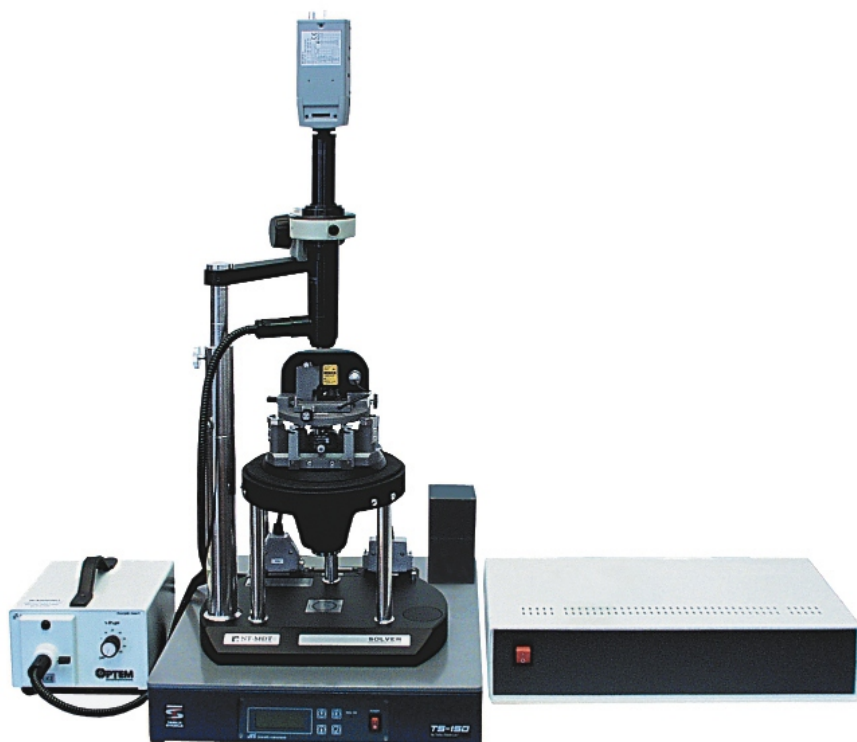


Solver PRO SPM INSTRUCTION MANUAL



NT-MDT Co., Zelenograd
Research Institute
of Physical Problems
124460, Moscow, Russia
tel.: +7(095) 535-03-05
fax: +7(095) 535-64-10
e-mail: spm@ntmdt.ru
<http://www.ntmdt.com>

Windows Control Program

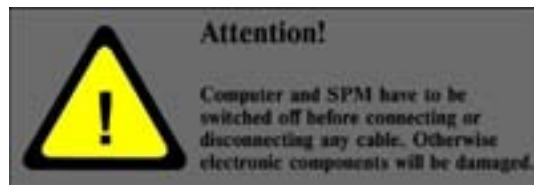
PLEASE, READ

Notice: A delivery set of your device may differ from the set described in the given manual. For more detailed information refer to the specification of your contract.

Copyright: No part of this manual for no purposes may be reproduced or transmitted in any form and by any means, electronic or mechanical, including photocopying and video-recording, without a written permission from the NT-MDT company.

GENERAL SAFETY MEASURES

- Observe safety measures for operation with electrical installations. Prior to begin operation with the device, provide its grounding. Prior to connect or disconnect the connectors, turn off the device. Connecting or disconnecting of the connectors in the process of work may lead to damage of the electrical circuit and death of the device. Warning label is located on the back panel of electronics block.



- Observe safety measures for operation with instruments having laser radiation source. Do not stare into beam. Warning label is located on the measuring head



- Do not disassemble any part of the device! Disassembling of the product is permitted only for experts certified with the NT-MDT company.
- Do not connect additional devices to the instrument without advice from NT-MDT specialists.
- Protect the device from powerful mechanical effects.
- Protect the device from the effect of high temperatures and liquids ingestion.
- When transporting, provide packaging of the device which eliminates damage in the process of transportation.

Solver PRO SPM Instruction Manual

Contents at a Glance

1	FIRST TIME INSTALLATION	7
2	INSTRUMENT PREPARATION FOR AFM MODE OPERATION	20
3	CONTACT ATOMIC FORCE MICROSCOPY.....	65
4	SEMICONTACT ATOMIC-FORCE MICROSCOPY.....	91
5	MANY-PASS TECHNIQUES	114

SPM Solver PRO Instruction Manual

Contents

1	FIRST TIME INSTALLATION	7
1.1	INTERFACE BOARD INSTALLATION.....	7
1.2	SOFTWARE SETUP.....	7
1.3	CONNECTION OF ELECTROMECHANICAL UNITS OF THE INSTRUMENT	11
1.4	INSTRUMENT AND CONTROL SOFTWARE LAUNCH	13
1.5	CONTROL SOFTWARE INTERFACE	14
1.5.1	Main menu	15
1.5.2	Key parameters panel.....	16
1.5.3	Key operations bookmark panel	16
1.5.4	Status line.....	16
1.5.5	Working window	16
1.5.6	Additional Window.....	17
1.5.7	Input fields and sliders.....	18
1.6	SAVING THE DATA.....	18
1.7	INSTRUMENT AND PROGRAM SHUTDOWN	19
2	INSTRUMENT PREPARATION FOR AFM MODE OPERATION	20
2.1	BASIC PROCEDURE OF THE INSTRUMENT PREPARATION FOR THE OPERATION	20
2.2	ELECTROMECHANICAL CONFIGURATION	20
2.2.1	Scanning by sample	21
2.2.2	Scanning by probe	22
2.2.3	Connection specifics when working with the CLE.....	23
2.2.4	Deactivating scanning axes.....	23
2.2.5	Connection specifics for Solver PRO-M.....	23
2.3	INSTRUMENT TURNING ON	24
2.4	LOADING SCANNER CALIBRATION PARAMETERS	24
2.5	PREPARING THE CLE SCANNER FOR OPERATION.....	26
2.5.1	Adjusting the CLE sensors.....	26
2.5.1.1	<i>Program launching of the CLE.....</i>	<i>27</i>
2.5.1.2	<i>Troubleshooting: how to avoid parasitic oscillations.....</i>	<i>28</i>
2.6	PREPARING THE SCANNER WITH BUILT-IN SENSORS FOR OPERATION.....	29
2.7	PREPARATION OF THE INSTRUMENT FOR THE "SCANNING BY SAMPLE" CONFIGURATION	29
2.7.1	More detailed description of basic operations and procedures listed above is given below. Universal measuring head preliminary preparation	29
2.7.2	Installing the probe	31
2.7.3	Adjusting the optical system of the cantilever deflection detection.....	33
2.7.3.1	<i>Laser turning on.....</i>	<i>33</i>
2.7.3.2	<i>Window of the optical system adjustment</i>	<i>33</i>
2.7.3.3	<i>General information about the laser beam alignment with the cantilever.....</i>	<i>34</i>
2.7.3.4	<i>The suggested procedure of the laser spot steering onto the cantilever</i>	<i>35</i>
2.7.3.5	<i>Photodiode alignment</i>	<i>41</i>
2.7.3.6	<i>Fine-adjustment of the optical system using the photodiode indicator</i>	<i>42</i>
2.7.4	Measuring head preinstallation	42
2.7.5	Preparation and mounting of the sample.....	44
2.7.6	Installing the measuring head on the approach unit.....	45
2.8	PREPARATION OF THE INSTRUMENT FOR THE "SCANNING BY PROBE" CONFIGURATION.....	47
2.8.1	Installing the probe	47
2.8.2	Adjusting the optical system of the cantilever deflection detection.....	49
2.8.2.1	<i>Laser turning on.....</i>	<i>49</i>
2.8.2.2	<i>Window of the optical system adjustment</i>	<i>49</i>

2.8.2.3	General information about the laser beam alignment with the cantilever	50
2.8.2.4	The suggested procedure of the laser spot steering onto the cantilever.....	51
2.8.2.5	Alignment of the photodiode position with the help of the photodiode indicator.....	58
2.8.2.6	Accurate alignment of the optical system of registration with the help of photodiode indicator.....	59
2.8.3	Preparation and mounting of the sample	59
2.8.3.1	Mounting of samples of small size.....	59
2.8.3.2	Installation of the samples of big sizes.....	62
2.8.4	The installation of scanning measuring head	62
2.8.4.1	Installation of measuring head on the approach unit.....	62
2.8.4.2	Checking the plane of the SPM head base and the sample base for being parallel....	63
2.8.4.3	A preliminary landing of the sample to the probe.....	63
3	CONTACT ATOMIC FORCE MICROSCOPY.....	65
3.1	CONSTANT FORCE MODE	65
3.1.1	Introduction: initial state and basic operations of contact microscopy mode.....	65
3.1.2	Switching the device over to the contact mode of operation.....	66
3.1.3	Setting the initial level of DFL signal	66
3.1.4	Approaching the sample to the tip.....	68
3.1.5	Setting the operating level of Feedback Loop Gain	71
3.1.6	Setting the parameters of scanning.....	72
3.1.6.1	Setting SPM operating mode.....	72
3.1.6.2	Setting the scan size, the points number and the scanning step size	72
3.1.6.3	Setting the parameters of scanning: velocity of scanning	74
3.1.7	Scanning.....	74
3.1.7.1	Scanning start.....	75
3.1.7.2	Modifying the parameters during scanning.....	76
3.1.7.3	Adjusting the parameters during scanning.....	77
3.1.7.4	Certain recommendations on the optimization of the parameters of scanning	78
3.1.8	Saving the obtained results.....	78
3.1.9	Operation completion.....	79
3.2	LATERAL FORCE MODE.....	80
3.2.1	Brief description of the Lateral Force Mode	80
3.2.2	A signal, related to the torsion deformation of cantilever	80
3.2.3	Preparation and operation of the device in Lateral Force Mode	81
3.3	CONSTANT HEIGHT MODE	82
3.3.1	Brief description of the Constant Height Mode	82
3.3.2	Preparation and operation in Constant Height Mode	83
3.4	SPREADING RESISTANCE IMAGING	84
3.4.1	Measurement preparation.....	84
3.4.2	Mode selection and parameters setup.....	85
3.4.3	Scanning.....	85
3.4.4	Ways of image improvement	86
3.5	FORCE MODULATION	86
3.5.1	Measurement preparation.....	86
3.5.2	Mode selection and parameters setup.....	87
3.5.3	Scanning.....	88
3.5.4	Ways of image improvement	89
3.6	CONTACT ERROR MODE.....	89
3.6.1	A brief description of Contact Error Mode	89
3.6.2	Contact Error Mode preparatory procedures and operation	89
3.6.3	Examples of Contact Error Mode application.....	90
4	SEMICONTACT ATOMIC-FORCE MICROSCOPY.....	91
4.1	SEMICONTACT MODE.....	91
4.1.1	Introduction. Initial State. Major Operations When Working Under SemiContact Microscopy ..	91
4.1.2	Switching Instrument for Operation under SemiContact Mode.....	92
4.1.3	Setting Cantilever Operational Frequency	93
4.1.4	Setting MAG Signal Initial Level	96
4.1.5	Approaching a Sample to the Probe	97
4.1.6	Setting Feedback Gain Factor Operational Level	100
4.1.7	Setting Scanning Parameters.....	101

4.1.7.1	Setting Operational SPM Mode	101
4.1.7.2	Setting Scan Size, Point Number, Step Size.....	102
4.1.7.3	Setting Scanning Parameters: Scanning Rate.....	103
4.1.8	Scanning	104
4.1.8.1	Scanning Launch.....	104
4.1.8.2	Changing Parameters When Scanning	105
4.1.8.3	Adjusting Parameters When Scanning.....	107
4.1.8.4	Some Recommendations in Regard to Scanning Parameters Optimization.....	107
4.1.9	Saving Acquired Data	107
4.1.10	Operation completion	108
4.2	SEMICONTACT ERROR MODE	109
4.2.1	A brief description of SemiContact Error Mode.....	109
4.2.2	SemiContact Error Mode preparatory procedures and operation.....	109
4.2.3	Examples of SemiContact Error Mode application.....	110
4.3	PHASE CONTRAST MODE	111
4.3.1	Measurement preparation.....	111
4.3.2	Mode selection and parameters setup	112
4.3.3	Scanning	113
4.3.4	Ways of image improvement	113
5	MANY-PASS TECHNIQUES	114
5.1	SCANNING CAPACITANCE MICROSCOPY (SCM).....	114
5.1.1	Mode selection.....	115
5.1.2	Frequency-phase adjustment of cantilever oscillations for the second pass	115
5.1.3	Scanning	117
5.1.4	Ways of improving the image quality.....	118
5.2	MAGNETIC FORCE MICROSCOPY (MFM)	118
5.2.1	Mode selection.....	119
5.2.2	Frequency-phase adjustment of cantilever oscillations for the second pass	120
5.2.3	Scanning	121
5.2.4	Ways of improving the image quality.....	122
5.3	ELECTRIC FORCE MICROSCOPY (EFM)	123
5.3.1	Mode selection.....	124
5.3.2	Frequency-phase adjustment of cantilever oscillations for the second pass	124
5.3.3	Scanning	126
5.3.4	Ways of improving the image quality.....	127

1 First time installation

1.1 Interface board installation

As mentioned above, normally the control PC is supplied with the pre-installed interface board. If the control PC is supplied separately, the interface board can be installed by either a certified installation engineer or by the customer.

To install the interface board, follow this procedure:

1. Disconnect the control PC from the wall outlet;
2. Open the PC case;
3. Select an empty PCI slot on the motherboard where you want to install the interface board;
4. Remove (unscrew) the gap closure from the selected slot. Insert the board accurately into the slot against stop. Make sure the board is installed in the slot evenly without any skew;
5. Fix the interface board using the screw from the gap closure;
6. Make sure no cords and wires touch the board. If necessary, fasten free cords properly inside the PC case.
7. Close the PC case and connect it to the wall outlet.

1.2 Software setup

1. Turn on the control PC;
2. Insert the setup disk into CD-ROM drive;
3. Run **setup.exe**. The “**NT-MDT Nova installation**” window appears:

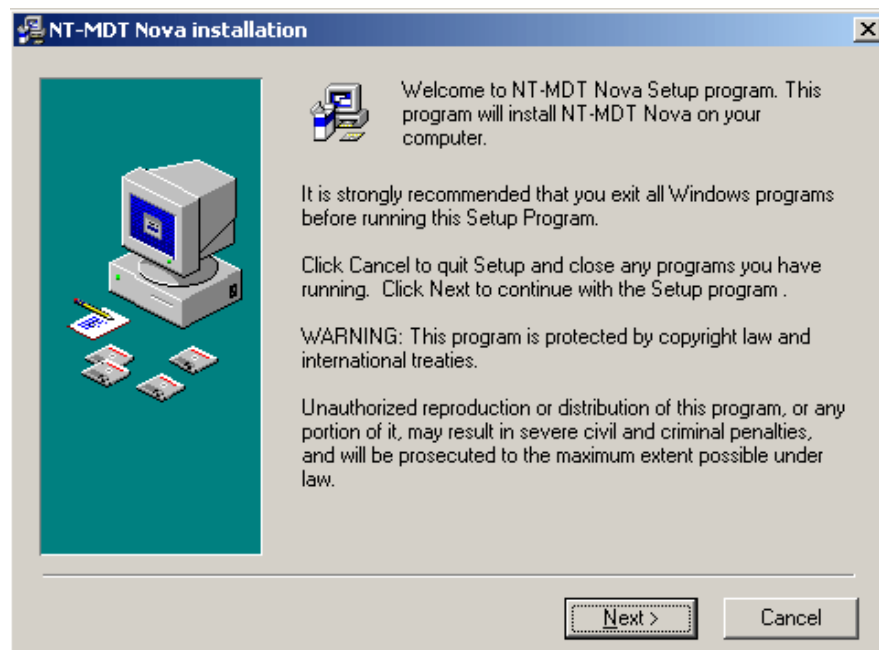


Fig. 1-1

To begin the installation, press “**Next**”

4. The “**License Agreement**” window appears:

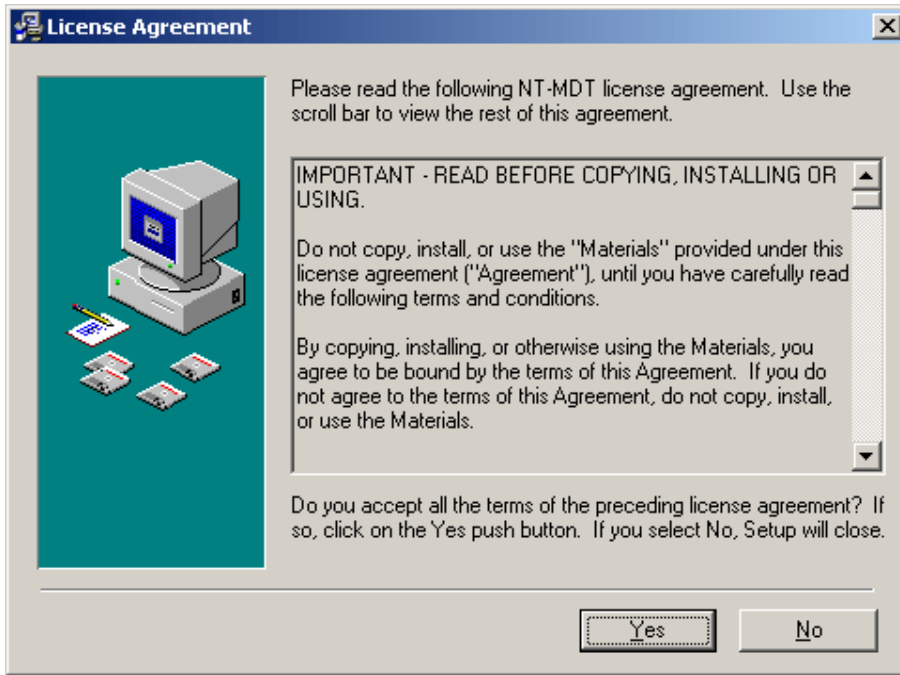


Fig. 1-2

If you agree with all the terms of the license agreement, press “Yes”. If you select “No”, Setup will close.

5. Select a destination folder where Setup will install the “**NT-MDT Nova software**”. By default the destination folder is “**C:\Program Files\NT-MDT\Nova**”;

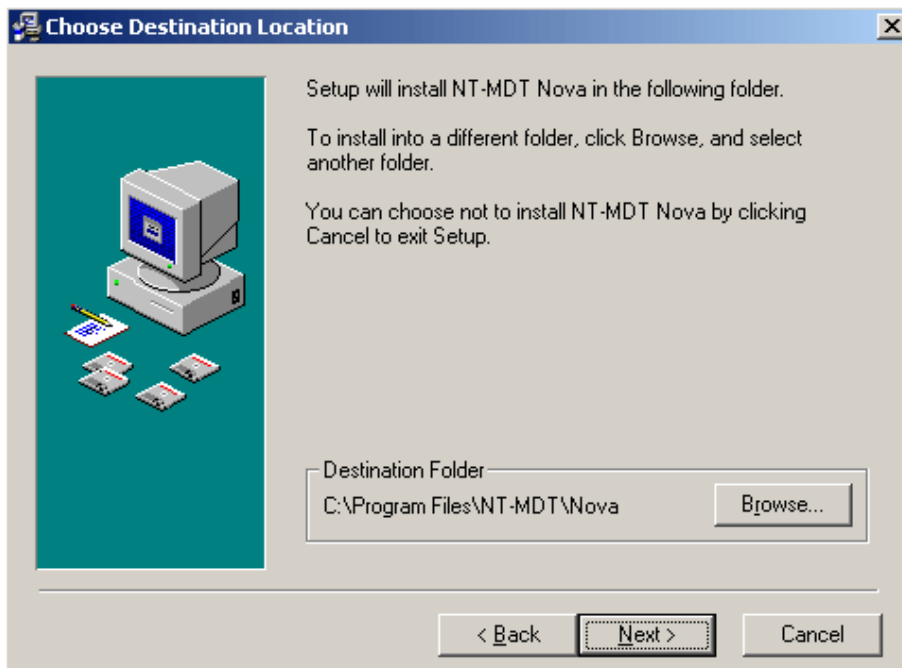


Fig. 1-3

- To begin the installation, press “Next” in the “Start NT-MDT Nova Installation” window;

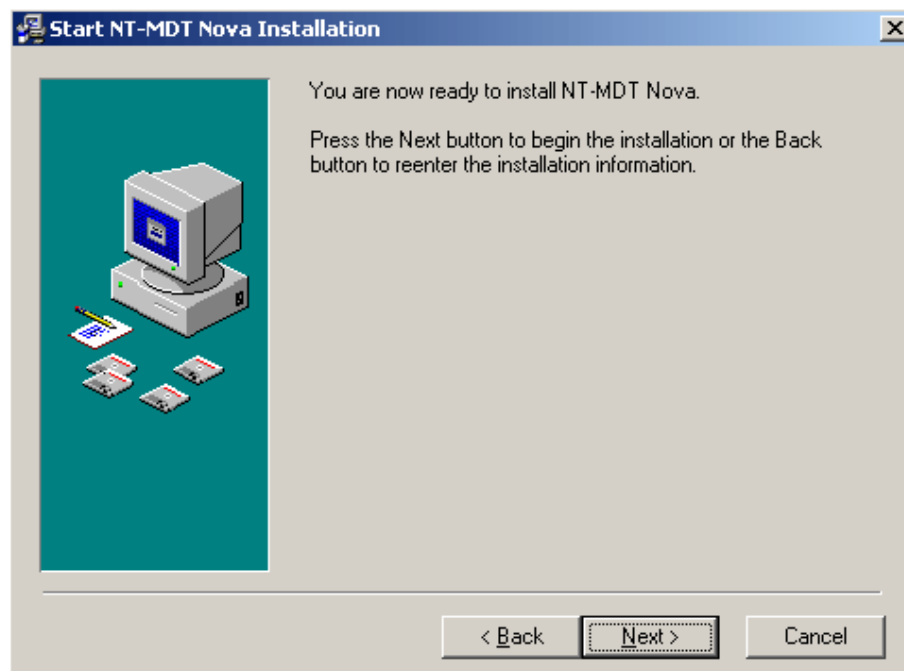


Fig. 1-4

- Setup will begin copying files into the destination folder.

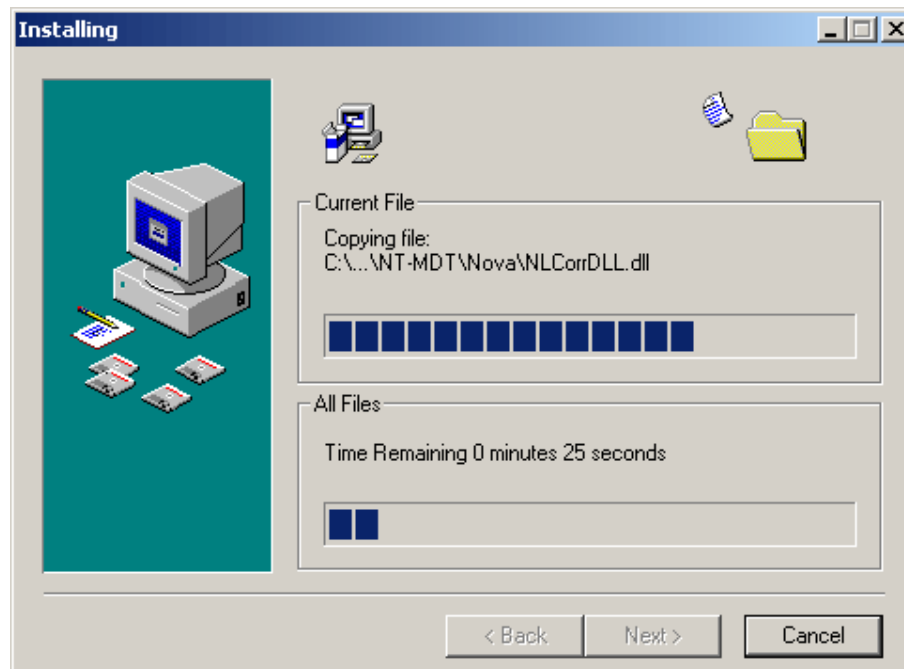


Fig. 1-5

- 8. In case you repeat the installation, the installation program can create backup copies of all files replaced during the installation. In the **“Backup Replaced Files”** window select if you want to create backups of the replaced files and the directory where the replaced files will be copied. By default the directory is **“C:\Program Files\NT-MDT\Nova\BACKUP”**.

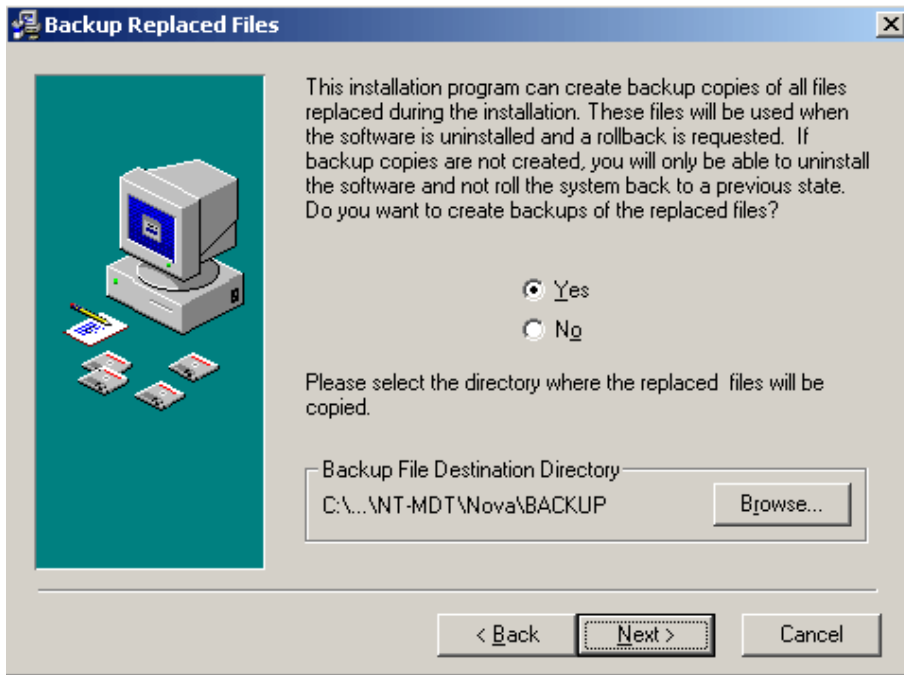


Fig. 1-6

- 9. The **“PNL driver installation”** window appears;

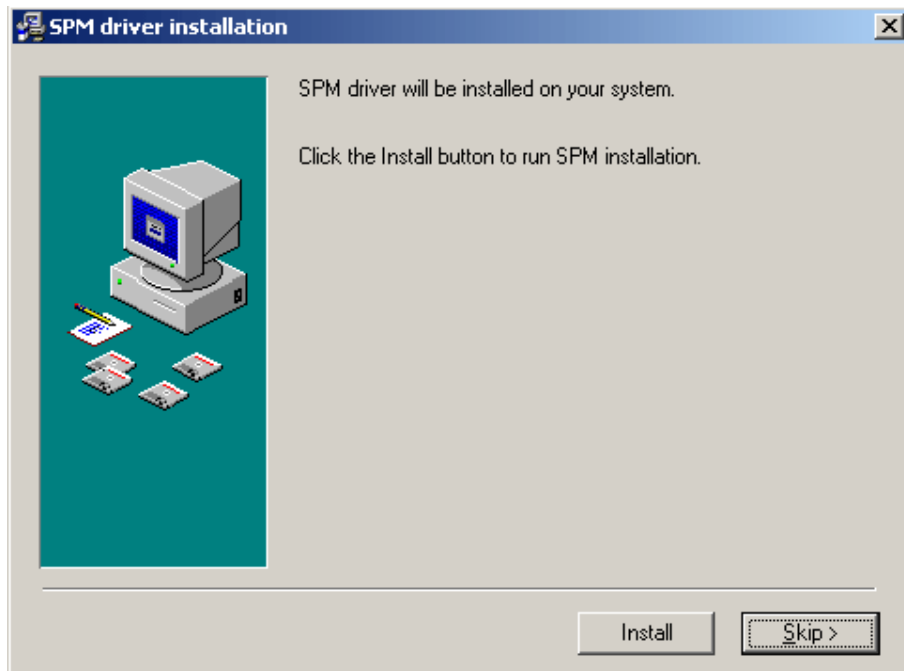


Fig. 1-7

10. Restart your computer before the new settings will take effect;

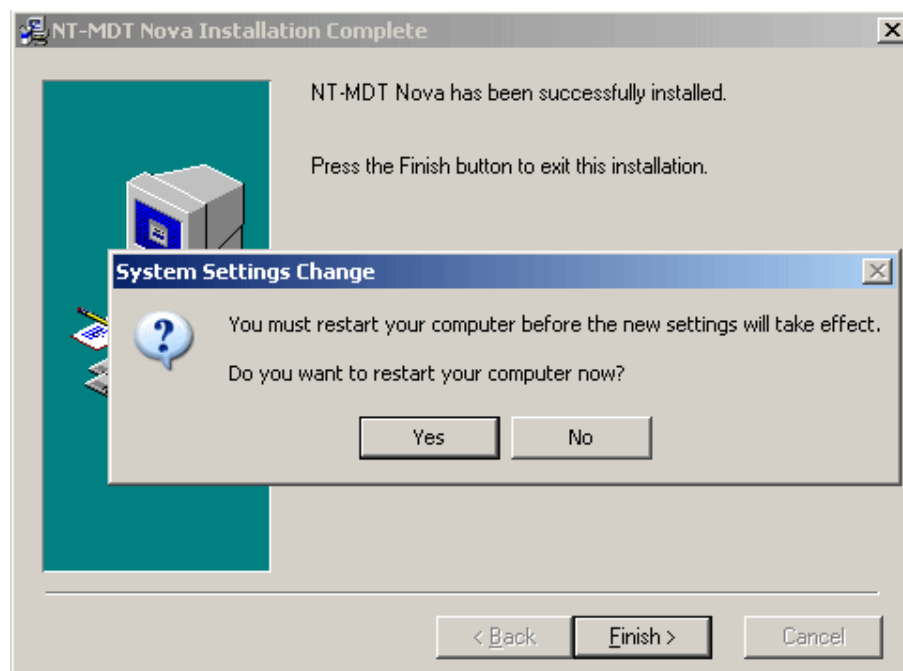


Fig. 1-8

11. The Nova icon appears on your desktop after successful installation.

1.3 Connection of electromechanical units of the instrument



Switch off the computer and the controller before making any connections/disconnections. Disconnection or connection during the device operation can result in damage of the electronic circuit and failure of the device.



Procedure of connection for Solver PRO-M model is different for Solver PRO model and will be described below

In order to connect the instrument units perform the following actions:

1. Use the cable to connect the approach unit and the measuring head to the switching unit (see [Fig. 1-9](#)) observing the connector labels.

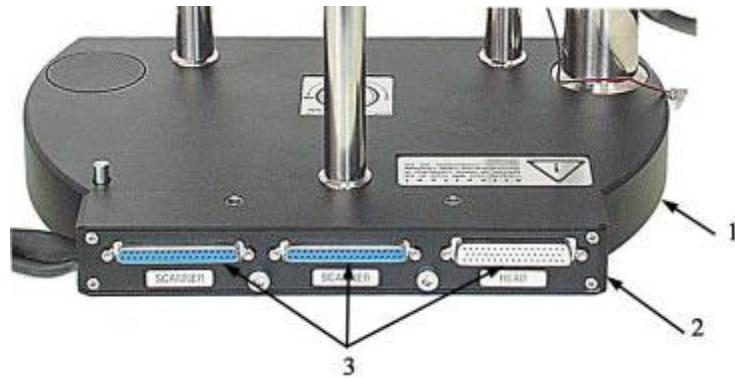


Fig. 1-9 Switching unit

1 – instrument base, 2 – switching unit, 3 - reciprocal connectors of the switching unit



*The switching unit has two identical **SCANNER** connectors.*

2. Connect the switching unit with The SPM controller as follows:

For a configuration with the CLE:

When working with the CLE, the instrument is connected according to the scheme presented on [Fig. 1-10](#).

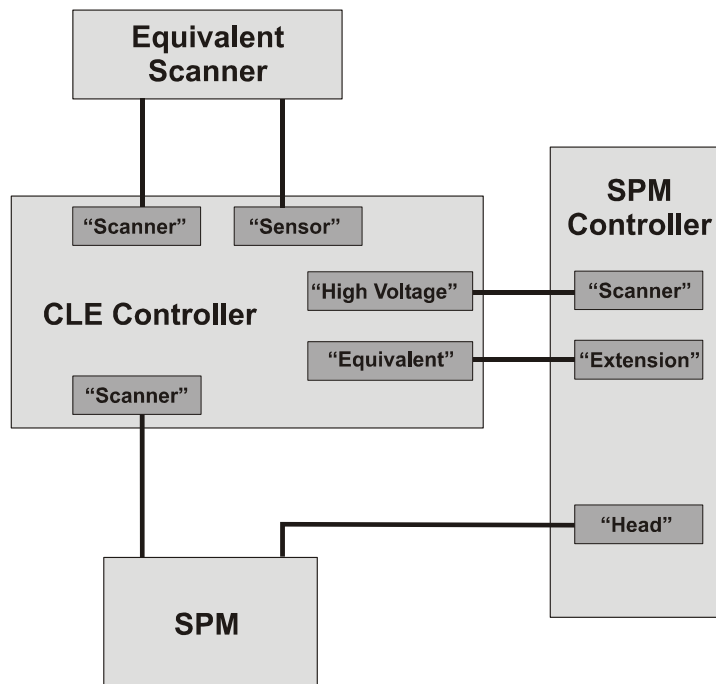


Fig. 1-10 Connecting scheme of the instrument units when using CLE

For a configuration without the CLE:

Connect the switching unit to the SPM controller observing the connector labels.



*SPM controller has two identical **SCANNER** connectors.*

3. Ground the SPM controller.

Connection specifics for Solver PRO-M

Solver PRO-M delivery set includes the scanning measuring head with capacitance sensors. Besides that, Solver PRO-M uses another model of the controller (see contract specification). The CLE is not included in the delivery set of the instrument.

In order to connect the Solver PRO-M units perform the following actions:

1. Connect the approach unit cable to any reciprocal part of **SCANNER** connector on the switching unit.
2. Connect the scanning measuring head to the SPM controller using **HEAD** and **CONTROLLER 2** cable connectors.
3. Connect the switching unit to the SPM controller using **SCANNER** cable connector.
4. Ground the SPM controller.

1.4 Instrument and control software launch

1. Connect controllers to a wall outlet.



Controllers have a universal input and may be connected to any AC power point between 90 and 240V (50/60Hz) once the voltage switcher is preliminary set to the position appropriate for your power specification. Disregard of this condition may lead to electronics damage.

2. Turn on the computer.
3. Run the control software using one of the following methods:
 - desktop program icon;
 - launching **NOVA.exe** file located in the program directory.

The main program window appears.

4. Use the power switch on the SPM controller front panel to switch on the instrument.



Warning: Before turning on the instrument, make sure all connectors are plugged and fixed tightly. Loose connection may lead to electronics damage!

After the instrument launching, the control software performs **initialization of the device** to determine its configuration. After the initialization is complete, the instrument status indicator, displayed in the left bottom corner of the main program window, can be in one of the following three states:



- initialization successful. The instrument is ready for operation;



- controller is not turned on;



- interface board not installed or the controller is faulty.

5. Use the power switch on the controller front panel to turn on the Closed-Loop Scanner Equivalent (CLE).



It is recommended to turn on the controllers only after the control software is run


Now the instrument is ready to operate.

6. It is recommended to turn on the controller 40 minutes before starting measurements to achieve the steady state condition.

1.5 Control software interface

The basic components of **Nova** control software interface are (see. [Fig. 1-11](#)):

- Main Menu;
- Panel of Main Parameters;
- Bookmark Panel of the basic operations;
- Working Window;
- Status Bar.

Besides that, in the right top corner of the main program window there is a button , which opens the **Additional Window**.

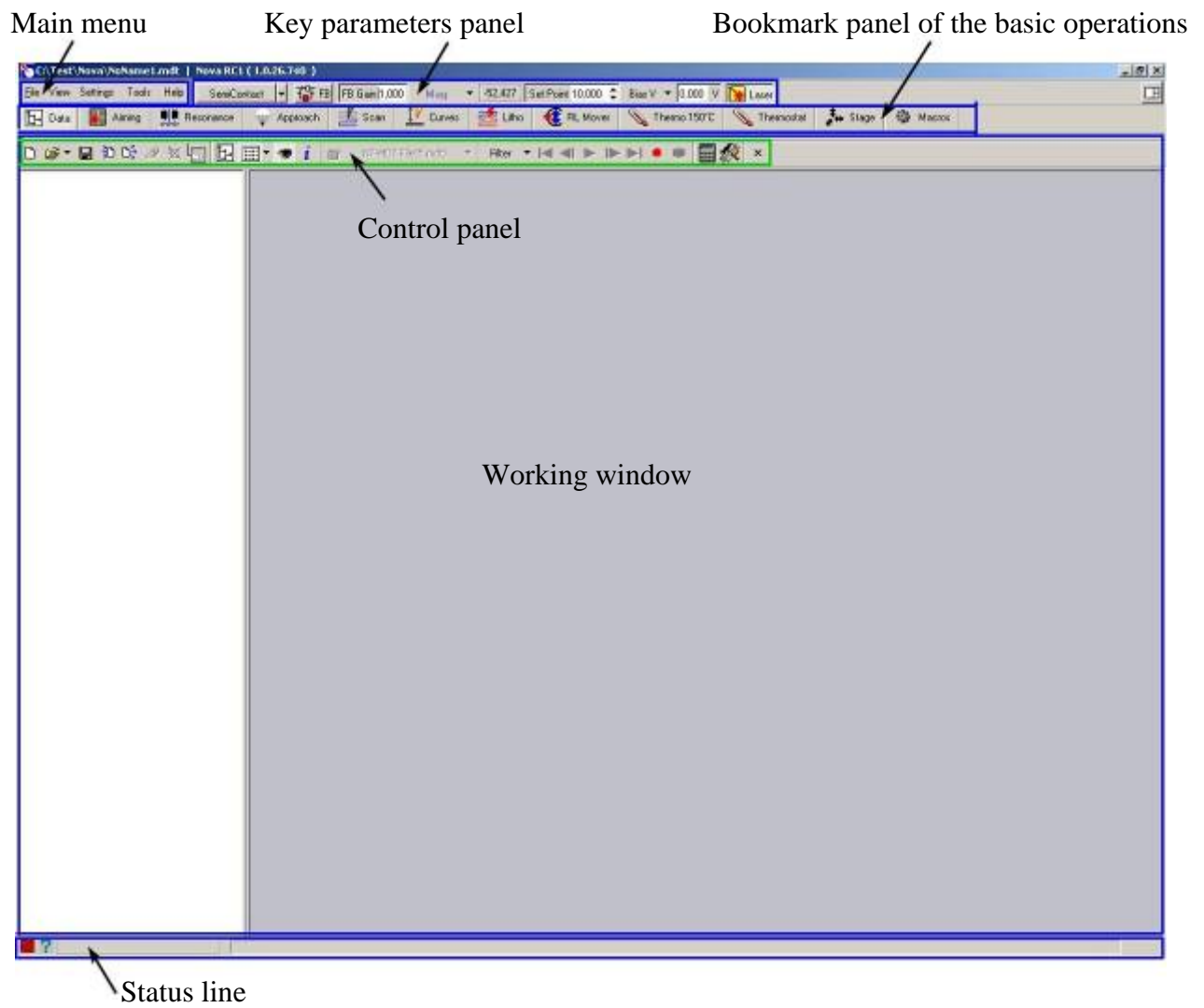


Fig. 1-11. Main control program window

1.5.1 Main menu

There are the following dropdown menus in the main control program menu:

- File** – operations with data files;
- View** – interface settings;
- Settings** – program and instrument settings;
- Tools** – work with the macrolanguage;
- Help** – display help.

1.5.2 Key parameters panel

The key parameters panel is located on the top part of the working screen. It contains a number of most frequently used control elements, which allow to set key scanning parameters.

The first button on the key parameters panel contains the dropdown select menu of an electronic configuration of the instrument ([Fig. 1-12](#)).



Fig. 1-12. Instrument configuration select menu

When **Contact**, **SemiContact** and **TunnelCurrent** menu items are selected, the electronic circuit of the instrument automatically switches, and key parameters are set according to the selected configuration.

When **Custom** menu item is selected, all settings are made manually.

1.5.3 Key operations bookmark panel

Buttons on the key operations bookmark panel are located according to the most typical instrument operating procedure. Using bookmarks it is possible to switch quickly to corresponding working windows. The number of bookmarks depends on the instrument configuration.

1.5.4 Status line

The Status Bar contains the instruments status indicator and the scanner piezotube protraction indicator.

1.5.5 Working window

The main part of the screen is occupied with the working window with the control panel on the top. The example of **Approach** working window is presented on [Fig. 1-13](#).



