition to the graphical polarization plot, textual information about the number of filtered rays is listed in the output window.



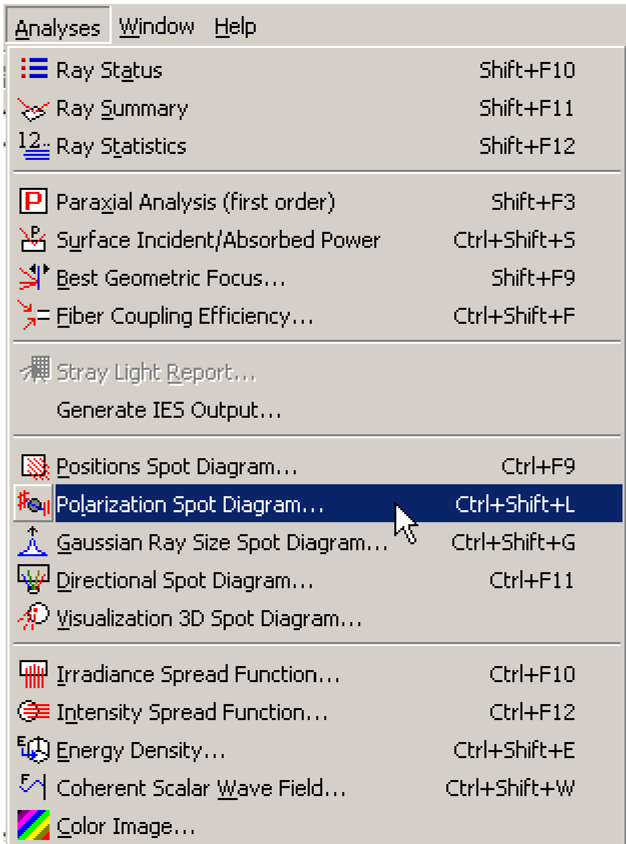
Polarization plot information is printed in the output window

How Do I Get There?

Polarization Spot Diagram

There are three different ways to execute this command:

1. Select Intensity Spread Function in the Analysis Menu

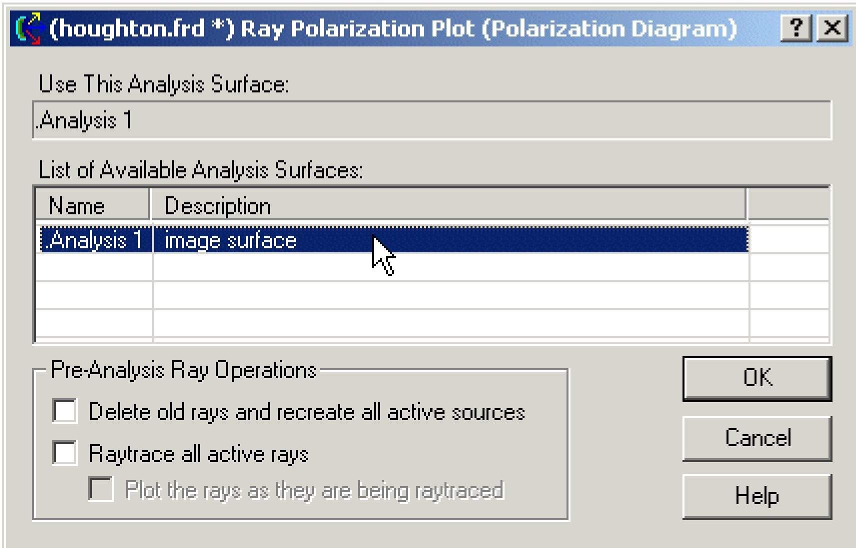


2. Press the keyboard accelerator keys: Ctrl+Shift+L

3. Press the toolbar button: 

Dialog Box and Controls

Polarization Spot Diagram



Control	***Inputs***	***Defaults***
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	Highlighted Analysis Surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First valid Analysis Surface
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Unchecked
OK	Plot Ray Polarization and close dialog box.	
Cancel	Discard Ray Polarization Plot and close dialog box.	
Help	Access this Help page.	

Application Notes

Polarization Spot Diagram

The data in the chart can be saved to a text data file, but only the ray locations are presently saved. The polarization information is not saved with the ray locations.

A modified chart style can be saved and made the default file.

See Also….

Polarization Spot Diagram

Scale Polarization Ellipse

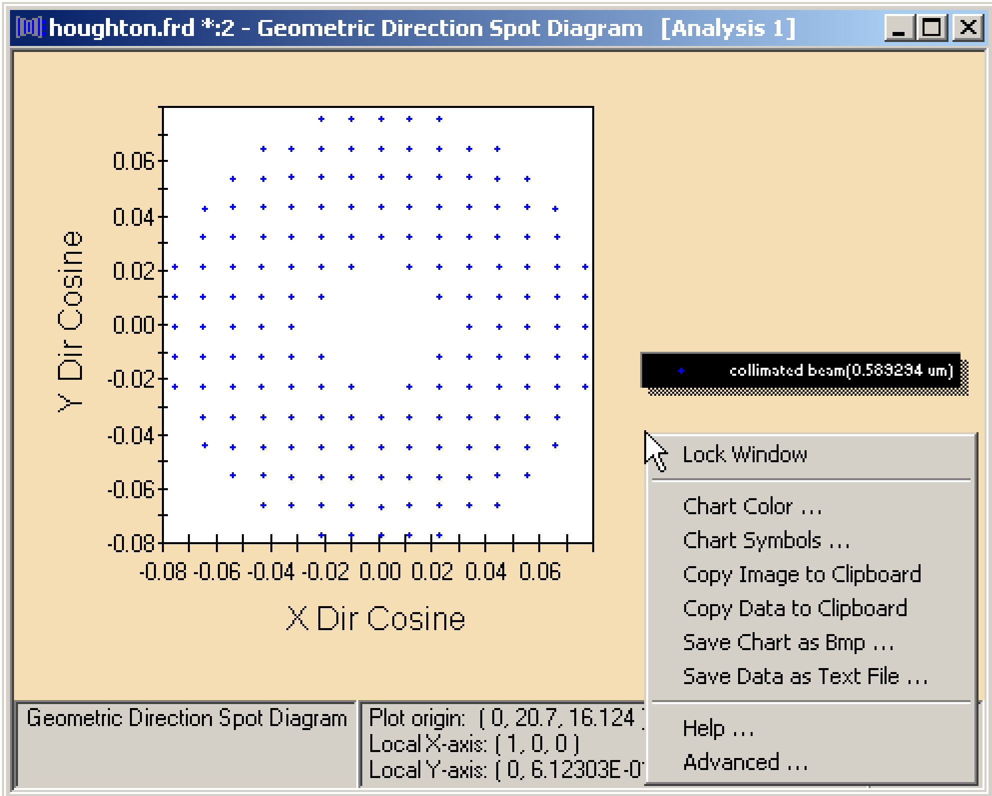
Analyses - Directional Spot Diagram

Description

Directional Spot Diagram

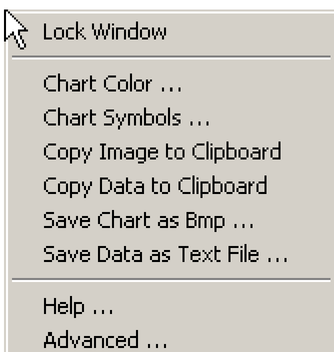
This command generates a ray direction spot diagram based on the rays filtered by one of the available analysis planes. The ray directions are plotted in direction cosines relative to the local X and Y-axes of the analysis plane and *not* relative to the surface with the rays on it (see Examples). Chart crosshairs are available by holding the left mouse button down inside the plot area (see Application Notes)

Note	The default operation of the spot diagrams and spread plot views in FRED is that they are deleted when a new raytrace is done. A plot view can be locked so it is not deleted when the rays are deleted via a right mouse click pop-up menu.



Direction Spot Diagram

The following commands are available via a right mouse click pop-up menu.



Right mouse click menu options

[Lock Window]
Chart Color …
Chart Symbols …
Copy Image to Clipboard …
Copy Data to Clipboard …
Save Chart as Bmp …
Save Data as Text File …
Help …
[Advanced…]

In addition to the graphical ray direction plot, textual information about the number of filtered rays is listed in the output window.

```
RAY DIRECTION SPOT DIAGRAM:                         (houghton.frd)

Rays plotted:          164
Incoherent power:      0.224938
RMS:                   0.060050
Power weighted RMS:    0.060050
                                                     Power Weighted
                          x          y               x          y
Average:               7.44e-18  -2.285e-5        1.36e-17  -2.285e-5
RMS:                   0.042461   0.042461        0.042461   0.042461
Min:                  -0.076302  -0.076325
Max:                   0.076302   0.076279
```

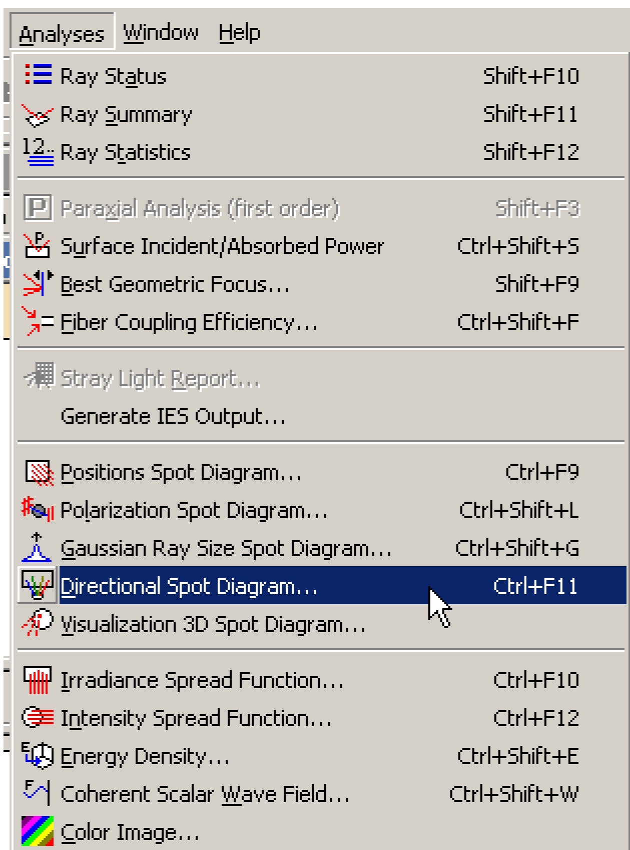
Direction spot diagram plot information is printed in the output window

How Do I Get There?

Directional Spot Diagram

There are three different ways to execute this command:

1. Select Directional Spot Diagram in the Analysis Menu

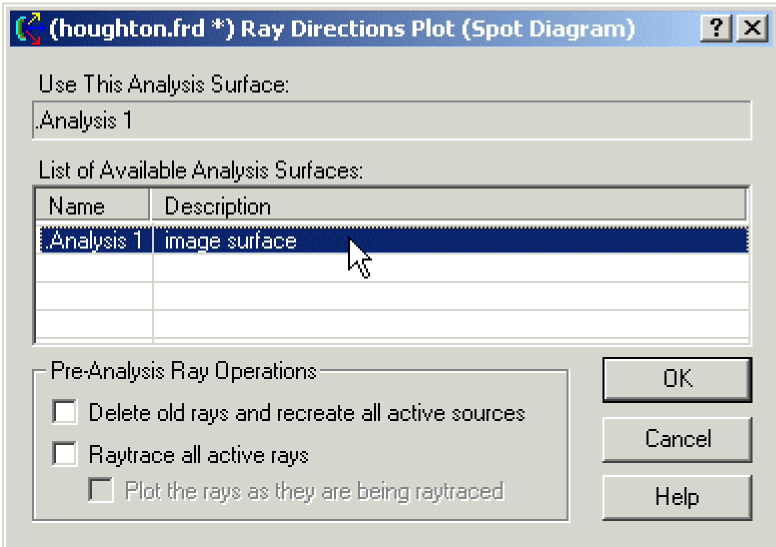


2. Press the keyboard accelerator keys: Ctrl+F11

3. Press the toolbar button: 

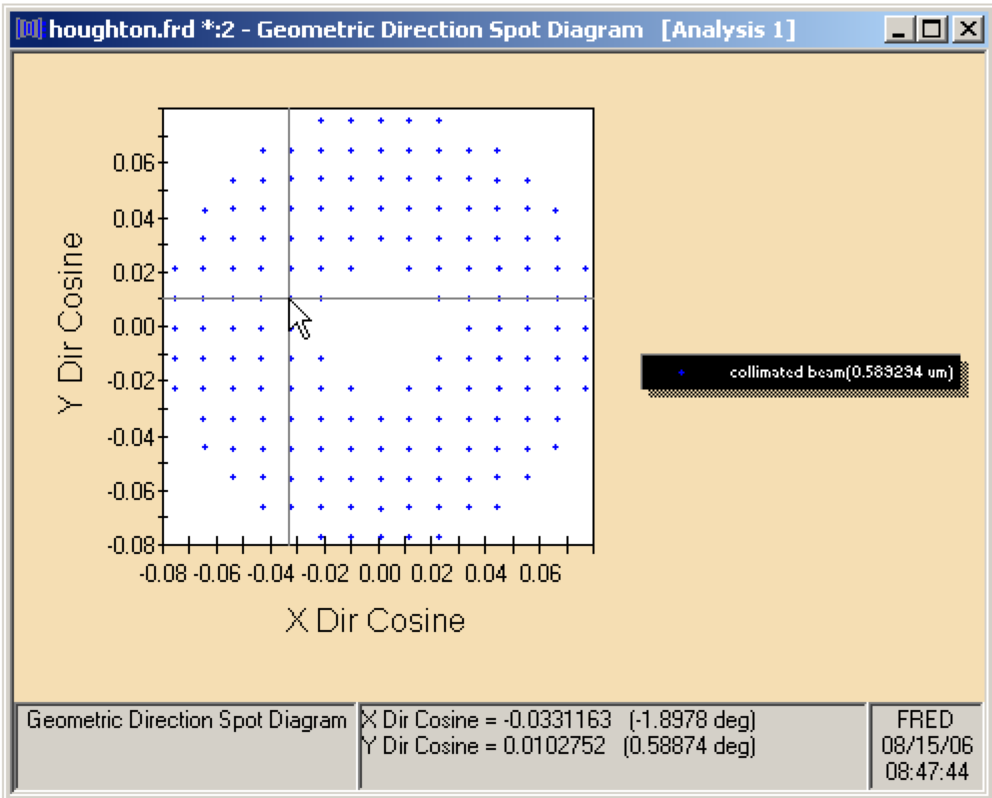
Dialog Box and Controls

Directional Spot Diagram



Control	***Inputs***	***Defaults***
Use This Analysis Surface:	Lists the analysis surface used to filter rays in the spot diagram.	Highlighted Analysis surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	.Analysis *n*
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and are traced before the spot diagram is plotted.	Unchecked
Plot the rays as they are being raytraced	If checked, the rays will be plotted when they are raytraced.	Unchecked
OK	Accept Ray Directions Plot and close dialog box.	
Cancel	Discard Ray Directions Plot and close dialog box.	
Help	Access this Help page.	

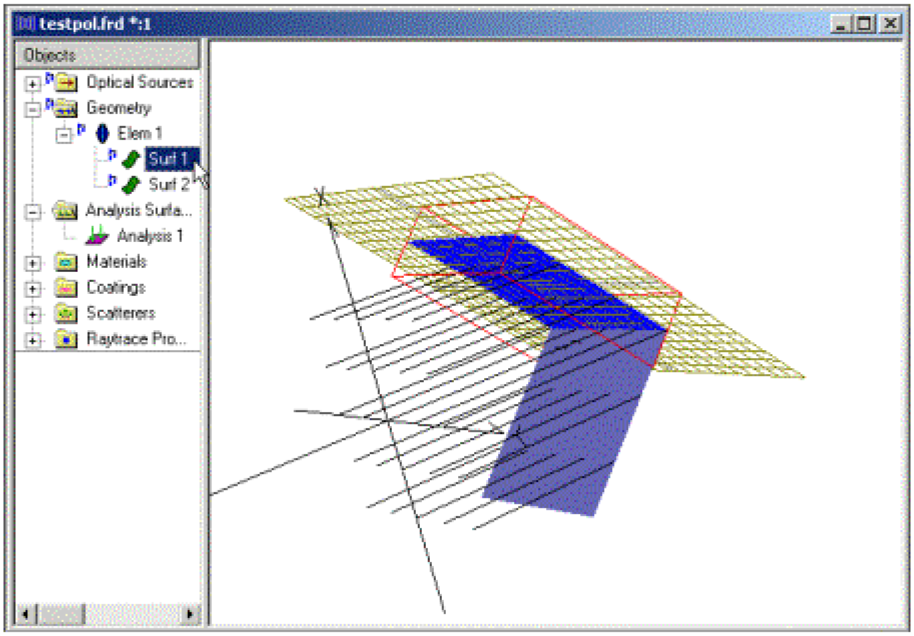
Chart crosshairs are available by holding the left mouse button down inside the plot. The plot value under the cursor is reported at the bottom of the chart in both direction cosines and angles (both relative to the local analysis plane X and Y axes).



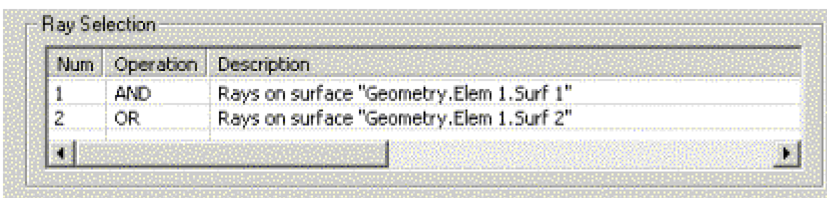
An example of crosshairs

Examples
Directional Spot Diagram

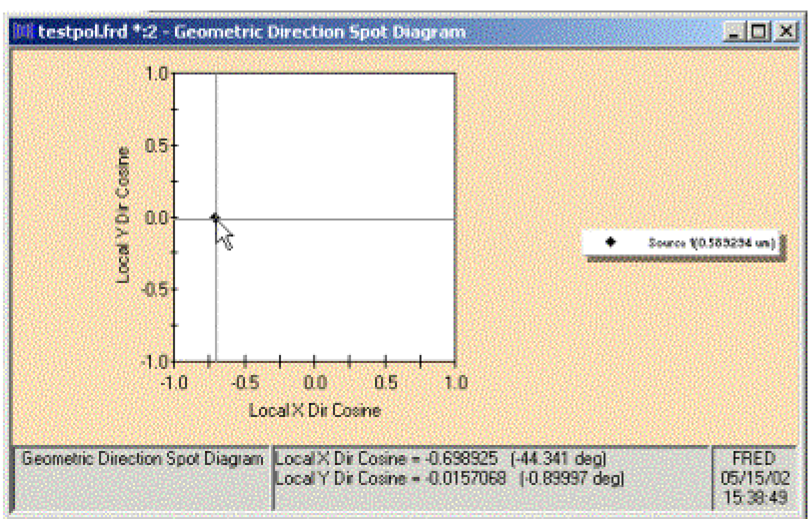
The ray directions are reported in direction cosine space relative to the analysis plane. This is illustrated in the example below where there are two surfaces at 90 degrees to one another. There is an analysis plane attached to surface Surf 1 and the ray selection filter for the analysis plane includes rays hitting both surfaces Surf 1 and Surf 2. The direction spot diagram shows all the ray angles at one angle, the angle all the rays have to the analysis plane even though half the rays are on Surf 2.



The geometry



The ray filter for the analysis plane



The resulting direction spot diagram is shown above. Note that the approximate angle is shown with the crosshairs.

See Also….

Directional Spot Diagram

Position Spot Diagram

Analyses - Irradiance Spread Function

Description

Irradiance Spread Function

The Irradiance Spread Function command generates a 3D irradiance plot of the rays filtered by the user-selected Analysis Plane. The irradiance, in units of flux/area, is summed at the center of each pixel and plotted. Incoherent, coherent, and coherent polarized rays can all be summed together based on what rays the analysis plane filters. The summation process follows these steps at each pixel:

Step 1. The coherent polarized rays at each discrete wavelength are summed coherently using their electric field vectors. Each coherent polarized ray's electric field is decomposed into X, Y, and Z components. All the X components are summed coherently, all the Y components are summed coherently, and all the Z components are summed coherently. The X, Y, and Z components summations are all summed incoherently. Then all the discrete wavelengths are summed incoherently.

Step 2. The coherent unpolarized rays are coherently summed at each discrete wavelength. Then all the discrete wavelengths of coherent rays are summed incoherently.

Step 3. The incoherent rays are summed incoherently.

Step 4. All three summations are summed together for each pixel.

Note: If the wavelength of two coherent sources differs by any amount at any decimal place, they are summed incoherently.

If the source is coherent, then a complete coherent irradiance pattern is calculated from a relatively small number of rays using gaussian beamlet propagation. The coherent summation calculation accurately includes diffraction effects as long as the coherent rays have been propagated through the optical system meeting two rules at every surface. First, the gaussian beamlets must be significantly smaller than the apertures that they go through and second, the beamlets should be small relative to the local curvature of the optical surface. The diffraction effects of apertures are calculated by sampling the aperture with gaussian beamlets. If the beamlets are not small compared to the aperture, then the sampling will be inaccurate. If the beamlets are large relative to local surface curvature changes, then the gaussian beamlet may not maintain its quadratic curvature on refraction or reflection.

If the source is incoherent, then the irradiance plot does not include diffraction. The incoherent irradiance pattern is simply a binning of the incident rays into the bins or grids defined by the analysis plane. In addition to providing an irradiance pattern based on the binning of the incoherent rays, this command also provides an auxiliary spread function chart (fourth panel in the window) showing the number of the rays in each bin or alternatively an estimated percent error for each bin based on the number of rays in each bin.

Coherent and incoherent examples are shown below with exactly the same analysis plane and source definition. The only change made was setting the source coherent in the first case and incoherent in the second case. Note that the peak is significantly lower and broader in the coherent case than in the incoherent indicating that the system performance is limited by diffraction.

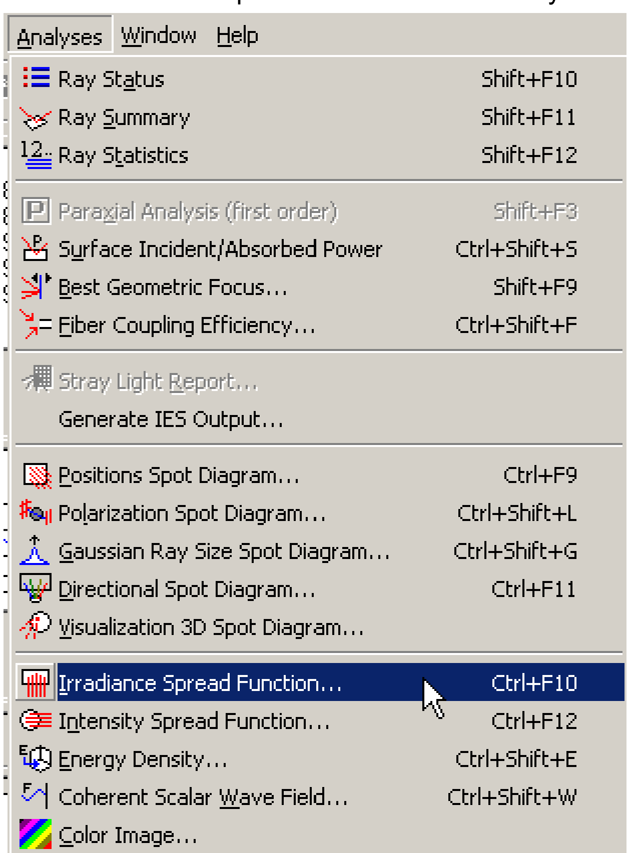
> Note: The spread function and spot diagram windows are deleted if anything in the FRED document is altered unless the spread function or spot diagram windows have been locked.

How Do I Get There?

