Nanosurf Easyscan 2 STM

Operating Instructions

for

SPM Control Software
Version 3.1

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About this Manual

For your convenience, this manual has been divided into three separate parts:

PART A: INTRODUCTION TO THE INSTRUMENT will familiarize you with the Nanosurf Easyscan 2 STM system, and will explain how to set up your system and operate it on a daily basis. Among other things, it will also describes how to set up basic experiments and how to generally improve measurement quality. Part A starts with *Chapter 1: The Easyscan 2 STM* (page 13) and ends with *Chapter 6: Finishing measurements* (page 57).

PART B: SOFTWARE REFERENCE is a reference for the software that comes with the Easyscan 2 STM system. It starts with *Chapter 7: The user interface* (page 63) and ends with *Chapter 15: Quick reference* (page 235). Its content applies to Nanosurf Easyscan 2 software version 3.1, Nanosurf Translation Stage Controller software version 2.1, and Nanosurf Batch Manger software version 1.3. If you are using newer software versions, download the latest manual from the Nanosurf Support pages or refer to the "What's new in this version.pdf" file that came with the newer software. For more information on the Nanosurf Scripting Interface, refer to the online help files "Easyscan 2 Script Programmers Manual". For more information on the Nanosurf Report software, refer to the online help included with this optional software.

PART C: APPENDICES contains information that you will use less frequently, such as general maintenance and troubleshooting. It starts with *Chapter 16: Maintenance* (page 239) and ends with *Chapter 19: Technical data* (page 257).

PART A:

INTRODUCTION TO THE INSTRUMENT

CHAPTER 1:

The Easyscan 2 STM

1.1: Introduction

The Nanosurf Easyscan 2 STM system was designed to allow people without training as a physicist to do experiments in the world of atoms. Its design is compact, simple and comfortable to operate. With the Easyscan 2 STM, it is possible to do all STM experiments that can be carried out in air. The tip–sample approach stage allows simple handling of samples and tips, while at the same time providing maximum stability of the tip–sample distance. All functions can be carried out using a computer and the SPM Control Software.

The Easyscan 2 STM system is a modular scanning probe system that can be upgraded to obtain more measurement capabilities. The main parts of the basic system are the Easyscan 2 STM Scan Head, the Vibration Isolation Platform, the Easyscan 2 Controller, and the SPM Control Software.

The content of the system and the function of its major components are described in this chapter. Detailed technical specifications and system features can be found in *Chapter 19: Technical data* (page 257).

Several other Nanosurf products can be used in conjunction with the Easyscan 2 STM:

- STM Scan Head: makes atomic scale measurements. Refer to the *Easyscan 2 STM Operating Instructions* for more details.
- Signal Module A: allows monitoring of microscope signals and creating custom operating modes. Refer to *Section 19.4.1: Signal Module A* (page 261) for more details.
- Nanosurf Report: software for simple automatic evaluation and report generation of SPM measurements.
- Nanosurf Analysis: software for detailed analysis of SPM measurements.
- Scripting Interface: software for automating measurements. Refer to *Section 10.4.2: Scripting group* (page 127) and the *Programmer's Manual* for more details.
- Lithography Option: software for professional lithography applications. Refer to *Chapter 12: Lithography* (page 157) for more information.
- The Nanosurf Isostage: a highly compact active vibration isolation table.
- The Halcyonics_i4 Active Vibration Isolation Table: a large and heavy-duty active vibration isolation solution, which features load adjustment.

1.2: Components of the system

This section describes the parts that may be delivered with an Easyscan 2 STM system. The contents of delivery can vary from system to system, depending on which parts were ordered. To find out which parts are included in your system, refer to the delivery note shipped with your system. Some of the modules listed in the delivery note are built into the controller. Their presence is indicated by the status lights on the top surface of the controller when it is turned on (see *Section 1.3.2: The Easyscan 2 Controller* (page 17)).

Before unpacking the instrument, verify that the package contains the following components:

Figure 1-1: Components. The Easyscan 2 STM system

1. The Easyscan 2 Controller (optionally with built-in additional modules).
2. Easyscan 2 STM Scan Head.
3. Magnifying cover with 10× magnifier.
4. USB cable.
5. Mains cable.
6. STM Tool set (option). The items contained in the STM Tool set are described in the next section.
7. The Easyscan 2 Installation CD (not shown): Contains software, calibration files, and PDF files of all manuals.
8. A calibration certificate for each scan head (not shown).
9. This Easyscan 2 STM Operating Instructions manual (not shown).
10. Vibration isolation platform (option).
11. Signal Module A connector box (option; comes with Signal Module A).
12. Two Signal Module cables (option; come with Signal Module A).
13. Scripting Interface certificate of purchase with Activation key printed on it (option; not shown; comes with Scripting Interface).

14. Lithography Option certificate of purchase with Activation key printed on it (option; not shown; comes with the Nanosurf Lithography Option).
15. Instrument case (not shown).

The package may also contain Easyscan 2 AFM head(s) and modules for the AFM, which are described in the *Easyscan 2 AFM Operating Instructions.*

Please keep the original packaging material (at least until the end of the warranty period), so that it may be used for transport at a later date, if necessary. For information on how to store, transport, or send in the instrument for repairs, see *Section 6.3: Storing the instrument* (page 59).

1.2.1: Contents of the Tool Set

The content of the Tool set depends on the modules and options included in your order. It may contain any of the following items:
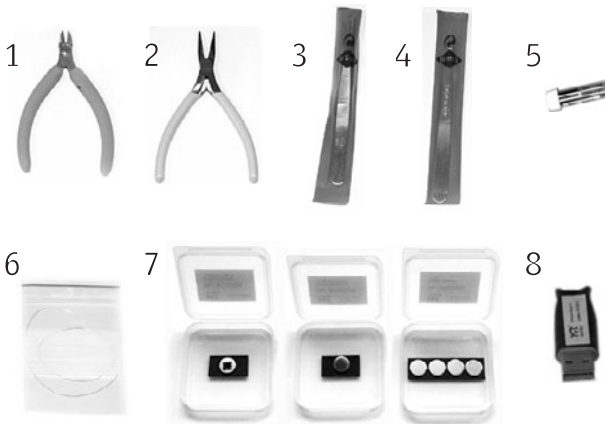
Figure 1-2: Contents of the Tool set

1. Wire cutters.
2. Flat Nose Pliers.
3. Pointed tweezers (00D SA).
4. Rounded tweezers (2A SA-SL).
5. Sample holder.
6. Pt/Ir wire (90% Pt / 10% Ir alloy; 0.25 mm / 30 cm): Used for making STM tips (option).
7. STM Basic Sample Kit (option) with HOPG (graphite), gold thin film and four spare sample supports.

8.   USB dongle for Nanosurf Report software (option).

1.3: Connectors, indicators and controls

Use this section to find the location of the parts of the Easyscan 2 STM that are referred to in this manual.

1.3.1: The Easyscan 2 STM scan head

Two types of Easyscan 2 STM scan heads with different approach stages exist. In type one stages, the Sample Holder slides on guide bars. In type two stages, the Sample Holder slides on a point support (see *Figure 1-3: Parts of the Scan Head*).
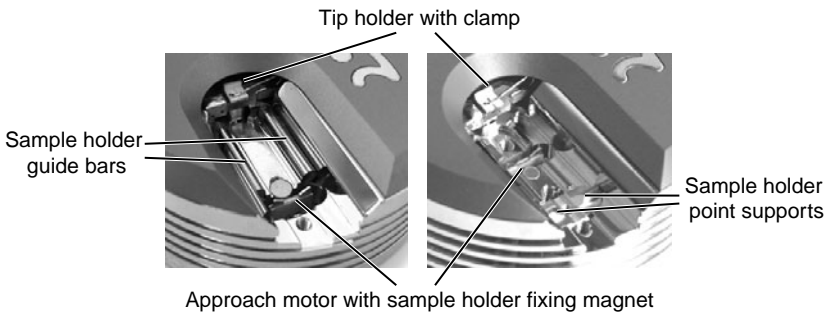
Figure 1-3: Parts of the Scan Head. (left) Type one Scan Head, (right) Type two Scan Head.

1.3.2: The Easyscan 2 Controller

Status lights

All status lights on top of the controller will light up for one second when the power is turned on.

The Probe Status light
Indicates the status of the Z-feedback loop. The Probe Status light can be in any of the following states:

– Red
  The scanner is in its upper limit position. This occurs when the tip–sample interaction is stronger than the Setpoint for some time. There is danger of damaging the tip due to an interaction that is too strong.
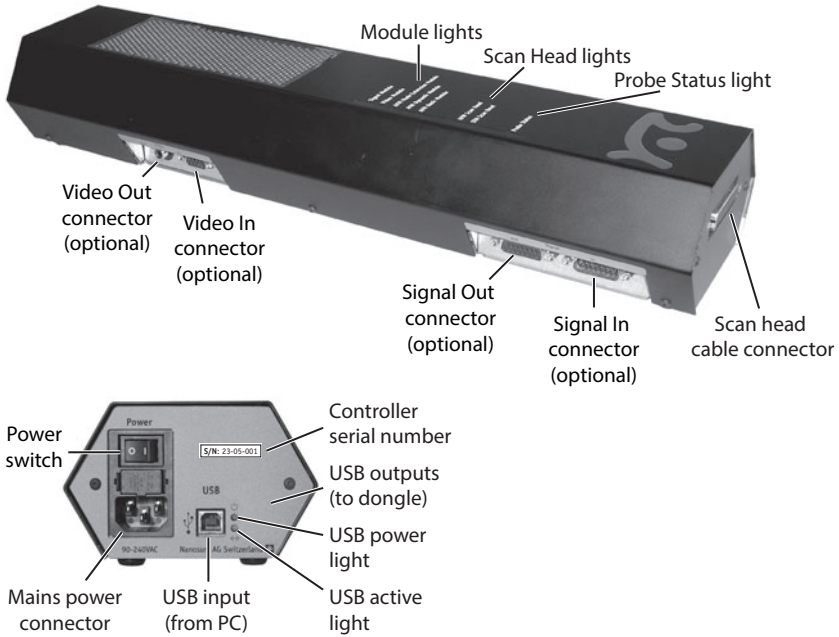
Figure 1-4: The Easyscan 2 controller

– Orange/yellow
The scanner is in its lower limit position. This occurs when the tip–sample interaction is weaker than the Setpoint for some time. The tip is probably not in contact with the sample surface.

– Green
The scanner is not in a limit position, and the feedback loop is able to follow the sample surface.

– Blinking green
The feedback loop has been turned off in the software.

The Scan Head lights
Indicate the Scan Head type that is connected to the instrument. The Scan Head lights blink when no Scan Head can be detected, or when the controller has not been initialized yet.

The Module lights
Indicate the modules that are built in into the controller. The module lights blink when the controller has not been initialized yet. During initialization, the module lights are turned on one after the other.

CHAPTER 2:

Installing the Easyscan 2 STM

2.1: Installing the SPM Control Software

2.1.1: Preparations before installing

Before installation, the following steps need to be performed:

❶ Make sure the computer to be used meets the minimal computer requirements, as described in *Chapter 19: Technical data* under *Computer requirements* (page 261).

❷ Make sure none of the Easyscan 2 STM system's hardware is connected to the computer.

❸ Turn on the computer and start Windows.

❹ Log on with Administrator privileges.

> **IMPORTANT**
>
> Do not run any other programs while installing the Easyscan 2 software.

2.1.2: Initiating the installation procedure

To initiate the installation procedure:

❶ Insert the Easyscan 2 Installation CD into the CD drive of the computer.

In most cases, the Autorun CD Menu program will open automatically. Depending on your Autoplay settings, however, it is also possible that the Autoplay window opens, or that nothing happens at all. In these cases:

➥ Click "Run CD_Start.exe" in the Autoplay window, or manually open the Easyscan 2 Installation CD and start the program "CD_Start.exe".

> **IMPORTANT**
>
> The Easyscan 2 Installation CD contains calibration information (.hed files) specific to your instrument! Therefore, always store (a backup copy of) the CD delivered with the instrument in a safe place.

❷ Click the "Install Easyscan 2 Software" button.

The CD Menu program now launches the software setup program, which will start installation of all components required to run the Nanosurf Easyscan 2 software.

In Windows Vista/7, the User Account Control (UAC) dialog may pop up after clicking the "Install Easyscan 2 Software" button, displaying the text "An unidentified program

wants access to your computer". If the name of the program being displayed is "Setup.exe":

➥ Click the "Allow" button.

After the software setup program has started:

❶ Click "Next" in the "Welcome", "Select Destination Folder", and "Select Start Menu Folder" windows that sequentially appear, accepting the default choices in all dialogs.

❷ When the "Ready to install" window appears, click on the "Install" button.

The setup program now performs its tasks without any further user interaction. Depending on the configuration of your computer, a reboot may be required at the end of the software installation process. If this is the case, the setup program will inform you of this, and will provide you with the opportunity to do so.

This completes the driver and control software installation procedure. If you wish to use the Lithography features of the Easyscan 2 software and want to design your own vector graphics for import into the lithography module, you can opt to install the LayoutEditor software by clicking the "Install CAD Program" button in the CD Menu program. This will launch the LayoutEditor installation program, which will guide you through the CAD program setup. Otherwise, you may exit now by clicking the "Exit" button and continue with *Section 2.2: Installing the hardware* and *Section 2.3: Hardware recognition*.

2.2: Installing the hardware

IMPORTANT

- Make sure that the mains power connection is protected against excess voltage surges.

- Place the instrument on a stable support in a location that has a low level of building vibrations, acoustic noise, electrical fields, and air currents.

IMPORTANT

To allow measurements with atomic resolution to be made, the following precautions must be taken to keep the equipment dust- and grease-free:

- Never let your fingers touch either the wire for tips (*Figure 1-2: Contents of the Tool set* (page 16), item 6), the sample (*Figure 1-2: Contents of the Tool set* (page 16), item 7) nor the parts of the STM scan head indicated in *Figure 1-3: Parts of the Scan Head* (page 17).

- Only touch the Sample Holder (*Figure 1-2: Contents of the Tool set* (page 16), item 5) at the black plastic end.

2.2.1: Installing the Easyscan 2 controller

❶ Connect the USB Cable (*Figure 1-1: Components* (page 15), item 4) to the Easyscan 2 Controller (item 1), but do not connect it to the computer yet.

❷ Connect the Easyscan 2 Controller to the mains power using the Mains Cable (item 5), but do not turn on the controller yet.

Figure 2-1: Measurement setup. Complete Easyscan 2 STM system.

2.2.2: Installing the Signal Module A

To install the Signal Module A:

❶ Connect one Signal Module cable (*Figure 1-1: Components* (page 15), item 12) to the Signal Out connector on the Controller and to the Output connector on the Signal Module A Connector Box.

❷ Connect the other Signal Module cable to the Signal In connector on the Controller and to the Input connector on the Signal Module A Connector Box.

In case of an upgrade, the Easyscan 2 Controller must be sent in to your local Nanosurf distributor for installation of the Signal Module A electronics in the controller housing.

2.2.3: Installing the Easyscan 2 STM Scan Head

To mount the Scan Head

❶ Attach the Scan Head cable to the Easyscan 2 Controller.

❷ Place the Scan Head onto the vibration isolation platform (*Figure 1-1: Components* (page 15), item 10).

❸ Fix the scan head cable under the strain relief clip on the platform.

If the vibration isolation of your table is insufficient for your measurement purposes, use an active vibration isolation table such as the Nanosurf Isostage or the Halcyoncis_i4. Refer to the respective manuals for installation instructions.

2.3: Hardware recognition

To initiate the automatic hardware recognition process for the devices present in your system:

❶ Install all hardware as described in *Section 2.2: Installing the hardware*.

❷ Power on the Easyscan 2 controller.

❸ Connect the Easyscan 2 controller to the computer with the supplied USB cable (*Figure 1-1: Components* (page 15), item 4).

A popup balloon appears in the Windows notification area, stating that new hardware devices have been found and drivers are being installed. Depending on the configuration of your controller and computer, the detection process can take quite some time (20 seconds or more). Please be patient! After successful automatic installation, the popup balloon indicates that the installation has finished and that the devices are now ready for use.

CHAPTER 3:

Preparing for measurement

3.1: Introduction

Once the system has been set up (see *Chapter 2: Installing the Easyscan 2 STM* (page 19)), the instrument and the sample have to be prepared for measurement. The preparation consists of three steps: *Initializing the Easyscan 2 Controller*, *Preparing and installing the STM tip*, and *Installing the sample*.

3.2: Initializing the Easyscan 2 Controller

To initialize the Easyscan 2 controller:

❶ Make sure that the Easyscan 2 controller is connected to the mains power and to the USB port of the control computer.

❷ Turn on the power of the Easyscan 2 controller.

First all status lights on top of the controller briefly light up. Then the Scan Head lights and the lights of the detected modules will start blinking, and all other status lights turn off.

❸ Start the SPM Control Software on the control computer.

The main program window appears, and all status lights are turned off. Now a Message "Controller Startup in progress" is displayed on the computer screen, and the module lights are turned on one after the other. When initialization is completed, a Message "Starting System" is briefly displayed on the computer screen, and the Probe Status light, the Scan Head status light of the detected scan head, and the Module lights of the detected modules will light up. If no scan head is detected, both Scan Head Status lights blink.

3.3: Preparing and installing the STM tip

The STM tip can be prepared and installed by yourself. This is the most difficult part of your preparations. It usually needs patience and some practise to get the first good tip. Only an accurately cut tip enables optimal measurements. Therefore, cutting and installing should be carried out with great care. On delivery, the tip with which the STM was calibrated in the factory is installed in the head. This tip should give atomic resolution, so you may wish to try to use this tip before preparing your own.

Before cutting the tip:

❶ Clean the cutting part of the wire cutters (*Figure 1-2: Contents of the Tool set* (page 16), item 1), the Flat nose pliers (item 2) and the pointed tweezers (item 3) with ethanol.

Only touch the Pt/Ir wire (item 6) with these tools.

❷ Remove the old tip from the instrument using the pointed tweezers.

If the tip wire is still long enough, you may try to cut the same wire again, otherwise cut the Pt/Ir wire.

To prepare the tip:

❶ Hold the end of the wire firmly with the pliers.

❷ Holding the wire with the pliers, move the cutters at a length of approximately 4 mm, as obliquely as possible (*Figure 3-1: Cutting the STM tip*).
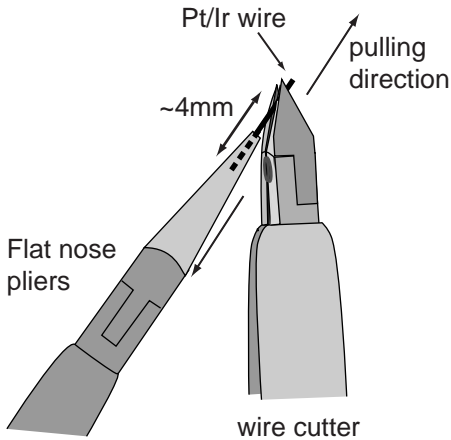
Figure 3-1: Cutting the STM tip

❸ Close the cutters until you can feel the wire, but do not cut the wire.

❹ Pull in the direction shown in *Figure 3-1: Cutting the STM tip*. The tip needs to be torn off rather than cleanly cut through, in order to obtain the required tip sharpness.
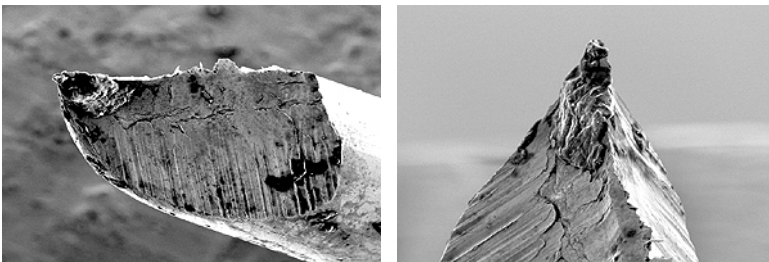
Figure 3-2: STM tip. Scanning Electron Microscope images of an STM tip

❺ Use the pointed tweezers to hold the tip wire with just behind the tip.

❻ Release the flat pliers.

IMPORTANT

- Never touch the end of the tip with anything.

- Ensure that the tip wire is straight.

- Do not twist the tip clamp in any way, nor lift it too high.

The procedure for mounting the tip under the tip clamp depends on the type of clamp on your scan head (single or double clamp).

Single clamp
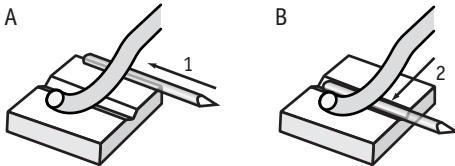
Figure 3-3: Mounting the tip under the single clamp

In case of a single clamp scan head, proceed as follows:

❶ Put the tip wire on the tip holder parallel to the groove in the tip holder, so that it crosses below the tip clamp (*Figure 3-3: Mounting the tip under the single clamp*, A).

❷ Move the tip wire sideways until it is in the groove in the tip holder (*Figure 3-3: Mounting the tip under the single clamp*, B).

The freshly cut tip should be securely held under the clamp and extend about 2–3 mm beyond the tip holder.

The tip is now installed.

Double clamp
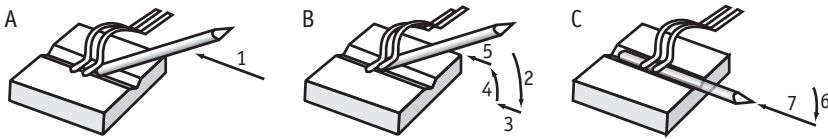
Figure 3-4: Mounting the tip under the double clamp

Always use the following procedure for mounting the tip under the double clamp, as using a different procedure may cause a gradual deterioration of the measurement quality due to loosening of the clamp:

❶ Hold the tip wire at a slight angle, and move it along the groove against the first clamp, so that the end of the wire is under the clamp (*Figure 3-4: Mounting the tip under the double clamp*, A).

❷ Lower the wire so that it lifts the first clamp (*Figure 3-4: Mounting the tip under the double clamp*, B).

❸ Push the wire in, until it touches the second clamp.

❹ Lift the wire.

❺ Push the end of the wire below the second clamp.

❻ Lower the wire so that it lifts the second clamp (*Figure 3-4: Mounting the tip under the double clamp*, C).

❼ Push the wire under the second clamp.

   The freshly cut tip should be securely held under the clamp and extend about 2–3 mm beyond the tip holder.

The tip is now installed.

3.4: Installing the sample

3.4.1: Preparing the sample

IMPORTANT

Never touch the sample surface once it is prepared.

The STM can be used to examine electrically conductive materials. In practice, however, the choice of material is more limited, because the surface of the sample must be totally clean

and mirror-like to obtain useful results, and it must be in a non-oxidized state to be conductive. Because of this, some samples need special preparation.

3.4.2: Nanosurf samples

Nanosurf delivers various optional samples, which are usually packed in the STM Tool Set. These samples are briefly described here. Further samples are available in the STM Extended Sample Kit, which contains its own sample description.

All samples should be stored in their respective box. This way, it should not be necessary to clean them. Cleaning of the samples is generally not advisable (unless indicated below), because their surfaces are often rather delicate.

Gold thin film

Cleaning the sample is neither possible nor necessary. Never touch the sample with your fingers or put it upside down anywhere, this will only make it unusable faster.

Graphite (HOPG) on sample support

This sample can be used for STM as well as AFM measurements. In STM measurements, atomic resolution can be obtained on this sample.

Sample specifications:

Size: 5 mm × 5 mm

Material: Highly Oriented Pyrolytic Graphite (HOPG)

Sample support: Magnetic Steel disc, galvanized with Nickel.

The surface of the graphite sample can be cleaned when it is very dirty or uneven. Due to the layered structure of graphite this can easily be done using a piece of adhesive tape (*Figure 3-5: Cleaving graphite*):

❶ Put the sample on the table using a pair of tweezers.

❷ Stick a piece of adhesive tape gently to the graphite and then pull it off again.
The topmost layer of the sample should stick to the tape.

❸ Remove any loose flakes with the tweezers.

The graphite sample is now ready for use and should not be touched anymore.

Other samples

You can mount other samples on the spare disc shaped sample supports (*Figure 1-2: Contents of the Tool set* (page 16), item 7). The supports are made of a magnetic steel that is
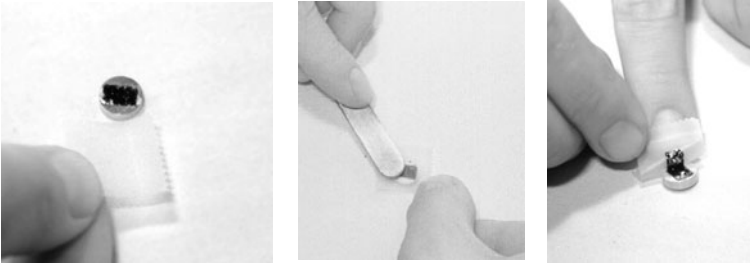
Figure 3-5: Cleaving graphite

galvanically coated with nickel. Use conducting glue to attach the sample to the sample support. Contact your Nanosurf distributor if you have difficulties obtaining such a glue.

3.4.3: Mounting a sample

To mount a sample onto the Sample Holder:

❶ Unpack the Sample Holder (*Figure 1-2: Contents of the Tool set* (page 16), item 5) touching only its black plastic handle.

> **IMPORTANT**
>
> Always store the Sample Holder in its package, in order to prevent corrosion (see *Chapter 16: Maintenance* (page 239)).

❷ Put the prepared sample onto the magnetic end of the Sample Holder using a pair of tweezers (*Figure 3-6: Putting the sample on the Sample Holder*).
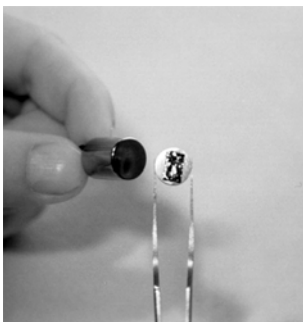
Figure 3-6: Putting the sample on the Sample Holder

❸ Place the Sample Holder carefully in the scan head so that it doesn't touch the tip, and in such a way that the sample is not pulled from the Sample Holder by the magnet that holds the Sample Holder in place (*Figure 3-7: Placing the Sample Holder in the Scan Head*).

Figure 3-7: Placing the Sample Holder in the Scan Head

❹ Put the Sample Holder down on to the Sample Holder guide bars first and release it gently on to the approach motor's support.

First measurements

4.1: Introduction

In this chapter, step-by-step instructions are given to operate the microscope and to perform simple measurements. More detailed explanations of the software and of the system can be found elsewhere in this manual.

4.2: Running the microscope simulation

The SPM Control Software can be started without having the microscope connected to your computer in order to explore the Easyscan 2 system (measurements and software) without danger of damaging the instrument or the STM tip. In simulation mode, most functions of the real microscope are emulated. The sample is replaced by a mathematical description of a surface.

When the SPM Control Software is started without a microscope connected to your computer, the following dialog appears:
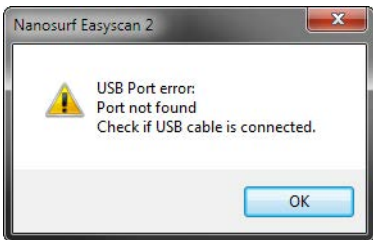
- Click "OK".
  The status bar will now display the text "Simulation".

You can also switch to simulation mode with the microscope connected:

- In the Hardware group of the Settings tab, click the "Simulation" button.
  The "Simulation" button will now be highlighted and the status bar will display the text "Simulation".

To exit the microscope Simulation mode:

- In the Hardware group of the Settings tab, click the "Simulation" button again.
  The highlighting of the "Simulation" button will now disappear, and the status bar will display the text "Online".

4.2.1: Entering and changing parameter values

When using the Nanosurf Easyscan 2 STM and SPM control software, you may from time to time need to change or enter parameter values. These can be found in the parameter sections of the Operating windows and in various dialogs.

To change a parameter or enter a value:

❶ Activate the parameter by clicking inside the (white) parameter edit box with the mouse:

Image size 20µm

❷ In case of a drop-down menu selection list, change the selection using the mouse or the up and down arrows on the keyboard. In case of a numerical value, use one of the following methods:

- Use the up and down arrow keys on the keyboard to increase or decrease its value. The new value is automatically used after one second.
- Click the arrow buttons next to the parameter value with the mouse pointer. Normally, the parameter value is changed by a small amount (usually in the range of 1–10%). Some edit boxes are doubling or dividing the parameter value by two (e.g. the "points/line" parameter). The new value is automatically used after one second.
- Enter the new value using the keyboard. The entered value is applied upon pressing the "Enter" or "Return" key, or by activating another input. The entered value is discarded upon pressing the "Esc" key. The unit prefix can be changed by typing one of the following keyboard keys:

  f = femto   space bar = no prefix
  p = pico   k   = kilo
  n = nano   M (shift-m) = mega
  u = micro   G (shift-g) = giga
  m = milli   T (shift-t) = tera

  Examples: if the basic unit is Volts, type "m" to change to millivolts, type the space bar for volts, type "u" for microvolts.

Sometimes the program will change an entered value to a slightly different value. This happens when the desired value is outside the digitization range of the Easyscan 2 controller, for example due to resolution or timing limits. In such cases, the desired value is automatically changed to the nearest possible value.

When you are finished with the microscope simulation you are now ready to use the Easyscan 2 STM scan head for measurements.

4.3: Preparing the instrument

Prepare the instrument as follows (see *Chapter 3: Preparing for measurement* (page 25) for more detailed instructions):

❶ Prepare and install a Pt/Ir tip.

❷ Install the HOPG sample.

To make sure that the configuration is correct, do the following:

➥ Open the menu item "File" >> "Parameters" >> "Load..." and load the file "Default_EZ2-STM.par" from the directory that holds the default Easyscan 2 configurations.
Usually this is "C:\Program Files\Nanosurf\Nansurf Easyscan 2\Config".

4.4: Approaching the sample to the tip

To start measuring, the sample must be very close to the tip to enable a tunneling current to flow. Approaching the sample without touching the tip is a delicate operation carried out in three steps: *Manual coarse approach*, *Manual approach using the approach motor*, and the *Automatic final approach*. The color of the Status light on the controller shows the current status of the approach:

– Orange/yellow
Normal state during approach: the Z-scanner is fully extended toward the sample.

– Red
The approach has gone too far: the tip was driven into the sample, and the Z-scanner is fully retracted from the sample. In this case, the tip is probably damaged and you will have to prepare and install a new tip again.

– Green
The approach has finished successfully: the Z-scanner is within the measuring range.

To prepare for the approach process:

➥ Select the Acquisition tab
The controls for positioning the sample with respect to the tip are located in the Approach group.

4.4.1: Manual coarse approach

In this step, the sample surface is brought close enough to the tip by hand to allow further motorized approach afterwards.

To perform a manual coarse approach:

❶ Push the sample holder carefully to within 1 mm distance of the tip.

Figure 4-1: Manual Coarse approach

❷ If the tip is pointing toward a rough area of the sample, try turning the sample holder around its axis so that the tip points towards a flat, mirror-like area of the sample.

❸ Put the magnifying cover (*Figure 1-1: Components* (page 15), item 3) over the scan head without touching the sample holder.

❹ Place the magnifier in such a way that you can see the mirror image of the tip in the sample.

The cover reduces air flow around the scan head and reduces thermal drift in measurements at atomic scale.

4.4.2: Manual approach using the approach motor

In this step, the sample surface is brought as close to the tip as possible, without touching it. The closer the two are together, the less time the automatic final approach takes.

❶ Watch the distance between tip and sample with help of the magnifier.

❷ Click the "Advance" button in the Approach group of the Acquisition tab to move the sample to within a fraction of a millimeter of tip:
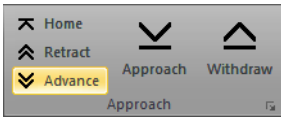
You should only just be able to see the gap between the tip and its mirror image (*Figure 4-2: Tip–sample position*). The smallest visible gap depends on the observation angle of the magnifier and the illumination of the sample.

Figure 4-2: Tip–sample position. Position at the end of the Manual approach with the approach motor.

❸ If you cannot see the motor moving, clean the sample holder guide bars and the surfaces of the approach motor following the procedure described in *Chapter 16: Maintenance* (page 239).

4.4.3: Automatic final approach

In this last step, the sample automatically approaches the tip until a given Setpoint is reached. First check that the Setpoint and the feedback speed are set properly. The easiest way to do this is to use the Imaging Wizard:

❶ In the Preparation group of the Acquisition tab, click the "Wizard" button:
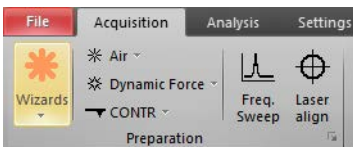
❷ Select "Imaging..." from the drop-down selection menu.

A dialog will pop up, which will ask you some basic questions about your sample and your measurement needs.

❸ Answer the questions of the wizard to the best of your knowledge.