Each working window has its own control panel

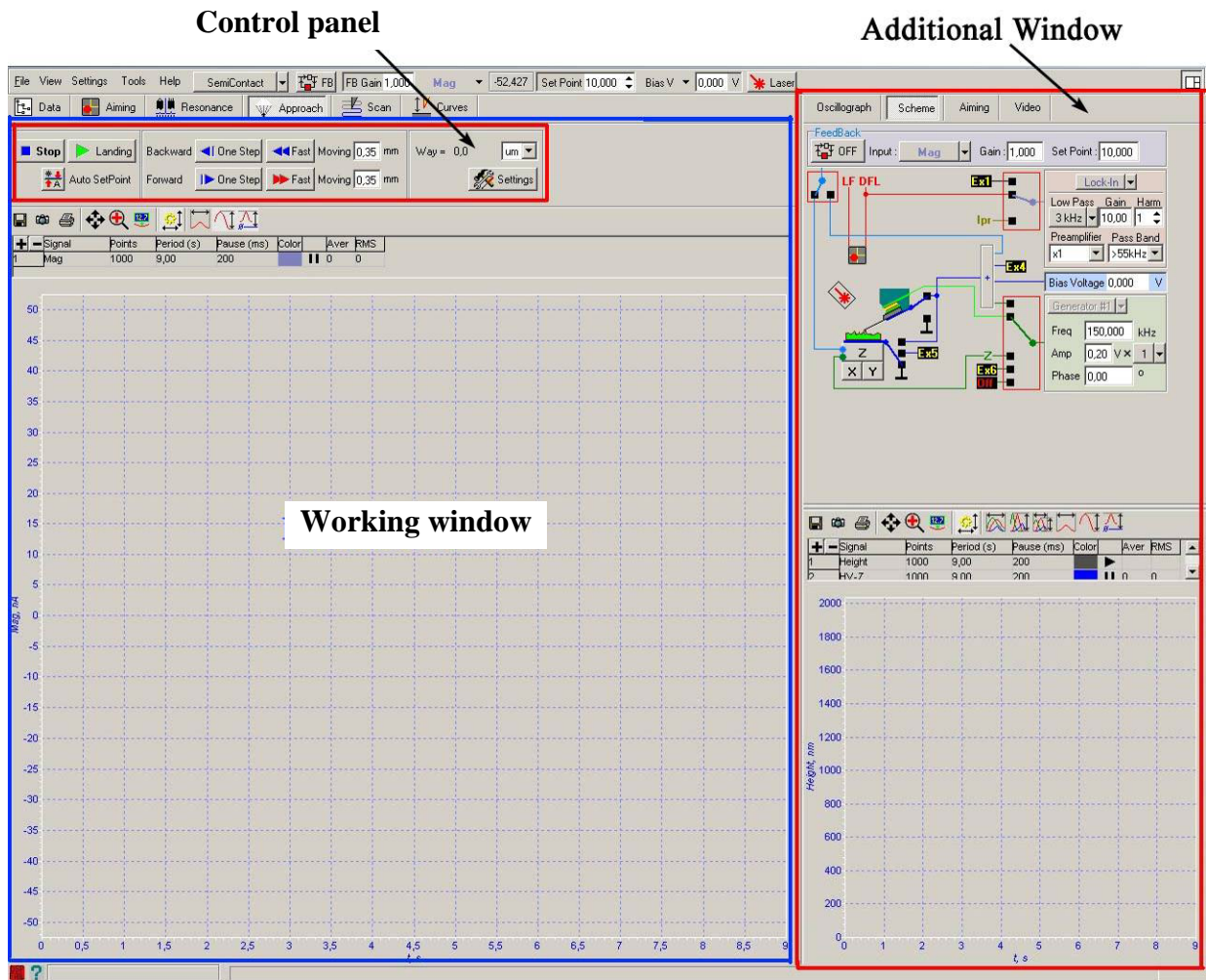



Fig. 1-13. Approach working window. Right: Additional Window is open

1.5.6 Additional Window

In the right top corner of the screen there is a button , which opens the **Additional Window** (see [Fig. 1-13](#)).

The **Additional Window** working area consists of two parts. The bottom part contains a program oscilloscope, which can receive from one up to six signals.

The top part of **Additional Window** contains the bookmarks panel, which opens corresponding additional windows.



The number of bookmarks depends on the instrument configuration.

Instrument block diagram

Scheme bookmark opens a window containing interactive block diagram of the instrument (see [Fig. 1-13](#)). The block diagram is a visual tool allowing to perform software and electronic configuration of the instrument in an interactive mode.

1.5.7 Input fields and sliders

The control program has many input fields (see Fig. 2-14) for entering numeric values of various parameters.

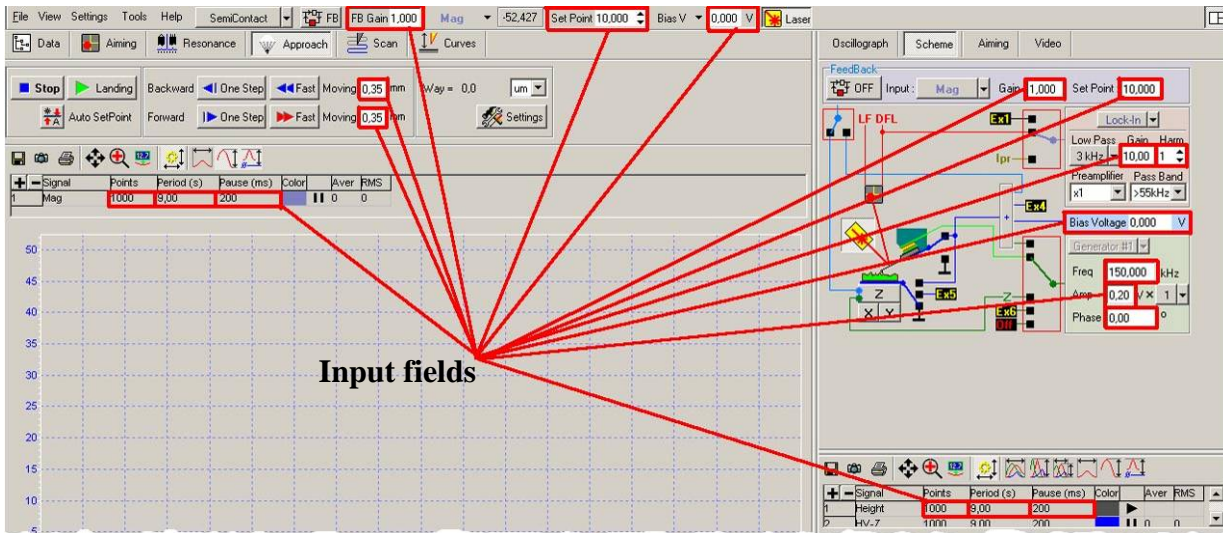


Fig. 1-14. Input fields

Each parameter value can be entered directly from the keyboard, or by double-clicking a corresponding input field and using the appearing slider (Fig. 1-15).

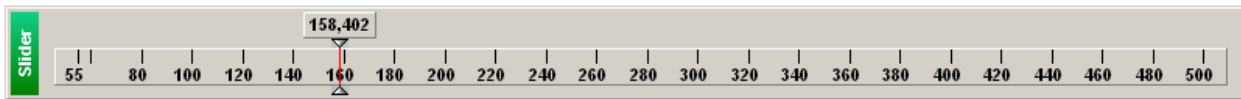


Fig. 1-15. Slider

1.6 Saving the data

To save the obtained data on a hard disk, execute the following:

1. Choose File → Save in the main menu;
2. Select the directory in the pop-up dialogue window to store the obtained data; enter the filename and save it with .mdt extension.



Note: After the sample surface scanning is complete, the obtained data are stored in the operative memory. A separate frame corresponds to each scanned image. Numbering of frames corresponds to the order of their acquisition

1.7 Instrument and program shutdown

1. Use the power switch on the controller front panel to turn off the CLE.
2. Use the power switch on the SPM controller front panel to turn off the instrument.
3. Close all program sub-windows.
4. Close the main program window.

2 Instrument preparation for AFM mode operation

This section describes general preparation procedures with the instrument to perform AFM measurements. These procedures are mandatory during the instrument preparation for operation using any AFM technique.

2.1 *Basic procedure of the instrument preparation for the operation*

Instrument preparation for AFM mode operation generally can be divided into the following basic operations:

1. Select and install necessary configuration;
2. Switch on the device;
3. CLE preparation for operation;
4. Initial preparation of the measuring head;
5. Select and install the probe;
6. Setup of cantilever deflection detection system (point the laser beam onto the cantilever, install the maximal value of **LASER** signal, zero values of **DFL** and **LF** signals);
7. Preliminary installation of the measuring head;
8. Preparation and installation of a sample;
9. Installation of the measuring head on the approach unit.

These operations are described in details below.

2.2 *Electromechanical configuration*



Attention! All commutations during the setting of a required configuration are performed with the electrical power switched off.

The instrument completed with all components, parts and accessories allows the user to choose one of three typical configurations:

1. **Scanning by sample** configuration, including the Universal measuring head, approach unit and the scanner;
2. **Scanning by probe** configuration including the Scanning measuring head and approach unit with a sample holder;
3. **DualScan** configuration including the Scanning measuring head, approach unit and the scanner.

2.2.1 Scanning by sample

In this configuration:

1. The approach unit cable is connected to the **SCANNER** socket on the connecting unit ([Fig. 2-1](#));
2. The universal measuring head cable is connected to the **HEAD** socket on the connecting unit ([Fig. 2-2](#));

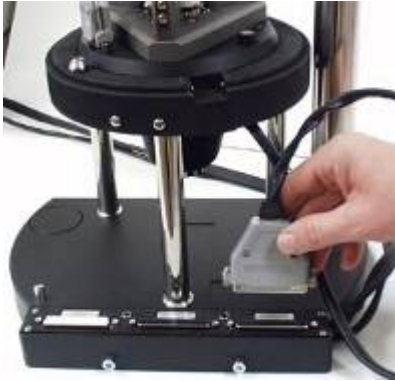


Fig. 2-1

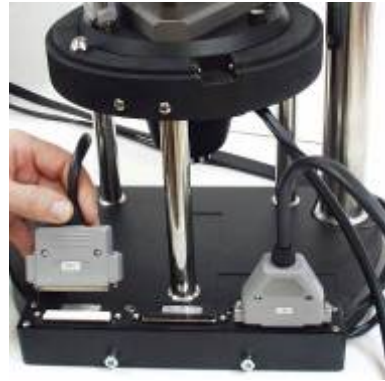


Fig. 2-2

3. The needed scanner is inserted into the positioner on the universal stage unit of the approach unit ([Fig. 2-3](#), [Fig. 2-4](#), [Fig. 2-5](#));



Fig. 2-3



Fig. 2-4

4. The scanner cable is connected to the approach unit connector ([Fig. 2-5](#)).



Fig. 2-5

5. When working without CLE, switching unit cables with HEAD and SCANNER connectors are connected to corresponding SPM controller connectors.

2.2.2 Scanning by probe

In this configuration:

1. The approach unit cable is connected to the «SCANNER» socket on the connecting unit ([Fig. 2-1](#));
2. The scanning head cable with the «HEAD» connector is connected to the «HEAD» socket on the connecting unit ([Fig. 2-6](#));



Fig. 2-6

3. The scanning head cable with the «SCANNER» connector is connected to free socket «SCANNER» on the connecting unit ([Fig. 2-6](#));



Note. The connecting unit has two equivalent «SCANNER» sockets

4. Sample holder is installed into the positioning device ([Fig. 2-7](#), [Fig. 2-8](#)).

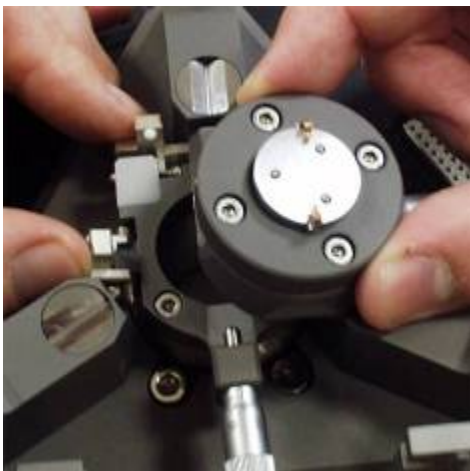


Fig. 2-7

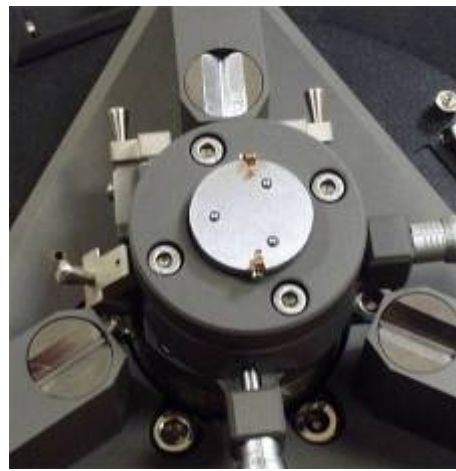


Fig. 2-8

5. When working without CLE, switching unit cables with HEAD and SCANNER connectors are connected to corresponding SPM controller connectors

2.2.3 Connection specifics when working with the CLE

In order to connect the instrument when working with the CLE, perform the following actions:

1. Connect the switching unit cable with **HEAD connector** to a reciprocal connector of the SPM controller.
2. Connect the switching unit cable with **SCANNER** connector to a reciprocal connector of the CLE controller.

2.2.4 Deactivating scanning axes

In "Dual Scan Scanning" configuration scanning can be performed in three following ways:

- with simultaneous scanning by both scanners along all three axes,
- with deactivating of scanning along axis Z of one of scanners,
- with deactivating of scanning along axes X, Y of one of scanners.

Scanning is deactivated using special **Z-OFF** или **X,Y-OFF** adapters ([Fig. 2-9](#))



Fig. 2-9 Adapters for deactivating of scanning along XY and Z axes

Scanner is connected using special adapter to deactivate scanning along specific axes.

2.2.5 Connection specifics for Solver PRO-M

In order to connect the Solver PRO-M units perform the following actions::

1. Connect the approach unit cable to any reciprocal part of **SCANNER** connector on the switching unit.
2. Connect the scanning measuring head to the SPM controller using **HEAD** and **CONTROLLER 2** cable connectors.
3. Connect the switching unit to the SPM controller using **SCANNER** cable connector.

2.3 Instrument turning on

1. The launching is accomplished with the help of the program icon on the desktop. (The program can be started with the help of **NOVA.exe** file, located in the program directory).

The program window will appear in the display.

2. Turn on the PNL controller with power switch located on the front panel.

If turning on is a success, a green "tick" appears in the monitor screen bottom left corner.

2.4 Loading scanner calibration parameters

At program start-up the file **Default.par** is loaded by default, in which the calibration parameters of some certain scanner are contained. If only one scanner is supplied with the system, then **Default.par** contains just the parameters of this scanner. If more than one scanner is supplied with the system, then initially **Default.par** contains the parameters of one of the scanners.

Load a corresponding "par" file once you change a scanner.

"PAR" file load procedure

1. Press the "Settings" button from the top menu bar ([Fig. 2-10](#))

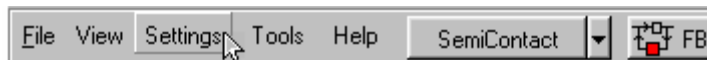


Fig. 2-10

2. Select «Calibrations» from the pop-up menu and then «Load Calibrations» ([Fig. 2-11](#));

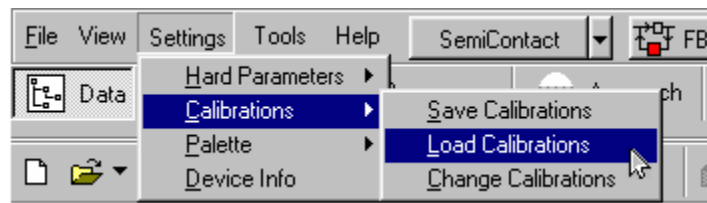


Fig. 2-11

3. The list of PAR files from the PARFiles folder appears, for example, as shown on [Fig. 2-11](#). File names, which correspond to the certain scanners, begin from the letter "z", first two digits after "z" correspond to the max scan size, and next three digits is the scanner serial number. In the given example z10019Y file corresponds to the 10um scanner, z50087Y file to the 50um scanner and z03067Y to the 3um scanner;

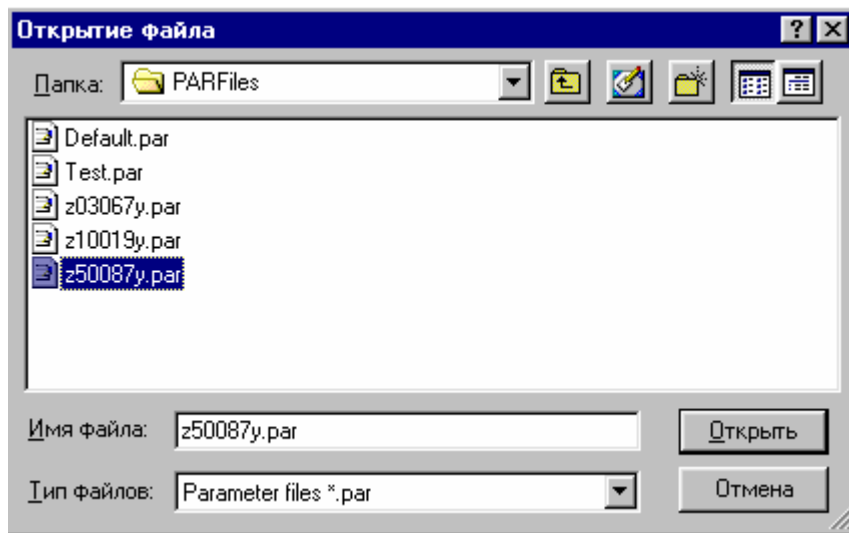


Fig. 2-12

4. Select the required file from the opened PAR file list. For example, if the 50um scanner is installed, you need to select z50087y.par. The file information will be loaded immediately. The calibration parameters remain active until you exit the program. Please notice that next time you run the program again the calibration parameters will be loaded from **Default.par**;
5. If you plan to work with the same scanner for a long time, you can save its parameters in Default.par to make it automatically loaded once you run the program. To do so, after you load the required file as described above (see items 1-4), press **Settings -> Calibrations -> Save Calibrations** (Fig. 2-13). Save file as Default.par (Fig. 2-14).

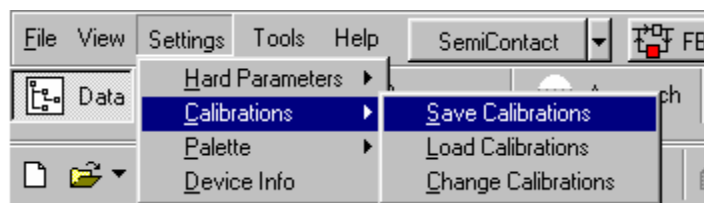


Fig. 2-13

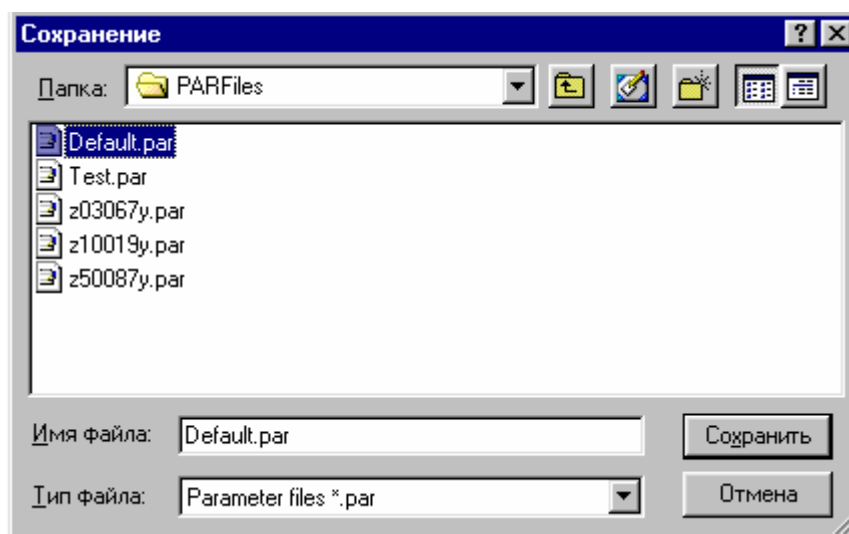


Fig. 2-14

2.5 Preparing the CLE Scanner for operation

In case if a scanner without sensors and the CLE are installed on your device, then in order for that scanner to work in combination with the CLE it is necessary to perform the following procedures:

- Adjustment of capacitance sensors of the CLE
- Program launching of the CLE

2.5.1 Adjusting the CLE sensors



Attention! Adjust the CLE sensors only when the probe is retracted from the sample surface

It is recommended to adjust the sensors once a week.

To adjust the CLE sensors, follow the procedure described below.

1. Turn off the feedback loop if it is on.
2. Click the “**Additional Window**” button on the top right corner of the main window to open the control panel (auxiliary control panel) that provides the access to some additional devices ([Fig. 2-15](#)).

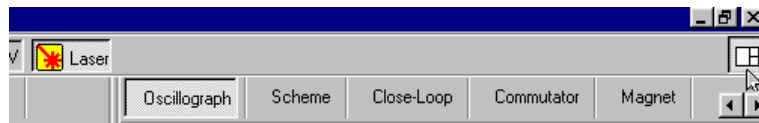


Fig. 2-15

3. Click «**Close Loop**» ([Fig. 2-16](#))

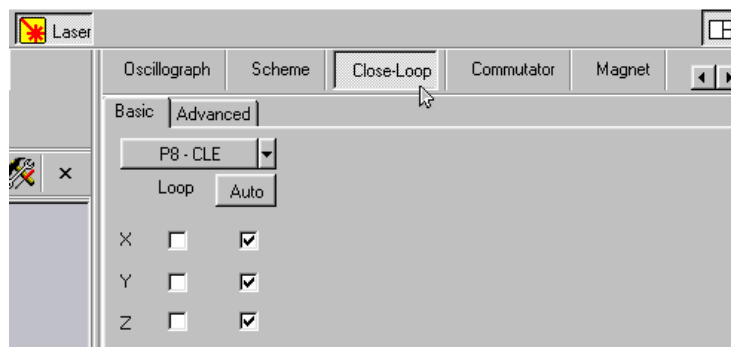


Fig. 2-16

4. Select the «**Basic**» tab ([Fig. 2-16](#))
5. Make sure the automatic adjustment option for X, Y and Z is selected (i.e. three checkboxes under the “**Auto**” button are checked as shown on [Fig. 2-16](#))

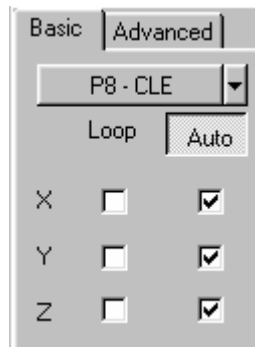


Fig. 2-17

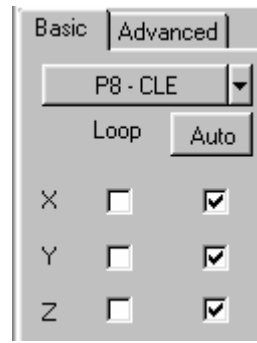


Fig. 2-18

6. Start the automatic CLE sensors adjustment by pressing the «**Auto**» button ([Fig. 2-17](#))

The «**Auto**» button will be unpressed automatically as soon as the procedure is over ([Fig. 2-18](#))

2.5.1.1 Program launching of the CLE

To launch the CLE:

1. Click the «**Additional Window**» button to open the auxiliary control panel ([Fig. 2-15](#))
2. Click «**Close Loop**» ([Fig. 2-16](#)) and select the «**Basic**» tab ([Fig. 2-16](#))
3. Turn on the feedback loop on X and Y by checking the corresponding checkboxes under the «**Loop**» label as shown on [Fig. 2-19](#). The CLE turns off if the checkboxes are unchecked accordingly.



Fig. 2-19

4. Turn off the scanner non-linearity correction option by changing the state of the NLCor button to «**NLCor OFF**» after turning on the feedback on X and Y .



*Note: To turn off the CLE, uncheck the corresponding checkboxes under the «**Loop**» label. Turn on the scanner non-linearity correction by changing the state of the «**NLCor**» button to «**NLCor ON**»*



Note: The CLE is inactive by default once you run the program.

2.5.1.2 Troubleshooting: how to avoid parasitic oscillations

If the AFM image quality becomes worse when using the CLE, check if there are any parasitic oscillations.

1. Press the “**Additional Window**” button to open the auxiliary control panel on the top right corner of the main window (Fig. 2-15). Select «**Oscillograph**» (Fig. 2-20).

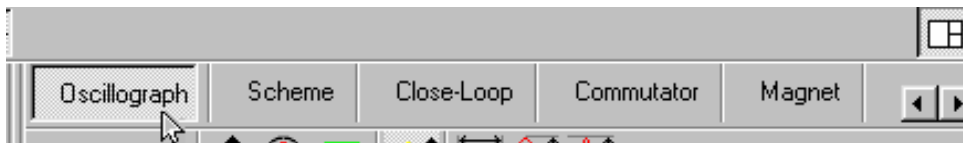


Fig. 2-20

2. Select the “**X Sensor**” signal from the “**Signal**” drop down menu (Fig. 2-21).

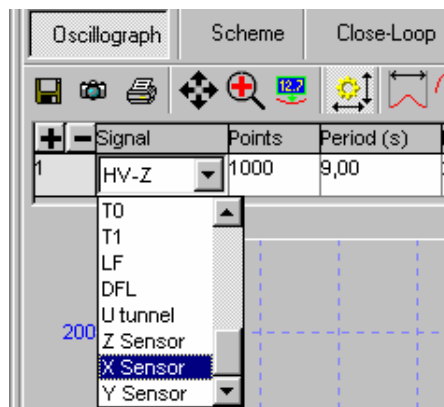


Fig. 2-21

As a result the oscilloscope will display the “**X sensor**” signal (Fig. 2-22)

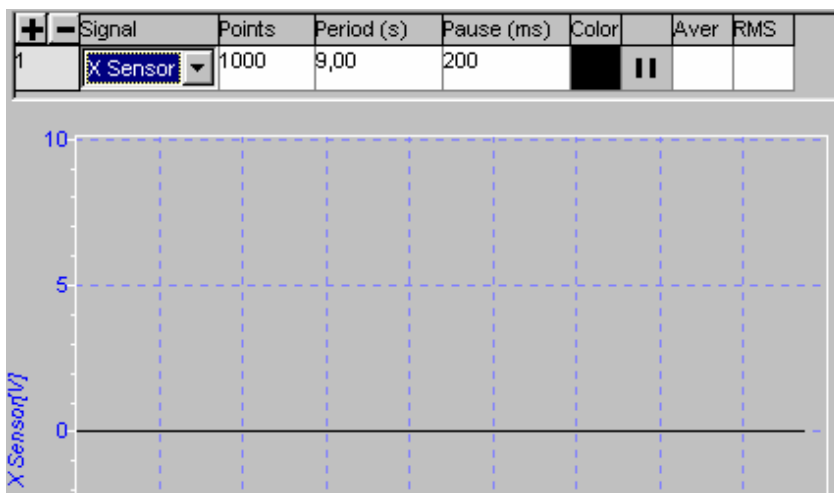


Fig. 2-22

3. Check the amplitude of the “**X sensor**” signal variable component. It must be less than 0.4mV.
4. Set the “**Y Sensor**” signal the same way and check its variable component. Its amplitude must be also less than 0.4mV.

If the amplitudes of «**X Sensor**» and «**Y Sensor**» signals are higher than 0.4mV, then you need to check the environment in which the instrument operates:

- Detect and eliminate any possible external sources of noise and disturbance (electrical, mechanical and acoustical).
- Make sure if the instrument is properly grounded and there are no pulsed current sources that can disturb the normal environment at the frequencies of tens of kHz (it is recommended to use power-line filters).
- Make sure that there is no mechanical vibration (it is strongly recommended to use vibration isolation systems).

2.6 Preparing the scanner with built-in sensors for operation

If you use the scanner with built-in capacitance sensors, follow the same preparation procedure as for the CLE which is described above in i. [2.5](#).

2.7 Preparation of the instrument for the "Scanning by sample" configuration

General procedure of preparation and installation of the measuring head and a sample consists of the following sequence of basic operations and procedures:

1. Initial preparation of the measuring head;
2. Installation of the probe;
3. Setup of cantilever deflection detection system ;
4. Preliminary installation of the measuring head;
5. Installation of a sample;
6. Installation of the measuring head.

2.7.1 More detailed description of basic operations and procedures listed above is given below. Universal measuring head preliminary preparation

Major parts of the universal measuring head are shown in [Fig. 2-23](#), [Fig. 2-24](#):



Fig. 2-23. Universal measuring head front view

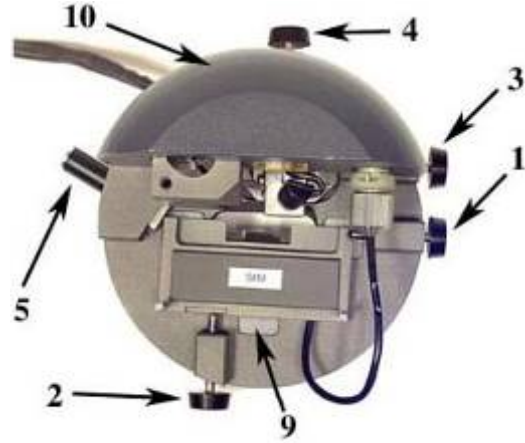


Fig. 2-24. Universal measuring head top view

- 1,2 – Adjustment unit X,Y axes micrometer screws; 3,4 – Photodiode X,Y axes adjusters ;
 5 – Hold-down; 6 – Laser; 7 – Quad photodiode;
 8 – Socket for an adjustment unit connection;
 9 – Polycrystalline sapphire platform; 10 – Case

Place the universal measuring head near the instrument base on a plane surface covered with a sheet of white paper (Fig. 2-25).



Fig. 2-25



Fig. 2-26



Note. It is supposed that measuring head cable is connected to the «Head» socket on the connecting unit

If the adjustment unit is already installed on the universal measuring head and it is necessary to install or replace a cantilever, remove the unit from the measuring head and put it near the head without disconnecting the unit cable [Fig. 2-26](#).

To remove the unit from the universal measuring head, do the following:

- unscrew hold-down 5 (rotating its handle clockwise),
- remove the unit.

If the adjustment unit is not installed on the measuring head:

- choose the unit needed for your measurements,
- turn the unit over and place it near the measuring head ([Fig. 2-26](#));
- connect the unit cable to the measuring head socket (remove socket cap beforehand).

2.7.2 Installing the probe

1. Release the probe clip spring. To do this, turn downward the trapeziform lever, located on the outer side of the holder body, with sharp forceps ([Fig. 2-27](#));

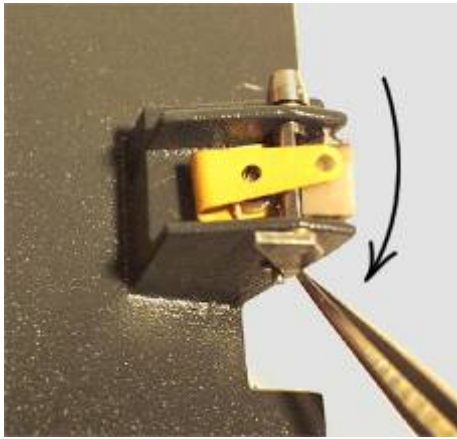


Fig. 2-27

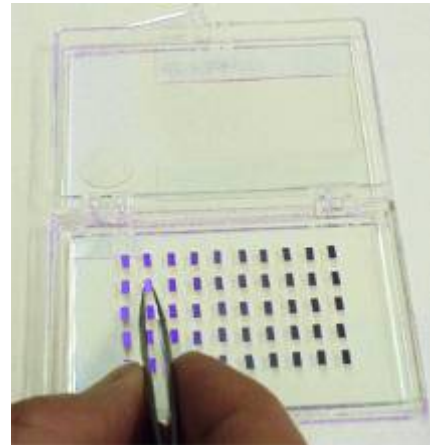


Fig. 2-28

2. Take the probe from the box with the forceps ([Fig. 2-28](#)) making sure that the working side of the chip with cantilevers is directed to you during the installation. Do not turn the chip over because probes in the box are placed with their tips pointing upwards;
3. Place the probe on the polycrystalline sapphire pedestal to the left of the working position ([Fig. 2-29](#), [Fig. 2-30](#)) which is in the right corner under the clip;

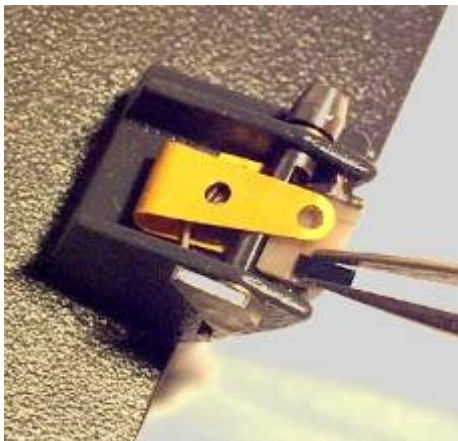


Fig. 2-29

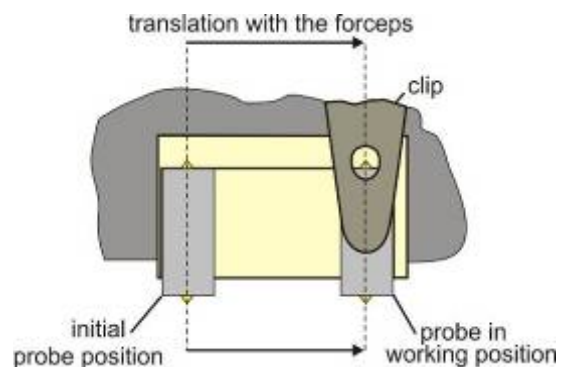


Fig. 2-30

4. Move the probe with the forceps to the working position ([Fig. 2-31](#)) as shown schematically in [Fig. 2-30](#). The probe working position is shown in [Fig. 2-32](#);



Fig. 2-31

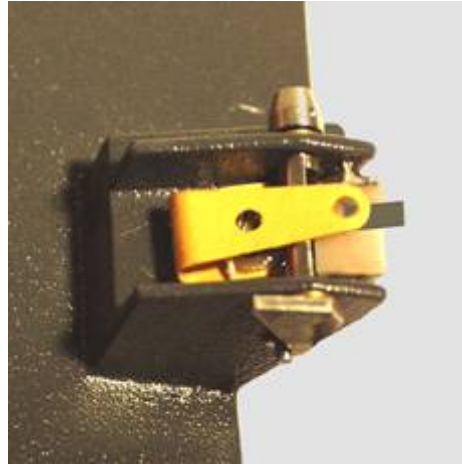


Fig. 2-32

5. Once the probe is in working position, clamp it with a clip. To do this, turn the lever to the holding position using the forceps ([Fig. 2-33](#));

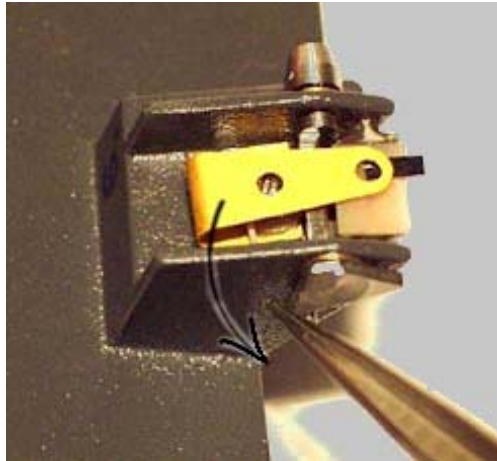


Fig. 2-33

6. Install the adjustment unit into the measuring head ([Fig. 2-34](#)).

Mind that:

- support balls of the unit ([Fig. 2-35](#)) must rest upon polycrystalline sapphire platforms ([Fig. 2-23](#));
- Adjustment screws must rest upon unit respective seats;
- Hold-down 5 ([Fig. 2-23](#)) should be loosen by turning its handle counterclockwise.



Fig. 2-34

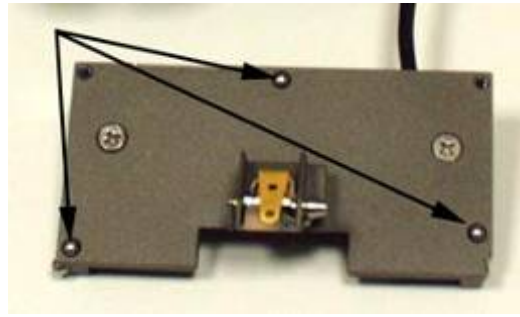


Fig. 2-35

2.7.3 Adjusting the optical system of the cantilever deflection detection

2.7.3.1 Laser turning on

- Laser turning on and off is performed with the «Laser» button located to the right in the main parameters bar (In [Fig. 2-36](#) the button is enabled);



Fig. 2-36

- By default, the «Laser» button is enabled upon the control program loading.



Warning! Do not stare into the laser beam! (The laser safety class provides the safe contact between a laser beam and human eye during the period of time corresponding to a normal human reaction to irritation (about 0.25 s). This time is enough for a person to blink and turn away. Extended exposure can lead to short-term eyesight disorder.)

2.7.3.2 Window of the optical system adjustment

To adjust the optical system, open the "window of the optical system adjustment" by clicking on the «Aiming» button in the task bar ([Fig. 2-37](#)).

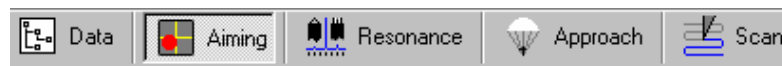


Fig. 2-37

The window of the optical system adjustment ([Fig. 2-38](#)) contains an indicator of the laser spot position relative to the photodiode segments (left side) and a panel for displaying the photodiode signals current value.

The displayed signals have the following meaning:

- DFL** the difference signal between top and bottom halves of the photodiode;
- LF** the difference signal between left and right halves of the photodiode;
- LASER** the total signal that comes from all four segments of the photodiode and, therefore, is proportional to the intensity of the laser radiation reflected from the cantilever.

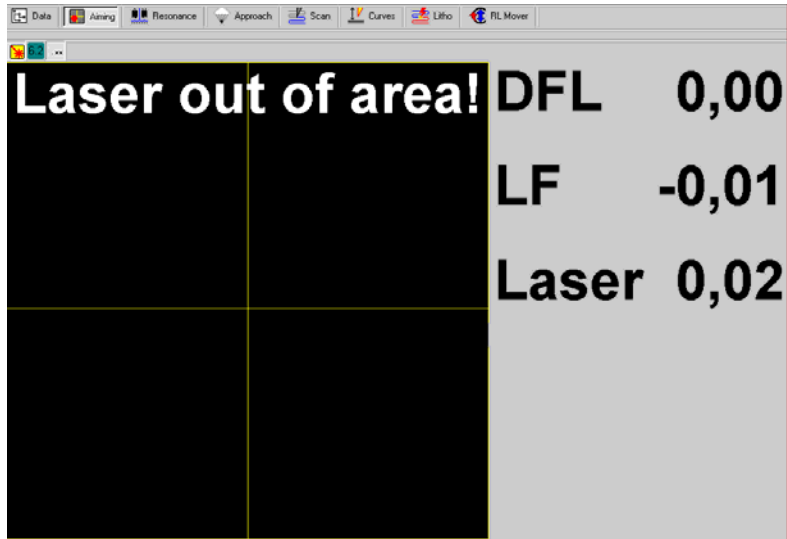


Fig. 2-38

2.7.3.3 General information about the laser beam alignment with the cantilever

- The purpose of the laser beam aligning is to steer the laser spot onto the cantilever's end as shown schematically in Fig. 2-40;
- The universal measuring head design allows to use the cantilevered probe, mounted in the holder on the adjustment unit, to move relative to the laser beam using the unit adjustment screws 1 and 2 (Fig. 2-39, Fig. 2-40). Thus, the laser beam alignment means the cantilever move relative to the fixed beam;
- For convenience, hereinafter, «the laser beam move relative to the cantilever» or «the laser spot steering onto the cantilever» implies that the laser beam is in fact fixed but the cantilever is moved.



Fig. 2-39

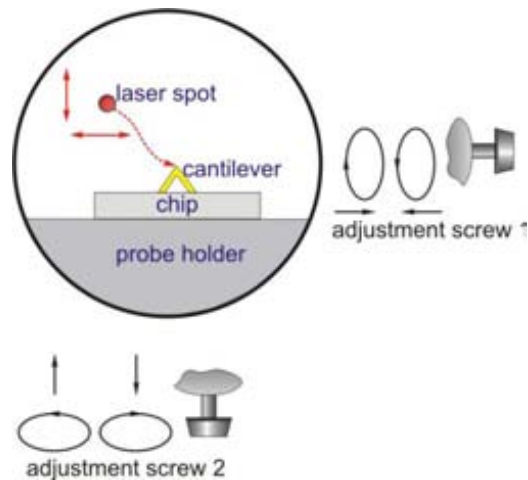


Fig. 2-40

2.7.3.4 The suggested procedure of the laser spot steering onto the cantilever

To align the laser spot, the following procedure is recommended:

1. First, trace the laser beam path relative to the cantilever.

View the image of the passed through the measuring head laser beam. For that, lift the measuring head approx. 10-15 cm above a sheet of white paper serving as a screen ([Fig. 2-41](#)).

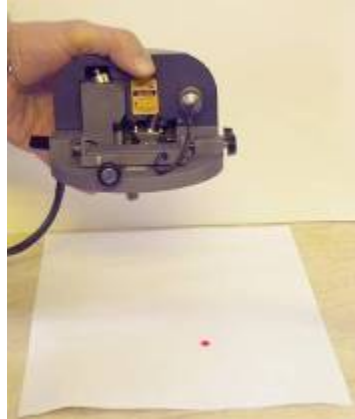
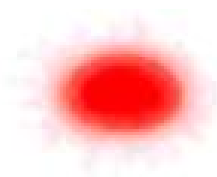


Fig. 2-41

Three cases are possible:

- a. **"Undistorted"** image on paper. ([Fig. 2-42](#)) This means that the laser beam is off the cantilever or the cantilever chip;
- b. **"Distorted"** laser image on paper. This means that the laser beam hits the edge of any construction element or the cantilever. Note that image shape can be different (see examples in [Fig. 2-43](#));
- c. No image at all. This means that the laser beam falls onto the chip or the probe holder ([Fig. 2-44](#)) and can not pass through the measuring head.

**Undistorted image
on a screen:**



The beam passes free

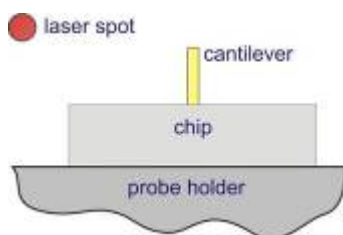


Fig. 2-42

**Distorted image of arbitrary
shape on a screen:**



The beam touches the edge

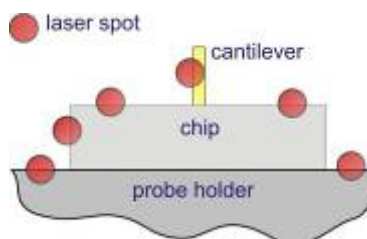


Fig. 2-43

**No image
on a screen:**

**The beam spots the chip or
the holder**

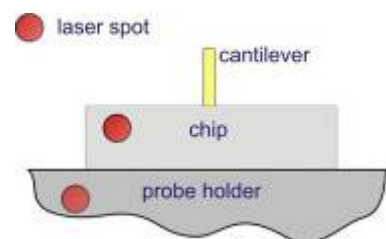


Fig. 2-44

The measuring head design allows to watch the cantilever and adjacent to it elements as well as to notice the laser spot position with the naked eye.

Depending on what is seen, do the following.