Irradiance Spread Function

There are three different ways to execute this command:

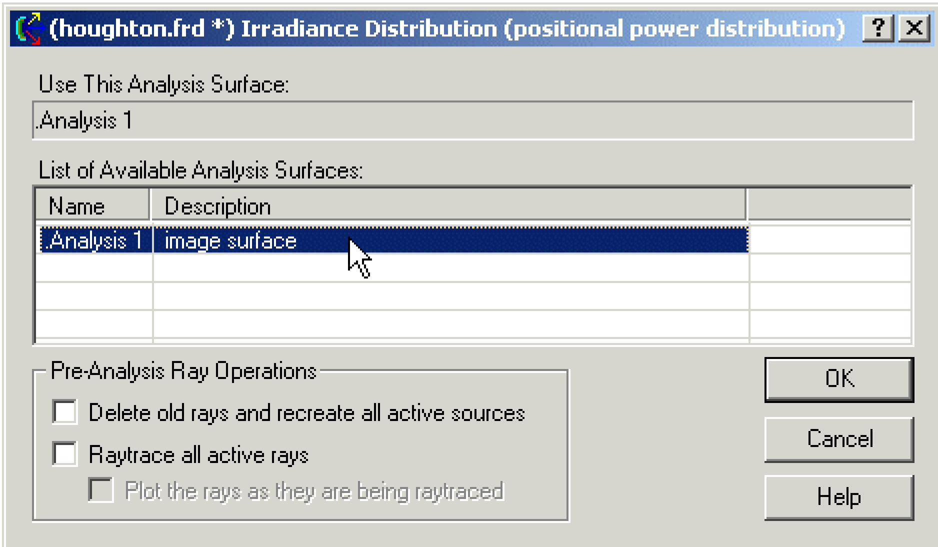
1. Select Irradiance Spread Function in the Analysis Menu



2. Press the keyboard accelerator keys: Ctrl+F10

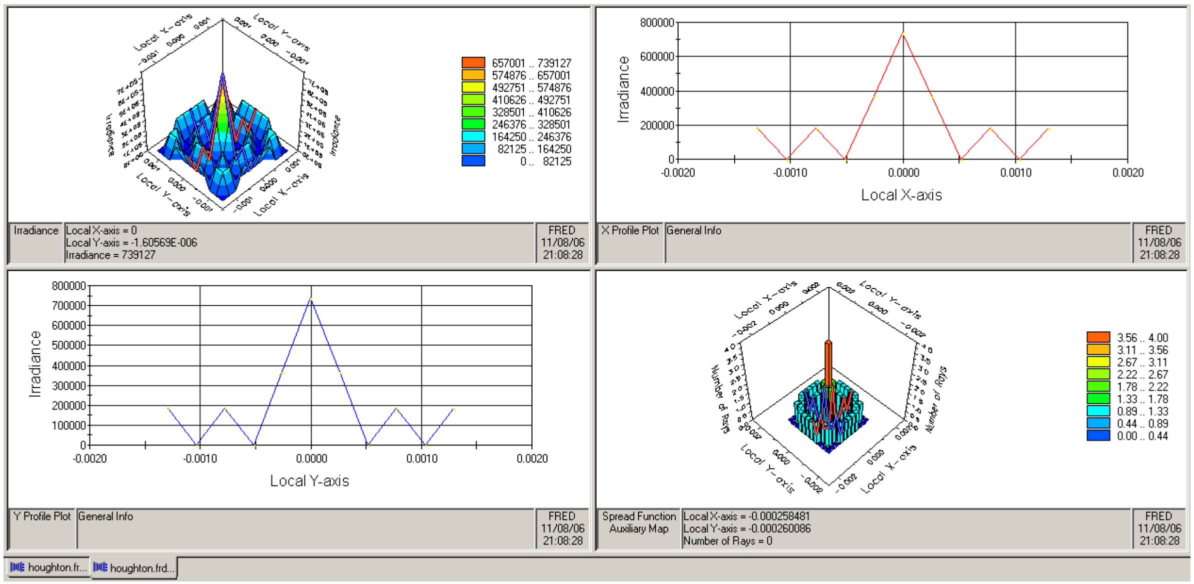
3. Press the toolbar button: 

Dialog Box and Controls
Irradiance Spread Function

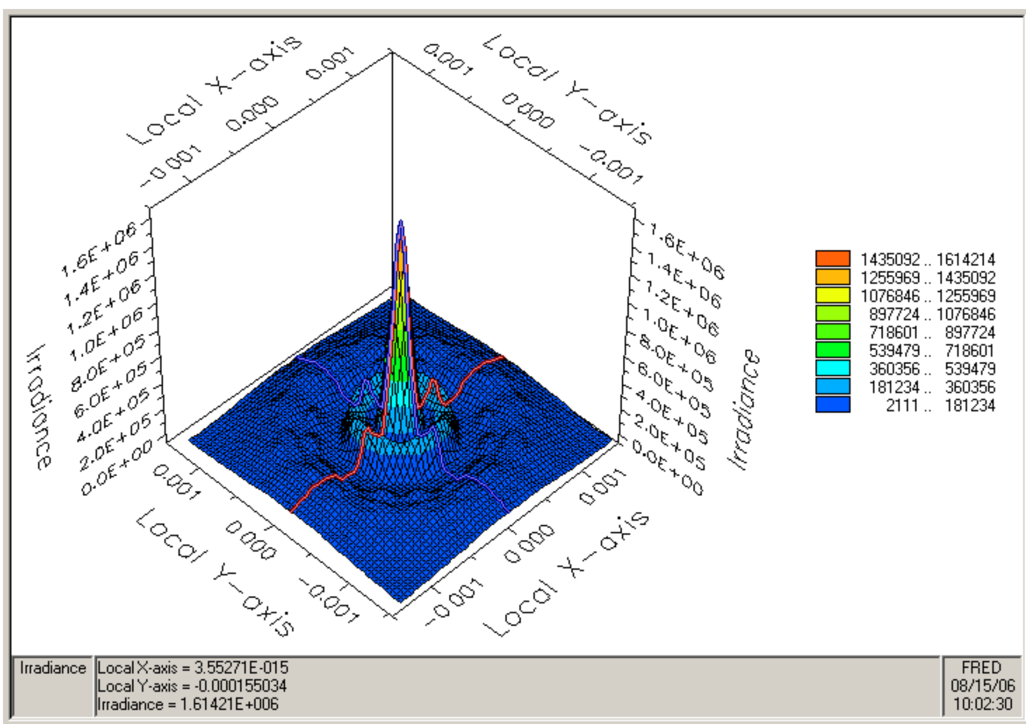


Control	Inputs	Defaults
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	Highlighted analysis surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First valid analysis surface
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Unchecked
OK	Plot Irradiance Distribution and close dialog box.	
Cancel	Discard Irradiance plot and close dialog box.	
Help	Access this Help page.	

Application Notes
Irradiance Spread Function



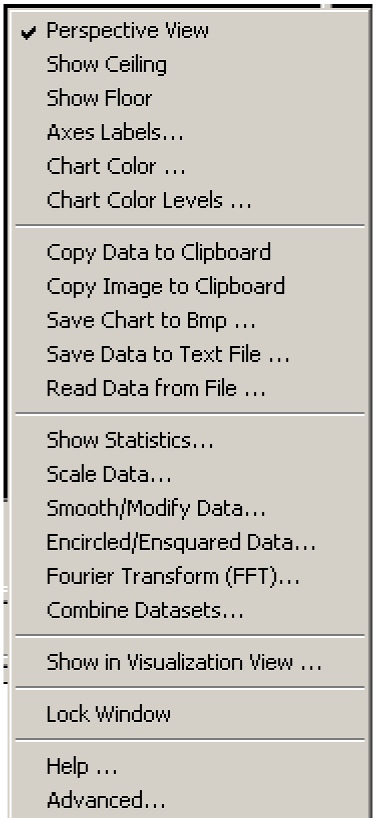
Incoherent irradiance pattern is shown in the first panel and the number of rays per bin is shown in the auxiliary spread function chart in the fourth panel for the Houghton sample.



Coherent irradiance pattern for the Houghton sample

Chart crosshairs are available by holding the left mouse button down inside the plot. The irradiance and location under the cursor is reported at the bottom of the chart in position (relative to the local analysis plane X and Y axes).

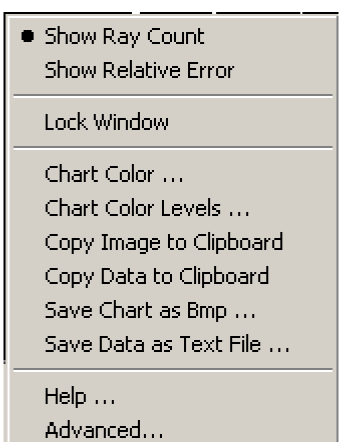
In both the coherent and incoherent cases, the following commands are available in the first panel via a right mouse click pop-up menu.



First panel right mouse click menu options

Perspective View
Show Ceiling
Show Floor
Axes Labels…
Chart Color…
Chart Color Levels…
Copy Data to Clipboard…
Copy Image to Clipboard…
Save Chart to Bmp…
Save Data to Text File…
Read Data from File…
Show Statistics…
Scale Data…
Smooth / Modify Data…
Encircled/Ensquared Data…
Fourier Transform (FFT)…
Combine Datasets…
Show in Visualization View…
Lock Window
Help…
Advanced…

In the incoherent case only, the following commands are available in the auxiliary spread function chart (second panel) via a right mouse click pop-up menu.



The spread function auxiliary chart right mouse click menu options in the 2nd panel (incoherent spread functions only)

Show Ray Count
Show Relative Error
Lock Window
Chart Color …
Chart Color Levels …
Copy Image to Clipboard …
Copy Data to Clipboard …
Save Chart as Bmp …
Save Data as Text File …
Help …
Advanced…

In addition to the graphical irradiance plots, textual information about the filtered rays, the analysis plane, and the irradiance profile is output to the output window.

	A	B	C	D	E	F	G	H	I	J	K
2360											
2361	IRRADIANCE DISTRIBUTION:					(houghton.frd)					
2362	0.023290	sec total time									
2363											
2364					# Rays						
2365			# Rays		Not Included						
2366	Ray Type		Included		(Errors)		Time (sec)				
2367	Incoherent:		0		0		0				
2368	Coherent Unpolarize		0		0		0				
2369	Coherent Polarized:		164		0		0.023249				
2370											
2371	Totals		164		0		0.023249				
2372											
2373	Total Power:			1.854667	(contained in the entire analysis plane)						
2374	Total Average Irradiance:			95798.93	(over the entire analysis plane)						
2375	Valid Average Irradiance:			95798.93	(over valid pixel area only)						
2376											
2377	Length units are:		in								
2378											
2379	Min/Max		Irradiance		X		Y		Row		Column
2380	Maximum:		1136897.752526		0		0		6		6
2381	Minimum:		33.64182627426		-0.002		0.002		1		11
2382											
2383	Widths/Heights		X width		Y height		Width (pixels)		Height (pixels)		
2384	Analysis Plane:		0.0044		0.0044		11		11		
2385	Single Pixel:		0.0004		0.0004		1		1		
2386											
2387	Areas		Area		Pixel Count						
2388	Analysis plane:		1.936e-5		121						
2389	Valid pixels:		1.936e-5		121						
2390	Single pixel:		1.6e-7		1						
2391											
2392	Local Coordinates		X		Y		Row		Column		
2393	Lower left corner:		-0.0022		-0.0022		0.5		0.5		
2394	Upper right corner:		0.0022		0.0022		11.5		11.5		
2395											

Irradiance plot information printed in the output window for every irradiance plot

Examples

Irradiance Spread Function

None.

See Also….

Irradiance Spread Function

The data in the chart can be saved to a text data file.

A modified chart style can be saved and made the default file.

Analyses - Intensity Spread Function

Description

How Do I Get There?

Dialog box and Controls

Application Notes

See Also…

Description
Intensity Spread Function

The Intensity Spread Function command generates a 3D intensity plot of the rays filtered by the analysis plane selected by the user. The intensity, Watts/steradian, is summed at the center of each pixel and plotted. A steradian, [sr], is a measure of solid angle. Incoherent, coherent, and coherent polarized rays can all be summed together incoherently based on what rays the analysis plane filters. It is important to note that unlike the irradiance calculations, the summation process for intensity is entirely incoherent and does not include diffraction.

> Note: The intensity calculation is incoherent.

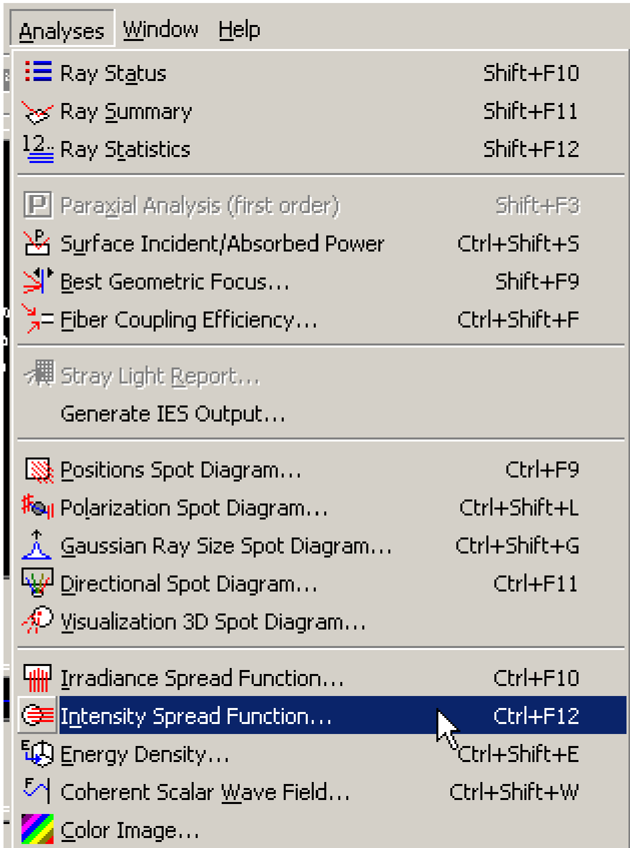
The intensity pattern is simply a binning of the incident rays into the bins or grids defined by the analysis plane. In addition to providing an intensity pattern based on the binning of the incoherent rays, this command also provides an auxiliary spread function chart (fourth panel in the window) showing the number of the rays in each bin or alternatively an estimated percent error for each bin based on the number of rays in each bin.

> Note: The spread function and spot diagram windows are deleted if anything in the FRED document is altered. Locking the window prevents its deletion.

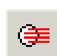
How Do I Get There?
Intensity Spread Function

There are three different ways to execute this command:

1. Select Intensity Spread Function in the Analysis Menu

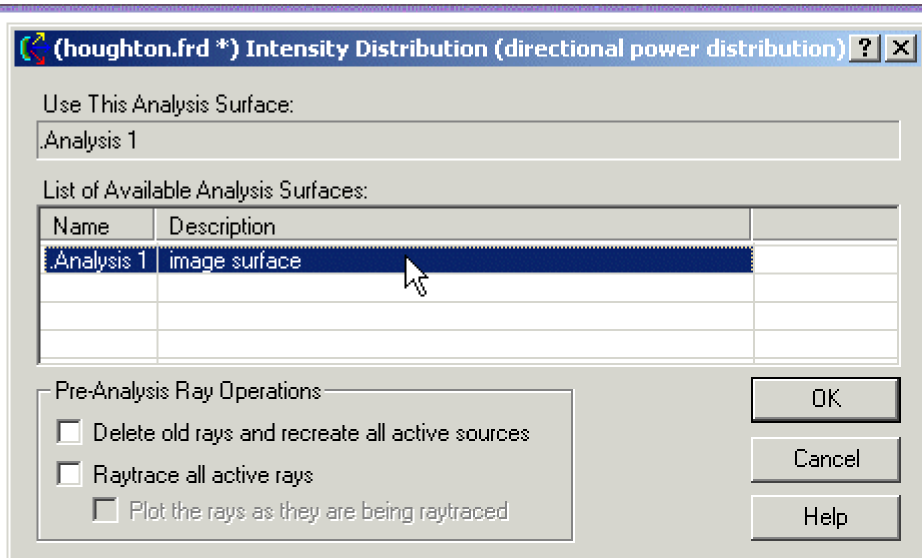


2. Press the keyboard accelerator keys: Ctrl+F12

3. Press the toolbar button: 

Dialog Box and Controls

Intensity Spread Function

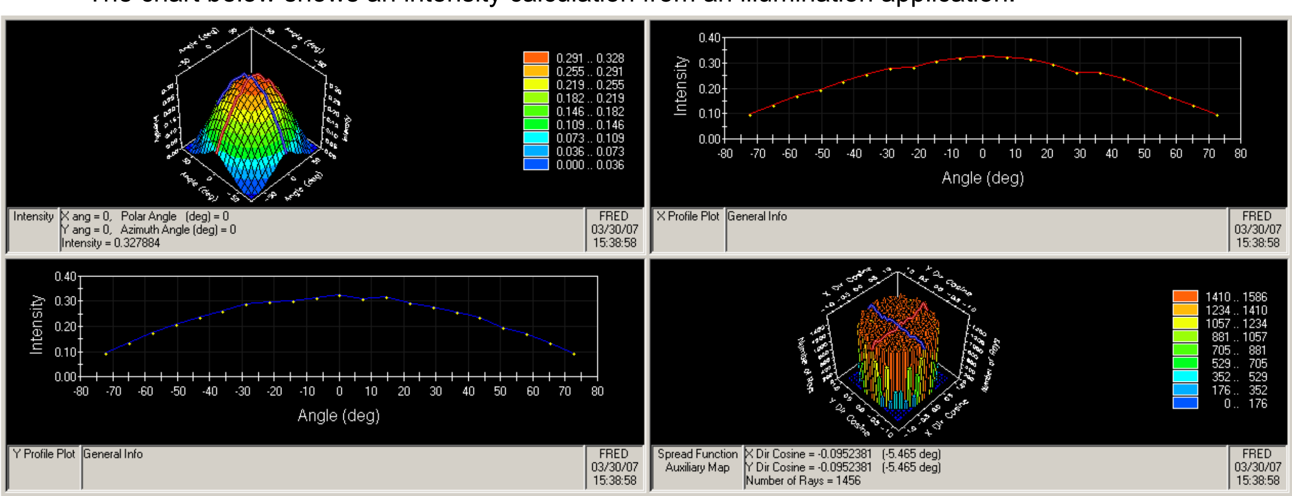


Control	Inputs	Defaults
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram.	Highlighted Analysis Surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First surface in list
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Grayed out, unchecked
OK	Display Intensity Distribution and close dialog box.	
Cancel	Discard Intensity Distribution and close dialog box.	
Help	Access this Help page.	

Application Notes

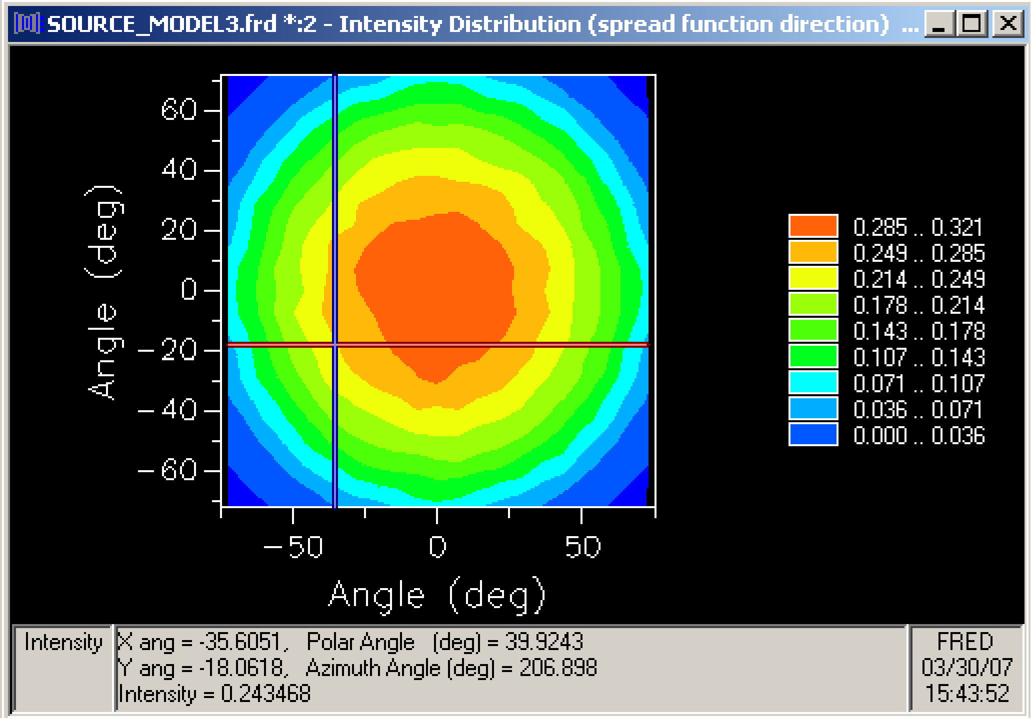
Intensity Spread Function

The chart below shows an intensity calculation from an illumination application.



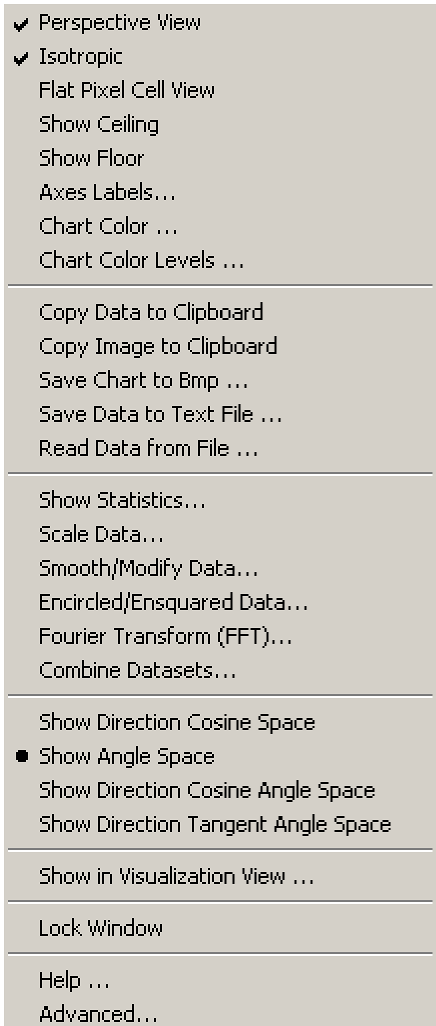
Incoherent intensity pattern is shown in the first panel and the number of rays per bin is shown in the auxiliary spread function chart in the fourth panel for a Lambertian angular distribution.

Chart crosshairs are available by holding the left mouse button down inside the plot. The intensity and location under the cursor is reported at the bottom of the chart in both xy-angles and in polarazimuthal angles (relative to the local analysis plane X axis).



An example of crosshairs

The following commands are available in the first panel via a right mouse click pop-up menu.

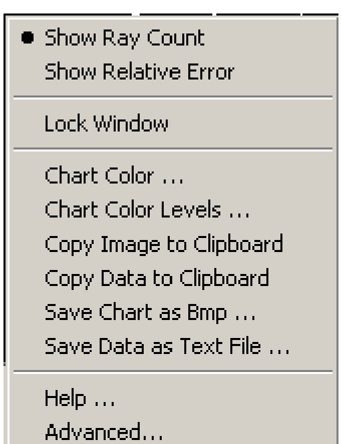


First panel right mouse click menu options

Perspective View
Isotropic
Flat Pixel Cell View
Show Ceiling
Show Floor
Axes Labels…
Chart Color...
Chart Color Levels...
Copy Data to Clipboard
Copy Image to Clipboard
Save Chart as Bmp...
Save Data to Text File...
Read Data from File...
Show Statistics…
Scale Data…
Smooth / Modify Data…
Fourier Transform (FFT)…
Combine Datasets…
Show Direction Cosine Space
Show Angle Space
Show Direction Cosine Angle Space
Show Direction Tangent Angle Space
Show in Visualization View...

Lock Window
Help
Advanced…

The following commands are available in the auxiliary spread function chart (fourth panel) via a right mouse click pop-up menu.



The spread function auxiliary chart right mouse click menu options in the 2nd panel

Show Ray Count
Show Relative Error
Lock Window
Chart Color …
Chart Color Levels …
Copy Image to Clipboard …
Copy Data to Clipboard …
Save Chart as Bmp …
Save Data as Text File …
Help …
Advanced…

In addition to the graphical intensity plots, textual information about the filtered rays, the analysis plane, and the intensity profile is output to the output window.