For descriptions of the features of standard Nanosurf samples refer to *Section 3.4.2: Nanosurf samples* (page 30).

Now that the initial software settings have been given suitable values, you need to name the measurement series (see *Section 13.4.1: History File mask* (page 190)). Each completed measurement (scan/image) will be temporarily saved (automatically) in the History folder under this name, with index numbers (or, optionally, date and time attributes) added to identify the individual measurements. It is best to enter the measurement series' name now, since the control software will (by default) start measuring as soon as the final approach is done. It is also strongly recommended to move all relevant measurements to a new folder when you are finished, since the files in the History folder will be overwritten over time (see *Max History Files* (page 218)).

To set the measurement series name:

❶ Activate the Gallery panel (see *Section 13.4: Gallery panel* (page 189)) in the Info pane.

❷ Click the History tab at the top of the Gallery panel with the mouse.

❸ In the entry box at the top of the panel, enter a name by hand or use the Mask Editor dialog (see *Section 13.4.4: Mask Editor dialog* (page 191)) to create the name mask.

If no [INDEX] attribute is explicitly added to the name mask, it will be implicitly applied to the end of the file name so that individual measurements can be stored and distinguished.

The automated final approach can now be started. To do this:

❶ In the Approach group of the Acquisition tab, click the "Approach" button:
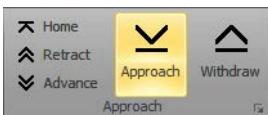
The sample holder is now moved towards the tip by the approach motor. After each step, the Z-scanner is fully retracted from the sample, and released to move towards the sample. The approach is finished if the current determined by Setpoint is detected before reaching the maximum extension of the Z-scanner, otherwise the approach motor will continue with the next step. Due to the motion of the Z-scanner, the Probe Status light will blink red–green–orange/yellow in cycles (see *The Probe Status light* (page 17)). When the approach has finished successfully, the probe status light

changes from a blinking state to a constant green, and the message box "Approach done" appears:
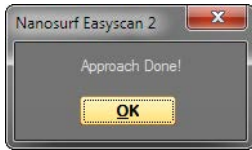
❷ Click the "OK" button.

If the status light changes to red instead of green, or if the approach has not finished after 10–20 seconds, try to decrease the tip–sample distance a little more using manual operation of the approach motor.

If the automatic final approach never works, refer to *Chapter 17: STM measurement problems* (page 247) for the next steps to take.

4.5: Starting a measurement

Now that the tunneling current defined by Setpoint is flowing between tip and sample measurements can start. By default, the instrument is set to automatically start measuring after the automatic approach. If this is not the case:

➡ Start measurements manually by clicking the "Start" button in the Imaging group of the Acquisition tab:
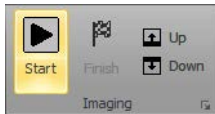
If the preparation of tip and sample and the approach were successful, images of the measurement will show a more or less straight line in the Line graph (*Figure 4-3: Starting image*, left) and a plane in the Color map. Watch the displays for a while until the Color map image has been drawn about three times.

A "nervous" line in the Line graph indicates a bad tunneling contact (*Figure 4-3: Starting image*, right). Usually this is caused by the tip being too blunt or instable. This means that you should stop measuring and cut a new tip:

❶ Click the "Stop" button in the Imaging group of the Acquisition tab:
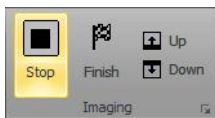
❷   Follow the instructions of the *Chapter 17: Problems and solutions* (page 243).

If the line in the Line graph is calm and reproduces consistently, you can continue with the next section.
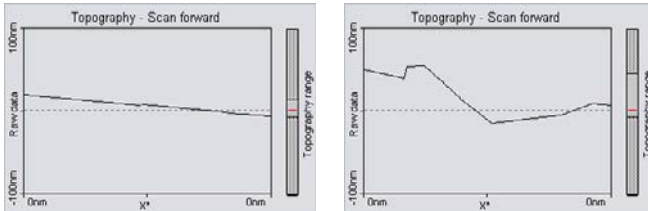
Figure 4-3: Starting image. (Left) A good Line graph. (Right) A "nervous" Line graph.

4.6: Achieving atomic resolution

4.6.1: General instructions

Once the Topography in the Line graph is reproducing stably, the scan range has to be decreased in order to observe atomic structures.

IMPORTANT

Measurements on the micrometer/nanometer scale are very sensitive to environment influences. Direct light or fast movements — causing air flow and temperature variations near the Scan Head — can influence and disturb the measurement. It is best to let a promising measurement run for some time in order to stabilize thermally.

To decrease the Imaging area:

❶   Click the Color map chart to make it active.
A blue square is now drawn around the Color map chart.

❷   Click the "Zoom" button in the Chart bar:
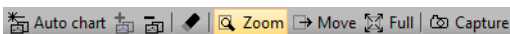
The mouse pointer becomes a pen when moving over the selected chart.

❸   Move the mouse cursor to a "flat" region (similar color) in the Color map and click on it.
The software will now draw a square that indicates the new scan range. The size of the new scan range is displayed in the Tool Results Panel (see *Figure 4-4: Zooming*). If no flat region is available, refer to *Chapter 5: Improving measurement quality* (page 47) for further instructions.

❹ Change the size of the new scan range to about 30–50 nm by clicking and dragging a corner of the square with the mouse cursor.
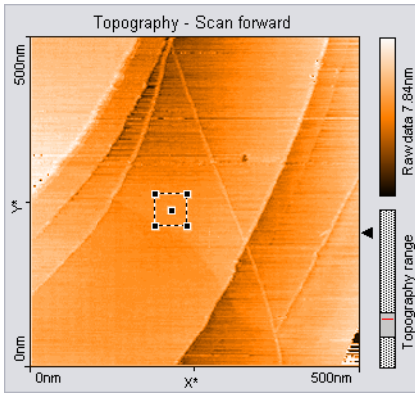
Figure 4-4: Zooming. (left) Square drawn in the Color map.

❺ Double click the chart when the scan new area is set as you want it. You can abort the zoom function by clicking with the right mouse button.

The imaging settings are now set in such a manner that the new measurement will correspond to the area that was indicated by the square.

❻ Let the Topography reproduce stably again.

To achieve atomic resolution, the image size should be decreased even further, considering that one nanometer is the diameter of between four and eight atoms. Atomic arrangements can normally be recognized at an image size of about 4 nm. Therefore:

➡ Set the Image size in the Imaging panel to 4 nm.

Some parts of the scan head react to the slightest temperature changes. As these thermal "movements" influence the measurements on the nanometer scale, the sample has to be scanned as fast as possible:

➡ Set the Time/Line in the Imaging Panel to 0.06s for atomic resolution.

You may also try to decrease noise by decreasing the Loop gain of the Z-Controller. Try varying all of the above parameters to get a good image (such as the one in *Figure 4-5: A successful graphite measurement*).

When you're satisfied with the image quality obtained, you may want to save the measurement. Refer to *Section 4.7: Storing the measurement* (page 45) for details on how to do this.
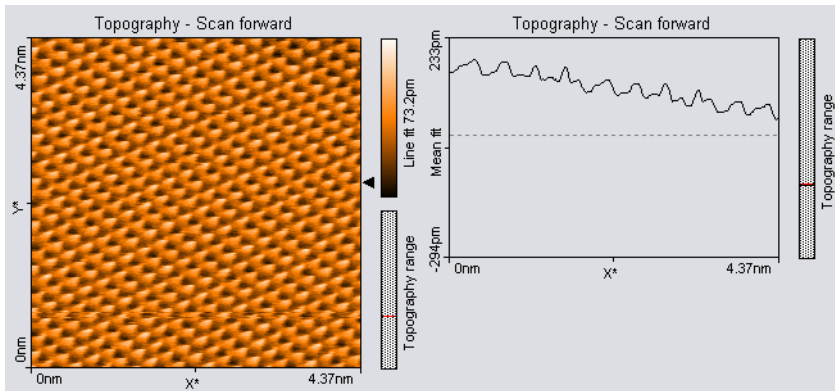
Figure 4-5: A successful graphite measurement

4.6.2: The graphite surface

In a good color map chart of graphite you will see a pattern consisting of bright, intermediate, and dark spots. It looks like a three dimensional image of balls lying next to each other, but be careful: these are not the single atoms!

To interpret the image correctly you must first be aware that bright spots show high points and dark spots low ones.

In the lattice model of graphite (*Figure 4-6: The graphite surface* (page 43)) one can see that there are two different positions of the carbon atoms in the graphite crystal lattice: one with a neighboring atom in the plane below (gray) and one without a neighbor in the lattice below (white). As a consequence, the electrical conductivity of the graphite surface slightly varies locally, so that the atoms without neighbors appear higher than the others.
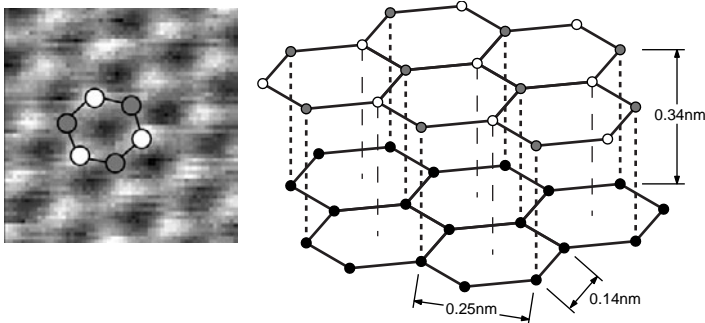
Figure 4-6: The graphite surface. (left) Measurement. (right) Lattice model.

This also causes the lattice constant between the bright "hills" to have the higher than normal value of 0.25 nm.

4.6.3: Measuring Gold

It is more difficult to obtain good images of gold. Atomic structures are difficult to observe, because the electrons on the surface are much more homogeneously distributed than in graphite. But, with some training, the mono-atomic gold steps can be observed.
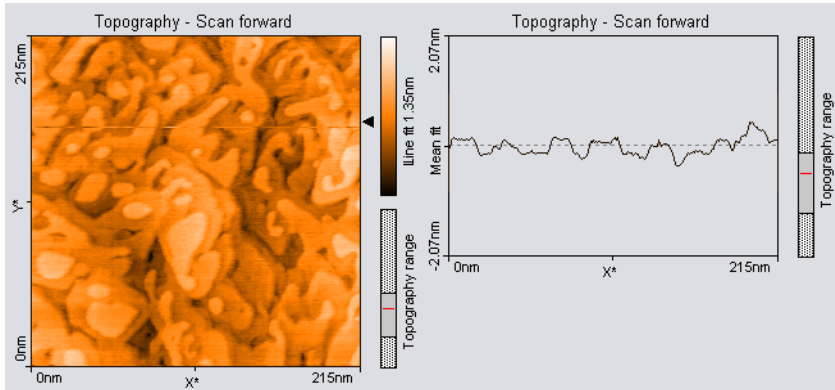
Since the gold sample cannot be cleaned by simple means, it is possible that over time contaminants may prevent you from obtaining good results. If you have problems measuring the gold sample because of this issue, please order a replacement from your local Nanosurf distributor.

Tip

Before performing any experiments with the gold sample it is necessary to practise on the graphite sample. The graphite sample is also a good test sample to judge the quality of the installed STM tip.

To perform measurements on gold:

➥ Proceed as describe for the graphite sample, but with the following changes to the settings:
- Set the Tip voltage in the Z-Controller section of the Imaging window to 0.5 V.
- Set the Time/Line in the Imaging Panel to 0.3 s.

If you do not get stably reproduced scan lines, try to re-approach:

➜ Press the "Withdraw" button followed by the "Approach" button:
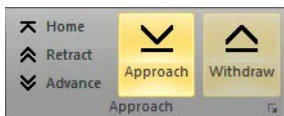
If that does not improve the measurement:

Ⓐ Retract the sample holder.

Ⓑ Rotate it a little by hand.

Ⓒ Repeat the approach.

If you still don't get stable scan lines:

➜ Cut a new tip and start over.

If the image reproduces stably:

➜ Select an Image size between 200 and 300 nm, and evaluate your measurements in the same way as you did with the graphite images.

4.7: Storing the measurement

By default, each completed measurement is temporarily stored (automatically) on your computer so that it can be used later. Additionally, you can also take snapshots of measurements still in progress. To do this:

➜ Click the "Capture" button in the Chart bar:
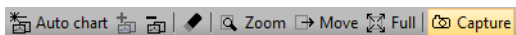
The current measurement is immediately stored and will show up in the History page of the Gallery panel, together with all other finished/stored measurements (see *Section 13.4: Gallery panel* (page 189) for details). In addition, the captured document will remain open in the Document space of the SPM Control Software.

Measurement documents in the temporary History folder should always be moved to a new location for permanent storage when you are done measuring. For details on how to do this, see *Save as* (page 190). Measurement documents thus permanently stored can always be loaded with the SPM Control Software or the optional Nanosurf Report or Nanosurf Analysis software packages for later viewing, analysis, and printing. A brief introduction on how to create a basic report using the Report software is given in the next section. For more detailed information on starting and using the Report software, see *Section 22.2: Creating a report* (page 452), or refer to the Nanosurf Report online help.

4.8: Creating a basic report

The optional Nanosurf Report software can be used to evaluating the measurement, and to create visually appealing reports. Here, we will just briefly explain how to start the software and create a basic report.

To create a basic report of a completed measurement:

❶ Open a measurement from the Gallery panel.

❷ In the Report group of the Analysis tab, click the "Report" button.
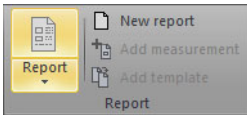
The Nanosurf Report software will now launch, import the currently open measurement, and evaluate the data using the default template.

IMPORTANT

After a fresh installation of the Report software, the Report software has to be run at least once before it can be automatically started from within the SPM Control Software. To run the Report software for the first time, select it from the Microsoft Windows "Start" menu.

4.9: Further options

From this point on, there are several things that can be done. Please refer to the respective chapters for detailed instructions:

• Performing a new measurement on another sample by repeating the instructions given in *Chapter 3: Preparing for measurement* and *Chapter 4: First measurements* with the new sample.

• Improving measurement quality, as described in *Chapter 5: Improving measurement quality* (page 47).

• Performing a different type of measurement by choosing a different operating mode, as described in *Chapter 6: Operating modes* (page 66).

• Finishing measurements, turning off the instrument, and/or storing the instrument, as described in *Chapter 6: Finishing measurements* (page 57).

CHAPTER 5:

Improving measurement quality

5.1: Removing interfering signals

Interfering signals can be recognized because they have a fixed frequency, usually a multiple of the local mains frequency (50 or 60 Hz) throughout the image. Thus, they are manifested by straight lines that run throughout the entire image.

Possible interference sources are:

- *Mechanical vibrations* from machines or heavy transformers in direct vicinity (e.g. pumps).
- *Electrical interference* (in the electronics, or in electrical forces of the tip–sample interaction).

5.1.1: Mechanical vibrations

Measure the frequency of the vibrations to find out if the interference is due to mechanical vibrations. Such vibrations have a frequency that is (a multiple of) the rotation frequency of the source. This frequency is usually not a multiple of the local mains frequency, and may change slightly over time. Try the following to find out if the interfering signal is due to mechanical vibrations:

❶ If possible, turn off all rotating machines (i.e. pumps) in the room.

❷ Change the vibration isolation by putting the Scan Head directly on the table, instead of on the Sample stage.

To reduce the influence of these vibrations, either improve the isolation of these machines, or improve the isolation of the instrument by using an active vibration isolation table (e.g. the optional Nanosurf Isostage or halcyonics_i4.

5.1.2: Electrical interference

Electrical interference may be caused by interference in the electronics, or by electrostatic forces acting between the tip and the sample. Try the following in order to reduce the influence of electrical interference:

❶ Connect the instrument to the mains power supply using sockets with line filters and surge protection.

❷ Remove interfering electromagnetic field sources, such cathode ray tube displays, loudspeakers, etc.

5.2: Decreasing thermal drift

Temperature variations cause so-called "thermal drift". This will cause images to be distorted. This effect is present when the observed upward scan is very different from the downward scan, for example showing two differently distorted lattices.
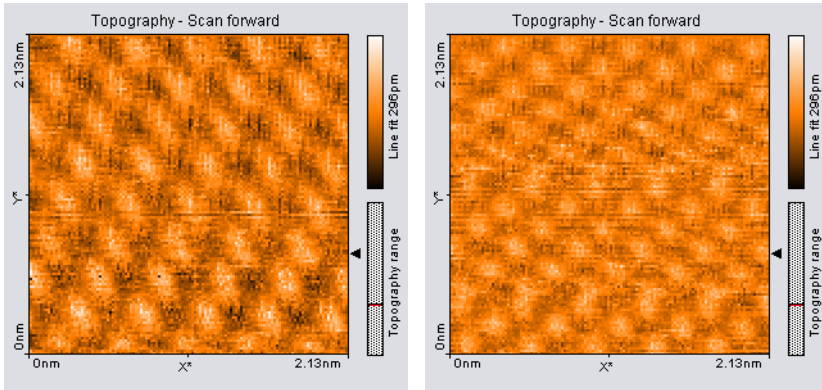
Figure 5-1: Consecutive upward and downward scan showing thermal drift.

Thermal drift is very clearly visible on an atomic scale. Variations of 0.1°C already cause variations of several nanometers in length of (for example) the steel sample holder.

To decrease thermal drift, keep the measurement running for some time to let the system stabilize (up to about one hour), and prevent air currents in the room from reaching the scan head.

5.3: Adjusting the measurement plane

Ideally, the sample surface and the XY-plane of the scanner run parallel to each other. In most cases, however, the sample plane is tilted with respect to the XY-plane of the scanner. In this case, the sample cross section in the X* measurement direction has a certain slope. The Line graph chart in *Figure 5-2: Maladjusted slope* is an example.

This slope depends on the direction of the X* direction and therefore on the rotation of the measurement, as shown in *Figure 5-3: Sample and measurement orientation before slope adjustment*.

This slope is undesirable for several reasons:
• It makes it difficult to see small details on the sample surface, because the Average, Plane fit, or higher order filters cannot be used properly.

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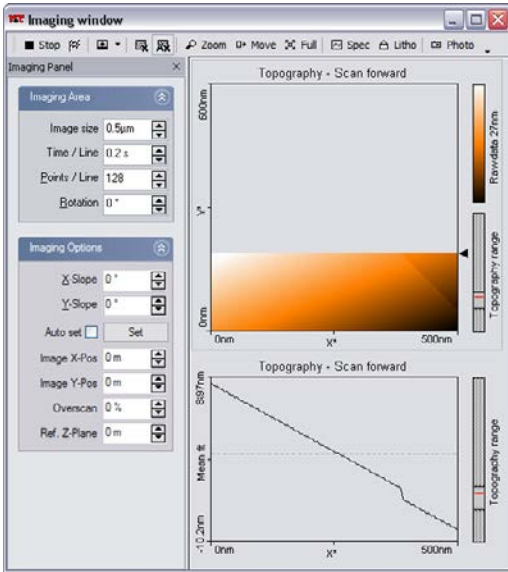
Figure 5-2: Maladjusted slope. Measurement with improperly set X*-slope.
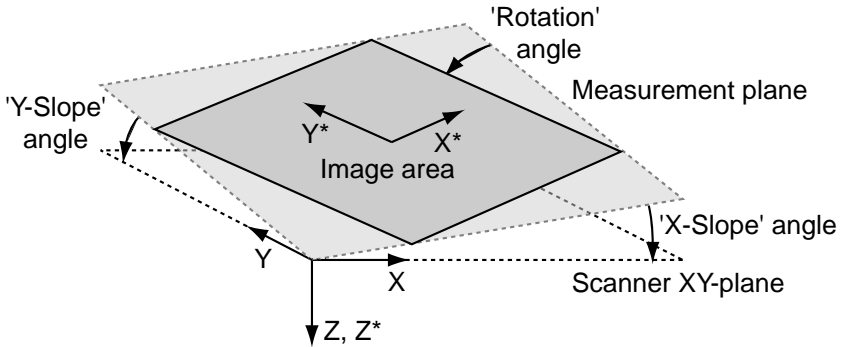
Figure 5-3: Sample and measurement orientation before slope adjustment

- The Z-Controller functions less accurately, because it continuously has to compensate for the sample slope.

After approach, the measurement plane should therefore be adjusted electronically. This can be done automatically or manually. Both procedures are described below.
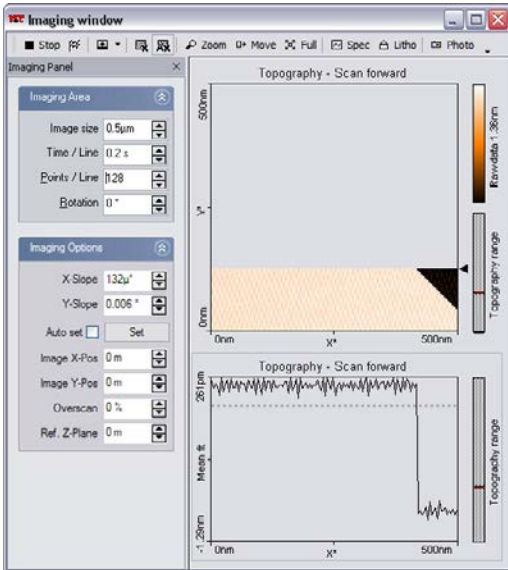
Figure 5-4: Adjusted slope. Measurement with properly set X*-slope.

To automatically adjust the measurement plane once:

❶ In the Parameters section of the Imaging panel, click the "More" button:
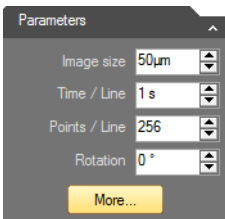
The SPM Parameters dialog will now open (see *Section 7.9: SPM Parameters dialog* (page 74) for details). This dialog contains all possible parameters and settings that influence the behavior of your Nanosurf Easyscan 2 STM system.

❷ Make sure that "Imaging" is selected in the SPM Parameters dialog:
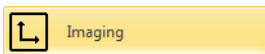
❸ Click the "Adjust slope" button:

Adjust slope

The SPM Control Software will automatically perform a slope determination procedure similar to the manual procedure described below and will enter the slope angles into the X- and Y-Slope parameters.

IMPORTANT

If the sample surface contains large jumps or steps in height, the line fitting procedure used to determine the slope in X- and Y-direction may not deliver the best possible results. In such cases it is recommended to perform a manual slope adjustment as described below.

To automatically adjust the measurement plane before each measurement:

➡ Check the "Auto set" checkbox next to the "Adjust slope" button.

To manually adjust the measurement plane:

❶ Measure the slope for X in the Line graph using the angle tool (see *Measure Angle* (page 197)).

Use a single click instead of dragging the first line to create a horizontal line and measure the angle relative to the X*-Axis.

❷ Enter the result of the angle determination as X-Slope (see *Imaging options* (page 130)) and fine-tune its value until the X-axis of the scan line lies parallel to the X-axis of the sample.

❸ Set Rotation to 90° to scan along the Y-direction of the scanner.

❹ If the scan line in Y-direction is not horizontal, perform the same procedure as described for correction of the slope in X but now for Y.

❺ Reset "Rotation" to 0°.

The scanner scans in X-direction again.

5.4: Judging tip and tunneling contact quality

When all prerequisites for measurement are optimal, the measurement quality mainly depends on the quality of the tip and of the tunneling contact. A sharp tip and a good tunneling contact are necessary for high quality images of atomic resolution.

If during a good measurement the image quality diminished dramatically, the tip has most probably picked up some particles or you are near a step in the surface.
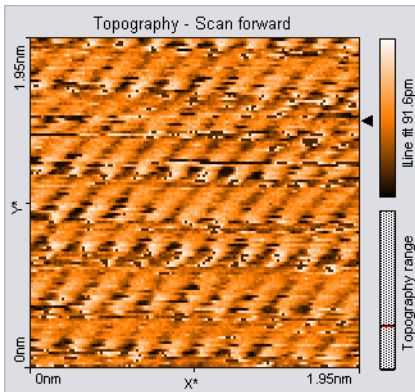
In this case:

➲ Continue measuring for a while (4–5 images).

 The tip may eventually lose the picked up material again.

If this does not help, try to induce changes at the tip's end using one of the following procedures:

- While measuring, open the SPM Parameters dialog by clicking the "More" button in the Mode Properties section of the Imaging window. Then click the "STM Tip cleaning pulse" button.
- Retract the sample and then perform a new approach.

If no improvement can be seen after going through these procedures, it is necessary to prepare a new tip:

❶ Follow the instructions in *Section 6.1: Finishing scanning* (page 58).

❷ Follow the instructions in section *Section 3.3: Preparing and installing the STM tip* (page 26).

Examples of images made with unusable tips

Prepare a new tip when your image looks like one of the examples below.
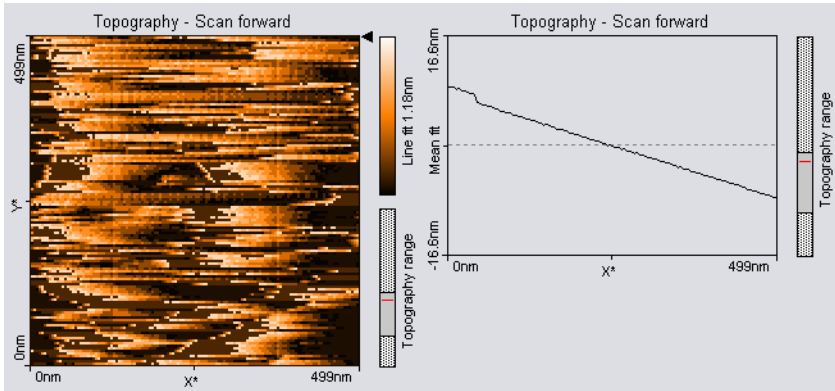
Figure 5-5: The color map image consists of uncorrelated lines.
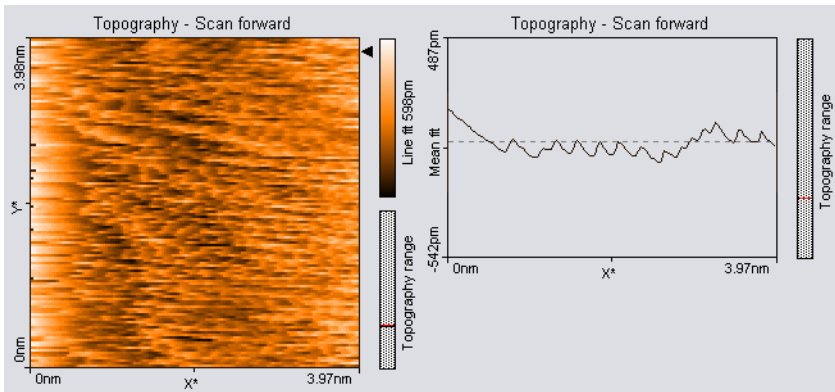
Figure 5-6: The image is "smeared out" on one border (here on the left border).
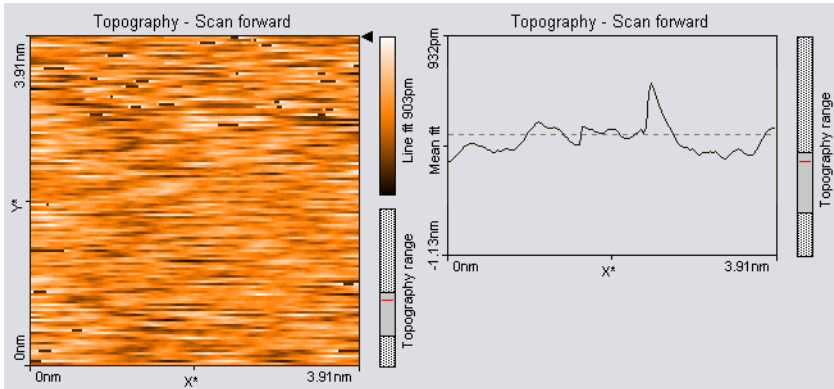
Figure 5-7: Each image looks different.
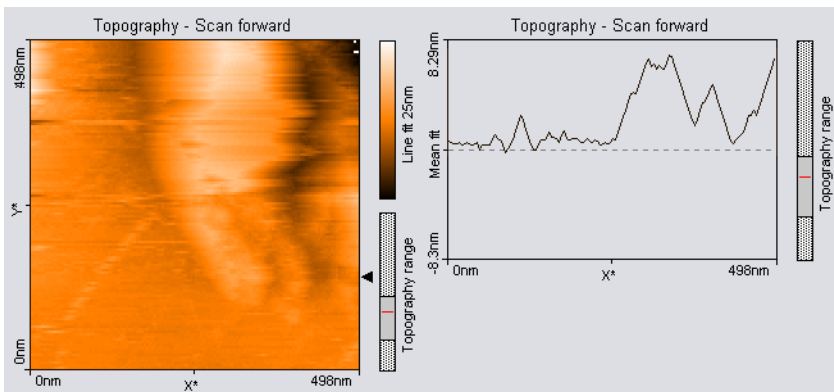
Figure 5-8: The scan lines in Line graph are unstable and the image in the Color map is blurred.

CHAPTER 5: IMPROVING MEASUREMENT QUALITY

CHAPTER 6:

Finishing measurements

6.1: Finishing scanning

Once you are done measuring:

❶ In the Imaging group of the Acquisition tab, click the "Stop" button to stop measuring.

❷ Retract the sample holder by first clicking on the "Withdraw" button in the Approach group of the Acquisition tab, followed by clicking and holding the "Retract" button until the sample holder is away far enough from the tip to safely remove it.

❸ Remove the magnifying cover from the scan head.

❹ Remove the sample holder with one hand.

❺ Remove the sample from the sample holder and store it in its case with the other hand.

❻ Store the sample holder in its container.

6.2: Turning off the instrument

To turn off the instrument:

❶ Finish as described in *Section 6.1: Finishing scanning*

❷ Select the measurements that you want to keep in the History page of the Gallery panel and save them in a new folder (see *Save as* (page 190)).

❸ Exit the SPM Control Software.

❹ Turn off the power switch on the controller (see *Figure 1-4: The Easyscan 2 controller* (page 18) for its location).

If you perform measurements regularly:

➡ Leave the instrument with the Magnifying cover over the scan head to protect it against dust.

If you do not operate the instrument for several weeks:

➡ Store the instrument as is described in *Section 6.3: Storing the instrument*.

6.3: Storing the instrument

If you are not using the instrument for an extended period of time, if you have to transport it, or if you send it in for repairs, put the instrument in the original packaging material or instrument case.

❶ Turn off the instrument as described in *Section 6.2: Turning off the instrument*, and remove all cables.

❷ Leave the cantilever in the scan head, or replace it with an old one.

❸ Remove the Sample and Sample Holder. The tip can be left in the scanner.

❹ Store the Sample Holder in its container.

❺ Pack all components in the original Nanosurf packaging material or instrument case, as shown in *Figure 6-1: Packing*.

IMPORTANT

Before transport, always put the instrument in the original Nanosurf packaging material or instrument case.

Figure 6-1: Packing. The Easyscan 2 STM system packed in the Instrument Case.

PART B:

SOFTWARE REFERENCE

CHAPTER 7:

The user interface

7.1: General concept and layout

The SPM Control Software provides all functions to operate the microscope during imaging of surfaces and more advanced operating modes. It also provides data analysis functions for post-processing of measurement data.
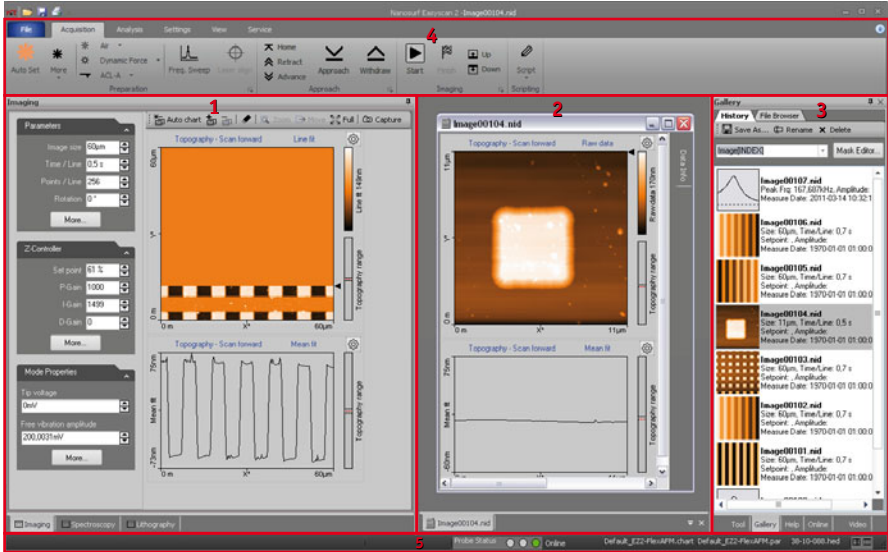
Figure 7-1: The main window in "Normal" workspace mode

The main SPM Control Software window (also referred to as workspace) consists of five major areas:

1. The Measurement pane on the left. This area contains the so-called *Operating windows*, which are used to acquire and display ongoing measurement data.
2. The *Document space* in the middle. This area is used for displaying and analyzing previously stored measurement documents.
3. The Info pane on the right. This area contains several stacked *Panels* and is used to group a diverse array of functionality and information.
4. The *Ribbon* at the top. This area is used to access all action functions.
5. The *Status bar* at the bottom. This area is used to display additional information.