1. If undistorted laser image is seen on the screen (i.e the laser beam passes freely through the measuring head), move the spot towards the holder perpendicular to the chip front edge (or, depending on the spot initial position, perpendicular to the holder front edge) and position it just near an edge as shown in [Fig. 2-45](#). This laser spot alignment is performed by turning the adjustment screw 2 clockwise. Then, notice the spot approx. position and proceed to step 4).

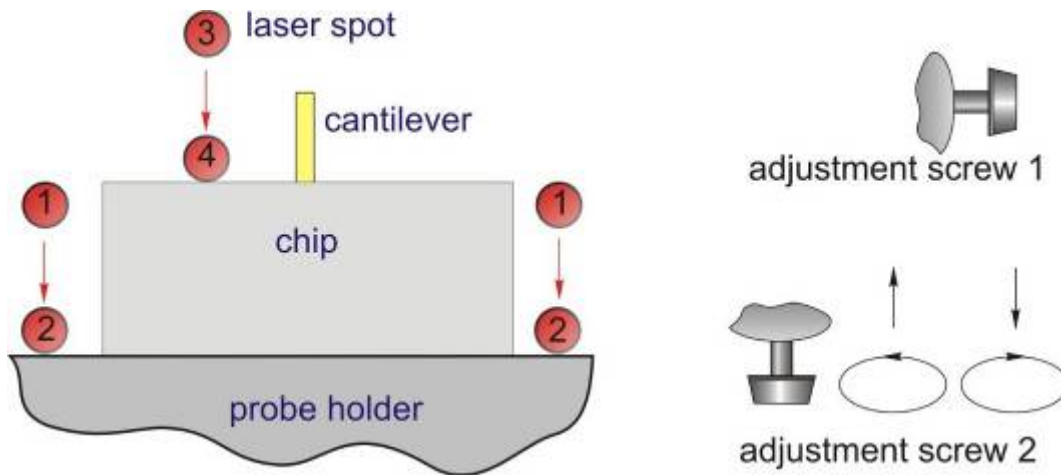


Fig. 2-45

Detailed description of this procedure is given below:

- The undistorted (pristine) elliptical laser image is seen initially on the paper screen, i.e. the laser beam passes through the measuring head freely;
- Begin turning adjustment screw 2 clockwise. The spot will move towards the chip front edge or the probe holder front edge. This is shown schematically in [Fig. 2-45](#) as a travel from locations 1,3 into locations 2,4;
- In the process of travel, the laser image will start to distort at a certain moment. This indicates that the laser beam starts to impinge on the probe holder edge or on the chip edge (depending on the spot initial location 1 or 3). As soon as the image starts to distort, stop turning adjustment screw 2;
- Then notice approximately what element the beam hits (chip edge or the probe holder edge). For that, move the spot slightly back and forth with adjustment screw 2 for the beam to fall on and off an edge;
- Next, fine - position the spot just near an edge (locations 2,4 in [Fig. 2-45](#)). To do so, turn slightly adjustment screw 2 counterclockwise until the image distortion vanishes.

Next, proceed to step 4)

2. If there is no laser image (case c) or the distorted image is seen on the screen (case b), move the spot in the direction from the holder perpendicular to the holder front edge until the undistorted laser image is seen on the paper screen. Position the spot just near an edge as shown in [Fig. 2-46](#) turning screw 2 counterclockwise. Then notice the spot approx. position and proceed to step 4).

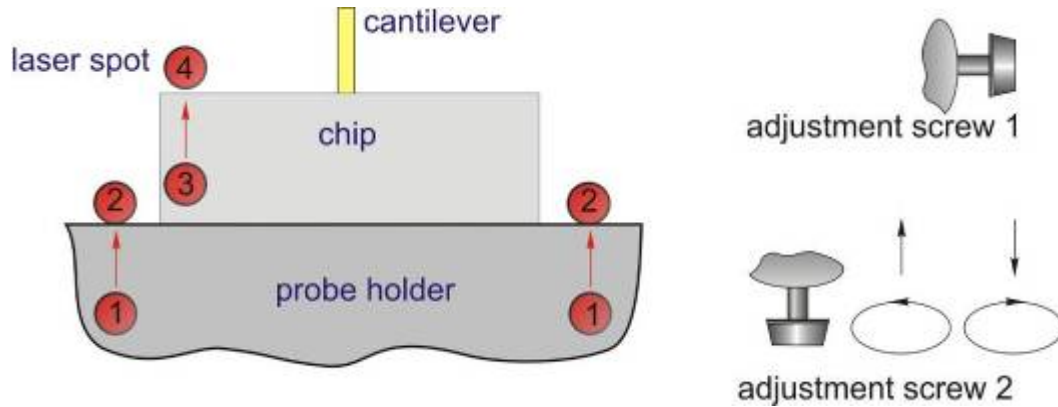


Fig. 2-46

Detailed description of this procedure is given below:

- Initially there is no laser spot on the screen or the distorted laser image is seen, i.e. the beam hits the holder or the chip, or the edge of the holder or the chip;
- First, turn the measuring head so that part of the chip and adjacent to it part of the probe holder are visible from above and locate the approximate position of the laser beam watching the beam diffuse reflection;
- Next, start turning adjustment screw 2 counterclockwise. The spot will move towards the chip front edge or the probe holder front edge. This is shown schematically in [Fig. 2-46](#) as a travel from locations 1,3 into locations 2,4;
- In the process of travel, the laser image will change to undistorted one at a certain moment. This indicates that the laser beam is falling off the probe holder edge or the chip edge ([Fig. 2-46](#), locations 2,4);
- As soon as the image changes to an undistorted one, stop turning adjustment screw 2. If necessary, turn screw 2 back slightly to fine - position the spot just near an edge;
- You may need to check the spot position relative to the probe once again. For that, move the spot slightly back and forth with screw 2 for the laser beam to fall on and off an edge.

Next, proceed to step 4)

3. If the spot is positioned near the probe holder edge, it should be moved to the chip front edge using adjustment screws 1 and 2 as shown in [Fig. 2-47](#).

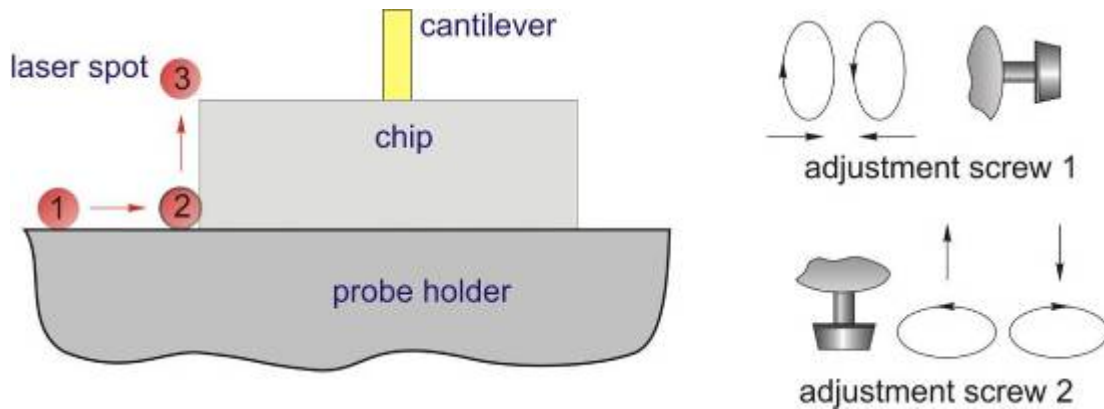


Fig. 2-47

Detailed description of this procedure is given below:

- The undistorted (pristine) elliptical laser image is seen initially on the paper screen, i.e. the laser beam passes just near the probe holder edge, for example, to the left of the chip (as shown schematically in [Fig. 2-47](#));
- Begin turning adjustment screw 1 clockwise (otherwise, if the beam is located to the right of the chip, turn the screw counterclockwise). The spot will move towards the chip;
- Turning adjustment screw 1, move the spot laterally along the edge until the laser image on the screen starts to distort, i.e. when the beam starts to hit the chip left edge. This step is illustrated in [Fig. 2-47](#) as a travel from location 1 into location 2. Stop turning the screw when the laser image is slightly distorted;
- Next, start turning adjustment screw 2 counterclockwise to move the spot along the chip side edge. Stop turning when the laser image distortion vanishes. This corresponds to the spot location 3 near the chip front left corner ([Fig. 2-47](#));
- Thus, the spot is positioned near the chip front edge.

4. If the laser beam passes near the chip front edge, it should be steered onto the cantilever longitudinal axis (Fig. 2-48, Fig. 2-49) by moving the beam laterally with adjustment screw 1 (detailed procedure is given below).

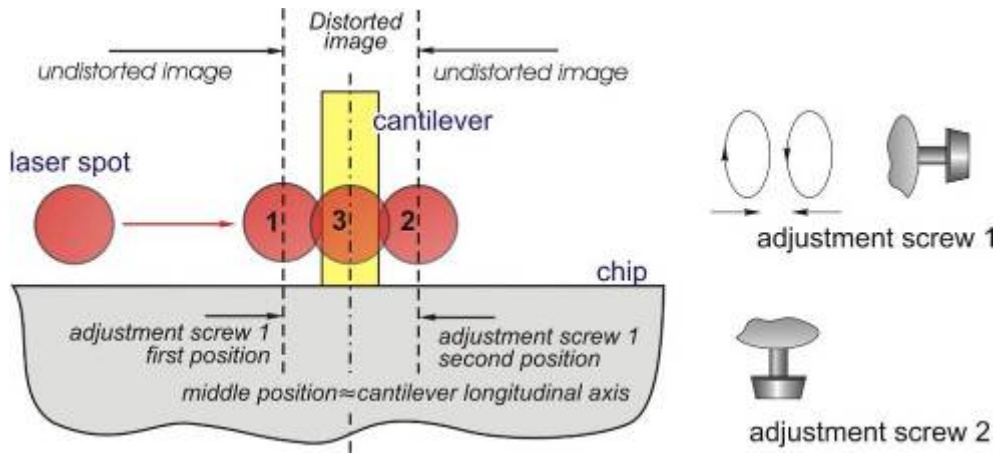


Fig. 2-48

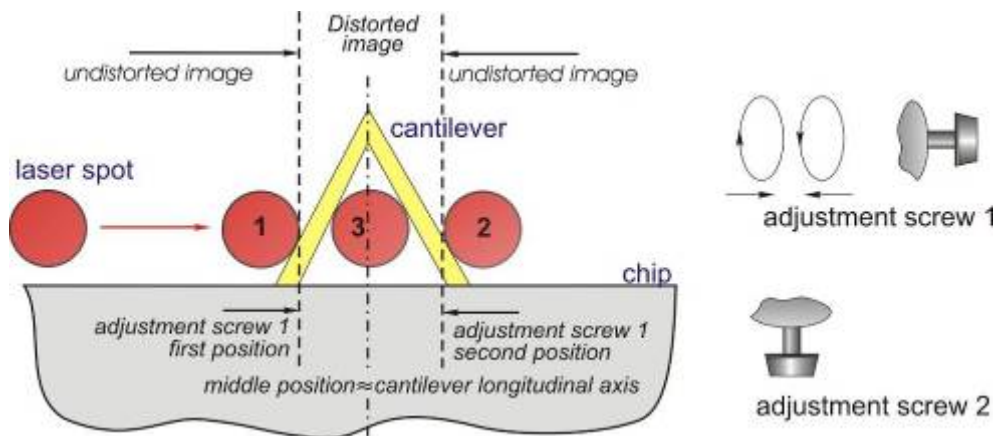


Fig. 2-49

The recommended procedure of the beam steering onto the cantilever longitudinal axis

- Initially the beam is positioned near the front edge of the chip;
- If you noticed the beam position relative to the cantilever, move the beam laterally towards the cantilever using adjustment screw 1;
- In the process of travel, the laser image on the paper screen will start to distort at the certain position of adjustment screw 1. This indicates that the laser beam starts to impinge on the cantilever as shown schematically in Fig. 2-48, Fig. 2-49. Memorize this first position of the screw;
- Keep on moving the beam in the same direction, slowly turning screw 1. Remember that one turn of adjustment screw 1 corresponds to the beam translation of 350 micron while the cantilever width ranges from a few tens micron (in case of rectangular cantilevers) to a few hundreds micron (in case of triangular cantilevers). At a certain position of screw 1, the

image distortion vanishes which indicates that the beam is off the cantilever edge. Memorize this second position of the screw;

- Next, turn adjustment screw 1 into the middle position between the first and the second positions, i.e approx. in the middle of "distortion" range ([Fig. 2-48](#), [Fig. 2-49](#));
- Thus, the laser spot is positioned onto the cantilever longitudinal axis ([Fig. 2-48](#), [Fig. 2-49](#)).



Note. If the beam is positioned initially near the chip front edge but you do not notice its exact location relative to the cantilever, start moving the beam in any direction. Remember that the cantilever chip width is about 1.5 mm while one turn of adjustment screw 1 corresponds to the beam travel of 0.35 mm. This means that for the beam to move the distance equal to the chip width it is necessary to make about 5 turns of screw 1. Therefore, if you started turning adjustment screw 1 and made more than five turns without finding the cantilever (undistorted laser image is seen), you should change the rotation direction (to move the beam back)

As soon as the spot is positioned on the cantilever longitudinal axis (position 3, [Fig. 2-50](#), [Fig. 2-51](#)), it should be moved to the cantilever end (position 4) using adjustment screw 2.

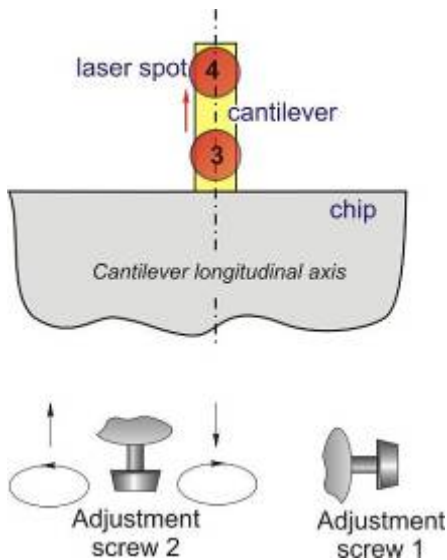


Fig. 2-50

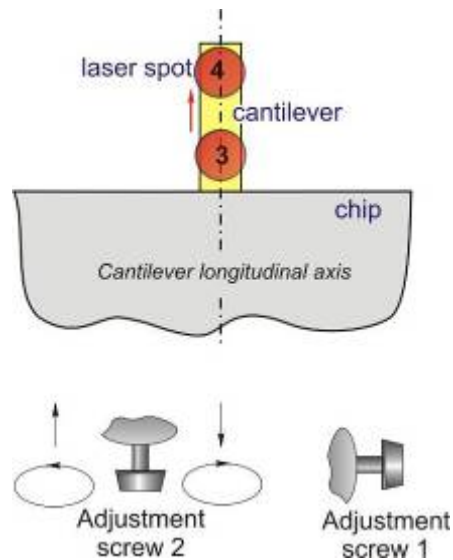


Fig. 2-51

Case of rectangular cantilever:

- Once the laser spot is positioned on the rectangular cantilever longitudinal axis ([Fig. 2-50](#)), the laser image on the screen looks like that shown in [Fig. 2-52](#) regardless of the spot location on the cantilever. Therefore, the image shown in [Fig. 2-52](#) as an example, only indicates that the beam has been centered on the cantilever in the transverse direction;
- Next, turning screw 2 counterclockwise, the spot should be moved towards the cantilever end as shown in [Fig. 2-50](#);

Case of triangular cantilever:

- When the laser spot is positioned on the triangular cantilever longitudinal axis, the laser image seen on the screen can be different;
- As in case of rectangular cantilever, the spot should be moved along the longitudinal axis towards the cantilever end rotating adjustment screw 2 counterclockwise (this is shown schematically in [Fig. 2-51](#));
- When the beam is aligned with the end of triangular cantilever, the laser image on the screen looks like that in [Fig. 2-53](#). This image is about the same for all triangular cantilevers regardless of their size.



Fig. 2-52



Fig. 2-53

2.7.3.5 Photodiode alignment

- Normally, once the laser beam is aligned with the cantilever, the nonzero photodiode signals appear in the window digital indicator ([Fig. 2-54](#));
- The goal of the photodiode alignment is to adjust its position so that the laser beam reflected from the cantilever strikes it in the center and equally illuminates all four segments of the photodiode;
- The photodiode alignment is performed with the help of two adjustment screws 3 and 4 located on the measuring head ([Fig. 2-39](#)). Screw 4 moves the photodiode in the Y-direction (along the cantilever longitudinal axis) while screw 3 moves the photodiode in the X-direction (along the cantilever transverse axis);
- Using adjustment screws 3 and 4 ([Fig. 2-39](#)) center the light spot on the photodiode indicator ([Fig. 2-55](#)); at the same time the **VER.DFL (DFL)** and **LAT.DFL (LF)** readings should be close to zero while the total signal **LASER** should read the maximum value;
- The spot centering can be confirmed by reversal sign of the **DFL** and **LF** readings upon turning adjustment screws 4 (**DFL**) and 3 (**LF**) forward/backward near the zero position. If any of these signals is set to zero by adjustment screw but sign reversal does not take place, this adjustment screw should be turned back until reversal of the signal sign takes place.

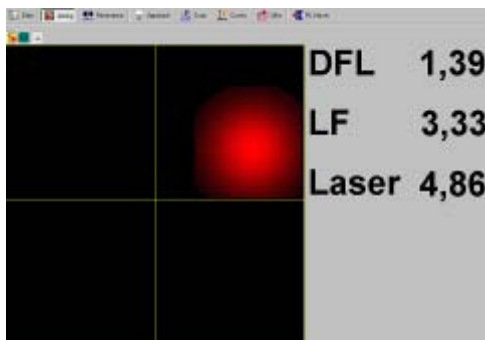


Fig. 2-54

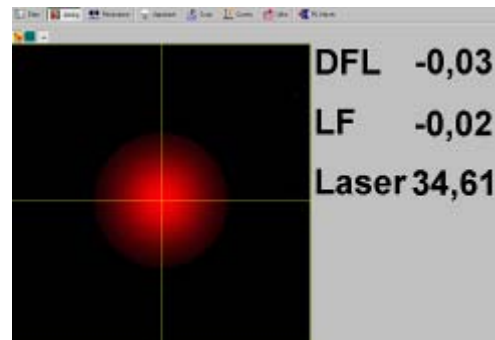


Fig. 2-55

2.7.3.6 Fine-adjustment of the optical system using the photodiode indicator

After aligning the laser and the photodiode you should fine-position the laser spot on the cantilever end to maximize the total photodiode signal.

To do so:

- Using laser adjustments 1 and 2, slightly move the beam along the cantilever in order to maximize the total photodiode signal (**LASER**). Remember that the laser spot should stay on the cantilever end;
- Upon laser readjustment repeat the photodiode alignment procedure with photodiode adjustments 3,4 because of the beam possible shifting from the center.

2.7.4 Measuring head preinstallation

After the adjustment unit and the photodiode aligning, but prior to a sample mounting, it is recommended to perform the measuring head preinstallation.

This operation is needed to:

- orient the measuring head relative to the scanner vertical axis so that the probe is approximately on the scanner axis;
- set such a separation between the probe and the sample holder that when a sample is mounted a safe distance (more than 1-2 mm) exists between the sample surface and the probe.

Procedure of the measuring head preinstallation:

1. Install the measuring head with its legs into the seats of the universal stage ([Fig. 2-56](#)) so that the head cable is opposite the corresponding connector ([Fig. 2-57](#)).



Before the measuring head installation you should estimate the future probe-sample separation (after the sample mounting) and make sure it is enough (more than 2-3 mm) to avoid the damage of the tip or the sample. You may need to move the stage down using the manual approach knob



Fig. 2-56



Fig. 2-57

2. Looking from the side and turning the approach screw located under the approach unit [Fig. 2-58](#), advance the sample holder to the probe so that the probe-sample separation after the future sample mounting is more than 2 mm ([Fig. 2-59](#));



Fig. 2-58

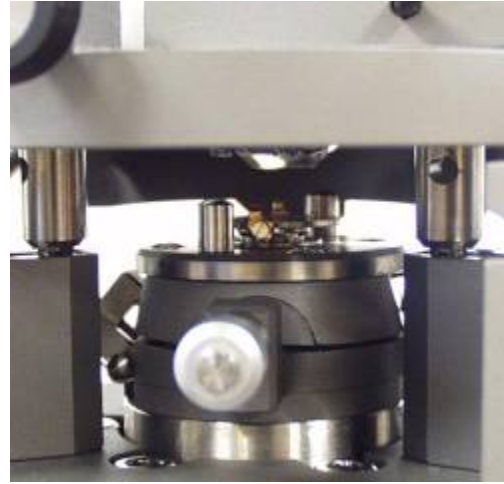


Fig. 2-59

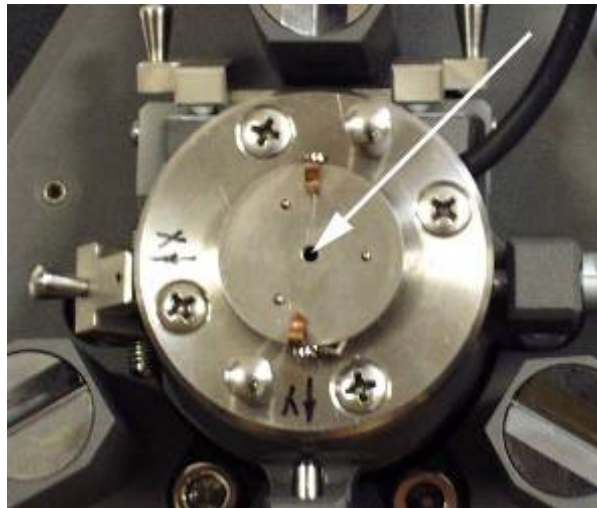


Fig. 2-60

3. Watching from above the cantilever position in the horizontal plane, move the scanner using the positioner micrometer screws so that the probe is positioned opposite the central opening in the sample holder ([Fig. 2-60](#)) which corresponds to the intersection point of the holder plane and the scanner longitudinal axis;
4. Upon completion of this procedure you can remove the measuring head from the approach unit and proceed to a sample preparation and installation.



Note. The probe alignment with the scanner vertical axis allows to reduce the interfering surface tilt at scan due to the probe deviation from the scanner axis.

2.7.5 Preparation and mounting of the sample

- The instrument allows to study samples having sizes up to 40-50 mm and thickness up to 10 mm;
- Samples are mounted onto the substrate which is installed on the holder stage;
- As a substrate it is recommended to use the standard polycrystalline sapphire substrate ([Fig. 2-61](#)) sized 24x19x0.5 mm;
- To fix the sample on the substrate, a two-sided scotch tape can be used;

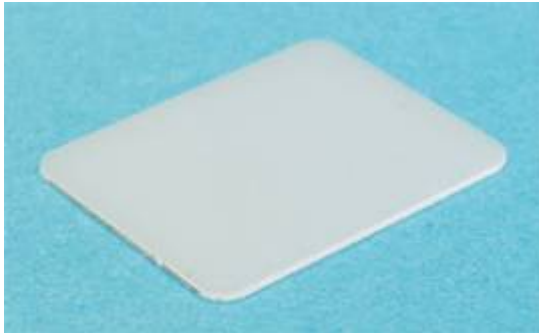


Fig. 2-61

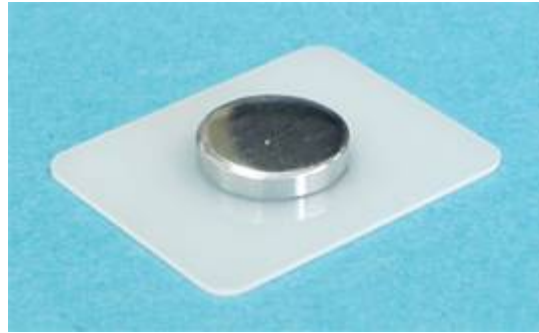


Fig. 2-62

- Samples having sizes more than 10-15 mm should be mounted onto the adapter substrate ([Fig. 2-62](#)). The standard substrate with a glued to it adapter wafer which is about 2 mm thick can be used as well. The wafer thickness should provide that the sample raises above the stage clips while the wafer width should be less than the distance between clips. In this case the sample is mounted onto the adapter wafer;
- If an electric contact is to be provided between the sample and the instrument circuits, a special substrate with a spring contact must be used ([Fig. 2-63](#));

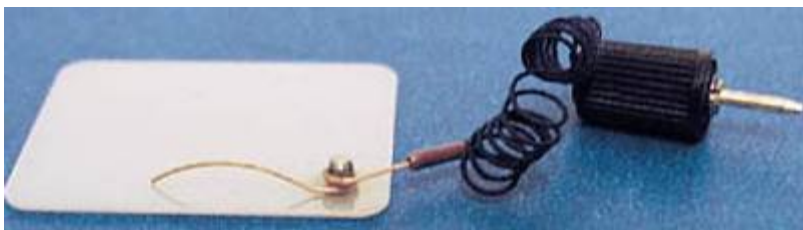


Fig. 2-63

- With this special substrate the sample is connected to the instrument via the contact spring wire with a plug which is inserted into the bias voltage socket on the approach unit. There are two sockets ([Fig. 2-64](#)) on the approach unit: 1 is for bias voltage or sample grounding, 2 is for grounding;

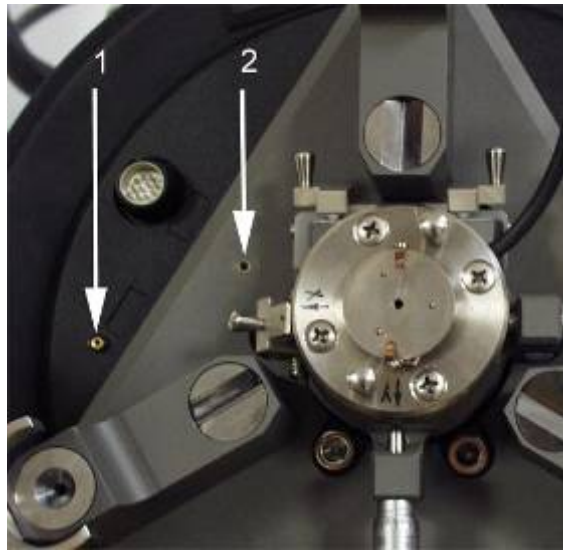


Fig. 2-64
1 –Bias voltage socket; 2 – ground socket

- To install the sample on the stage, the substrate is pushed under clips from the side of two supporting balls ([Fig. 2-65](#)) until it is held down with clips to three supporting balls ([Fig. 2-66](#)).

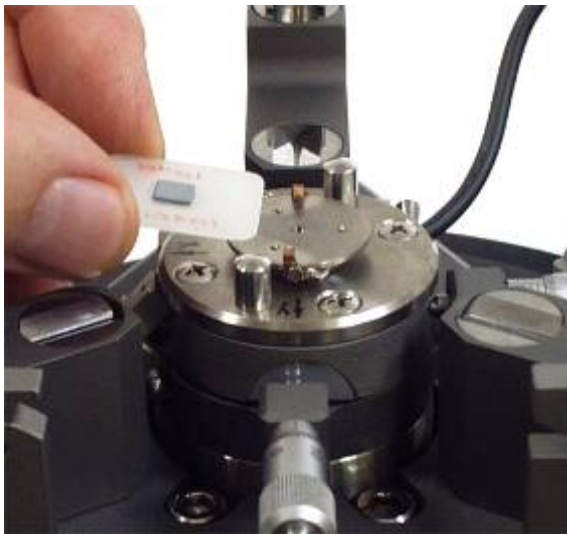


Fig. 2-65



Fig. 2-66

2.7.6 Installing the measuring head on the approach unit

Install the measuring head with its legs into the seats of the universal stage. Remember that the separation between the probe and the sample should be large enough (more than 1.5-2 mm) to avoid the tip damage. The head cable should be opposite the corresponding receptacle.

Upon the measuring head installation on the approach unit:

- Plug the measuring head into the receptacle ([Fig. 2-67](#));

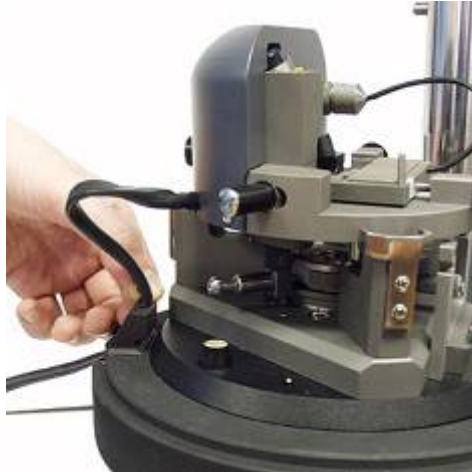


Fig. 2-67

- Looking from the side ([Fig. 2-58](#)) and turning the manual approach knob ([Fig. 2-68](#)), bring the sample to the probe within 0.5-1 mm;
- Looking from above, make sure the probe is properly positioned relative to the sample. Looking from the side, make sure the probe will not touch anything during the future approaching;
- Check the adjustment of the optical system of the cantilever deflection detection using the photodiode indicator and readjust if needed;
- Install the protective cover if needed ([Fig. 2-69](#)). Ground the cover by connecting it to the approach unit case with a grounding wire.



Note. It is recommended to use the cover in order to:

- a) obtain high resolution in XY plane or in Z;*
- b) perform measurements in the temperature range;*
- c) protect against temperature drop;*
- d) lower an acoustic noise.*

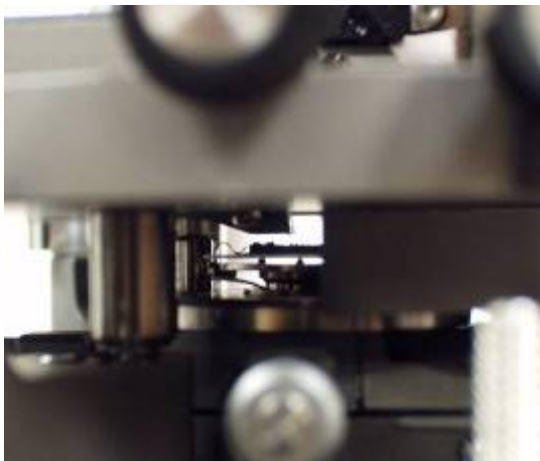


Fig. 2-68



Fig. 2-69

2.8 Preparation of the instrument for the "Scanning by probe" configuration

General procedure of preparation and installation of the scanning measuring head and a sample consists of the following sequence of basic operations and procedures: Control program starting up. Instrument turning on;

1. Installing the probe;
2. Adjusting the optical system of the cantilever deflection detection;
3. Preparing and mounting the sample;
4. Installing the measuring head.

These operations are described in detail below.

2.8.1 Installing the probe

To install or replace the probe, do the following:

1. Turn the scanning measuring head over and place it on a table upside down ([Fig. 2-70](#));



Fig. 2-70



Fig. 2-71

2. Lift the probe spring clip. To do this, turn downward the trapeziform lever, located on the outer side of the holder body, with the forceps ([Fig. 2-71](#));



Attention! Lift the clamping spring only by turning the lever. Do not bend it with the forceps or the hand as this can result in irreversible deformation



Attention! The probe holder is attached to the scanner, so excessive forces applied to the holder can result in damage to the scanner

3. Take the probe from the box with the forceps ([Fig. 2-72](#)) making sure that the working side of the chip with cantilevers is directed to you during the installation. Do not turn the chip over because probes in the box are placed with their tips pointing upwards;

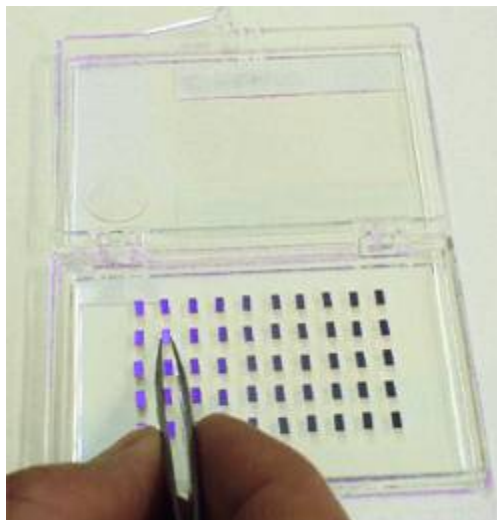


Fig. 2-72



Fig. 2-73

4. Place the probe on the polycrystalline sapphire pedestal to the left of the working position ([Fig. 2-73](#), [Fig. 2-74](#)), which is in the right corner under the clip;

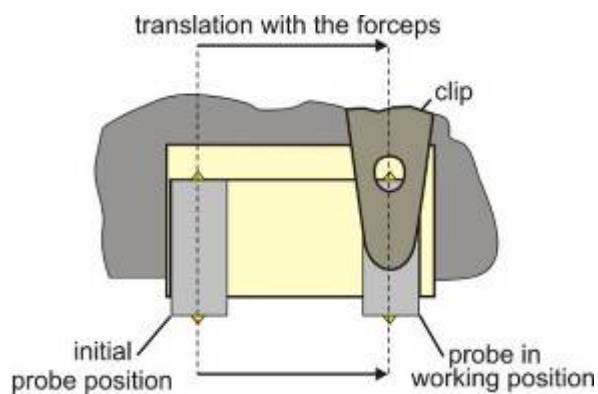


Fig. 2-74



Fig. 2-75

5. Move the probe with the forceps to the working position ([Fig. 2-75](#)) as shown schematically in [Fig. 2-73](#). The probe working position is shown in [Fig. 2-76](#);



Fig. 2-76

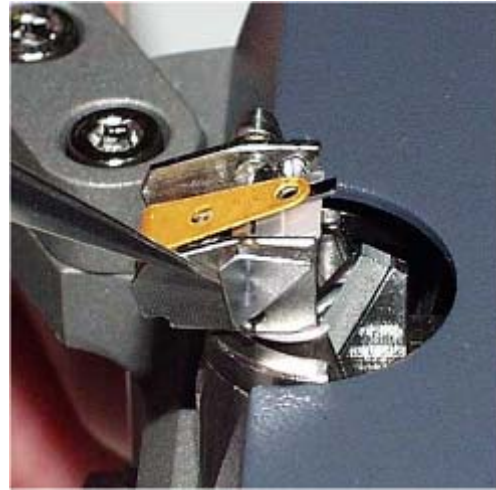


Fig. 2-77

6. Once the probe is in working position, clamp it with a clip. To do this, turn the lever to the holding position using the forceps ([Fig. 2-77](#)).

2.8.2 Adjusting the optical system of the cantilever deflection detection

2.8.2.1 Laser turning on

- Laser turning on and off is performed with the «**Laser**» button located to the right in the main parameters bar (In [Fig. 2-78](#) the button is enabled);



Fig. 2-78

- By default, the «**Laser**» button is enabled upon the control program loading.



Warning! Do not stare into the laser beam! (The laser safety class provides the safe contact between a laser beam and human eye during the period of time corresponding to a normal human reaction to irritation (about 0.25 s). This time is enough for a person to blink and turn away. Extended exposure can lead to short-term eyesight disorder)

2.8.2.2 Window of the optical system adjustment

- To adjust the optical system, open the "window of the optical system adjustment" by clicking on the «**Aiming**» button in the task bar ([Fig. 2-79](#));



Fig. 2-79

- The window of the optical system adjustment ([Fig. 2-80](#)) contains an indicator of the laser spot position relative to the photodiode segments (left side) and a panel for displaying the photodiode signals current value.

The displayed signals have the following meaning:

- DFL** the difference signal between top and bottom halves of the photodiode;
- LF** the difference signal between left and right halves of the photodiode;
- LASER** the total signal that comes from all four segments of the photodiode and, therefore, is proportional to the intensity of the laser radiation reflected from the cantilever.



Fig. 2-80

2.8.2.3 General information about the laser beam alignment with the cantilever

- The laser beam is focused in a point on the plane in which the cantilever lies. The beam can be moved relative to the cantilever with a help of adjustment screws 1 and 2 ([Fig. 2-81](#), [Fig. 2-82](#));

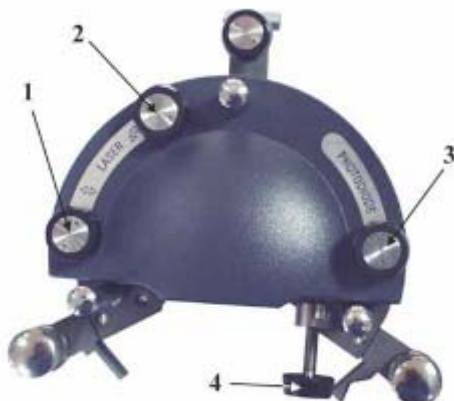


Fig. 2-81

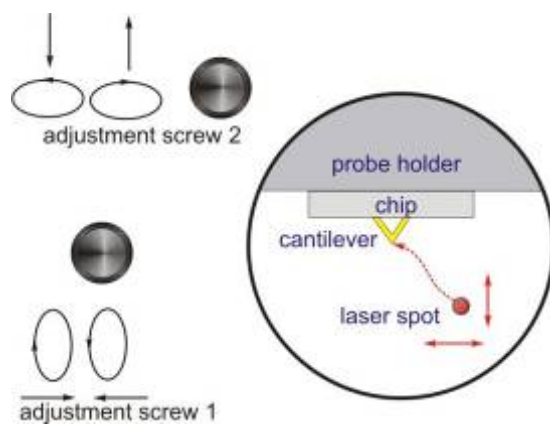


Fig. 2-82

- The purpose of the beam aligning is to steer the laser spot onto the cantilever's end using adjustment screws 1 and 2 as shown schematically in [Fig. 2-82](#);

- The measuring head is equipped with a special mirror for viewing the cantilever and the studied sample. The mirror is attached to the measuring head base near the probe holder. Viewing is performed through an opening in the cylinder tip of the scanner at an angle of 30° to the horizontal plane (sample plane) ([Fig. 2-83](#), [Fig. 2-84](#));

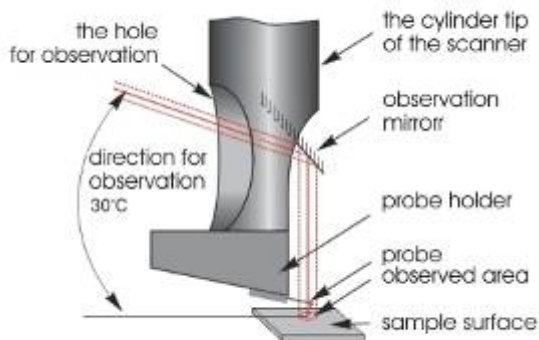


Fig. 2-83

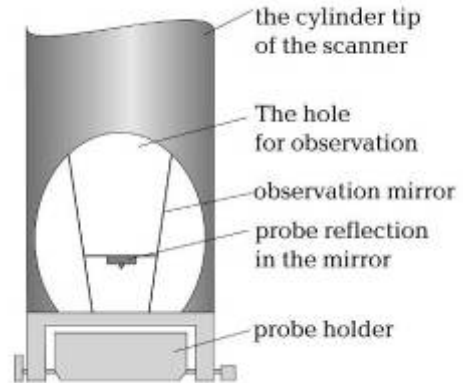


Fig. 2-84

2.8.2.4 The suggested procedure of the laser spot steering onto the cantilever

To align the laser spot, the following procedure is recommended:

1. First, trace the laser beam path relative to the cantilever.

View the image of the passed through the measuring head laser beam. For that, lift the measuring head approx. 10-15 cm above a sheet of white paper serving as a screen ([Fig. 2-85](#)).



Fig. 2-85

Three cases are possible:

- a. "Undistorted" image on paper. ([Fig. 2-86](#)) This means that the laser beam is off the cantilever or the cantilever chip;
- b. "Distorted" laser image on paper. This means that the laser beam hits the edge of any construction element or the cantilever. Note that image shape can be different (see examples in [Fig. 2-87](#));
- c. No image at all. This means that the laser beam falls onto the chip or the probe holder ([Fig. 2-88](#)) and can not pass through the measuring head.

Undistorted image on a screen



The beam passes free

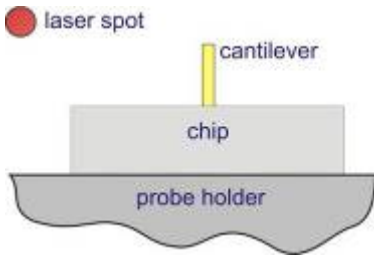


Fig. 2-86

Distorted image of arbitrary shape on a screen



The beam touches the edge

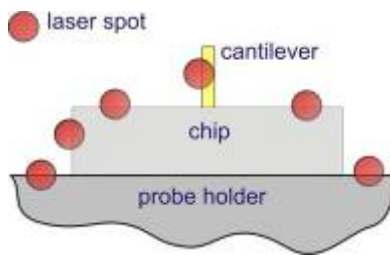


Fig. 2-87

No image on a screen

The beam spots the chip or the holder

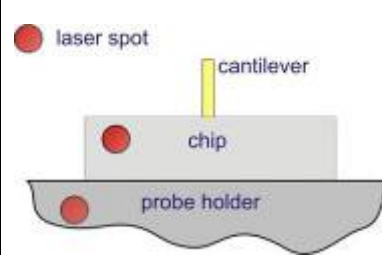


Fig. 2-88

The viewing mirror allows to watch the cantilever and adjacent to it elements as well as to notice the laser spot position with the naked eye.

Depending on what is seen, do the following:

1. If undistorted laser image is seen on the screen (i.e the laser beam passes freely through the measuring head), move the spot towards the holder perpendicular to the chip front edge and position it just near an edge as shown schematically in [Fig. 2-89](#). This laser spot alignment is performed by turning adjustment screw 2 counterclockwise. Then, notice the spot approx. position relative to the cantilever and adjacent to it elements.