	A	B	C	D	E	F	G	H	I	J	K
293	INTENSITY DISTRIBUTION:					(SOURCE_MODEL3.frd)					
294	Analysis Surf:		Analysis 1								
295											
296											
297	Ray type			# rays							
298	Incoherent Rays:			500000							
299	Coherent Unpolarized:			0							
300	Coherent Polarized:			0							
301	Total:			500000	(3.51 secs)						
302	Errors:			0							
303											
304	Length units are:		mm								
305											
306	Integrated Power:			0.950476	(over the entire analysis area)						
307	Total Average Intensity:			0.307494	(over the entire analysis area)						
308	Valid Average Intensity:			0.309646	(over non-zero (valid) pixels only)						
309											
310	Min/Max		Intensity		X		Y		Row		Column
311	Maximum:		0.320647		7.224720		0		12		11
312	Minimum:		0.004434		-72.24720		-50.57304		1		4
313											
314	Widths/Heights		X width		Y height		Width (pixels)		Height (pixels)		
315	Analysis Surface:		151.7191		151.7191		21		21		
316	Single Pixel:		7.224720		7.224720		1		1		
317											
318	Areas		Area		Pixel Count						
319	Analysis surface:		23018.69		441						
320	Valid pixels:		21765.97		417						
321	Single pixel:		52.19659		1						
322											
323	Local Coordinates		X		Y		Row		Column		
324	Lower left corner:		-75.85957		-75.85957		0.5		0.5		
325	Upper right corner:		75.85957		75.85957		21.5		21.5		

Intensity information is printed in the output window for every intensity plot

3. As of version 6.40, the Intensity Spread function default display mode is angle space. Conversions to other spaces are available on the popup menu.

See Also….
Intensity Spread Function

The data in the chart can be saved to a text data file.

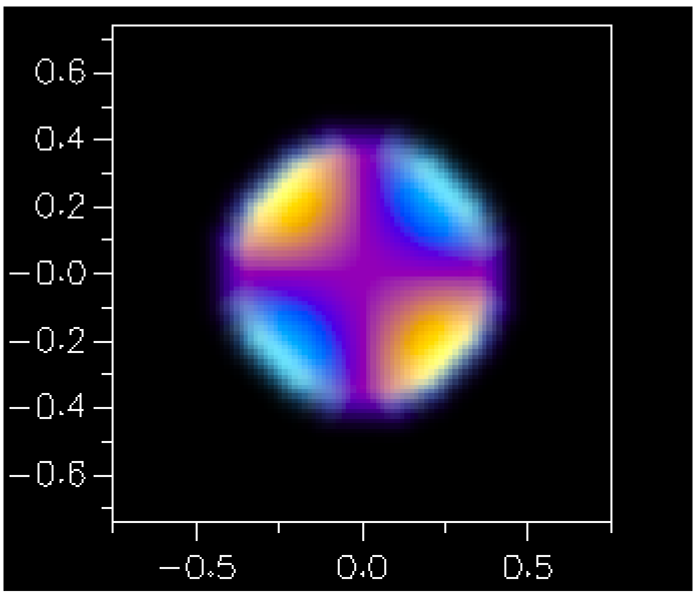
A modified chart style can be saved and made the default file.

Analyses - Color Image

Description

Color Image

Calculates and displays an RGB spatial map of a user-selected Analysis Surface.

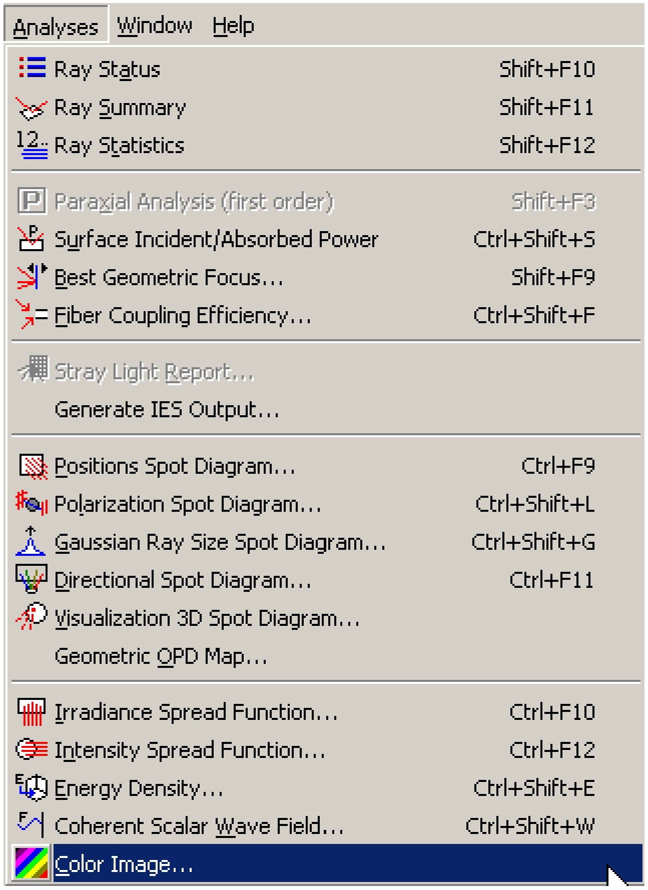


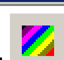
How Do I Get There?

Color Image

There are two different ways to execute this command:

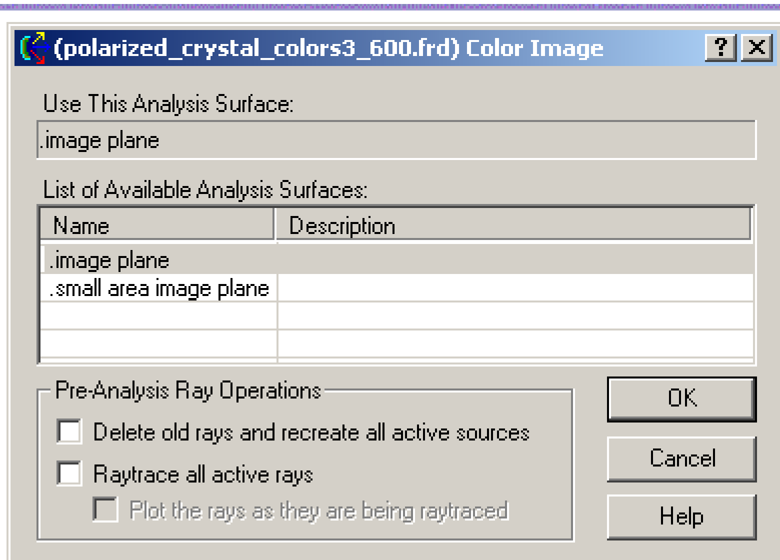
1. Menu



2. Toolbar Button - 

Dialog Box and Controls

Color Image



Control	Inputs / Description	Defaults
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	Highlighted analysis surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First valid analysis surface
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Unchecked
OK	Plot Irradiance Distribution and close dialog box.	
Cancel	Discard Irradiance plot and close dialog box.	
Help	Access this Help page.	

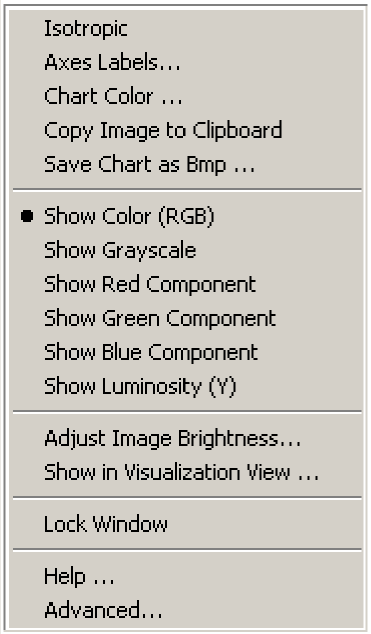
Application Notes

Color Image

- The Color Image feature calculates the XYZ chromaticity coordinates for each pixel of the Analysis Surface. Those coordinates are converted into RGB values and displayed in the Chart Viewer.

- The Color Image Chart View presents four (4) panes; an RGB spatial map of color on the Analysis Surface, two cross-sectional profiles of the spatial map, and a chromaticity diagram. As the cursor is moved in the spatial map, a cursor in the chromaticity diagram indicates the XY chromaticity coordinate corresponding to the specific pixel where the spatial map cursor is positioned.

- The Chart View allows data to be displayed as RGB, Greyscale, Luminosity, or either of the three RGB components alone. Right-click in the Chart to invoke this menu:

	Isotropic [Axes Labels…] [Chart Color…] Chart Color… Copy Image to Clipboard… Save Chart to Bmp… Show Color (RGB) Show Greyscale Show Red component Show Green Component Show Blue Component Show Luminosity (Y) Adjust Image Brightness... [Show in Visualization View…] [Lock Window] Help… [Advanced…]

See Also….

Color Image

Adjust Image Brightness

Help - Menu commands

The Help menu offers the following commands:

Help Topics	Brings up this help file.
Tutorials	
Keyboard Map	Shows a listing of which commands do what in FRED.
Frequently Asked Questions	
Script Language Reference	
Tip of the Day...	Bring up the Tip of the Day dialog box.
Open the Photon Engineering Website...	Opens a web browser turned to http://www.photonengr.com.
License Authorization...	Brings up the License Authorization dialog
Demo Version…	Displays a message box describing the Demo Version of FRED.
About...	Brings up the About dialog box.

Help – Keyboard Map - Accelerator Keys

This page has two accelerator keys tables.

1. By command.
2. By accelerator key

There is also a set of accelerator keys that work with the different graphs available in FRED. They are listed here.

Accelerator Keys By Command

Command	Accelerator Key	
	Visualization View	Tree View
Open the help file	F1	F1
Switch to the Tree View / OpenGL View	F6	F6
Bring up a context menu	Shift+F10	Shift+F10
Close the file	Ctrl+F4	Ctrl+F4
Create a new optical system	Ctrl+N	Ctrl+N
Create a new macro	Ctrl+Shift+N	Ctrl+Shift+N
Open a file	Ctrl+O	Ctrl+O
Save the file	Ctrl+S	Ctrl+S
Print a file	Ctrl+P	Ctrl+P
Go to the command line	Ctrl+I	Ctrl+I
Switch between open documents	Ctrl+Tab	Ctrl+Tab
Import an IGES or STEP file	Ctrl+Shift+J	Ctrl+Shift+J
Import a CodeV, Zemax or OSLO lens prescription	Ctrl+Shift+I	Ctrl+Shift+I
Import an ASAP output file	Ctrl+Shift+K	Ctrl+Shift+K
Cut an element	none	Ctrl+X

Copy an element	none	Ctrl+C
Paste an element	none	Ctrl+V
Rename a selected element in Tree View	none	F2
Switch to trackball mode	F5	none
Switch to magnify mode	F7	none
Select an object	F8	none
Toggles between orthographic and perspective views	F9	none
View all objects in the scene	F10	none
Orbit the camera	Ctrl+F5	none
Translate the camera	Ctrl+F7	none
Rotate the camera	Ctrl+F8	none
Create a Positions Spot Diagram	Ctrl+F9	Ctrl+F9
Create an Irradiance Spread Function	Ctrl+F10	Ctrl+F10
Create a Directional Spot Diagram	Ctrl+F11	Ctrl+F11
Create an Intensity Spread Function	Ctrl+F12	Ctrl+F12
Toggle animation mode for continuous scene rotation	Shift+F5	none
Translate the scene	Shift+F7	none
Rotate the scene	Shift+F8	none
Perform a Best Focus Analysis	Shift+F9	Shift+F9
Create a Ray Summary	Shift+F11	Shift+F11
Display Ray Statistics	Shift+F12	Shift+F12
Delete existing rays	Ctrl+Shift+F5	none

and trace all optical sources		
Trace and draw all optical sources	Ctrl+Shift+F7	none
Create rays for all traceable optical sources but don't trace or draw them	Ctrl+Shift+F8	none
Delete all existing rays	Ctrl+Shift+F9	none
Edit the properties of the background grid	Ctrl+Shift+F12	none
Switch to looking towards the positive X direction	Ctrl+1	none
Switch to looking towards the positive Y direction	Ctrl+2	none
Switch to looking towards the positive Z direction	Ctrl+3	none
Switch to looking towards the negative X direction	Ctrl+4	none
Switch to looking towards the negative Y direction	Ctrl+5	none
Switch to looking towards the negative Z direction	Ctrl+6	none

Accelerator Keys By Key

Accelerator Key	**Command**	
	Visualization View	Tree View View
F1	Opens the help file	Opens the help file
F2	none	Allows for renaming the

		selected element
F3		
F4		
F5	Switches to trackball mode	none
F6	Switches to the Tree View	Switches to the OpenGL View
F7	Switches to Magnify mode	none
F8	Switches to Select Object mode	none
F9		
F10	View All objects in the system (zoom out)	none
F11		
F12		
Ctrl+1	Switch to looking towards the positive X direction	none
Ctrl+2	Switch to looking towards the positive Y direction	none
Ctrl+3	Switch to looking towards the positive Z direction	none
Ctrl+4	Switch to looking towards the negative X direction	none
Ctrl+5	Switch to looking towards the negative Y direction	none
Ctrl+6	Switch to looking towards the negative Z direction	none
Ctrl+F1		
Ctrl+F2	none	Allows for renaming the selected element
Ctrl+F3		

Ctrl+F4	Asks if you want to save and closes the file	Asks if you want to save and closes the file
Ctrl+F5	Orbits the camera	none
Ctrl+F6		
Ctrl+F7	Translates the camera	none
Ctrl+F8	Rotates the camera	none
Ctrl+F9	Positions Spot Diagram	Positions Spot Diagram
Ctrl+F10	Irradiance Spread Function	Irradiance Spread Function
Ctrl+F11	Directional Spot Diagram	Directional Spot Diagram
Ctrl+F12	Intensity Spread Function	Intensity Spread Function
Shift+F1	Opens the help file	Opens the help file
Shift+F2	none	Allows for renaming the selected element
Shift+F3		
Shift+F4		
Shift+F5	Toggles animation mode for continuous scene rotation	none
Shift+F6	Switches to the Tree View	Switches to the Visualization View
Shift+F7	Translates the scene	none
Shift+F8	Rotates the scene	none
Shift+F9	Performs a Best Focus Analysis	Performs a Best Focus Analysis
Shift+F10	Prints out the Ray Status	Prints out the Ray Status
Shift+F11	Ray Summary	Ray Summary
Shift+F12	Ray Statistics	Ray Statistics
Ctrl+Shift+F1		
Ctrl+Shift+F2		

Ctrl+Shift+F3		
Ctrl+Shift+F4	Closes the file and asks if you want to save	Closes the file and asks if you want to save
Ctrl+Shift+F5	Deletes existing rays and trace all optical sources	none
Ctrl+Shift+F6	Switches between open documents	Switches between open documents
Ctrl+Shift+F7	Traces and draws all optical sources	Traces and draws all optical sources
Ctrl+Shift+F8		
Ctrl+Shift+F9		
Ctrl+Shift+F10		
Ctrl+Shift+F11		
Ctrl+Shift+F12		

2D and 3D Graph Accelerator Keys

The following keystrokes are available when viewing graphs. You can use the middle mouse button instead of the left + right button combination, if your mouse driver has not mapped the middle button to something else.

Accelerator Key Combination	*Command*	
	2-D Graph	*3-D Graph*
Both mouse buttons	nothing	rotate the graph freely
Both mouse buttons + Ctrl		zoom into or out of the graph
Both mouse buttons + Shift		shift the graph left, right, up, or down
Ctrl + Left mouse button + drag		Zoom in on a portion of the graph
Shift + Left mouse button + drag		Zoom in on a portion of the graph and display axes values
R		Return the camera to its original (unzoomed, unshifted) view of the graph
Both mouse buttons + X	nothing	Rotate the grid about the X axis
Both mouse buttons + Y	nothing	Rotate the grid about the Y axis
Both mouse buttons + Z	nothing	Rotate the grid about the Z axis

Help - About Command (Help menu)

Description

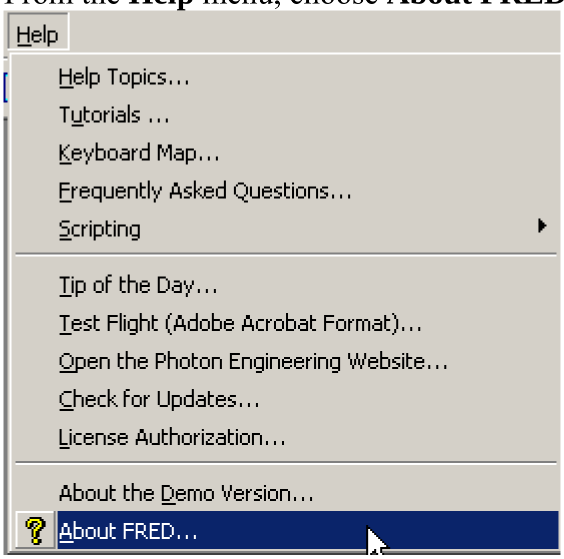
About FRED (Help menu)

Use this command to display the copyright notice and version number of your copy of FRED.

How Do I Get There?

About FRED (Help menu)

From the **Help** menu, choose **About FRED…**



Help - Script menu commands

The Script menu offers the following commands:

Run	Runs the current script.
Debug Run Start	Begins the current script in the script debugger, stopping at any breakpoints.
Debug Step Into	Advances into the next execution statement
Debug Step Over	Advances over the next execution statement
Debug End	Ends the script debugging session.
Toggle Debug Breakpoint	Sets a debug breakpoint on the current line if one does not

	exist, or removes one if it does exist.
Clear All Debug Breakpoints	Removes all debug breakpoints from the script.
Associate With FRED Document...	Associates the script with a FRED document that is open.

Run command

Description

How Do I Get There?

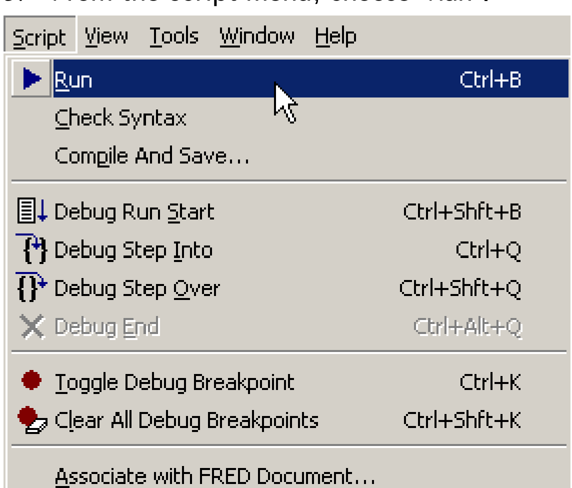
Description - Run command

Use this command to Run a FRED Script.

How Do I Get There? - Run command

There are three ways to execute this command:

1. On the Script Toolbar, press this button: 
2. Use the keyboard shortcut Ctrl+B.
3. From the Script menu, choose "Run".



Debug Start command

[Description](#)

[How Do I Get There?](#)

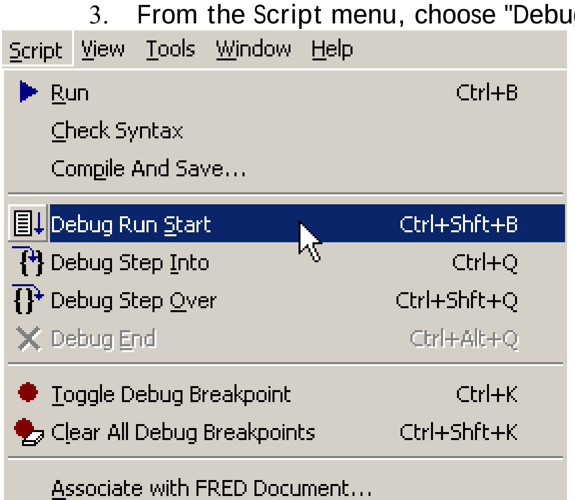
Description - Debug Start command

Use this command to begin running a FRED Script in the debugger. This command differs from the Run command in that it pauses the script at a breakpoint, if one exists. This command is only available when a Script is active.

How Do I Get There? - Debug Start command

There are three ways to execute this command:

1. On the Script Toolbar, click this button: 
2. Use the keyboard shortcut Ctrl+Shift+B.
3. From the Script menu, choose "Debug Run Start".



Debug Step Into command -

[Description](#)

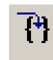
[How Do I Get There?](#)

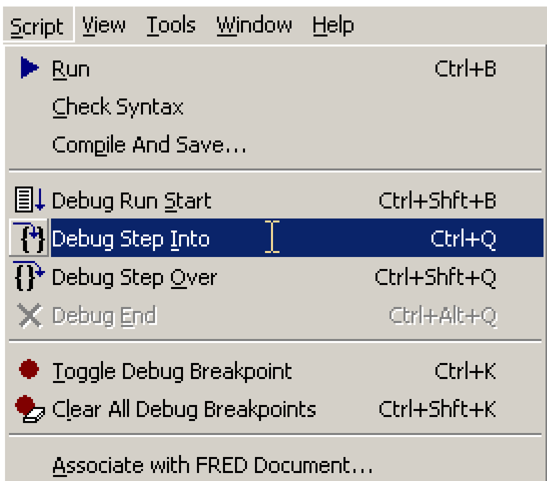
Description - Debug Step Into command

Use this command to execute the next line of script code, then pause again. If the next line is a call to a function or subroutine you have written, this command will advance to the first line of that function or subroutine. This command is only available if the script is being run in the debugger.

How Do I Get There? - Debug Step Into command

There are three ways to execute this command:

1. On the Script Toolbar, click this button: 
2. On the Script menu, choose "Debug Step Into".



3. Use they keyboard shortcut Ctrl+Q.

Debug Step Over command

Description

How Do I Get There?

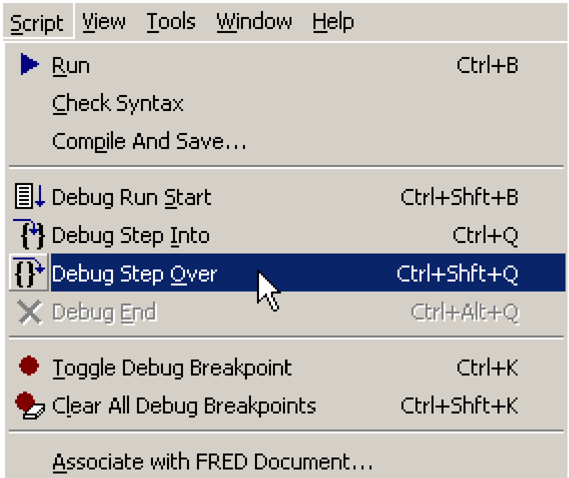
Description - Debug Step Over command

Use this command to copy selected data onto the clipboard. This command is unavailable if there is no data currently selected.

How Do I Get There? - Debug Step Over command

There are three ways to execute this command:

1. Toolbar: 
2. Menu: Script->Debug Step Over



3. Keyboard Shortcut: Ctrl+Shift+Q

Debug End command

Description

How Do I Get There?

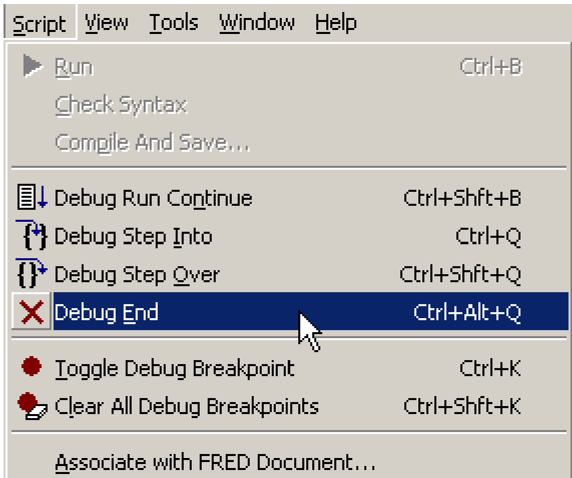
Description - Debug End command

Use this command to end a script debugging session. This command is unavailable if a script is not running.

How Do I Get There? - Debug End command

There are two ways to execute this command:

1. On the Script Toolbar, click this button: 
2. From the Script menu, choose "Debug End".



Toggle Breakpoint command

[Description](#)

[How Do I Get There?](#)

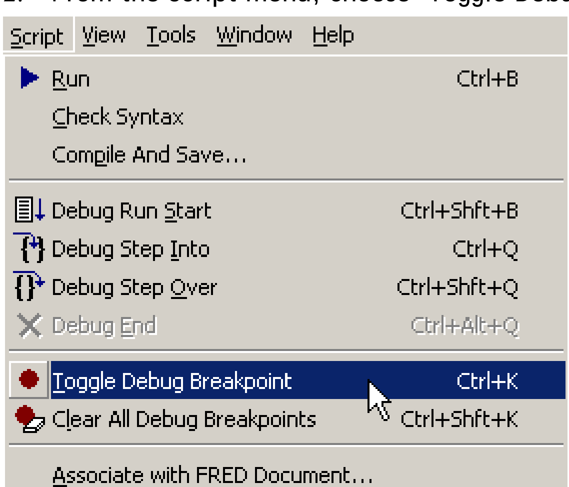
Description - Toggle Breakpoint command

Use this command to copy selected data onto the clipboard. This command is unavailable if there is no data currently selected.