7.2: The workspace

With the Nanosurf SPM Control Software, measurement of newly acquired data and analysis of already stored data (in multiple documents) can be performed in parallel, since these tasks are partly performed in different areas of the workspace. It may however require a high resolution monitor (or multiple monitors) to make this process efficient. To offer the same functionality on systems with a limited resolution, the user can switch between a "Normal" (*Figure 7-1: The main window in "Normal" workspace mode*) and a "Document" mode (*Figure 7-2: The main window in "Document" workspace mode*). See also *Section 7.8.1: Workspace group* (page 73).
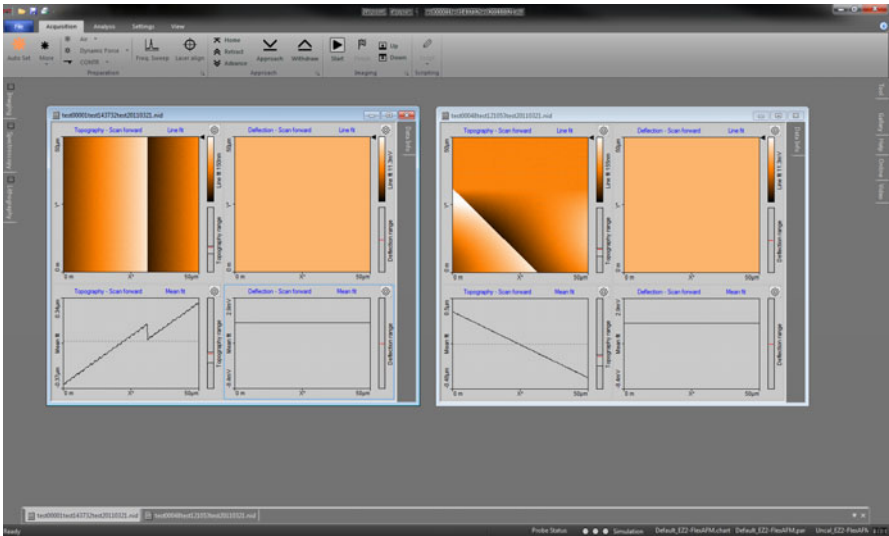
Figure 7-2: The main window in "Document" workspace mode

In "Normal" mode, the emphasis lies on the Measurement and Info panes. The inside border of the two panes can be dragged by the mouse to adjust their individual widths to your needs. Document space on the other hand is rather limited (see *Figure 7-1: The main window in "Normal" workspace mode*). This mode is most suited for measurements.

In "Document" mode, the Document space is maximized while the Measurement and Info panes are minimized to the left and right side of the main window, respectively (see *Figure 7-2: The main window in "Document" workspace mode*). The various window and panel titles are shown in tabs so that you can still open them when needed. A click or a mouse-over on one of these tabs will cause the respective window or panel to slide out automatically, so

that you can work on it. It will automatically minimize again when you are done. This mode is most suited for analyzing stored measurement data.

7.3: Operating windows

Operating windows are used to perform specific operations with the microscope. The Operating windows are grouped together in the Measurement pane and can be accessed by clicking the respective tab. The operations themselves are usually controlled using the action buttons of the Ribbon.
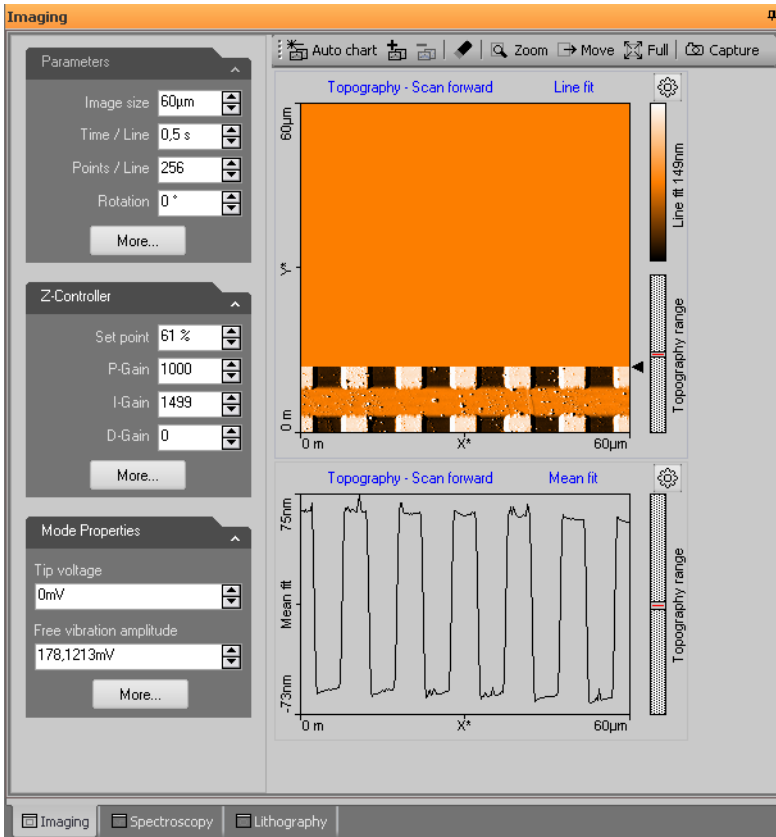
Figure 7-3: Elements of Operating windows. Shown here is the Imaging window, with the Parameter area (Imaging panel) on the left, the Chart area on the right, and the Chart bar on top. Clicking the tabs at the bottom of the Measurement pane switches between the Operating windows.

The Operating windows are:

- The Imaging window; used for generating images of a sample (for details see *Chapter 10: Imaging* (page 119)).
- Spectroscopy window; used for measuring various "A as a function of B" curves at certain sample locations, such as force–Distance curves or current-voltage curves (for details see *Chapter 11: Introduction* (page 134)).
- Lithography window; used for performing Lithography on the current scan area (for details see *Chapter 12: Lithography* (page 157)).

All Operating windows contain three distinct elements, which are described in *Figure 7-3: Elements of Operating windows* and in the next chapters:

1. The "*Parameter area*", where the main parameters influencing the current measurement are grouped into different sections.
2. The "*Chart area*", where one or more charts, showing different aspects/signals of the current measurement, are being displayed.
3. The "*Chart toolbar*", where several functions that directly influence the current measurement (or the way its displayed) are located.

7.3.1: Entering and changing parameter values

Parameter values can be found in the parameter sections of the Operating windows and in special dialogs (such as the *SPM Parameters dialog* (page 74)). Depending on your measurement (or optimization thereof), you may from time to time need to make changes there. To change a parameter or enter a value:

❶ Activate the parameter by clicking inside the (white) parameter edit box with the mouse:

❷ In case of a drop-down menu selection list, change the selection using the mouse or the up and down arrows on the keyboard. In case of a numerical value, use one of the following methods:

- Use the up and down arrow keys on the keyboard to increase or decrease its value. The new value is automatically used after one second.
- Click the arrow buttons ⬍ next to the parameter value with the mouse pointer. Normally, the parameter value is changed by a small amount (usually in the range of 1–10%). Some edit boxes are doubling or dividing the parameter value by two (e.g. the "points/line" parameter). The new value is automatically used after one second.
- Enter the new value using the keyboard. The entered value is applied upon pressing the "Enter" or "Return" key, or by activating another input. The entered value is discarded upon pressing the "Esc" key. The unit prefix can be changed by typing one

of the following keyboard keys:

f	= femto	space bar	= no prefix
p	= pico	k	= kilo
n	= nano	M (shift-m)	= mega
u	= micro	G (shift-g)	= giga
m	= milli	T (shift-t)	= tera

Examples: if the basic unit is Volts, type "m" to change to millivolts, type the space bar for volts, type "u" for microvolts.

Sometimes the program will change an entered value to a slightly different value. This happens when the desired value is outside the digitization range of the Easyscan 2 controller, for example due to resolution or timing limits. In such cases, the desired value is automatically changed to the nearest possible value.

7.4: Document space

In the document space, stored measurements can be displayed for evaluation and analysis. Each measurement is contained within its own document window. These windows can be arranged in document space to your liking.
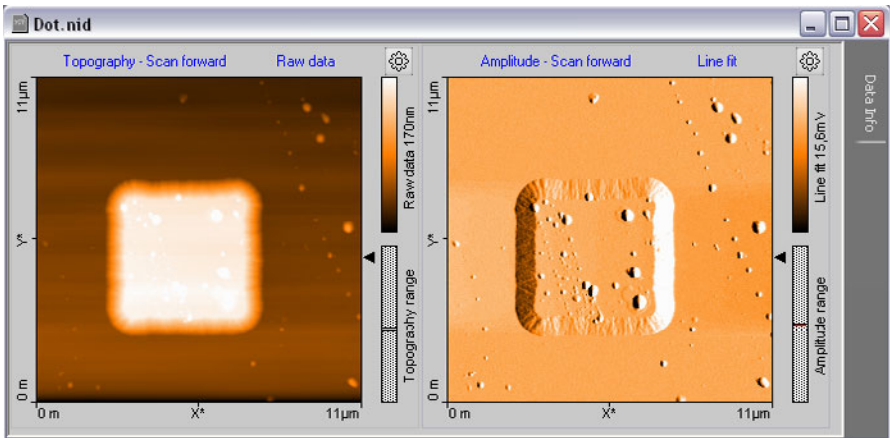
Figure 7-4: Example of a measurement document window

By default, all measurements are temporarily stored (automatically) during imaging and spectroscopy. They can be opened at all times from the Gallery panel (see *Section 13.4: Gallery panel* (page 189)), but should be moved to a new folder for permanent storage as soon as you have finished measuring (see *Save as* (page 190)).

Everything related to documents is described in more detail in *Chapter 13: Working with documents* (page 177).

7.5: Panels

In the panels of the Info pane, the control software provides additional information that can be useful to the user. These panels are normally docked to the Info pane and are stacked to save space. The panels have several features, however, that allow you to arrange them in a way that is most efficient for your application (see *Figure 7-5: Arranging panels*).
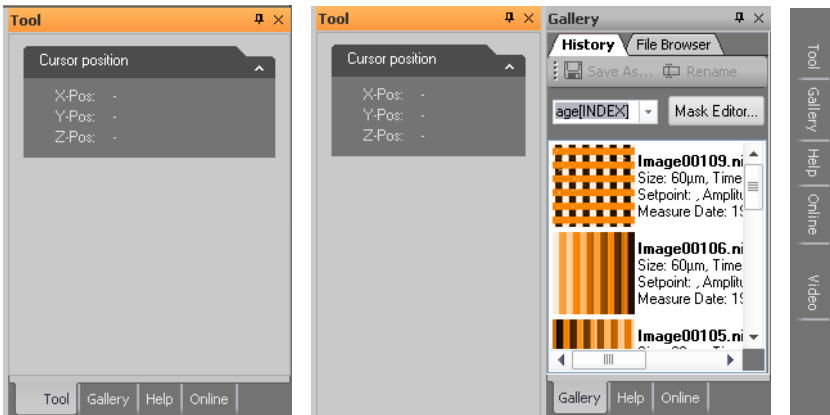
Figure 7-5: Arranging panels. (Left) Stacked panels. (Center) Separated panel that is docked to a stack. (Right) Panels that are minimized in "Document" mode.

To separate a panel and dock it individually to the side of/below another panel that is already docked to this window, drag its title bar to the desired position using the mouse cursor.

To add a control panel to a stack, drag either its title bar or its label to either the title bar or labels of the stack. To remove a panel from a stack, drag its label away from the stack.

When panels are stacked, their title labels are displayed on the bottom of the Info pane. To move a control panel to the top of the stack, click its tab.

With the "pin" button (🔲) in the tile bar of the individual panel or the Info pane, the auto hide feature is controlled. If "unpinned", the panel or the Info pane minimizes to the right border of the main window and only the panel titles are visible (similar to the "Documents" workspace mode, but now only for the panel/Info pane and not for the Measurement area). A mouse hover over (or click on) a title tab will slide this panel into view.

It is possible to scroll the content of a control panel up and down, when it is too small to display all the parameters it contains. To do this, move the mouse cursor over an area where it changes to a four pointed arrow. Then, drag the content up and down with the mouse.

Tool

The Tool panel contains the results of the various analysis tools available to you during and after measurement, displays the current mouse position during selections, and displays the size of those selections (e.g. during zooming). The Tool panel is described in more detail in *Section 13.6: Tool panel* (page 206).

Gallery

The Gallery panel displays a list of stored measurements for quick opening (viewing and analysis). A File Browser is also integrated for general file management tasks. The Gallery panel is described in more detail in *Section 13.4: Gallery panel* (page 189).

Help
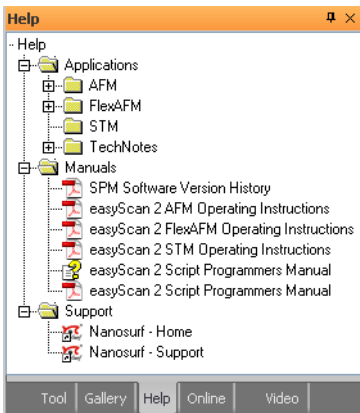
The Help Panel provides quick access to PDF versions of the user manuals belonging to your system, to relevant application notes and technical notes, and to online sources of information (direct links to the Nanosurf website).

Online

The Online Panel provides you with an overview of the current scan range within the maximum range the scanner is capable of (Scan Position section), a "Master image" that can be used as a reference for multiple zoomed scans on different points of interest (Master Image section) and a simple illumination control (Illumination section). The Online panel is described in more detail in *Section 9.3: Online panel* (page 105).

Video

The Video panel with its top and side view of cantilever and sample is particularly useful during sample positioning and approach (see also *Section 4.4: Approaching the sample to the tip* (page 36)). The elements and usage of the Video panel is described in *Section 9.2: Video panel* (page 98).

Stage

The Stage panel can be used to control the automated translation stages (ATS A100 or ATS C301), but is only available when the Translation Stage software is installed. The Stage panel is explained in *Section 9.4: Stage panel* (page 107).

7.6: Ribbon

The Ribbon provides access to all major actions and commands by grouping them according to their usage.
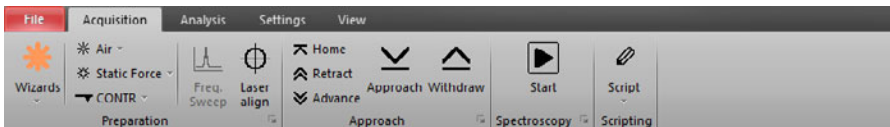
Figure 7-6: The Ribbon.

The File menu

The File menu contains commands to open, save and print measurements. Other files such as those containing parameter settings or chart properties can be loaded or saved here as well. The file menu also provides data export functions. General program settings are configured through the Options dialog, which is opened by clicking the "Options" button of the File menu. The File menu is described in *Section 14.1: File menu* (page 212).

The Acquisition tab

Guides you through the measurement process. There are groups of buttons for measurement preparation, sample approach and the measurement itself. The Preparation and Approach groups are constant and described in *Chapter 9: Positioning* (page 97) and *Chapter 9: Positioning* (page 97), respectively. The content of the other groups varies with the Measurement window that is selected (*Imaging*, *Spectroscopy* and *Lithography*) and is therefore described in the respective chapters.

The Analysis tab

Contains measurement data functions for extracting information from your measurements (e.g. "step height" or "roughness"). It also provides functions to permanently modify your image data (e.g. "backplane removal" or "noise filtering". All of these functions are described in *Section 13.5: Analysis tab* (page 194).

The Settings tab

Contains functions to configure the microscope controller hardware and calibrating the scan head. It is described in *Section 14.2: Settings tab* (page 219)

The View tab

Provides access to the workspace modes "Normal" and "Documents" (see *Section 7.4: Document space* and *Section 7.8.1: Workspace group*), the Panels of the Info pane, and Document window arrangement options. Since it has a great impact on the overall look of the user interface of the SPM Control Software, it is described below (see *Section 7.8: View tab*).

7.7: Status bar

Figure 7-7: The Status bar. Numbers in this figure correspond to those in the list below.

The status bar displays relevant microscope information and the loaded settings (see *Figure 7-7: The Status bar*). It contains the following elements:

1. Help text information about the current menu button or latest error messages
2. Status signal of the Z-feedback controller (red: in upper limit positions; orange: in lower limit position; green: tip in normal feedback contact with sample).
3. Software status: "Online" or "Simulation" (depends on the presence or absence of a scan head, or on user choice).
4. Currently loaded file (".chart") used for chart settings.
5. Currently loaded file (".par") used for parameter settings.
6. Currently loaded scan head calibration file (".hed").
7. Buttons to access the Workspace "Normal" and "Document" view.

7.8: View tab
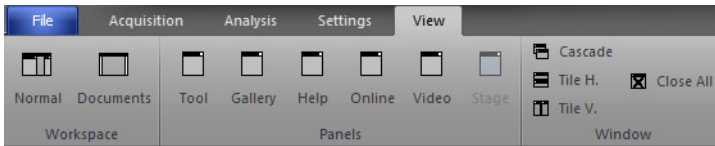
7.8.1: Workspace group
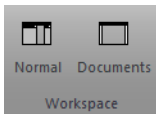
The workspace group in the view tab gives you the ability to switch between the two workspace modes "Normal" and "Documents". To switch, click on either of the buttons, or on the corresponding smaller buttons ( ) on the right-hand side of the status bar (see also *Section 7.7: Status bar*). With these you don't even need to switch to the view tab while measuring.

Normal

The optimal workspace choice during measurements.

Documents

The best choice for viewing or analysis of stored documents (see *Chapter 13: Working with documents* (page 177)).

7.8.2: Panels group
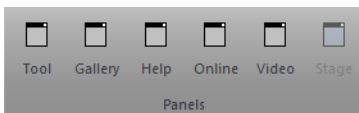
The buttons of the Panels group have the same function as the tabs at the bottom of the Info pane (i.e., to bring the respective panel to the top of Info pane). If the panel was undocked from the Info pane (see *Section 7.5: Panels*) and subsequently closed (i.e., no longer visible as panel or tab), it will re-appear by pressing its button in the Panels group.

IMPORTANT

The "Video" and "Stage" buttons are only available when the appropriate hardware is present.

7.8.3: Window group
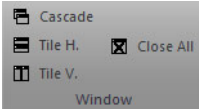
The window group provides you with tools to arrange open measurement documents in different ways or quickly close them all.

Cascade

Open document windows are stacked on top of each other and slightly offset with respect to each other so that individual windows can be easily accessed. Width and position of the windows is optimized by the control software.

Tile H.

Tiles the open document windows horizontally, so that individual measurements can be easily compared. Width of the document windows is maximized. Height is evenly distributed over the available document space.

Tile V.

Tiles the open document windows vertically, so that individual measurements can be easily compared. Height of the document windows is maximized. Width is evenly distributed over the available document space.

Close all

Closes all open document windows. If unsaved data exists, you will be asked to save it.

7.9: SPM Parameters dialog

While not directly visible upon starting the Nanosurf SPM Control software, the SPM Parameters dialog is essential for controlling many advanced parameters during measuring. The dialog is opened by clicking the "More" button that can be found in many of the parameter sections of the measurement panels. It can stay open during all

operations to provide the advanced user with a permanent and detailed control over all measurement parameters.
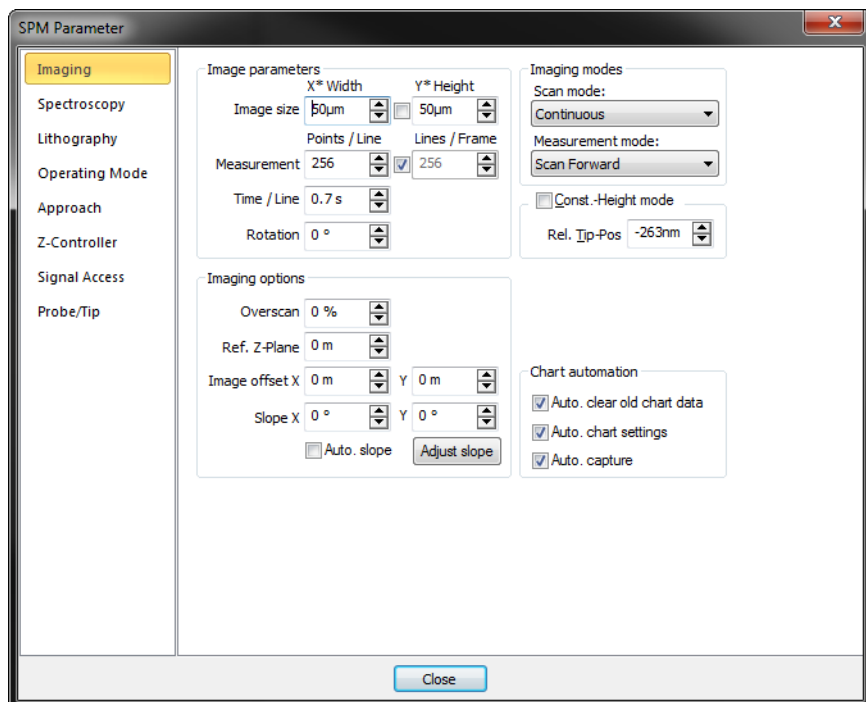
The SPM Parameters dialog is divided into several (sub-)pages:

- Imaging (see *Section 10.5.1: Imaging page* (page 129))
- Spectroscopy (see *Section 11.6.1: Spectroscopy page* (page 150))
- Lithography (see *Section 12.7.1: Lithography page* (page 175))
- Operating mode (see *Section 8.5.1: Operating Mode page* (page 82))
- Approach (see *Section 9.6.1: Approach page* (page 111))
- Z-Controller (see *Section 8.5.2: Z-Controller page* (page 84))
- Signal Access (see *Section 14.8.1: Signal Access page* (page 229))
- Probe/Tip (see *Section 14.8.2: Probe/Tip page* (page 232)

For a detailed description of all available functions and settings, see the respective manual pages.

CHAPTER 8:

Operating modes

8.1: Introduction

Operating modes determine how a sample is measuered. They can be selected in the Preparations group of the Ribbon's Acquisition tab. Appropriate parameters can either be set manually or via one of the Preparation wizards. These possibilities are explained in *Section 8.2.1: Preparation group*.

8.2: Acquisition tab

8.2.1: Preparation group
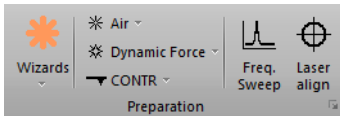
Wizards

The "Wizards" button opens up various Parameter preparation wizards (select the appropriate one from the drop-down menu). Available options are:

– Imaging...

Prepares imaging parameters based on the currently selected operating mode, your sample description, and your imaging requirements (as provided in the Imaging Wizard dialog screens):
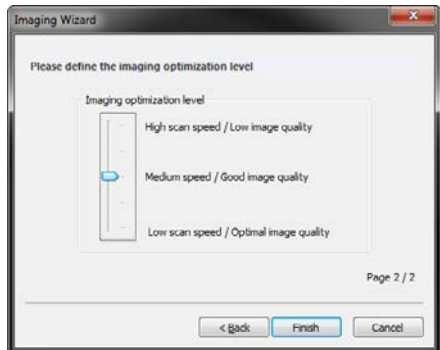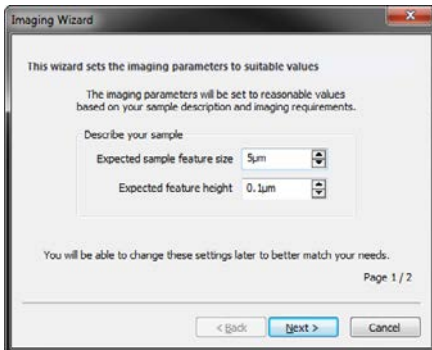
– Spectroscopy...

Quickly set parameters for spectroscopy measurements on a sample (see *Section 11.2: Spectroscopy Wizard* (page 136) for further details):
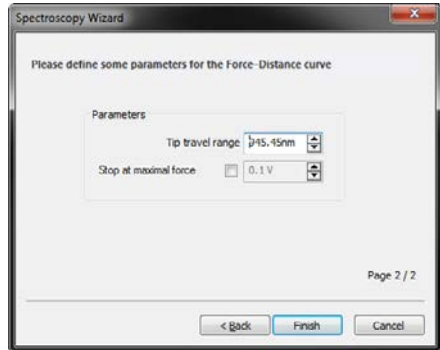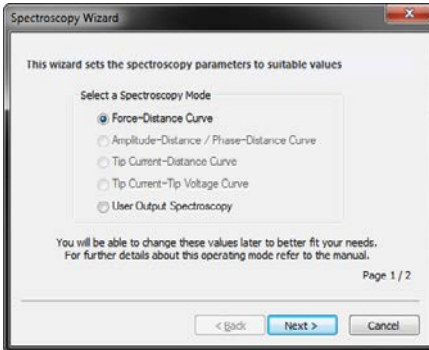
– KPFM ...
Automatically set parameters for the KPFM operating mode:
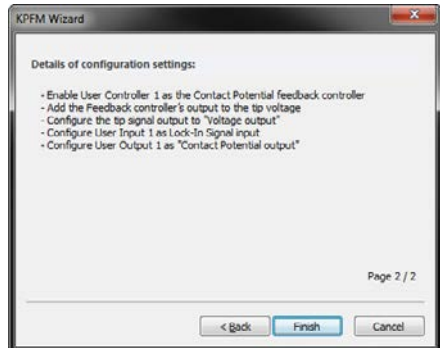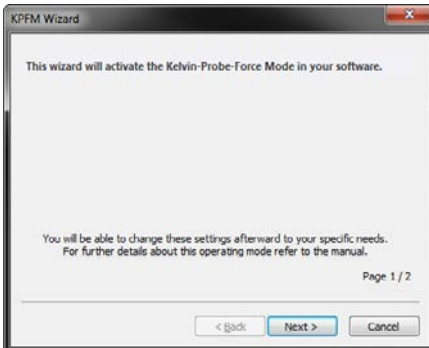
Environment
This drop-down box allows the selection of either "Air" or "Liquid" as measurement environment. Depending on the used scan head, certain options may or may not be available.

Operating Mode
This drop-down box allows the selection of the Operating mode used for measuring (see *Section 8.3: Constant Current mode* and *Section 8.4: Constant Height mode*). Depending on the installed controller modules and the mounted scan head, certain options may or may not be available.

Cantilever Selector
This drop-down box allows the selection of the mounted cantilever in case of AFM scan heads. Depending on your scan head type, certain options may or may not be available. The entry "Cantilever Browser…" opens the Cantilever Browser dialog, which allows you to

edit existing or define new cantilever types (see *Section 8.6: Cantilever Browser dialog* (page 86))

Freq. Sweep

This button opens the Vibration Frequency Search dialog. In this dialog, amplitude versus frequency plots can be measured and the operating frequency for dynamic modes can be set manually. In "Air" environment, setting of the vibration frequency is normally performed fully automatically, without user intervention. In "Liquid" environment, the Vibration Frequency Search dialog opens after the control software determined a suitable vibration frequency. You need to fine adjust and confirm the selected resonance frequency prior to approach. For more details about this dialog see *Section 8.6: Cantilever Browser dialog* (page 86).

Laser Align

This button opens the Laser Align dialog. In this dialog, laser power and the current position of the laser beam on the detector are monitored. It is used to check for good detector and laser alignment. With FlexAFM scan heads it guides the user to manually adjust these positions if required or desired (see FlexAFM Laser and detector alignment).

Launcher icon

More advanced settings are available through the "Dialog Launcher" icon (⬚ at the bottom right corner of the Preparation group), which opens up the SPM Parameters dialog on the Operating Mode page (see *Section 8.5.1: Operating Mode page* (page 82)).

8.3: Constant Current mode

In Constant Current mode, the tunneling current is kept constant by the Z-Controller. The output of the Z-Controller thus corresponds to the height of the sample surface. This output is recorded as a function of X and Y position, and is displayed as the Topography signal.

8.4: Constant Height mode

In Constant Height mode on the other hand, the tip does not follow a surface of constant tip current. Instead the variation of the tunneling current is directly recorded as a function of the X and Y position in plane parallel to the sample surface.

The Easyscan 2 STM is normally configured to measure in the Constant current mode. To switch to the Constant height mode, you could theoretically just turn off the Z-Controller. However, several problems arise:

• The tip would crash into the slightest unevenness of the surface.

• The scan plane of the scanner must be very well adjusted to the plane of the sample.

- The thermal drift in the Z-Direction will cause the tip to rapidly move away from the sample, or even worse, to crash into it.

For a large part, these problems can be avoided by setting the Loop gain to a very low value. Thus, the feedback loop can follow the slow movement of the sample caused by thermal drift and the sample plane, but not the fast height changes due to the presence of the atoms.

To measure in Constant height mode:

❶ Find a flat area of the sample by imaging it in Constant current mode, and zoom in on this area.

❷ In the Z-Controller section of the Imaging tab, set I-Gain to 4.

❸ Set P-Gain to 0.

To visualize the current:

➥ In the Color map chart that is displayed in the Imaging Window, set the Input channel to "Tip Current".

The bar next to Color map should now display the text "Tip Current" and should have the units "pA" or "nA" instead of "nm".

8.5: SPM Parameters dialog

8.5.1: Operating Mode page
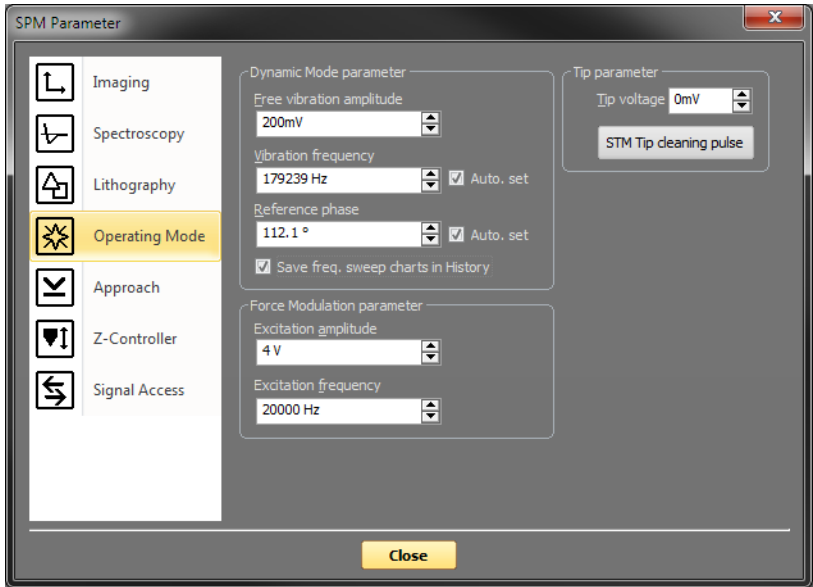
Dynamic Mode parameters

Free vibration amplitude
The desired reference amplitude of the cantilever vibration. The cantilever vibrates at this amplitude when it is far away from the sample. The excitation strength is adjusted so that this vibration amplitude is reached.

Vibration frequency
The frequency at which the cantilever vibrates during the measurement. This frequency can be set automatically as described at the start of this section. When "Auto set" is enabled, the Vibration frequency is automatically set. Immediately at activation and each time an approach is started. When "Auto set" is disabled, the frequency can be set manually, either by directly changing its value in the control box, or by using the Vibration Frequency Determination dialog (see *Section 8.7: Vibration Frequency Search dialog* (page 89)).

Reference Phase
The reference phase for the detected cantilever vibration. Changing the reference phase changes the offset of the phase signal. The phase reference can be automatically set so that

the phase signal is zero. When "Auto set" is enabled the phase reference is automatically set after finishing the approach.

Force Modulation parameters

Excitation amplitude
The amplitude of the sensor excitation during a force modulation mode measurement.

Excitation frequency
The frequency of the sensor excitation during a force modulation mode measurement.

Tip Parameter

Tip Voltage
This parameter defines the potential to be applied to the tip. The voltage that can be used lies between -10V and +10V.

> **Info:**
>
> With the STM scan head the sample is automatically connected to the ground of the instrument. With AFM scan heads the sample has to be electrically connected to the instrument chassis ground for accurate measurements.