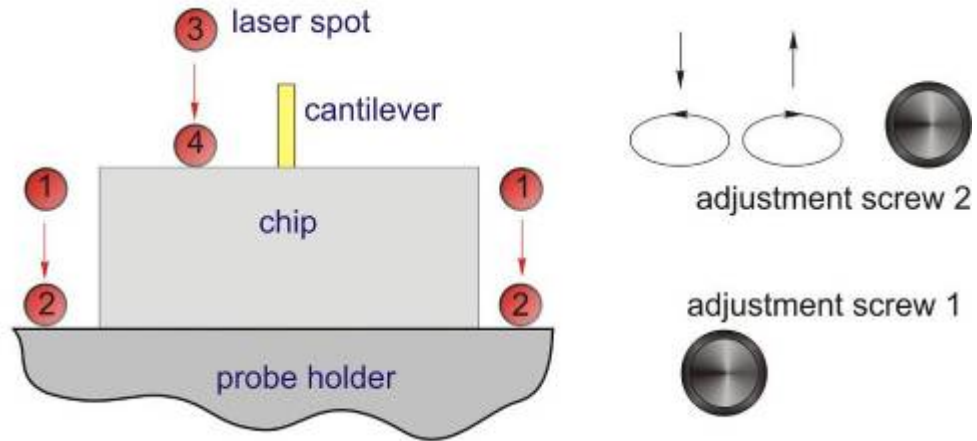


Fig. 2-89

Detailed description of this procedure is given below:

- The undistorted (pristine) elliptical laser image is seen initially on the paper screen, i.e. the laser beam passes through the measuring head freely;
- Begin turning adjustment screw 2 counterclockwise. The spot will move towards the chip front edge or the probe holder front edge. This is shown schematically in [Fig. 2-89](#) as a travel from locations 1,3 into locations 2,4;
- In the process of travel, the laser image will start to distort at a certain moment. This indicates that the laser beam starts to impinge on the probe holder edge or on the chip edge (depending on the spot initial location 1 or 3). As soon as the image starts to distort, stop turning adjustment screw 2;
- Then, using the viewing mirror, notice approximately what element the beam hits (chip edge or the probe holder edge). For that, move the spot slightly back and forth with adjustment screw 2 for the beam to fall on and off an edge;
- Next, fine-position the spot just near an edge (locations 2,4 in [Fig. 2-89](#)). To do so, turn slightly adjustment screw 2 clockwise until the image distortion vanishes.

Next, proceed to step 4)

2. If there is no laser image (case c) or the distorted image is seen on the screen (case b), move the spot in the direction from the holder perpendicular to the holder front edge until the undistorted laser image is seen on the paper screen. Position the spot just near an edge as shown schematically in [Fig. 2-90](#) turning screw 2 clockwise. Then notice the spot approx. position.

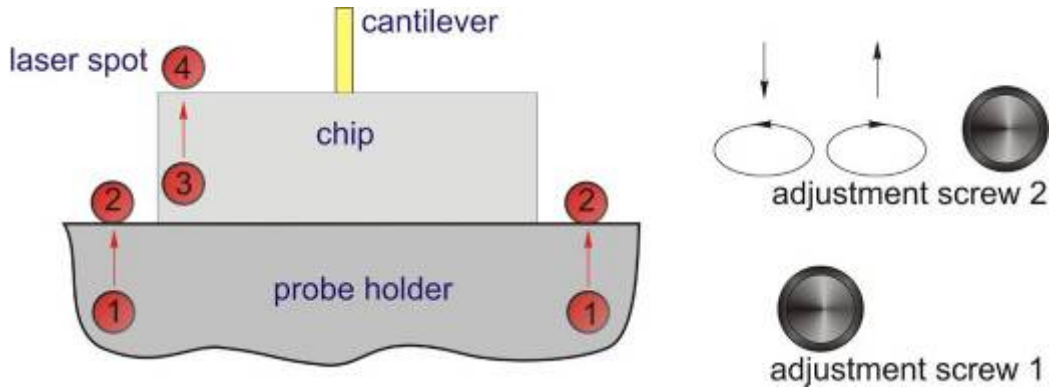


Fig. 2-90

Detailed description of this procedure is given below:

- Initially there is no laser spot on the screen or the distorted laser image is seen, i.e. the beam hits the holder or the chip, or the edge of the holder or the chip;
- First, look attentively through the viewing mirror at the visible part of the chip and adjacent to it part of the probe holder. Locate the approximate position of the laser beam watching the beam diffuse reflection;
- Next, start turning adjustment screw 2 clockwise. The spot will move towards the chip front edge or the probe holder front edge. This is shown schematically in [Fig. 2-90](#) as a travel from locations 1,3 into locations 2,4;
- In the process of travel, the laser image will change to undistorted one at a certain moment. This indicates that the laser beam is falling off the probe holder edge or the chip edge ([Fig. 2-90](#), locations 2,4);
- As soon as the image changes to an undistorted one, stop turning adjustment screw 2. If necessary, turn screw 2 back slightly to fine-position the spot just near an edge;
- You may need to check the spot position relative to the probe once again using the viewing mirror. For that, move the spot slightly back and forth with screw 2 for the laser beam to fall on and off an edge.

Next, proceed to step 4)

3. If the spot is positioned near the probe holder edge, it should be moved to the chip front edge using adjustment screws 1 and 2 as shown in [Fig. 2-93](#).

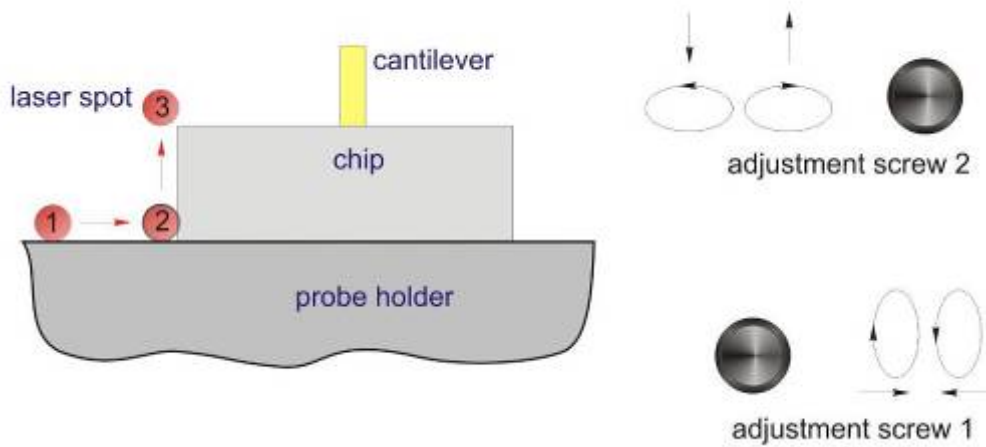


Fig. 2-91

Detailed description of this procedure is given below:

- *The undistorted (pristine) elliptical laser image is seen initially on the paper screen, i.e. the laser beam passes just near the probe holder edge, for example, to the left of the chip (as shown schematically in [Fig. 2-91](#));*
- *Begin turning adjustment screw 1 clockwise (otherwise, if the beam is located to the right of the chip, turn the screw counterclockwise). The spot will move towards the chip*
- *Turning adjustment screw 1, move the spot laterally along the edge until the laser image on the screen starts to distort, i.e. when the beam starts to hit the chip left edge. This step is illustrated in [Fig. 2-93](#) as a travel from location 1 into location 2. Stop turning the screw when the laser image is slightly distorted;*
- *Next, start turning adjustment screw 2 clockwise to move the spot along the chip side edge. Stop turning when the laser image distortion vanishes. This corresponds to the spot location 3 near the chip front left corner (location 3 in [Fig. 2-91](#)).*

Thus, the spot is positioned near the chip front edge.

4. If the laser beam passes near the chip front edge, it should be steered onto the cantilever longitudinal axis (Fig. 2-92, Fig. 2-93) by moving the beam laterally with adjustment screw 1 (detailed procedure is given below).

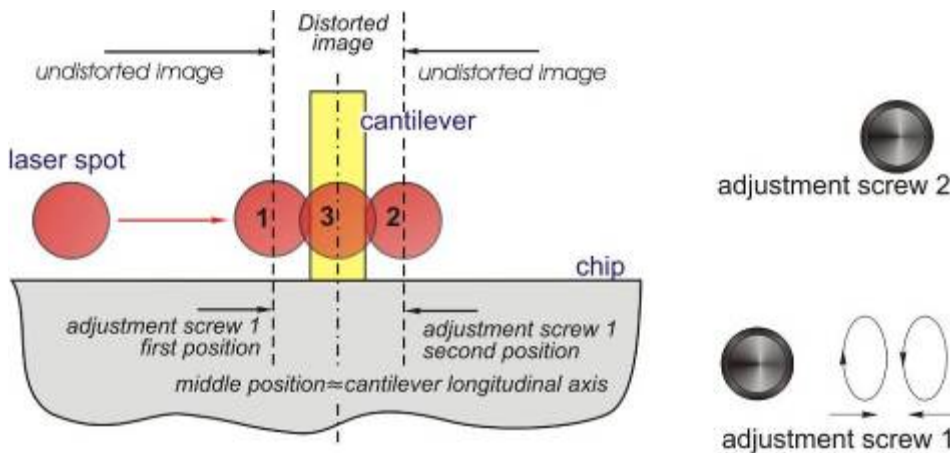


Fig. 2-92

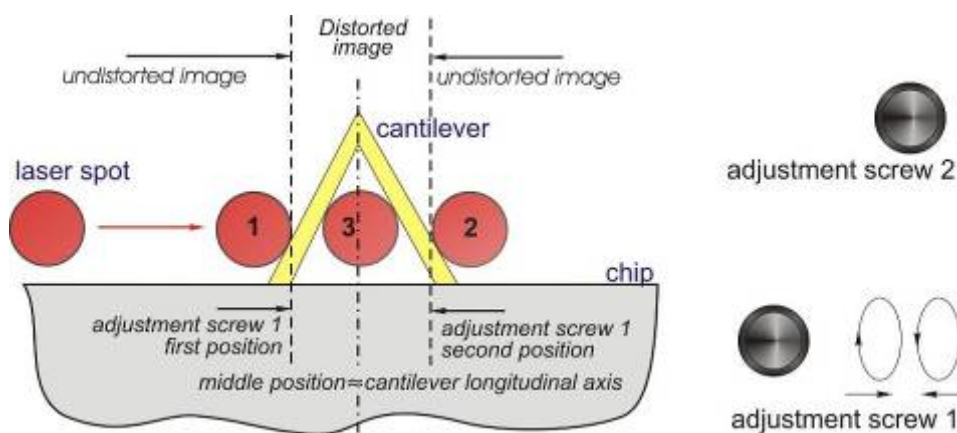


Fig. 2-93

The recommended procedure of the beam steering onto the cantilever longitudinal axis

- Initially the beam is positioned near the front edge of the chip;
- If you noticed the beam position relative to the cantilever, move the beam laterally towards the cantilever using adjustment screw 1;
- In the process of travel, the laser image on the paper screen will start to distort at the certain position of adjustment screw 1. This indicates that the laser beam starts to impinge on the cantilever as shown schematically in Fig. 2-92, Fig. 2-93. Memorize this first position of the screw;
- Keep on moving the beam in the same direction, slowly turning screw 1. Remember that one turn of adjustment screw 1 corresponds to the beam translation of 350 micron while the cantilever width ranges from a few tens micron (in case of rectangular cantilevers) to a few hundreds micron (in case of triangular cantilevers). At a certain position of screw 1, the **image distortion** vanishes which indicates that the beam is off the cantilever edge. **Memorize** this second position of the screw;

- Next, turn adjustment screw 1 into the middle position between the first and the second positions, i.e approx. in the middle of "distortion" range ([Fig. 2-92](#), [Fig. 2-93](#));
- Thus, the laser spot is positioned onto the cantilever longitudinal axis ([Fig. 2-92](#), [Fig. 2-93](#)).



Note. If the beam is positioned initially near the chip front edge but you do not notice its exact location relative to the cantilever, start moving the beam in any direction. Remember that the cantilever chip width is about 1.5 mm while one turn of adjustment screw 1 corresponds to the beam travel of 0.35 mm. This means that for the beam to move the distance equal to the chip width it is necessary to make about 5 turns of screw 1. Therefore, if you started turning adjustment screw 1 and made more than five turns without finding the cantilever (undistorted laser image is seen), you should change the rotation direction (to move the beam back)

5. After the ray has been directed onto a longitudinal axis (position 3, [Fig. 2-94](#), [Fig. 2-95](#)), the laser spot should be placed to the very end of the cantilever (position 4), using the screw 2 for this purpose

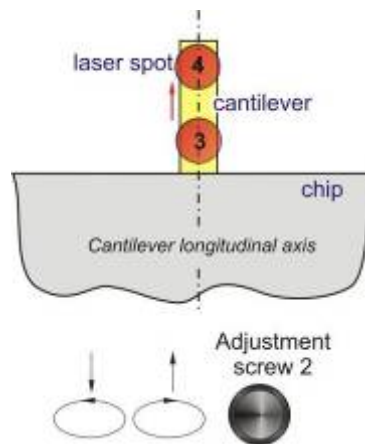


Fig. 2-94

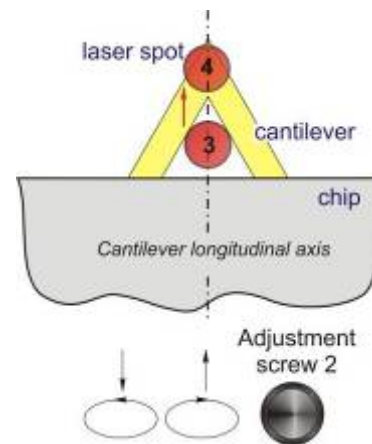


Fig. 2-95

In case of a rectangular cantilever:

- In case of a rectangular cantilever, after you've directed the ray to the longitudinal axis of the cantilever ([Fig. 2-94](#)), the image of the spot at the screen will look approximately the same as it's shown in [Fig. 2-96](#). And it doesn't matter if the spot is near to the very end of the cantilever or it's rather far from it. That's why the image at the screen, like it's shown at [Fig. 2-96](#), only shows that with the help of screw 1 in a lateral direction it's managed to place the ray to the approximate middle of the cantilever;
- Rotating the screw 2 clockwise, you should move the laser spot closer to the end of the cantilever as it's shown schematically at the [Fig. 2-94](#).

In case of a triangle cantilever:

- *In case of a triangle cantilever, after you've directed the ray approximately to the longitudinal axis, the image at the screen can be different;*
- *The same as in case with a rectangular cantilever, you should move the ray along the lateral axis, in the direction of the cantilever's end, rotating screw 2 clockwise (it's shown schematically at [Fig. 2-95](#));*
- *In case of triangular cantilevers, when the ray will be directed to the very end of the cantilever, the image at the screen must have a look, approximately, as it's show at [Fig. 2-97](#). Meantime, this image is approximately the same for any cantilevers of triangular form, not depending on their sizes.*

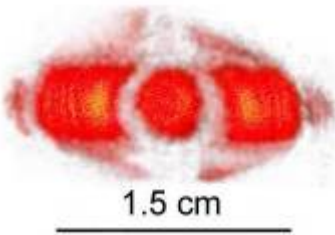


Fig. 2-96

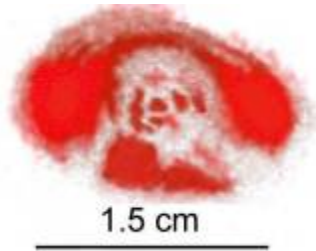


Fig. 2-97

2.8.2.5 Alignment of the photodiode position with the help of the photodiode indicator



Note. When making the alignment it's necessary to place the photodiode in such position in relation to the laser ray so that reflecting from a cantilever it goes to the central part of the photodiode, illuminating all for segments to the equal extent. Movement of the photodiode is effected with the help of two aligning screws 3 and 4, placed on the measuring head ([Fig. 2-81](#)). Meantime, the screw 4 corresponds to the movement of photodiode in vertical direction in relation to the cantilever's plane, and screw 3 – in a lateral direction

- Usually, as soon as it's managed to place the laser ray to the cantilever, some indications different from zero appear at the indicator of the photodiode ([Fig. 2-98](#));
- Using screw 4 and 3 head ([Fig. 2-81](#)), it's necessary to move the spot at the indicator of photodiode into the center ([Fig. 2-98](#)), so, accordingly, meantime, the values of DFL and LF signals must be lead to zero and the amount of the summary LASER signal must be rather big;
- Meantime DFL and LF signals, when rotating handles 4 (DFL) and 3(LF) into forward and backward directions relatively to the zero direction, must change the sign. If some of these signals, when rotating the correspondent screw decreases to zero value, but doesn't change a sign, then it's necessary to rotate this screw into the opposite direction until it's found the position where the signal changes the sign.

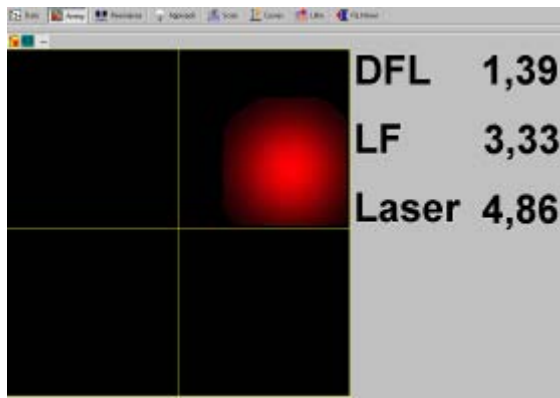


Fig. 2-98

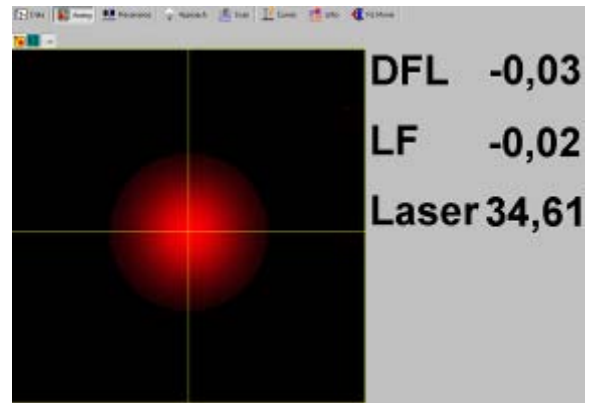


Fig. 2-99

2.8.2.6 Accurate alignment of the optical system of registration with the help of photodiode indicator

After placing the laser to the cantilever and aligning the photodiode, one should execute a more accurate placement of the laser ray to the end of cantilever according to the value of summary signal of the photodiode.

In order to do that:

- Using aligning laser screws 1 and 2 and a bit moving the beam relatively to the cantilever, align to the maximal value of summary photodiode signal (LASER). Accordingly, don't forget that the spot from the laser ray may stay meantime at the end of a cantilever;
- After the direction of the laser ray has been aligned, repeat the alignment of photodiode position with the help of screws 3,4 because the ray may move relatively to the photodiode.

2.8.3 Preparation and mounting of the sample

The instrument makes it possible to explore the samples, which have linear dimensions in the plane up to 100 mm and width up to 15 mm.

2.8.3.1 Mounting of samples of small size

Standard substrate for fixing the samples:

- The samples, which have small sizes (less than 10-12 mm), it's recommended to fix them on the substrate, which is placed at the sample's holder;
- It's recommended to use substrate ([Fig. 2-100](#)). The substrate is made of poly-crystal sapphire and has dimensions 24 x 19 x 0.5 mm;
- You can also use any other substrate of such type with a width of 0.5 mm as a substrate for fixing the samples;
- The samples, which have sizes more than 10-15 mm but less than 40-50 mm, it's recommended to fix them on a special transition substrate ([Fig. 2-100](#)). You can also use a standard backing with with a transition substrate stuck on it with a width of 2 mm. The width

of the plate must be enough to lift up the sample above the clips of the holder. And the width must be less than the distance between the clips. The sample is fixed on a transition substrate;

- For fixing samples on substrate you can use a double side sticky tape;

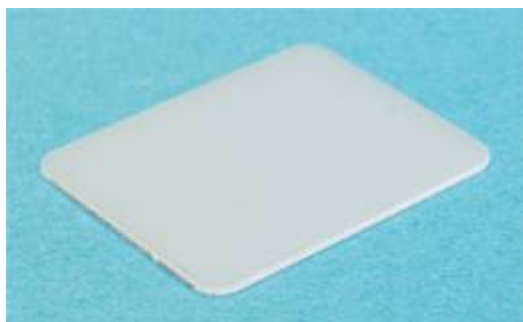


Fig. 2-100

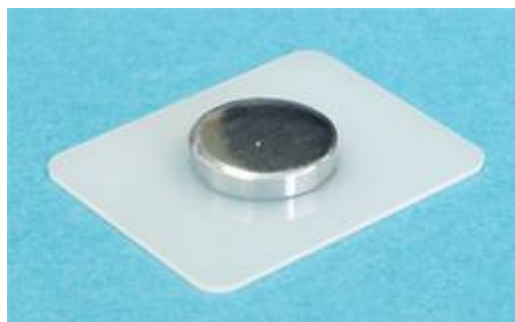


Fig. 2-101

- If it's necessary to provide electric connection between the sample and the elements of the device, then it's recommended to use a special substrate with a spring contact ([Fig. 2-102](#));

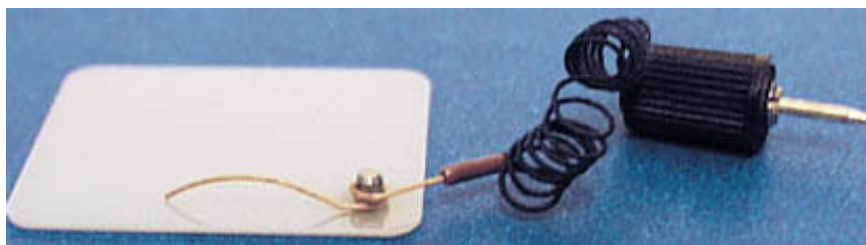


Fig. 2-102

- When using a special substrate the electric connection of the sample with the device is provided by a spring contact. The contact is connected through a connective wire with a plug to the correspondent receptacle placed on the block of feed. On the block of feed there are two receptacles ([Fig. 2-103](#)). Receptacle 1 is meant for provision of a fixed Bias voltage (**BV**) and receptacle 2 for grounding.

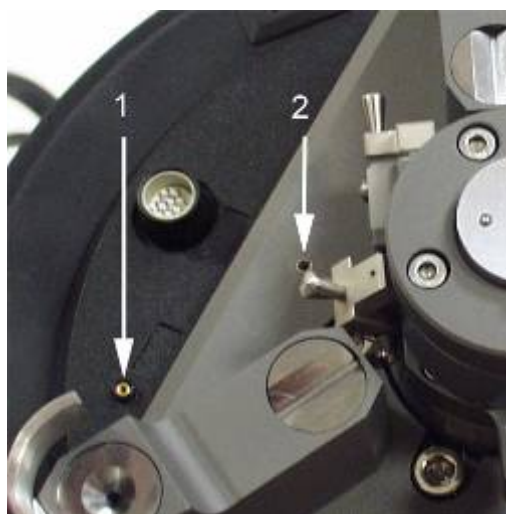


Fig. 2-103

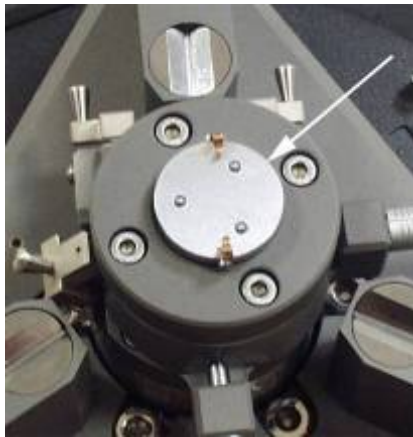
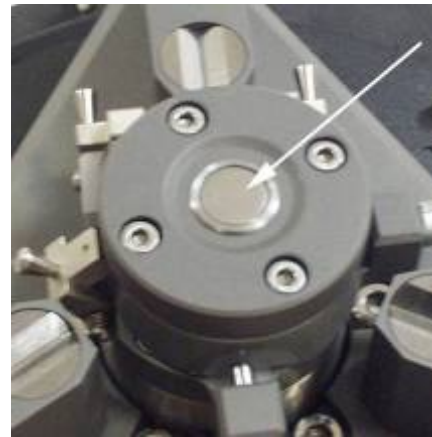
1 – “Bias voltage” socket; 2 – Ground socket

Sample's holder:

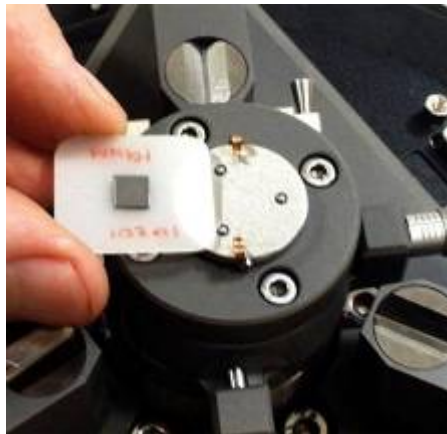
- For installation of the samples of small sizes there is a special table for objects ([Fig. 2-104](#), [Fig. 2-105](#)), which base is made of magnetic material;

**Fig. 2-104**

- The table for objects is placed on a magnetic fixing arm ([Fig. 2-106](#)), placed on the flange of the sample holder. Such a construction makes it possible to rotate the table for objects around the vertical axle for any angle, which provides the installation of any necessary orientation of the sample in the planes X, Y;

**Fig. 2-105****Fig. 2-106**

- The substrate with a fixed sample is installed onto the object table of the sample holder. During the installation the substrate is inserted from a side under the clips from the sides of two balls ([Fig. 2-107](#)) in such a way that the clips press the substrate and the lower surface of the substrate is supported by three supporting balls ([Fig. 2-109](#)).

**Fig. 2-107****Fig. 2-108**

2.8.3.2 Installation of the samples of big sizes

- The samples, which have linear dimensions more than 20 mm and less than 100 mm, you can install them directly to the table for objects of the holder;
- You can also use some transitive flat parallel plate, which has enough large dimensions. You can fix a sample on this transitive plate, and the plate itself can be placed on the table. Also the samples, having not big linear dimensions, can be fixed on such a plate.

2.8.4 The installation of scanning measuring head

During this process it's necessary to make the following:

1. install measuring head on the approach unit;
2. check if plane of measuring head bottom is parallel to the plane of the sample;
3. move the sample to the probe at the distance of approx. 0.5-1 mm.

2.8.4.1 Installation of measuring head on the approach unit

- Before installing the measuring head it's necessary to estimate the difference between the probe and the surface of the sample after the measuring head will be installed. It's necessary to make sure that this distance is enough (not less than 1-2 mm) in order to avoid damaging the probe and the surface of the sample. If you see that the distance is not enough, it's necessary to lower the sample to the sufficient distance;
- In order to move the sample the easiest way is to use the handle of fast feed, which is situated down on the approach unit ([Fig. 2-109](#)). The sample moves down when rotating the handle clockwise (if you look from the side of this handle). Besides, the sample may be moved with the help of a step engine with the use of the program of the device operation, please, see (see this Instruction Manual, part 3);

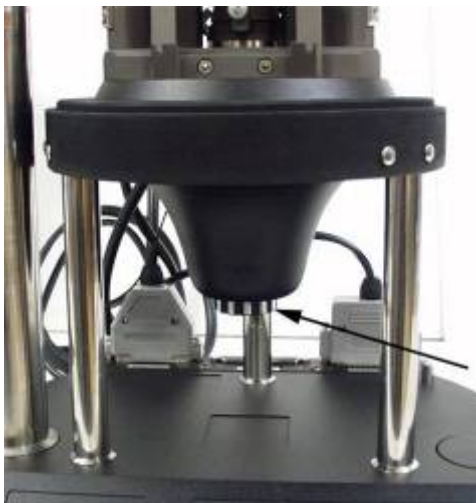


Fig. 2-109

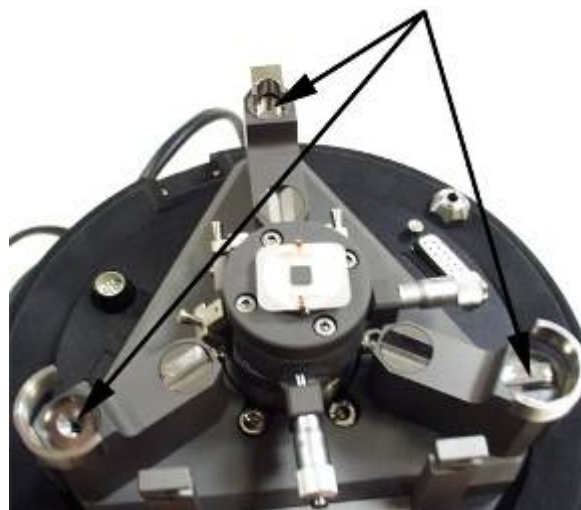


Fig. 2-110

- The measuring head is installed with inserting the screw supports into the fitting socket ([Fig. 2-110](#)) in such way that the front supports of the measuring head, fixed with contra-nuts, fit into the sockets with a hollow and a groove.

2.8.4.2 **Checking the plane of the SPM head base and the sample base for being parallel**



Note. It's necessary to carry out this procedure only when installing the measuring head for the first time. If the correlation between the plane of the measuring head base and the plane of the universal stage of the approach unit for being parallel has been already carried out and if you are sure that the length of measuring head supports hasn't changed, then you don't have to execute the procedure of checking the base of measuring head and universal stage for being parallel

- For lessening the “parasite” inclination when scanning, it's necessary that the plane of measuring head base is parallel to the plane of the table for objects. (In the suggestion that the form of investigated sample is near to the flat-parallel one);
- For checking the base of measuring head for being parallel to the plane of the table for objects it's enough to use a usual ruler;
- It's necessary to measure the distance between the base of measuring head and the plane of universal stage near to each of three supports, for example, as it's shown on [Fig. 2-111](#);
- It's necessary to make the distances in these points the same through regulating the length of the supports. Using a ruler with millimeter divisions provides setting the distance with 0.5 mm accuracy that is completely enough.

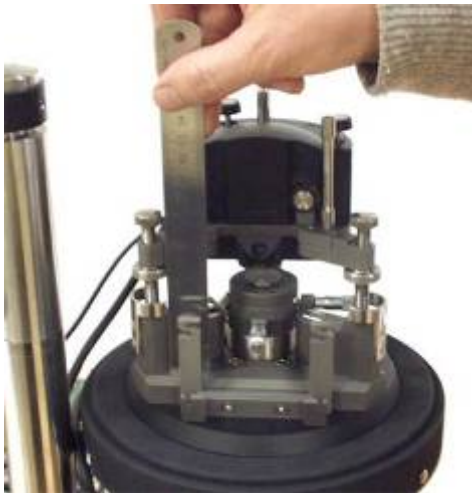


Fig. 2-111

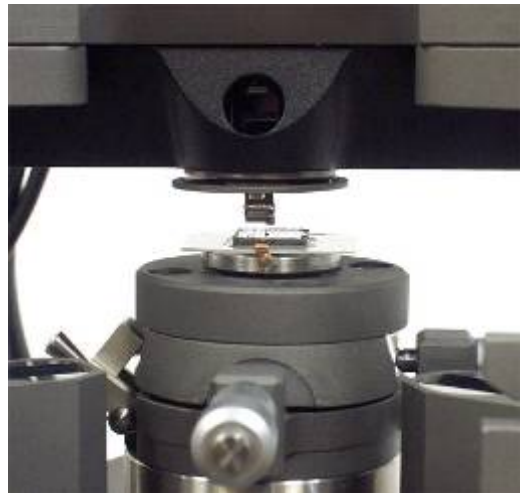


Fig. 2-112

2.8.4.3 **A preliminary landing of the sample to the probe**

- The easiest way to execute the preliminary landing is to make it by hands with the help of a handle of fast feed ([Fig. 2-109](#)). Let us remind you that rotating the handle counter clockwise lifts the sample up (if you look from the side of the handle);
- Looking from a side convey the sample to the probe at the distance of 0.5-1 mm ([Fig. 2-112](#));

- If it's necessary place a protective cap ([Fig. 2-113](#)). Ground it having connected it with the body of the approach unit by a grounding wire.



Note. It's recommended to work with the cap in the following cases:

- a) if it's necessary to get a high resolution in XY plane or over Z;*
- b) when you carry out temperature measurements ;*
- c) for protection from temperature jumps, for example, when there are draughts;*
- d) in order to lessen the level of acoustic noises;*
- e) when carrying out electric measurements*



Fig. 2-113

3 Contact Atomic Force Microscopy

The operation of the device involving the modification of the surface topography using contact mode of scanning forms the basis for the implementation of a number of other modes and techniques, such as Lateral Force Mode, Force Imaging Measurement Mode, Adhesion Force Imaging Measurement Mode and Local Hardness and Viscosity Imaging Measurement Mode (in combination with modulation techniques).

3.1 *Constant Force Mode*

3.1.1 Introduction: initial state and basic operations of contact microscopy mode

Initial State

It is assumed, that the device is prepared for operation.

- The device is switched on;
- The program is started and the program main window is displayed;
- The cantilever is mounted and the optical registration system is adjusted;
- The sample is mounted and SPM detecting head is installed with the sample landed to the tip.

Basic operations of contact microscopy mode

The operation of the device in contact microscopy mode can be subdivided into a sequence of the following basic operations:

1. Switching the device over to the contact mode of operation;
2. Setting the initial level of **DFL** signal (feedback loop signal);
3. Landing the sample to the tip;
4. Setting the operating level of the Feedback Loop Gain;
5. Selecting an SPM mode;
6. Selecting and setting the scanning size, the points number and the scanning step size;
7. Selecting and setting the velocity of scanning;
8. Checking other settings of the parameters of scanning;
9. Starting the scanning process;
10. Adjusting the parameters of scanning (if necessary);
11. Saving the obtained results;
12. Switching the device off.

Each of the above operations consists of a certain series of elementary operations.

Below follows a more detailed description of the abovementioned basic operations.

3.1.2 Switching the device over to the contact mode of operation

- To switch the device over to the contact mode of operation, it is necessary to set the mode selection switch (the fourth in the main bar) to **Contact** position, as shown on [Fig. 3-1](#);

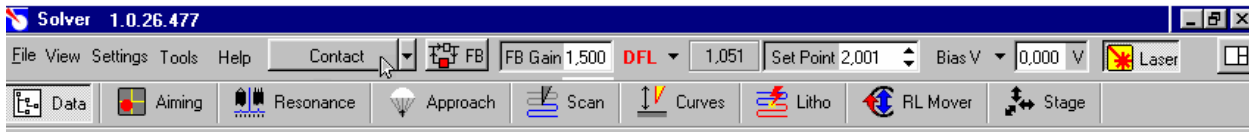


Fig. 3-1

- If this switch is set to **SemiContact** position, for example, as shown on [Fig. 3-2](#), then select **Contact** in the menu that opens when the switch is pressed;

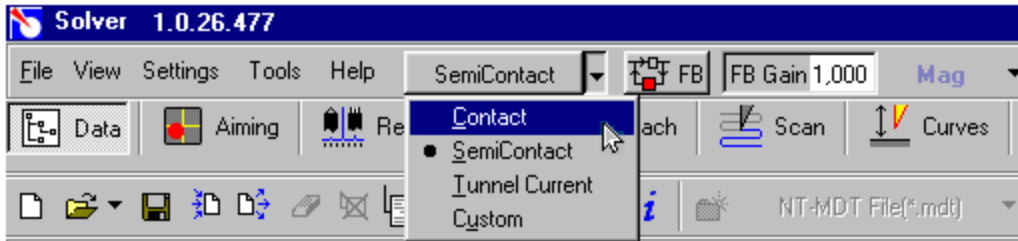


Fig. 3-2



Note

- The mode selection switch of the device can be set to one of the following positions: Custom, Contac, SemiContact and Tunnel current;
- When the switch is set to Contact position the device automatically performs all commutations, necessary for operating in the contact mode: DFL signal is fed to the feedback input with the generator set to off and the required parameter values are set, etc. Similarly, the selection of SemiContact, (or Tunnel current) positions results in the automatic commutations necessary for operating in the SemiContact (or tunnel) modes;
- If Custom position is selected, a user is free to adjust the device settings and implement different configurations and positions of the device.

3.1.3 Setting the initial level of DFL signal

The value of the initial level of **DFL** signal, corresponding to the free unbent state of the cantilever is determined by the way the photodetector is installed relative the cantilever reflected beam. Zero value of **DFL** signal corresponds to the laser spot positioned in the middle between the upper and the lower parts of the photodiode with the spot area distributed evenly.

The value of the initial level of **DFL** signal can be adjusted using knob 4 ([Fig. 3-3](#)) performing the mechanical movement of the photodiode in transverse direction relative the cantilever reflected laser beam.

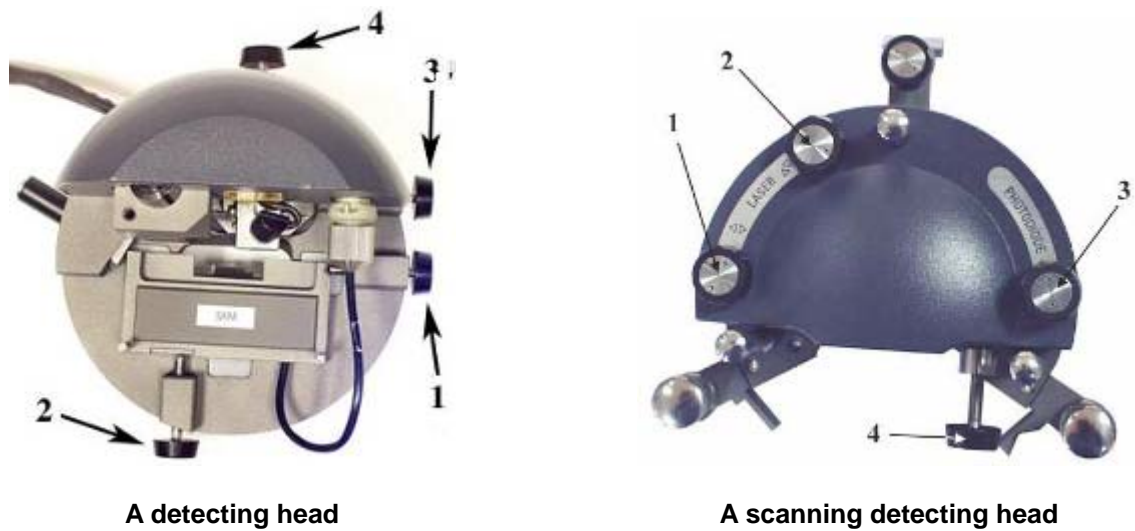


Fig. 3-3. Photodiode vertical movement screw

DFL signal level adjustment procedure

1. Go to the window of photodiode signal adjustment **Aiming** using **Aiming** bookmark of the operations bar (Fig. 3-4). The window comprises a table representing the current values of photodiode signals and an indicator of the position of the laser spot relative the photodiode segments.

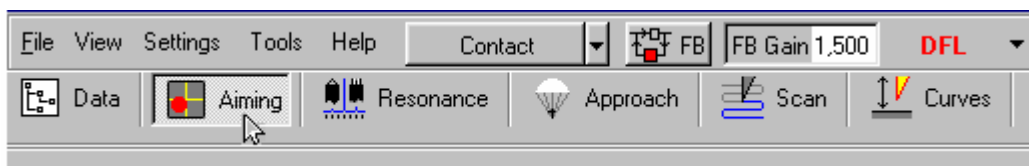


Fig. 3-4

2. Watching the signal level on the indicator set the initial level of **DFL** signal close to zero (Fig. 3-5), using the photodiode vertical movement screw (see Fig. 3-3)

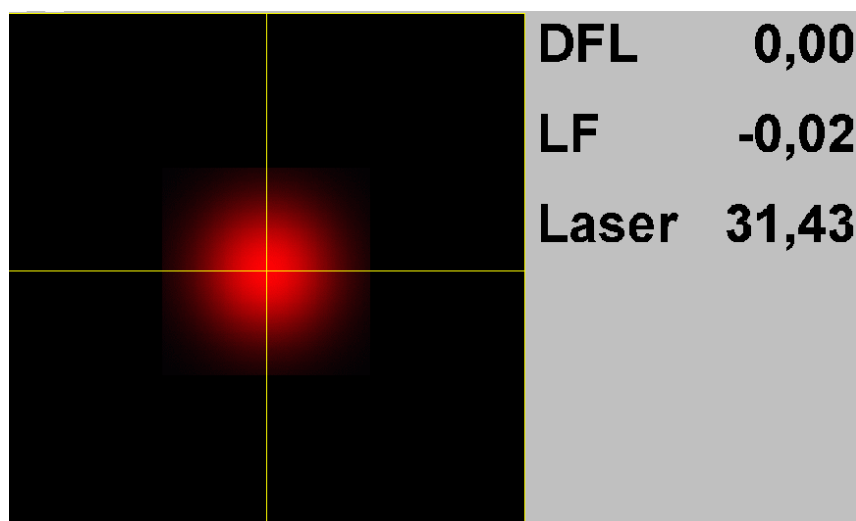


Fig. 3-5

3.1.4 Approaching the sample to the tip

1. Go to **Approach** window using **Approach** bookmark of the operations bar (Fig. 3-6);

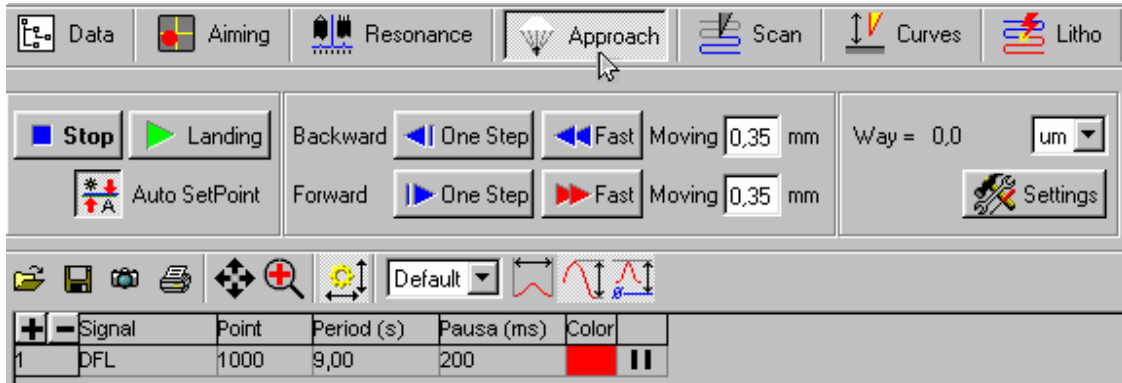


Fig. 3-6

2. Check the position of the button for the automatic setting of **Set Point** parameter. **Auto SetPoint** button should be activated as shown on Fig. 3-7;



Fig. 3-7

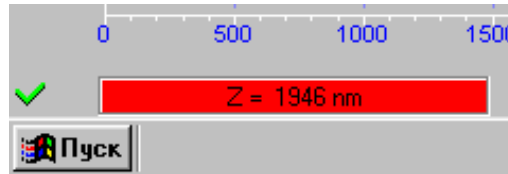


Fig. 3-8

3. Start the approach procedure by pressing **Landing** button.

All of the above should yield the following results

- The value of **Set Point** parameter is automatically set exceeding the current value of DFL signal by two units (i.e. **Set Point=DFL+2**).
- The feedback is switched on and Z-direction piezo scanner is protracted to the maximum. The protraction of Z-direction scanner is illustrated by the analog indicator of scanner protraction, located in the left lower field of the program main window (Fig. 3-8). The degree of scanner protraction is characterized by the length of the color bar.
- The incremental mover is switched on, moving the scanner with the sample in the direction of the tip.

