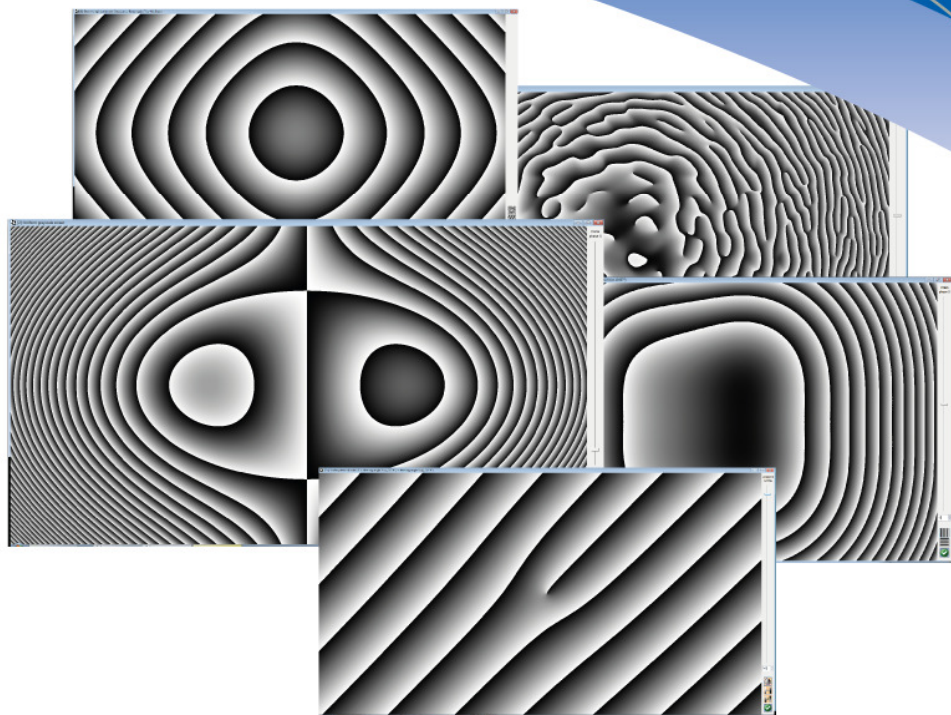


SLM Software

HOLOEYE SLM Pattern Generator Software



Pioneers in Photonic Technology

Note

This Instruction explains the correct usage of the device and serves prevention of danger. All persons who apply or use, care of, maintain and control the device have to read and follow it. It is part of the device and should always be at the user's disposal.

*** * ***

Copyright notice

Copyright © by HOLOEYE Photonics AG. All rights reserved. Under the copyright laws, this manual cannot be reproduced without prior written permission by HOLOEYE.

Technical specifications given in this document are subject to change without notification.

Table of contents:

SLM Pattern Generator	4
1 HOLOEYE SLM Pattern Generator Software.....	4
1.1 Installation.....	4
1.1.1 Microsoft® Windows®	4
1.1.2 Mac OS X	4
1.1.3 Ubuntu	5
1.2 Starting the software.....	6
1.2.1 SLM device detection	6
1.2.2 SLM full-screen support within extended desktop.....	7
1.2.3 Operating-System power saving features	8
1.2.4 Selection of optical parameters	8
1.3 The image window.....	9
1.3.1 Opening an image file.....	9
1.3.2 Image window functions	10
1.4 Calculating a diffractive optical element (DOE).....	11
1.5 Full-Screen window functions.....	12
1.5.1 Main Toolbar of the full-screen window.....	12
1.5.2 Wavefront components for superposition.....	12
1.5.3 Superposition of a first order phase function.....	14
1.5.4 Superposition of a second order phase function.....	14
1.5.5 Superposition of a third order Zernike phase function....	16
1.5.6 Superposition of a fourth order Zernike phase function .	17
1.5.7 Modification of displayed grayscale values (Gamma correction)	18
1.5.8 Displaying the full-screen image on the SLM 'screen'....	19
1.5.9 Saving the displayed full-screen image	20
1.5.10 Copying the displayed image to the clipboard.....	20
1.6 Creating essential optical functions	21
1.6.1 Blank Screen	21
1.6.2 Horizontally Divided Screen.....	22
1.6.3 Vertically Divided Screen.....	22
1.6.4 Random Bitmap.....	22
1.6.5 Random Binary Bitmap.....	22
1.6.6 Aperture Functions	22
1.6.6.1 Rectangular Aperture.....	22
1.6.6.2 Circular Aperture.....	22
1.6.6.3 Single Slit and Double Slit	23
1.6.7 Fresnel Zone Lenses	23
1.6.7.1 Binary Fresnel Zone Lens.....	23

1.6.7.2	Fresnel Zone Lens.....	23
1.6.7.3	Cylindrical Fresnel Zone Lens	23
1.6.8	Binary Axicon.....	24
1.6.9	Axicon	24
1.6.10	Vortex Phase	24
1.6.11	Concentric ring segments.....	24
1.6.12	Binary beam-splitter gratings.....	25
1.6.12.1	Linear Gratings and Crossed Linear gratings.....	25
1.6.12.2	Exemplary binary beam-splitter designs.....	25
1.6.13	Sinusoidal Grating	25
1.6.14	Blazed Grating	26
1.7	Calculating a beam-shaping phase function for Gaussian Input beams.....	26
1.7.1	Transformation of a Gaussian beam to a circular 'flat-top' beam	26
1.7.2	Transformation of a Gaussian beam to a rectangular 'flat- top' beam	27
1.8	Superposition with an additional phase map.....	27
1.8.1	Loading	28
1.8.2	Unloading.....	28
1.9	The 'Window' Menu	28
1.9.1	Windows inside the main window.....	28
1.9.2	Full-screen windows outside the main window.....	28

SLM Pattern Generator

1 HOLOEYE SLM Pattern Generator Software

The HOLOEYE SLM Pattern Generator software allows the computation of computer generated holograms (CGH's) from user defined signals as well as the generation of elementary optical functions such as different kind of gratings etc. as well as the superposition of different CGH's. The generated CGH's can be displayed on the SLM within the software and can be modified by a superposition of holographic functions on the fly.