8.5.2: Z-Controller page
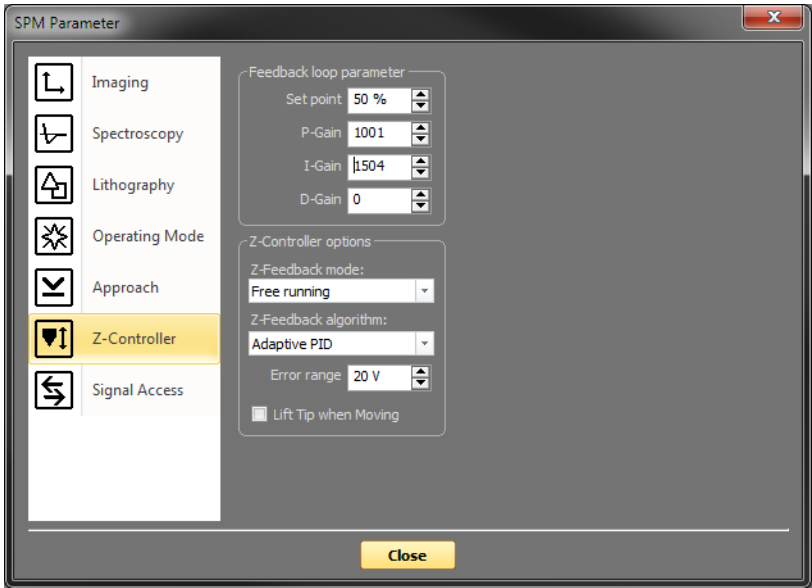
Feedback loop parameter

Setpoint
The working point for the Z-Controller. Depending on the operating mode, this is the tunneling current (STM mode), cantilever deflection (Static Force mode) or relative cantilever vibration amplitude (Dynamic Force mode). In the later case, the set amplitude is relative to the operating amplitude, set in the Mode Properties Section. For example, when a Setpoint of 70% is used, the Z-Controller will move the tip closer to the sample until the vibration amplitude has decreased to 70% of the vibration amplitude far away from the sample.

P-Gain
The strength of the Z-Controller reaction that is proportional to the error signal. Increasing the P-Gain decreases the error signal.

I-Gain
The strength of the Z-Controller reaction that is proportional to the integral of the error signal. Increasing the I-Gain decreases the error signal over time. It is the least sensitive to noise, and usually the dominant contributor to the topography measurement.

D-Gain

The strength of the Z-Controller reaction that is proportional to the derivative of the error signal. Increasing the D-Gain decreases fast changes in the error signal, but also amplifies high frequency noise.

Z-Controller options

Z-Feedback Mode

The following modes are available:

– **Free Running**
   The Z-Controller is active.

– **Freeze Position**
   The Z-Controller is not active, the scanner remains in its current Z-position.

– **Stop and Clear**
   The Z-Controller is not active, the scanner is moved to the "Ref. Z Plane", set in the Imaging page of the SPM Parameters dialog. The Probe Status Light will blink green as long as the Z-Controller is deactivated.

CAUTION

The tip may be damaged when the Z-Controller is not active during scanning. This will happen when Ref. Z Plane is much lower than the current position of the tip, or when the scan range contains large height differences.

Z-Feedback algorithm

The following algorithms are available:

– **Standard PID**
   A standard PID controller is used for Z-Feedback.

– **Adaptive PID**
   A standard PID controller is used for Z-feedback. In addition, the bandwidth of the Topography measurement is adapted to the number of measured points per second. The adaptive PID controller thus reduces noise in the measurement. However, topography changes that happen faster than the time between two measured points are also lost. This makes it more difficult to detect vibrations due to instability of the feedback loop. These vibrations remain visible in the Current, Amplitude, or Deflection signal, however, so always monitor these signals when optimizing Z-Controller settings, especially when using the Adaptive PID.

Error Range

The range of the error signal used to control the Z-Position. The error signal is the difference between the signal used for topography feedback and the current Setpoint. When the value of "Error Range" is reduced, the resolution of the error signal is increased.

8.6: Cantilever Browser dialog
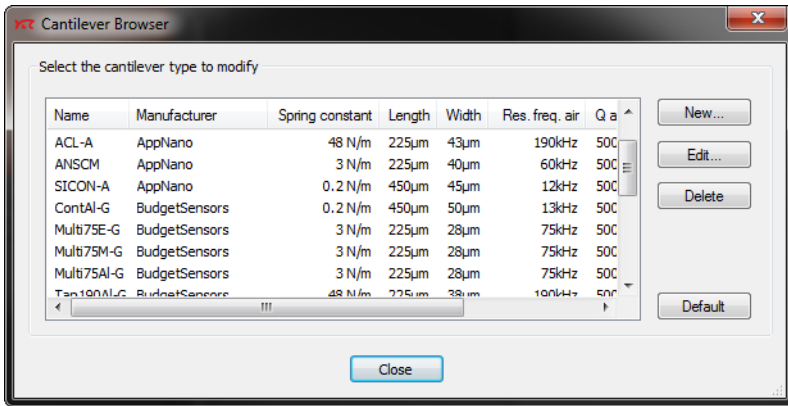
The Cantilever Browser dialog displays the list of stored cantilever types in the database of the SPM Control Software. In this database, many cantilevers of different manufactures are saved with their typical physical properties. The Cantilever Browser dialog is opened via the drop-down menu entry "Cantilever browser" of the "cantilever" button in the Preparation group of the Acquisition tab.

New...
Opens the Cantilever Editor dialog for a new cantilever type. You can create new cantilever types that are not defined in the default configuration. See section x.1 The Cantilever Editor

Edit...
Opens the "Cantilever Editor" dialog to modify the currently selected cantilever type. See section x.1 The Cantilever Editor

Delete
Deletes the currently selected cantilever type.

Default
Sets all known cantilevers types back to their default factory settings. It also restores deleted known cantilevers. After a software update, new known cantilevers are added. User defined cantilevers are always kept as defined.

Attention:

Please note that scan heads with cantilever holders based on the Alignment Chip technology can only be used with cantilevers possessing the following properties:

- The sensor chip must have grooves that fit onto the alignment chip.

> **Attention:**
>
> - The cantilever should have a nominal length of 225 µm or more, and a top width of 40 µm or more (please distinguish between mean width specified by most manufacturers and the actual top width of trapezoid-shaped cantilevers).
>
> - The back of the cantilever must have a coating that reflects infrared light. Uncoated cantilevers transmit much of the infrared light of the cantilever deflection detection system.

8.6.1: Cantilever Editor dialog
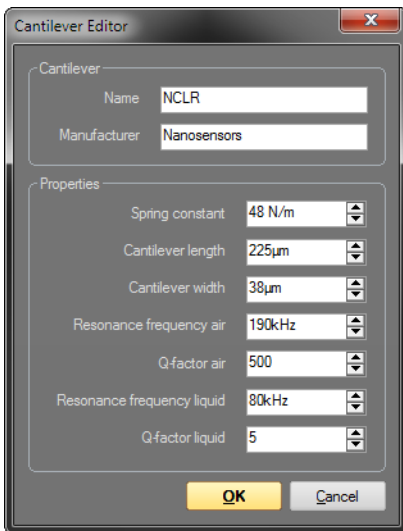
The Cantilever Editor dialog allows and editing of existing cantilever types and the creation of new cantilever types that are not defined in the default configuration.

Cantilever

Name
Name of the cantilever type. This name appears in the Cantilever type drop-down menu in the Preparation group of the Acquisition tab. The list is sorted by the manufacturer's name.

Manufacturer
Name of the cantilever manufacturer.

Properties

Spring constant

This parameter defines the nominal spring constant of the cantilever type. This value is used to calculate the correct force used for Z-Controller Setpoint and chart signals in all operating modes that use the Static Force for Z-control.

IMPORTANT

The deflection calibration value of the current scan head calibration file is used to calculate the force:

$$Force~[N] = Spring~Constant~[N/m] * Deflection~[m]$$

Cantilever length

The nominal length of this cantilever type (for information only, currently not used by the control software).

Cantilever width

The mean width of this cantilever type (for information only, currently not used by the control software).

Resonance frequency air / Resonance frequency liquid

The nominal resonance frequency of the cantilever type in air or in liquid measurement environment. This frequency is used for calculation of the automatic coarse frequency sweep search range (see *Section 8.7: Vibration Frequency Search dialog* (page 89)).

Q-factor air / Q-factor liquid

The apparent quality factor of the cantilever in air or in liquid measurement environment. The higher the number, the sharper the peak. By default, this number is 500 in air and 5 in liquid. The quality factor is used for calculation of the automatic fine frequency sweep search range (see *Section 8.7: Vibration Frequency Search dialog* (page 89)).

8.7: Vibration Frequency Search dialog
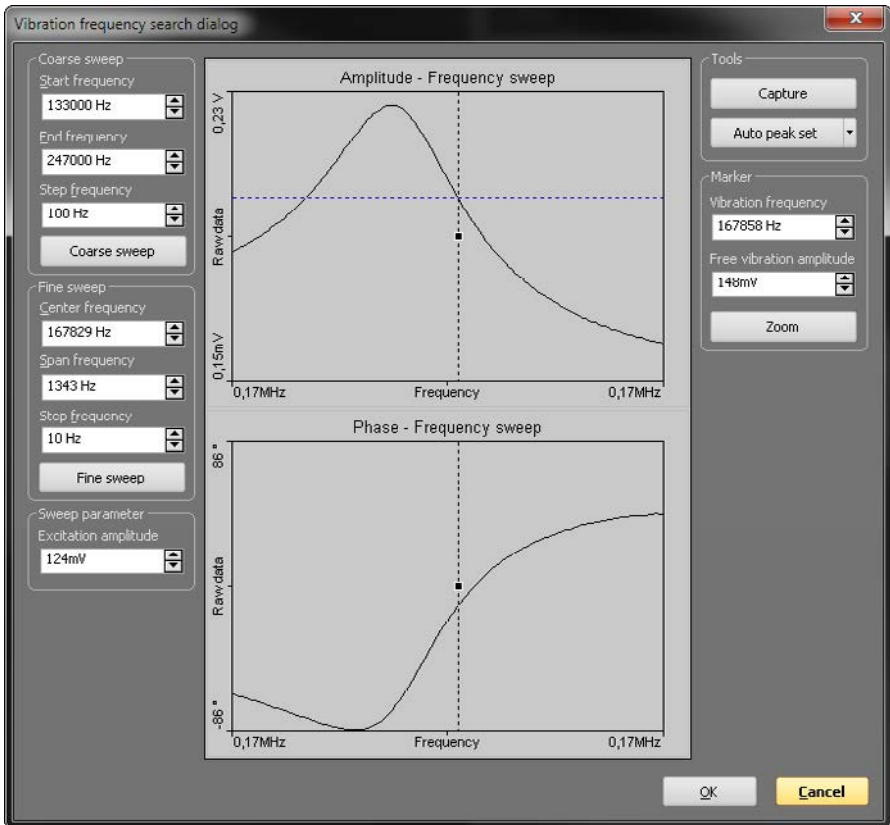
8.7.1: General concept

The Vibration Frequency Search dialog provides all functionality to view, search and change the vibration frequency used by the dynamic measurement modes. It is opened by clicking the "Freq. Sweep" button in the Preparation group of the Acquisition tab. When opened, the previous frequency sweep is shown. If no previous sweep was performed, the charts are empty.

To find the cantilevers best operation frequency the control software measures a so called Bode-Plot. This Bode-plot displays the cantilevers amplitude and phase response versus excitation frequency. Based on this Bode-plot, the SPM Control Software is able to

automatically detect the cantilever resonance peak and adjust the operating frequency accordingly. In some cases (mostly in Liquid environment) it is necessary for the user to adjust the operating frequency manually (based on the Bode-plot result), because the automatic algorithm is not able to find the right frequency peak.

For recording the Bode-plot, the SPM Control Software tunes the cantilever excitation from a start frequency slowly up to a higher frequency. During this tuning (or sweeping) the cantilevers amplitude and phase response is measured and saved. The result is plotted in an Amplitude and a Phase versus Frequency chart. The Excitation amplitude is held constant during the sweep. Therefore, any change in detector amplitude and phase signal is a result of cantilever response.

Resonance frequencies vary greatly between cantilevers, depending on the cantilever's respective physical properties. Cantilever manufacturers provide information on the resonance frequency range of each cantilever type. The SPM Control Software therefore has a built-in database of commonly used cantilevers. Other cantilever can be manually added by the user (see *Section 8.6: Cantilever Browser dialog* (page 86)). Based on this database information, the control software selects the frequency sweep range.

After a coarse and a fine sweep, the optimal operating frequency is chosen close to the resonance frequency of the cantilever.

> ## IMPORTANT
>
> The Phase measurement and chart plot is performed only if a Mode Extension Module is installed in the SPM controller. The Phase is always measured, independent on the selected Operating Mode.

8.7.2: Automated vibration frequency search

Tools

Auto frequency set

A click to this button starts an automated vibration frequency peak search and optimization procedure. This procedure consists of four phases:

1. First a coarse frequency sweep based on the database information of the currently selected cantilever is performed. The frequency range of this sweep is shown in the coarse sweep section.

2. Based on the best frequency peak found in this coarse sweep a narrow band fine sweep is done. The frequency peak and sweep range used for the fine sweep is shown in the fine sweep section.

3. Based on the amplitude reduction settings (accessed by choosing "Config..." from the "Auto frequency set" buttons drop-down menu) the optimal vibration frequency is

selected and the excitation amplitude tuned to get the desired free vibration amplitude at this frequency.

4. After the amplitude tuning, a final fine sweep is performed with the new excitation amplitude.

At the end of the procedure, the new operating frequency is shown by the marker (both graphically and in numbers). Additionally, the "excitation amplitude" parameter shows the amplitude required to obtain the desired free vibration amplitude.

The user may now just leave the dialog and accept the new frequency using the "OK" button, reset to previous values with the "Cancel" button, do manual adjustment with the marker, or change amplitude settings and/or customize frequency sweep ranges through use of the edit boxes and action buttons.

Capture
Stores a copy of the current Bode-plot in the History page of the Gallery panel. The data is stored as a new measurement and remains open in the Document space of the SPM Control Software.

Config...
Selected from the "Auto frequency set" button's drop-down menu, this menu option opens the Auto frequency config dialog (see *Section 8.7.4: Auto Frequency Config dialog* (page 93)).

8.7.3: Manual sweep controls

Marker

The marker represents the currently selected frequency. It is shown as a dotted vertical line in the amplitude and phase chart. The corresponding "Vibration frequency" and "Free vibration amplitude" values (see below) are shown as automatically updating numbers in the Vibration frequency and Free vibration amplitude edit boxes as well.

To move the marker by mouse, click and hold the line's handle (small black box in the center of the line) and move it around. The vibration frequency is updated immediately during the movement. At release of the marker the amplitude is measured and drawn as a horizontal line in the amplitude chart and its value is displayed in the Free vibration amplitude edit box.

To use the currently shown frequency as the new vibration frequency, leave the dialog with the "OK" button.

Vibration frequency
This parameter shows the frequency at the marker's position. It is used as the actual vibration frequency during operation of the microscope in the Dynamic operating modes. The value of this frequency can be changed manually by typing in the desired value, by

using the arrow keys beside the parameter field, or by dragging the frequency marker line in the charts as described above.

Free vibration amplitude
This parameter shows the actual amplitude at the current marker frequency. If the user enters a new value, the excitation amplitude is adjusted to obtain a free cantilever amplitude with this new value. A new frequency sweep is immediately performed and its results displayed. If the desired amplitude could not be set, an error dialog is shown.

Zoom
A click on this button starts a new frequency sweep with a smaller frequency range than currently displayed in the charts. The center of the sweep is at the markers position. The new sweep range and center position is shown in the Fine sweep parameter section.

Coarse sweep

Start / End Frequency
These parameters defines the sweep range of a coarse frequency sweep. This range is normally set large enough to search for the initial resonance peak. "Auto frequency set" sets these parameters to the range found in the Cantilever database for the currently selected cantilever.

Step Frequency
This parameter defines the frequency steps used during the sweep. Therefore, the number of data points of the sweep is defined as:

$$Datapoint = (End - Start) / Step.$$

Typical step sizes during a coarse sweep are 100 Hz or more.

Coarse s weep
The "Coarse sweep" button performs a coarse frequency sweep according to the coarse sweep parameters entered (see above).

Fine sweep section

Center / Span Frequency
These parameters defines the sweep range of a fine frequency sweep. The range is normally smaller than the coarse sweep range. "Auto frequency set" sets the center frequency to the resonance peak found during the coarse sweep. The span is set according to the quality factor found in the Cantilever database for the currently selected cantilever. Span defines the start and end frequencies for the fine sweep as follows:

$$Start = Center - (Span / 2)$$

$$End = Center + (Span / 2)$$

Step Frequency
This parameter defines the frequency steps used during the sweep. Therefore, the number of data points of the sweep is defined as:

$$Datapoints = (End - Start) / Step.$$

Typical steps are 10 Hz or less.

Fine sweep
The "Fine sweep" button starts a fine frequency sweep according to the fine sweep parameters entered (see above).

Sweep parameter section

Excitation amplitude

This parameter defines the used excitation amplitude during the sweep. If the user enters a new value a new frequency sweep is immediately performed and its results displayed. The "Auto frequency set" sets this value to a predefined value according to the scan head calibration file settings and the currently selected environment parameter.

8.7.4: Auto Frequency Config dialog
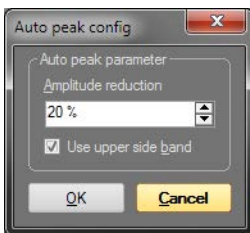
Auto frequency parameters

Amplitude reduction
This parameter defines the final position of the automated operating frequency search. Normally, the operating frequency is not at the resonance peak but somewhere beside it. "Auto frequency set" adjusts the free vibration frequency in such a way that the cantilever vibration amplitude is smaller than the vibration amplitude at the resonance frequency as defined by this parameter:

$$Amplitude_{Vibr.\ freq.} = Amplitude_{Res.\ freq.} \times (1 - Amplitude\ reduction/100)$$

Use upper side band

When checked, the vibration frequency is set to a frequency higher than the resonance frequency. When unchecked, the vibration frequency is set to a frequency lower than the resonance frequency.

8.8: Laser Alignment dialog
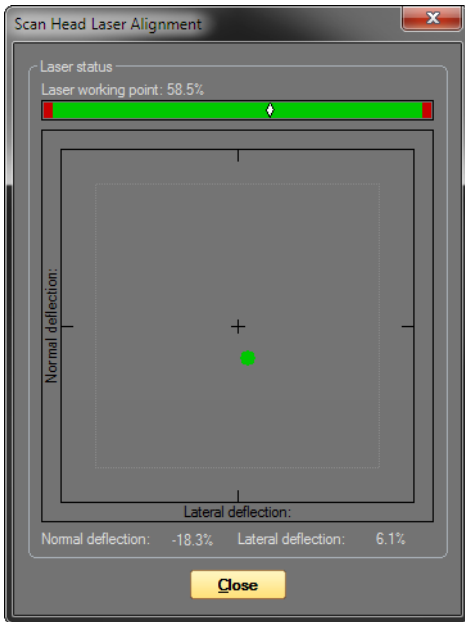
The Scan Head Laser Alignment dialog displays the current position of the AFM laser spot on the detector and the used laser power. It is only available when a Nanosurf FlexAFM scan head is attached. The dialog is opened by clicking the "Laser align" button in the Preparation group of the Acquisition tab.

Laser working point

This graph shows the efficiency of the laser detection system. A small white diamond-shaped marker should be found anywhere within the green area, meaning that a sufficient amount of the laser signal is being reflected by the cantilever and correctly makes it back to the photodiode detector.

If the marker resides in the red area to the right, it will turn red too, signaling that too little laser light is being detected. This can be caused by a misaligned cantilever, or by something blocking the optical path of the laser.

If the marker resides in the red area to the left, too much light is being detected by the photodiode detector, usually caused by strong environmental light. This condition is very rare, however.

Laser position

This graphical area shows where the deflected laser beam hits the photodiode detector. A green spot anywhere within the area enclosed by the dotted square means that the cantilever deflection detection system (consisting of laser, cantilever, and detector) is properly aligned. If the laser spot falls outside this area, it will become red, meaning that the alignment does not allow proper measurements to take place. Usually this is caused by a misaligned cantilever, which can be easily corrected. The position of the laser spot is also given as a percentage of the maximum deflection the detector can identify.

CHAPTER 9:

Positioning

9.1: Introduction

Positioning of the sample with respect to the tip is a prerequisite for starting any measurement. This process consists of two distinct steps:

1. An area of interest has to be found and positioned directly underneath the tip before an approach and subsequent measurement can be initiated. Several panels of the Info pane can assist with this process. They are explained in *Section 9.2: Video panel*, *Section 9.3: Online panel*, and *Section 9.4: Stage panel*.

2. The tip has to approach the sample until a given setpoint is reached. The approach step is controlled through the Approach group of the Ribbon's Acquisition tab (see *Section 9.5.1: Approach group*).

9.2: Video panel

The Video panel displays the available video signals. Each of the graphical sections used for this contains a toolbar with control options to adjust the display properties of the respective video signal. The settings for each of these controls is stored independently for each video signal (i.e. different setting can be set for both top and side view).

INFO

If your system is not equipped with a Video Camera or the SPM Controller is not equipped with a Video Module, this Panel will not be available.

9.2.1: Analog video camera display

If your system is equipped with analog cameras and the analog video module (e.g. Easyscan 2 AFM), only one camera view can be displayed at any given time.
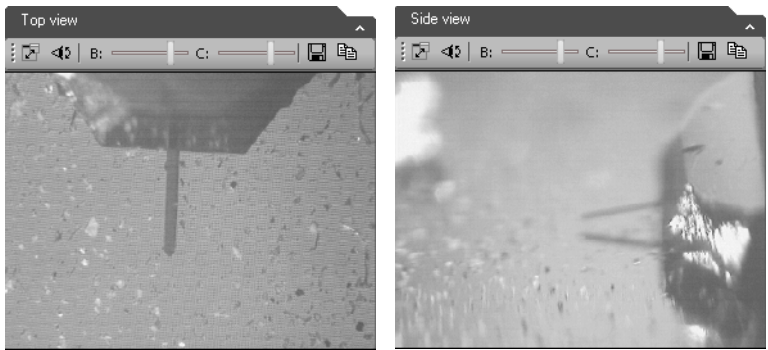
Figure 9-1: Analog video signal in the Video panel. (Left) Top view. (Right) Side view.

Analog Video Camera toolbar

Show Window
The "Show Window" button ( ) allows you to switch between display of the video signal in a section of the Video panel and display of the video signal in a separate window (see *Figure 9-2: Free floating video window*).

Figure 9-2: Free floating video window

Switch view
The "Switch View" button ( ) allows you to switch between the two analog video cameras. Either the Top view signal or the Side view signal is displayed.

Brightness
The "Brightness" slider ( ) regulates the brightness of the video display.

Contrast
The "Contrast" slider ( ) regulates the contrast of the video display.

Save As...
The "Save As..." button ( ) allows you to save the current video image as a JPG file.

Copy
The "Copy" button ( ) allows you to copies the current video image to the Windows Clipboard for "pasting" into other applications.

9.2.2: Digital Video Camera display

If your system is equipped with a digital USB camera (e.g. for FlexAFM or NaniteAFM scan heads), two camera views can be displayed simultaneously and more video controls are

available when compared to the analog camera options. The digital video cameras support digital Zoom and Focus adjustment via additional toolbar buttons, and an anti-moiré and a high-resolution mode are available too (see below).
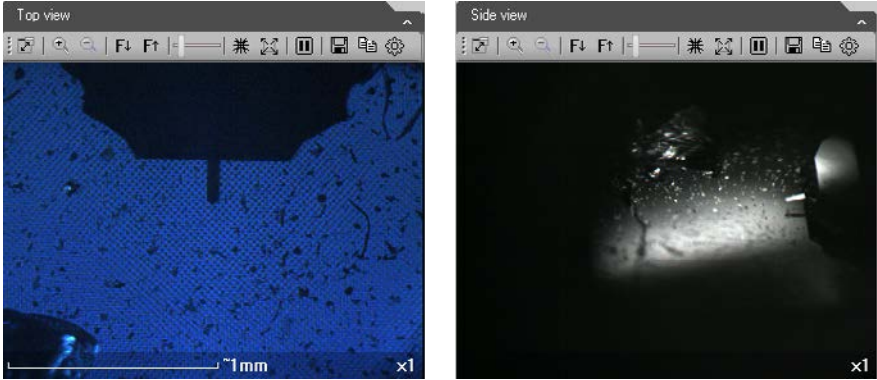
Figure 9-3: Digital video signal in the Video panel. (Left) Top view. (Right) Side view.

Digital Video Camera toolbar

In addition to the options available for analog cameras (see *Analog Video Camera toolbar*), the following options exist:

Zoom + / Zoom –
The "Zoom" buttons ( ) allow you to zoom in or out digitally (by binning of pixels). The zoom area is always in the center of the image. The number of pixels displayed is kept constant. Therefore, the video rate is independent of the zoom factor. The current zoom factor is displayed in an overlay at the bottom of the video image.

Focus up / Focus down
The "Focus" buttons ( ) adjust the focus of the current camera view. Motors in the respective camera physically adjust lenses to change the focus plane.

Gain slider
The "Gain" slider ( ) regulates the amount of gain applied to the video signal.

Anti-Moiré Button
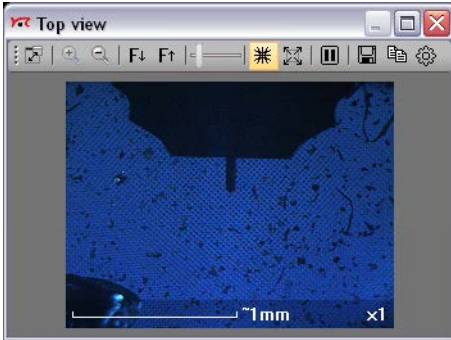
The "Anti-Moiré" button ensures that the ratio between the number of camera pixels and video display pixels is always a whole number. This prevents moiré patterns from occurring in the video image. The moiré effect is mostly visible on samples with regular structures like grids or lines if this option is not enabled.

When the Anti-Moiré mode is active, the button is highlighted. Clicking the highlighted button will deactivate the Anti-Moiré mode and will cancel the button's highlighting.

High-Resolution Mode Button
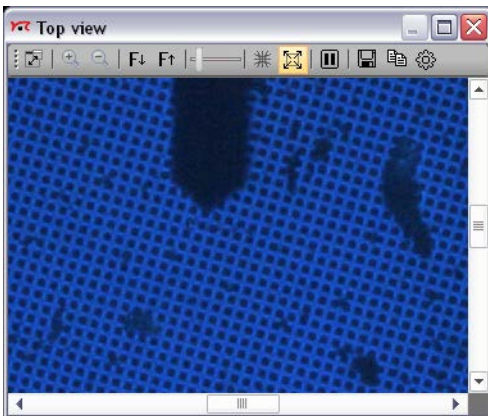
The "High-Resolution Mode" button If this mode is activated, the video display shows all camera pixels on the display one-to-one. No Zoom is available in this mode. If the video display's pixel size is lower than the camera's, scroll bars are automatically shown on the borders of the video display. This mode is only useful in a large separate window (e.g. on a second LCD monitor) when you need to see a sample in full detail.

When the High Resolution mode is active, the button is highlighted. Clicking the highlighted button will deactivate the High-Resolution mode and will cancel the button's highlighting.

IMPORTANT

In high-resolution mode the amount of (video pixel) data that needs to be transferred over the USB connection is huge. As a result, the video frame rate typically drops below 5 Hz and a high-performance PC is required to keep the system stable.

Pause Button

If the "Pause" button (⏸) is activated the video image update is stopped and the frozen image (last frame received) is shown continuously. A second click on this button restarts the real time video display.

Video Properties Button

A click on this button opens the Digital Video Properties Dialog. See the next section (*Section 9.2.4: Digital Video Properties dialog*) for details.

9.2.3: Illumination section

The Illumination section of the Video panel contains an Illumination slider that controls the intensity of the sample illumination LED. It may be used to adjust the amount of light on the sample, thereby optimizing the video image.

If you have an analog camera installed in your system, the illumination settings will depend on the selected camera view (top or side view) and will be stored individually.

In case you have a digital camera in your system, where top and side view are shown simultaneously, only one illumination setting is used.

If no camera is installed, the Video panel will not be accessible, and the Illumination slider will therefore be present in the Online panel (see *Section 9.3.3: Illumination section*).

9.2.4: Digital Video Properties dialog
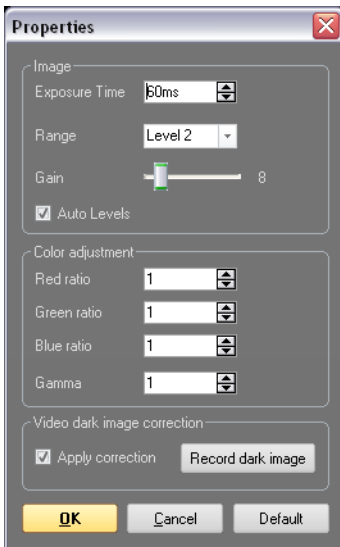
The Digital Video Properties dialog can be accessed via the Video Display toolbar or the video display's context menu. The properties accessible through this dialog directly influence the respective camera's behavior at the camera driver level.

Image

Exposure time
Adjusts the exposure time (time to record one image frame) for the respective video camera. Changing this setting allows the camera to cope with very bright or very dark sample illumination conditions, or to fine-tune the predefined illumination condition ranges (see *Range* below).

Range
Allows the selection of different illumination ranges (levels) for quick adjustment of the video camera to the current sample illumination conditions. Lower level numbers are suitable for lower illumination conditions.

Gain
Identical to the "Gain" slider in *Digital Video Camera toolbar* (page 100), which adjusts the amount of gain applied to the video signal.

Auto Levels
When checked, this option automatically adjusts the camera data to fill the dynamic range of the Video display (similar to the "Auto set" option for the Chart data range (see *Section 13.3.2: Chart Properties dialog* (page 182)). Using this option will automatically give you a good quality image. You will find that changing the other image parameters while this option is checked (within limits) hardly has an effect on the video display anymore.

Color adjustment

Red ratio
Adjusts the relative amount of red color information in the RGB color mix for each pixel. Not available for the (monochrome) side view.

Green ratio
Adjusts the relative amount of green color information in the RGB color mix for each pixel. Not available for the (monochrome) side view.

Blue ratio
Adjusts the relative amount of blue color information in the RGB color mix for each pixel. Not available for the (monochrome) side view.

Gamma
Adjusts the midpoint of the video image's dynamic range. Adjusting this setting can be beneficial for images that show too low or too high contrast. In such cases, increase or decrease the gamma setting, respectively.

Video dark image correction

At higher gains levels, digital cameras tend to exhibit differences in intensity for individual image pixels, making some pixels stand out unfavorably from the rest. Applying the Video dark image correction (on by default) will remove any such pixels from the video display. This is done by using a so-called "dark image" as a reference. The SPM Control Software will attempt to record this dark image the first time it is started with the FlexAFM Video Camera attached. This process is silent. If successful, the "Apply correction" checkbox (see below) will be available in the Video Display Properties dialog. If the ambient light is too high, however, the process will fail, and the "Apply correction" checkbox will be grayed out. To activate the checkbox, it will be necessary to record the dark image manually by clicking the "Record dark image" button. If the light levels are still too high, you will be advised to cover the instrument or darken the room.

Apply correction
Applies the dark image correction.

Record dark image
Records the dark image for video correction. Each time this button is clicked, the previous dark image reference will be overwritten.

9.3: Online panel

The Online Panel displays scan area information and various other data.

9.3.1: Scan Position section
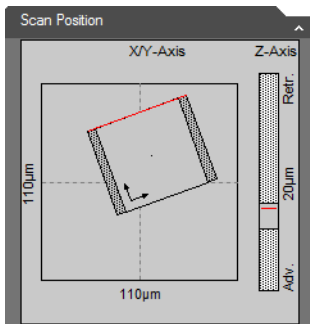
The Scan Position section displays information about the maximum scan head scan area, the current measurement area and the tip position.

The left side of the section shows the maximum scan range of the scan head (outer square and numbers) and the currently set image size (inner square). The dotted bars to the left and right of the inner square represent the "Overscan" area (see *Overscan* in *Section 10.5.1: Imaging page* (page 129)).

The red line in the inner square represents the currently measured scan line during imaging. The two arrows represent the orientation of the axes of the image coordinate system. The small dot in the center of the image square represents the Offset and Rotation point (see *Image offset X/Y* and *Rotation* in *Section 10.5.1: Imaging page* (page 129)).

The dotted bar on the right side of the Scan Position section represents the maximum Z-range (bar and numbers), the used range for the current measurement (gray box) and the actual Z-position (average of the current scan line) of the tip (red line).