How Do I Get There? - Toggle Breakpoint command

There are three ways to execute this command:

1. On the Script Toolbar, click this button: 
2. From the Script menu, choose "Toggle Debug Breakpoint".



3. Use the keyboard shortcut Ctrl+K.

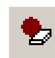
Clear All Breakpoints command

Description - Clear All Breakpoints command

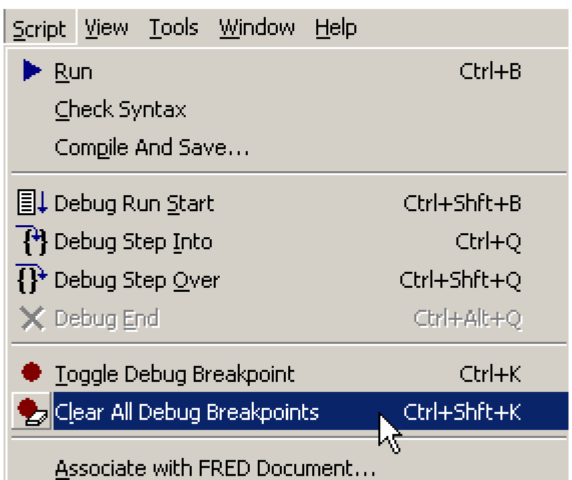
Use this command to remove all breakpoints in the current script.

How Do I Get There? - Clear All Breakpoints command

There are three ways to execute this command:

1. On the Script Toolbar, click this button: 

2. On the Script menu, choose "Clear All Debug Breakpoints".



3. Use the keyboard shortcut Ctrl+Shift+K.

Associate With FRED Document

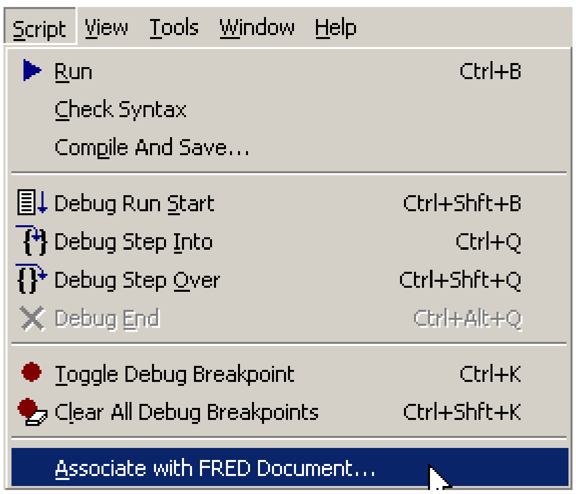
Description

How Do I Get There?

Description - Associate With Document

Associates a FRED script with an existing FRED document.

How Do I Get There? - Associate With Document



Output Window Cut

Description
How Do I Get There?

Description
Output Window: Cut

This command takes the current selection in the text output window and cuts it to the Windows clipboard. The selected area remains selected. If nothing is selected, nothing gets cut.

How Do I Get There?

Output Window: Cut

There are three ways to execute this command:

1. From the Output Window toolbar, press this button: 
2. Use the Ctrl+Shift+X keyboard shortcut.
3. From the edit menu, select "Output Window Cut".

Chapter 27 – Examples

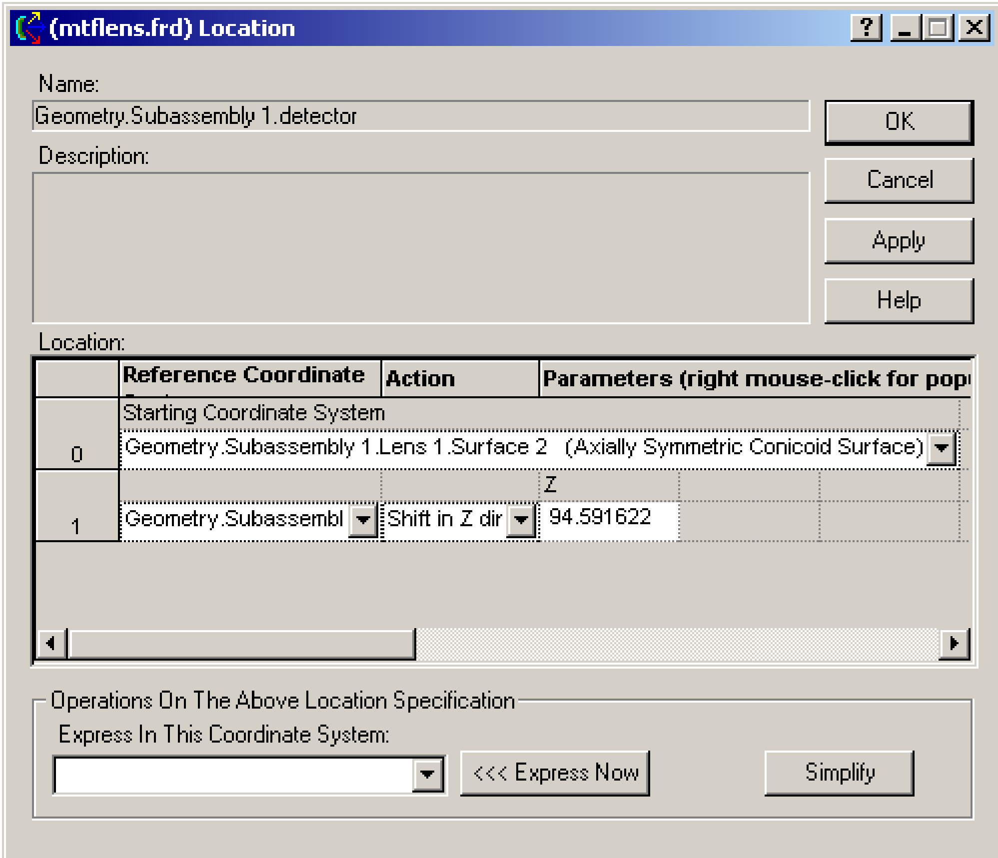
Example 1 - MTF Calculations in FRED

Description - MTF Calculations in FRED

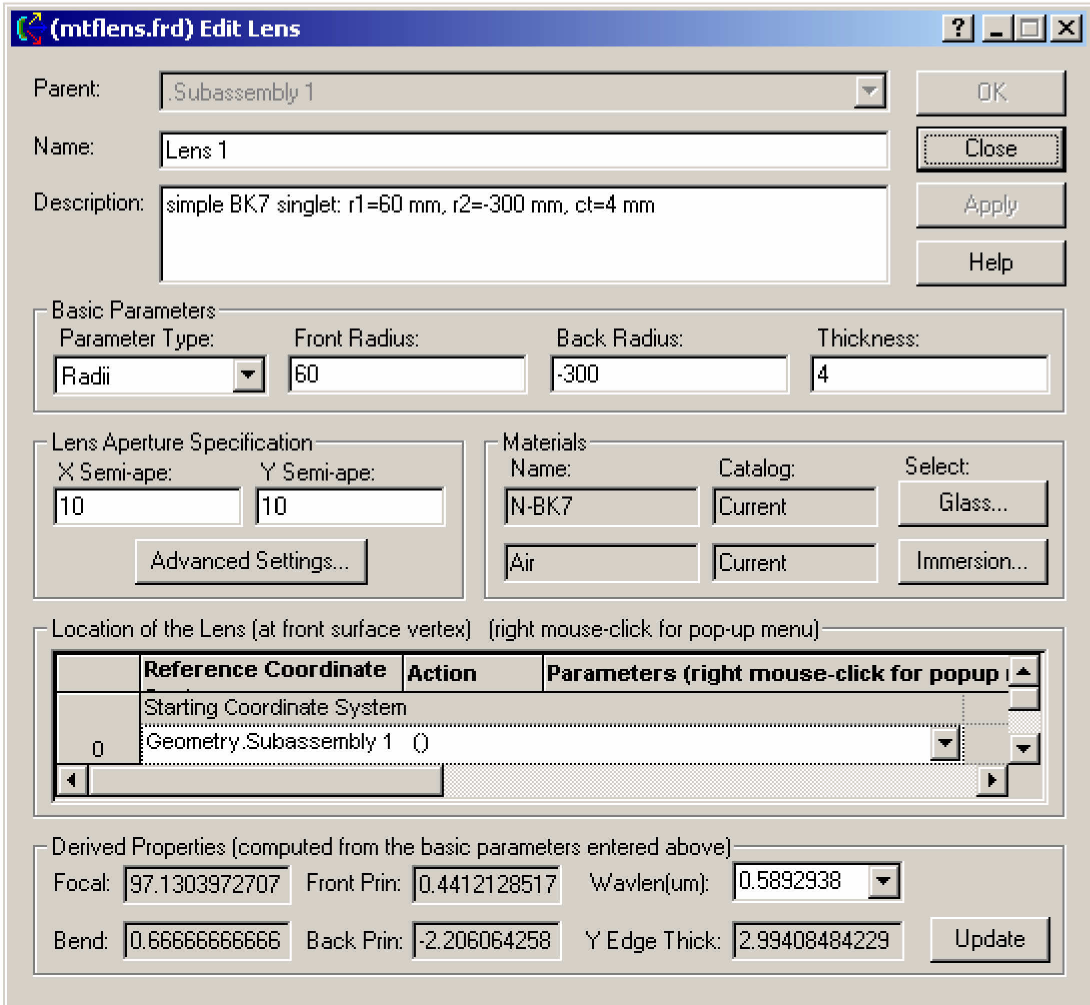
This help article describes how to perform a Modular Transformation Function in FRED.

Geometry & Sources - MTF Calculations in FRED

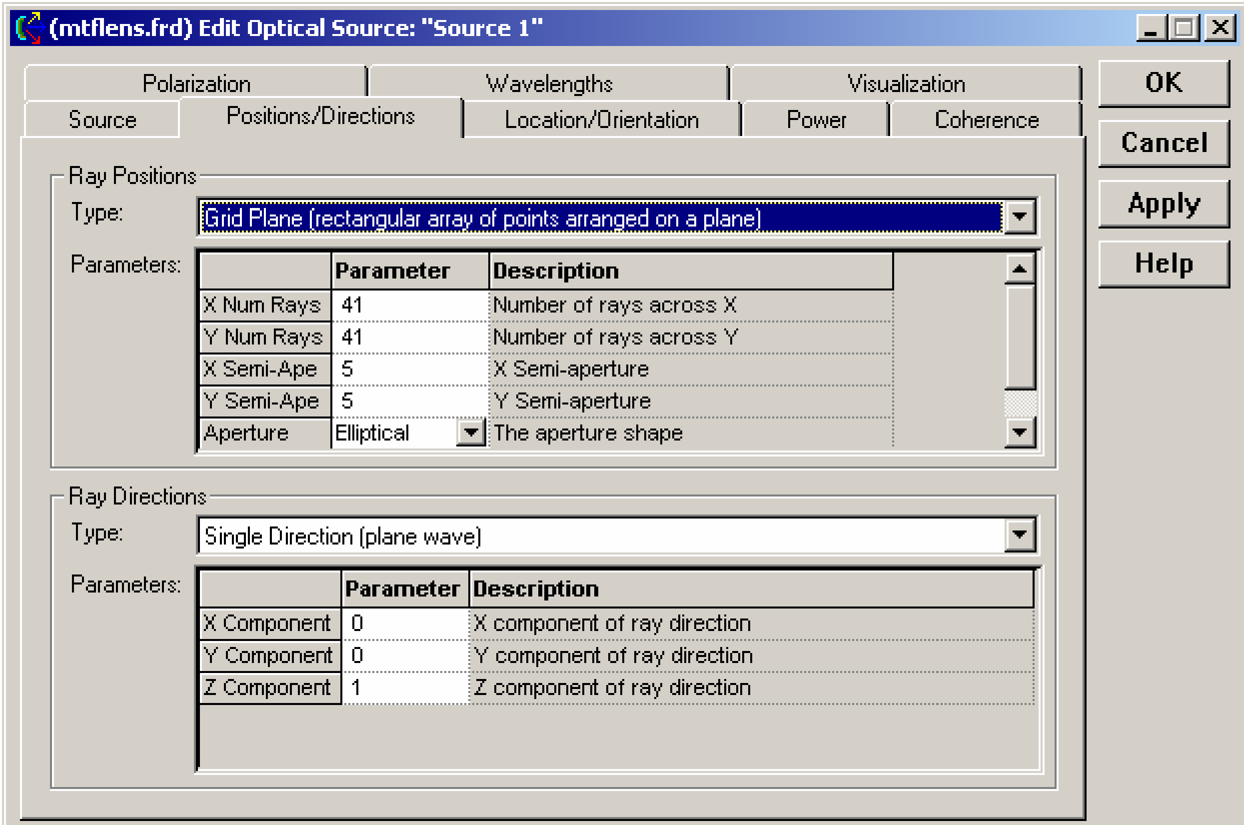
MTF Calculations can be performed on any system that has a coherent source. In this example, we use the file mtflens.frd, found in the Complete Systems Samples directory (C:\Program Files\Photon Engineering\FRED <version number>\Samples\Complete Systems, by default). It consists of a coherent source, a BK7 lens, and a focal plane. The lens is shifted in the Z direction by 1, while the focal plane is shifted in Z by 94.591622 units relative to surface 2 of the lens.



The detector location



The lens specification



The source position & direction

Setting up the Calculation - MTF Calculations in FRED

MTF Comparison 1- MTF Calculations in FRED

MTF Comparison 2 - MTF Calculations in FRED

Example 2 - Fluorescence in R6G

This example demonstrates the methodology of simulating fluorescence in FRED. Fluorescence is implemented through the wavelength attribute *g_w* associated with a scripted Scatter model. This attribute permits the wavelength of individual rays to be altered according to a user-programmed probability distribution. The ability to alter the wavelength assignment of individual rays is a key architectural feature of FRED. Indeed, the scripting language offers increased capability in wavelength manipulation. The power of FRED allows the user to carry out accurate color simulations for a wide range of physical phenomena; fluorescence being just one example.

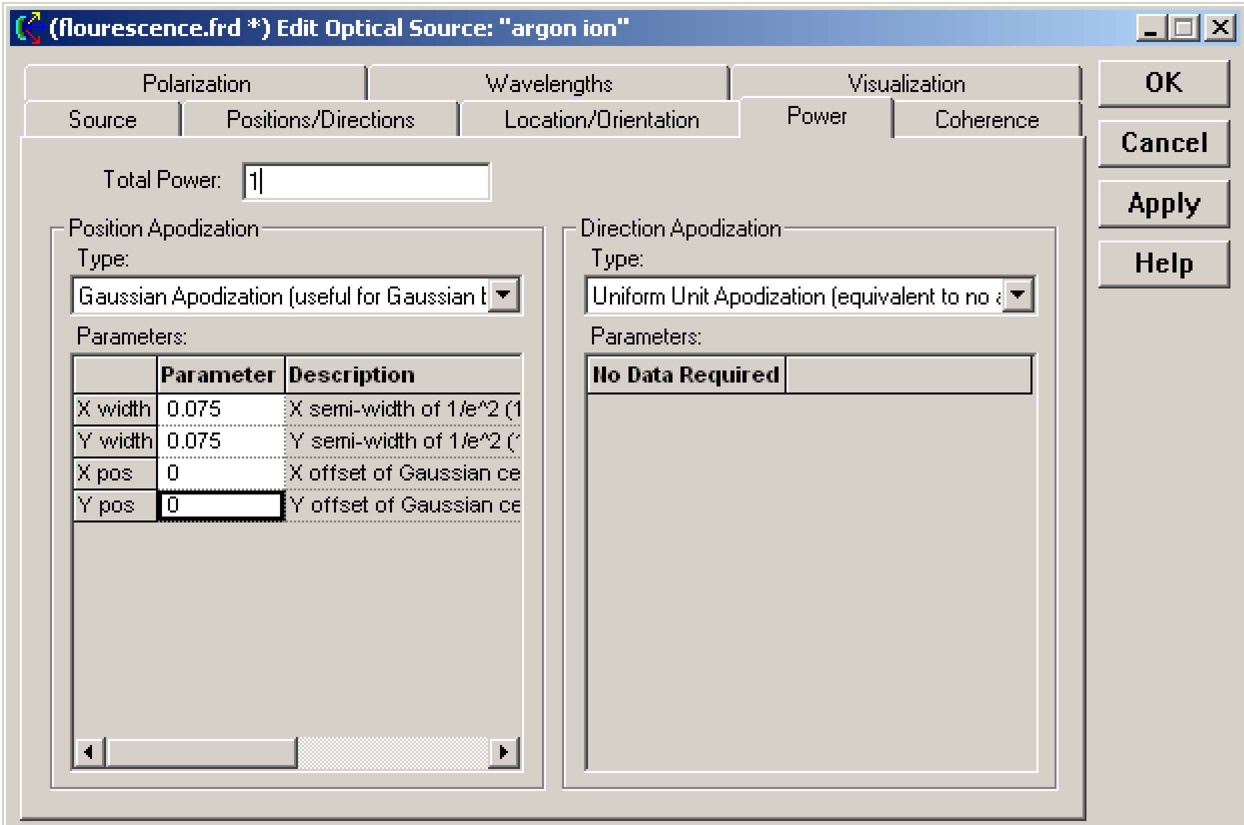
The example has four parts:

Setting Up the Problem

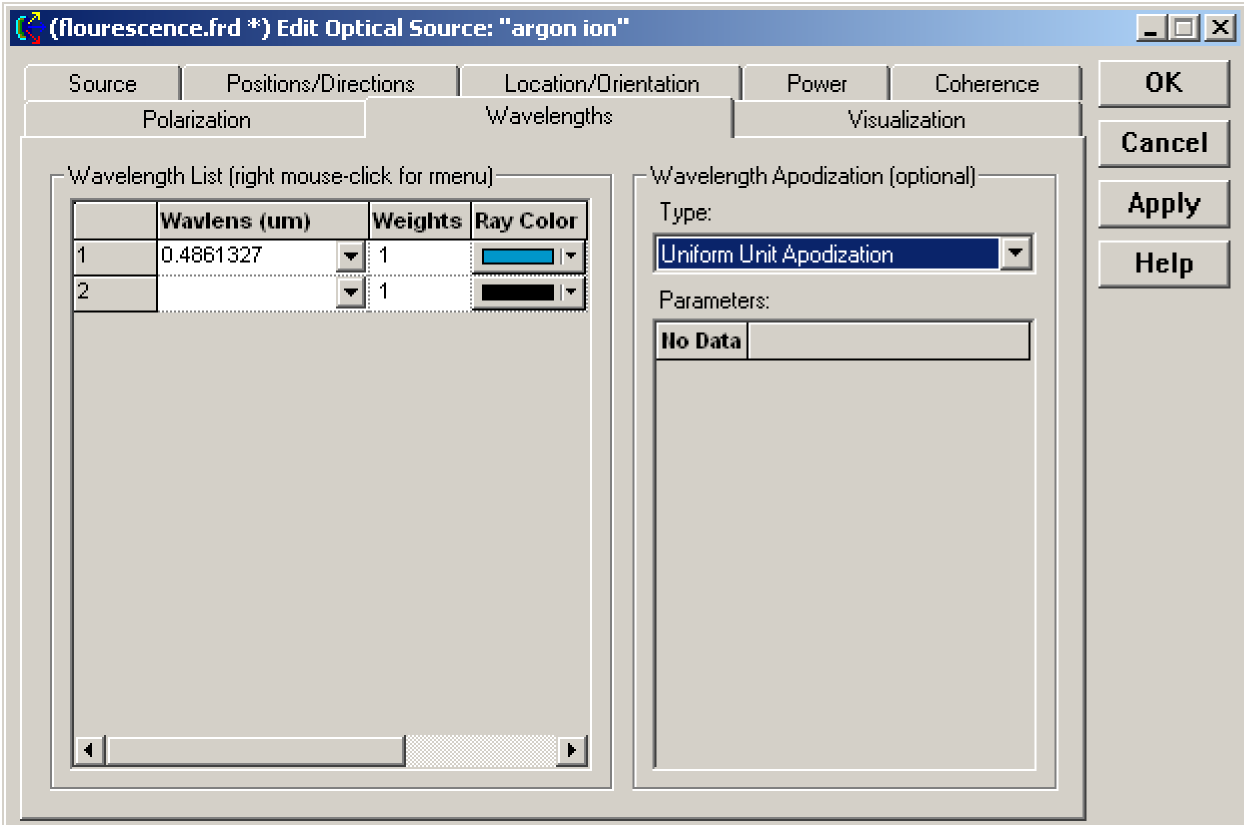
This simulation involves 0.486 μm light from an Ar^+ ion laser incident upon a host layer impregnated with Rhodamine 6G dye.

Add a Source

Let this source have a gaussian width of 0.075 mm,

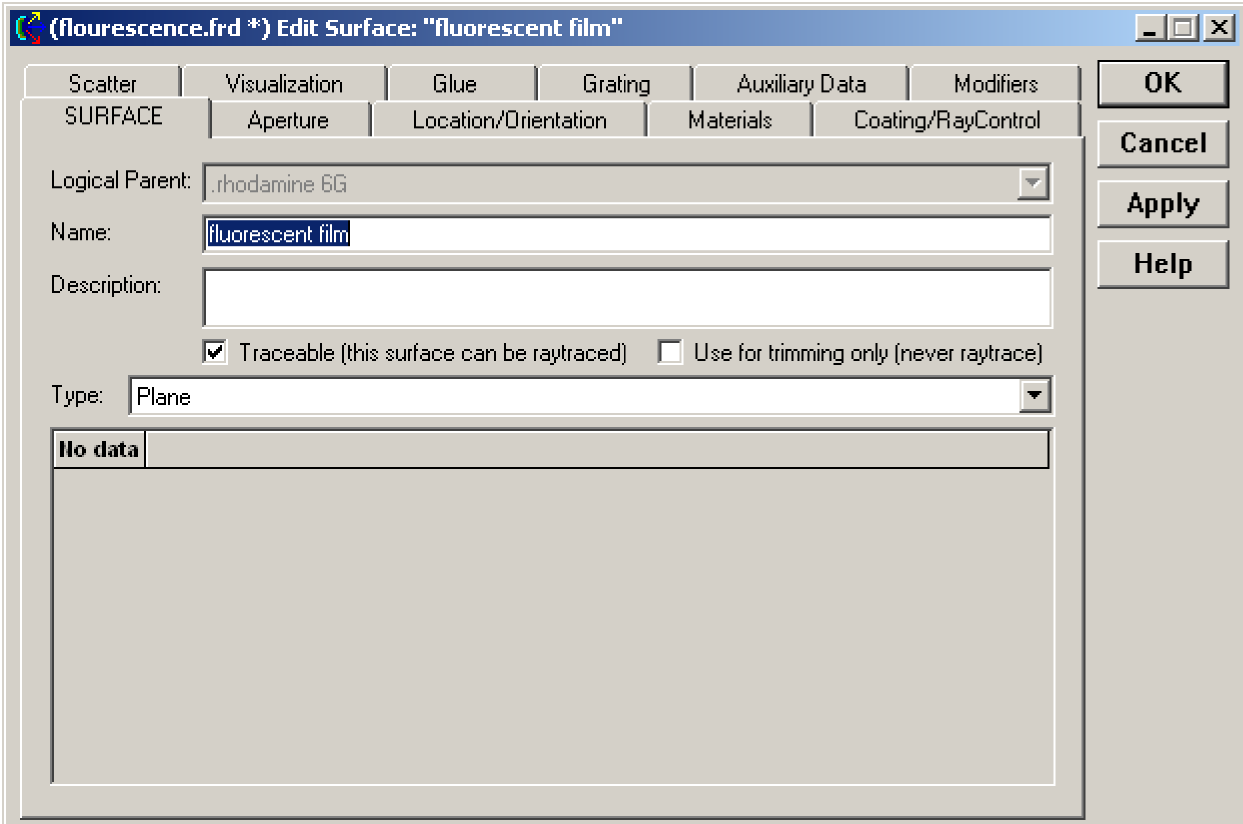


and a wavelength of 0.486 μm.