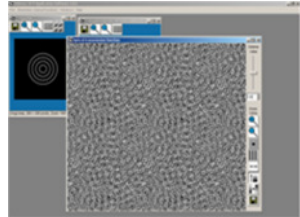


Figure 1: Screenshot of SLM Pattern Generator Software

1.1 Installation

1.1.1 Microsoft® Windows®

In order to make a successful installation, you should make sure that you have sufficient privileges in the computer's operating system (Microsoft Windows™ 7 or higher). You should be permitted to create a directory in the directory that contains programs and copy files into that directory, and to write into the 'all users' section of the start menu of your operating system. Of course administrator privileges will be sufficient for all these operations.

Start the executable file 'HOLOEYE SLM Pattern Generator 3.3 (64|32 bit).exe' for 32- or 64-bit OS and follow the instructions of the installation menu.

Please accept the license agreement before selecting the program components to install. In order to install the complete version, mark all checkboxes. Choose the destination folder as well as the start menu folder. Select 'Install' to start the installation procedure and finally 'Close' to finish the installation.

1.1.2 Mac OS X

- This software needs Mac OS X 10.7 or higher
- Open by double click on "HOLOEYE SLM Pattern Generator 3.3.dmg" the image file

- Shift the Holoeye Application into App Folder



Figure 2: Install dialog on MacOS X

- When running the software for the first time, a warning concerning 'unknown external software' may be displayed. Click 'open' for confirmation.
- To prevent the display of the top-bar on the SLM the option "Displays have separate Spaces" needs to be disabled in the System Preferences -> Mission Control Settings. (see Figure 3)

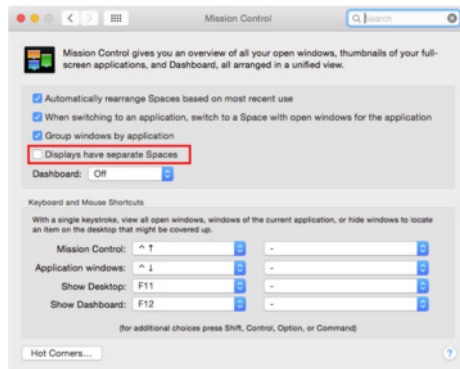


Figure 3: Mission Control Settings

1.1.3 Ubuntu

This software was designed for Ubuntu 14.04 LTS or higher. Please install the package by typing

```
cd path_to_installer_file/  
sudo dpkg -i "HOLOEYE SLM Pattern Generator 3.3.deb"  
sudo apt-get install -f
```


in “Terminal” or open it with “Software Center” by double click and press the “install” button.

The second command in “Terminal” is only needed if some remaining dependencies could not be resolved in the installation step.

1.2 Starting the software

Before starting the Software it is recommended to connect the SLM and set it up as an extended Desktop Monitor. (This mode is so called in Microsoft Windows OS. When using other operating systems, the name of this mode may called different). In this mode the software is able to address a full-size output to the SLM. (See comments in 1.2.2 SLM full-screen support within extended desktop).

1.2.1 SLM device detection

Start the program using the icon  of the software which was created during the installation process.

Upon start-up, the SLM device will be detected. A dialog will open which shows the available SLMs. If only one was detected, the dialog will disappear automatically after a short time and the software starts (see Figure 4). If the device could not be detected clearly, there is the option to configure the screen configuration. The options appear in a menu after clicking the “Configure” button (see Figure 5). There are options to either solve the problem automatically or to open the operating systems screen configuration dialog and correct the problems manually.

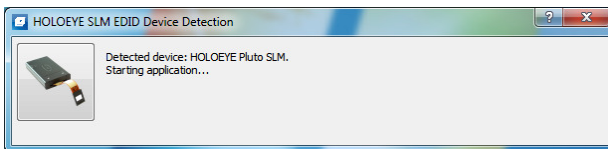


Figure 4: Device detection dialog continues automatically if SLM was clearly detected.

If multiple devices are found, each device can be identified by hovering the mouse cursor above the device image. A hint will show up after a short time and will show details about the SLM, including the current position on the desktop.

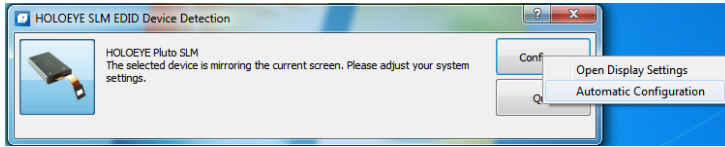


Figure 5: Device detection dialog in case the SLM is not properly configured.

The device selection dialog prevents the usage of the following screen configurations:

- Wrong SLM resolution
- Wrong SLM refresh rate

The selected SLM device can later be seen in the “About Device” menu inside the “Help” sub-menu.

1.2.2 SLM full-screen support within extended desktop

With more than one screen the program will display the content of full-screen windows to the SLM with the correct resolution, and in addition open a monitor window on the GUI screen for convenient supervision of what is being displayed.