9.3.2: Master Image section
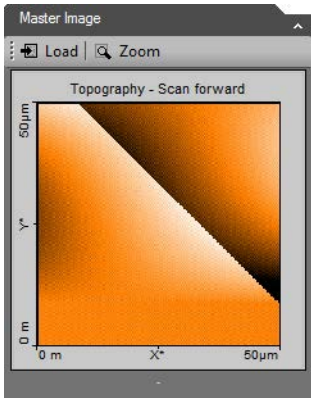
The Master Image section displays a topography measurement, which can be used as a reference for comparison with other measurements, or as an overview image for multiple (zoomed) measurements on several points of interest. The Master Image section starts out blank. A reference image has to be loaded manually. When this is done, a box with a black outline will show the current measurement area inside the reference/overview image.

Load
The Load button captures the actual topography image of the active Measurement Tab into the Master Image Section.

Zoom
A click to this tool activates the Zoom Tool in the Master Image chart area to select a new scan area size and position (within the loaded image). After selecting the Zoom button the user draws a zoom frame in the chart area. To select the new scan area, double-click within the selection area. A right mouse click aborts the zoom operation.

9.3.3: Illumination section

With the Illumination slider the intensity of the sample illumination LED is controlled. This slider is only present in the Online panel when no video camera is present in your system. When a camera is present, this slider automatically moves to the Video panel (see *Section 9.2.3: Illumination section*).

9.4: Stage panel
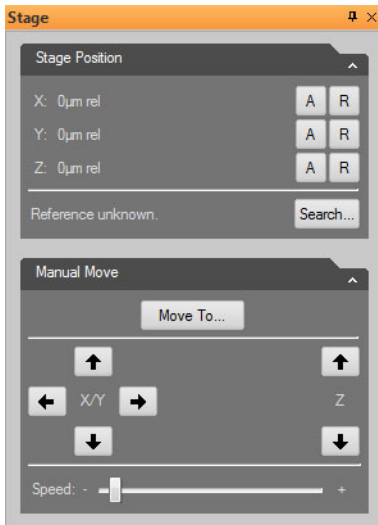
This panel is only available to Nanosurf AFM systems when the Translation Stage Software is installed on the computer that contains the SPM Control Software (usually with Nanite systems). The Stage panel allows moving of the translation stage in the same way as the corresponding panel in the Batch manager is operated.

Stage Position section
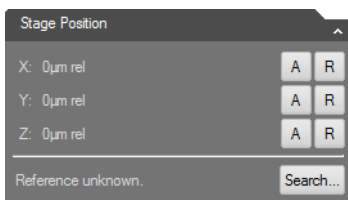
The upper part of the Stage Position section displays the current position of the translation stage in coordinates relative to the zero point of the translation stage, or in coordinates relative to a previously set zero point. On start-up, the coordinates are shown relative to the start up position, until the reference position of the stage has been found (e.g. after clicking the "Search" button).

Absolute

Clicking the "Absolute" button (A) (re)sets the zero point of this axis' coordinate display to the absolute zero point of the translation stage. The Stage Position coordinates (X,Y,Z) now display the absolute position of the stage.

Relative

Clicking the "Relative" button (R) sets the zero point of this axis' coordinate display to the current position. The Stage Position coordinates (X,Y,Z) now display the position of the stage relative to the position where the "Relative" button was last clicked.

Search

Clicking the "Search" button (Search...) starts a search for the reference position of the translation stage. The reference position can be different from the zero point of the stage.

Manual Move section
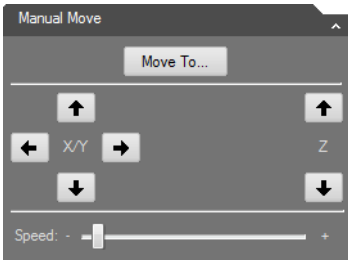
Move To

Clicking the "Move To" button (Move To...) opens the Move Stage To dialog (see *Section 9.4.1: Move Stage To dialog*).

Arrow buttons

Move the translation stage in the direction of the arrow for as long as the button is clicked and held.

Speed

The speed with which the translation stage moves.

9.4.1: Move Stage To dialog

> **CAUTION**
>
> It is recommended to always keep the approach stage in the upper limit position. When repeatedly moving to the same position, it is possible that the tip will crash into the sample if the approach stage is in a lower position than it was before.
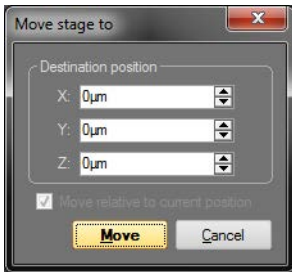
This dialog is only available to Nanosurf Nanite AFM systems with an automated translation stage attached and the corresponding software installed. It is used to move the translation stage to a specific destination position. It is opened by clicking the "Move To" button in the Manual Move section of the Stage panel (see *Manual Move section* (page 108)).
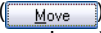
X/Y/Z
The (X, Y, Z) coordinate of the destination position.

Move relative to current position
When checked, the (X,Y,Z) coordinates are interpreted relative to the current position. When not checked, the coordinates are interpreted as a position relative to the absolute zero point of the translation stage. This checkbox is only enabled when the reference position has been found (e.g. after clicking the "Search" button in the Stage Position section of the Stage panel).

Move
Clicking the "Move" button ( ) moves the translation stage to the destination position entered by the user (see above).

9.5: Acquisition tab

9.5.1: Approach group
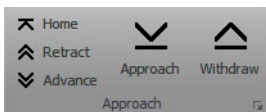
Home
Increases the tip–sample distance to its maximum value to ensure that the maximum motorized approach range is available during final automatic approach.

Retract
Increases the tip–sample distance at maximum speed until the button is released.

Advance
Decreases the tip–sample distance at maximum speed until the button is released.

Approach
Starts the automatic approach. During automatic approach, the tip–sample distance is decreased until the Setpoint (set in the Z-Controller section) is reached, or until the maximum number of approach steps is reached (see *Section 9.6.1: Approach page* (page 111)).

Withdraw
Increases the tip–sample distance with approach speed settings.

Launcher icon
More advanced settings are available through the "Dialog Launcher" icon (at the bottom right corner of the Preparation group), which opens up the SPM Parameters dialog on the Approach page (see *Section 9.6.1: Approach page* (page 111)).

9.6: SPM Parameters dialog

9.6.1: Approach page
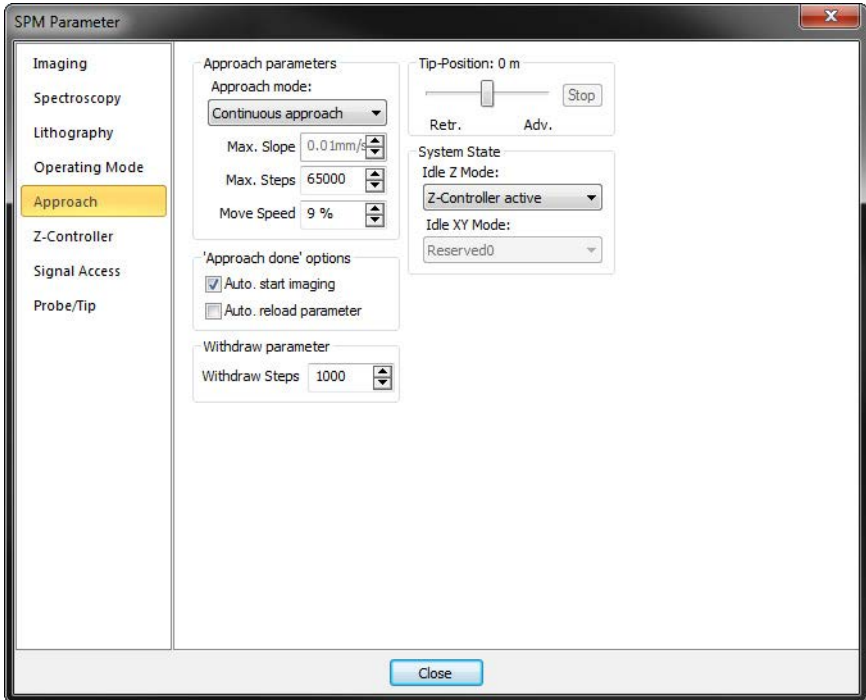
Approach parameter

Approach Mode

For STM scan heads no selection is possible (approach is always performed step-by-step through the stick-slip motion of the STM approach stage).

For AFM scan heads, two approach options are available for AFM:

– Continuous approach

Approach with continuous slow motorized stage movement until surface contact point is reached. Z-Axis stays at Tip-Position during approach. This is the default approach method, and was the only method available in the Nanosurf SPM Control Software before version 3.

– Step-By-Step approach
Approach is performed by moving the motorized stage quickly over a distance that is less than the scanner's Z-range. During the movement of the motorized stage, the tip is fully retracted. When the motorized movement is finished, the scanner extends the tip along the Z-axis to probe for the sample surface. The approach is considered done when the Setpoint (defined in the Z-Controller page of the SPM Parameters dialog, or in the Z-Controller section of the Imaging panel of the Imaging window) has been reached. If it is not reached within the Z-range of the scanner, the tip is again fully retracted and the next motorized step is performed. This process of 'step-and-probe' is repeated until the Setpoint has been reached (and approach is done). This approach method is considered to be more 'gentle' to tip and sample and should be considered for very sharp tips and/or very soft samples. In general, it does however take more time than Continuous approach.

Max. Slope
This parameter defines the speed of extending the z-axis. This parameter is only available in Step-By-Step approach mode. Slower speeds help to preserve sharp tips.

Max. Steps
This parameter defines the maximal duration of an automatic approach:
• In Continuous approach mode it defines the maximum time.
• In Step-By-Step approach mode it defines the maximum number of cycles.

Move Speed
This parameter defines the move speed during automatic approach and withdraw:
• In Continuous Approach mode this value should be small. If the approach is too fast, the tip or the sample surface can be damaged. On the other hand, the motor will not move when the move speed is too small.
• In Step-By-Step Approach mode should be around full speed. Lower values help to stop in the z-range of the scanner. On the other hand the approach time increases.

Approach done options

Auto Start imaging
When selected, the system automatically starts imaging after a successful approach. Scanning automatically stops the approach motor is moved.

Auto Reload parameter
When selected, the control software reloads the default startup parameter file for each approach.

Withdraw parameter

Withdraw Steps
The number of steps to use for withdrawing the tip from the sample (see *Withdraw* (page 110)).

Tip-Position

This value determines the Z-Position of the scanner when the approach motor stops. When the Tip-Position is changed when the tip is already approached to the sample, the motor will move the approach stage so, that the Z-Position of the tip becomes equal to the set Z-Position. When a high resolution scanner is used, the Tip-Position before approach is set to approximately +500 nm (advanced) by default. This compensates for the residual motion of the approach stage that occurs after the approach motor has stopped.

System State

Idle Z Mode
Defines the state of the Z-feedback loop while not measuring. Available options are:

– **Z-Controller active**
   Keep the Z-feedback active; the tip is tracking the sample surface.

– **Retract Tip**
   This causes the tip to be retracted to the scanner's upper-most Z-position (farthest away from the sample).

9.7: ATS Stage and TSC 3000 driver configuration

The configuration of the ATS Stage and TSC 3000 Controller is accessed through the TSC 3000 driver software. It is only required for AFM systems equipped with such stages and controllers (usually Nanite systems).

Starting the TSC 3000 driver

Usually, the TSC 3000 driver start together with the Easyscan 2 control software and will be running in the background. If this is the case, the tray icon 🔷 will be visible in the Windows Notification Area (bottom right part of the Windows desktop, also known as System Tray).

When the driver is not running:

❶   Open the Microsoft Windows "Start" menu.

❷ Select the menu item "Programs" >> "Nanosurf Translation Stage" >> "Nanosurf TSC 3000 Driver".

The name of the menu "Programs" may vary, depending on the language of your Windows operating system.

Checking the stage configuration

To check the stage configuration:

❶ Move the mouse over the [icon] icon and wait for the configuration filename to pop up.

❷ Check that the name of the stage configuration file displayed in the Window title matches the automated stage that is connected.

CAUTION

Using an incorrect stage configuration will cause the stage to behave incorrectly. This may cause damage to the system. Only change settings when instructed to do so by Nanosurf support personnel.

The driver menu
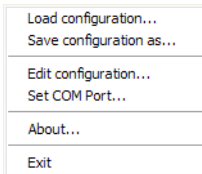
To change the TSC 3000 driver configuration and to access further driver functionality, the driver menu has to be opened. To do this:

➡ Right-click the [icon] icon in the Windows Notification Area.

TSC 3000 driver menu

Load configuration...
Allows a predefined or custom-saved configuration (".stage" file) to be loaded into the driver software.

Once you have changed the configuration, you must search for the reference position of the stage (see *Stage Position section* (page 107) in *Section 9.4: Stage panel*).

Save configuration as...
Allows the current configuration to be saved (".stage" file).

Save configuration as...

Allows the current configuration to be edited via the Stage Configuration dialog (see below). As with the "Load configuration option", you must search for the reference position of the stage (see *Stage Position section* (page 107) in *Section 9.4: Stage panel*) whenever changes to the stage configuration have been made.

Set COM Port...

Opens the COM Port Configuration dialog (see *Section 9.7.2: The COM Port Configuration dialog*), which allows the appropriate COM port for the TSC 3000 Controller to be set.

About

Shows the TSC 3000 driver version information in a separate dialog.

Exit

Closes the TSC 3000 driver software.

9.7.1: Stage Configuration dialog

The Stage configuration dialog reflects various properties of the ATS stage. This dialog should only be used for trouble-shooting.

CAUTION

Using an incorrect stage configuration will cause the stage to behave incorrectly. This may cause damage to the system. Only change the settings when instructed to do so by Nanosurf support personnel.
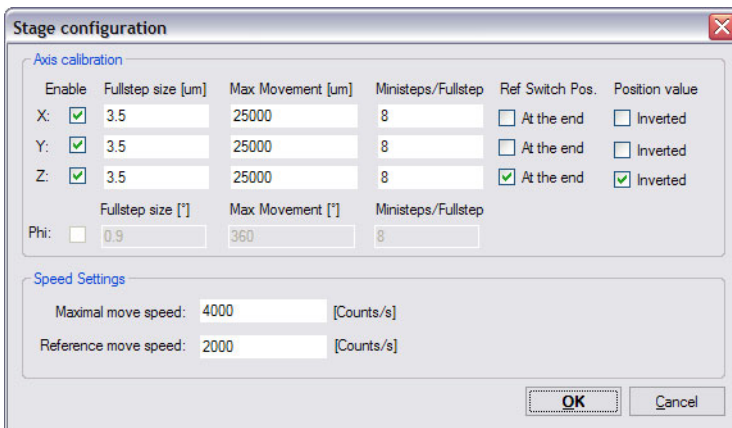
Figure 9-4: The Stage configuration dialog

Axis calibration

The axis calibration determines the relationship between the number of steps that the motor that drives a certain axis has made and the physical position coordinates of that axis. The motor controller converts the Stepcount to the position according to the formula:

$$Position\,[\mu m] = \frac{Stepcount\ from\ Limit\ position \times Fullstep\ size\,[\mu m]}{Ministeps\,/\,Fullstep}$$

Enable

Allows individual axis (X, Y, Z, or phi) to be enabled or disabled. Depending on the type of translation stage used and on the axes selected, the rotation axis "phi" may become available.

Fullstep size

The amount of distance that the stage travels when the stepper motor makes one step.

Max Movement

The maximum distance that the stage moves.

Ministeps/Fullstep

The number of steps in which a full stepper motor step can be sub-divided by the controller.

Ref Switch Pos.

"At the end" must be checked when the limit switch is located at the end of the translation stage's movement range (i.e., the position most distant to the motor). When checked, the controller will move the stage towards the end of the range until it finds the position of the reference switch of the stage.

Position value

"Inverted" must be checked when the axis coordinate should decrease (rather than increase) when the stage moves towards the end.

Speed Settings

Maximal move speed:

In (Ministep)counts/second. If the Maximal move speed is set too high, the stepper motor in the stage may fail to finish a step before the TSC 3000 controller commands it to make the next one. As a consequence the stage will not be in the correct position after moving.

Reference move speed:

In (Ministep)counts/second.

9.7.2: The COM Port Configuration dialog
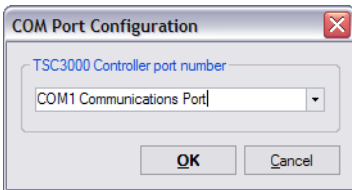
The TSC 3000 COM Port Configuration dialog sets the Serial Interface/COM port that the TSC 3000 Controller is connected to. The dialog is opened via the TSC 3000 Driver menu option "Set COM Port" (see *Section 9.7: ATS Stage and TSC 3000 driver configuration* (page 113)).

CHAPTER 10:

Imaging

10.1: Introduction

Imaging measurements of the sample are controlled using the Imaging window. This chapter describes all elements of the Imaging window in detail. For procedures describing a basic measurements, refer to *Chapter 4: First measurements* (page 33). For details on how to use the charts see *Section 13.3: Charts* (page 179). For advanced imaging settings see *Section 10.5.1: Imaging page*.

The Imaging window is contained within the Measurement pane and can be opened by clicking the Imaging tab. The largest part of the Imaging window consists of a number of charts that display the data from the ongoing measurement: the Chart area. The imaging window can display as many charts as required. Scroll bars will appear automatically as soon as the content is larger than the window can accommodate. By default, two charts groups are displayed: 2 color maps of the sample and their corresponding line graphs. Usually, these show Topography on the left and another measurement signal on the right (e.g. Deflection), depending on the current operating mode. For more information on adding and changing charts, which basically works the same for charts in Operating windows and in stored measurements documents, see *Chapter 13: Working with documents* (page 177).

The Parameter area on the left side of the Imaging window, the so-called Imaging panel, is organized in 3 sections: the "Parameters", "Z-Controller" and "Mode Properties" section. These sections are an integral part of the Imaging window and represent the most commonly used parameters for the currently selected operating mode. Possible parameters in these sections are described in *Section 10.2: Imaging panel*. Advanced parameters can be accessed via the "More" button in each section, which will open the SPM Parameters dialog on the respective page (see *Section 7.9: SPM Parameters dialog* (page 74)).

At the top, the Imaging window contains a toolbar with commands to control the imaging process: the Imaging toolbar. It is described in *Section 10.3: The Imaging toolbar*.

Apart from the necessary settings, several actions have to be performed before being able to image a sample. These are accessed via the Acquisition tab of the Ribbon, the elements of which are described in detail in *Section 10.4: Acquisition tab*.

Before and during imaging, several panels of the Info pane provide additional information for your reference. The relevant panels are explained in *Section 9.2: Video panel* (page 98) and *Section 9.3: Online panel* (page 105). A description of the other panels is found elsewhere in this manual. Please refer to the *Chapter 15: Quick reference* (page 235) to locate them.
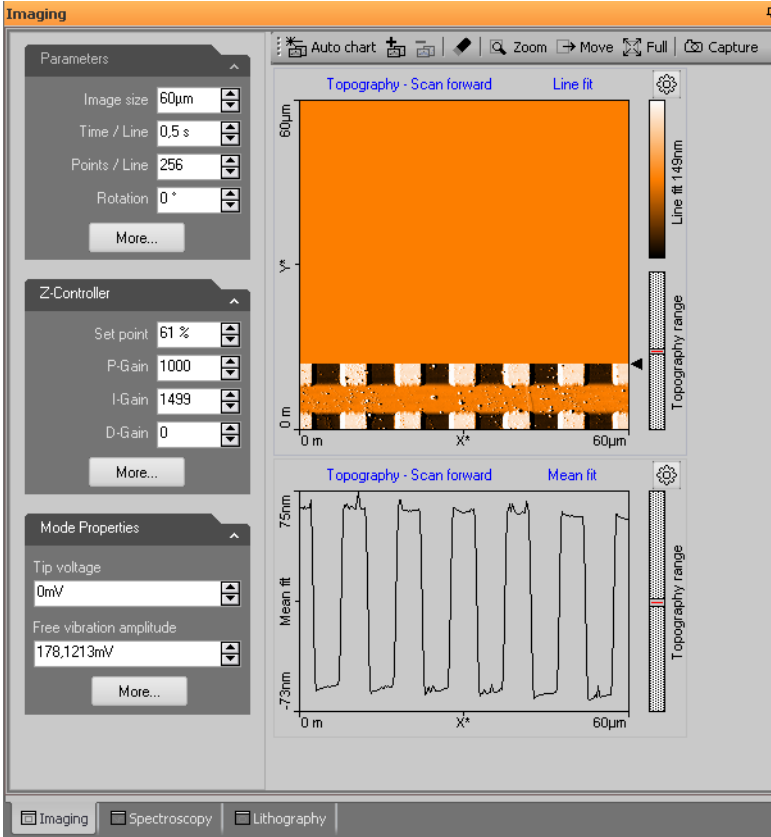
Figure 10-1: The Imaging window

10.2: Imaging panel

The imaging settings use two coordinate systems: the Scanner coordinate system and the Measurement image coordinate system. To separate the two systems, the image axes are denoted by an asterisk (i.e. X*, Y*). The relation between the two coordinate systems is determined by various parameters in the imaging panel. The effect of these parameters is illustrated in *Figure 10-2: Coordinate systems*. In the SPM Control Software, a 'live' schematically illustration is displayed for the active imaging settings in the Scan Position section of the Online panel of the Info pane (see *Section 9.3: Online panel* (page 105)).
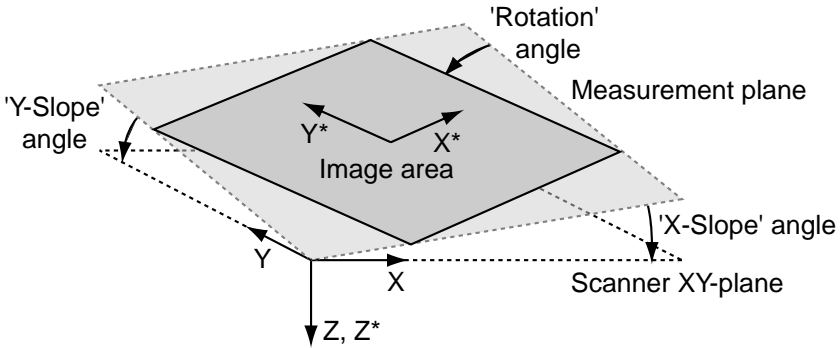
Figure 10-2: Coordinate systems

Imaging Parameter section
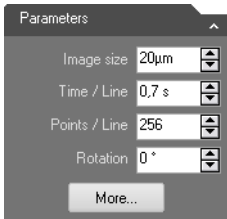
Image size
Defines the image size in both the X* and Y* direction. The size is doubled or halved when the arrows next to the edit box are used.

Time / Line
The time needed to acquire a single data line. The time needed for the entire image is displayed in the status bar.

Points / Line
The number of measured data points per line. It also sets the number of lines to the same value.

Rotation
The angle between the X-direction of the scanner and the X* direction of the measurement (Figure 15-2: Coordinate systems).

"More" button
Opens up the SPM Parameters dialog on the "Imaging" page for more advanced parameters (see *Section 10.5.1: Imaging page*).

Z-Controller section
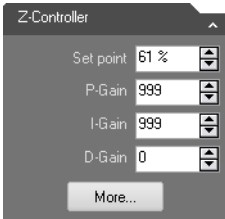
During imaging, the tip–sample interaction is kept constant through the Z-Controller. The Z-Controller is a standard PID controller as is shown in *Figure 10-3: Z-Controller*.
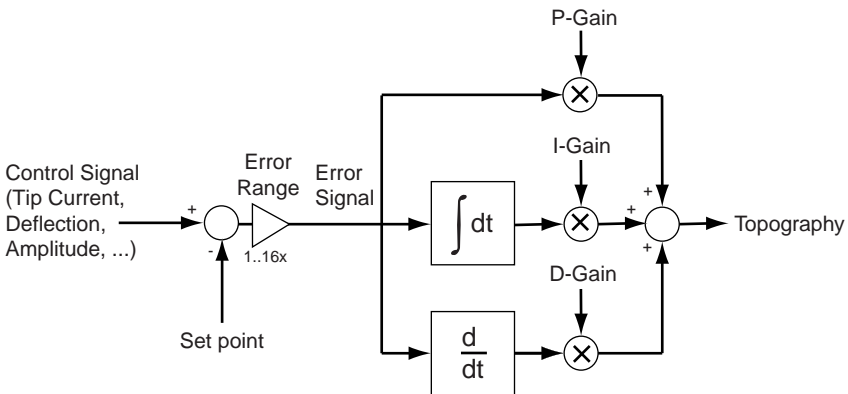
Figure 10-3: Z-Controller

Setpoint
The working point for the Z-Controller. Depending on the operating mode, this is the tunneling current (STM mode), cantilever deflection (static force mode) or relative cantilever vibration amplitude (dynamic force mode). In the later case, the set amplitude is relative to the operating amplitude, set in the Mode Properties Section. For example, when a Setpoint of 70% is used, the Z-Controller will move the tip closer to the sample until the vibration amplitude has decreased to 70% of the vibration amplitude far away from the sample.

P-Gain
The strength of the Z-Controller reaction that is proportional to the error signal. Increasing the P-Gain decreases the error signal.

I-Gain
The strength of the Z-Controller reaction that is proportional to the integral of the error signal. Increasing the I-Gain decreases the error signal over time. It is the least sensitive to noise, and usually the dominant contributor to the topography measurement.

D-Gain
The strength of the Z-Controller reaction that is proportional to the derivative of the error signal. Increasing the D-Gain decreases fast changes in the error signal, but also amplifies high frequency noise.

"More" button

Opens the SPM Parameters dialog on the "Z-controller" page for more advanced parameters (see *Section 8.5.2: Z-Controller page* (page 84)).

Mode Properties section
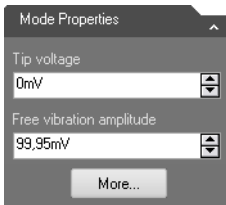
Tip Voltage
This parameter defines the potential to be applied to the tip. The voltage that can be used lies between -10V and +10V.

IMPORTANT

With the STM scan head the sample is automatically connected to the ground of the instrument. With AFM scan heads the sample has to be electrically connected to the instrument's chassis ground for accurate measurements.

Free vibration amplitude
The desired reference amplitude of the cantilever vibration. The cantilever vibrates at this amplitude when it is far away from the sample. The excitation strength is adjusted so that this vibration amplitude is reached.

"More" Button
Opens up the SPM Parameters dialog on the "Operating Mode" page for more advanced parameters (see *Section 8.5.1: Operating Mode page* (page 82).

10.3: The Imaging toolbar
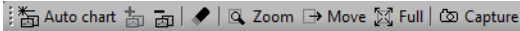
| 📇 Auto chart 📇 📇 | ◆ | 🔍 Zoom ➡ Move ⤢ Full | 👁 Capture |

Auto chart

Using this button, the control software displays all meaningful charts for the currently selected operating mode. The actual number of charts varies depending on the mode.

"+" and "−"

With these buttons you can add and remove chart groups, respectively, but not more than minimally makes sense. There will always be a chart group left. Conversely, you can't add more chart groups than the Auto tool would display. You can however still remove or add charts manually (See 13.7 Working with charts)

Clear old chart data

Deletes chart data from a previous measurement. Old chart data can be deleted at all times, regardless of whether a measurement is running or not.

Zoom

Selects an area that is to be measured in more detail. The size and area of the selected zoom area is displayed in the Tool Results panel.

The zoom area is defined by two opposite corners of the area. Pressing the left mouse button at the first corner and holding it down while moving the mouse pointer to the other corner will create a zoom area of user-defined size. Alternatively, an area that has a third of the current measurement size and a center at the current mouse pointer position is defined with a single mouse click at the desired zoom position.

The area defined by the marker can be resized by dragging one of its corners, or moved to a new position by dragging its center point.

To accept the new zoom area:

➥ Double-click the chart with the left mouse button, or click the "Zoom" button in the Tool Results panel.
This action modifies the parameters "Image size", "Image offset X" and "Image offset Y" in the Imaging page of the SPM Parameters dialog accordingly (see *Section 10.5.1: Imaging page*).

To abort the zoom function

➥ Click Zoom again, or use the right mouse button to select "Abort" in the context menu.

Move

The "Move" button moves the position of the imaged area. An interesting corner can thus be moved to the center of the measurement. The Tool Results panel numerically displays the change in position.
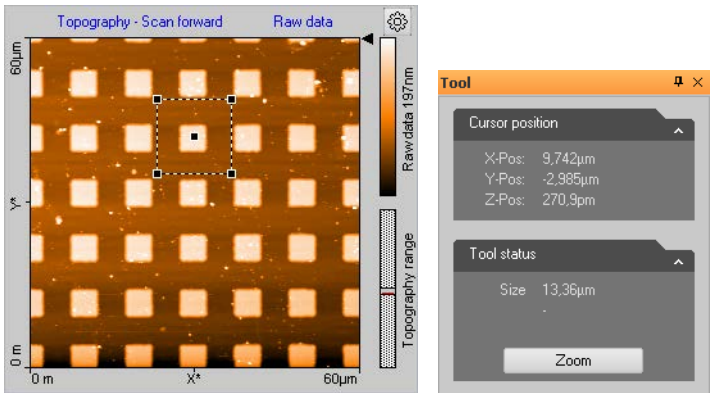
Figure 10-4: Zooming. (Left) The Zoom tool area marker. (Right) The Zoom tool information in the Tool panel of the Info pane.

The change in position is indicated by an arrow. The start of the arrow is defined by the mouse cursor position where the left mouse button is pressed; the end of the arrow by the position where the button is released. With a single click of the left mouse button an arrow ending in the center of the measurement is drawn. The direction of the arrow can be adjusted by dragging its end markers. It can be moved by dragging the center marker.

The image is moved by double clicking, or clicking the "Move" button in the Tool Results panel. To abort the Move function, click the Move-Button again or click the right mouse button and select "Abort" in the context menu.

Full
The Full button returns the parameters Scan range to the largest possible values, and "X-Offset" and "Y-Offset" to zero (see *Section 10.5.1: Imaging page*).

Capture
With the "Capture" button, you can immediately copy the current measurement to the History page of the Gallery panel without waiting for the scan to be completed (see also *Section 13.4: Gallery panel* (page 189)). It is stored as a new document and remains open in the Document space of the SPM Control Software.

10.4: Acquisition tab
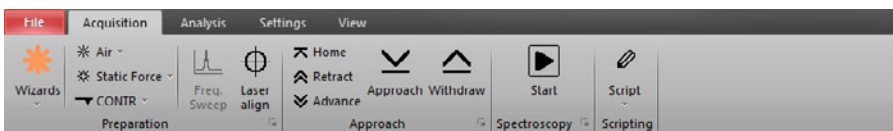
The Acquisition tab of the Ribbon contains several groups that are important for the imaging of samples. While the Preparation group is explained in *Section 8.2.1: Preparation group* (page 78) and the Approach group is explained in *Section 9.5.1: Approach group* (page 109), the Imaging and Scripting groups are described here.

10.4.1: Imaging group
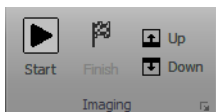
Start
Clicking "Start" starts a measurement and changes the button to "Stop". Clicking "Stop" aborts the measurement as soon as the current scan line is finished.

Finish
Selecting "Finish" will set the "Finish" flag, which will not abort the measurement directly, but will do so when the measurement is finished. Deselecting (i.e., clicking it again) will disable the "Finish" flag so that the measurement will no longer stop automatically when it is finished. The "Finish" button is highlighted when it is flagged.

Up / Down
Starts a single measurement or restarts an ongoing measurement from the selected scanning direction. With the "Up" button the image is scanned from bottom to top. With the "Down" button it is scanned from top to bottom.

Launcher icon
More advanced settings are available through the "Dialog Launcher" icon (at the bottom right corner of the Preparation group), which opens up the SPM Parameters dialog on the Imaging page (see *Section 10.5.1: Imaging page*).

10.4.2: Scripting group
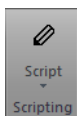
The Scripting Interface is an optional component for creating user defined scripts (software components) to add new features or automating tasks. For details, see "Help Panel" >> "Manuals" >> "Script Programmer's Manual".

> ### Important:
> The Scripting Interface is a purchase option and has to be activated using the Access Codes page (see *Access Code* (page 219) of the Options dialog.

The "Script" button
This button opens the Script Editor Dialog. In this Dialog, a script source code can be Loaded, Edited, Saved and Run directly.

The "Script" button drop-down menu
Accessed by clicking the arrow head at the bottom part of the "Script" button. In this drop-down list, scripts from the standard scripting directory are displayed and can be started by selecting the corresponding menu item. The menu item's name is equal to the script's name without the script extension (*.vbs) and is sorted alphabetically. The standard directory is configured through the Scripting Acquisition and Analysis file paths (accessed via "File" >> "Options" >> "Scripting" (see *Scripting* (page 216)).

At the bottom of the drop-down menu, the "Run from File…" menu item is displayed. It allows selection and execution of a script file anywhere on your harddisk (or other storage media). With the selection of this menu item, a File Open dialog is displayed and a script file can be manually selected. This script file is executed directly after "Open" is selected.