Watch the **DFL** signal changes in the oscilloscope window during the approach procedure, while watching the progress of the scanner protraction indicator. Wait till the procedure is completed.

On condition the approach parameters are set correctly, the procedure is completed after some time, leading to the following:

- **DFL** signal increases to the value of **Set Point** parameter with the feedback maintaining Z-direction scanner in the position where **DFL** signal equals **SPoint** with the position corresponding to approximately a half of the scanner protraction range;
- The length of the indicator's color bar decreases and stops somewhere in the middle (Fig. 3-9);

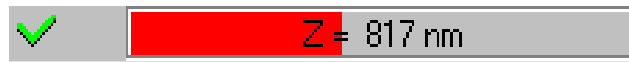


Fig. 3-9

- The incremental mover stops;
- The increase of **DFL** signal to the value of **Set Point** parameter is represented on **DFL (t)** dependence on the oscilloscope (Fig. 3-10);
- The oscilloscope displays an «OK» message box (Fig. 3-10).

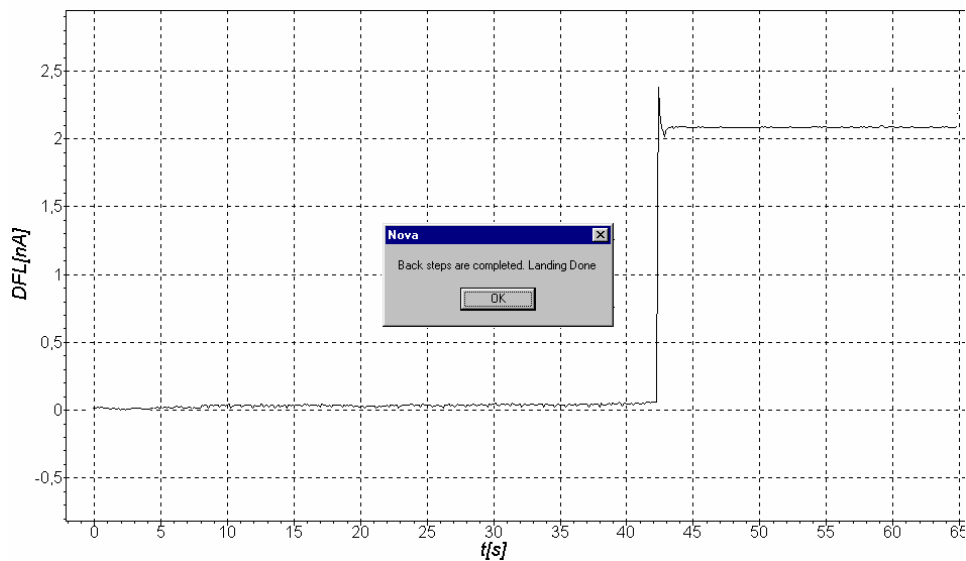


Fig. 3-10

To continue, press **OK** button and go to the next operation (see page 71, i. 3.1.5).



Note: Special cases

*It can be so that after the approach procedure is performed and **DFL** signal is increased to the value of **Set Point** parameter, **DFL(t)** dependence demonstrates a considerable increase of **DFL** signal variable component (as shown on Fig. 3-11 for example). This means that a generation occurs in the feedback loop due to the fact that the value of **FB Gain** parameter is too high. In this case the value of **FB Gain** parameter should be decreased to 0.5-07 of the threshold level. The procedure of **FB Gain** parameter adjustment is described below in i. 3.1.5 on page 71.*

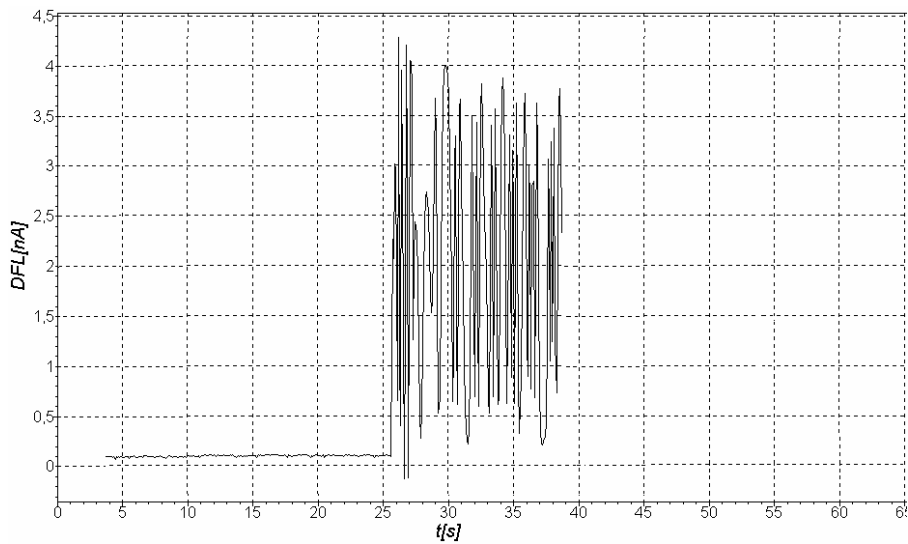


Fig. 3-11



Note: On selecting and setting of Set Point parameter

- *The value of **Set Point** parameter is automatically set to exceed the current value of DFL signal by two units (i.e. $\text{Set Point} = \text{DFL} + 2$) with the option of “automatic setting of Set Point parameter” deactivated (i.e. with **Auto SetPoint** button activated)*
- *If **Auto SetPoint** button is deactivated, it is necessary to set the value of **Set Point** parameter manually, using **Set Point** parameter field located in the upper bar.*
- *The recommended initial value of **Set Point** parameter should be equal to the sum of the following: **DFL** signal plus (5-10)% of **LASER** signal value (i.e. $\text{Setpoint} = \text{DFL} + (0.05 \div 0.1) \times \text{Laser}$).*
- *When selecting an optimal value of **Set Point** parameter the considerations presented below should be taken into account. The difference between the value of **Set Point** parameter and the initial value of **DFL** signal defines the value of interaction between the apex of the tip and the sample surface. The greater is the difference between the value of **Set Point** and the initial value of **DFL** signal, the greater is the value of cantilever deviation and the greater is the force of the tip-surface interaction. Thus, modifying the value of **Set Point** parameter relative the initial value of **DFL** signal can result in modifying and setting a certain force of the tip-surface interaction, which provides the possibility to obtain surface topography images with certain levels of the tip-surface interaction.*
- *If the difference between the value of **Set Point** parameter and the initial value of **DFL** signal is too great, which corresponds to the tip-surface interaction of considerable force, it can result in the destruction of the tip, as well as the surface during scanning.*
- *If the difference between the value of **Set Point** parameter and the initial value of **DFL** signal is too little, which corresponds to maintaining the tip-surface interaction of medium force, the operation of the tracking system may turn unstable.*
- *The value of **Set Point** parameter cannot be less than the value of the initial level of **DFL** signal or cannot exceed the value of **LASER** signal.*

3.1.5 Setting the operating level of Feedback Loop Gain

The greater is the value of Feedback Loop Gain (**FB Gain** parameter), the greater is the velocity of feedback loop operation. But at a considerable value of feedback loop gain (let us call it the threshold value) the operation of the tracking system becomes unstable, triggering the process of “generation”. This is manifested in the form of **DFL** signal variable component of a considerable value.

To provide stable operation it is recommended to set the Feedback Loop Gain not greater than 0.6-0.7 of the threshold value, triggering the process of “generation”. The value of Feedback Loop Gain is adjusted by modifying the value of **FB Gain** parameter.

Setting the operating value of FB Gain parameter

- Open **FB Gain** adjustment window by double-clicking the mouse button in FB Gain value field (Fig. 3-12). Watch the value of **DFL** signal on the oscilloscope while increasing the value of **FB Gain**.

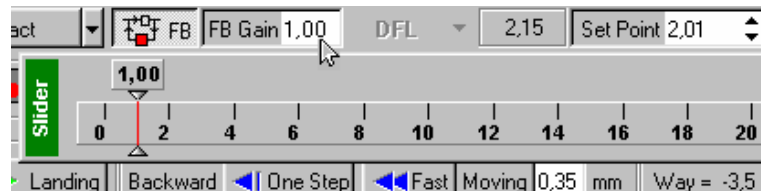


Fig. 3-12

- Determine the value of **FB Gain**, which triggers the process of generation. The start of this process is characterized by an abrupt increase of **DFL** signal variable component (Fig. 3-13).

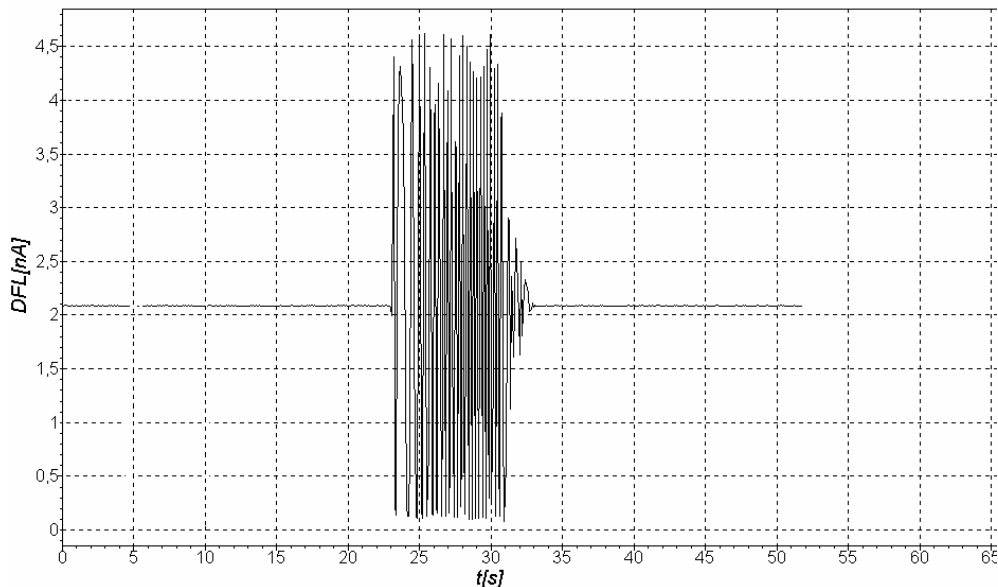


Fig. 3-13

- Decreasing the value of **FB Gain** parameter set the operating value of 0.6-0.7 from the value of **FB Gain**, which triggers **DFL** signal generation.

3.1.6 Setting the parameters of scanning

Go to **SCAN** window using **SCAN** bookmark of the operations bar ([Fig. 3-14](#)).

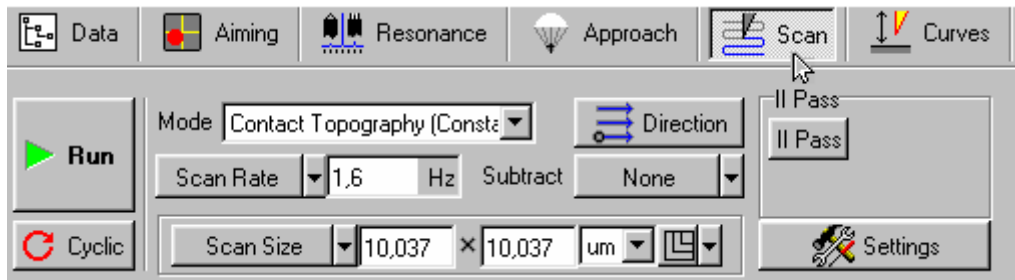


Fig. 3-14

The menu of the parameters of scanning is located in the upper part of **SCAN** window. The menu consists of three lines. Below is the univariate data representation field, displaying the measured signal row-wise during scanning. Below the invariate data representation field is the window for displaying the scanned image.

3.1.6.1 Setting SPM operating mode

The contact mode “**Contact topography**” is set as SPM operating mode by default with the name of the operating mode displayed in the mode selection field “**Mode**” ([Fig. 3-15](#)), located in the first line of “**SCAN**” window control panel.

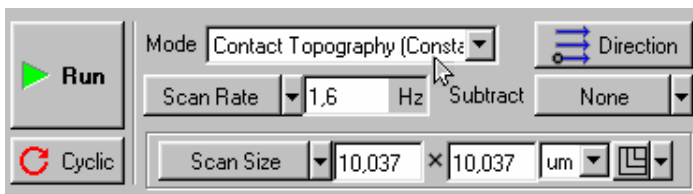


Fig. 3-15

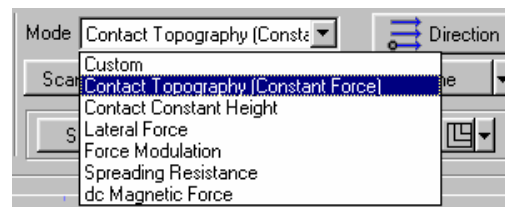


Fig. 3-16



Note:

Any SPM mode, compatible with contact microscopy can be set if necessary. To select a mode, it is necessary to double-click in the SPM mode selection field ([Fig. 3-15](#)) and select the required operating mode in the menu that opens ([Fig. 3-16](#)). All related commutations in the device, necessary for the implementation of the selected mode are performed automatically.

3.1.6.2 Setting the scan size, the points number and the scanning step size

The parameters «**Scan Size**» (the size of the scanned image), «**Point Number**» (the number of points in X and Y directions) and «**Step Size**» (the step of scanning) can be modified using the respective parameter selection button ([Fig. 3-17](#)), and entry fields, displaying the current value of a parameter set. An example below ([Fig. 3-17](#), [Fig. 3-18](#)) illustrates the selection of “**Scan Size**” parameter with the image size of 10,037x10,37 nm.

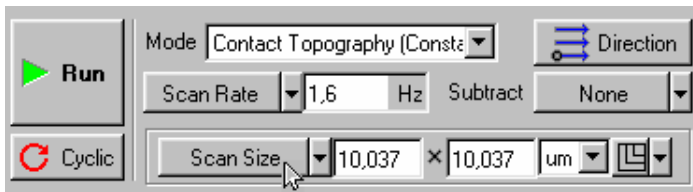


Fig. 3-17

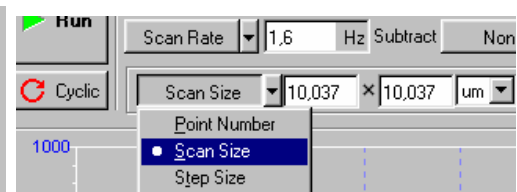


Fig. 3-18

To set the required parameter, it is necessary to press the parameter selection button and select the required parameter in the menu that opens (Fig. 3-18). **To modify the value of the parameter** it is necessary to double-click in the respective entry field and set the required value using a slider, that opens. The value of a parameter can also be modified directly in the respective entry field by editing the figures from the keyboard.

“Scan Size” parameter

The value of “**Scan Size**” parameter is automatically set to maximum by default. Thus, this value comprises **10x10 mcm²** for **10-micron scanner** as is shown in the example on Fig. 3-17, Fig. 3-18 and **50x50 mcm²** for **50-micron scanner**. This value for **3-micron scanner** comprises **3x3 mcm²** respectively.

The scan size, different from the maximal is set using the respective parameter selection button and an entry field as is described above (see p. 3.1.6.2).



Note. On the selection of the initial scan size:

What should be the initial scan size? The answer to this question depends on the properties of a sample, as well as on the tasks and goals set:

- *In case any preliminary data on the surface properties is available and a confidence is present that the differential of height of the expected surface topography does not exceed the limits of z-range of the scanner, a maximal scan size can be set.*
- *In case the data on the surface properties is not available, it is recommended to start the scanning from the smaller size area of 0.5÷1 mcm, for example. Based on the results of scanning of a smaller area the optimal values for such parameters as the velocity of scanning, Set point, FB Gain can be selected and set. The scan size can then be increased.*

«Point Number» parameter

The value of «**Point Number**» (the number of points in X and Y directions) is automatically set to **256X256** by default.

This value can be modified if required, as well as the value of scan size. The value of the parameter is modified by the respective parameter selection button or using the entry field, as described above (see p. 3.1.6.2).

«Step Size» parameter

With the scan size and point number set (“**Scan Size**” and “**Point Number**” parameters respectively) the step of scanning (“**Step Size**” parameter) is set automatically according to the set values of “**Scan Size**” and “**Point Number**” parameters.

Modification of «**Step Size**» parameter automatically modifies the value of «**Scan Size**» parameter correspondingly, whereas the value of «**Point Number**» parameter remains the same.

3.1.6.3 Setting the parameters of scanning: velocity of scanning

It is recommended to set the frequency of scanning of lines (**Scan Rate** parameter) within the range of **0.5-2 Hz**. The frequency of scanning is automatically set within this range at the program start, accompanied by the loading of standard parameters (Fig. 3-14).

The frequency of scanning (scanning velocity) can be modified, if required, by the scanning parameter selection button and the entry field, located next to the button.



Note. Ways of modification the velocity of scanning

- The velocity of scanning can be modified by modifying any of the four temporal parameters: the frequency of scanning of lines **Scan Rate**, or the velocity of scanning of a line «**Velocity**», or the time of scanning of the total area of scanning «**Scan time**» and the time, required for scanning of each point of the area of scanning «**Time/point**»;
- The button for the selection of temporal parameter is located in the third line of “SCAN” control panel, Fig. 3-19). The button displays the selected parameter (like **Scan Rate** in the example on Fig. 3-19). Press this button to set the necessary parameter and select the required parameter in the menu that opens (Fig. 3-20).

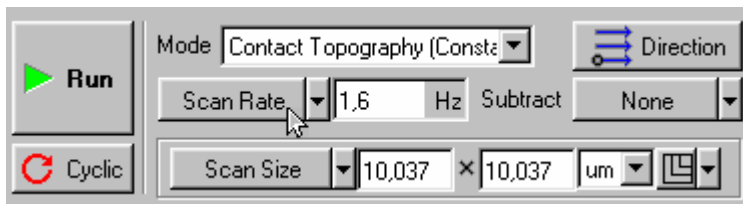


Fig. 3-19

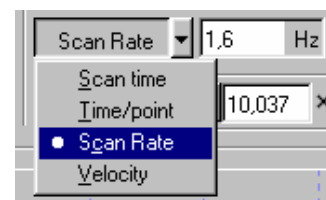


Fig. 3-20

- An entry field, displaying the current value of the parameter set is located next to the selection button. Double-clicking the mouse button in this field opens a slider, which can be used to modify the value of the selected parameter. The value of the parameter can also be modified directly in the entry field by editing the numbers from the keyboard.

3.1.7 Scanning

Let us consider an example of scanning of a sample in the form of a rectangular grid (standard TGZ-1 grid, scan step of 3 mcm, with the step height of 19 nm).

3.1.7.1 Scanning start

Once the preparatory operations are performed, the tip is landed to the sample, the set point is selected and the parameters of scanning are set, the process of scanning the sample surface can be started.

To start scanning it is necessary to press **RUN** button, located in the left upper part of **SCAN** window ([Fig. 3-21](#)).

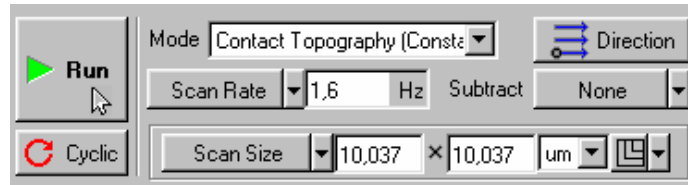


Fig. 3-21

Pressing RUN button yields the following results:

- The tip starts scanning the sample surface row-wise with the scanned surface image (the image of a rectangular grid in our example) appearing gradually in the image display window ([Fig. 3-22](#)).

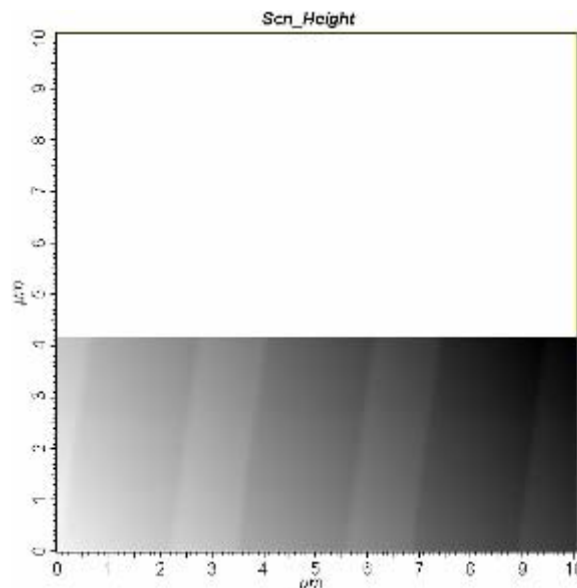


Fig. 3-22

- The univariate data representation field alternately represents the profile lines of the scanned surface topography ([Fig. 3-23](#)).

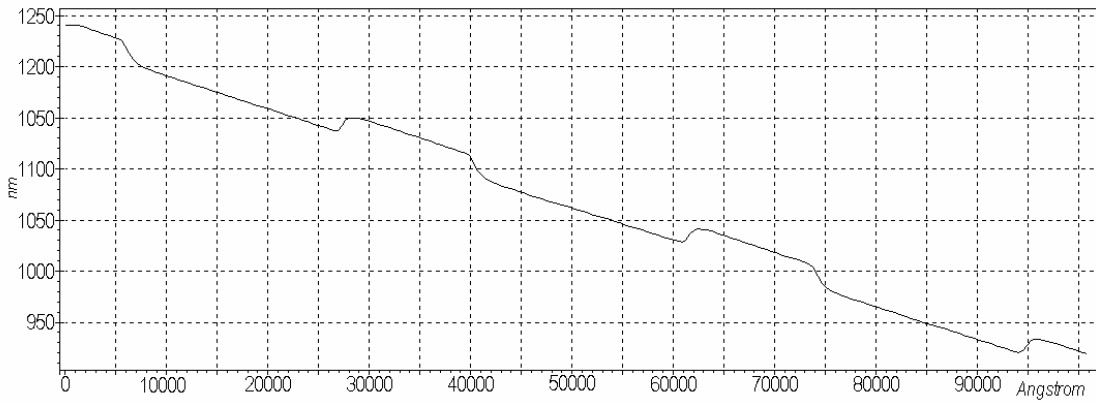


Fig. 3-23

- Some buttons on **SCAN** panel are replaced with buttons **Pause, Restart, Stop** (Fig. 3-24):.

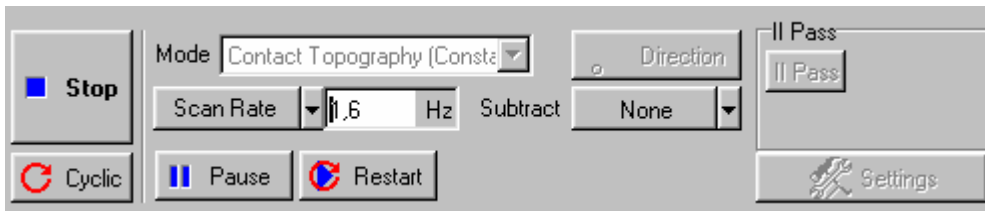


Fig. 3-24

In case the scanning should be stopped for some reason, press **Stop** button or use “Esc” button of the keyboard.

3.1.7.2 Modifying the parameters during scanning

Plane subtraction:

The sample is a bit tilted in X direction in the example above (Fig. 3-20, Fig. 3-21).

The tilt can be subtracted directly during the scanning (i.e. in on-line mode) using **Subtract** button switch. The button is set to **None** (Fig. 3-22, Fig. 3-23) by default.

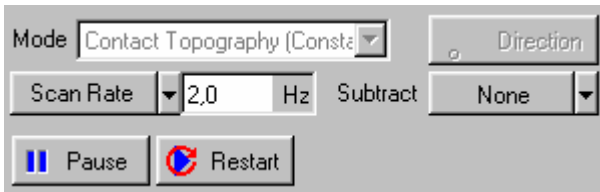


Fig.3-25

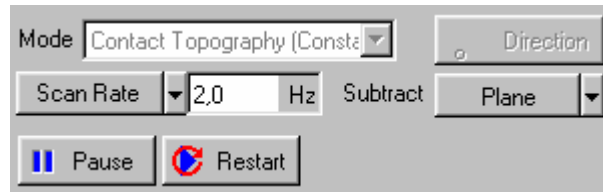


Fig.3-26

If this button is pressed, setting **Plane** position subtracts a plane and the previous image on Fig. 3-20 would approximately look like the image on Fig. 3-27.

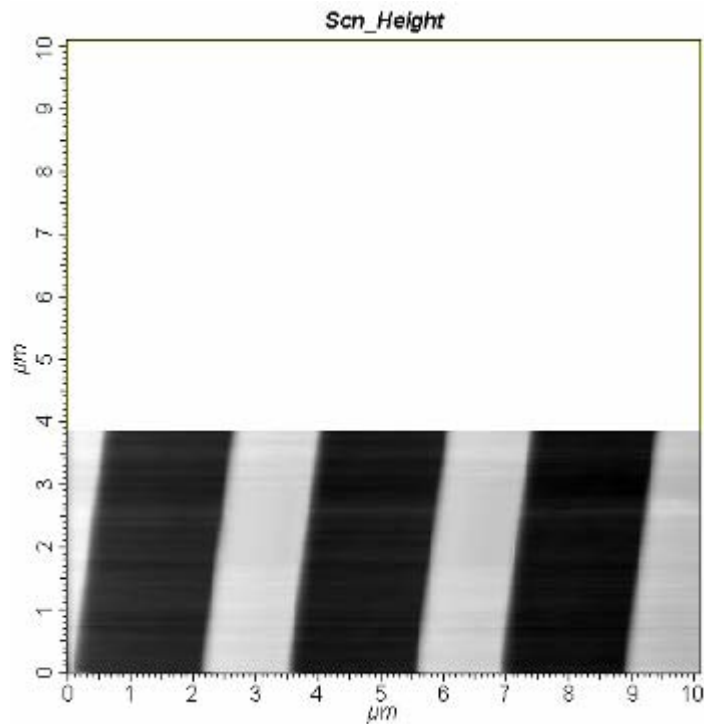


Fig. 3-27

The univariate data representation field would correspondingly represent the current line of the profile of scanning minus the subtracted plane. Instead of the profile on [Fig. 3-21](#) a profile on [Fig. 3-28](#) would be represented.

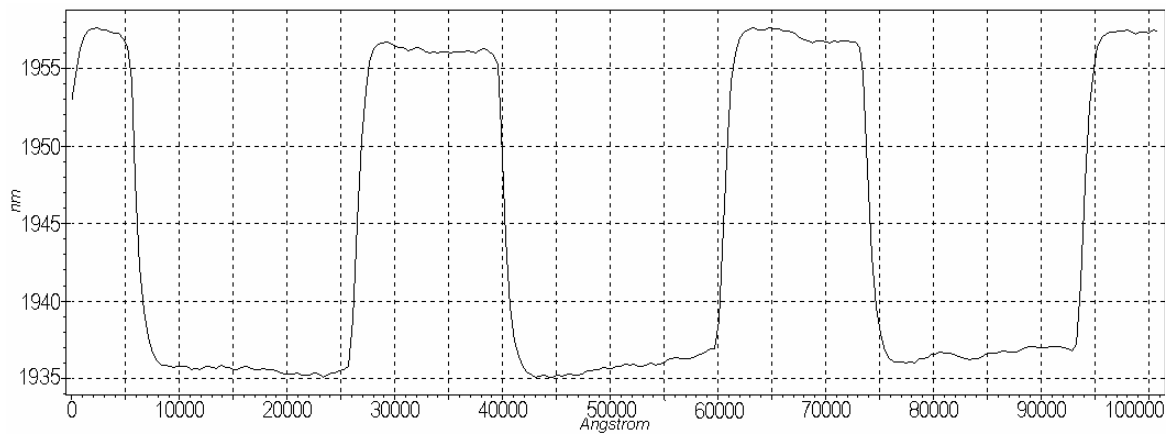


Fig. 3-28

Subtract button switch can alternately be set to the positions of **1st-order curve** and **2nd-order curve**. The first position subtracts the 1st order curve (plane subtraction), whereas the second position subtracts the 2nd order curve.

3.1.7.3 Adjusting the parameters during scanning

The quality of the obtained image essentially depends on such parameters as the velocity of scanning **Velocity** (frequency of scanning **Scan Rate**), the value of set point **Set Point**, and feedback loop gain **FB Gain**. Any of these parameters can be modified directly during scanning.

Pause button is intended specially for adjusting the parameters. When this button is activated, the scanning in the slow direction stops, whereas the scanning in the fast direction continues, going along one and the same line. This operation mode can be used for selecting the optimal parameters. The modification of the profile, corresponding to the scanned line resulting from the modification of the corresponding parameter, for example scanning velocity (or **Set Point** value or the value of **FB Gain**) can be observed during the procedure.

Press the special **Restart** button to restart scanning.

3.1.7.4 Certain recommendations on the optimization of the parameters of scanning

The selection of the **optimal value of the velocity of scanning** depends on the properties of the investigated object surface, the scan size and the environment conditions.

A surface with a smooth topography can be scanned with the velocity higher than that of scanning the surface with a more pronounced topography and considerable height differential.

The velocity of scanning should be decreased in case a slope of a projection or that of a hollow is not registered.

3.1.8 Saving the obtained results

To store the obtained results to the hard disc, it is necessary to do the following:

- Press **File** button (the first button in the upper bar of the program window, [Fig. 3-29](#)).



Fig. 3-29

- Press **Save** in the menu that opens and store the data in the form of a randomly named file with ***.MDT** extension.



Note: Once the sample surface scanning is completed, the resulting surface images are stored in random access memory. A separate frame corresponds to each of the scanned image of surface. The frames are numbered according to the order they were obtained. If no data saving is performed, the data is lost on exiting the program.

3.1.9 Operation completion

To complete the operation, perform the following actions:

1. Remove the sample from the tip by 2-3mm.

To accomplish this, it is necessary to do the following:

- Go to **Approach** window, using **Approach** bookmark in the operations bar ([Fig. 3-30](#)),



Fig. 3-30

- Double-click the mouse button in **Moving** parameter entry field, for **Backward** ([Fig. 3-31](#)),



Fig. 3-31

- Set the value of 2-3mm, using the slider ([Fig. 3-32](#)),

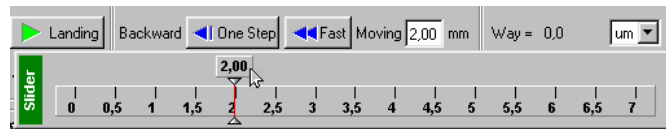


Fig. 3-32

- Press **Fast** button for **Backward** ([Fig. 3-33](#))



Fig. 3-33

2. Switch off the feedback loop using **FB** button in the pulled position ([Fig. 3-34](#)).



Fig. 3-34

3.2 Lateral Force Mode

3.2.1 Brief description of the Lateral Force Mode

The Lateral Force Mode allows to discern the areas with different friction ratios, as well as to underline the smallest features of surface topography. The Lateral Force Mode may prove useful in investigating semiconductors, polymers, film coatings and storage medium. It is also suitable for the investigation of physiochemical surface properties, chemical parameters (of pollution, for example) and tribological characteristics.

Physical implementation of the Lateral Force Mode involves the formation of torsion deformation of cantilever, which occurs in addition to cantilever's normal directional deformation during Constant Force Mode scanning in the direction, perpendicular to the long axis of cantilever ([Fig. 3-35](#)). This deformation is conditioned by the moment of force, acting on the apex of the tip.

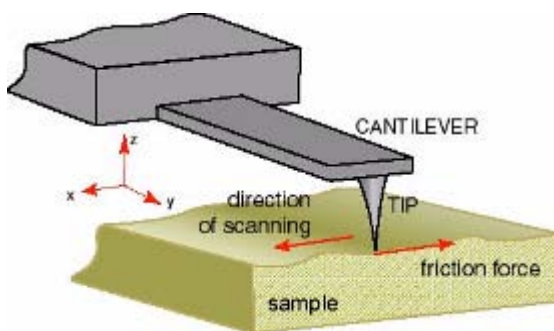


Fig. 3-35

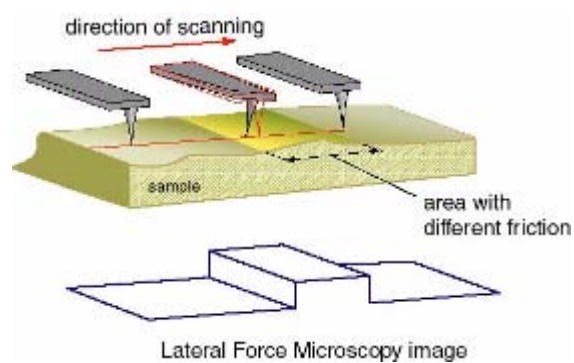


Fig. 3-36

The angle of twist is proportional to the lateral force on conditions the deflections are minor. The value of cantilever's angle of twist is measured by the optical registering system of microscope.

The angle of twist is changing as it moves from one area to another along a flat surface, consisting of areas with different friction ratios ([Fig. 3-36](#)). This allows the assumption of a local friction force measurement. Such interpretation is not possible in case of a developed topography.

This measuring mode nonetheless allows to obtain images with the smallest topography features clearly visible, thus making their search easier. Besides, the parameters of crystal lattice on mica and some other flaky materials can be easily measured in the process of measuring lateral forces.

3.2.2 A signal, related to the torsion deformation of cantilever

Optical registering system generates a "LF" electrical signal, which is modified in proportion to the value of torsion deformation of cantilever. This signal is used to obtain the image of local friction force, acting on a sample surface.

3.2.3 Preparation and operation of the device in Lateral Force Mode

To prepare and perform the measurements in Lateral Force Mode, it is necessary to carry out the operations, similar to those performed for operating in Constant Force Mode. These operations are described above in Chapter [3.1 Constant Force Mode](#).

A brief rendering of these operations comes to the following:

- Select a contact configuration (using “**Contact**” drop-down menu);
- Set the initial level of **DFL** signal;
- Perform the procedure of tip-sample landing;
- Set the operating level of feedback gain;
- Select a mode: «**Lateral Force**»;
- Select and set up the parameters of scanning (scan size, number of points, velocity);
- Perform the scanning, obtaining an image of surface topography and the distribution of lateral forces.

The main difference (as compared to operating in Constant Force Mode) lies in the fact, that performing i. [3.1.6.1 Setting SPM operating mode](#) on p. [72](#) a user should set “**Lateral Force**” instead of “**Contact Topography**”.

To do this, it is necessary to select **Lateral Force** in PNL mode drop-down menu ([Fig. 3-38](#)). All device commutations, necessary to implement the selected PNL mode are carried out automatically.

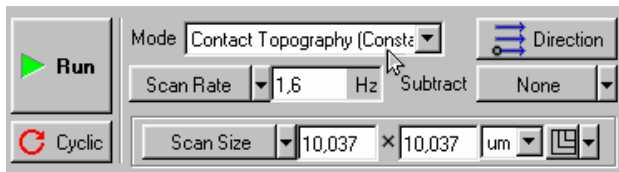


Fig. 3-37

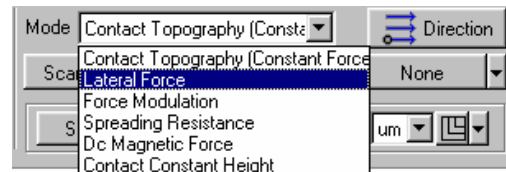


Fig. 3-38

The second difference lies in the fact that two images are represented in data viewing area during sample scanning ([Fig. 3-39](#)): the image of “**LF**” signal distribution is to the left, whereas to the right is the image of topography (obtained using **Constant Force Mode**).

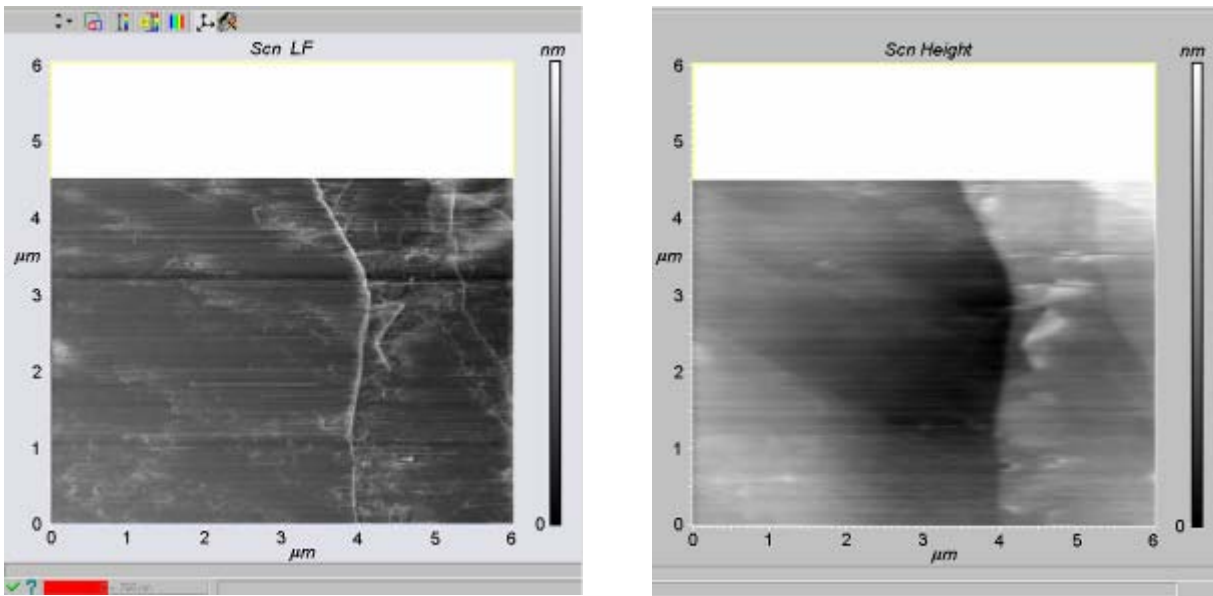


Fig. 3-39

One of the images is selected (active). The left image is active in the above example (Fig. 3-39). Clicking the mouse inverts the selection. The section profile of the image selected is represented per line in the oscilloscope window.

3.3 Constant Height Mode

3.3.1 Brief description of the Constant Height Mode

The apex of the tip in Constant Height Mode is in contact with the surface. The cantilever’s end, mounted to a chip is maintained on a constant height during scanning (in scanning with the feedback switched off). The value of cantilever deflection (deformation) is correspondingly proportional (on condition the deflections are minor) to the pressing force of cantilever and reflects the sample surface topography.

The cantilever’s surface tracking dynamics in scanning is restricted by the frequency characteristics of cantilever and not those of feedback, as is the case in Constant Force Mode. Resonance frequencies of cantilever are much higher than the typical feedback frequency, which comprises units of KHz. This allows scanning with higher velocities.

If the dependence of deformation of a cantilever used, on the distance between the chip of the probe and the sample (i.e. the dependence of “DFL” signal on the distance between the chip and Z surface in this example) is removed in advance, the image of “DFL” signal distribution can be transformed into the image of surface topography, using this dependence.

Besides, on condition the deflection rate constant and geometric sizes of a cantilever used are known, the image of distribution of the signal of cantilever’s normal deformation (“DFL” signal) can be transformed into the image of distribution of a local force, acting on the cantilever.

It should be remembered however, that in major deflections from zero position the dependence of “DFL” signal on the value of tip deflection becomes non-linear. The approximate range of linearity depends on the cantilever – the shorter is the cantilever, the lesser is the range.

The drawbacks of the mode include the requirement for sample surfaces to be rather smooth. Besides, in the process of investigation of soft samples (such as polymers, biological samples, LB-films and the like) their surfaces can deteriorate, as the tip maintains a constant mechanical contact with the surface. In scanning relatively soft samples with developed surfaces the force of a tip, pressing on the surface varies, accompanied by simultaneous irregular flexing of sample surfaces. The resulting surface topography may be distorted. Possible existence of considerable capillary forces, conditioned by the presence of water layer also degrades the resolution.

3.3.2 Preparation and operation in Constant Height Mode

- To prepare and perform the measurements in Constant Height Mode, it is necessary to carry out the operations, similar to those performed for operating in Constant Force Mode. These operations are described above in i. [3.1 Constant Force Mode](#).

Preparation and measurement of surface topography in **Constant Force Mode** should be performed in advance:

- Select a **Contact** configuration;
 - Set the initial level of **DFL** signal;
 - Perform the procedure of tip-sample landing;
 - Set the operating level of feedback gain;
 - Select a mode: **Contact topography**;
 - Select and set up the parameters of scanning (scan size, number of points, velocity);
 - Perform the scanning, obtaining an image of surface topography and setting up the parameters of scanning.
- Once the measurements of surface topography in Constant Force Mode are performed, do the following:
 - Set «**Contact Constant Height**» instead of «**Contact topography**» ([Fig. 3-40](#), [Fig. 3-41](#)).

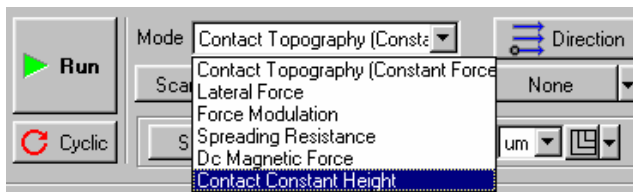


Fig. 3-40

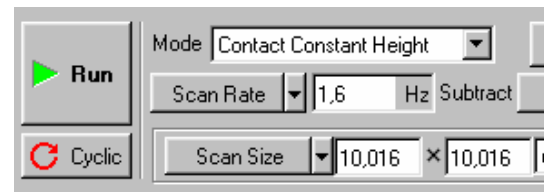


Fig. 3-41



Note: Setting «Contact Constant Height» results in automatic zeroing of FB Gain (feedback gain) parameter value, which is equivalent to switching the feedback off and fixing the mounted cantilever's end on a constant height relative the surface. "DFL" signal is applied to the input of ACR measuring channel simultaneously

- Start the scanning process by pressing «**Run**» button.

A per line representation of “**DFL**” signal value, obtained using **Constant Height Mode** is displayed in data viewing area **while scanning** a sample.