The most straightforward option is of course operating the SLM as an external monitor by setting the graphics adapter settings of the operating system to a ‘Display clone mode’. However, there are a few disadvantages of the ‘Display clone mode’ which make using an ‘Extended desktop’ configuration attractive.

Firstly, the full-screen window has a boundary (and potentially a button toolbar) which somewhat reduces the area of the SLM usable as an optical element. Secondly, the operation in ‘clone mode’ is easy only if the primary display and the SLM are operated at the same pixel resolution, which may not be desirable. Third, if the PC or Laptop that controls the SLM should be used for other tasks in parallel, the ‘extended desktop mode’ permits to do so without interacting with the operation of the SLM.

The use of the software with the ‘extended desktop mode’ can be tested most conveniently with the SLM in amplitude modulation (using a suitable polarizer configuration) – or with an additional computer display operated at the SLM’s pixel resolution in mirror mode.

Under Microsoft Windows, the screen magnifier in “docked” mode can also be used to inspect the content on the SLM easily. Another option is to make a screenshot of all displays by pressing the “Print” key on

the keyboard of the PC and pasting the content to e. g. Microsoft Paint.

1.2.3 Operating-System power saving features

As soon as there is content on the SLM, the software tells the operating system not to start any power saving features, including locking of the screen. This means, all automatic functions which would interrupt the SLM content display are disabled.

Please note that if automatic screen locking e. g. is switched on for a good reason on the user's PC, it will be disabled as long as there is an open window on the SLM. If you want to have a screen lock while displaying content on the SLM, please lock the screen manually. Also, energy saving features can be used manually while there is content displayed on the SLM.

1.2.4 Selection of optical parameters

At each start of the software, the dialog of the optical parameters is shown to make sure they are correctly set before using any functions inside the software (See Figure 6). Many functions depend on the wavelength of the incident light to the SLM. So please enter the wavelength used in the optical setup.

There is also the option to select the desired Zernike radius. The default Zernike radius (behaviour of versions prior to 3.3 of this software) is to use the height of the SLM to make sure the full Zernike area is on the SLM. There are two more predefined Zernike radius options, but every value from 0,001 mm to the diagonal of the SLM (full SLM is in Zernike area) is allowed.

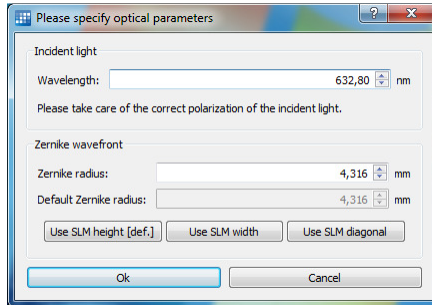


Figure 6: Optical parameters dialog

The optical parameters can later be accessed via the main menu under Preferences -> Optical Parameters. If any function is opened, then the values will not be editable. In such a case, if you like to change the values, please follow all instructions from the upcoming messages. The optical parameters are saved before closing and reopening the software.

1.3 The image window

1.3.1 Opening an image file

Choose from the *File* menu the point 'Open Image File'. The supported image formats are BMP, PNG, JPEG, GIF, XBM, XPM, MNG and the different PNM formats: PBM (P1 or P4), PGM (P2 or P5), and PPM (P3 or P6). The loaded picture will be transformed to a picture with 256 gray-scale values. In order to display all 256 gray-scale values a monitor setting of minimum 16 Mio. colors (24bit) is required.

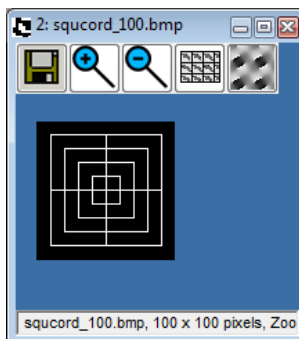


Figure 7: Image window of the SLM software

It is also possible to open an image by copying it to the clipboard with another application and inserting it into the application with the key combination CTRL-V.

1.3.2 Image window functions

The image window has a small toolbar with the following buttons:



'Zoom In' Button

Pushing this button will perform a fast 'zoom in' operation on the image.



'Zoom Out' Button

Pushing this button will perform a fast 'zoom out' operation on the image.



'Save' Button

Pushing this button will open a dialog in which a file name can be specified for saving the image in one of the supported formats (PNG or BMP Image, ASCII textfile matrix of integer values representing the grayscale values).



'Compute DOE' Button

This button will only appear if the displayed image (taking zoom operations into account) is no larger than 400x400 pixels.

Pushing this button will start a computation of a Computer-generated hologram (CGH) phase function for the signal displayed in the image window. Please see section 1.4 for more information.

The result of the computation will be displayed in a full-screen window where it can be manipulated as explained in section 1.4.



'Replicate to full screen size' Button

Pushing this button will open a full-screen window in which the shown image is used as a single tile which is replicated (i.e. tessellated) until the whole screen is covered. The 'basic tile' image is centered on the screen.

1.4 Calculating a diffractive optical element (DOE)

To compute a DOE, the signal image size needs to be smaller than 400x400 pixels. DOE computation for larger pictures is not supported by the HOLOEYE SLM software.

Load the image as described in section 1.3. If the image is not larger than the supported size pixels the '**Compute DOE**' Button will appear with the option to calculate a diffractive optical element (DOE) for this image.

Press this button to start the Iterative Fourier Transformation Algorithm (IFTA). Note that the process of computing may take a short while, depending strongly on the signal picture size. The dialog shown in Figure 8 displays the progress, but also permits interruption of the ongoing computation.