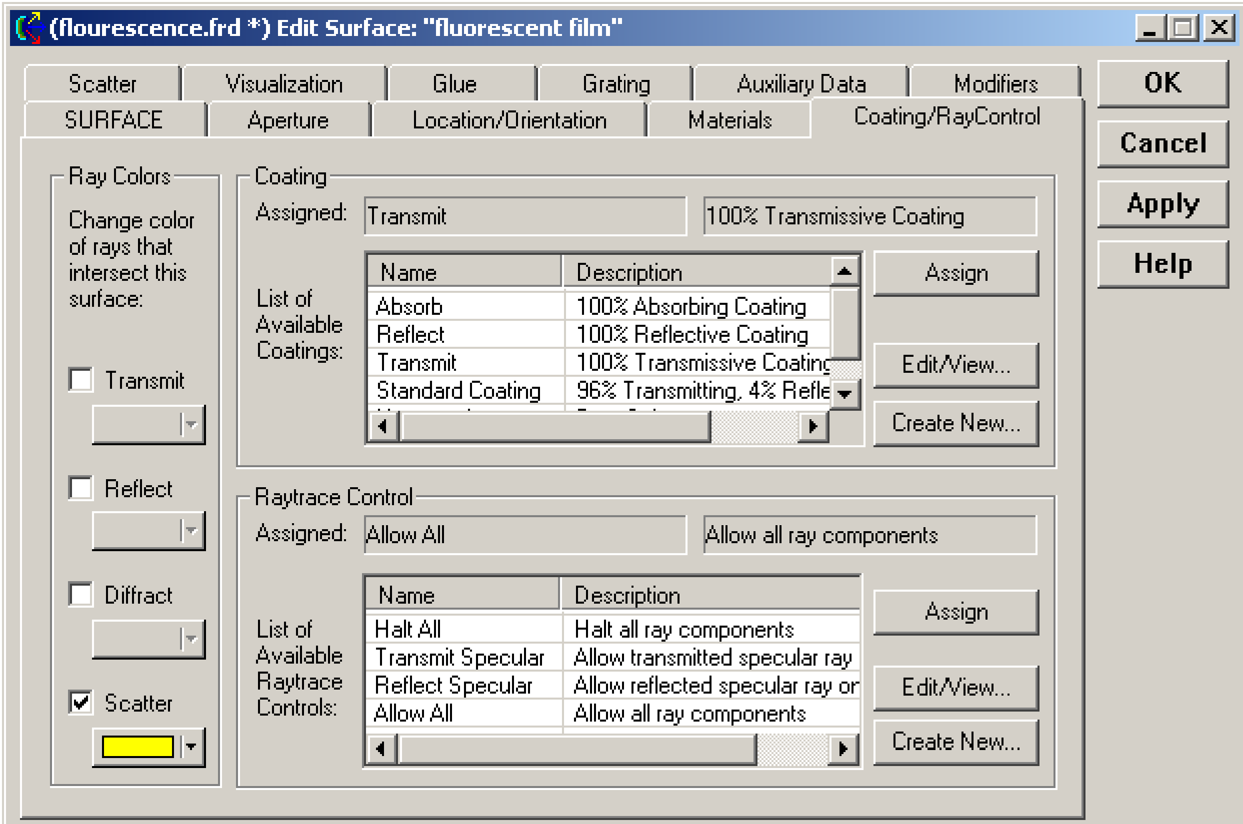


Add Geometry

Add now a plane surface to represent the film of Rhodamine 6G:

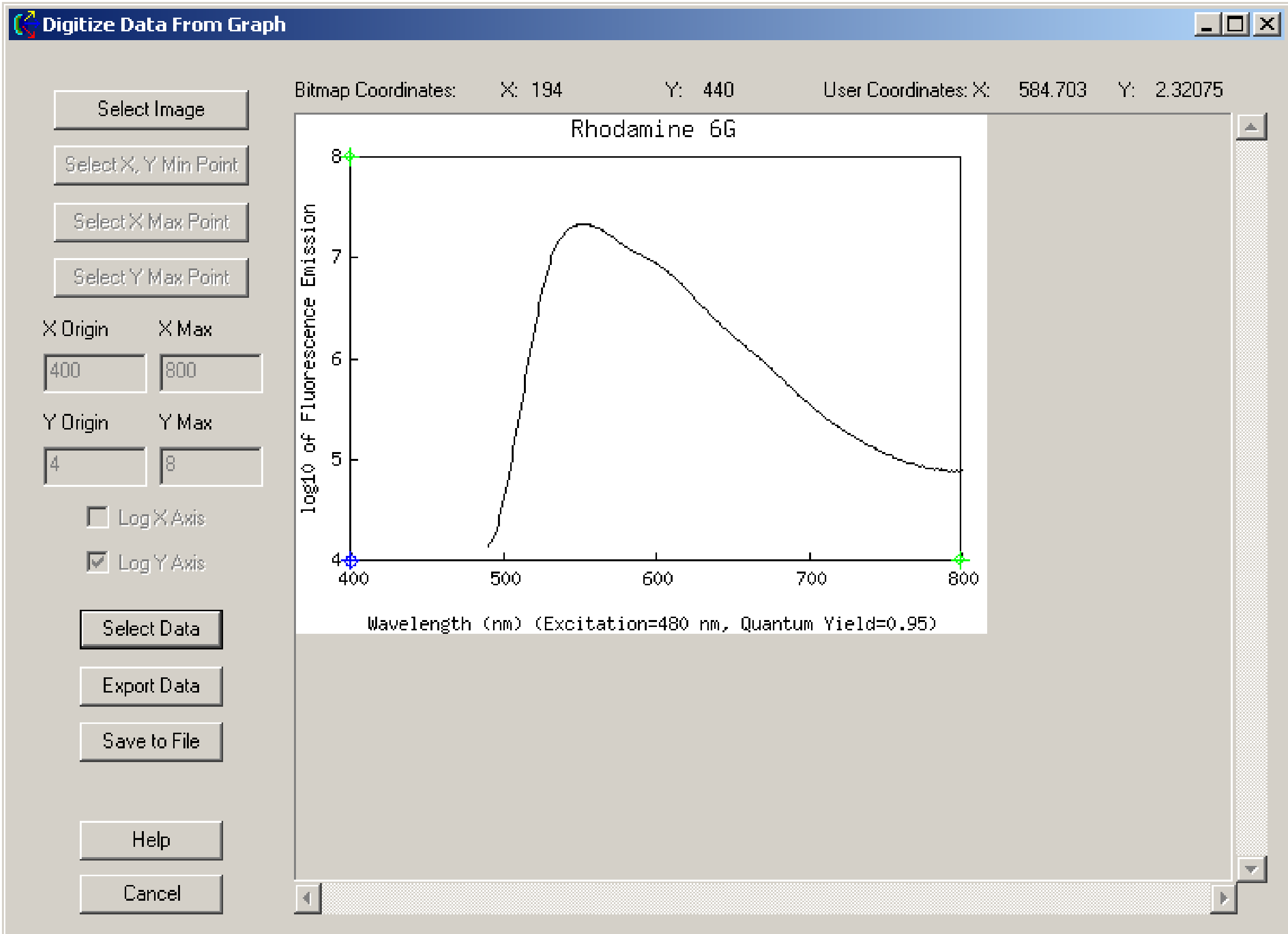


Set the Coating to "Transmit", the Raytrace Control to "Allow All", and make the scattered rays have a different color.

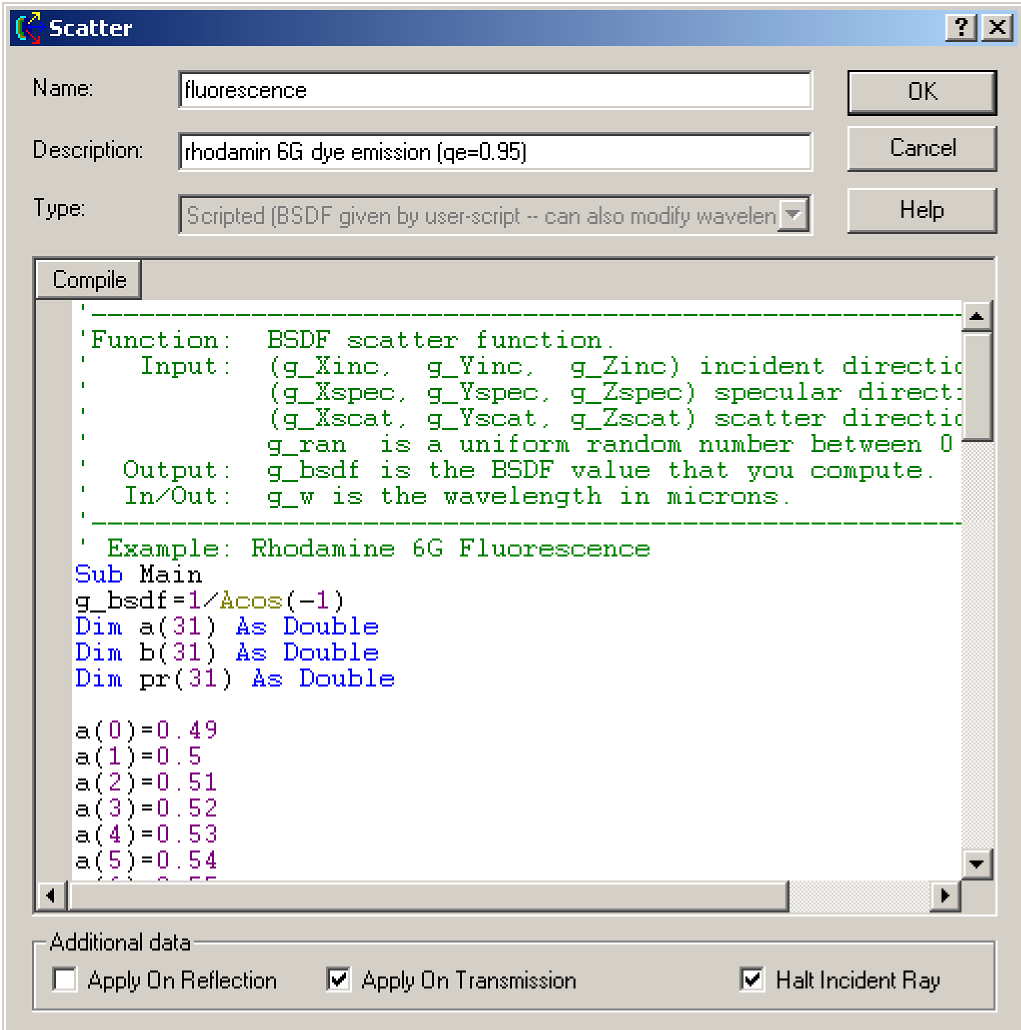


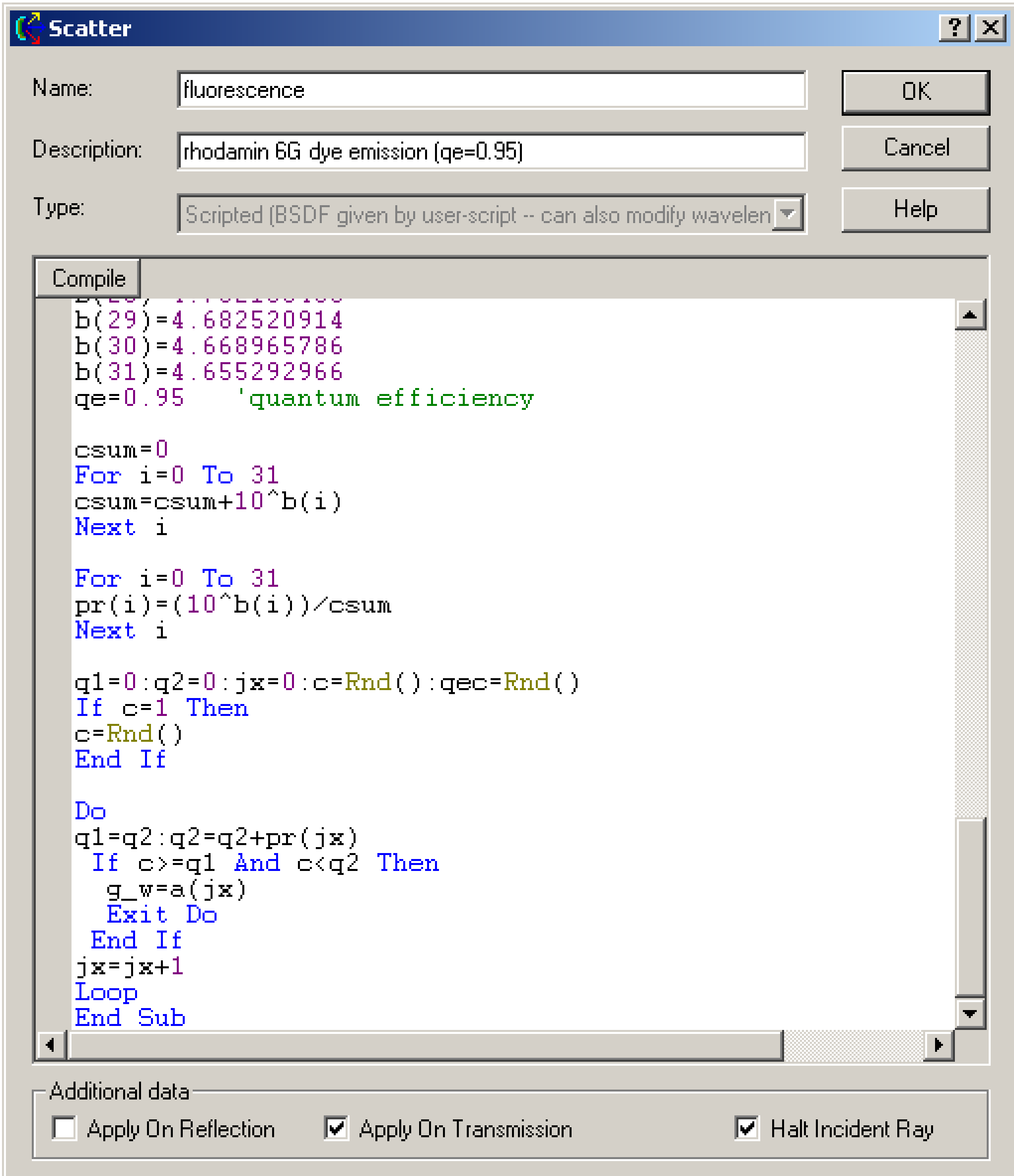
Add a Scatter Model

In order to complete the fluorescence surface definition, data for Rhodamine 6G must be inserted into a FRED scripted scatter model. FRED's Coating digitizer is convenient method of transforming graphic images into numerical data sets. Shown here is a bitmap image of the Rhodamine 6G emission spectra loaded into the digitizer.



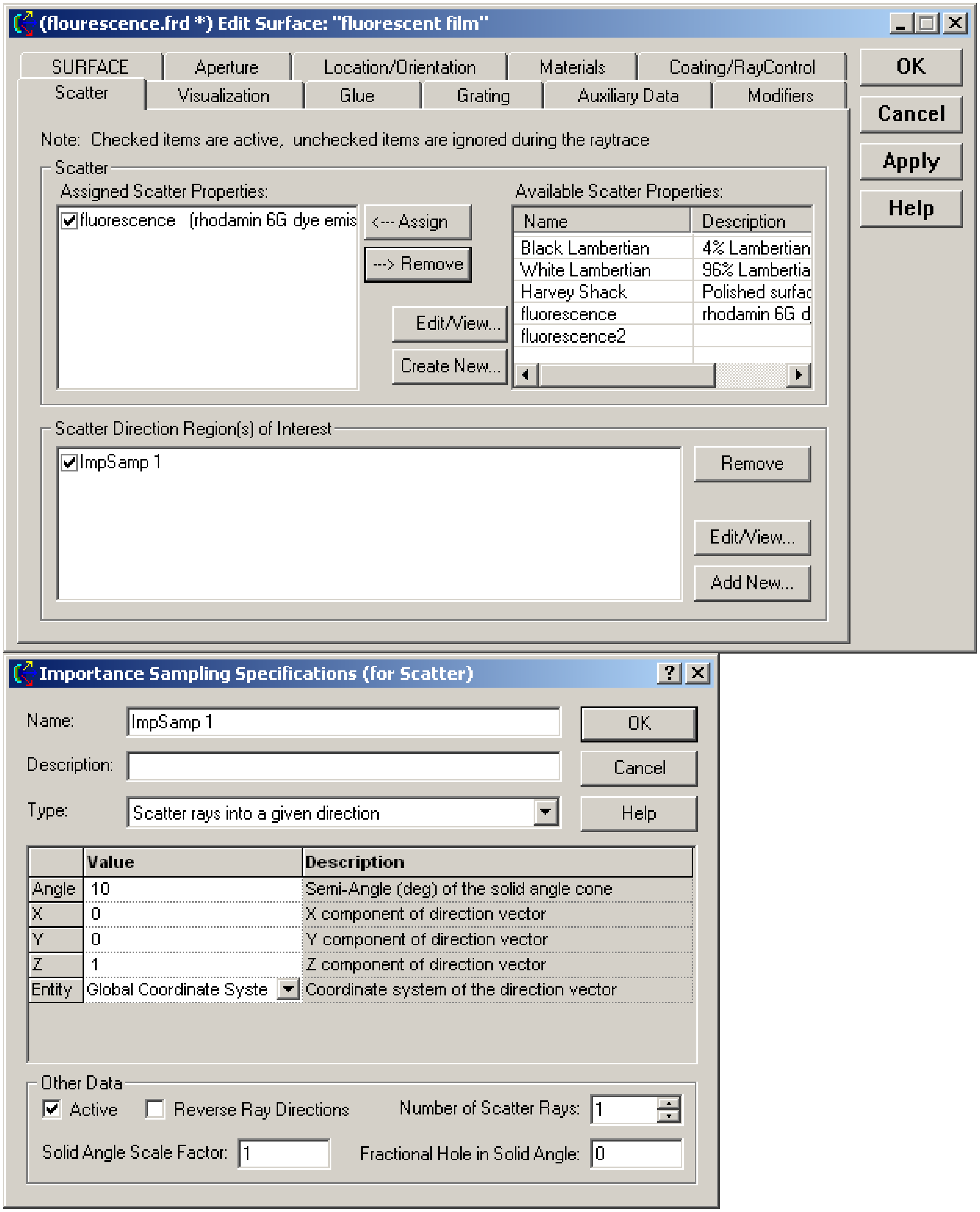
The data from the digitized file can then processed and included in a scripted Scatter model shown here in part:


Scatter
Name:
fluorescence
Description:
rhodamin 6G dye emission (qe=0.95)
Type:
Scripted (BSDF given by user-script -- can also modify wavelen
OK
Cancel
Help
Compile
'--
'Function: BSDF scatter function.
'   Input: (g_Xinc, g_Yinc, g_Zinc) incident directio
'   (g_Xspec, g_Yspec, g_Zspec) specular direct:
'   (g_Xscat, g_Yscat, g_Zscat) scatter directio
'   g_ran is a uniform random number between 0
'   Output: g_bsdf is the BSDF value that you compute.
'   In/Out: g_w is the wavelength in microns.
'--
' Example: Rhodamine 6G Fluorescence
Sub Main
g_bsdf=1/Acos(-1)
Dim a(31) As Double
Dim b(31) As Double
Dim pr(31) As Double
a(0)=0.49
a(1)=0.5
a(2)=0.51
a(3)=0.52
a(4)=0.53
a(5)=0.54
Additional data
Apply On Reflection
Apply On Transmission
Halt Incident Ray



Note: Even though scripted scatter models are compiled before execution, it is recommended that datasets included within them should be kept compact so as to have minimal impact on raytrace speed.

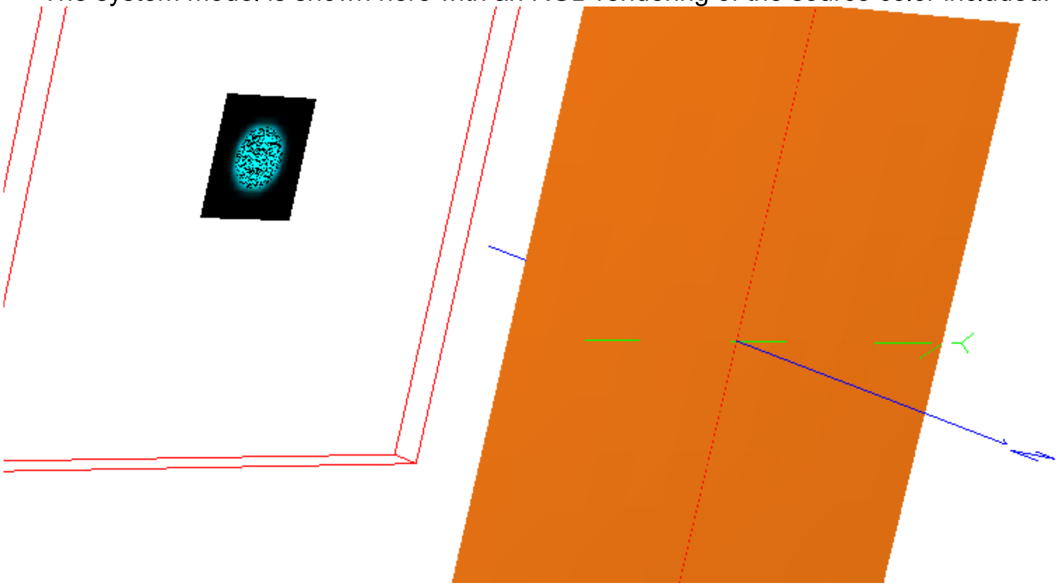
This scatter model is assigned to the film surface and scatter into a small angle around specular is chosen as the Scatter Direction:



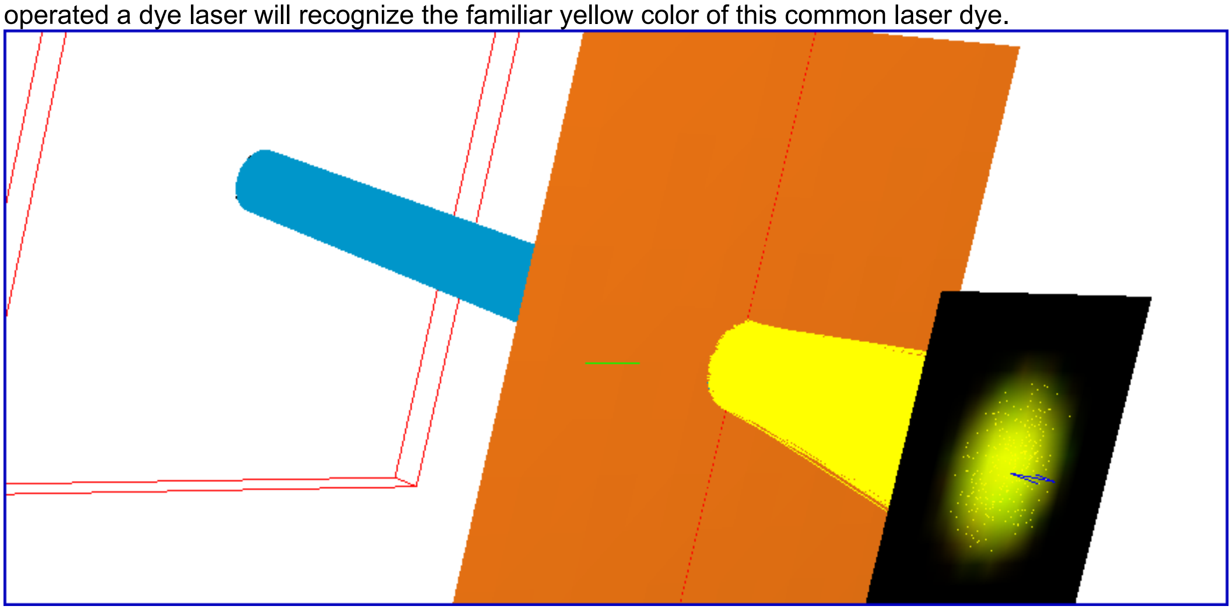
A detector surface is also created to catch the transmitted fluorescence and to accommodate an Analysis Surface.

Running the Simulation

The system model is shown here with an RGB rendering of the source color included:



The image below shows a Color Image calculation at the detector implemented with the *Show in Visualization View* feature of the Chart Viewer. This rendering is an RGB representation of the spectral content of fluorescence as described by the digitized data. Anyone who has operated a dye laser will recognize the familiar yellow color of this common laser dye.



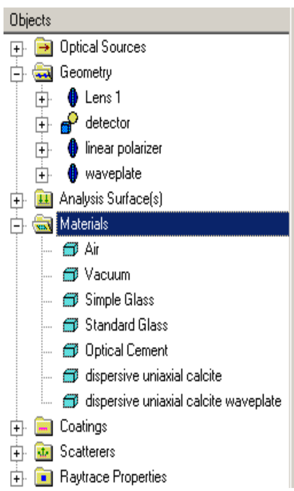
Example 3 - Color Separation by Polarization

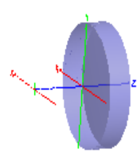
Description - Color Separation by Polarization

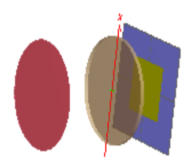
This example illustrates the spatial separation of color resulting from passage through birefringent optical elements. Polarized white light is incident upon a simple lens made from calcite, a uniaxial crystal. The converging bundle continues through a waveplate and a polarizing element and is captured on a screen. The Color Image feature in FRED is used to display the spatially distributed spectra.