3.4 Spreading Resistance Imaging

3.4.1 Measurement preparation

Probes with conductive coating are used to perform the measurements in question.

Prior to performing the spreading resistance imaging measurement do the following:

1. Select the type of scanning (“by sample”, “by tip”, or “double”) and **“Contact”** configuration in program menu:

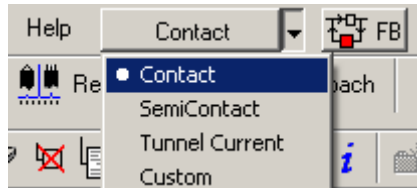


Fig. 3-42

Set the required value of **“Set Point”** parameter and activate the feedback loop.



Fig. 3-43



Fig. 3-44

2. Perform the landing procedure. To do this, go to **“Approach”** bookmark and press **“Landing”** button.

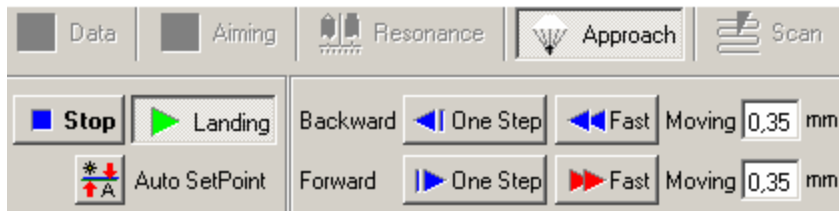


Fig. 3-45

3. Perform the sample surface preview scanning.
4. Select a sample area, suitable for measurement.
5. Perform the scanning of the selected sample surface area.

A detailed description of the above operations is to be found in i. [3.1 Constant Force Mode](#).

3.4.2 Mode selection and parameters setup

Select “**Spreading Resistance**” mode in “**Mode**” menu (Fig. 3-46).

The program sets up the signals, necessary for the measurement automatically.

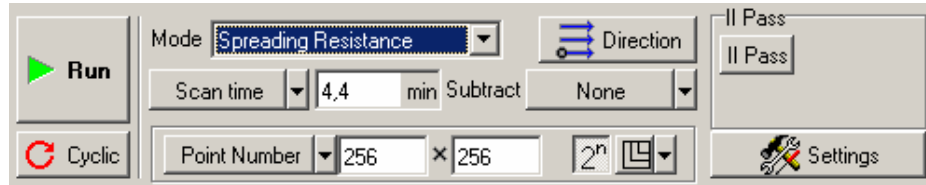


Fig. 3-46. A view of scanning parameters setup panel once “**Spreading Resistance**” mode is selected

Using “**Bias V**” parameter set the required difference between the sample and the tip potentials.



Fig. 3-47

3.4.3 Scanning

Go to “**Scan**” bookmark and press “**Run**” button (Fig. 3-46).

Two windows would appear on the display, one of them reflecting the surface topography (“**Height**” signal), whereas the other reflecting the distribution of spreading current (“**Ipr low**” signal).

Lighter areas of “**Ipr low**” signal correspond to higher conductivity and vice versa.

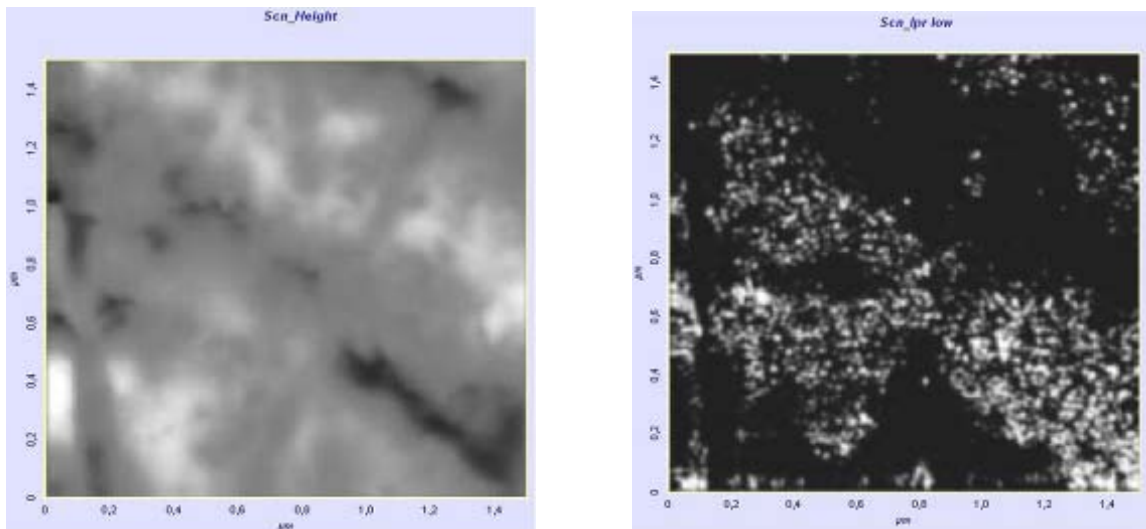


Fig. 3-48. The topography and spreading currents distribution images of Cu-CrN alloy

The topography and spreading currents distribution images of Cu-CrN alloy (the applied voltage comprising 0.1V) are exemplary.

3.4.4 Ways of image improvement

If the image quality is unsatisfactory, you can do any of the following:

- Replace the probe (with another of different rigidity or conductive coating type);
- Change the value of difference between the sample and the tip potentials in “**Bias V**” parameter (Fig. 3-47). A local surface oxidation is possible in case the voltage is too high;
- Change “**Set Point**” parameter (Fig. 3-43) (the force of the tip, pressing to the sample).

High pressing force can lead to the damage of conductive coating.

3.5 Force modulation

3.5.1 Measurement preparation

Prior to performing Force Modulation measurements, do the following:

1. Select the type of scanning (“by sample”, “by tip”, or “double”) and “**Contact**” configuration in program menu:

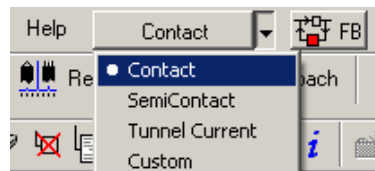


Fig. 3-49

Set the required value of “**Set Point**” parameter and activate the feedback loop.



Fig. 3-50



Fig. 3-51

2. Perform the landing procedure. To do this, go to “**Approach**” bookmark and press “**Landing**” button.

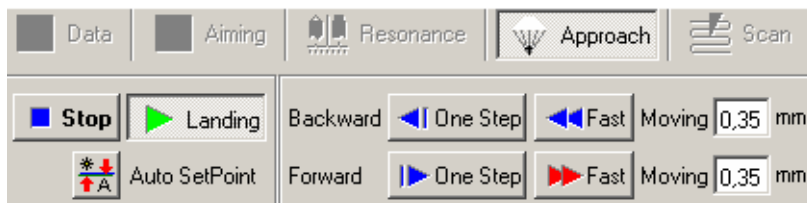


Fig. 3-52

3. Perform the sample surface preview scanning.
4. Select a sample area, suitable for measurement.
5. Perform the scanning of the selected sample surface area.

A detailed description of the above operations is to be found in i. [3.1 Constant Force Mode](#).

After the topography measurements by the Constant Force Mode have been completed, it is necessary to make set up the parameters for operation by the Force Modulation Mode.

3.5.2 Mode selection and parameters setup

Select “**Force Modulation**” mode in “**Mode**” menu ([Fig. 3-53](#)).

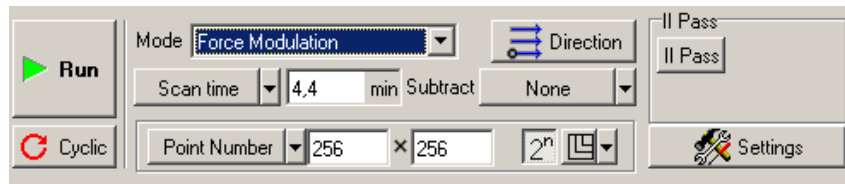


Fig. 3-53. A view of scanning parameters setup panel once “Force Modulation” mode is selected

The program shall automatically apply the generator alternating voltage to the scanner’s Z-electrode, setting the system resonance frequency scanning limits (scanner, sample, tip), switching over to the low frequency input of synchronous detector and setting the signals, necessary for measurement.

System oscillations frequency setup (scanner, sample, tip)

Go to “**Resonance**” bookmark and press “**Run**” button to scan the resonance frequency (the feedback loop should be kept active). To obtain optimal results, “**Auto peak find**” option should be deactivated.

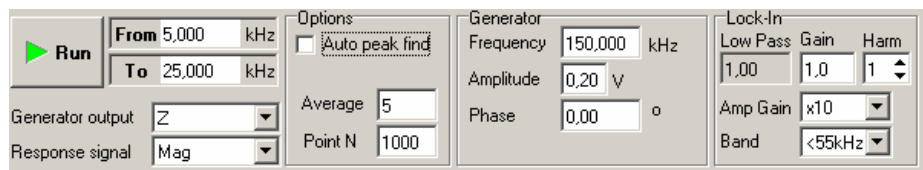


Fig. 3-54

A resonance curve should appear in the oscillograph window, like the one on [Fig. 3-55](#).



Fig. 3-55

Select “**Frequency**” parameter ([Fig. 3-54](#)), corresponding to one of the peaks.

The height of the selected peak should be in the range of 2-5 nA.

To achieve this the generator voltage (“**Amplitude**” parameter) ([Fig. 3-54](#)), or the synchronous detector gain (“**Gain**” parameter) ([Fig. 3-54](#)) (photodiode signal gain) can be increased. Applying

the maximal voltage of 1V to the scanner's Z-electrode yields optimal results in the majority of cases.

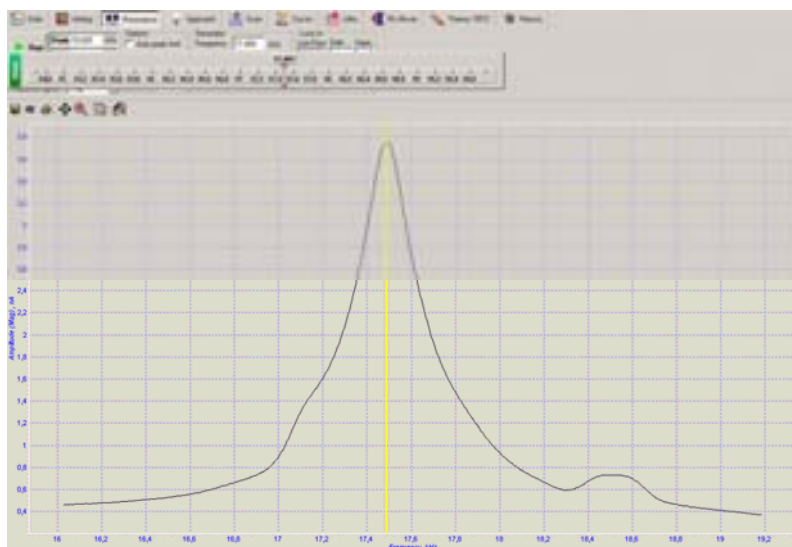


Fig. 3-56

3.5.3 Scanning

Go to “Scan” window and press “Run” button ([Fig. 3-53](#)).

Two windows would appear on the display, one of them reflecting the surface topography (“Height” signal), whereas the other reflecting local rigidity distribution (“Mag” signal).

Lighter areas of “Mag” signal correspond to higher rigidity and vice versa.

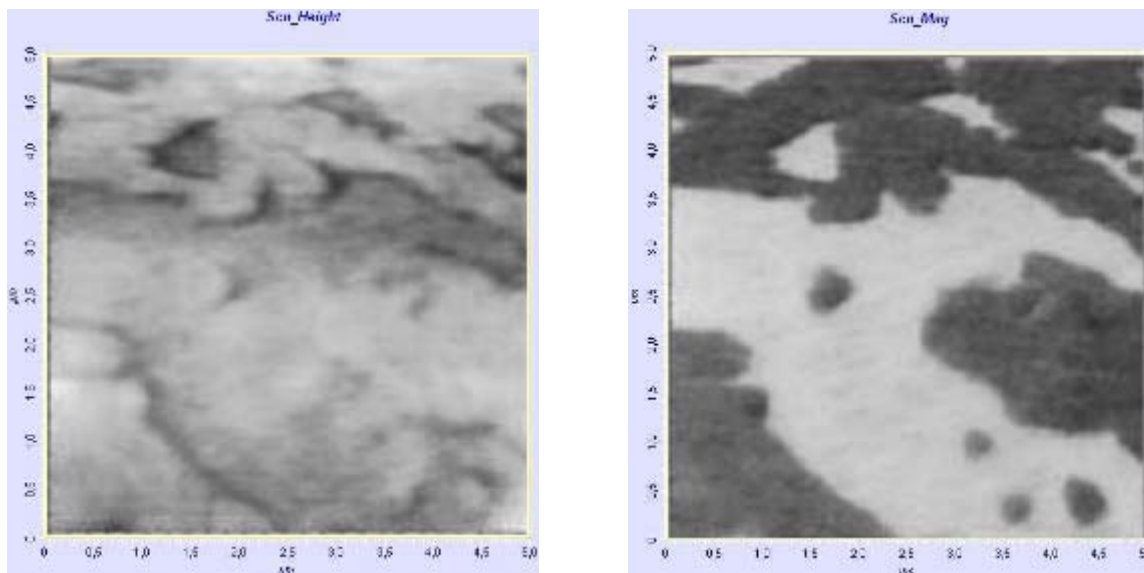


Fig. 3-57. The topography and local rigidity distribution images of two-component LB film

The topography and local rigidity distribution images of two-component LB film are exemplary.

3.5.4 Ways of image improvement

If the image quality is unsatisfactory, you can do any of the following:

- Replace the probe (with another of different rigidity and resonance frequency);
- Select a resonance frequency, which corresponds to another peak;
- Change the generator voltage (“**Amplitude**” parameter) ([Fig. 3-54](#)), and the synchronous detector gain (“**Gain**” parameter) ([Fig. 3-54](#));
- Change “**Set Point**” parameter ([Fig. 3-50](#)) (the force of the tip, pressing to the sample).

3.6 Contact Error Mode

3.6.1 A brief description of Contact Error Mode

The value of cantilever deflection changes in the process of scanning, depending on the sample surface topography. The tracking system aims at maintaining a certain set level of cantilever deflection value (**Set Point**), or the level of the deflection related signal (**DFL** signal in this case). However, the tracking system cannot immediately return the current **DFL** value to the set point, as it possesses a kind of inertia (characterized by the feedback loop time constant).

The current value of **DFL** signal (deflection related signal) is the signal of **Error** of the feedback loop system during scanning and contains the surface topography data, additional to z-scanner position. This signal can be used to perform a more precise topography imaging. A mode, involving the simultaneous surface height topography imaging by **Constant Height Mode** and the measurement of **Error** signal (**DFL** signal in this case) is called the “**contact**” **Error Mode**.

The **Contact Error Mode** can be considered to be the intermediate between the **Constant Force** and **Constant Height** modes on condition the speed of the error signal (the feedback loop gain in this case) effect is adjusted so that the feedback loop manages to follow the gradual modifications of topography, skipping the rapid ones.

Then, with the tip moving over the minor irregularities of the sample surface the scanning is performed preserving the length of piezo-scanner almost constant. This will result in a weaker manifestation of gradual topography modifications on the scanned image, whereas the rapid topography modifications will be manifested with high contrast. This may prove useful in finding smaller irregularities on the background of the greater ones and relatively smooth topography peculiarities.

3.6.2 Contact Error Mode preparatory procedures and operation

1. The preliminary operations include the accomplishment of preparations and the measurement of surface topography using Constant Force Mode (i. [3.1 Constant Force Mode](#)):
 - A **Contact** configuration is selected;
 - The initial level of **DFL** signal is set;
 - The landing procedure is performed;
 - The feedback loop gain operating level is set;
 - The **Contact topography** measuring mode is selected;
 - The parameters of scanning (scan size, number of points, velocity) are selected and set.

2. **Additionally** it is necessary to **activate the measurement of DFL signal** at the input of the second measuring channel.

To do this, perform the following:

- Open the measuring channels panel (Fig. 3-58) using “Settings” button on the scanning control panel

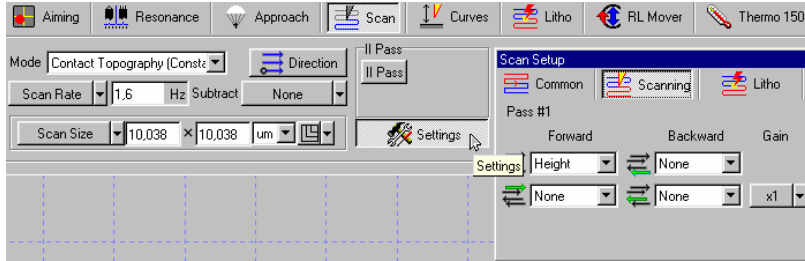


Fig. 3-58

- Click the mouse button on the “signal input field” of the second channel (Fig. 3-59)

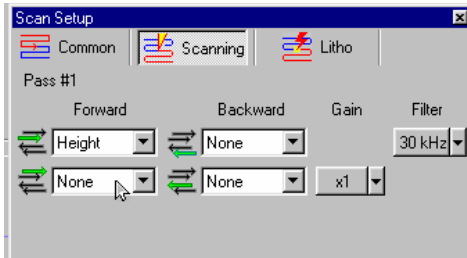


Fig. 3-59

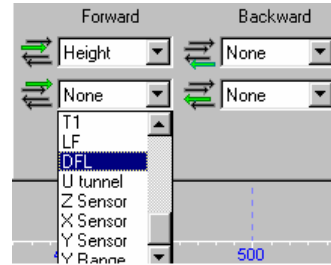


Fig. 3-60

- Select **DFL** in the “signals menu” that drops down. (Fig. 3-60)

3. **During the sample scanning** two images should be present in “SPM images field” (Fig. 3-61): **DFL** signal image on the left and the topography image (obtained using **Constant Force Mode**) on the right.

3.6.3 Examples of Contact Error Mode application

Below (Fig. 3-61) is the exemplary image of “DFL” signal (**Error Signal**) and the image of topography (**Constant Force Mode**), obtained simultaneously during scanning of one and the same area of sample surface (a standard rectangular TGZ-1 grid, the increment of 3mcm with the step height of 19nm).

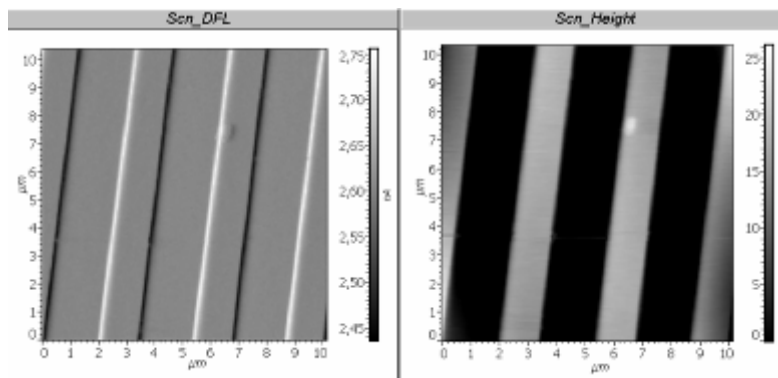


Fig. 3-61

4 SemiContact Atomic-Force Microscopy

Operation of the instrument when measuring a surface relief using a “SemiContact” (interrupted-contact) mode is a basis for implementation a number of other modes and techniques connected with application of resonance oscillations of the cantilever.

4.1 *SemiContact Mode*

4.1.1 Introduction. Initial State. Major Operations When Working Under SemiContact Microscopy

We assume a preliminary initial preparation of the instrument had been made.

Initial state:

- Instrument is turned on;
- Program is launched; screen displays a program main window;
- Cantilever is installed; optical registration system is adjusted;
- Sample and SPM head are installed; approaching initial probe to the sample is made.

Major operations when working under a SemiContact microscopy mode

Instrument operation under a SemiContact microscopy mode might be divided into the following sequence of major operations:

1. Switching the instrument for operation under a SemiContact mode;
2. Setting a cantilever operational frequency;
3. Setting a MAG signal initial level (feedback signal);
4. Approaching a probe to the sample;
5. Setting a feedback gain factor operational level;
6. Selecting an operational SPM mode;
7. Selecting and setting a scanning area size, number of scanning points, and scanning step;
8. Selecting and setting a scanning rate;
9. Scanning launch;
10. Tuning scanning parameters (if necessary) (§);
11. Saving acquired data;
12. Operation completion.

Each of the above-mentioned major operations consists of a certain sequence of easy actions.

Below is shown a more detailed description of the above-mentioned major operations.

4.1.2 Switching Instrument for Operation under SemiContact Mode

To switch the instrument for operation under a SemiContact mode, you need to set a button-switch (forth button in the main string) in **SemiContact** state as shown in [Fig. 4-1](#).

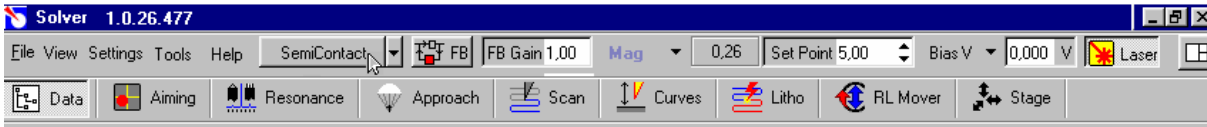


Fig. 4-1

If that button is in the other position, for example **Contact**, as shown in [Fig. 4-2](#), then you need to press it and select **SemiContact** in the opened menu ([Fig. 4-2](#))

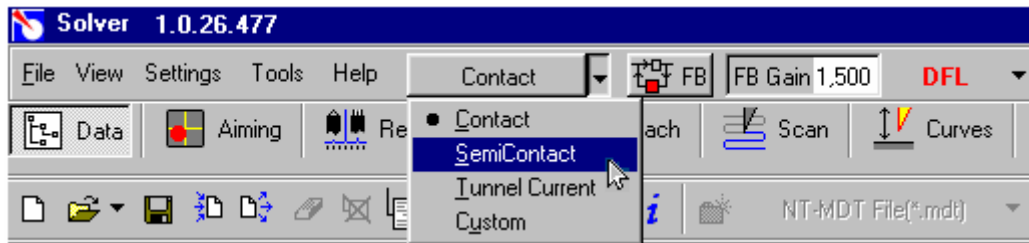


Fig. 4-2



Note:

- A button-switch for selection a mode of the instrument operation may be set in one of four states: **Contact**, **SemiContact** and **Tunnel current**, **Custom**;
- When setting **SemiContact** state, the instrument would perform all the required commutations that necessary for the SemiContact mode: **MAG** signal is applied to the feedback input, generator sets itself in **Probe** state, and necessary parameters are set and so on. Similarly, when setting **Contact** state (or **Tunnel current**), the instrument would automatically make commutations that necessary for a contact (or tunneling) mode;
- With setting **Custom** mode, a user acquires a full freedom in tuning the instrument and it may implement very different configurations and states of the instrument.

4.1.3 Setting Cantilever Operational Frequency

1. Shift to **Resonance** window under **Resonance** bookmark in the operations string ([Fig. 4-3](#))



Fig. 4-3

2. Check a state of the frequency automatic tuning option. It is to be turned on as shown in [Fig. 4-4](#);

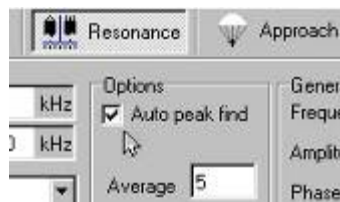


Fig. 4-4

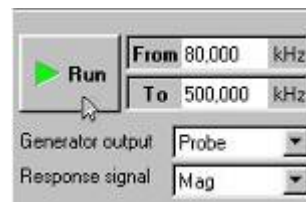


Fig. 4-5

3. Check a frequency range (**From...**, **To...**). It is to include a cantilever resonance frequency.
4. Launch a procedure of frequency automatic tuning by means of pressing **Run** button ([Fig. 4-5](#), [Fig. 4-3](#)).

As a result of that procedure there would be:

- Measured a frequency response of the cantilever oscillations (MAG's signal);
- Determined a resonance frequency of the cantilever;
- Set an operational frequency of the piezo-generator equal to the resonance frequency of the cantilever;
- Displayed a frequency response of the MAG signal near the maximum in the oscilloscope ([Fig. 4-6](#)).

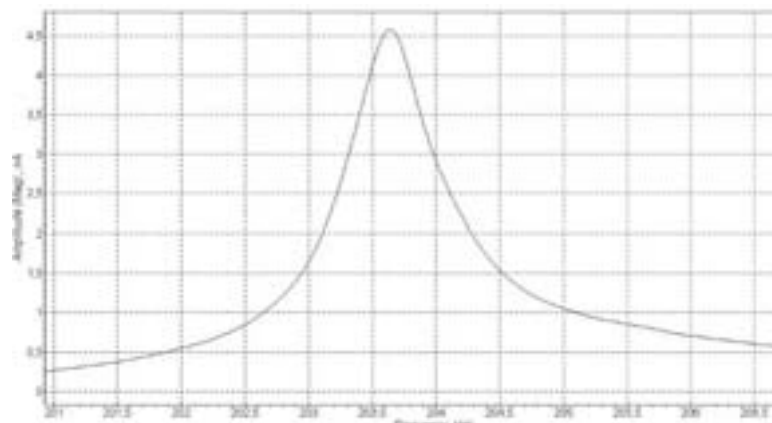


Fig. 4-6

5. Draw your attention to a shape of the resonance curve particularly to the area of its peak. If a view of the acquired dependence (especially in the area of the peak) roughly corresponds to the dependence shown as an example in [Fig. 4-6](#), then we may assume that automatic tuning had gone successfully. In that case, we may shift to execution of the next operation (to Setting MAG Signal Initial Level.)

In most cases, automatic tuning goes successfully, and a resonance frequency curve has a quite well shape.

Special Cases

It might be happened that after execution a procedure of the frequency automatic tuning, a resonance curve displayed in the oscilloscope has a distorted shape of the peak. Those distortions may be different, for example, a resonance peak may be widened as shown in [Fig. 4-7](#) or to have several local maximums.

Distortions may be connected, for example, with:

- That the cantilever has too large amplitude of oscillations (too large value of the generator voltage had been set.)
- Or too large gain factor had been set (a synchronous amplifier gain factor – Gain parameter – and a preamplifier gain factor.)
- Or both the listed factors are simultaneously available.

First case: A “tip” of the resonance curve has a distorted shape and at that values in the area of maximum do not exceed 35-40 units.

If a “tip” of the resonance curve has a distorted shape and values at that in the area of maximum exceed 35-40 units (for example, as shown in [Fig. 4-7](#)), then you need to reduce a value of the synchronous amplifier gain factor (Gain parameter); or to reduce a value of the preamplifier gain factor.

You need to reduce a value of the gain factor so much that a value of the MAG signal would be reduced to 20-25 units. (The preamplifier gain factor may have two values: 1 or 10.)

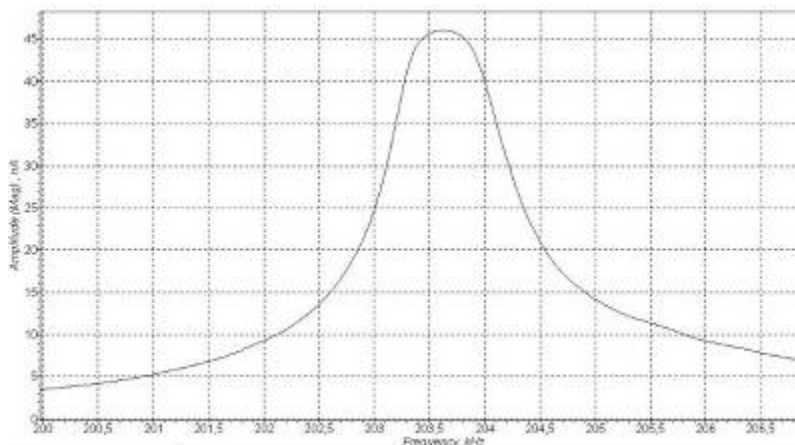


Fig. 4-7

To reduce a value of the synchronous amplifier gain factor (Gain):

- Double click in the Gain enter field (Fig. 4-8); as a result a slider would be opened (Fig. 4-9)

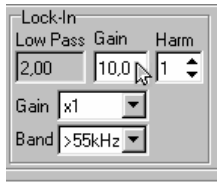


Fig. 4-8

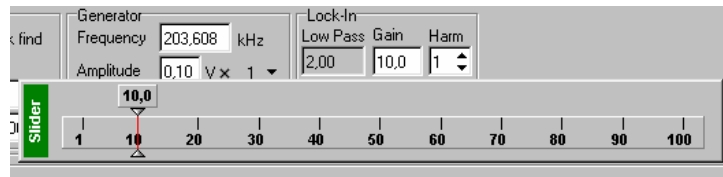


Fig. 4-9

Reducing with the help of a slider a value of the Gain parameter (Fig. 4-10), reduce a value of the MAG signal to 20-25 units. This value is monitored in the feedback signal window-indicator (Fig. 4-11)

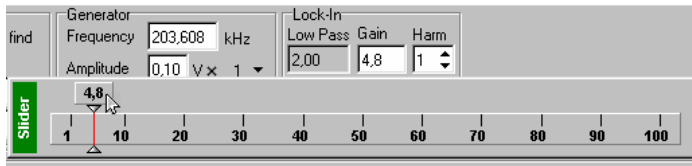


Fig. 4-10

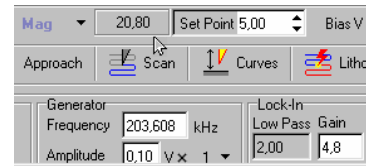


Fig. 4-11

- After reducing the MAG signal to 20-25 units, launch a procedure of frequency automatic tuning again by means of pressing Run button.
- If distortions of the resonance peak are disappeared, then shift to the next operation (see i. [4.1.4 Setting MAG Signal Initial Level](#) on p. 96) Otherwise, repeat actions 1-3 or reinstall the probe sensor.

Second case: A resonance peak has a distorted shape and at that values in the area of maximum are lower than 35-40 units.

If a resonance peak has a distorted shape, and at that values in the area of maximum are lower than 35-40 units (as shown in Fig. 4-12, for example), then you need to:

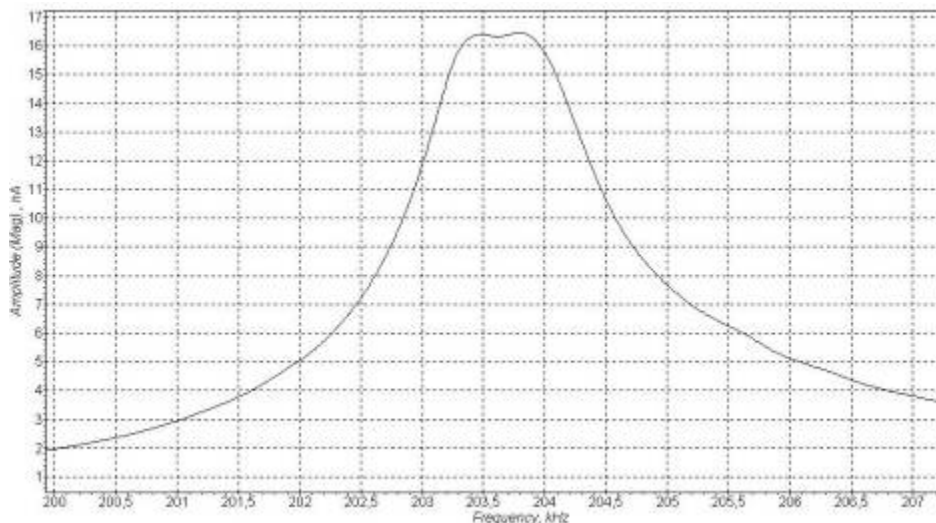


Fig. 4-12

Reduce a generator voltage. To that end, you need to double click in the Amplitude parameter entry field, [Fig. 4-13](#), and using a get opened slider ([Fig. 4-14](#)) to reduce Amplitude parameter in several times.

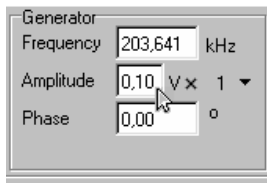


Fig. 4-13

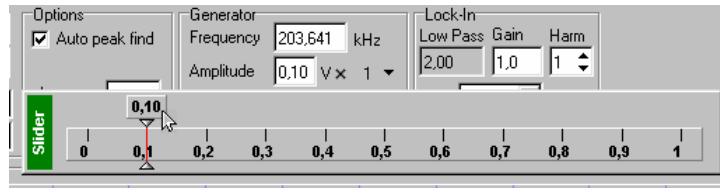


Fig. 4-14

1. Launch a procedure of the frequency automatic tuning again using Run button.
2. If distortions of the resonance peak are disappeared, then shift to the next operation (see i. [4.1.4 Setting MAG Signal Initial Level](#) on p. 96) Otherwise repeat actions 1-3 or reinstall a probe sensor.

4.1.4 Setting MAG Signal Initial Level

We recommend setting an initial level of **MAG** signal in the 20-25 units range.

We recommend making setting a **MAG** signal initial level by mean of adjusting a generator voltage (by means of changing **Amplitude** parameter) and a multiplier of the dividing-amplifying stage in the generator output.)



Note: In the case considered above in point 0 (when a cantilever frequency had been tuned, we were observing distortions of the resonance curve peak and reduced a generator voltage), adjustment of the MAG signal initial level is made by means of changing a gain factor of the synchronous amplifier (Gain.) A procedure of adjusting the synchronous amplifier gain factor is stated above in point 0

Adjustment of the initial level of the MAG signal by means of a generator voltage:

1. Open a slider of **Amplitude** parameter by means of double clicking in the entry box for the given parameter ([Fig. 4-15](#), [Fig. 4-16](#));

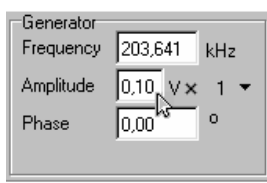


Fig. 4-15

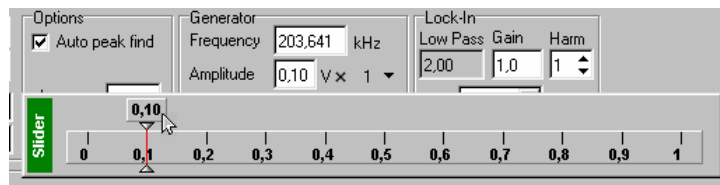


Fig. 4-16

2. Changing **Amplitude** parameter with the help of the slider set a value of **MAG** signal equal to 20-25 units. Monitor a signal value in the feedback signal value display field ([Fig. 4-17](#)). If necessary, switch a multiplier of the generator amplifying-dividing stage. That multiplier is

located next to the **Amplitude** parameter entry field, to the right, and may have one of three states: **0.1**, **1**, and **10**.

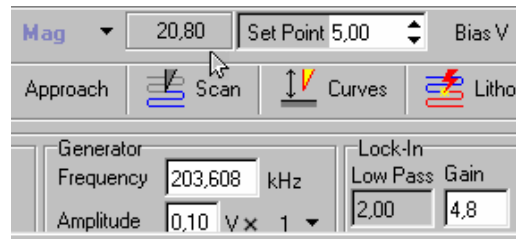


Fig. 4-17



Note:

- A MAG signal level you may adjust by means of changing a gain factor (Gain parameter of the synchronous amplifier and Gain parameter of the preamplifier) and a generator voltage value (Amplitude parameter);
- If you adjust a MAG signal value by means of changing a gain factor at the fixed generator voltage, at that a cantilever oscillations amplitude will be retained as fixed;
- Otherwise, if you adjust a MAG signal value by means of changing a voltage generator at the fixed gain factor, at that a cantilever oscillations amplitude will be changed (linearly with Amplitude parameter change.)

4.1.5 Approaching a Sample to the Probe

1. Shift to **Approach** window under **Approach** bookmark in the operations sting ([Fig. 4-18](#));

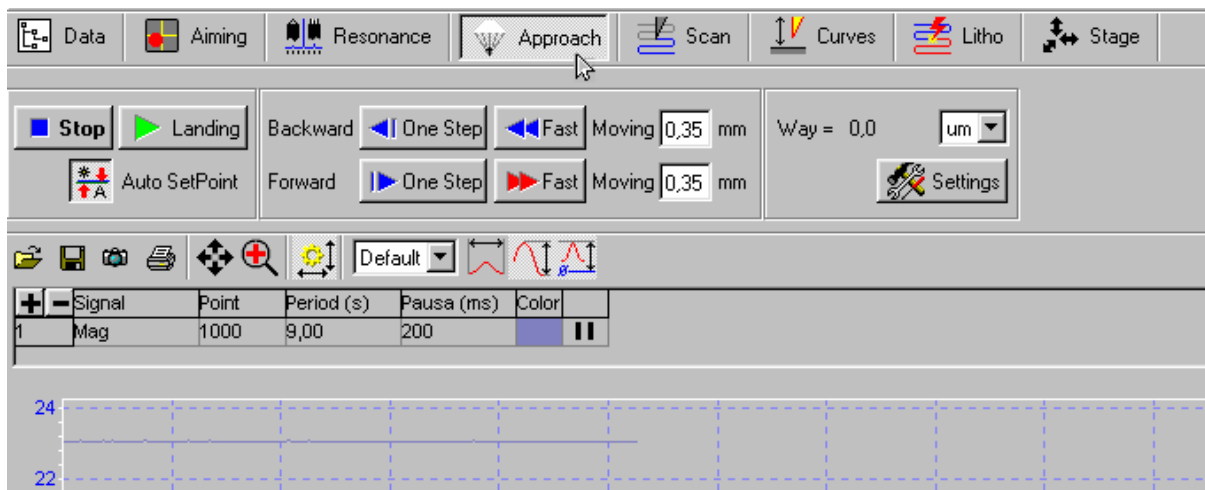


Fig. 4-18

2. Check condition of the option for **Set point** parameter automatic setting. **Auto SetPoint** button is to be in the turned on state as shown in [Fig. 4-19](#);



Fig. 4-19

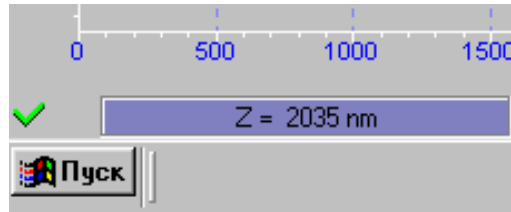


Fig. 4-20

3. Launch a procedure of approaching by means of pressing **Landing** button.

As a result:

- Value of **Set point** parameter would be automatically set equal to $\frac{1}{2}$ from the **MAG** signal value;
- Feedback would be turned on, and a **Z**-piezo-scanner would extend to the maximum value. A **Z**-scanner extension would be displayed in the scanner extension analog indicator located in the bottom left corner of the program main window (Fig. 4-20) Degree of the scanner extension is characterized with a length of the colored strip;
- Step motor would be turned on which begins to move a scanner with the sample in the direction of the probe.

4. In the process of approaching, monitor changes of **MAG** signal in the oscilloscope's screen as well as a state of the scanner extension indicator and wait for ending the process of approaching.

After a while, if tuning approaching parameters was correct, a procedure of approaching would be completed and there would happen the following:

- **MAG** signal would reduce down to the value of **Set point** parameter, feedback would keep a **Z**-scanner in the position where **MAG** signal is equal to **SetPoint**, moreover that position of the scanner would correspond to around a half of the scanner extension range;
- Length of the indicator colored strip would be reduced and would be in some intermediate position (Fig. 4-21);



Fig. 4-21

- Step motor would stop;
- **MAG(t)** dependence in the programmed oscilloscope would display reducing **MAG** signal down to the value of **Set point** parameter (Fig. 4-22);
- A window with an **OK** message would appear in the oscilloscope's window background (Fig. 4-22).

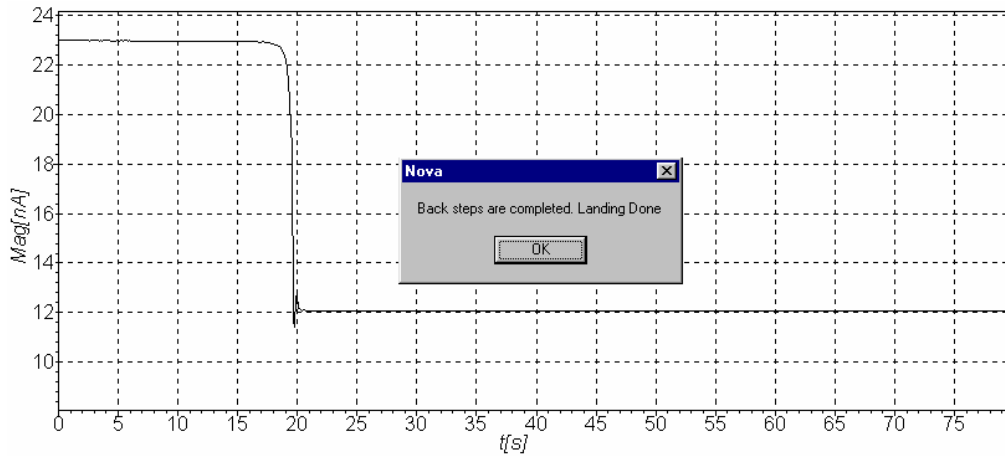


Fig. 4-22

Further, you need to press **OK** button and shift to execution of the next item ([4.1.6 Setting Feedback Gain Factor Operational Level](#)).



Note: Special cases

- It might be happened that after reducing MAG signal down to the value of Set point parameter, a sufficient increase of a MAG signal variable component is observed in the MAG(t) dependence. That means that a “generation” exists in the feedback system due to an excessively high gain factor (FB Gain parameter.)
- In this case, you need to reduce a value of FB Gain to 0.5 – 0.7 from the threshold. Adjusting FB Gain parameter is considered below, in Setting Feedback Gain Factor Operational Level point.