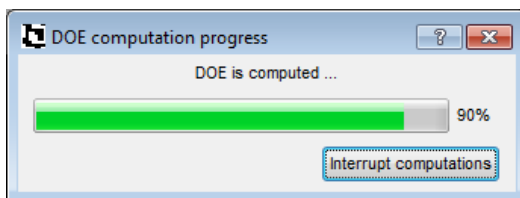


Figure 8: Progress of the DOE computation

When the process is finished, two windows will appear. The first window will display the DOE phase function in full-screen size. The basic tile of that window has a size of the smallest power of 2 being larger than the image size (e.g. 512 x 512). The second window will show the calculated intensity of the diffraction pattern, which looks quite similar to the original image, provided the DOE calculation has properly converged.

1.5 Full-Screen window functions

This full-screen image will display a task-bar immediately after its appearance. This taskbar will disappear if the SLM is used in 'display clone mode' and is shown in full-screen, but get visible again as soon as the mouse cursor is moved towards the right edge of the window.

1.5.1 Main Toolbar of the full-screen window

The functions accessibly by the taskbar buttons offer the possibility to manipulate the replicated 'basic tile' image by superposition of phase functions that represent optical elements (lens, prisms) or higher-order wavefront components, and by changing its grayscale values.

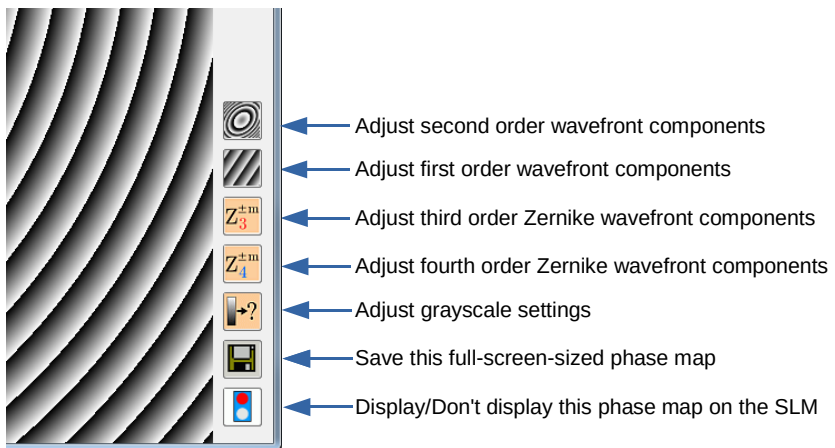


Figure 9: Lower right corner of a full-screen window displaying a phase map and the main toolbar

Some of the functions can be activated not only by pressing the buttons, but also by a key combination ('hotkey').

1.5.2 Wavefront components for superposition

The superposition of optical functions is done by adjusting sliders or entering integer values into the corresponding spinbox value field. In

the following table, we give a survey on the available superposition functions.

Name	Polynomial	Slider range
Tilt x	$r \sin \theta$	$\pm PN/2$
Tilt y	$r \cos \theta$	$\pm PN/2$
(De)focus	r^2	± 1000
Astigmatism 45°	$r^2 \sin(2\theta)$	± 400
Astigmatism 0°	$r^2 \cos(2\theta)$	± 400
Trifoil X	$r^3 \sin(3\theta)$	± 100
Trifoil Y	$r^3 \cos(3\theta)$	± 100
Coma (3 rd order) X	$(3r^2 - 2r) \sin \theta$	± 100
Coma (3 rd order) Y	$(3r^2 - 2r) \cos \theta$	± 100
Spherical aberration	$6r^4 - 6r^2 + 1$	± 100
Astigmatism 2 nd 45°	$(4r^4 - 3r^2) \sin(2\theta)$	± 100
Astigmatism 2 nd 0°	$(4r^4 - 3r^2) \cos(2\theta)$	± 100
Quadrafoil X	$r^4 \sin(4\theta)$	± 100
Quadrafoil Y	$r^4 \cos(4\theta)$	± 100

The Zernike radius for these polynomials is taken as $r_z = \min(\text{pixelnumber}_X, \text{pixelnumber}_Y) / 2 - 0.5$, so that the full Zernike diameter can always be displayed on the SLM.

For Tilt x and Tilt y, the range the software permits is chosen so that at the maximum values the phase switches between zero and π for the neighboring pixels, in order to maximize the available steering range.

For the (de)focus term, the maximum phase range is chosen so that the Moiree effects due to oversampling typically do not get dominant. The slider range is larger because thereby a fine focus adjustment can be obtained.

For all other Zernike wavefront components, the value is chosen so that at maximum slider positions, the wavefront amplitude obtained from the Zernike polynomial is multiplied by the slider value divided by 100. That means, the 1st order astigmatism terms have 4-fold wave amplitude compared to the remaining optional wavefront components.

1.5.3 Superposition of a first order phase function



'Adjust tip/tilt wavefront components' Button

Pushing this button will give access to the buttons that permit superposition with a linear phase function, which is equivalent to tip and tilt wavefront components.



'Superimpose prism in X direction' Button

Pushing this button will superimpose the replicated 'basic tile' image with a grayscale signal that resembles the optical phase function of a prism in X direction. This means that all diffraction angles created by the signal on the LC Display are changed when such function is superimposed. The corresponding angle is shown in the title of the window.

The strength of the optical prism function can be changed by adjusting the value given on the task bar, by moving the slider, or by directly entering a value.