10.5: SPM Parameters dialog

10.5.1: Imaging page
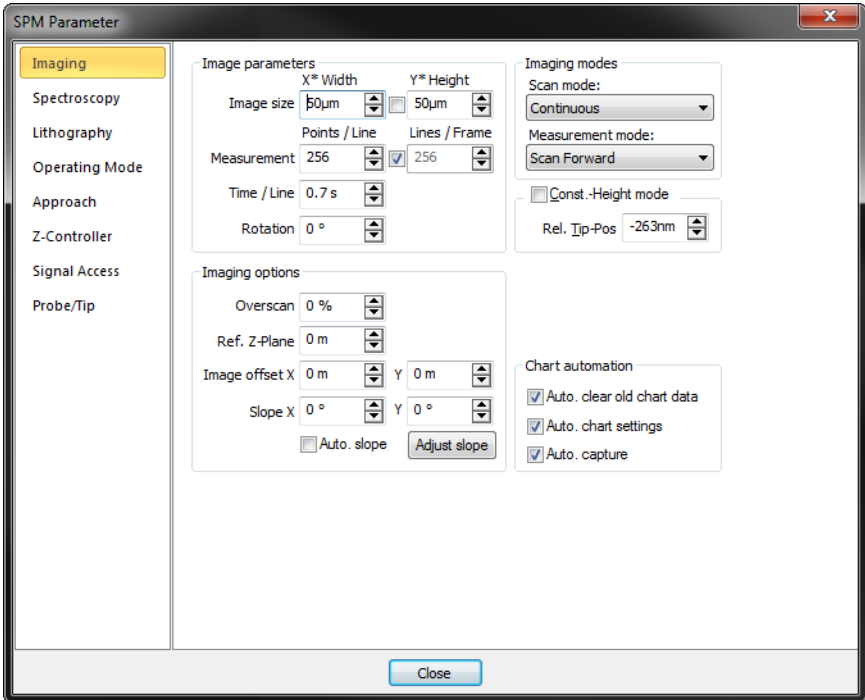
Image parameter

Image size
The image size in X*-direction and the image size in Y*-direction. When the Check-box is active, the image Height is always identical to the Image width.

Measurements
The number of measured data points and data lines in an image. When the Check-box is active, the number of Lines is always equal to the number of Points / Line.

Time / Line
The time needed to acquire a data line. The time needed for the entire image is displayed in the status bar.

Rotation
The angle between the X-direction of the scanner and the X* direction of the measurement (Figure 15-2: Coordinate systems).

Imaging options

Overscan
The "Overscan" determines how much the effective scan range is increased relative to the image width. This will eliminate edge effects caused by the reversal of the scanning motion by not recording or displaying them in the measurement image. Disadvantages of using Overscan are that the maximum scan range is reduced, the tip moves slightly faster over the sample with the same "Time/Line" setting, and the tip may hit large features outside the measured image.

Ref. Z-Plane
The height of the reference plane. This height reference is used when the Z-Controller output is cleared, and when the Z-position is not modulated relative to the current surface position during spectroscopy measurements.

The reference plane for the image can be aligned to the surface of the sample using the slope parameters (see *Figure 5-3: Sample and measurement orientation before slope adjustment* (page 50) or *Figure 10-2: Coordinate systems* (page 122)).

Image offset X/Y
The center position of the measured area.

Slope X
A positive value rotates the image plane around the Y-axis counterclockwise.

Slope Y
A positive value rotates the image plane around the X-axis counterclockwise.

The center position of the measured area can be changed by typing its position as well as by using the Move tool in the Imaging toolbar. The zero position corresponds to the center position of the scanner.

Adjust slope
The "Adjust slope" button will cause the control software to set appropriate values for X- and Y-slope by performing two single line scans (one in X- and one in Y-direction) and determining the respective slopes via line fitting, thus electronically compensating for these measurement plane slopes (see *Section 5.3: Adjusting the measurement plane* (page 49) for details).

Auto slope
Automatically performs the same action as the "Adjust slope" button does. It adjusts the slopes with each new "Start" of imaging.

Imaging modes

Scan mode
This parameter defines how the images are acquired and displayed:

– **Continuous**
  The acquisition direction is reversed after each scan: from bottom to top and vice versa.

– **Cont.Up**
  The acquisition direction is always from bottom to top.

– **Cont.Down**
  The acquisition direction is always from top to bottom.

Measurement mode
This parameter defines how each imaging line is acquired and stored:

– **Forward**
  During forward scan only (left to right in the image).

– **Backward**
  During backward scan only (right to left in the image).

– **Forw.&Backw.**
  During both forward and backward scan.

Const. Height mode

When the Constant Height imaging mode is enabled, the Z-Controller is turned off during the scan (as a consequence, the Probe Status light will blink green). Instead, the scanner scans along a straight line, that should be parallel to the surface. The slope of the line is defined by the X- and Y-Slope parameters. These parameters should be set as described in *Section 5.3: Adjusting the measurement plane* (page 49). The height of the line is determined at the start of each scan line: First the Z-Controller is turned on. Once the tip position is stable, the Z-Controller is turned off and the tip is moved away from the sample by the distance set by the parameter Rel. Tip-Pos.

The Constant Height Imaging mode is mainly useful for EFM and MFM measurements. For more information on how to do Magnetic Force Microscopy, refer to technical note "TN00031 — Operating Nanosurf AFMs in MFM mode" which can be found in the "Technote" section of the Help panel.

Rel. Tip-Pos
This parameter defines the distance by which the Tip is moved towards the sample from the position that corresponds to the Setpoint. A negative setting will move the tip away from the sample.

Chart automation

Auto clear old chart data

Automatically clear the chart data from a measurement when a measurement is restarted (either when a scan is restarted manually, or when a previous scan has finished and measurement recommences as determined by the scan mode (see *Scan mode* (page 131).

Auto chart settings

If checked, the chart arrangement is automatically updated (see also *Auto chart* (page 125)).

Auto Capture

If checked, all measurements are automatically stored in the history Gallery. If unchecked, you have to click the "Capture" button in the Imaging tool bar to manually save your measurement data.

CHAPTER 11:

Spectroscopy

11.1: Introduction
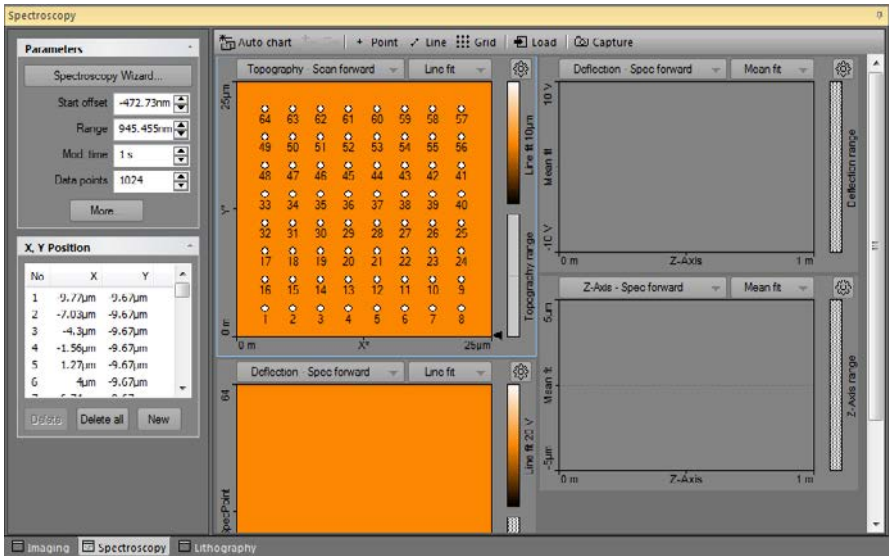
Figure 11-1: Spectroscopy window

Spectroscopic measurements are performed in the Spectroscopy window, which is opened by clicking the Spectroscopy tab in the Measurement pane. The Spectroscopy window contains the Spectroscopy toolbar, with commands that control the spectroscopy processes, and the Spectroscopy panel (parameter area), with parameters that determine how the spectroscopy measurement is performed.

The Spectroscopy window also contains a number of charts that display the data from a previous imaging measurement and the data from the ongoing spectroscopic measurement. The Spectroscopy window can display as many charts as the size of the window can accommodate. It is recommended to display at least two charts, one Color map of a previous Topography measurement of the area where the spectroscopy measurement is performed, and one Line graph of the current spectroscopy measurement. For more information on adding and changing charts see *Section 13.3: Charts* (page 179).

In general, a spectroscopic measurement is a measurement of an input signal as a function of a modulated output. Common spectroscopic measurement types are:

- Force–Distance curves in AFM Static, Spreading Resistance, and Lateral Force operating modes
- Amplitude–Distance or Phase–Distance curves in AFM Dynamic operating modes

- Tip Current–Distance curves for STM operating mode
- Tip Current– Tip Voltage curves in AFM and STM operating modes

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Tip

Use the Spectroscopy wizard ("Wizards" >> "Spectroscopy...") to quickly prepare spectroscopy parameters. The wizard can prepare appropriate parameters for all common spectroscopy modes.

The XY-Position section of the Spectroscopy panel stores a list of points where such measurements are to be performed. To define these positions, the "Point", "Line" or "Grid" tools in the Spectroscopy toolbar help you to define these positions graphically by using the mouse. Alternatively, individual positions can also be defined manually by entering their X and Y coordinates in the XY-Position dialog, opened by clicking the "New" button in the XY-Position section (also see *New* (page 148)). The positions in the list are also shown as numbered circles in the color map chart of the surface (see *Figure 11-2: Example of a multiple position measurement using the Grid tool*).
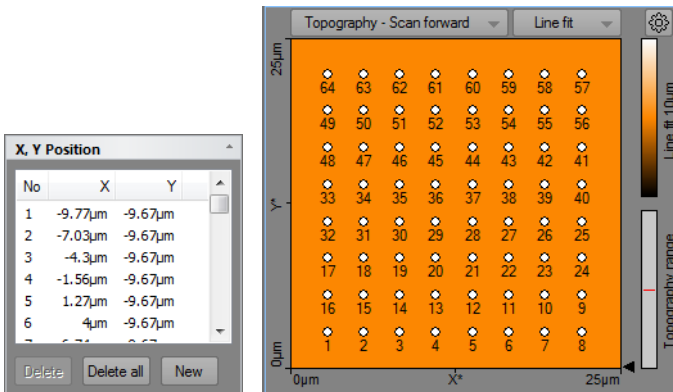
Figure 11-2: Example of a multiple position measurement using the Grid tool. ((Left) List of coordinates. (Right) Measurement positions as shown on the sample surface.

IMPORTANT

In the spectroscopy toolbar, the SPM control software has three graphical tools to define positions using the mouse. Use these graphical tools to easily define X/Y-positions:

`+ Point   ↗ Line   ⋮⋮⋮ Grid` (also see *Section 11.4: Spectroscopy toolbar* (page 148))

Individual points created using any method can be easily repositioned by dragging the respective circle to its new position in the Topography overview chart.

In general, there are two types of modulation methods:

– **"Fixed length" modulation**
This type of modulation has a fixed start and end value. It is freely available with the Standard spectroscopy level (see *Section 11.6.2: Spectroscopy page (standard level)*).

– **"Stop by value" modulation**
This type of modulation has a fixed speed from a start value until a certain measurement value is reached. This type of spectroscopy is only available with the Advanced spectroscopy level (see *Section 11.6.3: Spectroscopy page (advanced level)*).

11.2: Spectroscopy Wizard

The Spectroscopy Wizard helps you to setup the spectroscopy parameters for a spectroscopy experiment:
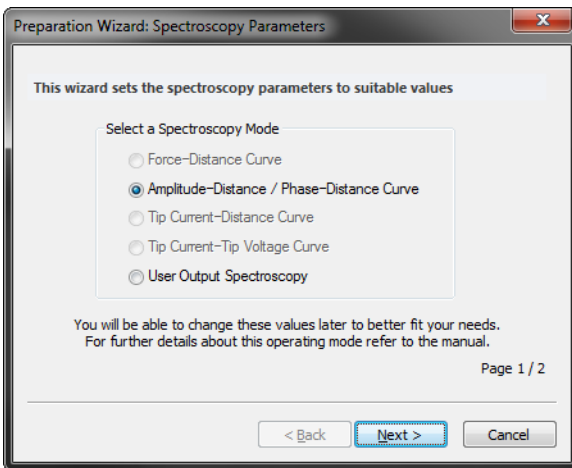
The wizard will set all spectroscopy parameters, modes and settings to reasonable values, so that the desired spectroscopy function is well prepared for almost all cases. The wizard takes overall system settings (e.g Cantilever type, Z- Feedback Setpoint, Free Vibration Amplitude, etc.) into account when it calculates the parameters it proposes as default values.

The Spectroscopy wizard takes you through a two-step process:

1. Select the spectroscopy mode you wish to perform.
2. Accept or change the proposed parameters.

After clicking the "Finish" button, the Wizard sets all spectroscopy parameters. These can be viewed in the Spectroscopy page of the SPM Parameters dialog (see *Section 11.6.1: Spectroscopy page*) and may be adjusted at any time to better fit your needs.

If already approached to the surface, you are ready to start the Spectroscopy by clicking the "Start" button in the Spectroscopy group of the Acquisition ribbon (see *Section 11.5.1: Spectroscopy group*). If no X/Y-Position is defined, spectroscopy will be performed in the center of the image, respecting the selected XY-offset in the imaging parameters.

IMPORTANT

- A disabled spectroscopy mode means that this mode is not available for the currently selected operating mode. "Amplitude–Distance curve", for example, is only possible in "Dynamic Force" or "Phase Contrast" operating modes and not in "Static Force" operating mode.

- A disabled parameter means that it is only available if the Advanced Spectroscopy Level is activated by a correct Access code (see *Access Code* (page 219)).

11.2.1: Force–Distance

The Force–Distance curve is a spectroscopy mode where the cantilever is moved while the deflection signal is measured. With Force–Distance spectroscopy, the typical snap-in and release effect of the tip–sample interaction can be measured. Additionally, the cantilever spring constant and the system's deflection sensitivity can be precisely calibrated (see *Section 14.8.2: Probe/Tip page* (page 232)).

A "fixed length" modulation can be safely performed with the Standard Spectroscopy level when the tip starts at the surface (and the Z-position of the surface is therefore already known) and is subsequently moved away to a retracted position and then back again.

A "stop by value" modulation can only be performed with the Advanced Spectroscopy level since only there the it is possible to enter an appropriate stop value. Here it is also possible to start from a retracted position and then move towards the surface until a given Stop criterion is reached and to retract again afterwards.

A "fixed length" Force–Distance spectroscopy experiment is typically divided into 4 distinct phases (see *Figure 11-3*, Left):

1. Tip is approached (i.e. in contact with the surface).
2. Move the tip to a defined position (Range) above the surface while measuring the deflection signal (and any other input signals that the current measurement mode may allow). This is called the "Forward Modulation phase".

3. Move the tip back to the surface while measuring deflection (and any other input signals). This is the "Backward Modulation phase". Its duration is the same as during the forward phase. The direction is opposite to that of the forward phase.
4. Remain approached (keep Z-controller active). If more spectroscopy measurements are to be performed, move to the next measurement (XY) position (also with active Z-feedback).

A "stop by value" Force–Distance spectroscopy experiment is typically divided into 8 distinct phases (see *Figure 11-3*, Right):

1. Start from a (fully) retracted Z-position.
2. Move the tip to a defined position above the surface (start offset).
3. Move the tip toward the surface and measure the deflection signal (and any other input signals that the current measurement mode may allow). This is called the "Forward Modulation phase".
4. Stop at a defined deflection value (Fwd Stop value) and maintain this Z-position for a certain amount of time. This is called the "Fwd pause phase". During the pause phase, data is still being recorded, but may have a different sample rate.
5. Move the tip away from the sample to a defined position while measuring deflection (and/or other input signals). This is the "Backward Modulation phase".
6. Stop at a defined deflection value (Bwd Stop value) and maintain this position for a certain amount of time, again while recording data. This is the "Bwd pause phase".
7. Change the modulation signal back to its initial value.
8. If more spectroscopy measurements are to be performed, move to the next measurement (XY) position.
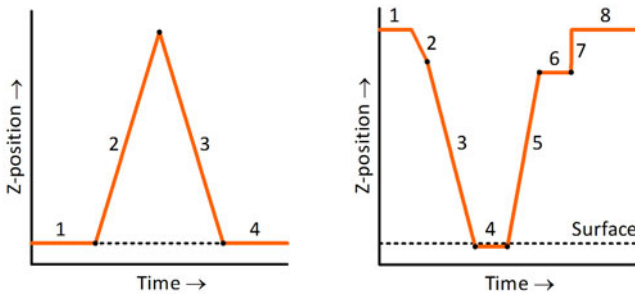
Figure 11-3: Typical phases of Force–Distance curves. (Left) Fixed length (standard) modulation. (Right) Stop by value (advanced) modulation.

IMPORTANT

- Force–Distance Curve is available in all Static force operating modes.

- Cantilevers with low spring constants are typically used.
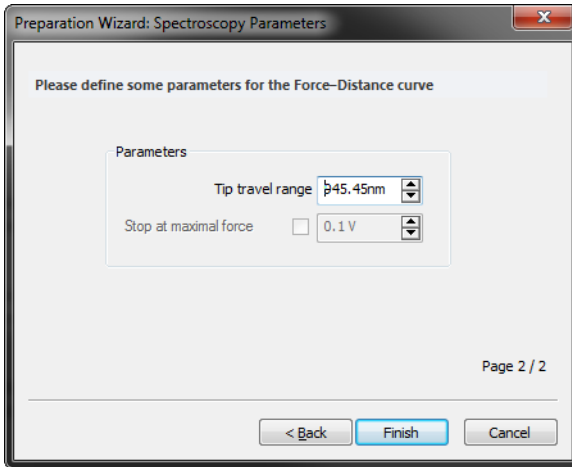
Parameters

Tip travel range
Defines the range of the desired tip movement toward/away from the sample during measurement. In fixed length modulation, this parameter sets the actual forward and backward travel ranges. In stop by value modulation, this parameter sets the maximum travel ranges (if not shortened by the respective stop values).

Stop value
If checked, the forward spectroscopy stops its forward movement as soon as the defined deflection value is reached. This parameter is only available when advanced spectroscopy has been activated via the proper access key.

Results

Typical measurement results will look as follows (Left: fixed length; Right: stop by value):
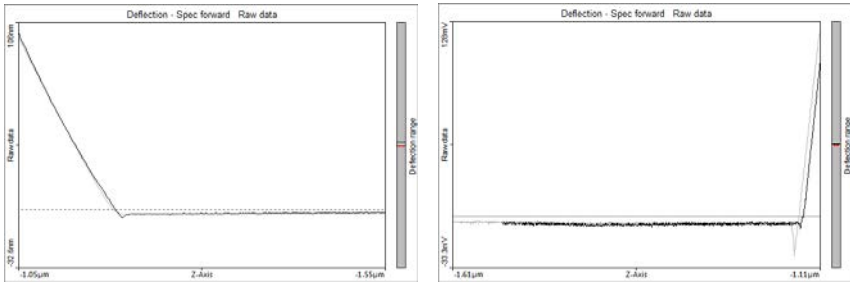
Usage

Force–Distance curves can be easily analyzed in the Nanosurf SPM control software to reveal the system's deflection sensitivity (see below). These can then be entered into the respective fields on the Probe/Tip page of the SPM Parameters dialog (see *Section 14.8.2: Probe/Tip page* (page 232)) and allow the software to correctly express measurement data (voltage) as height information (e.g. in nm). If the cantilever spring constant has been determined and entered in the corresponding field on the Probe/Tip page as well, the software can also accurately express measurement data as Force (in Newton).

To perform a calibration:

❶ Record a Force—Distance curve as described above.

❷ Use the Measure Length tool (see *Measure Length* (page 195)) on the Ribbon's Analysis and draw a line on the descending or ascending part of the force curve (see *Figure 11-4: Deflection sensitivity calibration*, Left).

❸ From the numbers shown in the Tool status area of the Tool panel of the Info pane (*Figure 11-4: Deflection sensitivity calibration*, Top right), divide Height by Width to obtain the slope in V/m. In the example shown in *Figure 11-4*, the slope calculates to 303 mV / 127.9 nm = 2369038 V/m.

❹ To obtain the Deflection sensitivity, divide 10 V (the scale of the AFM detector) by the slope. In the example shown in *Figure 11-4*, this corresponds to 4.221×10^{-6} m.

❺ Enter this number in the Detector Sensitivity field of the Probe/Tip page of the SPM Parameters dialog. In the example shown, 4.221 µm has to be entered (see *Figure 11-4: Deflection sensitivity calibration*, Bottom right).
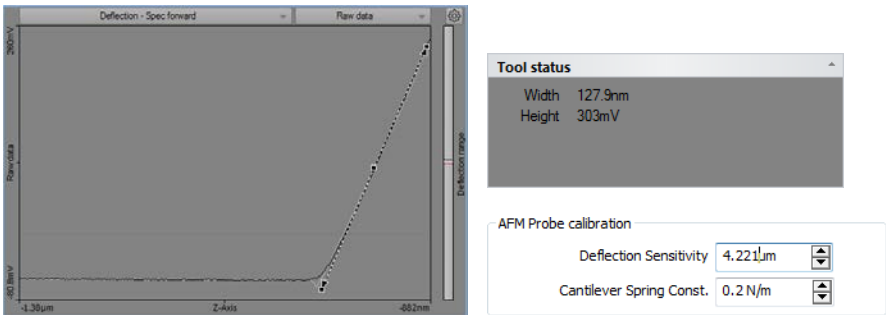
Figure 11-4: Deflection sensitivity calibration.

11.2.2: Amplitude–Distance / Phase–Distance

The Amplitude–Distance / Phase Distance curve is a spectroscopy mode where the cantilever is moved while the amplitude or phase signal is being recorded. With this modulation, the typical amplitude reduction or phase shift effect due to the increasing tip–sample interaction can be measured (see *Results* (page 142)). Note that while both amplitude and phase signal can be recorded simultaneously, only the amplitude signal can be used as Stop value in Advanced Spectroscopy mode.
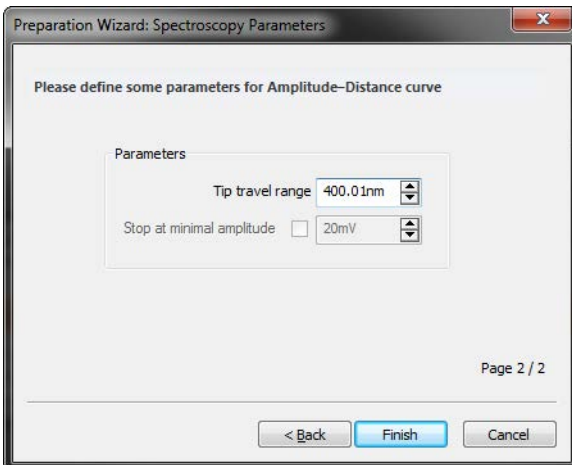
> **IMPORTANT**
>
> - Amplitude–Distance / Phase–Distance Curve is only available in "Dynamic Force" or "Phase Contrast" operating mode.
> - Cantilevers with high spring constants are typically used.

Parameters

Tip travel range
Defines the range of the tip movement.during the forward and backward phases of the spectroscopy measurement.

Stop value
If checked, the forward spectroscopy stops its forward movement as soon as a defined reduced amplitude value is reached. This parameter is only available when advanced spectroscopy has been activated via the proper access key.

Results

Typical measurement results will look as follows (Left: Amplitude; Right: Phase):
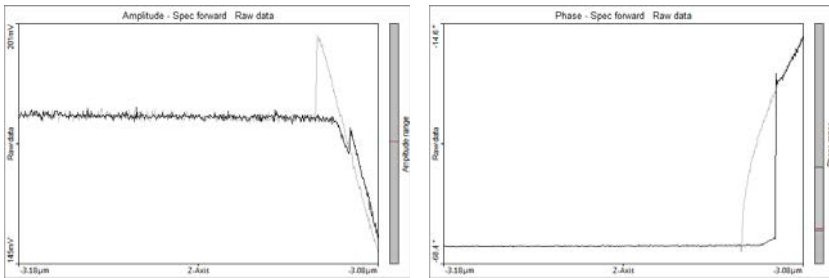
11.2.3: Tip current–Distance

The Tip current–Distance curve is a spectroscopy mode where tip current is measured while the tip is moved. In STM mode, this modulation is typical used to show that the tip current is exponentially increasing when approaching the sample surface.
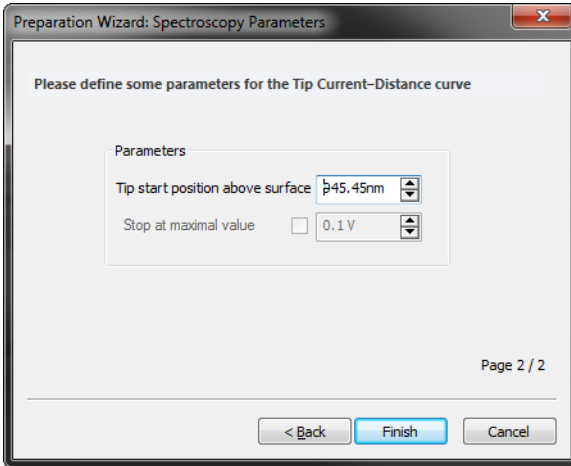
> **Info:**
> - The Tip current–Distance curve is only available in STM mode and in the AFM "Spreading Resistance" operating mode.
> - AFM users must electrically connect the sample to the ground connector on the scan head to apply a tip–sample voltage difference.

Parameters

Tip travel range
Defines the range of the desired tip movement toward the sample during the forward measurement phase.

Stop value
If checked, the forward spectroscopy stops its forward movement as soon as a defined value is reached. In STM mode, the stop value corresponds to a defined tip tunneling current. In AFM Spreading Resistance mode, the stop value does not correspond to a tip current, but (as with Force–Distance measurements) corresponds to a defined deflection signal. The tip current is measured as a separate channel in Spreading Resistance mode.

11.2.4: Tip current–Tip voltage

The Tip current–Tip voltage curve is a spectroscopy mode where the tip is not moved, but where the tip voltage is changed instead. During this voltage change, the tip current signal is measured.

A Tip current–Tip voltage spectroscopy experiment is typically divided into 5 distinct phases (see *Figure 11-3*, Left):

1. Tip voltage is at a resting potential (e.g. 0 V).
2. Tip voltage is set to a positive value (e.g. +5 V).
3. Tip voltage is slowly set to a negative voltage (e.g. –5 V) while the Tip current is being measured.
4. Tip voltage is returned to its resting potential.
5. Tip voltage remains at this potential. If more spectroscopy measurements are to be performed, move to the next measurement (XY) position.
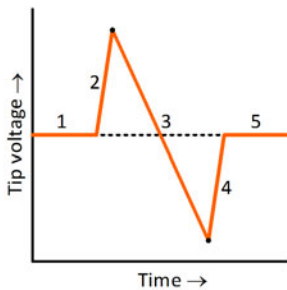
Figure 11-5: Typical Tip Current–Tip Voltage curve. Dotted line represents resting potential.

Info:

*   The Tip current–Tip voltage curve is only available in STM mode and in the AFM "Spreading Resistance" operating mode.
*   AFM users must electrically connect the sample to the ground connector on the scan head to apply a tip–sample voltage difference.
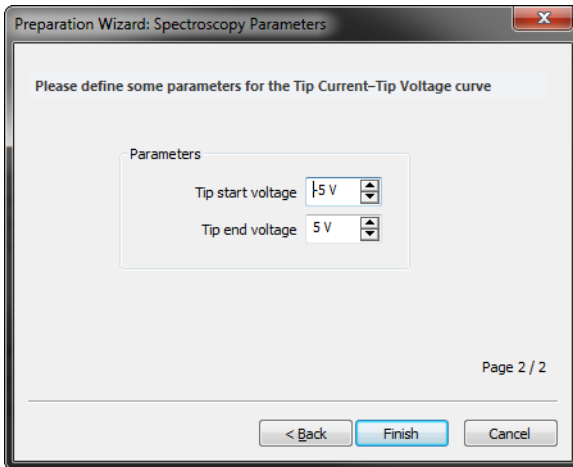
Parameters

Tip start voltage
Defines the start point of the voltage scan.

Tip end voltage
Defines the end point of the voltage scan.

11.2.5: User Output Spectroscopy

The User Output spectroscopy mode can be used to do spectroscopic measurements with external sources controlled by the User outputs of the Signal Module A. During spectroscopy, the currently active signals (defined by the selected operating mode) are measured.
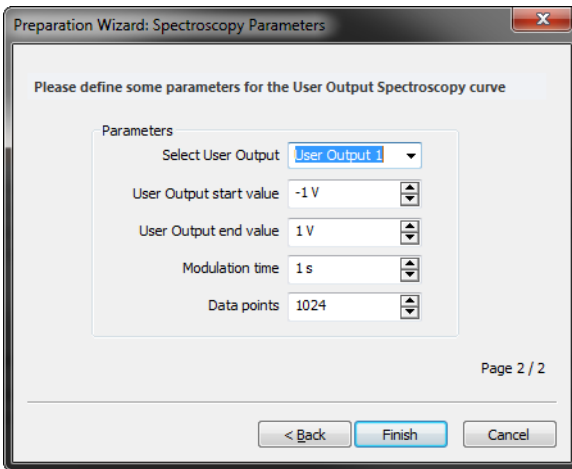
Parameters

Selected User Output
The User Output signal to use for modulation.

User Output start value
Defines the start point of the modulation.

User Output end value
Defines the end point of the modulation.

Modulation time
The time during which the modulation takes place.

Data point
The number of data points to record during modulation.

> **Info:**
> User output spectroscopy is only available if Signal Module A is present in your system.

11.3: Spectroscopy panel

Parameters section
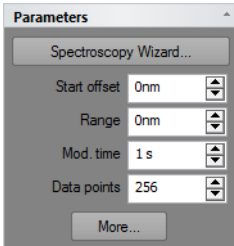
Spectroscopy Wizard
This button starts the Spectroscopy wizard (see *Section 11.2: Spectroscopy Wizard* (page 136) for details).

Start offset
The starting point for the spectroscopy modulation

Range
The range over which the Modulated output is changed. The "Spec Forward" data is measured from the "Start offset" value until "Start offset" + "Range". "Spec backward" data is measured in the opposite direction. The "Spec forward" data is always measured before the "Spec backward" data. For spectroscopy as a function of distance (Z-axis modulation), more negative values are further away from the sample whereas more positive values go towards (or even into) the sample.

Mod. time
The time used to change the Modulated output from its the start to end value.

Data points
The number of data points measured while the Modulation output is changed. The data points are equally distributed over the modulation range.

"More" button
Opens up the SPM Parameters dialog on the Spectroscopy page for more advanced parameter settings (see *Section 11.6.1: Spectroscopy page* (page 150)).

XY-Position section
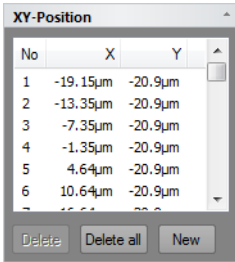
The Position section lists the positions to be used for spectroscopy measurements. The list can be populated using tools from the Spectroscopy toolbar or by adding individual positions using the "New" button (see below). Any position on this list can be moved to a new location by using the mouse to drag the corresponding circle in the overview chart.

Delete
Removes the currently selected measurement position from the list.

Delete all
Removes all measurement positions from the list.

New
Opens up a dialog to add a new XY-coordinate for Spectroscopy measurement.

11.4: Spectroscopy toolbar
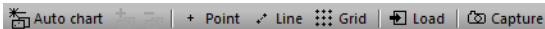
Auto chart
Using this button, the control software displays all meaningful charts for the currently selected operating mode. The actual number of charts varies depending on the mode.

"+" and "−"
With these buttons you can add or remove chart groups, respectively, but not more than what minimally makes sense. There will always be a chart group left. Conversely, you can't add more chart groups than the Auto tool would display. You can however still remove or add charts manually (See *Section 13.3.1: Working with multiple charts* (page 181)).

Point
Activates the single point spectroscopy mode. It defines the position of the spectroscopy measurement by mouse. Click in the topography Color Map chart at the position where the spectroscopy measurement should take place. A small white circle appears at this position. The positions coordinate is transferred to list in the XY-Position section.

Line

Activates the line spectroscopy mode. Defines the start and end position of the spectroscopy measurement by mouse. Click and hold the left mouse button in the topography Color Map chart at the position where the spectroscopy measurement should start. Move the mouse to the end position and release the left mouse button. A line with measurement positions is overlaid on the Color map. The position coordinates are transferred to the XY-Position section of the Spectroscopy panel.

Grid

Activates the grid spectroscopy mode. Defines opposite corners of a rectangular grid of spectroscopy measurements by mouse. Click and hold the left mouse button down while dragging from one corner of the grid to the opposite corner. Releasing the mouse button will overlay the grid's measurement positions on the topography view.