Example - Color Separation by Polarization

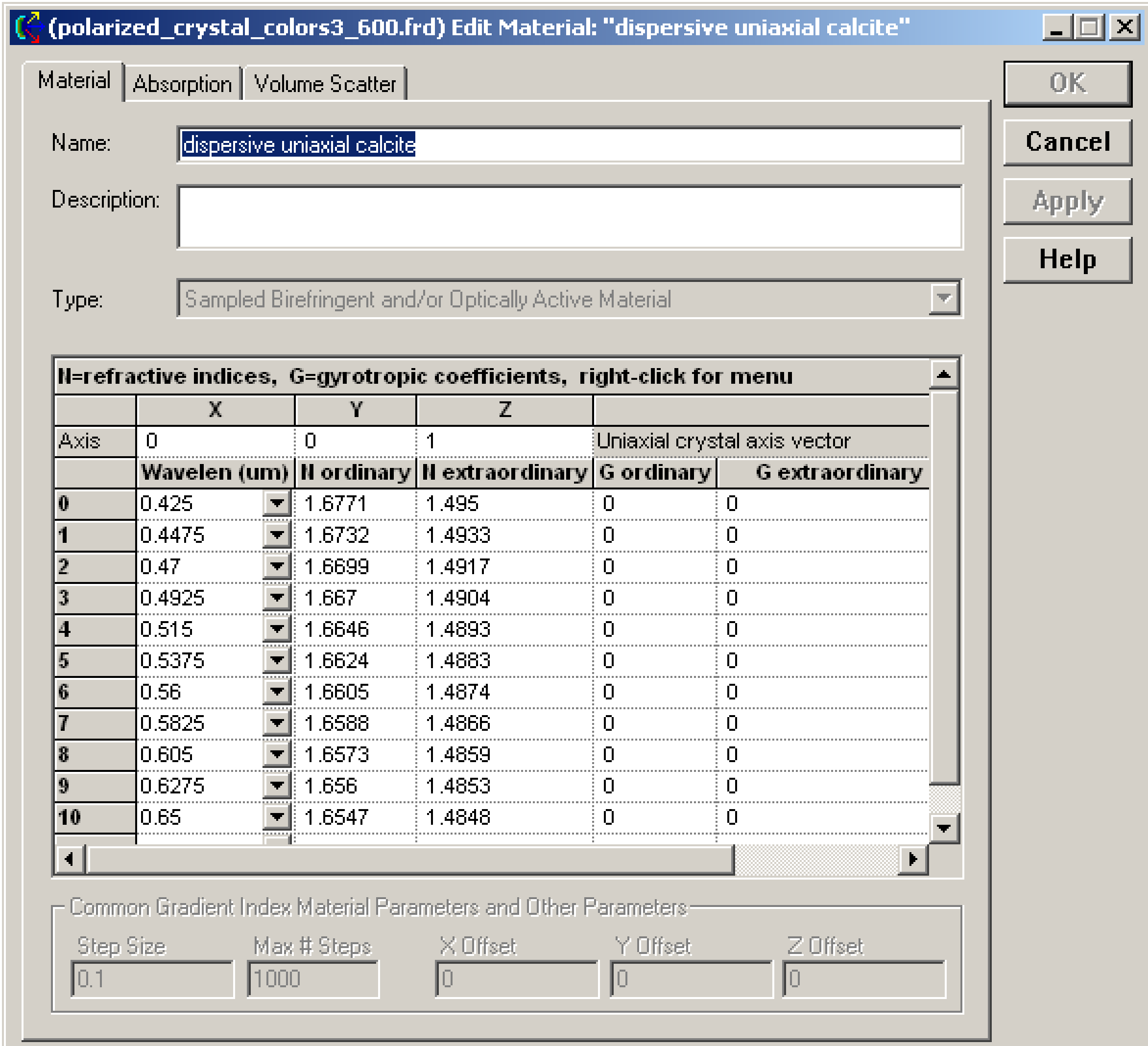
Start by setting up the geometry. Included here are a plano-convex calcite lens followed by a calcite waveplate, a linear polarizer and a collection plane.



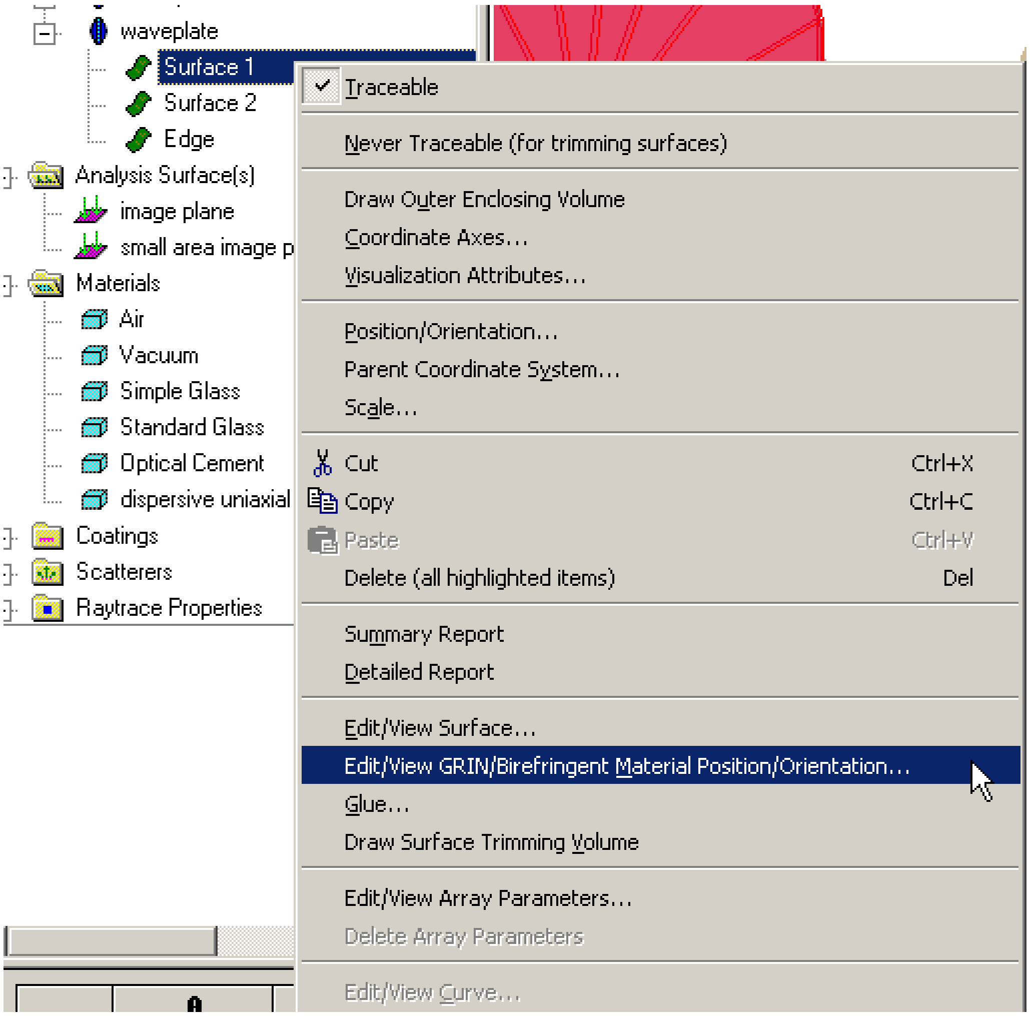


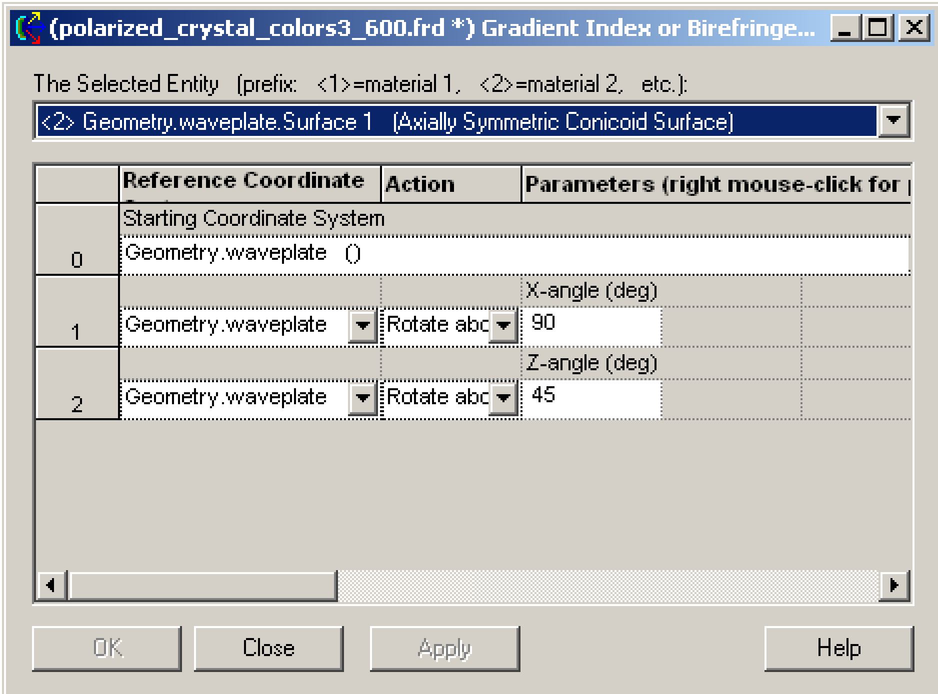


Even though there are two orientations of calcite in this model, only one calcite material need be created. The material orientation defined for the lens has its fast axis along global-z:

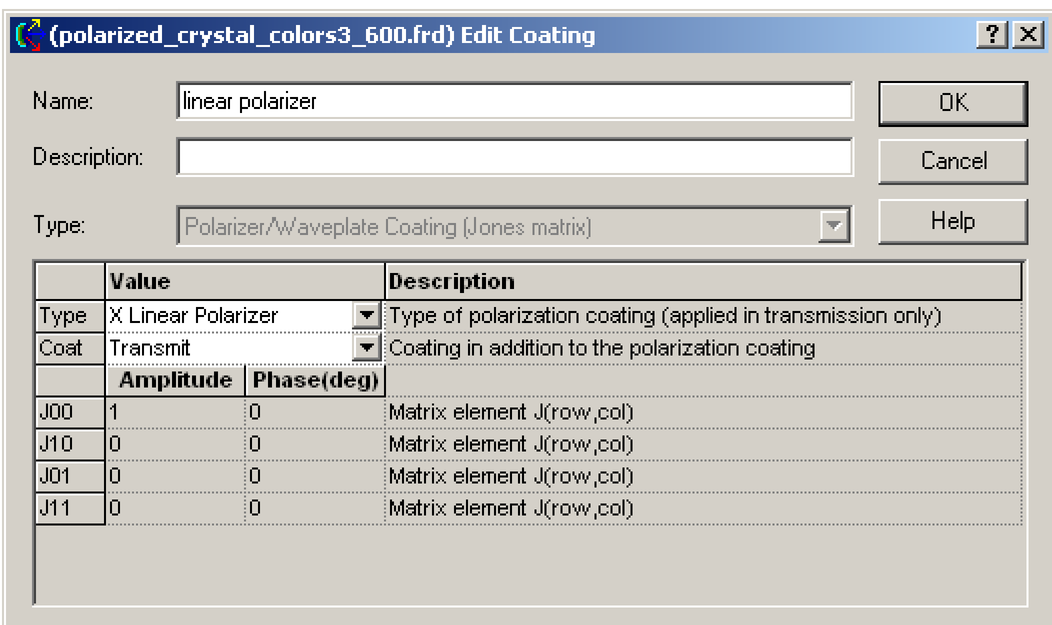


The calcite waveplate material is oriented with its fast axis bisecting the global +x & +y directions. The same birefringent material definition used for the lens can also be used for the waveplate by applying a coordinate transformation to the waveplate surfaces through the "Edit/View GRIN/Birefringent Position/Orientation" dialog:

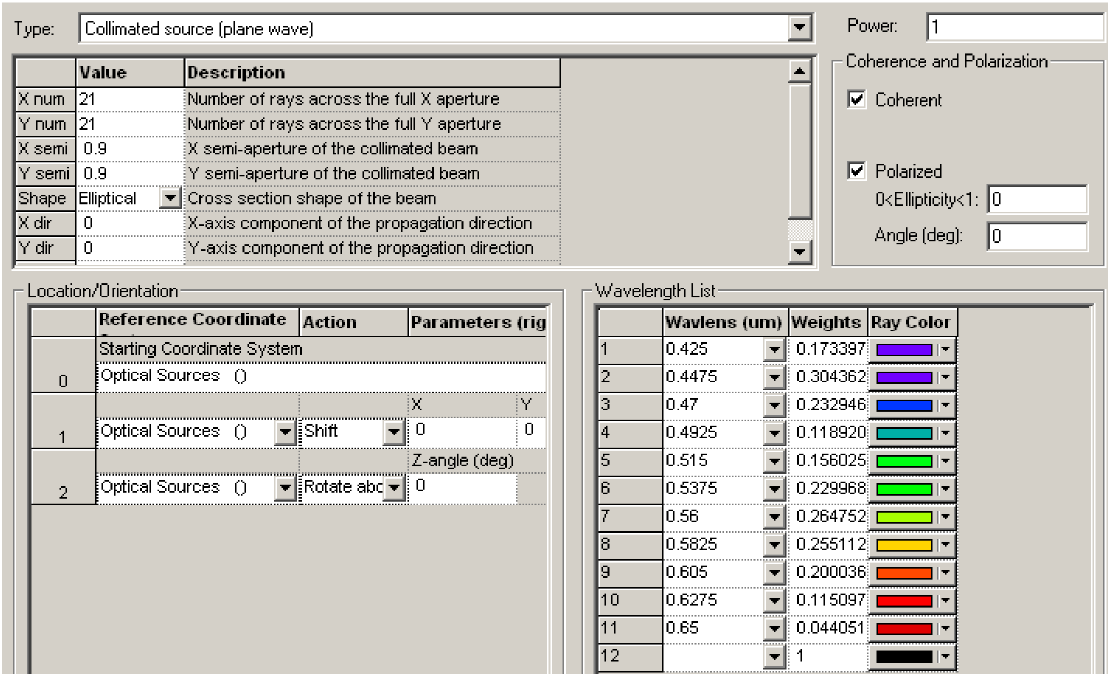

waveplate
Surface 1
Surface 2
Edge
Analysis Surface(s)
image plane
small area image p
Materials
Air
Vacuum
Simple Glass
Standard Glass
Optical Cement
dispersive uniaxial
Coatings
Scatterers
Raytrace Properties
Traceable
Never Traceable (for trimming surfaces)
Draw Outer Enclosing Volume
Coordinate Axes…
Visualization Attributes…
Position/Orientation…
Parent Coordinate System…
Scale…
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete (all highlighted items) Del
Summary Report
Detailed Report
Edit/View Surface…
Edit/View GRIN/Birefringent Material Position/Orientation…
Glue…
Draw Surface Trimming Volume
Edit/View Array Parameters…
Delete Array Parameters
Edit/View Curve…



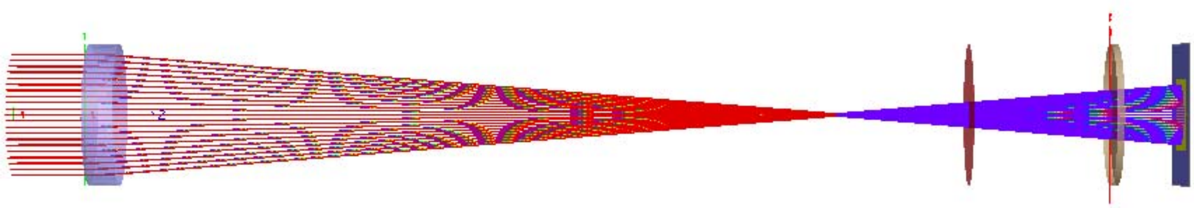
The polarizer has a coating that passes only light polarized along the global x-direction:



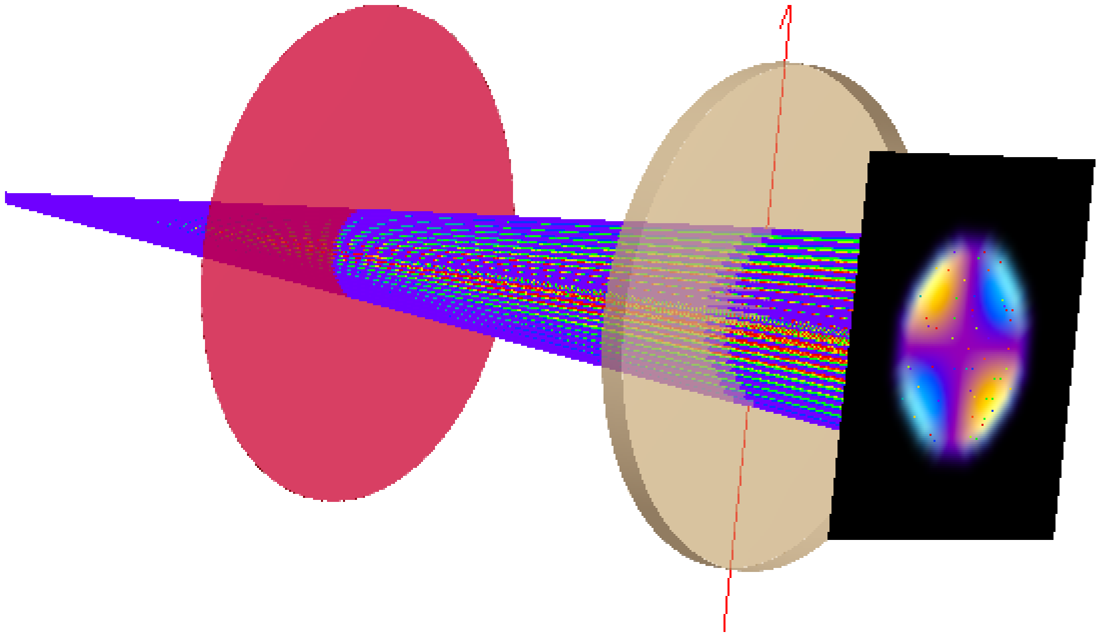
The source is a coherent, collimated bundle polarized along the global y-direction. The "Synthesize a Color" feature was used to create and weight a range of evenly spaced wavelengths simulating the color "white".



Upon tracing the source



and evaluating the rays on the detector using the Color Image feature, the image has the following appearance. This view is obtained by invoking the "Show in Visualization View.." option in the Chart Viewer and setting the detector Visualization Attribute *Opacity* to "Invisible".



Example 4 - Scripting With Libraries

Description

Scripting With Libraries

FRED's script language is the key to effecting specialized, repetitive or complex tasks. This example contains scripts that address two often requested features; the cumulative spot diagram and an efficient method of executing large raytraces. These tasks are implemented here in the compact and efficient form of Basic libraries.

Cumulative Spot Diagram

Scripting With Libraries

Spot diagrams, irradiance and intensity calculations require an Analysis Surface. Ray Filter Specifications are applied to an Analysis Surface to restrict which rays are used in the calculation, the default being AND All Rays. While there are nearly fifty Ray Filter Specifications (see Analysis Surface Ray Selection), none of these allow for inclusion of rays that intersect a given surface at one or more points along its path but terminate on some other surface. FRED does offer a solution to this dilemma by allowing the user to create temporary buffers that store information as the rays step through the system. When the raytrace finishes, these temporary buffers can be swapped into and out of the main buffer for calculation purposes. Please note that, in FRED, only rays in the main buffer can be analyzed.

Executing a cumulative spot diagram in FRED requires the following steps: 1) create a temporary buffer for storage; 2) run an Advanced Raytrace stepping the rays incrementally through the system. At each increment, the rays are polled based upon the object they are currently on. Rays on the target surface are stored in the buffer; 3) Upon completion, rays in the temporary buffer are copied to the main buffer and the temporary buffer is deleted. The subroutine SurfAccum has two arguments; cn, the number of single steps needed to finish the raytrace and surfid, the node number of the target surface. This routine should not be used with a totally absorbing surface. It is also recommended that your entire system be enclosed in an absorbing sphere to insure that rays are not overcounted.

```
Sub SurfAccum (surfid As Long, anode As Long, drawray As Boolean )

Dim rtemp&
Dim success As Boolean
Dim adv As T_ADVANCEDRAYTRACE
Dim fop As T_OPERATION
Dim tf As T_RAYFILTEROP
InitAdvancedRaytrace adv 'initalize the Advanced Raytrace with default settings

rtemp = AddRayBuffer () 'add a temporary buffer
```

```
adv.hitcount=1 'step one intersection at a time
adv.traceactivesources=True 'create new rays the first time
adv.draw=drawray

'set coordinate system of Analysis surface to snode
GetOperation anode, 0, fop
fop.parent=surfid
SetOperation anode, 0, fop

'set Analysis surface Ray filter spec
success = GetAnalysisSurfIthOp (anode, 0, tf)
tf.opCode=3:tf.text=GetFullName(surfid)
SetAnalysisSurfIthOp anode, 0, tf

count=1 'default count value
stepcount=0 'zero step counter

While count<>0 'loop until there are no more rays to trace

count=AdvancedRaytrace(adv) 'advance rays one intersection
stepcount=stepcount+1 'number of intersections traced

'loop over all rays. if ray is on the target surface, store ray in the temporary buffer
If count<>0 Then
For j=0 To GetRayCount()-1
If GetRayEntity(j)=surfid Then
CopyRayBufferToBuffer j,0,rtemp
End If
Next j
End If

adv.traceactivesources=False 'set to Trace Existing for remainder of process

Wend

DeleteRays 'empty main buffer before transfer

'move rays from temporary buffer to main buffer for analysis
For j=0 To GetRayBufferRayCount(rtemp)-1
CopyRayBufferToBuffer j,rtemp,0
Next j

'delete temporary buffer after use (frees RAM)
DeleteRayBuffer rtemp
```

```
Print stepcount, "steps taken. Rays intersecting ", GetName(surfid), " have been transferred to the main buffer for analysis"

End Sub
```

> **Warning**: Ray buffers use RAM. Delete them after use. Otherwise, memory will not be relinquished until the FRED document is closed.

As an alternative to including blocks of code in a working script, save them to a library and gain easy access as if the subroutine were a new FRED command. Follow these steps to create a FRED library:

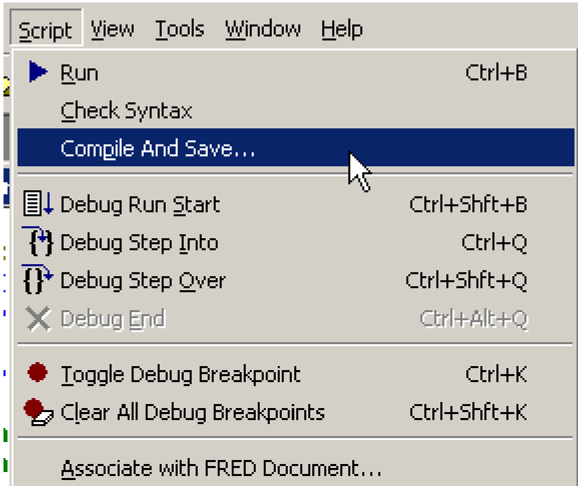
1) Copy the subroutine lines of code to the clipboard and paste them into a new FRED script.

Save this script as an .frs file to allow for future editing. The .frl libraries CANNOT be edited directly.

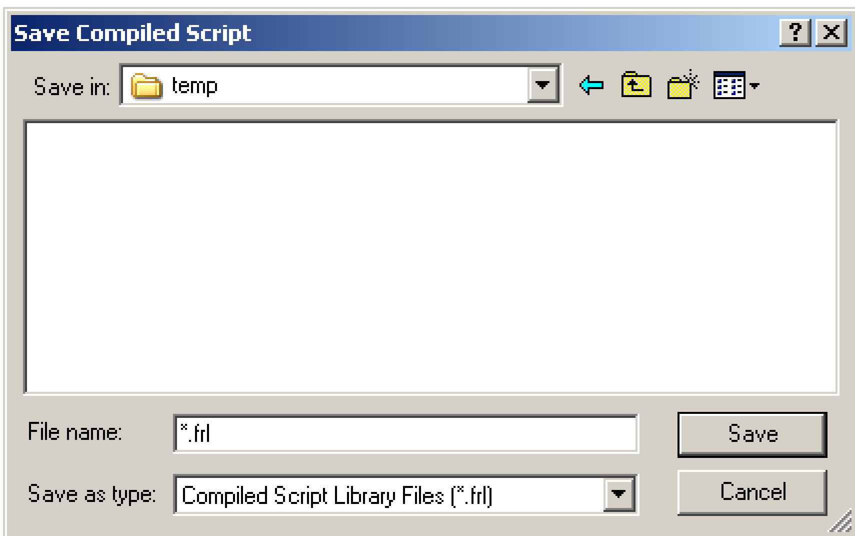
Script1

```
 If GetRayEntity(j)=surfid Then
 CopyRayBufferToBuffer j,0,rtemp
 End If
Next j

Next i

'move rays from temporary buffer to main buffer so they can be analyzed
'main buffer rays are lost (unless you make another buffer to temporarily store them ir
For j=0 To GetRayBufferRayCount(rtemp)-1
 CopyRayBufferToBuffer j,rtemp,0
Next j

'delete temporary buffer after use (if not done, this can eat up RAM)
 DeleteRayBuffer rtemp

Print "Done. Rays that intersected node ", surfid, " have been transferred to the main

End Sub
```

2) From the Script menu, select Compile and Save..