'Superimpose prism in Y direction' Button

Similarly, pushing this button will superimpose the replicated 'basic tile' image with a grayscale signal that resembles the optical phase function of a prism in Y direction.



'Go back to main toolbar' Button

Pushing this button will simply hide all buttons related the superposition with first order phase functions, and make the main toolbar visible again.

1.5.4 Superposition of a second order phase function



'Adjust defocus and astigmatism' Button

Pushing this button will give access to the buttons that permit superposition with a second order phase function, which is equivalent to defocus and astigmatism wavefront components.



'Superimpose lens' Button

This button will superimpose the displayed image with a XY grayscale signal that resembles the optical phase function of a lens. This means that the focal plane of the light source incident on the LC Display is changed when such function is superimposed. The corresponding focal length will be displayed in the title bar of the window.

The focussing/defocussing strength of the optical lens function can be changed by adjusting the value given on the task bar by moving the slider or by directly entering a value.

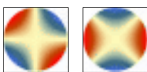
The resulting focal length for a given slider value x can be calculated by

$$f = \frac{1000}{x} \cdot \frac{1}{L_p} \cdot \frac{(r_z p)^2}{4 \lambda},$$

with the wavelength λ , the Zernike radius r_z (see above), and the pixel size p . The device specific power limit factor (L_p) of the defocus is given in Table 1 for specific HOLOEYE devices.

SLM device:	Limit factor L_p :
PLUTO	182.1555
LETO	182.1555
LC-R 1080	216.2630
LC-R 720	134.9122
LC-2012	154.2285
GAEA	364.4055

Table 1: Limit factor L_p for HOLOEYE devices.



'Superimpose 1st order astigmatism phase' Buttons

This button will superimpose the displayed image with a XY grayscale signal that resembles the optical phase function representing first-order astigmatic aberration of a wavefront. The coefficient of that

superimposed wavefront can be changed by adjusting the value given on the task bar by moving the slider or by directly entering a value.



'Go back to main toolbar' Button

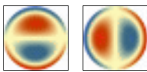
Pushing this button will simply hide the buttons related the superposition with second order phase functions, and make the main toolbar visible again.

1.5.5 Superposition of a third order Zernike phase function



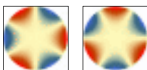
'Adjust Zernicke third-order wavefronts' Button

Pushing this button will give access to the buttons that permit superposition of phase functions that represent third order Zernike wavefront components.



'Superimpose coma wavefront x/y' Buttons

This button will superimpose the displayed image with a XY grayscale signal that resembles the optical phase function representing comatic aberration with respect to the x or y direction. The amplitude of that superimposed wavefront can be changed by adjusting the value given on the task bar by moving the slider or by directly entering a value.



'Superimpose trefoil wavefront x/y' Buttons

This button will superimpose the displayed image with a XY grayscale signal that resembles the optical phase function representing trefoil aberration with respect to the x or y direction. The amplitude of that superimposed wavefront can be changed by adjusting the value given on the task bar by moving the slider or by directly entering a value.



'Go back to main toolbar' Button

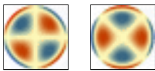
Pushing this button will simply hide the buttons related to the superposition with third order Zernike phase functions, and make the main toolbar visible again.

1.5.6 Superposition of a fourth order Zernike phase function



'Adjust Zernike fourth-order wavefronts' Button

Pushing this button will give access to the buttons that permit superposition of phase functions that represent third order Zernike wavefront components.



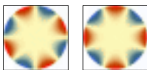
'Superimpose 2nd order astigmatism phase' Buttons

This button will superimpose the displayed image with a XY grayscale signal that resembles the optical phase function representing second-order astigmatic aberration of a wavefront. The coefficient of that superimposed wavefront can be changed by adjusting the value given on the task bar by moving the slider or by directly entering a value.



'Adjust spherical aberration' Button

This button will superimpose the displayed image with a XY grayscale signal that resembles the optical phase function representing first-order spherical aberration of a wavefront. The coefficient of that superimposed wavefront can be changed by adjusting the value given on the task bar by moving the slider or by directly entering a value.



'Superimpose quadrafoil wavefront x/y' Buttons

This button will superimpose the displayed image with a XY grayscale signal that resembles the optical phase function representing quadrafoil aberration with respect to the x or y direction. The amplitude of that superimposed wavefront can be changed by adjusting the value given on the task bar by moving the slider or by directly entering a value.



'Go back to main toolbar' Button

Pushing this button will simply hide the buttons related to the superposition with fourth order Zernike phase functions, and make the main toolbar visible again.

1.5.7 Modification of displayed grayscale values (Gamma correction)



'Adjust graylevel settings' Button

Pushing this button will show the buttons related to the modification of displayed grayscale values, and make the main toolbar reappear.



'Cycling of graylevel values' Button

This button will add a constant graylevel offset value to the displayed image. If the resulting value is larger than 255, an additional offset of -255 will be applied. The amplitude of that graylevel offset can be changed by adjusting the value given on the task bar by moving the slider, or by directly entering a value.

Adding such constant graylevel offset is equivalent to adding a constant phase value (or 'piston' wavefront component).



'Adjust Gamma curve' Button (Hotkey: CTRL+G)

Pushing this button will permit a simultaneous change of all grayscale values by moving the slider or by directly entering a value. The gamma curve is linear if the entered value is 0, and can be changed to concave and convex nonlinear curves by entering positive and negative values, respectively.