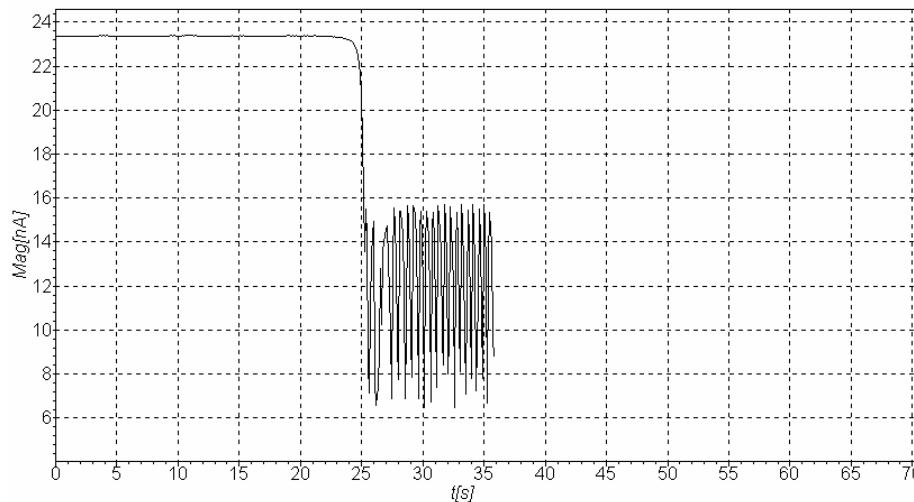


Fig. 4-23

4.1.6 Setting Feedback Gain Factor Operational Level

The more a value of the gain factor (FB Gain parameter) the more a feedback processing rate. However, with an enough high gain factor value (call it as a threshold), a mode of operation of the servosystem becomes unstable and a “generation” begins. That becomes apparent as appearance of a sufficient variable component in the MAG signal.

To achieve a stable operation, we recommend to set a level of the gain factor at most 0.6 - 0.7 from the threshold level where the “generation” begins. Gain factor adjustment is performed by means of a FB Gain parameter value.

Procedure of Setting Feedback Gain Factor Operational Level

- Open a slider of **FB Gain** parameter by means of double clicking in the entry field for the given parameter located in the panel for control of major tuning parameters of the instrument (Fig. 4-24) By means of increasing **FB Gain**, monitor a level of **MAG** signal in the programmed oscilloscope.



Fig. 4-24

- Определите значение коэффициента «**FB Gain**», при котором начинается генерация. Начало генерации регистрируется по резкому увеличению переменной составляющей сигнала **MAG** (Fig. 4-25).
- Determine a **FB Gain** factor value where generation begins. Beginning generation is registered as a sharp increase of the **MAG** signal variable component (Fig. 4-25).

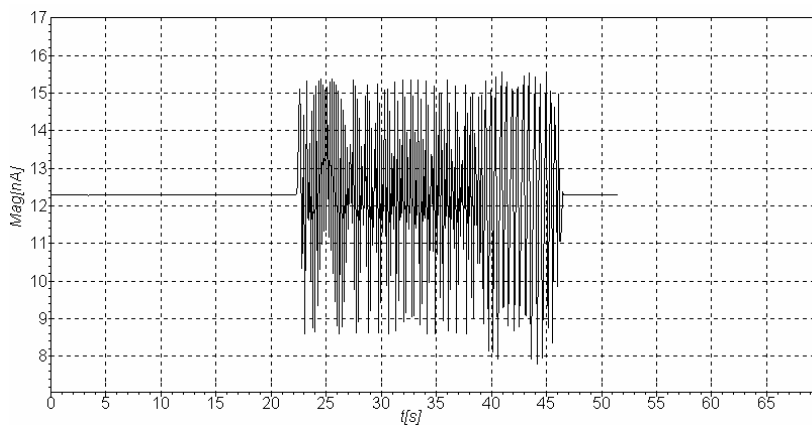


Fig. 4-25

- Reducing **FB Gain** parameter, set as an operational value a value equal to 0.6 – 0.7 from the **FB Gain** factor value where the **MAG** signal generation begins.



Note: Sometimes, after approaching the probe it is appeared an instable mode of operation of the feedback system such as “generation” which is not possible to eliminate by means of reducing the FB Gain factor value. That type of instability is connected with a “sealing” effect. The given type of instability is possible to eliminate by means of

increasing cantilever oscillations amplitude. To that end, you need to turn off the feedback, increase cantilever oscillations amplitude (Amplitude parameter value) and a value of Set point parameter approximately by 30%, and then turn on the feedback again

4.1.7 Setting Scanning Parameters

Shift to **SCAN** window under **SCAN** bookmark in the operations string ([Fig. 4-26](#)).



Fig. 4-26

An upper part of **SCAN** window has a panel for scanning parameters control which consists of three strings. Under them, a univariate data display field is located where row-by-row a measured signal would be displayed when scanning. Below, a window is located where a scanned image would be displayed.

4.1.7.1 Setting Operational SPM Mode

As an operational SPM mode by default, a SemiContact mode is automatically set - **Semicontact topography** (name of the operational mode is displayed in **Mode** select box, [Fig. 4-27](#)), located in the first row of the **SCAN** window control panel.

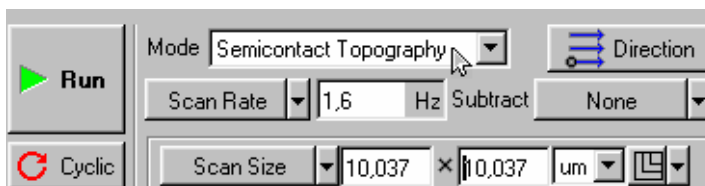


Fig. 4-27

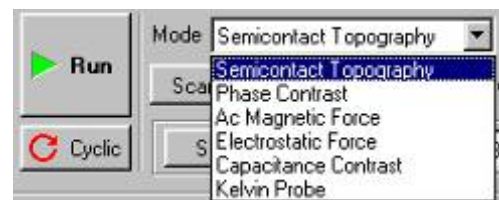


Fig. 4-28



Note:

- If necessary, you may set any SPM mode compatible with keeping from the side of the feedback system a SemiContact oscillations amplitude of the probe sensor, for example, a phase contrast displaying mode - **Phase Contrast**.
- To select a mode, you need to double click in the field for selecting SPM modes ([Fig. 4-27](#)) and select the required operational mode in the get opened menu ([Fig. 4-28](#)) Correspondingly, the instrument automatically would perform all the relevant commutations required for implementation of the chosen mode.

4.1.7.2 Setting Scan Size, Point Number, Step Size

Scan Size, Point Number (number of points along X and Y axes), **Step Size** parameters may be changed using a selection parameter button where a selected parameter is displayed (Fig. 4-29) and entry fields where a current value of the set parameters is displayed. In the given example (Fig. 4-29, Fig. 4-30), **Scan Size** parameter is selected and the 10.037x10.37 nanometers image size is set.

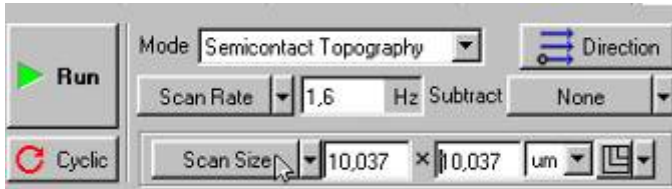


Fig. 4-29



Fig. 4-30

To set a required parameter, you need to press a selection parameter button and select a corresponding parameter in the get opened menu (Fig. 4-30). **To change values of the parameter**, you need to double click in the corresponding entry field and using a get opened slider set the required value. A value of the parameter might be also changed directly in the entry field by means of editing the required digits from the keyboard.

Setting Scan Size

By default, automatically a maximum value of **Scan Size** parameter is set. Correspondingly, in case of 10-microns scanner - **10x10 microns²**, as shown in Fig. 4-29, Fig. 4-30 in case of **50-microns scanner – 50x50 microns²**; for **three microns scanner – 3x3 microns²**.)

A different from the maximum scanning area size is set using a corresponding parameter selection button and an entry field as that stated above (see p.4.7.2.)



Note .In regard to selection of a scanning area initial size:

What should be setting of the scanning area initial size? Answer to that question depends on properties of the sample as well as goals and tasks which you need to resolve:

- *If some preliminary information is available about properties of the sample, and some confidence is present that the altitude difference of the expected relief do not go beyond the limits of the z-range scanner, you may set a maximum scanning field as shown in Fig. 4-26, Fig. 4-27*
- *In case if properties of the sample are entirely not known, we recommend to begin scanning with an area which has a small size, for example, 0.5÷1 microns. According to results of scanning a small area, you may match and set optimal values of such parameters as scanning rate, Set point, FB gain. Then, you may increase the scanning area.*

Setting Point Number (Number of Points along X and Y Axes)

By default, **Point Number** parameter (number of points along X and Y axes) is automatically set equal to **256X256**.

If necessary, that value as well as the scanning area might be changed. A value of the parameter is measured using a corresponding parameter selection button and an entry field as that was stated above.

Step Size

When the **Scan Size** and **Point Number** are already set, a **Scan Size** is being set automatically in accordance with the specified **Scan Size and Point Number** parameters.

When changing **Step Size** parameter in accordance with those changes, a value of **Scan Size** parameter is automatically changed, but a value of **Point Number** would be the same.

4.1.7.3 Setting Scanning Parameters: Scanning Rate

We recommend to set a frequency of strings scanning (**Scan Rate** parameter) in the **0.5-2 Hz** range. Specifically in that range the scanning rate is being set automatically when a program is launched and simultaneously performed at that operation of loading standard parameters.

If necessary, you may change the scanning frequency (scanning rate) using a button for selection a scanning parameter and an entry field located next to it.



Note: How can you change the scanning rate?

- *You may change the scanning rate by means of changing any of four time parameters: **Scan Rate** – frequency of strings scanning, **Velocity** – frequency of string scanning, **Scan time** – time of scanning entire scanning area, and **Time/point** – time which falls at a measurement in the every point of the scanning area;*
- *A time parameter selection button is located in the third string of the **SCAN** control panel, (Fig. 4-31), correspondingly, it displays the selected parameter (as shown in an example in Fig. 4-31 – **Scan Rate**). To set the necessary parameter, you need to press the given button and select the required parameter in the get opened menu (Fig. 4-32)*

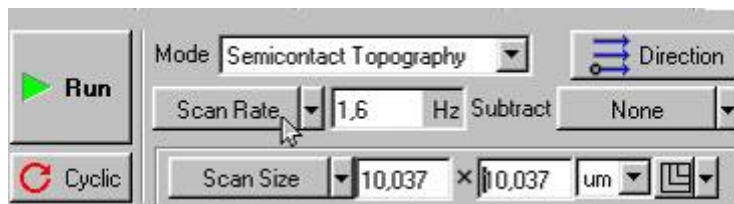


Fig. 4-31

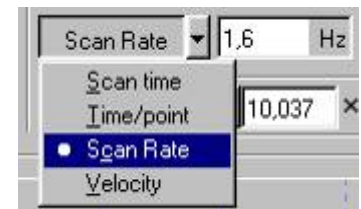


Fig. 4-32

- *Next to the button, a window is located which displays a current value of the specified parameter. If double mouse-click this entry field, a slider would be opened using which you may change a value of the selected parameter. A value of the parameter may be also changed directly in the entry field by means of editing the required digits from the keypad*

4.1.8 Scanning

As an example, let us examine a process of scanning the sample of a square lattice type (TGZ-1 standard lattice, step – 3 microns, steps height – 19 nanometers.)

4.1.8.1 Scanning Launch

1. To launch scanning, you need to press **RUN** button located in the **SCAN** window panel to the left in the top (Fig. 4-33);

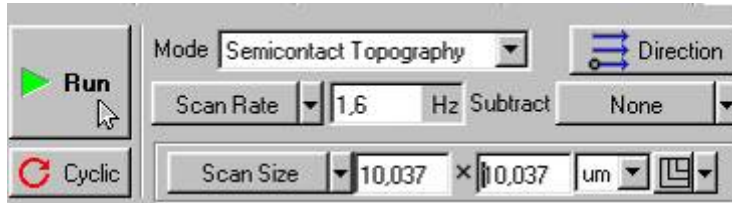


Fig. 4-33

After pressing RUN button:

- The probe would begin row-by-row scanning of the surface of the sample and an image window would begin to display an image of the being scanned surface in a string-by-string manner (Fig. 4-34), in our case – square lattice image.

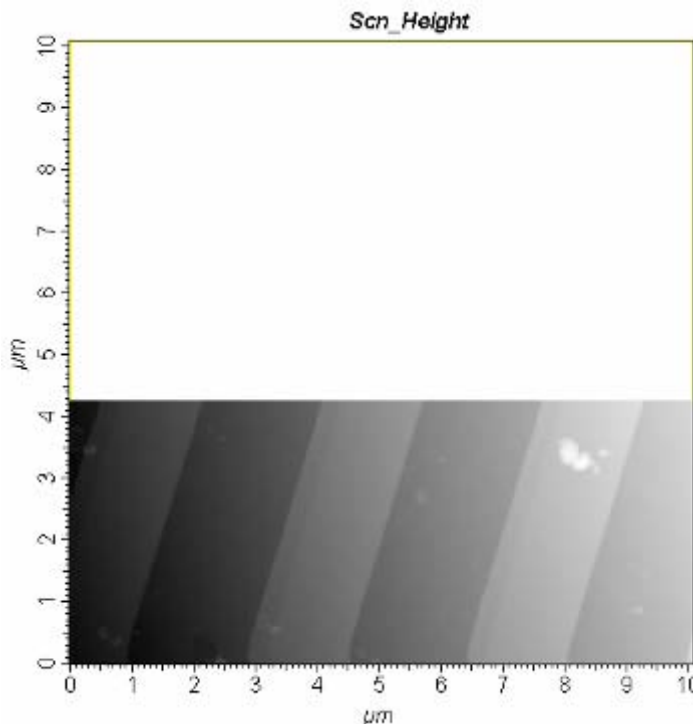


Fig. 4-34

- A univariate data display field would display in turn a relief of each of the being scanned line (Fig. 4-35).

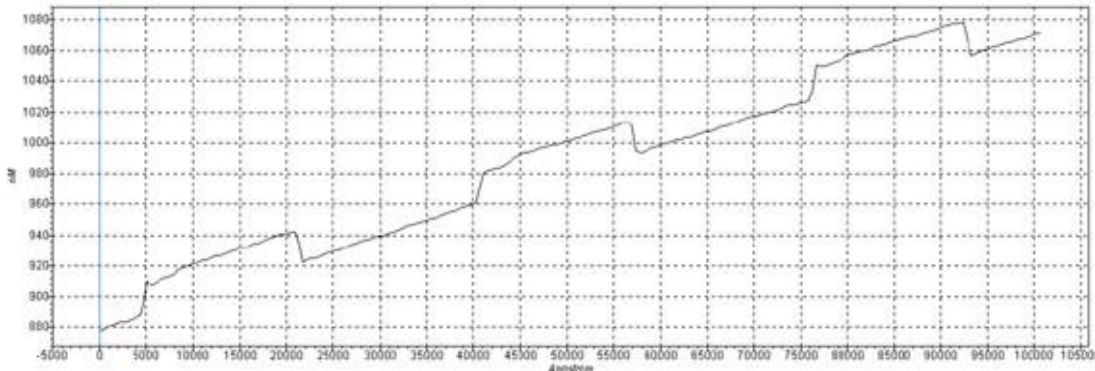


Fig. 4-35

- Some buttons would disappear from **SCAN** panel and a number of new buttons would appear (Fig. 4-36): **Pause**, **Restart**, and **Stop**.

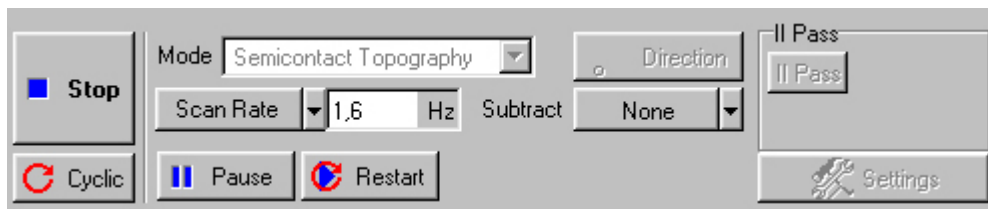


Fig. 4-36

2. If for any reason it is necessary to cancel scanning, it is enough to press **Stop** button or to make use of **Esc** button in the keyboard.

4.1.8.2 Changing Parameters When Scanning

Inclination subtraction

In the above shown example (Fig. 4-34, Fig. 4-35) it is seen that a sample has some inclination along the X axis.

That inclination might be subtracted in the process of scanning by means of use **Subtract** button. By default, it is in **None** state (Fig. 4-36, Fig. 4-37).

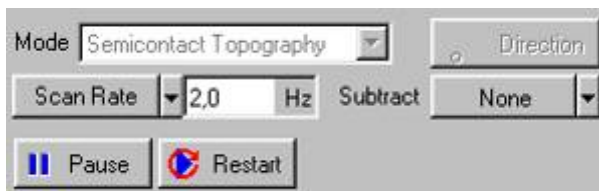


Fig. 4-37

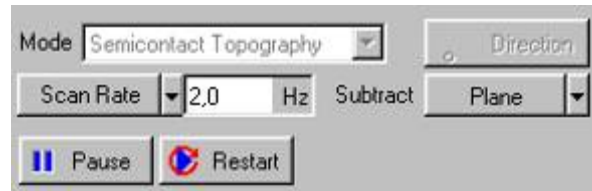


Fig. 4-38

If to press that button and set it in **Plane** position, then there would be made subtraction of the middle plane from the entire scanned area, and the image which before that procedure had a view like in Fig. 4-34, would have a view something like in Fig. 4-39

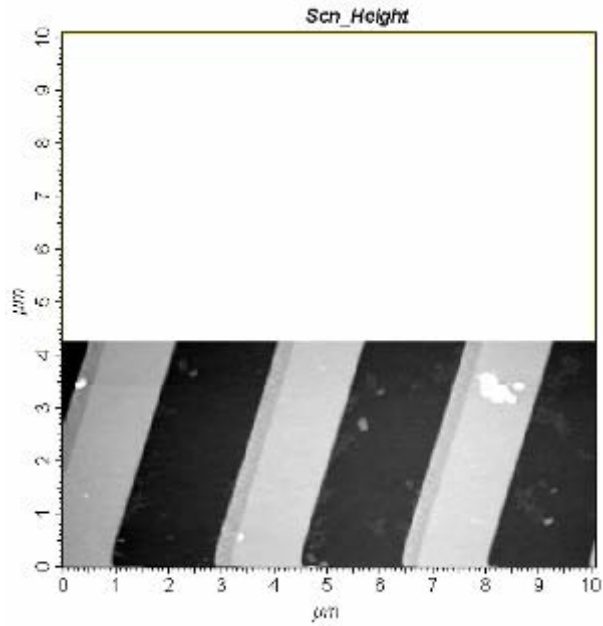


Fig. 4-39

Correspondingly, a univariable data display field would also display a profile of the current string with taking into account subtraction of the inclination. Instead of the profile in [Fig. 4-35](#) there would be displayed a profile something like in [Fig. 4-40](#).

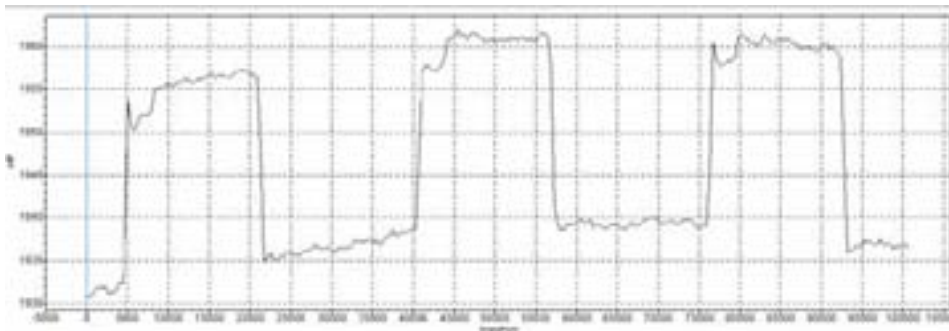


Fig. 4-40

Subtract button may have another two states: **1st-order** and **2nd-order**. Correspondingly, in the first case, each of the strings receive subtraction of the middle curve of the first order (inclination subtraction), and in the second case - a curve of the second order. As an example, [Fig. 4-41](#) illustrates a result of subtraction of **2nd-order** of the profile for the same string as shown in [Fig. 4-35](#) (without subtraction) and in [Fig. 4-40](#) (plane subtraction.)

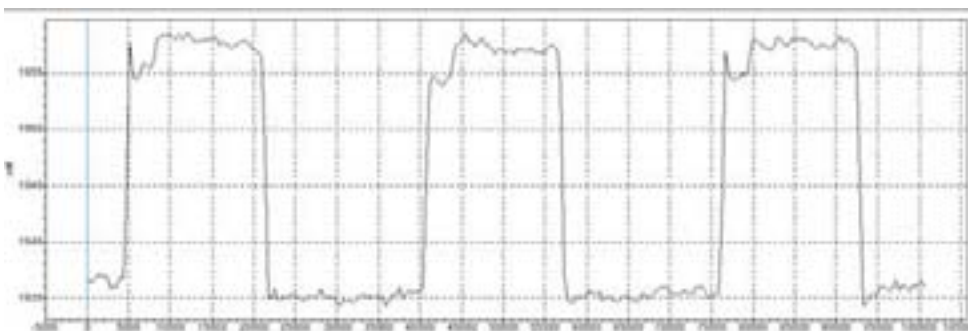


Fig. 4-41

4.1.8.3 Adjusting Parameters When Scanning

Quality of the acquired surface image sufficiently depends on such parameters as **Velocity** scanning rate (**Scan Rate** scanning frequency), **Set Point** operational point value, **FB Gain** feedback gain factor. You may change any of those parameters in the process of scanning.

Especially for the purpose of tuning scanning parameters a **Pause** button is envisioned. When that button is turned on, sweeping along the slow axis is stopped, but scanning along the fast axis is continued and passed along the same line. That mode of operation may be used for matching optimum parameters. At that, it is possible to visually observe how a profile of the scanned line is changed with changing the corresponding parameter, for example, the scanning rate (either **Set Pint** value or **FB Gain** feedback gain factor.)

A special **Restart** button is available for repeated scanning launch.

4.1.8.4 Some Recommendations in Regard to Scanning Parameters Optimization

Selection of an optimum value of the scanning rate depends on properties of the surface of the being examined object, scanning area size, and external conditions.

A surface with flat relief may be scanned with a higher rate than a surface with a more sharp relief and a sufficient altitude difference.

You need to reduce the scanning rate when a slope of the projection or cavity is not registered in the direction of scanning.

When operating with soft materials, the being scanned image may have “ties” in the direction of scanning in the projections of the surface. In this case we recommend to reduce the scanning rate as well as to increase a value of **Set Point** with the goal to reduce a value of influence onto the sample.

4.1.9 Saving Acquired Data

To write the acquired data in the hard disk you need to:

1. Press **File** button (right button in the upper string of the program window, [Fig. 4-42](#)).



Fig. 4-42

2. Press **Save** in the get opened menu and make writing in the form of a file with an arbitrary name under ***.MDT** extension.



After completing scanning the sample surface, acquired data are stored in the RAM. Each of the scanned surface images have a separate frame corresponded to it. Numeration of frames corresponds to a turn of their acquisition. If a procedure of saving is not made, then data would be lost with exiting from the program.

4.1.10 Operation completion

To complete the operation, perform the following actions:

1. Move away the sample from the probe in the distance of about 2-3 mm.

To that end, you need to make the following:

- Shift to **Approach** window under **Approach** bookmark in the operations string ([Fig. 4-43](#))

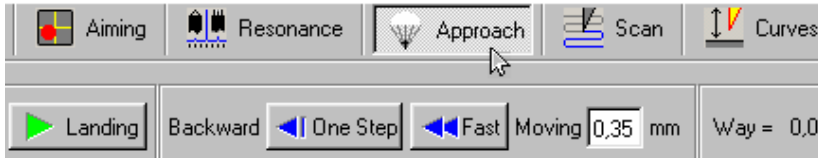


Fig. 4-43

- Double click in the **Moving** parameter entry field for **Backward** ([Fig. 4-44](#))



Fig. 4-44

- Using a slider, set a value equal to 2-3 mm ([Fig. 4-45](#))

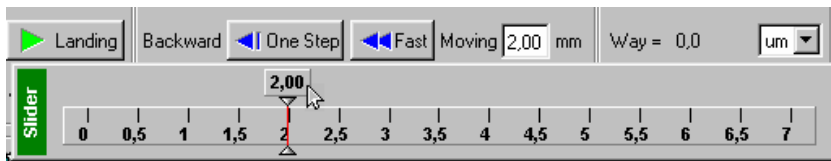


Fig. 4-45

- Press **Fast** button for **Backward** ([Fig. 4-46](#))



Fig. 4-46

2. Turn off feedback by means of switching off (settings in the released position) **FB** button ([Fig. 4-47](#))



Fig. 4-47

4.2 *SemiContact Error Mode*

4.2.1 A brief description of SemiContact Error Mode

A current value of cantilever oscillations amplitude deviates depending on the sample surface topography during the scanning in **SemiContact Mode**. The tracking system aims at maintaining a certain set level of cantilever oscillations amplitude (**Set Point**), or the level of amplitude related signal (**MAG** signal in this case). The tracking system cannot immediately return the current **MAG** value to the operating level, as it possesses a kind of inertia (characterized by the feedback loop time constant).

The current value of **MAG** signal (cantilever oscillations amplitude related signal) is the signal of **Error** of the feedback loop system during scanning and contains the additional surface topography data. This signal can be used to perform a more precise topography imaging. A mode, involving the simultaneous **SemiContact Mode** surface topography imaging and the measurement of Error signal (**MAG** signal in this case) is called the **SemiContact Error Mode**. The **SemiContact Error Mode**, similar to the **Contact Error Mode**, can be considered to be the intermediate between the **Constant Force** and **Constant Height** modes on condition the speed of the error signal (the feedback loop gain in this case) effect is adjusted so that the feedback loop manages to follow the gradual modifications of topography, skipping the rapid ones. Then, with the tip moving over the minor irregularities of the sample surface the scanning is performed preserving the length of piezo-scanner almost constant. This will result in a weaker manifestation of gradual topography modifications on the scanned image, whereas the rapid topography modifications will be manifested with high contrast. This may prove useful in finding smaller irregularities on the background of the greater ones and relatively smooth topography peculiarities.

4.2.2 SemiContact Error Mode preparatory procedures and operation

1. The preliminary operations include the accomplishment of preparations and the measurement of surface topography using SemiContact Mode:
 - A **SemiContact** configuration is selected;
 - The cantilever's operating frequency is set;
 - The initial level of **MAG** signal is set;
 - The landing procedure is performed;
 - The feedback loop gain operating level is set;
 - The “**Semicontact topography**” measuring mode is selected;
 - The parameters of scanning (scan size, number of points, velocity) are selected and set.

2. **Additionally** it is necessary to **activate the measurement of MAG signal** at the input of the second measuring channel.

To do this, perform the following:

- Open the measuring channels panel ([Fig. 4-48](#)) using “**Setting**” button on the scanning control panel;

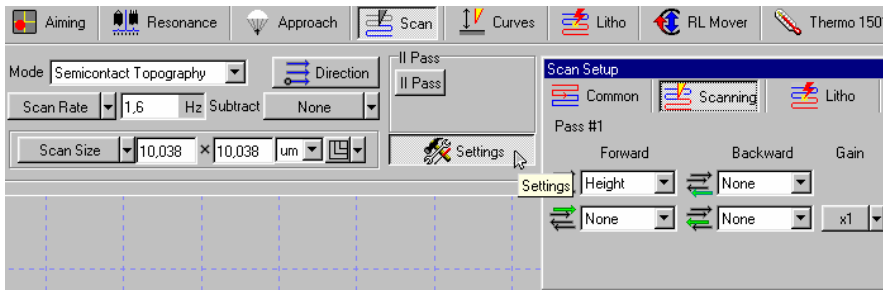


Fig. 4-48

- Click the mouse button on the “signal input field” of the second channel (Fig. 4-49);

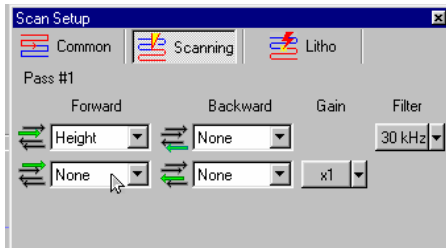


Fig. 4-49

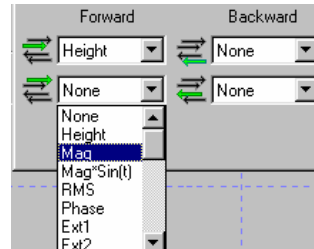


Fig. 4-50

- Select **MAG** in the “signals menu” that drops down (Fig. 4-50).
3. **During the sample scanning** two images should be present in “SPM images field” (Fig. 4-51): **MAG** signal image on the left and the topography image (obtained using **SemiContact Mode**) on the right.

4.2.3 Examples of SemiContact Error Mode application

Below (Fig. 4-51) is the exemplary image of **MAG** signal (**Error signal**) and the image of topography (**SemiContact Mode**), obtained simultaneously during scanning of one and the same area of sample surface (a standard rectangular TGZ-1 grid, the increment of 3 mcm with the step height of 19 nm).

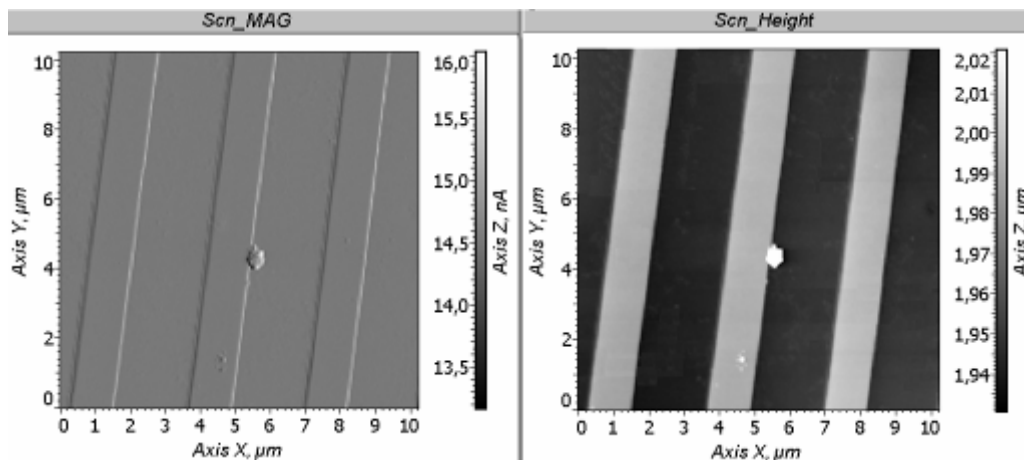


Fig. 4-51

4.3 Phase Contrast Mode

4.3.1 Measurement preparation

Prior to performing the phase contrast measurement do the following:

1. Select the type of scanning (“by sample”, “by tip”, or “double”) and “SemiContact” configuration in program menu:

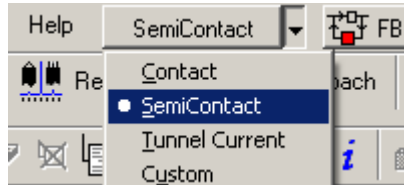


Fig. 4-52

Perform the resonance frequency scanning, set the value of “Set Point” parameter (according to “semi-contact” mode description) and activate the feedback loop.

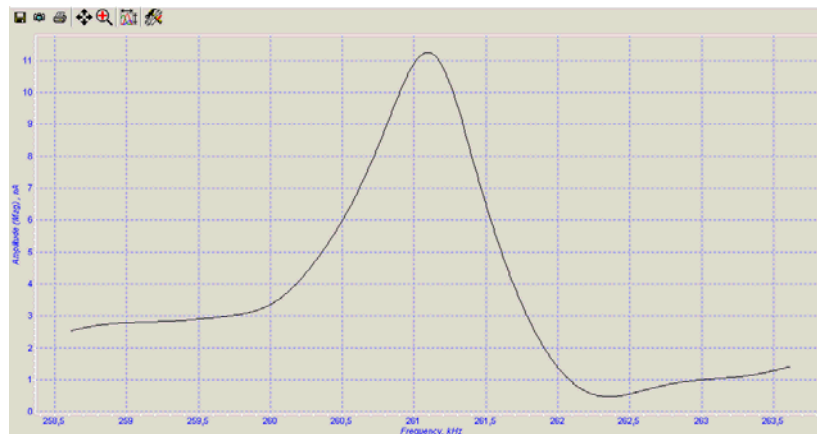


Fig. 4-53



Fig. 4-54

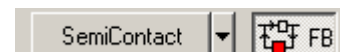


Fig. 4-55

2. Perform the landing procedure. To do this, go to “Approach” bookmark and press “Landing” button.

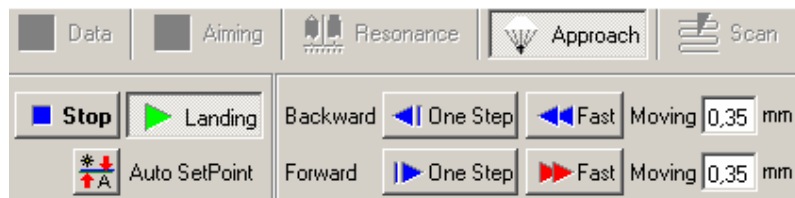


Fig. 4-56

3. Perform the sample surface preview scanning.
4. Select a sample area, suitable for scanning.
5. Perform the scanning of the selected sample surface area.

Mode selection and parameters setup

Select “Phase Contrast” mode in “Mode” menu.

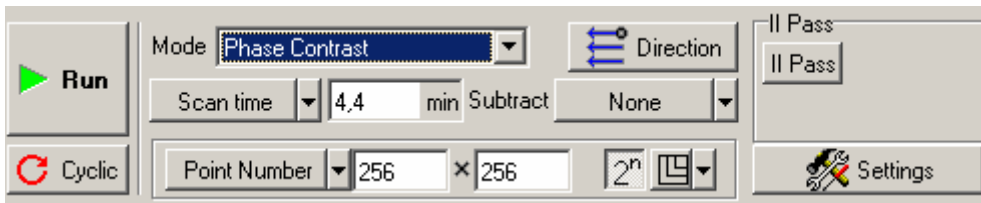



Fig. 4-57. A view of scanning parameters setup panel once “Phase Contrast” mode is selected

The program sets up the signals, necessary for the measurement automatically.

Generator initial phase setup

1. Activate  additional window in the right upper corner of the display.
2. Select “Phase” signal in the oscillograph window.

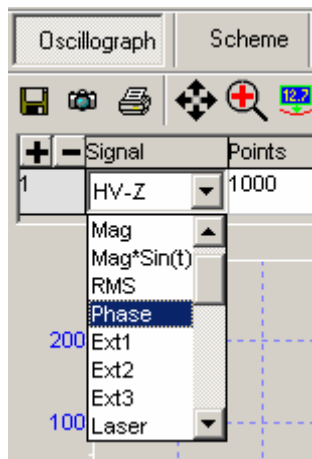


Fig. 4-58

“Phase” signal alternates in the range of 0 - 180 degrees, depending on the generator initial phase, which alternates in the range of 0 – 360 degrees.

3. Go to “Resonance” bookmark and modifying “Phase” parameter (Fig. 4-59) (generator initial phase), set the value of the measured phase in oscillograph in the middle of its range approximately (Fig. 4-60). The value cannot be set near the range limits, i.e. near 0 or 180 degrees, for in this case all possible modifications of the measured phase would be of the same sign.

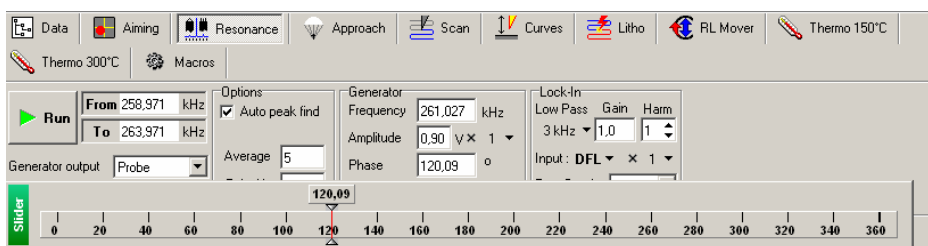


Fig. 4-59

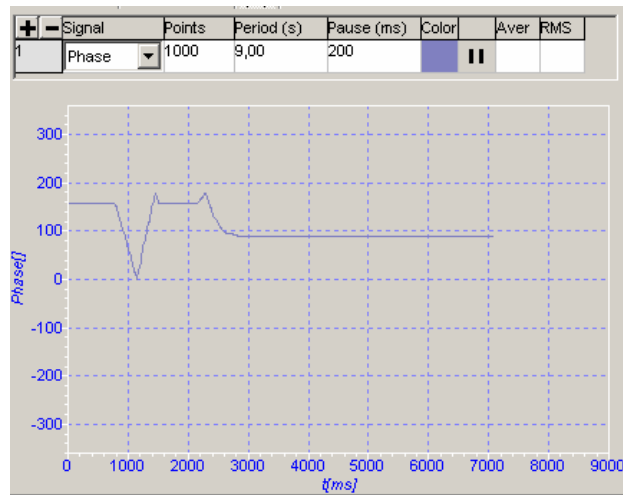


Fig. 4-60

4.3.2 Scanning

Select “**Scan**” bookmark and press “**Run**” button.

Two windows would appear on the display, one of them reflecting the topography (“**Height**” signal), whereas the other reflecting the phase distribution (“**Phase**” signal).

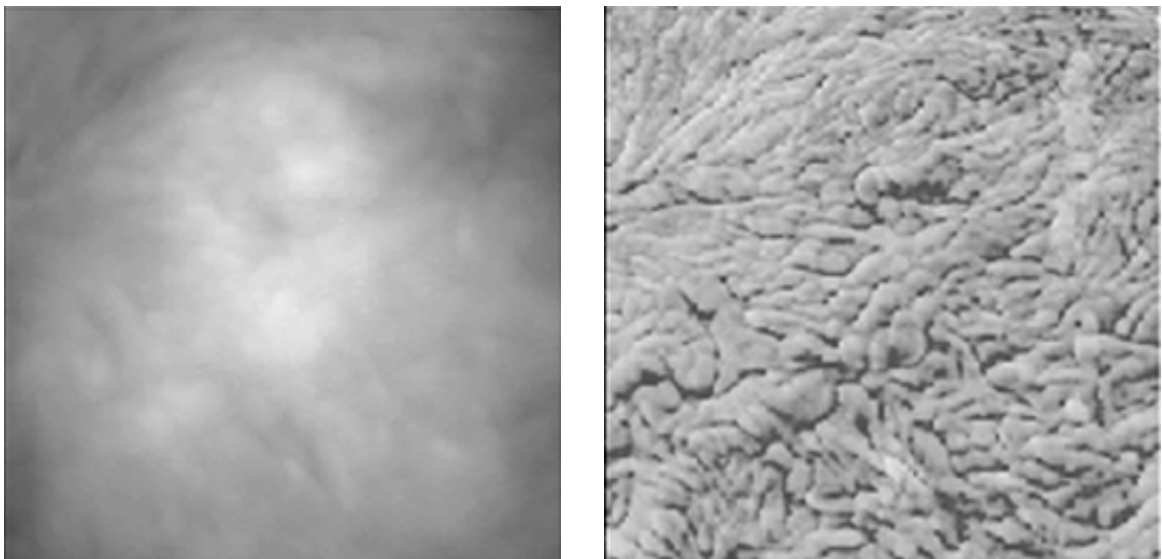


Fig. 4-61. The topography and phase images (lamellar structure) of spherulite

The topography and phase images (lamellar structure) of spherulite are exemplary.

4.3.3 Ways of image improvement

If the image quality is unsatisfactory, you can do any of the following:

- Replace the probe (with another of different rigidity and resonance frequency);
- Change the feedback loop ratio in “**FB**” parameter ([Fig. 4-54](#));
- Change the generator initial phase in “**Phase**” parameter ([Fig. 4-59](#));
- Change “**Set Point**” parameter (the force of the tip, pressing to the sample).

5 Many-Pass techniques

5.1 Scanning Capacitance Microscopy (SCM)

The following operations should be accomplished prior to SCM measurements:

- Select the type of scanning (“by sample”, “by tip” or “double”) and “SemiContact” configuration in program menu
- Perform the landing procedure;
- Perform a sample surface preview scanning;
- Select a sample surface area, suitable for measurement;
- Perform the scanning of selected sample surface area.

See the detailed description of the above listed operations in i. [4.1.1.-4.1.8](#) Chapter 4 “SemiContact Atomic-Force Microscopy”.

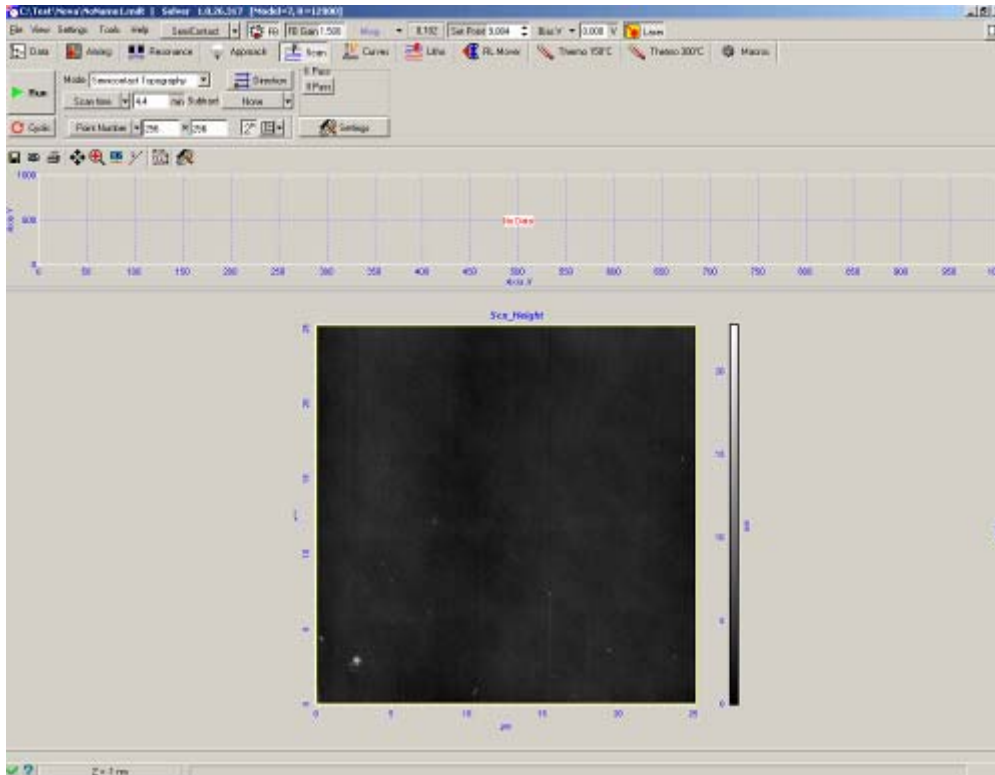


Fig. 5-1. Sample area scanned image

Performing the measurements in automatic setup mode comprises the following procedures:

- Mode selection;
- Second pass frequency adjustment;
- Scanning.