3) Save the file as a Compiled Fred Library (*.frl)



To use the subroutines or functions stored in a library, declare a Basic object name and call the library with the FRED command GetLib. For example, to use the SurfAccum subroutine from a library named mytoolkit.frl,

```
Dim mylib As Object
Set mylib = GetLib ("C:\Documents and Settings\My Documents\FRED files\mytoolkit.frl")

mylib.SurfAccum 20, 62, True
```

Large Raytrace
Scripting With Libraries

Since rays take up space in memory, tracing a large number of rays can be made more efficient by breaking up the task into many smaller traces. In the case when incoherent irradiance or intensity is needed for a large collection of rays, the calculation can be done incrementally and displayed at the end. The following subroutine traces a defined source numloop times accumulating the irradiance at the Analysis Surface with node number anode attached to the surface with node number snode.

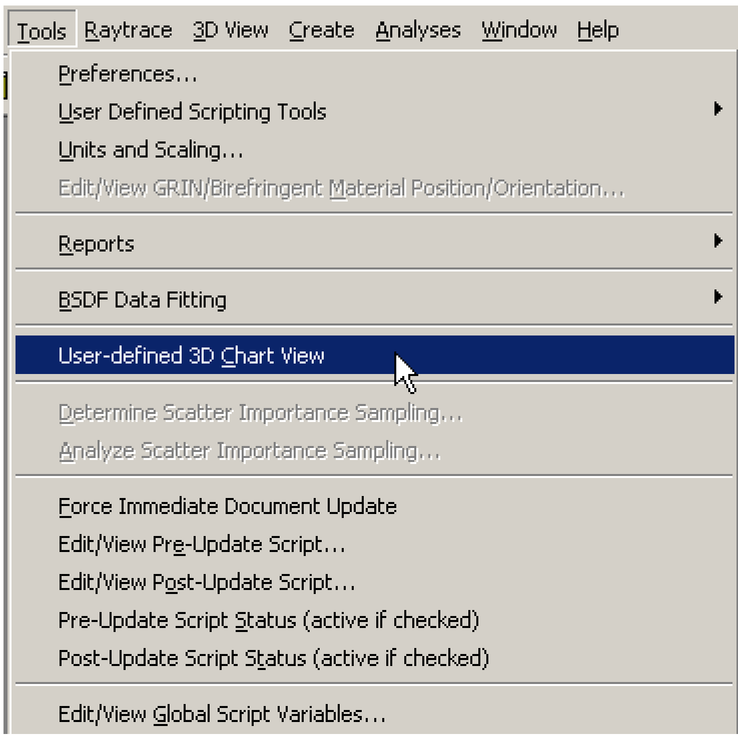
```
Sub largetraceirrad (snode As Long, anode As Long, numloop As Integer, fname As
String)

Dim filename$, rcount&, icount&, xdim&, ydim&, parent&, pwr#, xlim&, ylim&, ck&
Dim ana As T_ANALYSIS
Dim ent As T_ENTITY
Dim temp() As Double
Dim irrad() As Double

'load data from the Analysis Surface and transform to local coordinates of measurement
surface
LoadAnalysis anode, ana
TransformPosition -1, snode, ana.posX, ana.posY, ana.posZ
TransformDirection -1, snode, ana.AcellX, ana.AcellY, ana.AcellZ
TransformDirection -1, snode, ana.BcellX, ana.BcellY, ana.BcellZ
'number of pixels in x & y
xlim=ana.Amax-ana.Amin
ylim=ana.Bmax-ana.Bmin

'scale source power based upon number of loops
For l=0 To GetEntityCount()-1
If IsSource(l)=True Then
pwr=GetSourcePower(l)
pwr=pwr/numloop
SetSourcePower l, pwr
End If
Next l

t1=Time 'note start time

rcount=0 'zero counter

'loop over rays defined in Source Folder
For i=1 To numloop
Print "running trace ",i

TraceCreate 'trace with no render to use all available processors
```

```
'put additional Ray Specification Filters here
'*******************************************
'For s=0 To GetRayCount()-1
' If xxxxxx Then
' SetRayActive s,True
' Else
' SetRayActive s,False
' End If
'Next s
'*******************************************

'calculate irradiance
If i=1 Then
icount = Irradiance (snode, snode, ana, irrad() ) 'note: irradiance calculated in local
coordinates of snode
Else
icount = Irradiance (snode, snode, ana, temp() )
rcount=rcount+icount 'running count of rays used in irradiance calculation

'accumulate irradiance values in irrad()
For j=0 To xlim-1
For k= 0 To ylim-1
irrad(j,k)=irrad(j,k)+temp(j,k)
Next k
Next j

End If

Next i

DeleteRays 'delete rays upon completion to free up RAM

'write out irradiance calculation to PlotFile un user Current Directory
fileName = CurDir & "\" & fname & ".dat"
WriteToPlotFile fileName, ana, irrad()

t2=Time 'ending time

'Print begining And ending times
Print "end time ", t2
Print "start time ", t1
Print rcount & " rays combined"

End Sub
```

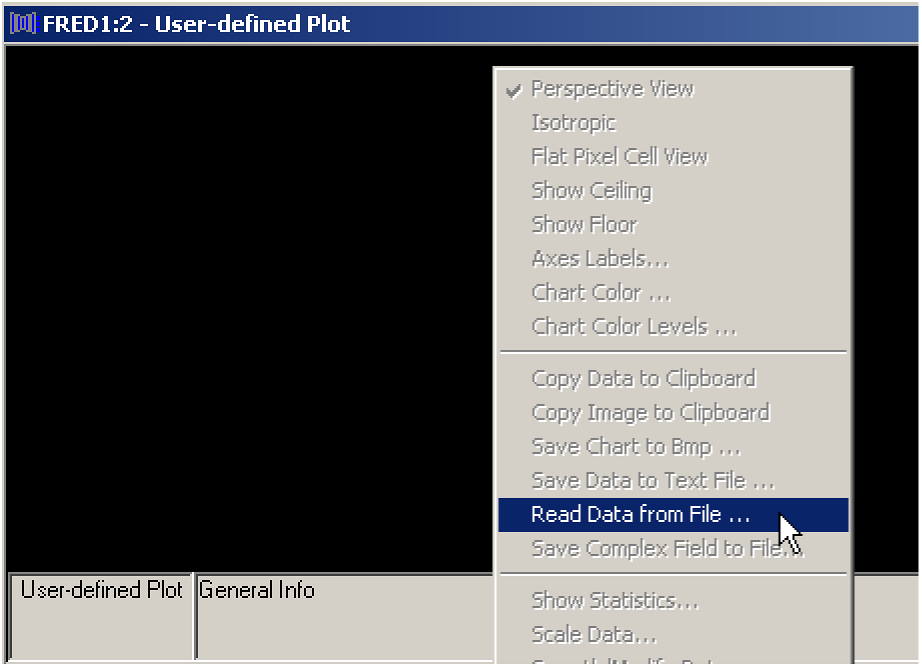
Add these lines to the library and recompile the library as shown above. The subroutine largetraceirrad is implemented in script as follows:

```
Dim mylib As Object
Set mylib = GetLib ("C:\Documents and Settings\My Documents\FRED files\mytoolkit.frl")

mylib.largetraceirrad 17,18,3,"myirradiance"
```

To view the irradiance data in the Chart Viewer, set focus to the FRED document and select User-defined 3D Chart View from the Tools menu



Right-click in the Chart and load the *.dat file saved by the subroutine:



See Also....
Scripting With Libraries

Chapter 28 – Troubleshooting Driver and Graphic Board Problems

3D View, OpenGL, and Video Board Driver Problems

OpenGL is a software interface to the graphics hardware (video board) that provides a 3D graphics and modeling library that is very fast and portable. Each video board manufacturer supplies its own drivers which implement the software interface. In most cases the drivers work quite well. However, in some cases the OpenGL driver has one or more bugs that can cause unusual behavior in the 3D rendering view of the optical model. A defect in the driver can even cause FRED to hang or crash, even though FRED adheres strictly to the OpenGL standard. Fortunately, there are several ways to deal with a video board and/or OpenGL driver that has problems.

Solutions - 3D View, OpenGL, and Video Board Driver Problems

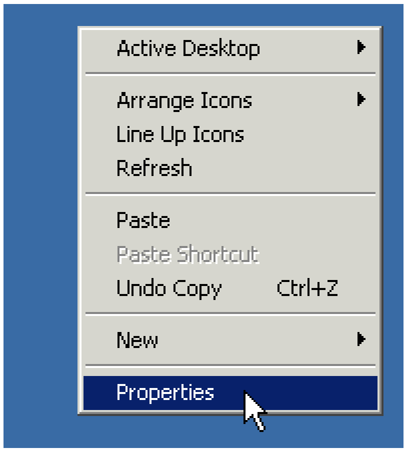
There are currently four possible solutions to a problem caused by a defective OpenGL driver.
Adjust the video board settings via the advanced options on the settings page of the display properties.
Adjust the OpenGL pixel-rendering mode in the FRED preferences. Move the option from Fast to Safe.
Download and install the latest video board drivers for the video board from the video board or computer manufacturer.
Install a new video board.

The first two options are quick fixes that will allow you to immediately get back to work. However, they may slightly adversely affect the speed and performance of the 3D rendering. The third and forth options are preferred and should be considered if the first two options result in slower 3D View operation.

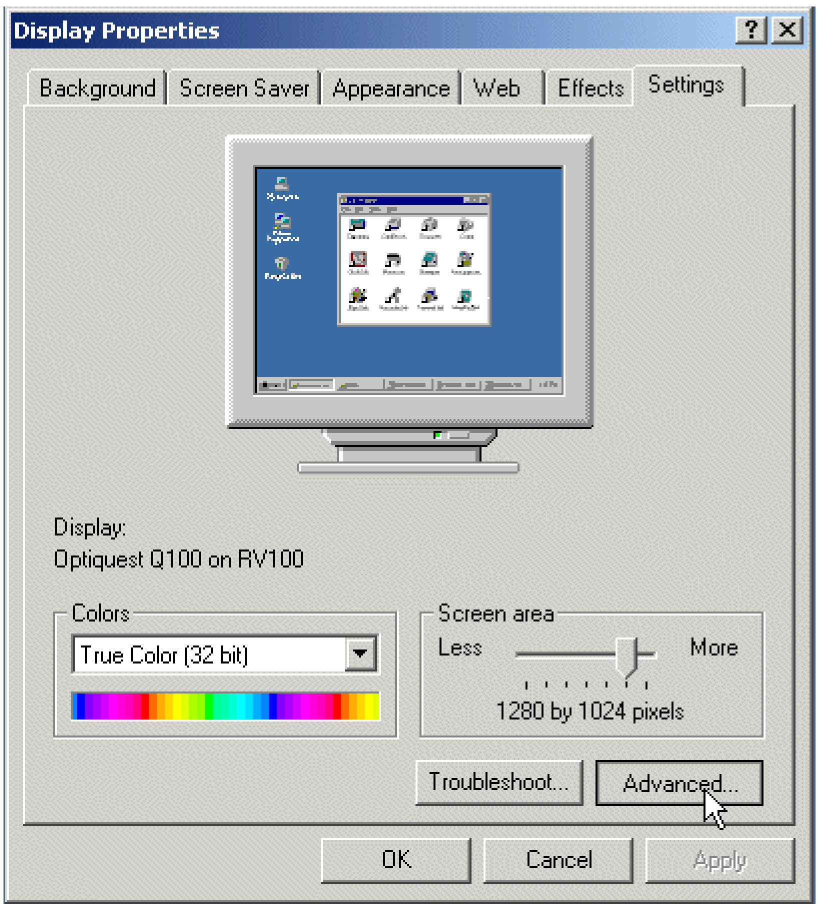
Adjust the Video Board Settings

With this option you will make a simple adjustment to the Windows operating system. The adjustment will cause the operating system to use the video board in a safer, software-only video mode instead of the most aggressive hardware accelerated mode. Because the adjustment occurs at the operation system level, it will affect all applications that run on your computer. Most users will not notice a difference in performance of their applications, but some high performance applications may have reduced rendering speed. If this results in undesirable behavior in some applications, then we suggest you try the second option discussed below.

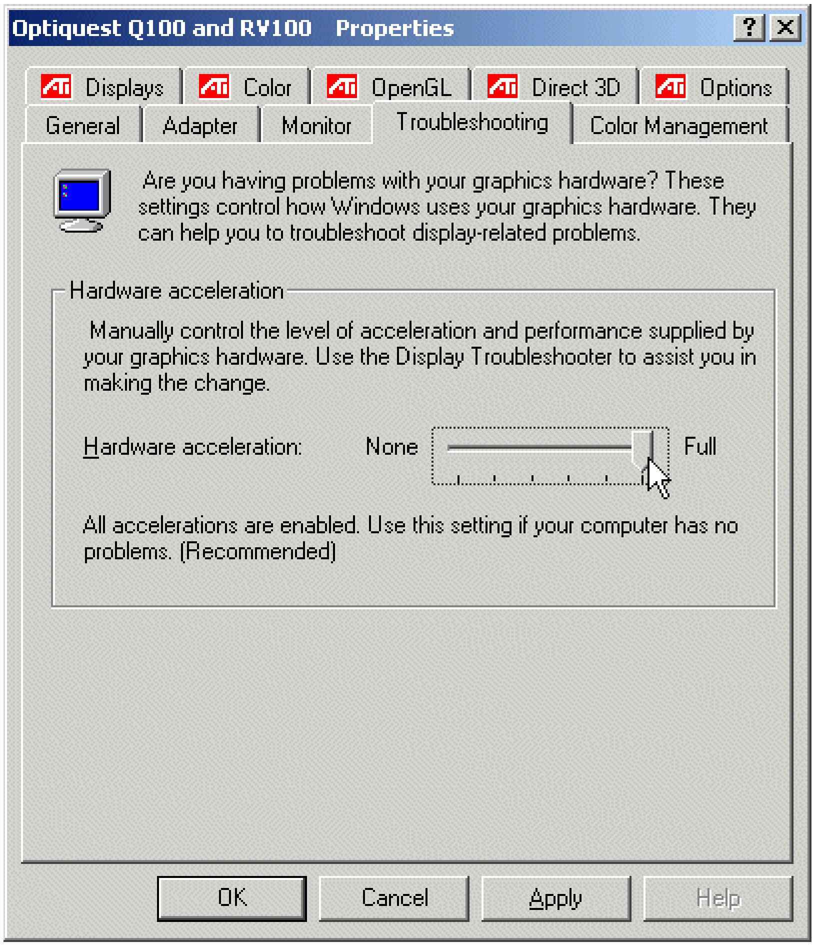
Right click anywhere in the desktop and select the Properties option in the pop-up menu. This will open the Display Properties dialog.



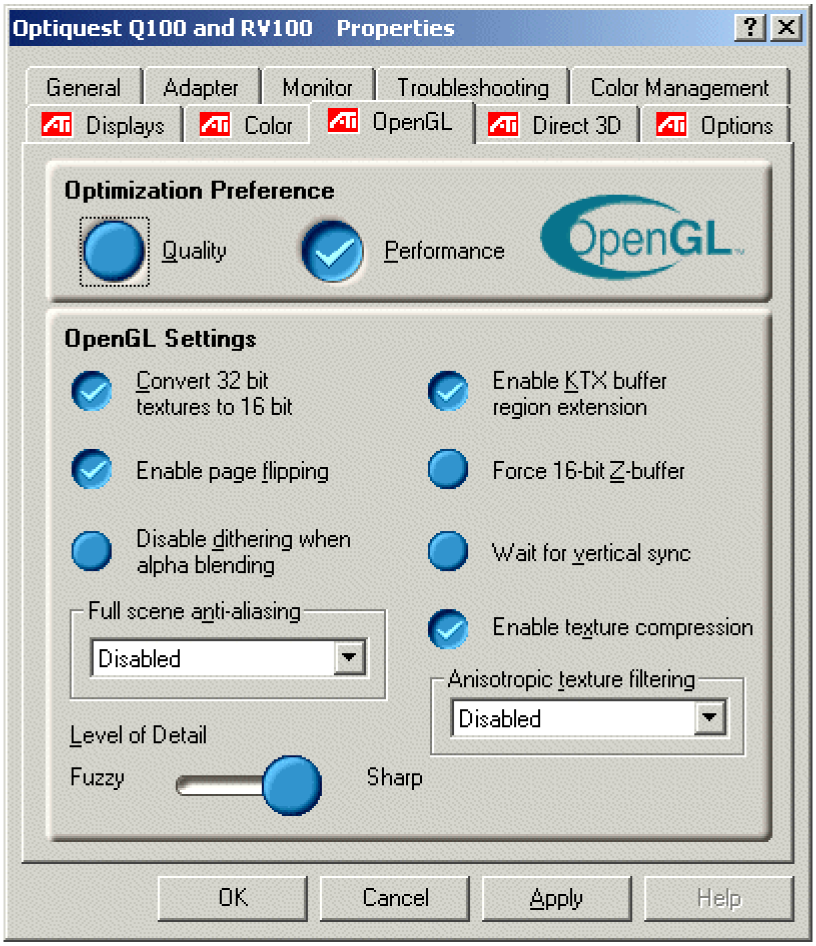
Now select the Advanced options in the Settings page of the Display Properties dialog.



The pages in the Advanced display properties dialog will have different options depending on the video board installed in the computer but five of the pages will be available on all computers with recent windows operating systems: General, Adapter, Monitor, Troubleshooting, and Color Management pages. Select the Troubleshooting page and adjust the Hardware Acceleration slide bar down one step at a time until the FRED visualization problems cease. Typically, you will have to adjust the slide bar down to the lowest first, second, or third setting. This slider adjusts what graphics acceleration processes are handled by the hardware and what processes are handled in software. The Software solution is more robust but slower than the hardware acceleration solution.



Depending on the video card installed in the computer, there may also be an OpenGL Properties page in the Advanced Display properties dialog. If so, the problems may possibly be fixed with the settings on the OpenGL properties page. An example of an OpenGL properties page is shown below. Please consult the video card manufacturer for support on the OpenGL properties page.

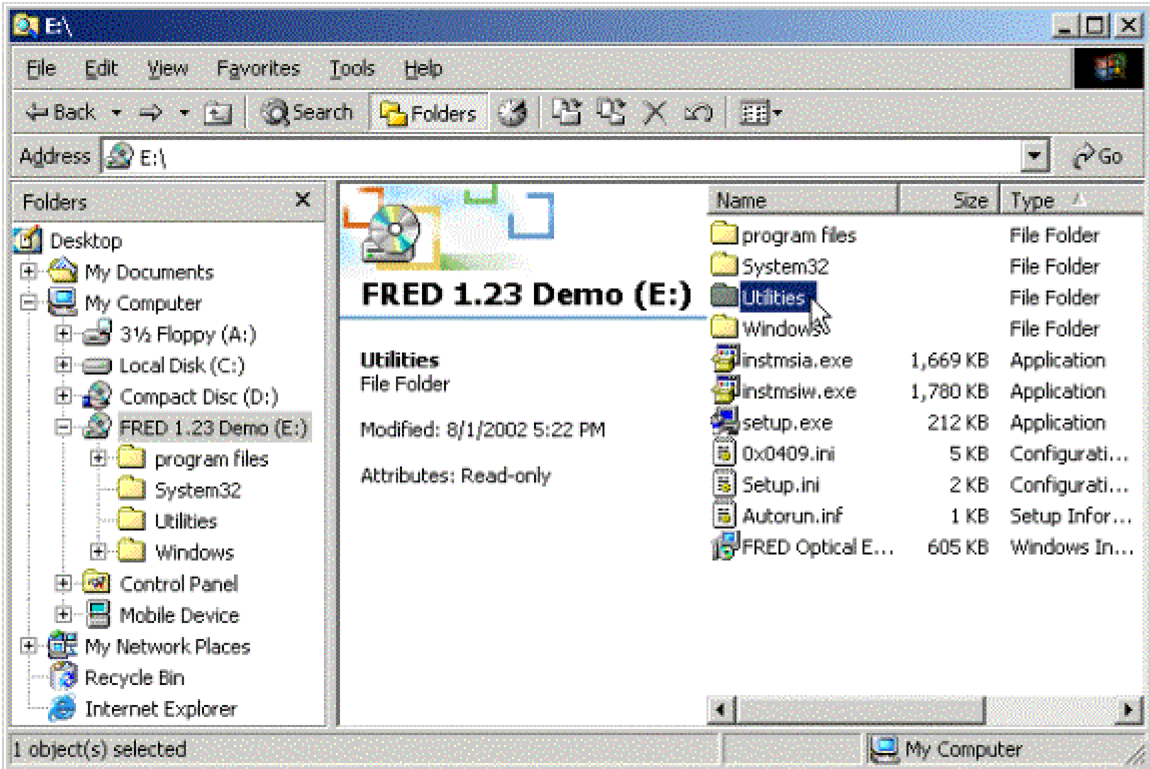


Adjust the OpenGL pixel-rendering mode

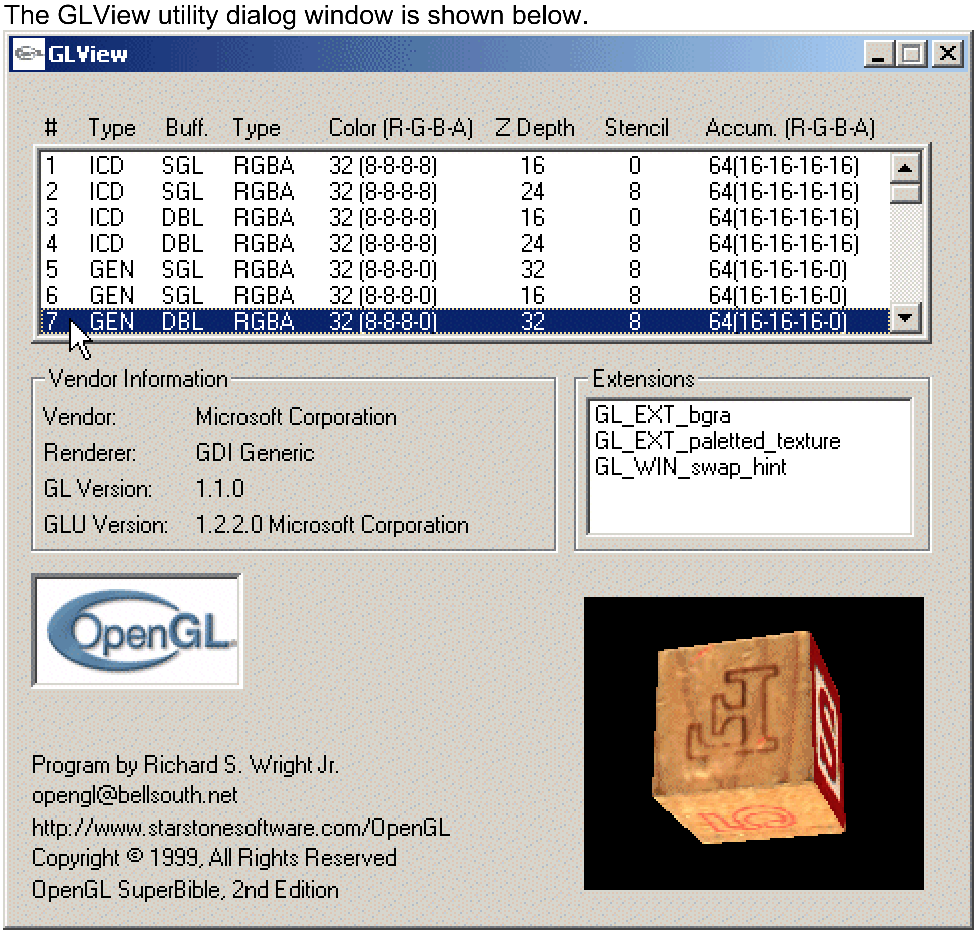
This option will change the OpenGL driver mode used by FRED but will not affect the OpenGL driver options for other programs using OpenGL.