Note that if the 'basic tile' image is binary, this button will be accessible only if a wavefront function is superimposed to the full-screen image. (Not that after such Gamma curve adjustment has been done, the button will even remain visible after setting the coefficients

of all wavefront components back to zero, until the Gamma correction itself has been set back to zero, too).



'Invert displayed bitmap' Button (Hotkey: CTRL+I)

This toggle button will invert the grayscale value of the displayed full-screen image. This includes any superimposed lens and or prism functions. This inversion can be reversed simply by clicking the button again, which will cause the button to be no longer toggled.



'Adjust Graylevel 1' Button

This button will only be accessible if the 'basic tile' image is binary, i.e. it consists of two different grayscale values only. Pushing this button will then permit a change of one of the two grayscale values by moving the slider or by directly entering a value.



'Adjust Graylevel 2' Button

This button will only be accessible if the 'basic tile' image is binary, i.e. it consists of two different grayscale values only. Pushing this button will then permit a change of the second of the two grayscale values by moving the slider or by directly entering a value.



'Go back to main toolbar' Button

Pushing this button will simply hide the buttons related to the modification of displayed grayscale values, and make the main toolbar visible again.

1.5.8 Displaying the full-screen image on the SLM 'screen'



'Connect to SLM' Button – Disconnected state

This button is only visible if the software is operated in the 'extended desktop support mode' (see section 1.2 for details how to achieve this). Toggling this button will change the button from a read to a

green traffic light button, and the displayed bitmap of the full-screen window will be displayed as a frameless window on the SLM.

Obviously, only one full-screen image can be displayed on the SLM at a time. Therefore, if another full-screen window is already 'connected' to the SLM, toggling the 'Connect to SLM' button will automatically 'disconnect' the other window.



'Connect to SLM' Button – Connected state

This button is only visible if the software is operated in the 'extended desktop support mode' (see section 1.2 for details how to achieve this) and the button has been toggled before. In this case the 'bitmap content' of the window is currently displayed at the connected SLM. Toggling this button will change the button to a red traffic light button, and the SLM screen will be erased and reveal whatever is displayed underneath (other windows or the desktop background).

Note that also the 'external window menu' (see section 1.9.2) can be useful for selecting the full-screen image to display on the SLM.

1.5.9 Saving the displayed full-screen image



'Save' Button (Hotkey: CTRL+S)

Pushing this button will open a dialog in which a file name can be specified for saving the full-screen image in one of the supported formats (PNG or BMP image, or ASCII text matrix of integer values representing the grayscale values).

The image will be saved as displayed, i.e. including effects by superposition of optical functions etc.

1.5.10 Copying the displayed image to the clipboard

By pressing Ctrl+C when a full-screen image is active, the full-resolution image is copied to the 'clipboard' of the Microsoft Windows™ operating system.

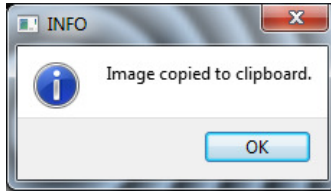


Figure 10: Message appears after copy operation

1.6 Creating essential optical functions

All optical functions from the menu point *Essential Optical Functions* appear in a new window after input of the required parameters. Depending on the optical function, binary or multilevel, the task bar of the full-screen window will be slightly different (compare section 1.5).

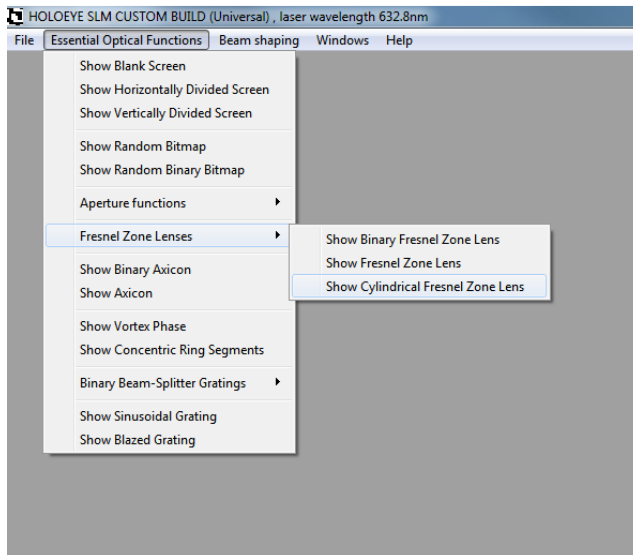


Figure 11: Menu entries for optical functions

1.6.1 Blank Screen

With this function you can create a homogeneous graylevel screen. You will be asked to enter the desired graylevel.

1.6.2 Horizontally Divided Screen

With this function you will create a horizontally divided screen, consisting of two homogeneous graylevel partial screens.

1.6.3 Vertically Divided Screen

With this function you will create a vertically divided screen, consisting of two homogeneous graylevel partial screens.

1.6.4 Random Bitmap

With this function you will create a random pixel distribution using 256 graylevels. This function can be used to realize the optical function of a random phase plate.

1.6.5 Random Binary Bitmap

With this function you will create a random pixel distribution using only two grayscale values. This function can be used to realize the optical function of a random binary phase plate.

1.6.6 Aperture Functions

1.6.6.1 Rectangular Aperture

Use this function to create a rectangular aperture. The size of the aperture can be defined by specifying the aperture width and aperture height. With the sliders on the taskbar one can change the gray levels of the background and of the aperture.

1.6.6.2 Circular Aperture

Use this function to create a circular aperture. The radius of the aperture can be defined by specifying a numbers of pixels. With the sliders on the taskbar one can change the graylevels of the background and of the aperture.