Load

Fills the Topography Color Map chart in the Spectroscopy window with the current measurement of the Imaging window. Selection of "point", "line", or "grid" measurement positions can be performed in this chart.

Capture

A click on "Capture" saves the current spectroscopy measurement data to the History page of the Gallery panel, even when the measurement(s) have not been completed yet. The spectroscopy data are stored as a new document and remain open in the Document space of the SPM software.

11.5: Acquisition tab

During spectroscopy, all groups of the Acquisition tab are identical to those during imaging of the sample, with exception of the Imaging group, which is replaced by the Spectroscopy group.

11.5.1: Spectroscopy group
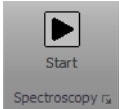
Start
Clicking "Start" starts a spectroscopy measurement sequence and changes the button to "Stop" until the measurement sequence is finished. Clicking "Stop" aborts the measurement sequence as soon as the current modulation period is finished.

Launcher icon
More advanced settings are available through the "Dialog Launcher" icon (⌐ at the bottom right corner of the Spectroscopy group), which opens up the SPM Parameters dialog on the Spectroscopy page (see *Section 11.6.1: Spectroscopy page*.

11.6: SPM Parameters dialog

11.6.1: Spectroscopy page

The Spectroscopy page of the SPM parameter dialog contains all parameters relevant for performing spectroscopy measurements. Two levels of parameter complexity are distinguished and can be selected at the top of the Spectroscopy page:

– Standard Spectroscopy
In this level, Spectroscopy works in fixed-length modulation mode and without pause phases. Forward and Backward phases will always have the same absolute range. This mode serves the most common spectroscopy needs and is easy to operate. For details see *Section 11.6.2: Spectroscopy page (standard level)*.

– Advanced Spectroscopy
In this level, the "Stop by value" modulation modes is also supported and many more parameters for each phase are available. For details see *Section 11.6.3: Spectroscopy page (advanced level)*. This level is only available when it has been unlocked with a valid access key (see *Access Code* (page 219).

11.6.2: Spectroscopy page (standard level)
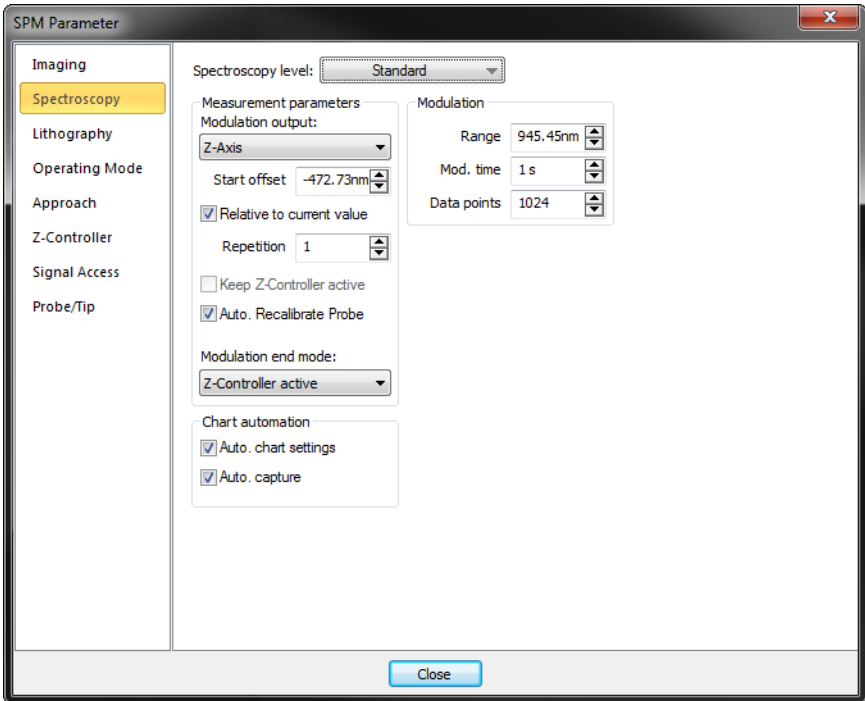
Measurement parameters group

Modulation Output

This parameter defines the output signal used to drive the spectroscopy (horizontal axis in the resulting spectroscopy graph). All possible signals (vertical axis in the spectroscopy graph) are recorded while this modulation output signal is changing its value from Start ("Start offset") to End ("Start offset" + "Range"). The number of available modulated outputs depends on the scan head and the number of installed modules. Possible values are: "Z-Axis", "Tip Potential" and the names of the User Outputs.

IMPORTANT

In Z-Axis modulation mode, positive values mean closer/into to the surface, while negative values are away from the surface.

Start Offset
Defines the absolute or relative start value of the modulated output signal during a new modulation.

Relative to current value
If checked, the start offset value is used as a value relative to the current value. If unchecked the Start Offset is used as an absolute value for the start of a new modulation. In case of Z-Axis modulation, the last known surface position is used as reference point. This means that if the tip was at some point retracted after approach, it still uses the Z-height at which contact was established.

Repetition
This value defines the number of times a modulation measurement is repeated at each XY-Position. Each measurement is stored individually.

Keep Z Controller active
When checked, the Z-Controller will continue to change the Z-position to keep the tip–sample interaction constant. This option is not available when the Modulated output is set to Z-Axis. This setting can for example be used to measure Tip current as a function of applied voltage while keeping the tip–sample force constant. If unchecked, the Z-Axis is kept at its last value prior to the start of the modulation.

Auto readjust probe
If checked, the offset of the probe signal is readjusted prior to each modulation. With this readjustment, changes of the probe's properties over time (e.g. temperature-induced drift) can be compensated.

Modulation End Mode
While moving from one X/Y-Position to the next, this parameter defines the tip's Z-Axis behavior. "Keep last Z-Pos" deactivates Z-feedback while moving and keeps the Z-Axis at the last Z-height. This selection is recommended for positive Range values (in particular during Advanced spectroscopy). "Z-Controller active" activates the feedback during the movement; the surface is tracked. This selection is recommended for negative Range values.

Modulation

Range
This value defines the range over which the output value is changed during the forward modulation phase, starting from Start Offset. The range can be positive or negative (also see *IMPORTANT* (page 151)). The backward modulation automatically follows the reverse direction range. After both (fwd/bwd) modulation phases, the modulation output will be at the Start offset value again.

Mod. time
This value defines the time used to move over the range set by the Range parameter during both modulation phases.

Data points
This value defines the number of data points that will be measured during each modulation phase. The data points are equally distributed over the complete modulation range.

Chart automation

Auto chart settings
If checked, the chart arrangement is automatically updated (see also *Auto chart* (page 148)).

Auto Capture
If checked, all spectroscopy measurements are automatically stored in the history Gallery. If unchecked, you have to click the "Capture" button in the Spectroscopy tool bar to manually save your measurement data.

11.6.3: Spectroscopy page (advanced level)
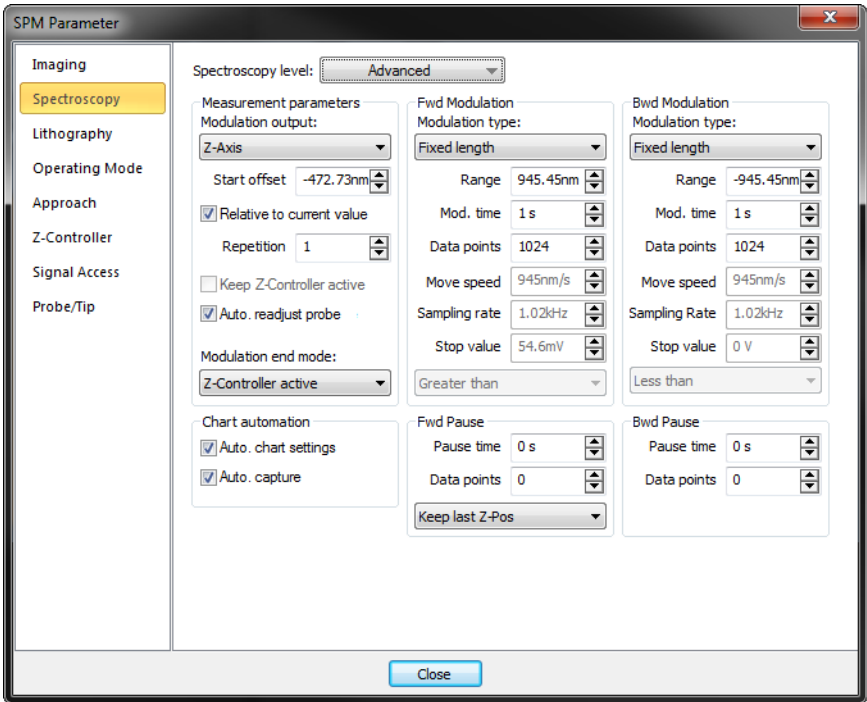
The advanced level of the Spectroscopy page of the SPM Parameters dialog provides much more control over Spectroscopy experiments than the standard level. In addition to the parameters described in *Section 11.6.2: Spectroscopy page (standard level)*, the advanced level Spectroscopy page contains the following elements:

Fwd Modulation / Bwd Modulation

Modulation Type
In "Fixed Length" the modulation phase is exactly defined by Range, Mod. Time and Data points. All measurements (repetitions, different positions) will have the same length. In "Stop by value" this is not the case; only maximum values are given. Since the input channel used for feedback during imaging (e.g. deflection or amplitude) is used to stop each modulation phase at a preset point (see *Stop Value* (page 155)), the lengths of each modulation phase (for each repetition, different position) will most likely be different.

Range
In "Fixed length" modulation, this value defines the change of the output value during the modulation phase. For forward modulation it starts from Start offset. The range can be positive or negative (also see *IMPORTANT* (page 151)). For the backward modulation it starts from the last value of the forward pause phase and with its own Range settings. Therefore, the modulation output value at the end of the backward modulation phase can be different from the start value of the forward phase. In "Stop by value" modulation, this field shows a maximum value, calculated from the Data points, Move speed, and Sampling rate parameters (see below).

Mod. time
In "Fixed length" modulation, this value defines the time used to move over the modulation range during the respective modulation phase. In "Stop by value" modulation, this field shows a maximum value, calculated from the Data points and Sampling rate parameters (see below).

Data points
This value defines how many data points will be measured during the respective modulation phase. Data points will be equally distributed over the entire modulation range. In "Fixed length" modulation, the number of data points are exactly defined by this value. In "Stop by value" modulation, this is the maximum is number of datapoints that will be recorded.

Move speed
In "Stop by value" modulation, this value defines the speed at which the modulation output is changed. The move speed can be positive or negative (also see *IMPORTANT* (page 151)). For the backward modulation it can have a different value than for the forward modulation. Therefore the modulation output value at the end of the backward modulation phase can be different from the start value (Start offset). In "Fixed length" modulation mode, this value is calculated from the Range and Mod. time parameters (see above).

Sampling rate
In "Stop by value" modulation, this value (in Hz) defines the number of data points measured per second during the respective modulation phase. In "Fixed length" modulation, this value is calculated form the Data points and Mod. time parameters.

Stop Value
In "Stop by value" modulation, this value defines the abort criterion that has to be reached in order to stop the respective modulation phase. The signal which is monitored is the Z-controller input signal (e.g. deflection or amplitude) and depends on the selected Operating mode. The value may be positive or negative. In "Fixed length" modulation mode the value shown here has no meaning.

Stop Mode

If "Greater than" is selected the modulation is stopped if the measured value is more positive than "Stop value". If "Less than" is selected the measured value has to be more negative. For Z-Axis modulations, "Greater than" should be selected for Static operating modes and "Less than" for Dynamic operating modes.

Fwd Pause / Bwd Pause

Pause time

This value defines the waiting time after the respective modulation phase before the next phase is initiated.

Data Points

This value defines the number of data points that will be recorded during the respective pause phase. The number of data point recorded during a pause phase can be different from the number of data points recorded during the respective modulation phase. If set to zero, the respective Pause time will be automatically set to zero as well (and vice-versa).

Z-Axis Pause Mode

In "Z-Axis Modulation" Mode (see *Modulation Output* (page 151)), it is possible to select the Pause-Phase behavior via this selector. With "Keep last Z-Pos" it maintains the final value of the modulation phase. With "Z-Controller active" it activates Z-controller feedback during the pause; the surface is tracked.

CHAPTER 12:

Lithography

12.1: Introduction
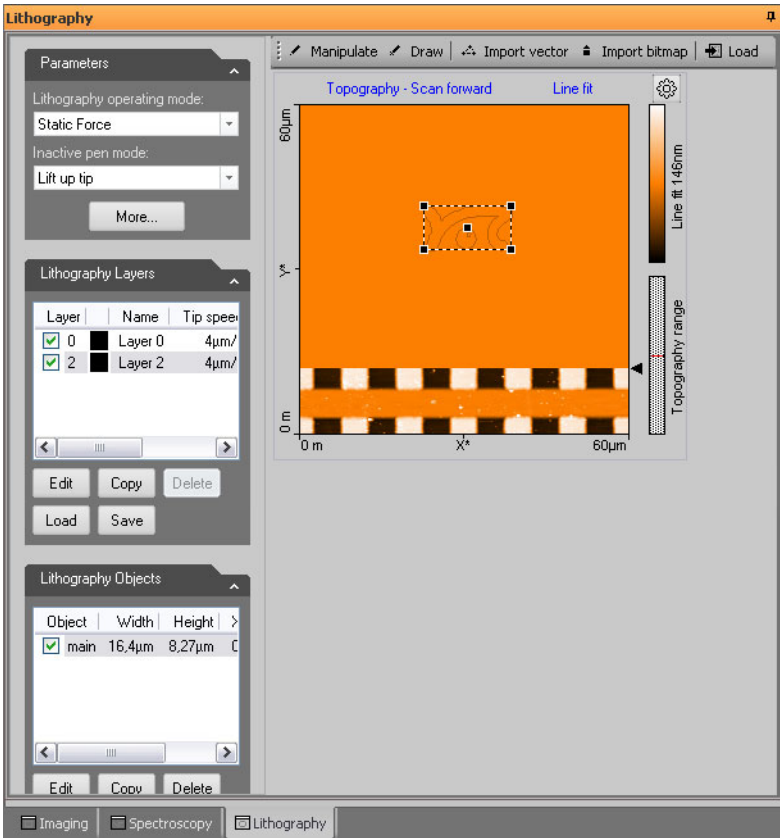
Figure 12-6: Lithography window

In the context of Scanning Probe Microscopy (SPM), Lithography is the process of modifying a sample surface with the goal of creating a pattern on that surface with the SPM tip. In the Nanosurf SPM software, this is accomplished in the Lithography window. The Lithography window is opened by clicking the Lithography tab in the Measurement pane.

The Lithography window contains the Lithography toolbar, with commands that control lithography-related processes, and the Lithography panel, with parameters that determine how the Lithography is performed.

By default, the Lithography window also contains the Lithography Preview display (see *Section 12.6: Lithography preview* (page 174)) and a Color map chart of the current Topography measurement. The Lithography window can however display more charts, should this be desirable. For more information on adding and changing charts, see *Section 13.3.1: Working with multiple charts* (page 181).

> ## IMPORTANT
>
> Lithography of objects drawn by hand and direct manipulation of the tip is available as standard. Issuing of lithography commands through the Scripting Interface requires a license for the Scripting Interface. Import of vector or pixel graphics files to be used as patterns in the lithography process requires the licensed Lithography Option. For information on how to activate the scripting interface or the Lithography Option, refer to *Access Code* (page 219).

12.2: Performing lithography

Lithography can be performed provided that suitable samples, tips, and lithography parameters are used. Depending on the operating mode and operating parameters used during the Lithography process, the surface modifications fall into two distinct categories:

1. Mechanical surface modification through "scratching", "indenting" (both Static Force mode), or through "hammering" (Dynamic Force mode). This type of modification require higher tip-sample interactions then normally used during imaging to mechanically transfer the desired pattern into the sample surface. The width and depth of the scratches or indentations made mainly depend on the force exerted on the cantilever tip and on the tip's shape.

2. Electrochemical surface modification through voltage-dependent surface reactions. This type of modification requires a voltage difference between sample and tip, and will add molecules to the surface (e.g. through oxidation). The width and height of the oxidative surface modifications depend on the relative humidity of the ambient air, on the strength of the electric field, and on the tip speed.

A typical lithography process is performed as follows:

1. The sample surface is imaged to identify an area that is suitable for transfer of a pattern. Suitable areas should preferentially be flat and dust-free.

2. The Lithography window is opened and the "Load" button of the Lithography toolbar is clicked to import the imaged sample surface.

3. A pattern that was previously designed is imported. Suitable sources for patterns can either be (multi-layered) vector graphics files (GDS II, DXF, CIF, OAS, OASIS) or (multi-color/grayscale) pixel graphics files (BMP, DIB, GIF, TIFF, PNG, JPEG). After import of a vector or pixel graphics file, the pattern is referred to as a "Lithography object" in the Lithography window.

> ## IMPORTANT
>
> - In case of vector-based objects, multiple lithography objects may be present (e.g. through sequential import) and used for lithography. In case of pixel-based objects, only one pixel-based object can be present at any given time (other objects will be deleted upon import).
> - A separate CAD program called "LayoutEditor" is included on the installation CD to create suitable GDS vector graphics (Newest version of LayoutEditor; http://layout.sourceforge.net). Pixel graphics files can be created or edited in any pixel-based image editor like the Windows Paint.
> - As an alternative to designing the lithography pattern in a vector or pixel graphics file and then importing it into the lithography software, a freehand drawing mode is available in the Lithography window.

4. The imported object is positioned and scaled to fit the target area.
5. The Lithography sequence is executed.
6. The sample surface is re-imaged to view the Lithography results.

> ## Tip
>
> As alternatives to step 3–5, you can also use the Direct Tip Manipulation or Free Drawing modes.

12.3: Lithography panel

Parameters section

Lithography operating mode
Used to select the operating mode during lithography operation:. The following options are available:

– **Static Force**
– **Dynamic Force**
– **STM (STM only)**

Inactive pen mode

Action to be performed when the tip is moving from one end point to a new start point, in case the end point and start point are not the same. The following options are available:

– Lift up tip

Only lift the tip (upper position of the Z-actuator of the scan head). No feedback will be performed by the Z-Controller during travel to the new start point.

– Standard operating mode

Switch the Z-Controller operating mode back to the one selected in the "Operating Mode Panel" during imaging. All values such as Tip speed, Tip voltage, Setpoint etc. will temporarily chance back to the values used for imaging. The Z-Controller will be active during travel to the new start point.

"More" button

Opens up the SPM Parameters dialog on the "Lithography" page (see *Section 12.7.1: Lithography page*).

Lithography Layers section
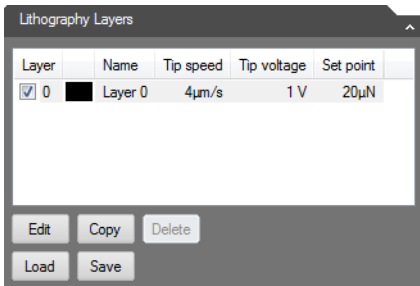
Layer list

Lists all layers that are present in the objects shown in the Lithography Objects list. Layer 0 is always present, even if no lithography objects exists, and may be used to set the default Lithography parameter values (see *Parameters* (page 172) in *Section 12.5.2: Pixel Graphic Import dialog* for details).

Edit

Edit will open the Layer Editor dialog to edit the selected layer.

Copy

Copy will open the Layer Editor dialog (see *Section 12.3.1: Layer Editor dialog*) to edit the selected layer before copying it. When changes have been made (if any) and the "OK" button is clicked, a new layer is generated.

IMPORTANT

Upon creation of a new layer, the layer number will be incremented to the next available layer number. If a total of 256 layers is reached, no more layers can be added.

Delete

Used to delete a layer. Delete will open a warning dialog to confirm the deletion of the selected layer.

IMPORTANT

Only layers currently not assigned to any object can be deleted.

Load

Load a predefined layer list ".lld". Layers that are needed to display the current objects that are not part of the loaded list will be created.

Save

Save all the layers to a layer list file ".lld".

Lithography Objects section
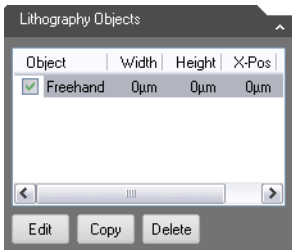
Contains a list of all available Lithography objects. Objects may be selected or deselected by checking or unchecking the checkbox. If the object is unchecked it will not be used for a lithography session.

Edit

Edit will open the Object Editor dialog to edit the selected object (see *Section 12.3.2: Object Editor dialog* (page 165)).

Copy

Copy will open the Object Editor dialog to edit the selected object before copying it.

Delete

Delete will delete the selected object. A warning dialog will appear for confirmation of this action.

12.3.1: Layer Editor dialog
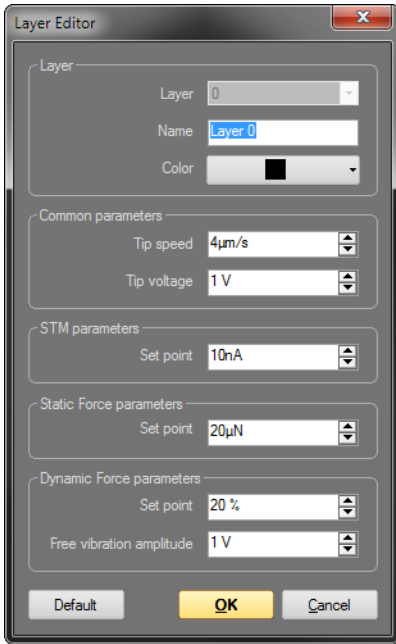
The Layer Editor sets the controller parameter values to be used during lithography.

Layer

Layer
Displays the selected layer's number.

Name
Displays and allows editing of the selected layer's name.

Color
Allows selection of the layer color for display of the layer elements in the Topography chart of the Lithography window.

Common parameters

Tip speed
Determines the drawing speed during lithography,

Tip voltage
Determines the voltage set to the tip during oxidative Lithography.

STM parameters

Setpoint
Used to set the tunnelling current Setpoint of the Z-Controller during STM Lithography.

Static Force parameters

Setpoint
Used to set the force Setpoint of a lithography sequence performed in the Static Force AFM mode.

Dynamic Force parameters

Setpoint
Used to set the amplitude Setpoint of a lithography sequence performed in Dynamic Force AFM mode.

Free vibration amplitude
Used to set the Free vibration amplitude of a lithography sequence performed in Dynamic Mode

"Default" button
Loads the default Lithography parameter values.

12.3.2: Object Editor dialog
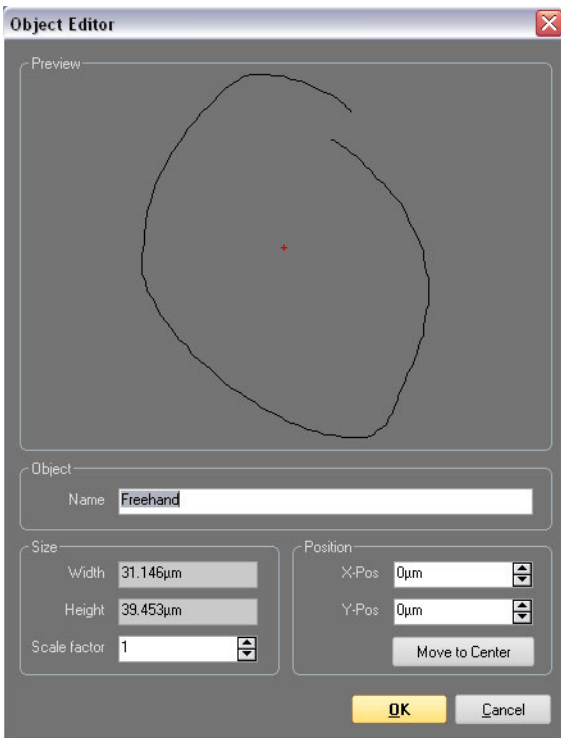
Preview

Graphical area that provides a preview of the selected Lithography object. The red cross (if visible) indicates the origin position of the object.

Object

Name
The name that is used to describe the object. Default names are generated during import, based on the GDS II object names, or on the pixel graphic filename, but may be edited here afterwards.

Size

Width/Height
Displays the width and the height of the object.

Scale factor
The factor by which the object can be scaled. If the scale factor is changed, the width and the height will be automatically recalculated. Scale factor 1 represents the original size.

Position

X-Pos/Y-Pos
The X-Pos and the Y-Pos may be used to move the object within the space of the topography map.

Move to Center
Moves the origin on the selected object back to the center of the topography map.

12.4: Acquisition tab

During Lithography, all groups of the Acquisition tab are identical to those during imaging of the sample, with the exception of the Imaging group, which is replaced by the Lithography group.

12.4.1: Lithography group
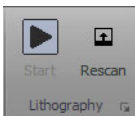
Start
Starts the lithography sequence and changes to "Stop" until the lithography sequence is finished. Clicking "Stop" aborts the sequence.

Rescan
Starts a single image measurement and changes to "Stop" until a full image has been scanned. The image is scanned from the bottom to top. Clicking "Stop" aborts the measurement.

> **IMPORTANT**
>
> When performing imaging from within the Lithography window, be sure to set valid imaging parameters in the Imaging and Z-Controller sections of the Imaging panel.

Launcher icon

The Lithography parameters can also be accessed through the "Dialog Launcher" icon (▣ at the bottom right corner of the Lithography group), which opens up the SPM Parameters dialog on the Lithography page (see *Section 12.7.1: Lithography page*.

12.5: Lithography toolbar

> ⋮ ✎ Manipulate ✎ Draw ⸫ Import vector ▮ Import bitmap ⊞ Load ▢ Capture
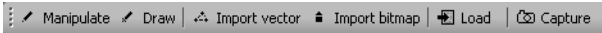
Manipulate

Starts the direct tip manipulation mode. It is now possible to control the movement of the tip by moving the mouse around the topography color map chart. When the left mouse button is held down, Lithography will be performed with the lithography operating mode set in Lithography panel, and with the parameters set in Layer 0 (the Tip speed setting is ignored). When the left mouse button is released, the tip will go to the inactive pen mode set in the Lithography panel, and will not move until the left mouse button is pressed again. Dragging the mouse slowly will produce smoother lines than dragging it fast.

Draw

Starts the free hand drawing mode. A shape can now be drawn in the topography color map chart by clicking and holding the left mouse button. A shape can only consist of a single line. Repeating the above will erase the previous drawing. Double clicking the drawing will save it to the Lithography Object list. The drawn shape can be executed by a click on "Start" in the Acquisition tab.

Import vector

Opens an "Open File" dialog to import a GDS II vector graphic file (extension ".gds"). Other formats (DXF, OAS, OASIS, CIF) can be converted to GDS II using the external program LayoutEditor (provided on installation CD).

IMPORTANT

- Since the Lithography software only supports a subset of the GDS II file format, an error message will appear when a file containing non-supported elements is loaded.
- To avoid most load error messages, the vector graphics project should be fully flattened before saving it as a GDS II file. LayoutEditor and most other CAD programs provide some form of flattening functionality. Refer to the manual or (online) help of your CAD program for details.

For more information on the available import options after selecting a valid GDS II file, refer to *Section 12.5.1: Vector Graphic Import dialog*.

Import bitmap

Opens a "Open File" dialog for importing a BMP, DIB, GIF, TIFF, PNG, or JPEG pixel graphics file.

> **IMPORTANT**
>
> The Lithography software supports files with 256 pixels or less in width and height.

For more information on the available import options after selecting a valid pixel graphics file, refer to *Section 12.5.2: Pixel Graphic Import dialog*.

Load

Loads the Topography image from the Imaging window into the Lithography Topography chart.

Capture

This button captures the measurement currently displayed in the "Lithography window" to the History page of the Gallery panel. If clicked during a measurement, a copy is generated as soon as the measurement in progress is finished. The capture process is cancelled by clicking second time. The captured measurement is stored as a new document and remains open in the Document space of the SPM Control Software.

12.5.1: Vector Graphic Import dialog
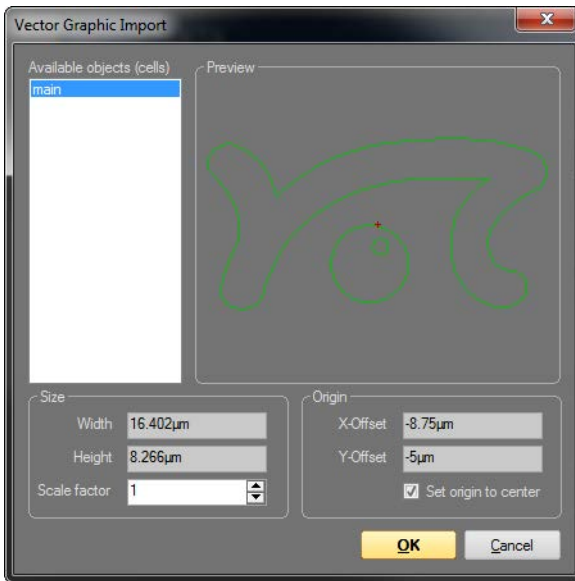
The Vector Graphic Import dialog appears after clicking the "Import Vector" button and selecting a valid GDS II file. It can be used to select the object (cell) of the GDS II file to import. Size and origin of the resulting lithography object can be set during import using the Size and Origin fields (see description below), or after import using the Object Editor (see Section 17.3.2: The Object Editor dialog (page 191) for details).

Available objects (cells)

Contains a list with all valid objects (cells) of the selected GDS II file. Selecting an object will results in the respective object being displayed in the preview area of the Vector Graphic Import dialog, and will cause the selected object to be imported when the "OK" button is clicked. Objects can only be imported one at a time. Clicking the "Cancel" button will abort the import process.

Preview

A graphical area that displays the selected object in the available objects list (see above). The red cross (if visible) indicates the position of the object's origin.

Size

Width / Height
Displays width and height of the selected object (cell).

Scale factor
The factor by which the selected object (cell) will be scaled. A scale factor of 1 corresponds to the original object size. If the scale factor is changed manually, the object's width and height will be recalculated and displayed automatically.

Origin

X-Offset / Y-Offset
The X-Offset and the Y-Offset of the origin of the selected object (cell).

Set origin to center
When enabled, the origin of the object (cell) will be set to the center of the rectangle that encloses the object. When disabled, the origin will remain at the position that is defined in the object.

12.5.2: Pixel Graphic Import dialog
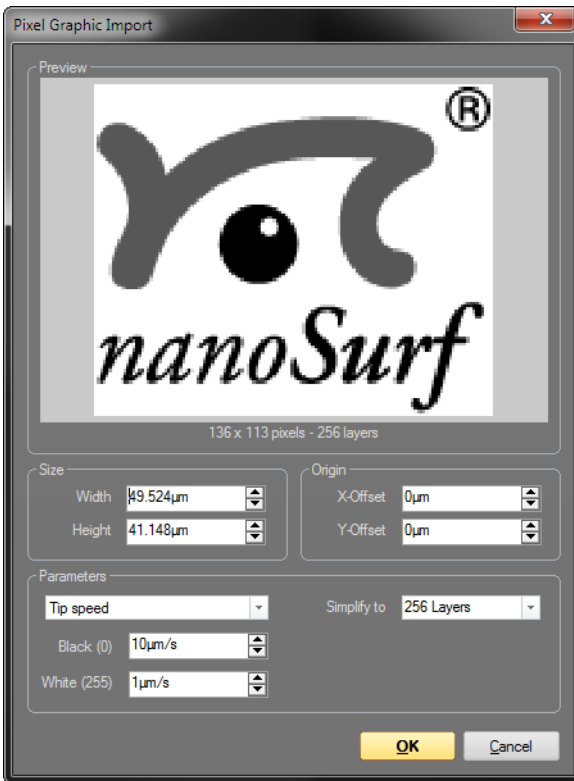
The Pixel Graphic Import dialog appears after clicking and selecting a supported pixel graphics file, and can be used to specify how such a file is converted to a lithography object. All images are first converted to an 8-bit grayscale (256 levels). Each set of pixels with the same grayscale value will correspond to a separate layer in the resulting lithography object. Layers will only be generated for those grayscale values that are actually occupied. In addition, the number of layers can be reduced upon import (see Simplify to (page 186)).

For each layer, individual lithography parameters can be set. One of these lithography parameters can be automatically varied upon import, by using the grayscale values of the imported pixel graphics file to define the selected parameter's range (see Parameters below). All parameters can of course always be modified manually after import (see Section 17.3.1: The Layer Editor dialog (page 188)).

Preview

Graphical area that displays the selected pixel graphics file and information about the file.

Size

Width / Height
The width and the height of the lithography object resulting from the Pixel Graphic import. The default settings for width and height are taken from the dimensions of the current color topography map of the Lithography window. The pixel graphic is automatically resized to fit into the area defined by these dimensions while maintain its aspect ratio. It is at this point however possible to change the automatically calculated size manually. If the width is changed manually, the height is recalculated to keep the aspect ratio. If the height is changed manually, the width is not recalculated.