This option has two steps. In the first step, a utility is used to determine what OpenGL pixel render mode is stable using the current OpenGL driver and video board. In the second step, the pixel render mode identified in the first step is selected for FRED in the FRED Visualization preferences page.

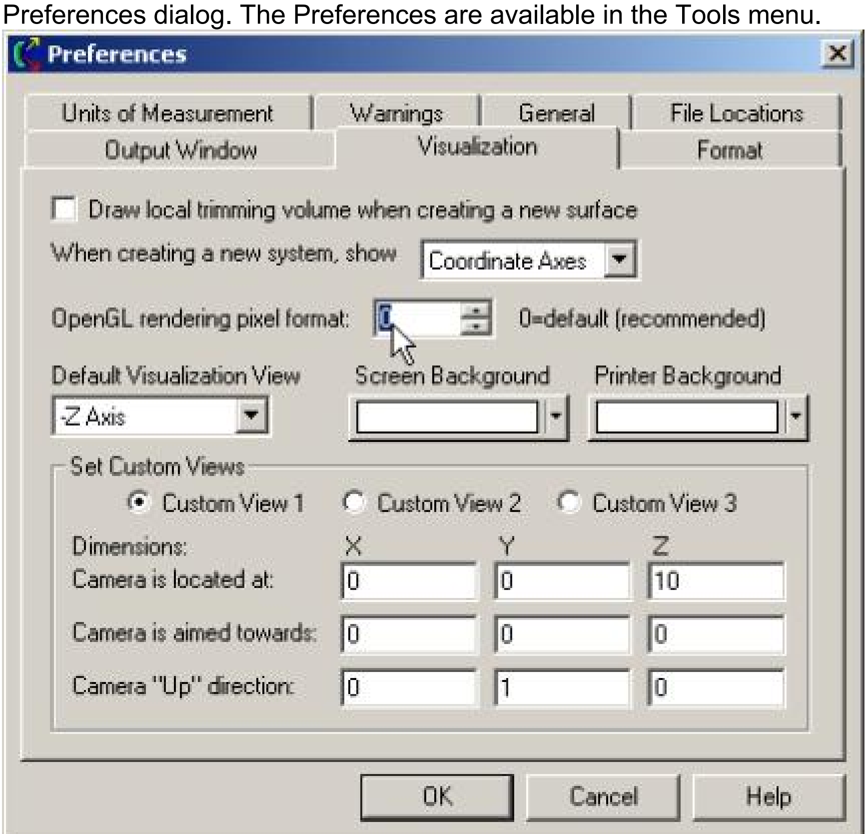
The utility is called GLView.exe, located on the FRED installation disk in the Utilities folder. The figure below illustrates the location of the utility directory on the installation disk. In this case, the installation disk is for the FRED demo version 1.23.



The GLView utility dialog window is shown below.



The GLView dialog lists a number of pixel rendering modes and the attributes for each mode. The ICD types are hardware accelerated modes. The GEN modes are software modes that do not have hardware acceleration. You should choose a mode of type GEN. The mode chosen MUST have a double buffer indicated with DBL in the Buff column. It should also have a type of RGBA. If the mode is a good mode to use, the letter block in the lower left corner will roll smoothly without any flickering. If the mode is not a good one, then the letter block will flicker. The speed that the letter block rolls is a rough indication of how fast the mode will operate.
Some of the modes listed are not available. If the mode is available, then a rolling letter block, , is shown in the window in the bottom left corner of the dialog. If the mode is not available, then a red X, , is drawn instead.
Once a good mode has been identified, make note of the mode number in the left most column. Now close the GLView utility and start FRED, but do not load a FRED file. The mode number should be entered into the pixel rendering mode on the Visualization page of the FRED Preferences dialog. The Preferences are available in the Tools menu.



If you later update your video board driver, you may want to update your FRED Preferences by entering an OpenGL pixel rendering mode of 0 (zero). This is the default setting and tells FRED to use the default aggressive rendering mode.

Download and install the latest video board drivers

Often there is a new video board driver that has enhanced OpenGL performance available from the video board manufacturer. FRED is using OpenGL extensively but if FRED is having problems with the OpenGL drivers then it is likely that other programs using OpenGL will have troubles with the drivers. In this case the manufacturer may have addressed the problem with an improved driver. Consult the video driver manufacturer's website for updates.

Install a new video board

Please contact Photon Engineering, LLC for a list of video boards that have worked well for other users.

Chapter 29 – How to setup FRED for use with Safenet

Setting up FRED for use with the Safenet hardware key

Description - Setting up the software for the SafeNet hardware key

This article details the software installation for the SafeNet hardware key used by FRED.

What Is It? - Setting up the software for the SafeNet hardware key

The SafeNet (formerly Rainbow) Corporation is a vendor of computer security products. Their Sentinel SuperPro software protection is used by the FRED Optical Engineering Software to prevent unauthorized duplication. It is a mandatory component, and must be installed in order to run FRED. It prevents FRED from running on multiple computers at once, but allows multiple instances of FRED to run on the same computer.

FRED launches the SafeNet SuperPro driver installation program automatically at the end of the FRED installation in a "silent" mode. This will automatically install or upgrade the driver unless one of the following conditions is met:

4. The version is already installed
5. A newer version is installed

The driver cannot coexist with older drivers and is, according to SafeNet, backwards compatible with previous versions.

The installation program briefly displays a dialog with a cancel button as it starts. If you do not wish to run the driver installation, press the spacebar when this dialog appears. This will press the cancel button and stop the driver installation, but will allow the FRED installation to finish.

The installation program installs the drivers for the parallel and the USB key, regardless of which key you received when you purchased FRED. If you wish to remove one of these components, you may do so via the Add/Remove Programs Control Panel applet.

Application Notes - Setting up the software for the SafeNet hardware key

The installation program requires System Administrator privileges to run, as it installs files to the Windows System directory. If, for whatever reason, the SafeNet installation needs to be run without running the FRED installation, it is available on the FRED CD in the "Rainbow Tools" directory. The most recent version is available from the SafeNet website, linked at the bottom of this page.

See Also - Setting up the software for the SafeNet hardware key

SafeNet website
SafeNet Network Setup

Setting up FRED for Networks

Description
Application Notes
See Also...

Description - Setting up FRED for Networks

This article details the software installation for using FRED on a network.

Application Notes - Setting up FRED for Networks

The FRED Network architecture is relatively simple: a PC designated as the "network server" manages FRED "execution licenses" requested by one or more "local" computers running FRED.

When a user launches FRED on a local computer, FRED requests an execution license from the server. If the hardware key is attached to the server and there is a license available, the server grants the request, reduces the number of available licenses by one, and FRED execution continues. If all the licenses are in use, the server denies the request and FRED terminates. When a user exits from FRED, FRED notifies the server which then releases the license.

The network server must have the network hardware key (dongle) connected to it, and it must have the associated dongle software installed. The FRED software itself does not need to be installed on the server.

FRED can be installed on as many local computers as desired. However, only a limited number of users may execute FRED simultaneously. The limiting number is determined by the number of purchased FRED network licenses.

1) PREPARATION OF THE SERVER COMPUTER

a) Install the SafeNet Sentinel protection software on the host. Run the “Sentinel Protection Installer XXXXX.exe” program found in the “SafeNet Tools” subdirectory on the FRED CD to begin the installation. The latest installer program can also be downloaded from the Safe Net website. The installed software is always backward compatible with earlier versions.

b) Direct the installation procedure to install two items: i) a hardware driver for the hardware key, and ii) a Windows service called “Sentinel Protection Server”.

c) The service must be running on the server so that the user computers can query the hardware key when running FRED. Also, the hardware key must be connected to the server whenever a user computer is running FRED.

d) Communication between the remote and host computers uses a specific port. You should make sure that one of the following ports is open for network communication:
For TCP/IP protocol: UDP port 6001
For IPX/SPX protocol: SAP messages are sent over 361hex

e) The "SafeNet Tools" subdirectory on the FRED installation CD contains software tools that can be of help to system administrators:
i) EndUserSentinelMedic.exe Problem diagnosing tool
ii) SPmedic.exe Problem diagnosing tool
iii) Monitor.exe Allows monitoring of FRED and license usage

2) PREPARATION OF LOCAL COMPUTERS

b) Install FRED.

c) You must set an environment variable called NSP_HOST. This environment variable specifies how FRED locates the server computer.

d) Valid values for the NSP_HOST environment variable are:
i) servername/IPadress/IPXaddress the most efficient and fastest access mode for locating the server
ii) RNBO_SPN_BROADCAST broadcast a request over the local subnet to find a server with an available license
iii) RNBO_SPN_LOCAL look for a hardware key on the local computer (stand-alone mode using a local server)
iv) RNBO_SPN_DRIVER look for a hardware key on the local computer (stand-alone mode without a local server)
v) RNBO_SPN_SERVER_MODES tries RNBO_SPN_LOCAL followed by RNBO_SPN_BROADCAST

e) You can get the NSP_HOST ip address by going to the DOS prompt on the server where the network key is and typing ipconfig on the command line.

See Also - Setting up FRED for Networks

SafeNet website

Chapter 30 - Contact Information

Internet

Web: www.photonengr.com

General Information: info@photonengr.com

Sales: sales@photonengr.com

Tech Support: support@photonengr.com

Address

Mailing Address:

Photon Engineering, LLC

P.O. Box 31316

Tucson, AZ 85751

Shipping Address:

Photon Engineering, LLC

440 S. Williams Blvd, Suite 106

Tucson, AZ 85711

Phone Numbers

Voice: (520) 733-9557

Fax: (520) 733-9609

Chapter 31 - Engineering Services Offered by Photon Engineering, LLC

We have broad-based experience in all phases of optical engineering: specification development, conceptual through detailed optical design of imaging and non-imaging systems, tolerancing, drawings for fabrication, CAD/mechanical design interfacing, customer and vendor interfacing, ghost/stray light analysis, thermal analysis, beam propagation, effects of contamination, "debugging" optical systems, and more. Combined with outstanding communication and presentation skills, Photon Engineering has the breadth and skills to make your project a success! (We've also been known to salvage an existing project in deep trouble from time to time!)

Photon Engineering offers optical engineering consulting services under two "customer-friendly" forms:

"Time and materials" contracts. Under this type of contract, there is no predetermined statement of work; the customer generally has an optical engineering idea/problem he wishes to investigate/solve and we tackle the project from there. We work closely with the customer to understand the idea/problem, select the optimum software and technical approach, and work toward an optimal solution.

Since these contracts tend to be rather loosely structured, we typically ask the customer to issue a purchase order for a not-to-exceed funding level. The specifics, schedule, and cost of each task are negotiated, sometimes on a day-to-day basis, as the work progresses. With frequent reports, discussions and other customer interactions (also sometimes on a day-to-day basis), Photon Engineering acts like a virtual "in-house" engineering resource without the associated overhead.

Fixed price contracts. Under this type of contract, we work to a specific statement of work on a specific schedule for a predetermined cost; all aspects of the contract are negotiated "up front" with the customer prior to beginning any work.

Other business arrangements may be considered. For example, we may accept future royalties as payment for consulting work under the appropriate circumstances. Contact us for more information.

Under any business scenario, Photon Engineering is extremely cost-effective. We keep our overhead low so that we can offer our services at rates affordable to even "start-up" companies.

Photon Engineering will keep your secrets! We routinely sign reasonable non-disclosure agreements intended to protect the proprietary nature of our customer's projects.

Photon Engineering, LLC
440 S. Williams Blvd, Suite 106
Tucson, AZ 85711
520-733-9557
www.photonengr.com

Glossary

curve

A curve is either a collection of points or a functional form defining a line. A curve can then be swept to make a surface.

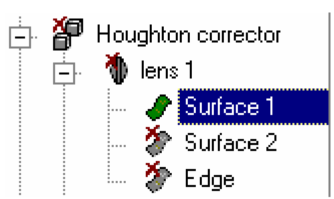
FRED document

All data, i.e. sources, materials, coatings, geometry, ray trace controls, etc. entered into FRED is stored in a document(s).

hierarchical raytrace search

This algorithm searched the FRED geometry nodes starting with a parent node and then working down through the children, grandchildren, etc. until the all progeny nodes have been searched. At each node (parent, child, grandchild, etc.), the algorithm first checks to see if the node is traceable. If the node is not traceable, then skips that node and all of its children and grandchildren. If the node is traceable, then it checks to see if the ray intersects the bounding box for that node. If the ray intersects the bounding box, then the algorithm checks to see if the node is a surface. If the node is a surface, then the algorithm checks to see if the ray intersects the surface. If the node is not a surface, and it has child nodes then it systematically follows the same process for the child nodes. This process continues until all of the nodes under a parent node have been checked. Then the algorithm moves on to the next parent node. After the algorithm has determined all the surfaces that the ray intersects, the closest surface is chosen as the next surface intersection. The process then repeats.

It is possible to have a traceable surface node that is a child of a non-traceable parent node. Because this algorithm ignores any nodes under a non-traceable node, this algorithm will not trace the surface 1 in the example shown below.



intensity

Intensity is a power per stradian radiometric unit. The SI units for intensity are

$$\frac{Watts}{str^2}$$

irradiance

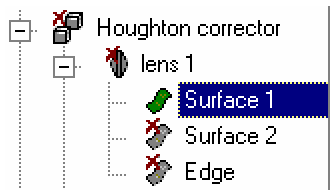
Irradiance is a power per unit area radiometric unit. The SI units for irradiance are

$$\frac{Watts}{meter^2}.$$

linear raytrace search

This algorithm systematically checks every traceable surface node to determine if the ray interests the bounding surface. If the ray intersects the bounding surface, then the algorithm checks to see if the ray intersects the surface. After the algorithm has determined all the surfaces that the ray intersects, the closest surface is chosen as the next surface intersection. The process then repeats.

This algorithm does not consider and non-surface nodes. It is possible to have a traceable surface node that is a child of a non-traceable parent node. This algorithm will trace the surface 1 in the example shown below.

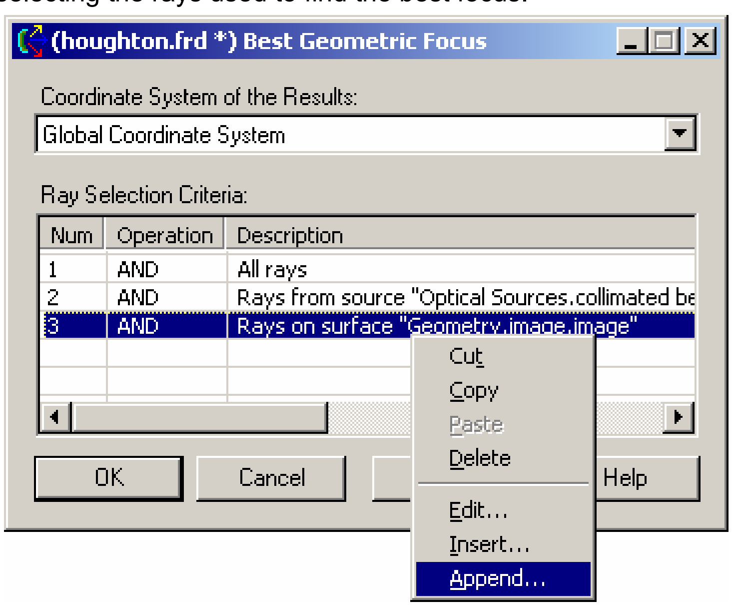


node

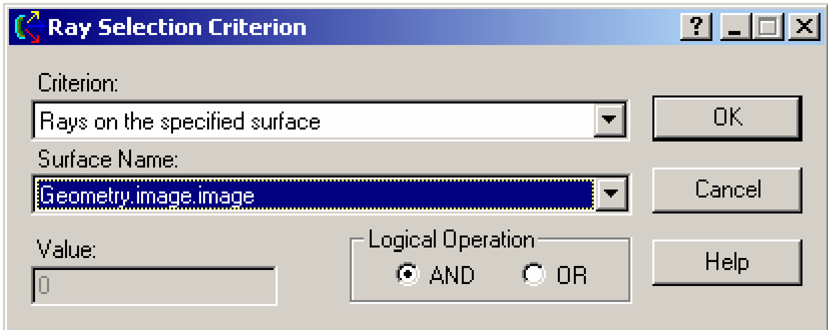
Every entry in the Tree View data structure has a node. Each node has an icon, i.e. , and a name. There is a hierarchical structure to the nodes. If a node has child nodes, it can be expanded, ⊟, or collapsed, ⊞, by left mouse clicking on the ⊞ or ⊟ symbols respectively or by double left mouse clicking on the node name to toggle back and forth.

ray filter

Specific rays can be selected from the ray set based on many criteria including their source, their location, coherence, etc. For example, the Best Focus command has a ray filter for selecting the rays used to find the best focus.



Editing, inserting, or appending a record to the ray filter will bring up the Ray Selection Criterion dialog.



rayset

The currently created set of rays in the FRED ray buffer. FRED creates rays (the rayset) from defined sources if one of the following commands are issued by the user: Create All Source Rays, Trace and Render, Trace All Sources, and Advanced Trace. Defining a source dos not create rays. The rayset can be delete use the Delete Existing Rays command. Note, single ray traces have their own separate buffer and are not part of the rayset.

RMS

Root mean sum.

steradian

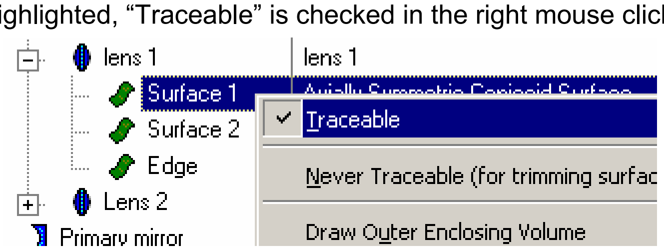
A steradian [sr] is the solid angle subtended by $\frac{1}{4}\pi$ of a the area of a sphere as viewed from the center of the sphere. A hemisphere subtends $2\pi\,[sr]$ and complete sphere subtends $4\pi\,[sr]$.

subassembly

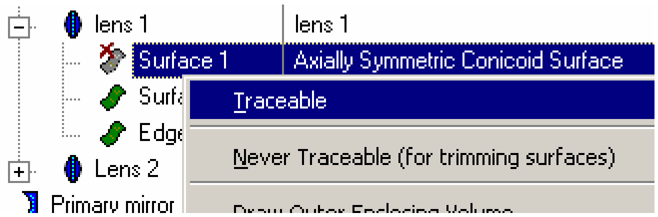
A subassembly is a collection of elements and/or custom elements in a FRED document. Note that surfaces and curves cannot be directly entered into a subassembly.

traceable

Only traceable objects are considered when rays are created and/or traced. Sources, parent nodes, element and custom element nodes, and surfaces by default are marked as traceable when they are created. Any source or geometry node can be marked as untraceable via the right mouse click pop-up menu in the Tree View. A node is traceable if when the node is highlighted, "Traceable" is checked in the right mouse click pop-up menu.



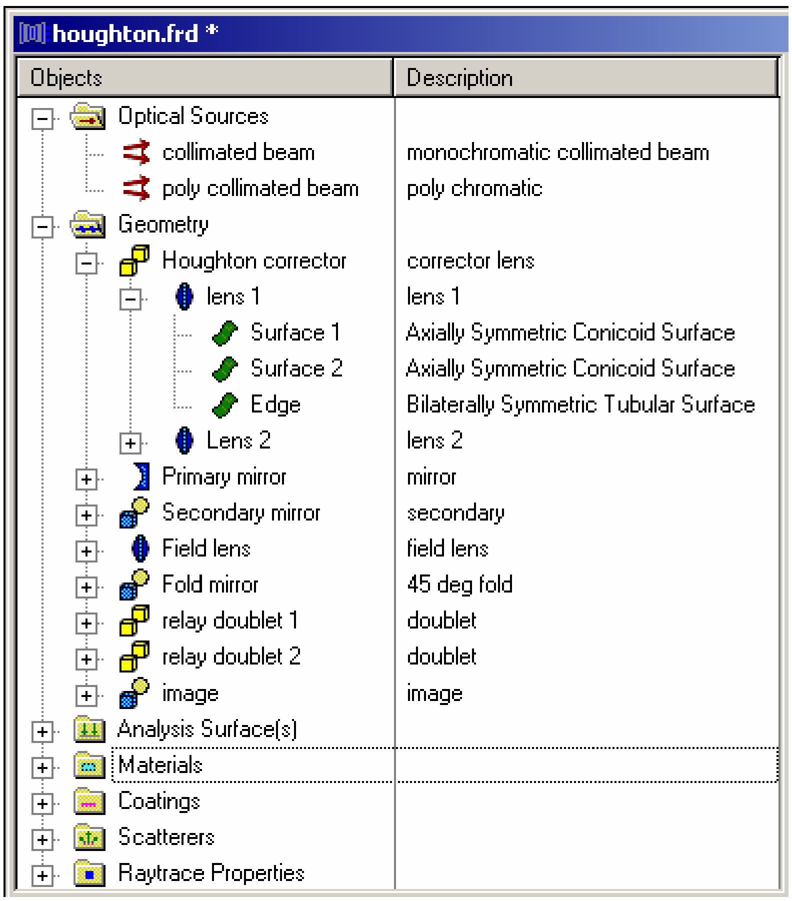
An object is not traceable if Traceable is unchecked in the right mouse click pop-up menu. In addition, untraceable [node](#) icons, i.e. , are colored gray and marked with an .



A count of the traceable and not traceable rays is available in the Ray Status output.

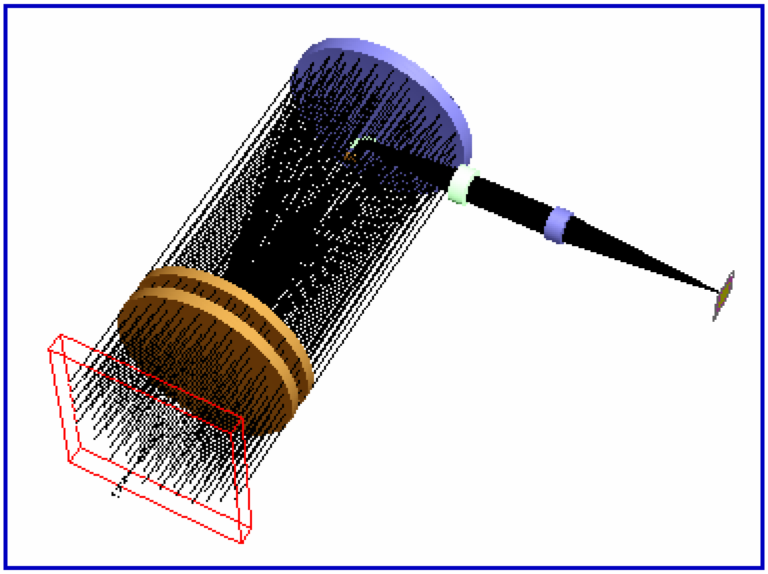
Tree View

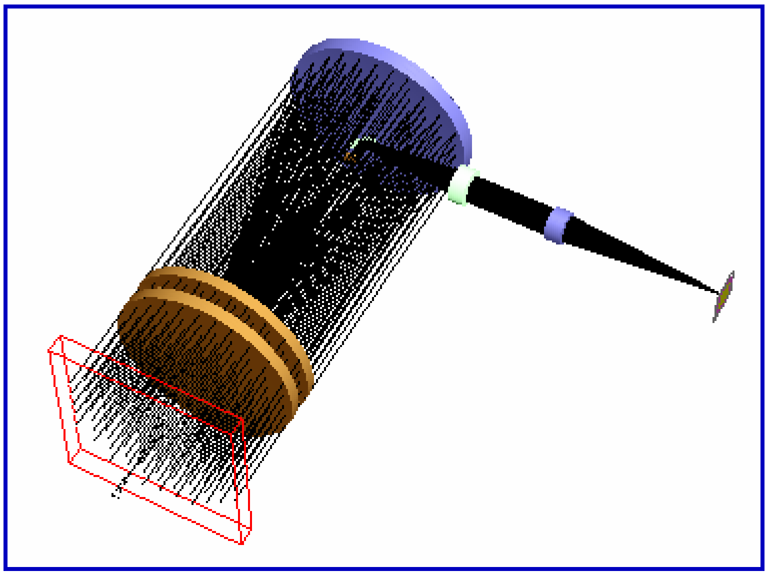
The Tree View is one of the two document views available in FRED. This view is a hierarchical data structure representing the optical model described in FRED. The other view is the Visualization Window.



Visualization Window

The Visualization Window is one of the two document views available in FRED. The other view is the Tree View.





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