1.6.6.3 Single Slit and Double Slit

To create a single slit choose the point 'Show Single Slit' from the menu point *Aperture Functions*. The slit width can be defined by the number of pixels in the dialog window.

To create a double slit choose the point 'Show Double Slit' from the menu point *Aperture Functions*. Moreover the slit distance can also be defined. This refers to the distance between both slits.

1.6.7 Fresnel Zone Lenses

1.6.7.1 Binary Fresnel Zone Lens

Use this function to create a Binary Fresnel Zone Lens graylevel image representation. In the dialog field the lens function can be characterized by the radius of the smallest ring, which is defined by a number of pixels $N_{r,min}$. The focal length of the lens is given by

$$f = \frac{(N_{r,min} p)^2}{\lambda}$$

where λ is the wavelength of the laser which was entered when starting the software.

1.6.7.2 Fresnel Zone Lens

Use this function to create a 256-level Fresnel Zone Lens grayscale image representation. In the dialog field the lens function can be characterized by the radius of the smallest ring, which is defined by a number of pixels. The focal length of the lens is given by

$$f = \frac{(N_{r,min} p)^2}{2\lambda}$$

where λ is the wavelength of the laser which was entered when starting the software.

It can be specified whether the image representing the lens should be positive or negative.

1.6.7.3 Cylindrical Fresnel Zone Lens

Use this function to create a 256-graylevel image representation of a Cylindrical Fresnel Zone Lens. In the dialog field the lens function can be characterized by the width of the central zone, which is defined by a number of pixels $N_{w,min}$. The focal length of the cylindrical lens is given by

$$f = \frac{(N_{w,min} p)^2}{8\lambda}$$

where λ is the wavelength of the laser which was entered when starting the software.

The angular orientation of the cylindrical lens can be entered in degrees (integer values only).

1.6.8 Binary Axicon

Use this function to create a Binary Axicon graylevel image representation. In the dialog field the lens function can be characterized by the radius of the smallest ring, which is defined by a number of pixels.

1.6.9 Axicon

Use this function to create a 256-level Axicon grayscale image representation. In the dialog field the axicon function can be characterized by the radius of the smallest ring, which is defined by a number of pixels. It can be specified whether the image representing the lens should be positive or negative.

1.6.10 Vortex Phase

Use this function to create a 256-graylevel image representation of a vortex phase (often also referred to as 'helical phase' or 'spiral phase'). In the dialog field the radius a central zone with constant phase can be specified as a number of pixels. The order of the vertex can be entered also as an integer value, for production of higher-order Laguerre-Gaussian beams.

Note that the angular orientation of the line where the phase changes from 0 to 2π can be modified by superposition of the displayed phase with a constant phase value (see section 1.5.7, 'Cycling of graylevel values').

1.6.11 Concentric ring segments

Use this function to create binary images consisting of concentric ring segments. In the dialog field the image function can be characterized by the radius of the smallest ring, which is defined by a number of pixels, and the desired number of segments, which can be varied from two to 20 (even numbers only).

1.6.12 Binary beam-splitter gratings

1.6.12.1 Linear Gratings and Crossed Linear gratings

Choose from the menu *Binary beam-splitter gratings* the item ‘*Show Binary Linear Grating*’ to create a grating. The grating period can be defined by the number of pixel. By selecting the boxes the grating direction can be chosen to horizontal or vertical. Check both boxes to overlap a horizontal with a vertical grating and obtain a crossed grating.

1.6.12.2 Exemplary binary beam-splitter designs

Choose from the menu *Exemplary binary beam-splitter designs* one of the menu items

- *Show Binary Linear 1-to-5 Linear Beamsplitter Grating* (Grating period 26 Pixels)
- *Show Binary 1-to-(2x2) Separable Array Beamsplitter Grating* (Grating period 18x18 Pixels)
- *Show Binary Array 1-to-(5x5) Separable Array Beamsplitter Grating* (Grating period 26x26 Pixels)
- *Show Binary Array 1-to-(5x5) Non-separable Array Beamsplitter Grating* (Grating period 26x26 Pixels)

to obtain a full-screen window with one of the mentioned diffractive elements.

The basic tiles of these gratings are fixed and usable as examples for separable and non-separable binary DOEs.

1.6.13 Sinusoidal Grating

Choose from the menu point *Essential Optical Functions* ‘*Show Sinusoidal Grating*’ to create a sinusoidal grating. The size of the grating period can be specified by the number of pixels.

1.6.14 Blazed Grating

Choose from the menu point *Essential Optical Functions* 'Show Blazed Grating' in order to create a blazed grating. The size of the grating period can be specified by the number of pixels.

1.7 Calculating a beam-shaping phase function for Gaussian Input beams

For incident laser beams with Gaussian beam profile, the SLM can modify that beam shape into other intensity profiles by utilization of an appropriate phase function. The HOLOEYE SLM software provides phase functions for two special cases of such transformation: conversion into spherical and rectangular flat-top profiles.

1.7.1 Transformation of a Gaussian beam to a circular 'flat-top' beam

Select '*Transformation of Gaussian to circular Top-Hat beam*' from the '*Beam Shaping*' menu. The required parameters are the beam diameters ($1/e^2$) in the plane of the SLM, and the parameters of the desired output beam. The parameter 'Order of Super-Gaussian' will influence the slope steepness of the obtained profile. Higher Super-Gaussian Modes have a higher slope steepness.