Each procedure is described below.

5.1.1 Mode selection

Select “Capacitance Contrast” in “Mode” menu (Fig. 5-2).

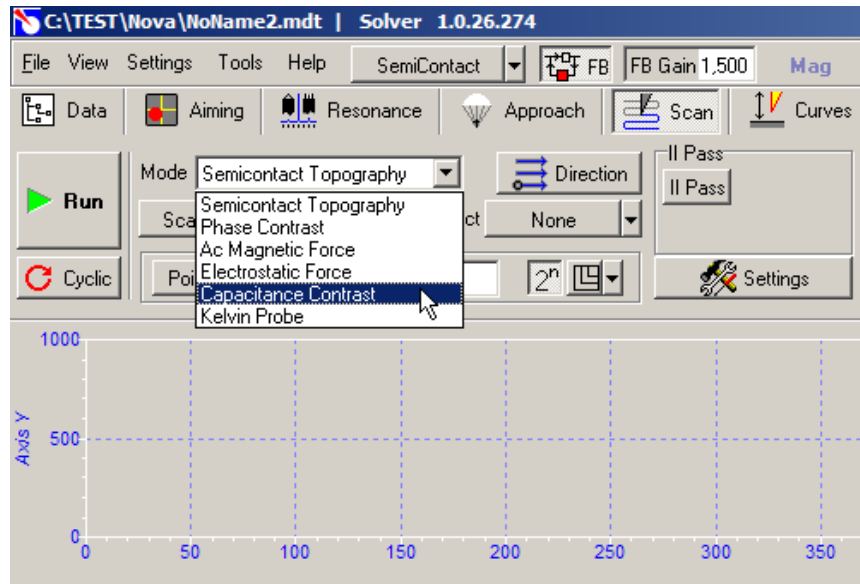


Fig. 5-2. “Capacitance Contrast” Mode selection

Scanning parameters setup control panel should look like this:

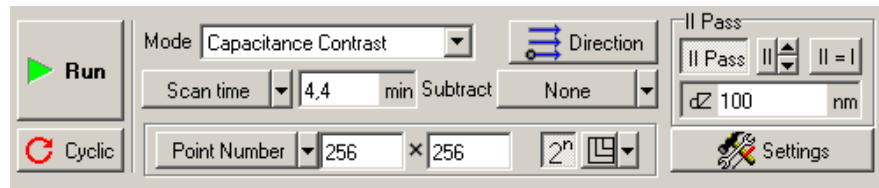


Fig. 5-3. View of scanning parameters setup control panel after “Capacitance Contrast” mode is selected

Note that “II Pass” option is activated.

5.1.2 Frequency-phase adjustment of cantilever oscillations for the second pass

Go to “Resonance” window to set up the second pass configuration. Frequency parameters setup panel should look like this:

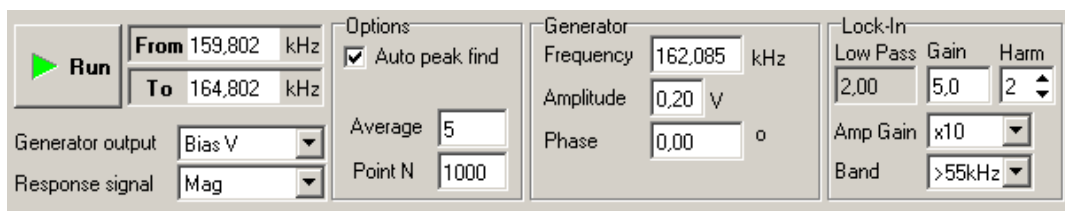


Fig. 5-4. View of frequency parameters setup panel on “Resonance” window

Bias voltage variable component (**Bias V**) is applied to the **Generator Output**. The amplitude of cantilever oscillations (**Mag**) is set as the **Response signal**. The option of resonance peak automatic

search “**Auto peak find**” is selected. The second harmonic (**Harm** = 2) is selected in synchronous detector (**Lock-in**) settings. Thus, the frequency parameters setup panel is configured to search for the resonance peak, which corresponds to the second harmonic of the cantilever oscillations amplitude-frequency parameter, depending on the alternating voltage applied to it. The frequency of the second harmonic comprises a half of the resonance frequency of cantilever’s own oscillations, set up during “**ASM**” Mode configuration. Therefore, to set up the required interval, it is necessary to modify the frequency limits of scanning (**From, To**) as it is shown on [Fig. 5-5](#):

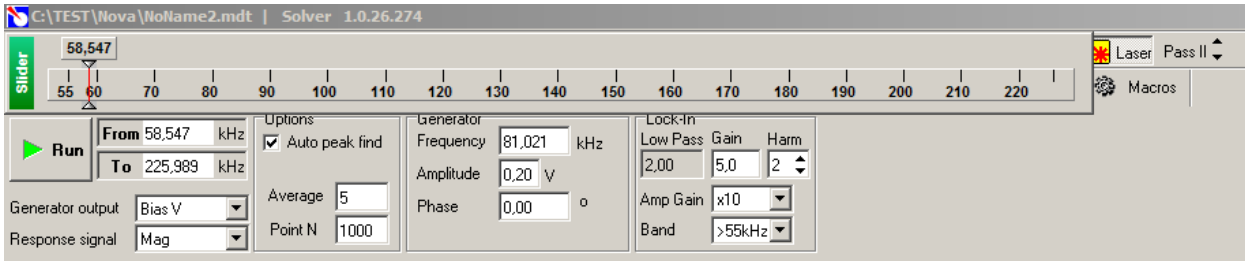


Fig. 5-5. Modifying the frequency intervals of scanning

To do this, double-click in the fields “**From**” and “**To**” with the cursor and modify the limits to the required range, using the slider.

Once the frequency limits of scanning are set, press **Run** button. If all the settings are adjusted correctly or if the cantilever and the sample form a system of “capacitor” type, a resonance curve is obtained, which should look like the one presented on [Fig. 5-6](#):

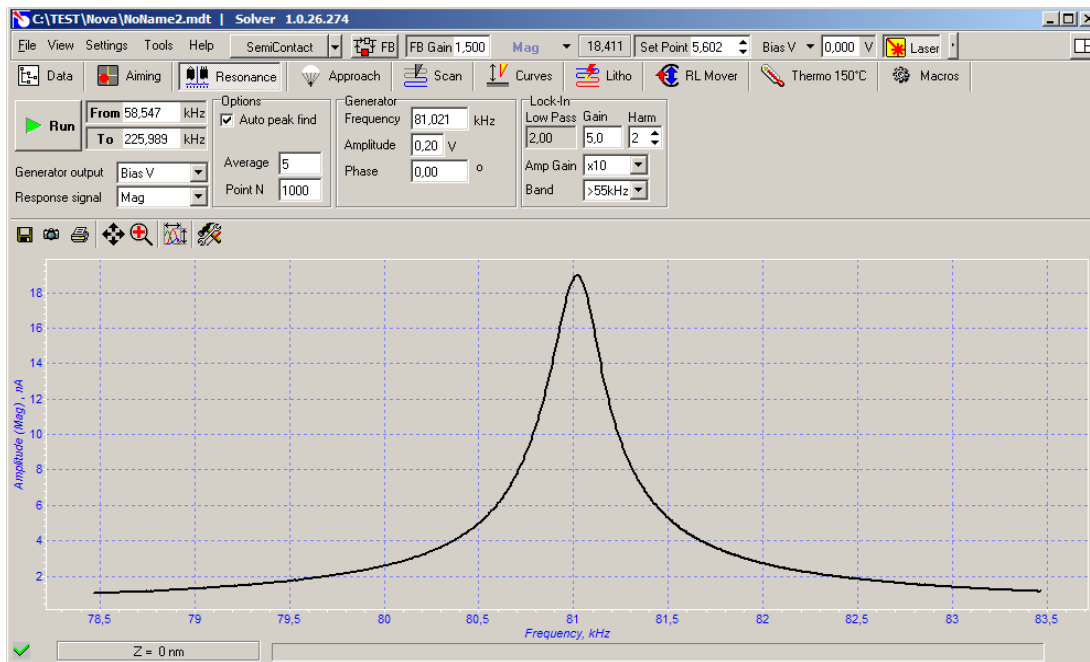


Fig. 5-6. Mag(BiasV) resonance curve

To obtain better results, the physical amplitude of cantilever oscillations should be decreased by decreasing the amplitude of alternating voltage, as shown on [Fig. 5-7](#) (**Generator, Amplitude** settings panel).

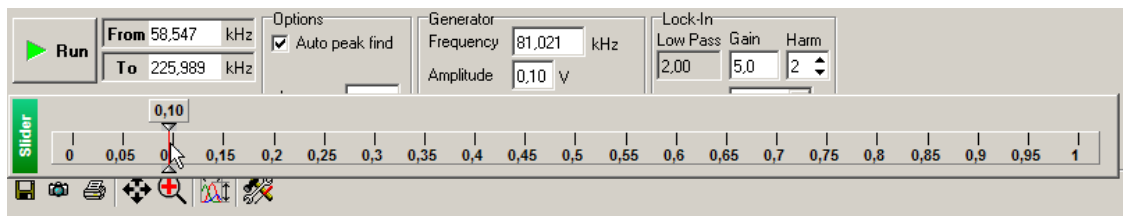



Fig. 5-7. Decreasing the alternating voltage amplitude.

This done, repeat the resonance peak search procedure. The recommended value of cantilever oscillations amplitude at the resonance frequency is 1...5 V. **Gain** value and **Amp Gain** amplification factor value (**Lock-in** panel) can be modified to adjust the amplitude.

5.1.3 Scanning

Once the frequency-phase adjustment of cantilever oscillations is completed, go back to “Scan” window and start the scanning process .

Two windows should be displayed in data visualization field, representing the height (**Height**) and the amplitude of cantilever oscillations in the second passage (**Mag**) respectively:

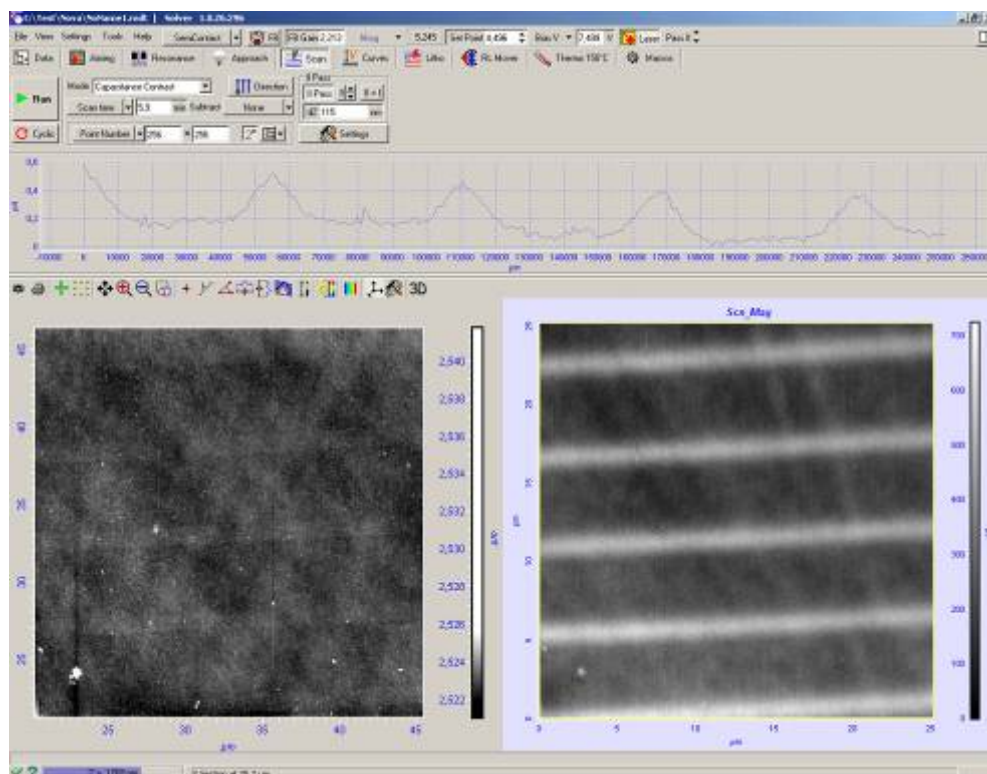


Fig. 5-8. Surface topography (left) and capacitance distribution (right) on the siliceous substrate with alloyed stripes

If all the settings are adjusted correctly, the image of cantilever oscillations amplitude distribution in the second passage should reveal contrasting areas with different capacitance characteristics. In the case, presented above ([Fig. 5-8](#)) the stripes are clearly visible, which differ from the substrate in conductivity.

5.1.4 Ways of improving the image quality

A user can improve the quality of magnetic field surface distribution image by modifying the following parameters:

- dZ** the height of probe rising (sample lowering) during second pass scanning. The greater is **dZ**, the lesser is the influence of surface topography on the second pass measurement results. Yet, the Mode sensitivity decreases as the height increases.
- Amplitude** output generator oscillations amplitude. Decreasing the generator and cantilever oscillations amplitude results in Mode resolution increase, but degrades signal to noise ratio.
- Bias V** changing the polarity and the value of bias voltage it is possible to identify the areas with different types of conductivity, modifying their contrast.

5.2 *Magnetic Force Microscopy (MFM)*

The following operations should be accomplished prior to MFM measurements:

- Select the type of scanning (“by sample”, “by tip” or “double”) and “**SemiContact**” configuration in program menu;
- Perform the landing procedure;
- Perform a sample surface preview scanning;
- Select a sample surface area, suitable for measurement;
- Perform the scanning of selected sample surface area.

See the detailed description of the above listed operations in items [4.1.1](#) - [4.1.8](#) Chapter [4](#) “[SemiContact Atomic-Force Microscopy](#)” on p. [91](#).

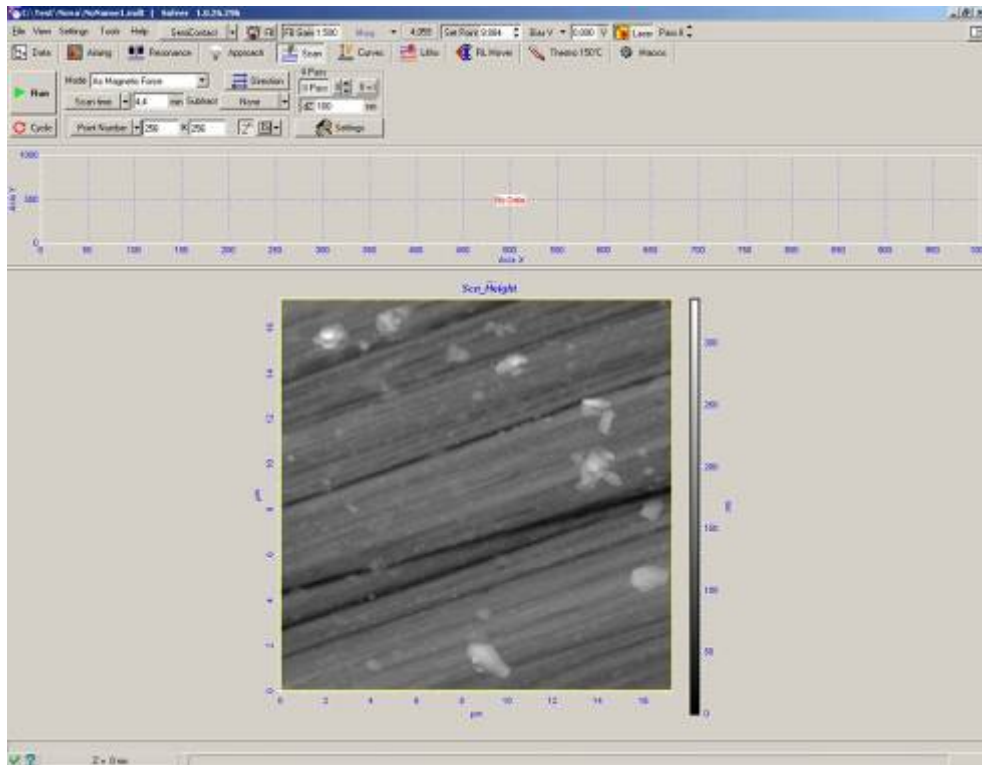


Fig. 5-9. Sample area scanned image

Performing the measurements in automatic setup mode comprises the following procedures:

- Mode selection;
- Frequency-phase adjustment of cantilever oscillations for the second pass;
- Scanning.

Each procedure is described below.

5.2.1 Mode selection

Select “AC Magnetic Force” in “Mode” menu of “Scan” window. The function of scanning parameters setup in the second pass is activated automatically:

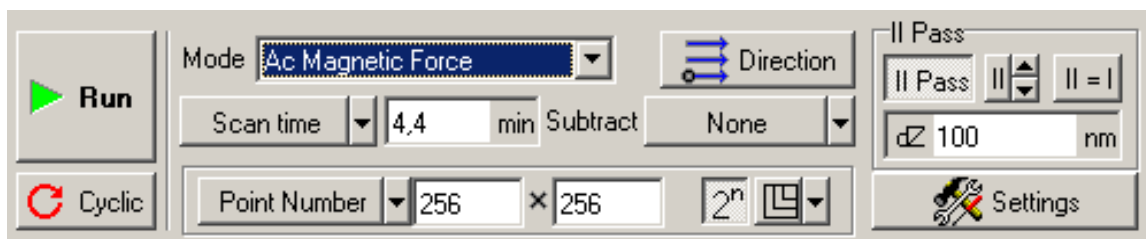


Fig. 5-10. View of scanning parameters setup control panel after MFM Mode is selected

The electric circuit is swapped automatically when using semi-automatic setup mode.

5.2.2 Frequency-phase adjustment of cantilever oscillations for the second pass

Keeping “**II Pass**” button pressed, go to “**Resonance**” window to set up the parameters of scanning for the second pass.

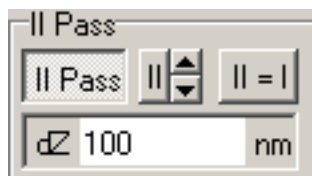


Fig. 5-11

“**II Pass**” button can be pressed either on “**Scanning**” window or in **Pass II** menu of Main SPM Parameters setup line.

Go to “**Resonance**” window and perform the amplitude-phase adjustment of cantilever for scanning in the second pass, as described in the manual.

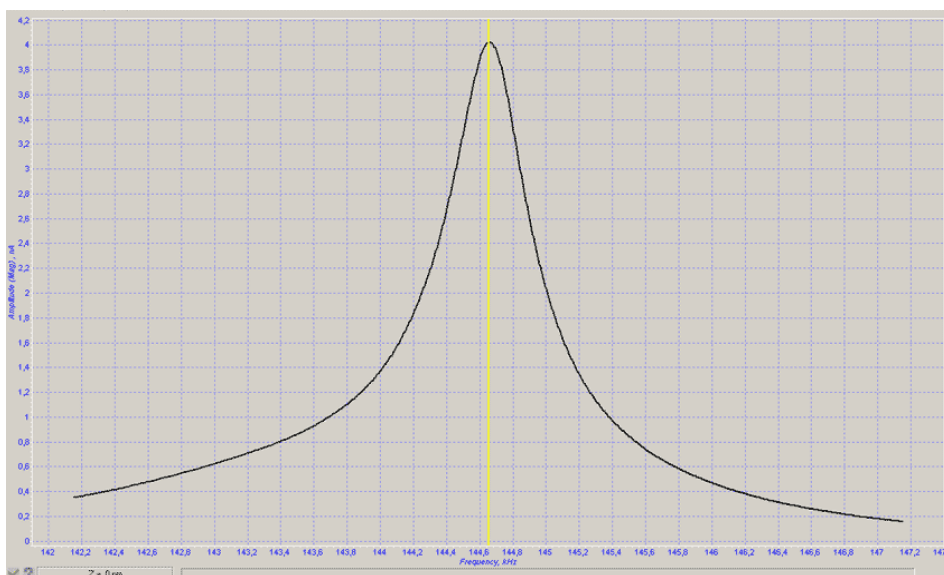


Fig. 5-12

Do not forget to switch off “**Auto Peak Find**” option when adjusting the phase.

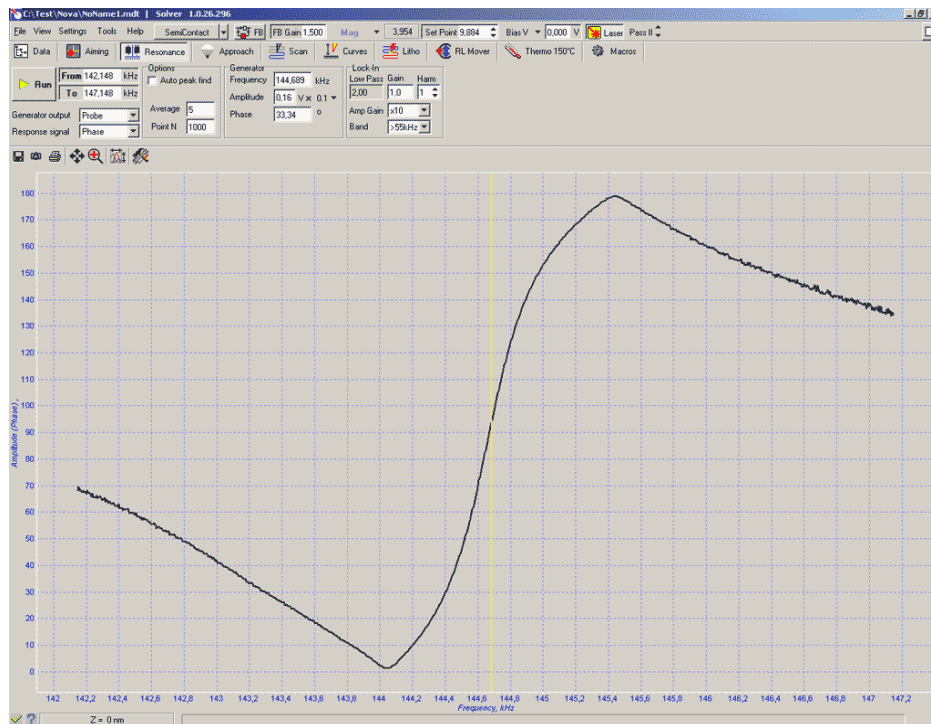


Fig. 5-13

Setting up cantilever oscillation parameters, it is recommended to use moderate values of generator amplitude (Amplitude = 0.1-0.5 x 0,1):

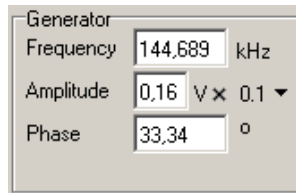



Fig. 5-14

5.2.3 Scanning

Once the frequency-phase adjustment of cantilever oscillations is completed, go back to “Scan” window and start the scanning process .

Two windows should be displayed in data visualization field, representing the height (**Height**) and the phase (**Phase**) respectively:

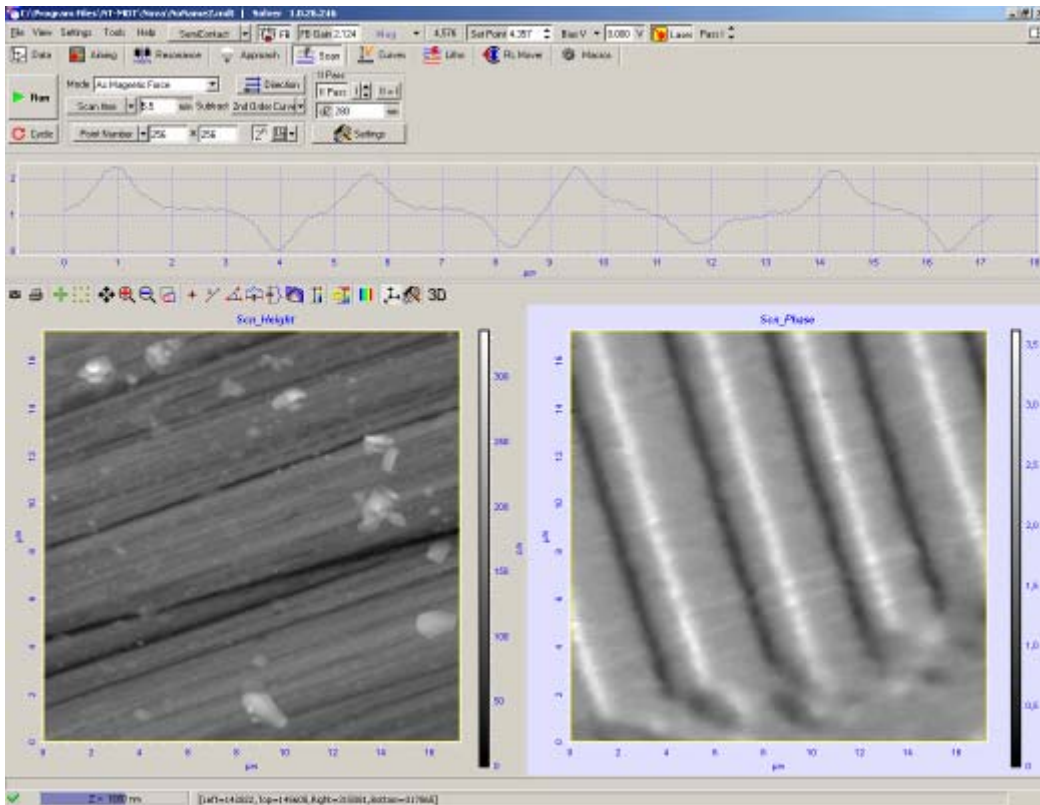


Fig. 5-15. Surface topography (left) and magnetic domains distribution (right) on the surface of magnetic disc

If all the settings are adjusted correctly, the image of phase contrast in the second pass should reveal the distribution of magnetic domains (Fig. 5-15).

5.2.4 Ways of improving the image quality

A user can improve the quality of the image of distribution of magnetic field on the surface by modifying the following parameters:

- dZ** the height of probe rising (sample lowering) during second pass scanning. The greater is **dZ** the lesser is the influence of surface topography on the second pass measurement results. Yet, the Mode sensitivity decreases as the height increases.
- Amplitude** output generator oscillations amplitude. Decreasing the generator and cantilever oscillations amplitude results in Mode resolution increase, but degrades signal to noise ratio.

5.3 Electric Force Microscopy (EFM)

The following operations should be accomplished prior to EFM measurements:

- Select the type of scanning (“by sample”, “by tip” or “double”) and **“SemiContact”** configuration in program menu;
- Perform the landing procedure;
- Perform a sample surface preview scanning;
- Select a sample surface area, suitable for measurement;
- Perform the scanning of selected sample surface area.

See the detailed description of the above listed operations in i. [4.1.1](#) - [4.1.8](#). Chapter [4](#) **“SemiContact Atomic-Force Microscopy”** on p. [91](#).

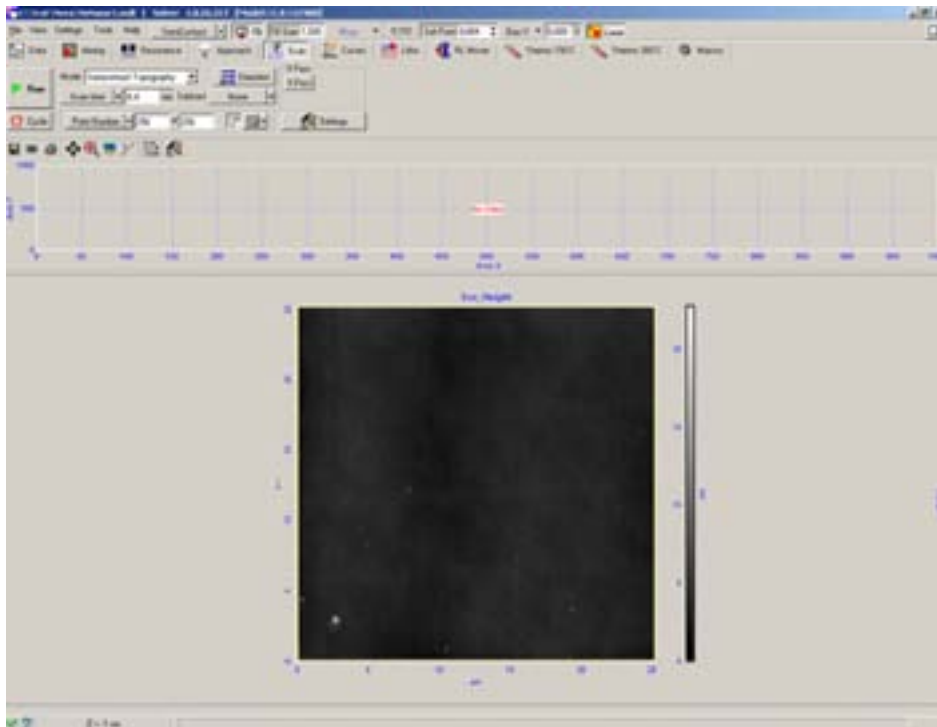


Fig. 5-16. Sample area scanned image

Performing the measurements in automatic setup mode comprises the following procedures:

- Mode selection;
- Frequency-phase adjustment of cantilever oscillations for the second pass;
- Scanning.

Each procedure is described below.

5.3.1 Mode selection

Select “Electrostatic force” mode in “Mode” menu (Fig. 5-17).

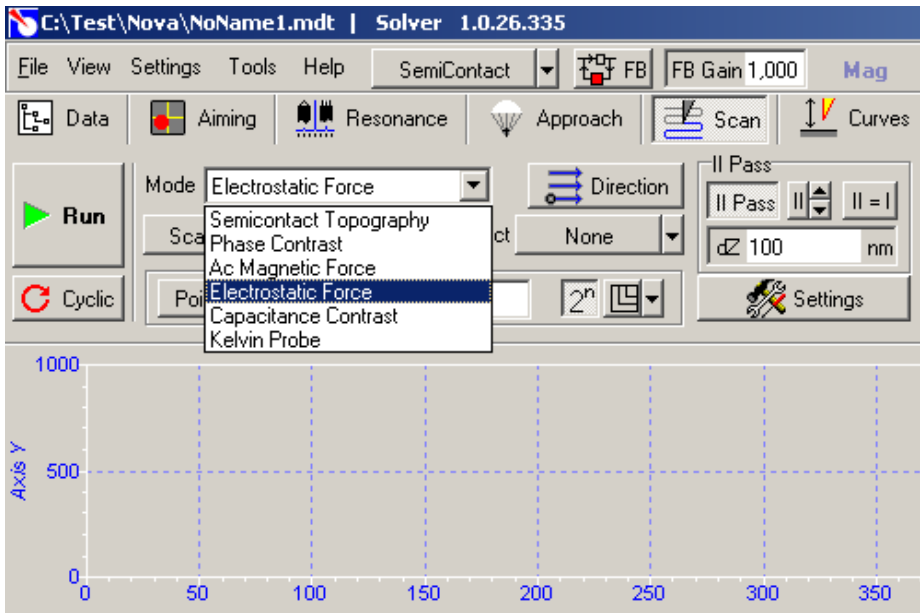


Fig. 5-17. “Electrostatic Force” Mode selection

Scanning parameters setup control panel should look like this:

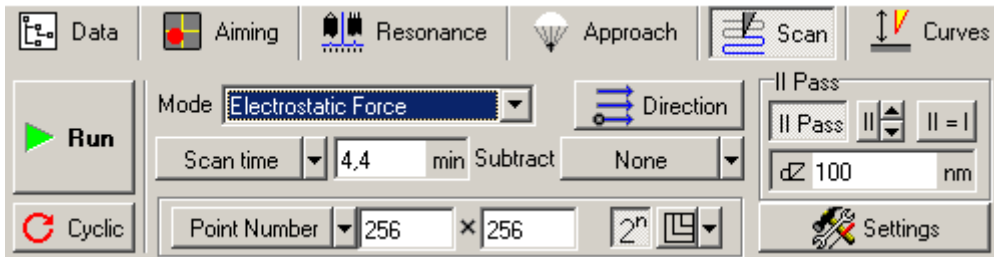


Fig. 5-18. View of scanning parameters setup control panel after “Electrostatic Force” Mode is selected

Note that “II Pass” option is activated.

5.3.2 Frequency-phase adjustment of cantilever oscillations for the second pass

Keeping “II Pass” button pressed, go to “Resonance” window to set up the parameters of scanning for the second pass.

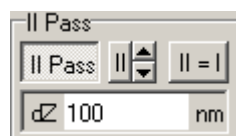


Fig. 5-19

“**II Pass**” button can be pressed either on “**Scanning**” window or in  menu of Main SPM Parameters setup line.

Go to “**Resonance**” window and perform the amplitude-phase adjustment of cantilever for scanning in the second pass, as described in the manual.

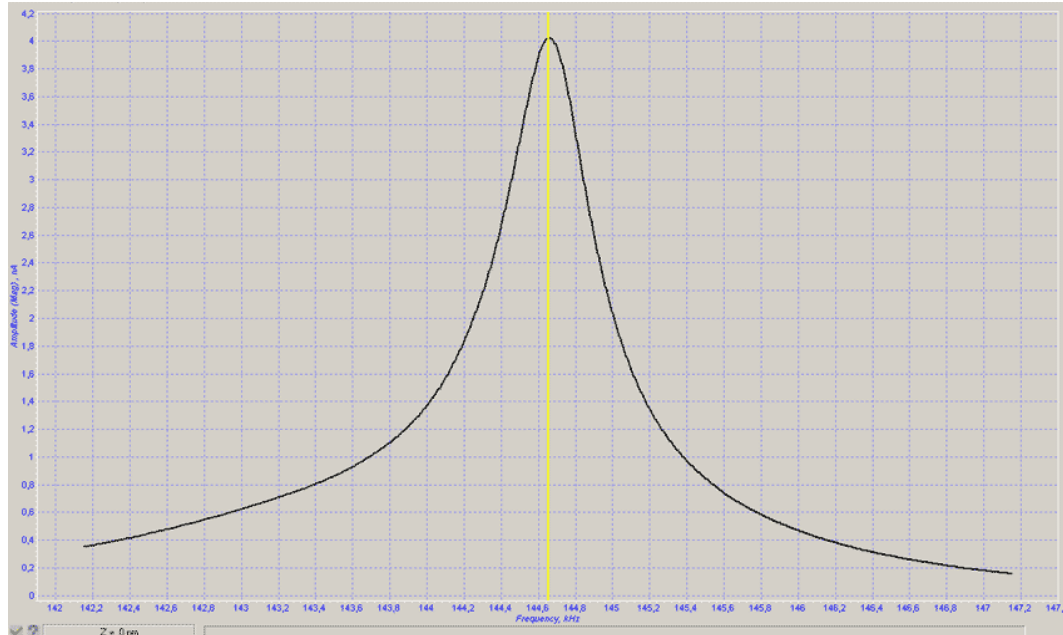


Fig. 5-20

Do not forget to switch off “**Auto Peak Find**” option when adjusting the phase.

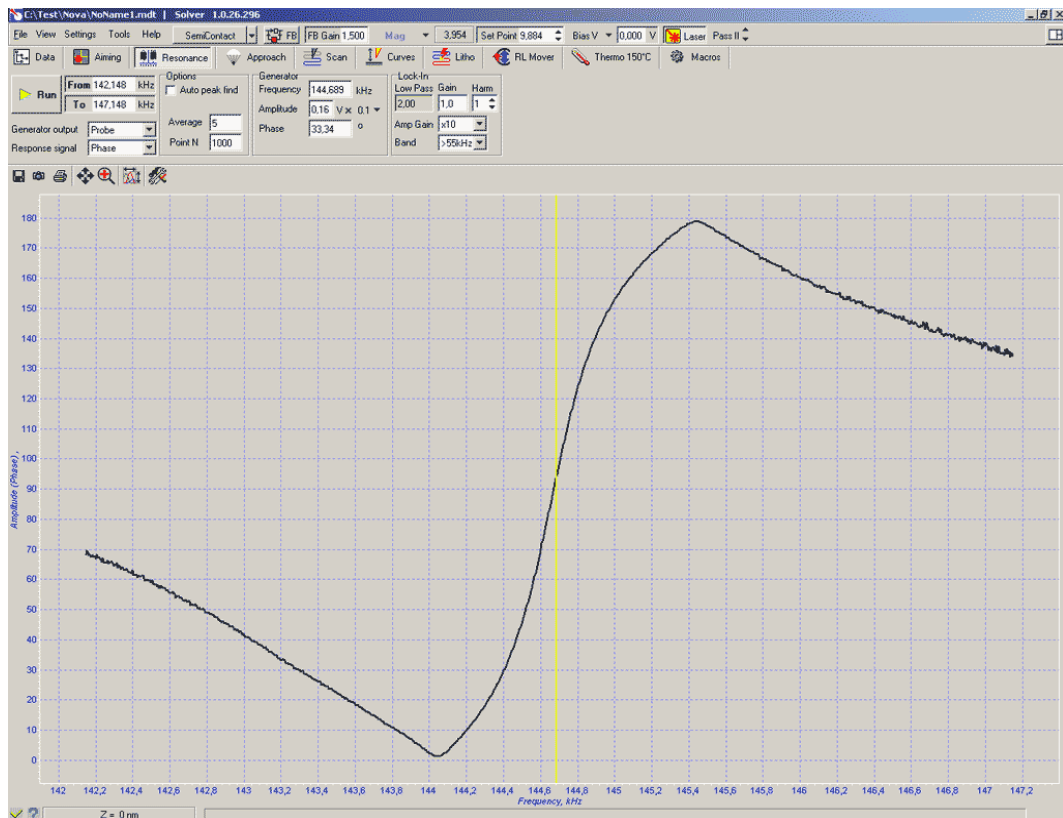


Fig. 5-21

Setting up cantilever oscillation parameters, it is recommended to use moderate values of generator amplitude (Amplitude = 0.1-0.5 x 0,1):

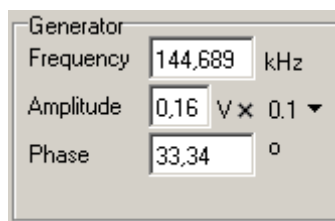



Fig. 5-22

5.3.3 Scanning

Once the frequency-phase adjustment of cantilever oscillations is completed, go back to “Scan” window and start the scanning process .

Two windows should be displayed in data visualization field, representing the height (Height) and the phase (Phase) respectively:

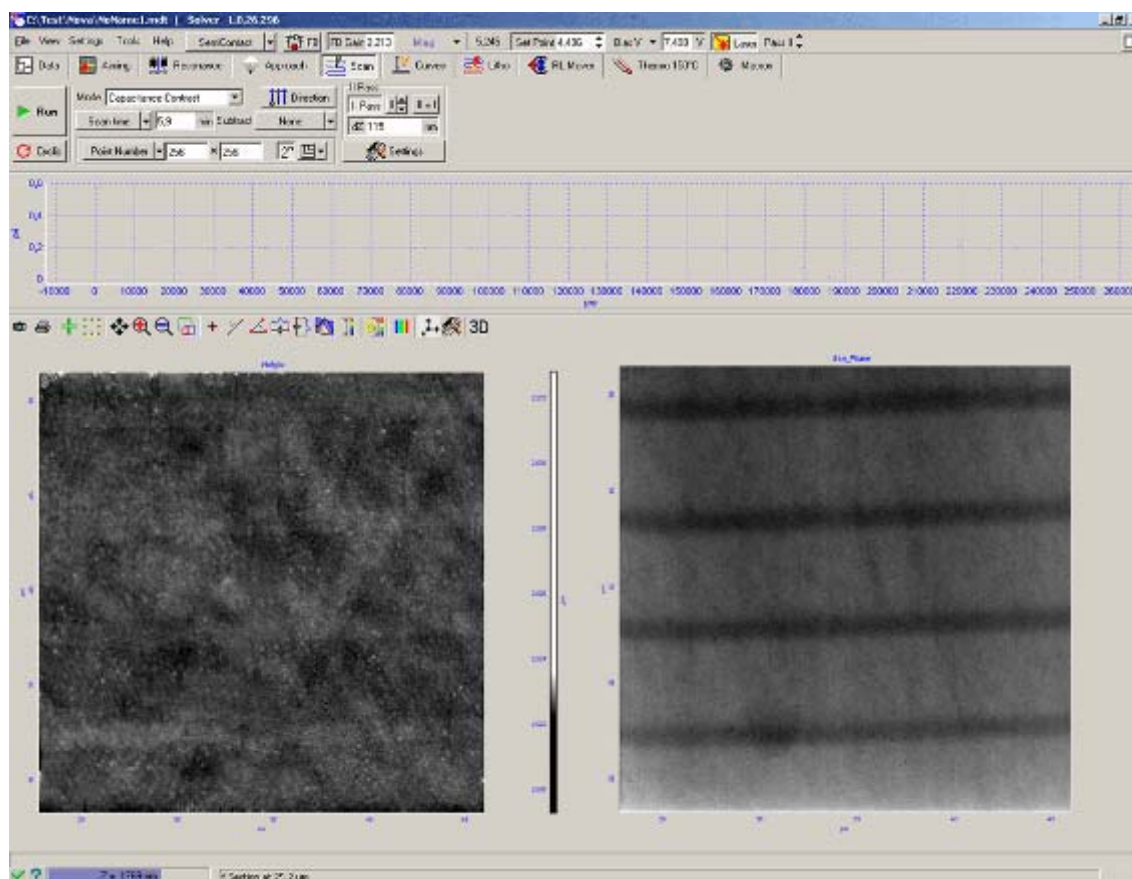


Fig. 5-23. Surface topography (left) and surface potential distribution (right) on the siliceous substrate with alloyed stripes

If all the settings are adjusted correctly, the image cantilever oscillations amplitude distribution in the second passage should reveal the distribution of electric potential on the sample surface ([Fig. 5-23](#)).

5.3.4 Ways of improving the image quality

A user can improve the quality of the image of distribution of magnetic field on the surface by modifying the following parameters:

- dZ** the height of probe rising (sample lowering) during second pass scanning. The greater is **dZ** the lesser is the influence of surface topography on the second pass measurement results. Yet, the Mode sensitivity decreases as the height increases.
- Amplitude** output generator oscillations amplitude. Decreasing the generator and cantilever oscillations amplitude results in Mode resolution increase, but degrades signal to noise ratio.
- Bias V** changing the polarity and the value of bias voltage it is possible to influence the way the surface potential is manifested in the second pass.