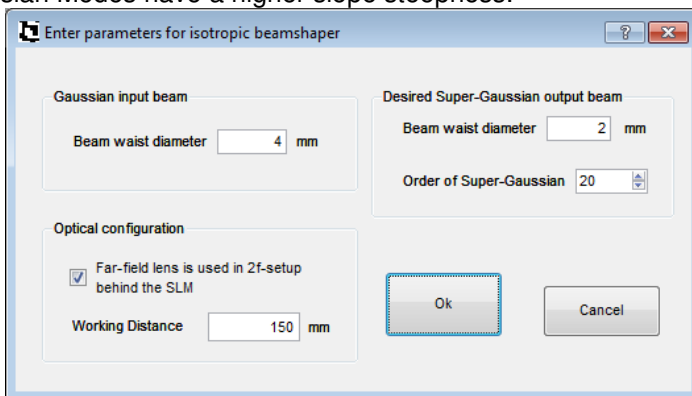


Figure 12: Parameters for computation of a beam-shaping phase

A laser beam can only be focused to a certain diameter depending on beam diameter, lens focal length and wavelength, and beam shaping

phases cannot enable focusing below such limit. Therefore, if the target beam diameter is too small, the software will issue a message and suggest a more realistic target value. (The software currently does not check if the desired target beam size may be too large.)

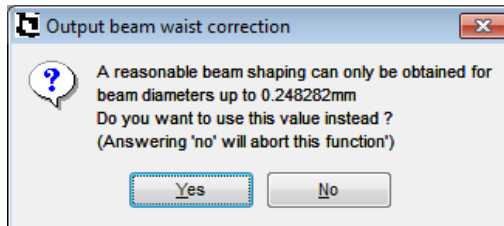


Figure 13: Warning message shown if target beam diameter is too small

The beam-shaping setup may incorporate a Fourier-lens and in this case the working distance is equal to its focal length, as the target plane is identical to the back focal plane. If no lens is used (and the corresponding checkbox is unchecked in the dialog shown above), the lens phase will just be superimposed to the beam-shaping phase.

1.7.2 Transformation of a Gaussian beam to a rectangular 'flat-top' beam

Select '*Transformation of Gaussian to rectangular Top-Hat beam*' from the '*Beam Shaping*' menu. The required parameters are the beam diameters ($1/e^2$) in x and y direction in the plane of the SLM, and the size in x and y direction of the desired output beam. The parameter 'Order of Super-Gaussian' will influence the slope steepness of the obtained profile. Higher Super-Gaussian Modes have a higher slope steepness.

If the target beam dimension is too small to be feasible in either direction, the software will suggest a suitable beam size, maintaining the aspect ratio of the originally desired target beam.

1.8 Superposition with an additional phase map

The HOLOEYE SLM software permits a superposition of the phase functions displayed in its full-screen windows with an additional phase map. This can be utilized to compensate for aberrations of the optical system or that of the SLM. This phase map has to be available in an

image file format (like .bmp, .png) where the grayscale values 0..255 represent phase values of $0 \dots 2\pi$. The phase value will be added to the already displayed phase function. For all pixels with resulting grayscale values of larger than 255, the software will subtract 255 in order to stay within the permitted range of 0..255.

Only one background compensation can be loaded into the software at a time.

1.8.1 Loading

Select '*Load Background Compensation Phase Map from file*' from the '*File*' menu. Note that all already opened full screen windows will be affected. Also, any newly opened full screen windows will be subject to superposition with this background map. The superposition will be indicated in the caption of the full-screen control window by the file name from which it was loaded.

1.8.2 Unloading

Select '*Unload Background Compensation Phase Map from file*' from the '*File*' menu. Note that all open full screen windows will be affected from the operation, i.e. after completion the background compensation phase map will not be applied to any full-screen window.

1.9 The 'Window' Menu

1.9.1 Windows inside the main window

The Menu '*Windows*' contains the usual options for tiling, cascading and closing windows that are opened inside the main window. Selecting an entry in that window list will simply make that window active.

1.9.2 Full-screen windows outside the main window

When full-screen windows are open outside the main window, they will be listed within this menu, with their index number in square brackets. Selecting the cursor position in front of one full-screen window will send the image of this full-resolution image to the screen representing the SLM. De-selecting an entry in this list will render the SLM screen blank.

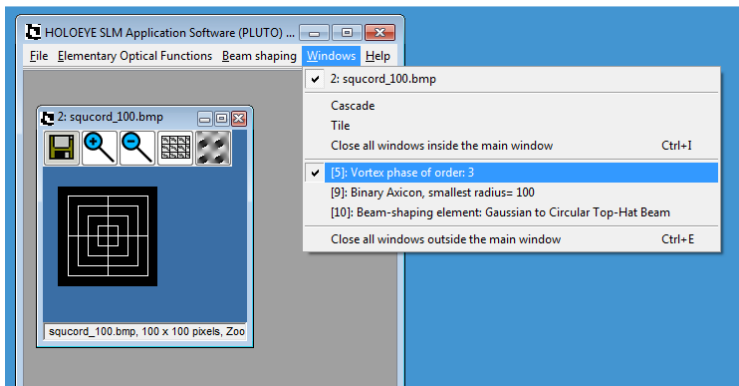


Figure 14: Window menu with list of internal and external windows

In addition, all of these windows can be closed at once via a separate menu point '*Close all windows outside the main window*'. Of course the menu item '*Close all windows inside the main window*' does not affect full-screen windows outside and vice versa.

If you have any further questions, please get in contact with
HOLOEYE:



HOLOEYE Photonics AG
Albert-Einstein-Str. 14
D-12489 Berlin
slm@holoeye.com
www.holoeye.com