Origin

X-Offset / Y-Offset
By default the origin is in the center of the pixel graphic. By manually changing X-Offset and Y-Offset, the origin may be moved to a different position.

Parameters

This area allows selection of the lithography parameter that will be automatically varied, based on the different grayscale values of the imported pixel graphics file. The parameter values for the black and white pixels of the imported pixel graphic can be set, after which the parameter values corresponding to any in-between grayscale values are interpolated.

IMPORTANT

Since it is only possible to select one automatically adjusted lithography parameter per import, the other parameters must be set elsewhere. This is achieved by setting the Layer 0 parameters before import. The values entered here will be used as default values for all imported layers, except for the parameter that was explicitly selected in the Pixel Graphics Import dialog.

All values and settings in the parameters section are stored when the dialog is closed. They will be automatically used the next time the dialog is opened.

From the drop-down list box, one of the following parameters may be selected for automatic calculation:

– **Tip speed**
– **Tip voltage**
– **STM Setpoint**

– **Static Force Setpoint**
– **Dynamic Force Setpoint**
– **Dynamic Force Amplitude**

Black / White
Used to enter the parameter values for black and white pixel values, which form the basis for the interpolation of the in-between color/grayscale pixel values.

Example

Setting the automatically adjusted Lithography parameter to "Static Force Setpoint", and Black (layer 0) and White (layer 3) to 25 µN and 10 µN, respectively, will result in:

- Layer 0 (black pixel layer) having a Static Force Setpoint of 25 µN
- Layer 1 (gray pixel layer 1) having a Static Force Setpoint of 20 µN
- Layer 2 (gray pixel layer 2) having a Static Force Setpoint of 15 µN
- Layer 3 (white pixel layer) having a Static Force Setpoint of 10 µN.

Simplify to
Select the number of layers the imported pixel graphics file should be simplified to. Selecting the number of layers to be identical to the number of grayscale values in the pixel graphics file will results in no simplification taking place. In all other cases, simplifications are performed through binning of layers.
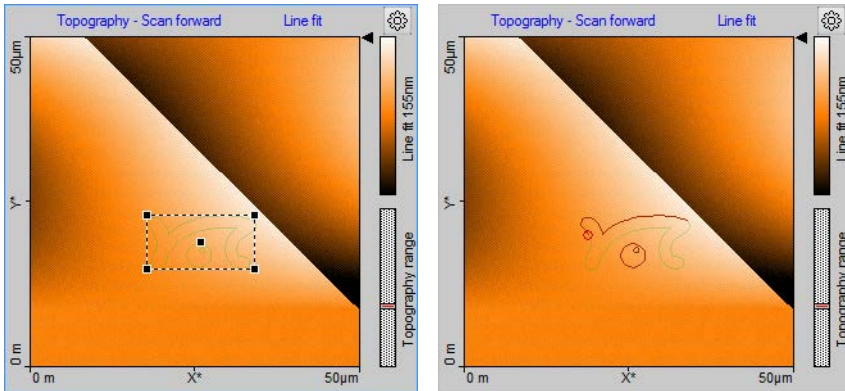
12.6: Lithography preview

Figure 12-7: Lithography preview. (Left) Before the Lithography sequence has been started. (Right) While the Lithography sequence is running.

The Lithography Topography chart is the only chart present in the Chart area of the Lithography window (*Figure 12-7: Lithography preview*, left). It displays the topography image of the sample surface to be used for lithography (after the Topography information has been loaded via the "Load" button of the Lithography toolbar (see *Load* (page 162)) and the superimposed preview images of the Lithography objects (when these have been loaded and selected; see *Import vector* or *Import bitmap* (page 168)).

Before running a lithography sequence, a box with the size and content of the selected lithography object is superimposed on the surface map. When selecting the center of the box with the mouse, the corresponding object can be moved around the scan area to reposition it. The new object location (X-Pos and Y-Pos) is however only transferred to the object's properties (as displayed in the Lithography Objects list, and graphically shown on the Topography chart) when the selection box is double-clicked after repositioning. If it is not, any changes made are not implemented. Position of an object (and in addition its size) can also be modified by editing the respective parameters for the selected object inside the Lithography Object Editor dialog (see *Section 12.3.2: Object Editor dialog* (page 165)).

When a lithography sequence is started, the selection box will disappear, while a red circle and a darker red trace line will be drawn on the Lithography object preview to provide a live progress report on the Lithography drawing process (see *Figure 12-7: Lithography preview* (page 174), right). After a lithography sequence has been completed, the red line and circle will remain visible until a new lithography sequence is started.

12.7: SPM Parameters dialog

12.7.1: Lithography page
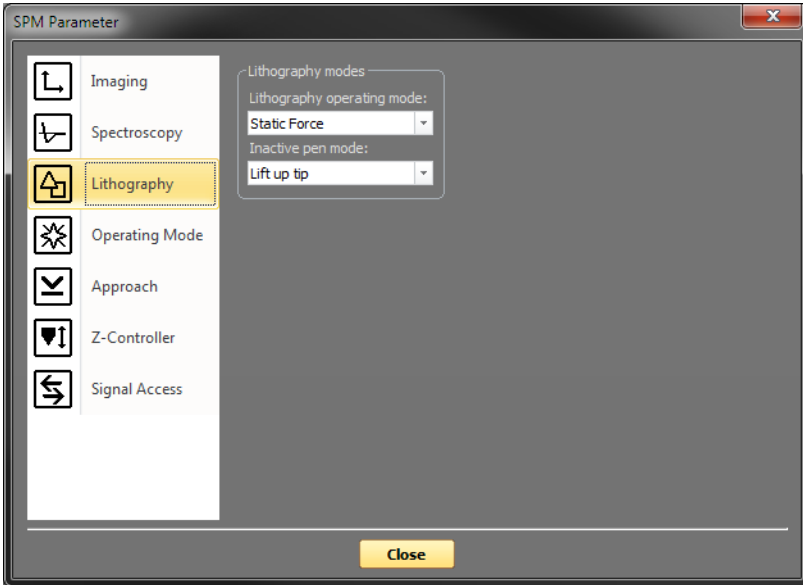
Lithography modes

Lithography operating mode
Used to select the operating mode during lithography operation. The following options are available:

– **Static Force**

– **Dynamic Force**

– **STM (STM only)**

Inactive pen mode
Action to be performed when the tip is moving from one end point to a new start point, in case the end point and start point are not the same. The following options are available:

– **Lift up tip**
  Only lift the tip (upper position of the Z-actuator of the scan head). No feedback will be performed by the Z-Controller during travel to the new start point.

– **Standard operating mode**
Switch the Z-Controller operating mode back to the one selected in the "Operating Mode Panel" during imaging. All values such as Tip speed, Tip voltage, Setpoint etc. will temporarily chance back to the values used for imaging. The Z-Controller will be active during travel to the new start point.

Chart automation

Auto chart settings
If checked, the chart arrangement is automatically updated (see also *Auto chart settings* (page 176)).

Auto Capture
If checked, all Lithography measurements are automatically stored in the history Gallery. If unchecked, you have to click the "Capture" button in the Lithography tool bar to manually save your measurement data.

CHAPTER 13:

Working with documents

13.1: Introduction

When working with the Nanosurf SPM Control Software, all finished measurements (a full image was recorded) will be temporarily stored according to the file name mask you specified in the Gallery panel (see *Section 13.4: Gallery panel*). These measurement documents can be opened and displayed in the document area of the SPM Control Software's workspace (see *Section 7.1: General concept and layout* (page 64) and *Section 7.4: Document space* (page 68)). It is strongly recommended to permanently store relevant documents to a new folder (see *Save as* (page 190) in *Section 13.4.3: Gallery toolbar*).
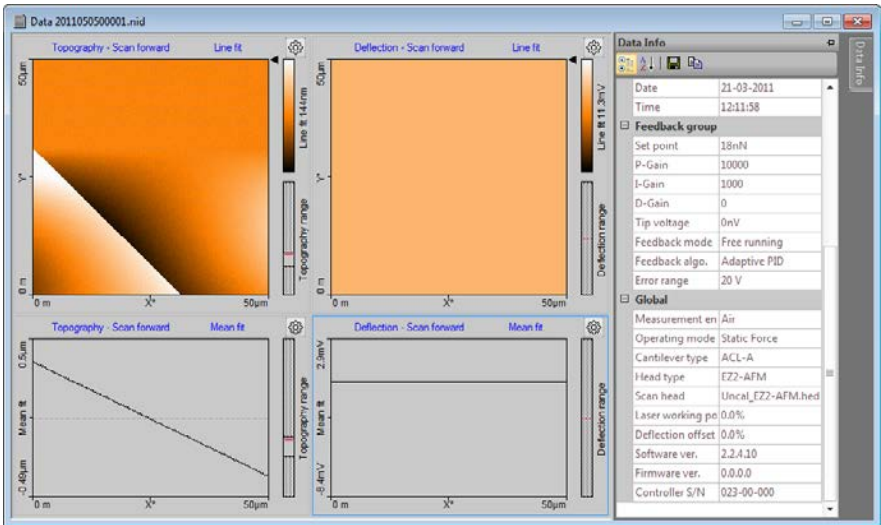
Figure 13-1: Measurement document. Typical measurement window with the Data Info panel expanded (see *Figure 7-4: Example of a measurement document window* (page 68) for a window with a minimized Data Info panel).

Charts and the Data Info panel together display all available measurement information.

13.2: Data Info panel

The Data Info panel (minimized by default, but expanded upon hovering of the mouse cursor over the Data Info tab on the right side of the measurement document window) displays measurement settings and the hardware used during the measurement. Its content is self-explanatory and will therefore not be discussed in this manual.

Just like the panels of the Info pane, the Data Info panel can be "pinned" and "unpinned" to disable or enable the Auto-hide function of the panel (see *Section 7.5: Panels* (page 69)). It cannot be undocked from the document window, however.

The Data Info panel also contains a small toolbar, which allows you to customize the presentation of the data and offers ways to export it.

13.2.1: Data Info toolbar

Categorized
The "Categorized" button ( ) will group the data entries for the measurement document by category. This is the default display method of the Data Info panel.

Alphabetical
The "Alphabetical" button ( ) will sort the data entries for the measurement document alphabetically.

Save
The "Save" button ( ) will save the information in the Data Info panel to file. Possible formats are text (.TXT) and comma separated values (.CSV) files.

Copy to Clipboard
The "Copy to Clipboard" button ( ) will copy the entries of the Data Info panel to the Windows clipboard for easy pasting into other applications.

13.3: Charts

Charts provide a graphical display of the measured data. Charts occur in Measurement document windows, in Operating windows, and in various other windows and dialogs. You can adjust them to your needs and liking. How to do this is explained in this section. This information is valid for charts in stored measurement documents as well as for ongoing measurements in one of the Operating windows (*Imaging*, *Spectroscopy*, and *Lithography*).

A Chart consists of a graphical representation of the measured data itself and elements that provide additional information. There are three basic chart types: Line graph, color map and 3D view (see *Figure 13-2: Elements of a chart*, items 1–3).

Chart titles

The title elements of each chart display the signal name and the background line filtering type that are used. A click on each of these titles opens a drop-down menu with other possible signals or filters:
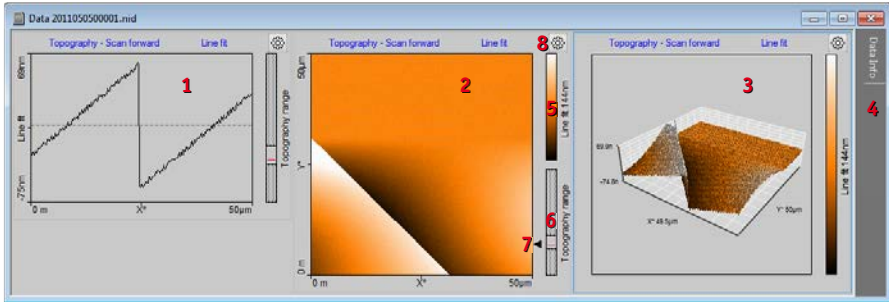
Figure 13-2: Elements of a chart. (1) Line graph. (2) Color map. (3) 3D view. (4) Data Info panel (see *Section 13.2: Data Info panel*). (5) Color scale for data Z-range. (6) Data range indicator, with scan head Z-range as dotted box, data Z-range as solid gray box and current scan line height as red line. (7) Line selection arrow. (8) "Chart Properties" button.
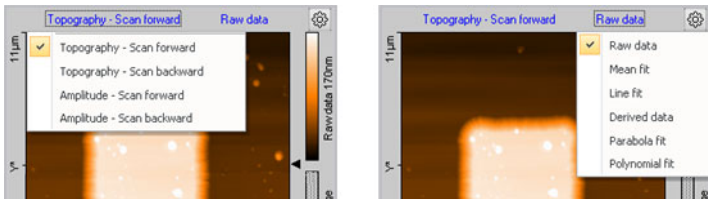
Changing the titles will change the content of the chart.

Color scales

The Color scale (*Figure 13-2: Elements of a chart*, item 5) shows which measured signal level is mapped to which color. The color mapping can be changed using the Color Palette dialog (see *Section Color Palette* (page 215)) .

Data range indicator

The Data range indicator (*Figure 13-2: Elements of a chart*, item 6) shows the Z-range of the scan head and of the values occupied by the measured data, and the current scan line height.

Hovering with the mouse cursor over the Color scale or Data range indicator of a color map chart opens a height histogram graph and two range selectors:

This histogram displays the current height distribution of the measurement data and the used color range. With the top and bottom range selectors, the color bar range can be adjusted to the actual height distribution of the measurement data. Changing these range settings changes the "Center" and "Span" parameters of the Chart Properties dialog (see *Section 13.3.2: Chart Properties dialog*) and immediately updates the color display of the data in the chart.

Line selection arrow

With the Line selection arrow (*Figure 13-2: Elements of a chart*, item 7) the shown data line on line charts displaying the same signal can be changed by holding down the left mouse button over the arrow and move the mouse up or down.

Chart properties

The "Chart Properties" button (⚙ ; *Figure 13-2: Elements of a chart*, item 8) opens the Chart properties dialog. This dialog is the center of all chart parameters and is described in more detail in section *Section 13.3.2: Chart Properties dialog*.

Most chart settings can also be accessed from a context menu, which is opened by right-clicking a chart.

13.3.1: Working with multiple charts

In some windows, multiple charts can be displayed and configured by the user at anytime (e.g. in the Imaging window or a Document window). The same signal can be displayed in different styles (e.g Line Graph and Color map) and / or multiple signals can be shown side by side (e.g. Topography and Phase Signal).

Adding or removing a chart, or setting chart parameters is all performed in the Chart Properties dialog (see *Section 13.3.2: Chart Properties dialog*). When opened, the settings displayed in the Chart Properties dialog refer to the currently selected chart. This (active)

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chart is indicated by a thin blue line around the chart area. A chart is activated by clicking on it with the mouse cursor anywhere in the chart area.

Arrangement of the charts is performed automatically by the control software based on the size of the window and based on the order in which the charts were generated/added. If the window is to small to display all charts, scrollbars are displayed at the border of the window.

Short cuts to add and remove charts are found in the chart context menu. Select "Create new chart" or "Delete current chart" from the menu list. It is also possible to use the "Insert" or "Delete" key of your computer's keyboard for this task. In all Operating windows, "Add Chart" and "Remove Chart" buttons ("+" and "−") can be found in the respective measurement toolbar.

13.3.2: Chart Properties dialog
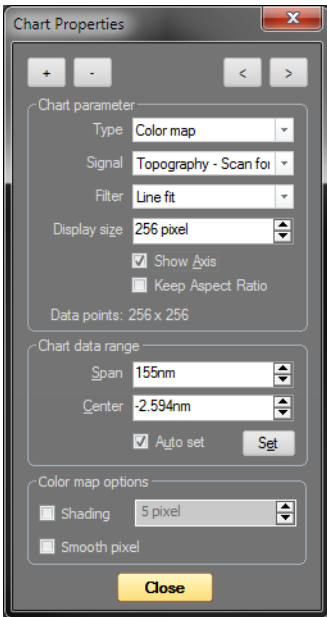
The Charts Properties dialog is used to set all chart properties that influence data display by the respective chart. It may be kept open at all times if many parameters have to be set for different charts.

Some parameters are chart type specific. They are therefore displayed at the bottom of the Chart Properties dialog in a separate group.

Add chart

The "Add Chart" button (+) creates a copy of the currently selected or active chart and adds it to the active window in last position.

Remove chart

The "Remove Chart" button (-) removes the currently active chart.

Previous chart

The "Previous Chart" button (<) activates the previous chart and updates the parameters displayed in the Chart Properties dialog to those of that chart.

Next chart

The "Next Chart" button (>) activates the next chart and updates the parameters displayed in the Chart Properties dialog to those of that chart.

Chart parameters
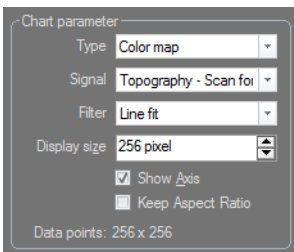
Type
Selects the chart type to be used for display of the measurement data:

– Line graph
Data is displayed as a line plot. Points outside the range of the scanner are displayed in red. The line being displayed is selected by dragging the Line selection arrow in a Color map (see *Line selection arrow* (page 181)). In ongoing measurements (e.g. during imaging) the position of the Line selection arrow is updated automatically and corresponds to the last measured scan line (but even here it is possible to select a different line for view in a line graph by dragging/holding the Line selection arrow in a different location).

– Color map
Z-height data is encoded using a color scale and displayed 2-dimensionally.

- **3D view**
  Data is shown in a 3-dimensional representation in parallel perspective. Color information (such as implemented in the Color map) is maintained.

Signal
Selects the input channel (signal data) to be used for the chart. The available signals depend on the operating mode (selected or used) and the status of the User inputs.

Filter
Selects the line filter method. The control software applies this filter to the measured data before displaying it (see *Figure 13-3: Data filter types*). No modification of the original measurement data occurs (selecting another filter is always possible). Available data filters are:

- **Raw data**
  No data processing.

- **Mean fit**
  Calculates the mean value of each line of data points and subtracts this number from the raw measurement data for each data point of that line.

- **Line fit**
  Calculates the first order least squares fit (mean value and slope) for each line of data points and subtracts the fitted values from the raw measurement data for each data point of that line.

- **Derived data**
  Calculates the difference between two consecutive data points (derivative) and displays this instead of the raw image data.

- **Parabola fit**
  Calculates the second order least squares fit for each line of data points and subtracts the fitted values from the raw measurement data for each data point of that line.

- **Polynomial fit**
  Calculates the fourth order least squares fit for each line of data points and subtracts the fitted values from the raw measurement data for each data point of that line.

Display size
The size of the chart in pixels.

Show Axis
When checked (default), the axis labels, color and range scales, and titles are displayed alongside the graph. When unchecked, they are hidden.

Keep Aspect ratio
When checked, the axis in the color map are drawn in their correct size-relation (according to their value and unit). When unchecked (default), the size of the display is always a square and data pixels are stretched if necessary.
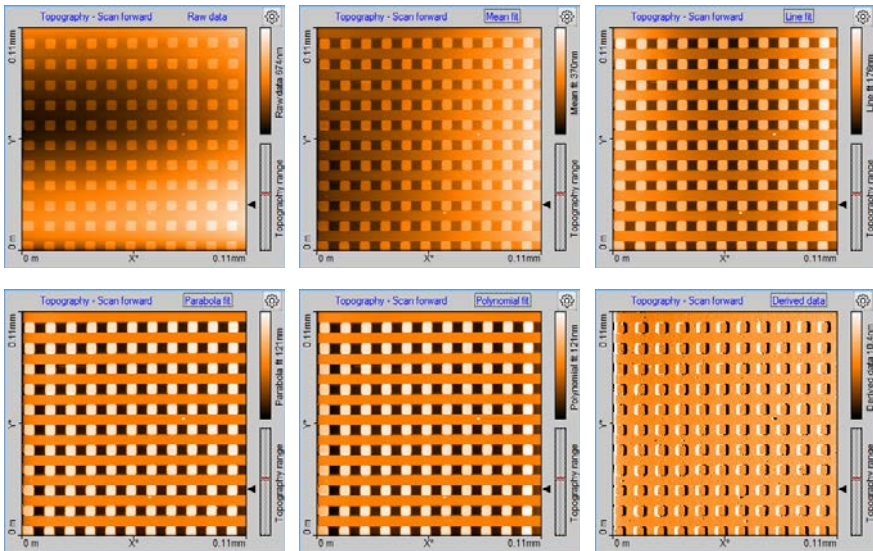
Figure 13-3: Data filter types. The same measurement data displayed using the available filters. A defective area on a calibration grid is shown here to illustrate the effect of the filters.

Chart data range
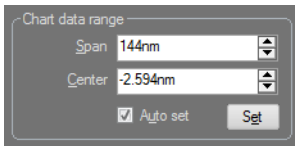
Span
The span that corresponds to the chart's displayed Z-range. Increasing Span decreases feature contrast and vice-versa. The current span is displayed next to the color scale in color maps, or can be inferred from the Z-axis labels in Line graphs and 3D views.

Center
The signal value that corresponds to the center of the "Span" parameter.

Auto set
When checked, the chart's Z-range is automatically set to optimally match the measurement data. During measurements, the Span and Center parameters will be updated continuously (i.e., the chart adapts to the available data).

Set button
Clicking this button starts the optimization of the Z-range manually. Mostly used when "Auto set" is off.

Line graph options
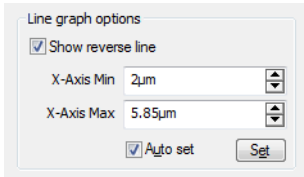
Show reverse line
When checked, the reverse scan data is drawn in gray (see *Figure 13-4: Show reverse line option*. It allows comparison of the forward and reverse measurements data. Whether or not this data is available depends on the measurement mode used during the acquisition of the data (see *Measurement mode* (page 131).
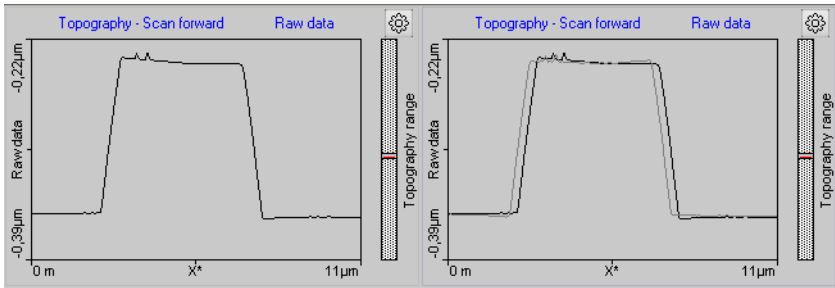
Figure 13-4: Show reverse line option. (Left) Reverse line disabled. (Right) Reverse line enabled.

X-Axis Min
Defines where the X-axis will start. Can be used to zoom in or out to a specific data range.

X-Axis Max
Defines where the X-Axis will end. Can be used to zoom or out to a specific data range.

Color map options
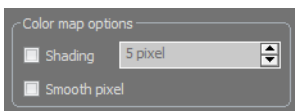
Shading

When checked, the color map creates the impression of a 3-dimensional surface which is lighted from the left. This is achieved by combining the topography with its derivative. The number of pixels in the edit box defines the amplification of the derivative add on.
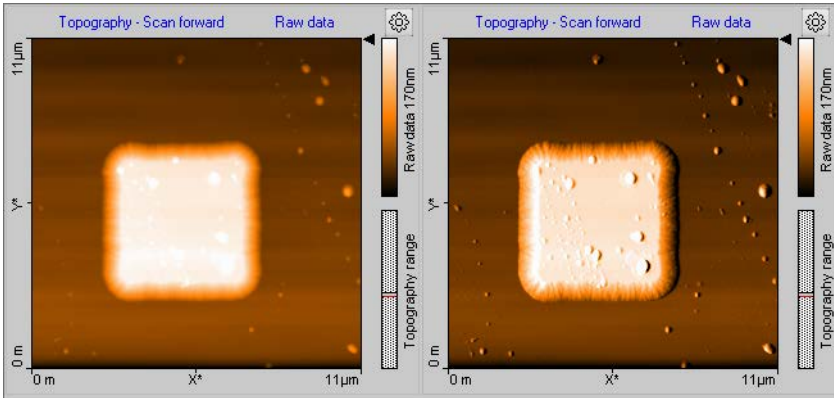
Figure 13-5: Shading option. (Left) Shading disabled. (Right) Five-pixel shading enabled.

Smooth pixel

When checked, the screen edge rendering of individual data pixels is smoothed with their neighboring pixels. Alternative data pixels are drawn as individual squares. This smoothing shows the most effect when the display size is larger that the number of measured of data points (e.g. a 256×256 measurement displayed at 512×512 pixels).

3D View options
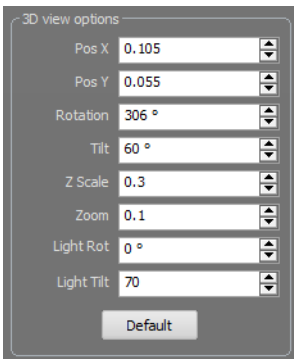
Pos X, Pos Y

Defines the center position of the 3D plot inside the chart area.

Rotation
Defines the z-axis rotation of the 3D plot relative to the view point.

Tilt
Defines the off-plane angle of the 3D plot.

Z-Scale
Defines a Z-axis 'stretch' factor. Use this e.g. to enlarge surface details.

Zoom
Defines the magnification of the 3D plot.

Light Rot
Defines the rotation angle of the light source relative to the Z-axis (360°)

Light Tilt
Defines the off-plane angle of the light source. The lowest value (0°) corresponds to "sunset" lighting, the highest value (90°) corresponds to mid-day lighting at the equator.

Default
The "Default" button resets all 3D parameters to their default values.

Keyboard and Mouse short cuts
Always click and hold the left mouse button on the 3D view chart while moving around the mouse to change the 3D view. The surface is reduced in feature complexity once the left mouse button is pressed to speed up redrawing on the screen. The surface will return to full detail once the mouse button is released.

Press the following additional keys/buttons to determine which chart property is changed:
– **Surface rotation**
  Mouse left/right
– **Surface tilt**
  Mouse up/down.
– **Size displayed surface**
  "Ctrl"- key + mouse up/down
– **Surface position**
  "Shift"-key + mouse up/down/left/right
– **Z-scale magnification**
  Left mouse button + right mouse button + mouse up/down
– **Light source direction**
  "Shift" + "Ctrl"-key + mouse left/right
– **Light source height**
  "Shift" + "Ctrl"-key + mouse up/down

13.4: Gallery panel
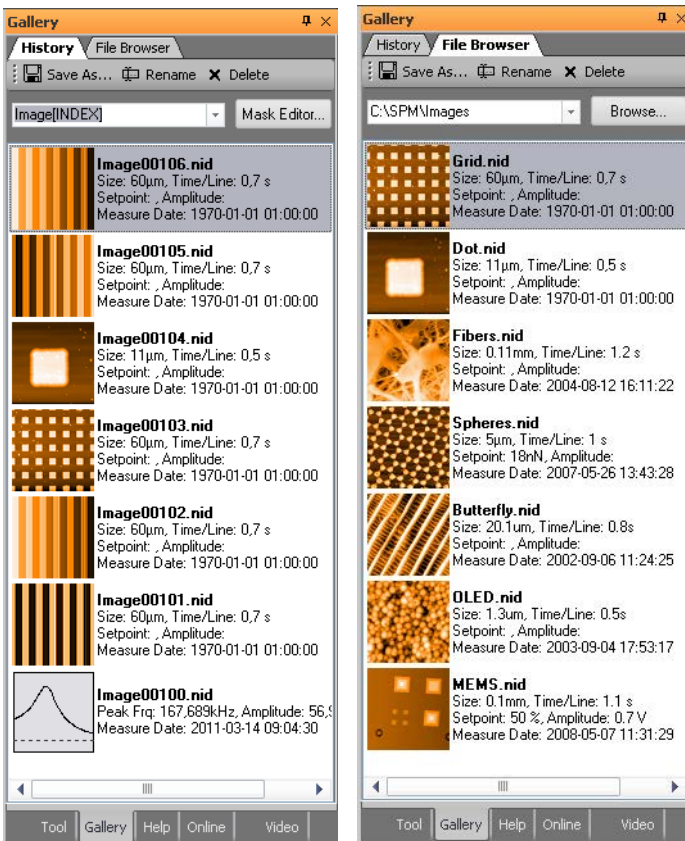
The Gallery Panel displays lists of thumbnails representing previous measurements for quick access to those documents. It contains two pages: the "History" page, with the temporarily (automatically) stored measurements (for details on how to change the default History folder and the maximum number of files to be stored see *Gallery Settings* (page 218)) and the "File Browser" page with measurements from a user-selected directory (e.g. containing older measurements that were previously moved there). The various elements of the Gallery panel are described in the next sections.

13.4.1: History File mask

Image[INDEX]   ▾   Mask Editor...

The temporary (automatic) storage of new measurements uses a File mask to create new file names each time a new measurement has to be saved. This mask can contain normal text, but also special variables like index number or date and time stamps. You may enter a new mask directly into the edit field in the History page, select an old mask from the drop-down menu, or define a new mask with the help of the Mask Editor dialog (see *Section 13.4.4: Mask Editor dialog*), which is opened by clicking the "Mask Editor" button next to the edit box.

13.4.2: Image list

In the Image list the stored measurement are shown. Each measurement is displayed as a thumbnail image of the measurement, together with some information about the measurement and measurement document.

The following mouse operations are possible inside the image list:
– **Double-click**
  Opens the respective measurement in the document space.
– **Single left mouse click**
  Selects the respective measurement and removes all other selections.
– **"Ctrl" key + left mouse click**
  Adds individual selections to the current selections.
– **"Shift" key + left mouse click**
  Selects all measurements from the last selection to the new selection.

13.4.3: Gallery toolbar

💾 Save As... ▭ Rename ✖ Delete
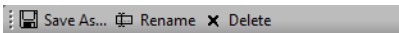
The Gallery toolbar is present in both the "History" and "File Browser" pages. It performs similar functions in both pages.

Save as
Selected measurements can be saved to a new location with this button.

If only a single measurement is selected a standard Windows "Save" Dialog is shown. Here you select the new location and the new file name.

If multiple measurements are selected a "Folder" dialog is shown, which allows you to select (or create) the folder that all selected files are to be copied to. It is strongly

recommended to do this for files in temporary storage of the History folder that you want to keep, because they may be overwritten as soon as the maximum number of files in the History folder is reached (see *Section Gallery Settings* (page 218)

Rename

Single or multiple measurements can be renamed by clicking the "Rename" button. It will open the File Rename dialog (see *Section 13.4.5: File Rename dialog*), which allows you to specify a mask for the new file names.

Delete

Single or multiple measurements can be deleted by clicking this button.

13.4.4: Mask Editor dialog
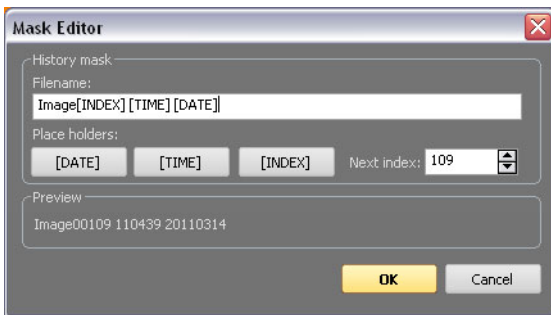
The Mask Editor dialog assists you in the creation of file name masks.

History mask

Filename

A file name mask is the template that is used to generate the file names for documents that are temporarily stored (automatically) during measurement. A file mask consists of standard text entered by the user and of variables for software-generated text or numbers (either specified by the user or added automatically).

Mask variables

Mask variables can be entered as specific words surrounded by square brackets. The following variables are defined in the SPM Control Software:

– [INDEX]

This variable represents a number that is automatically incremented each time a new filename is created. The index number is 5 digits in length and filled with zeros for missing digits. The next index number that will be used is shown in the "Next Index" field.

– **[TIME]**
This variable represents the actual time of file name creation. It is formatted with two digit numbers for the hours, minutes and seconds (HHMMSS). This time format is used regardless of the Regional Settings of the Windows operating system.

– **[DATE]**
This variable represents the date of the day the file was created (i.e., the day the measurement was performed). It contains four digit numbers for the year and two digit numbers for month and day (YYYYMMDD). This date format is used regardless of the Regional Settings of the Windows operating system.

To quickly insert a Mask variable at the current cursor position in the mask edit box, click the corresponding button.

Next Index
This entry field defines the next index number to be used. By default this value is identical to the highest number present in the History files, increased by one.

IMPORTANT
If no Mask variable is used, an index is automatically added to the text string defined in the filename mask.

Preview

The filename that will be used for the next measurement document to be saved (as specified by your entries) is shown here.

13.4.5: File Rename dialog
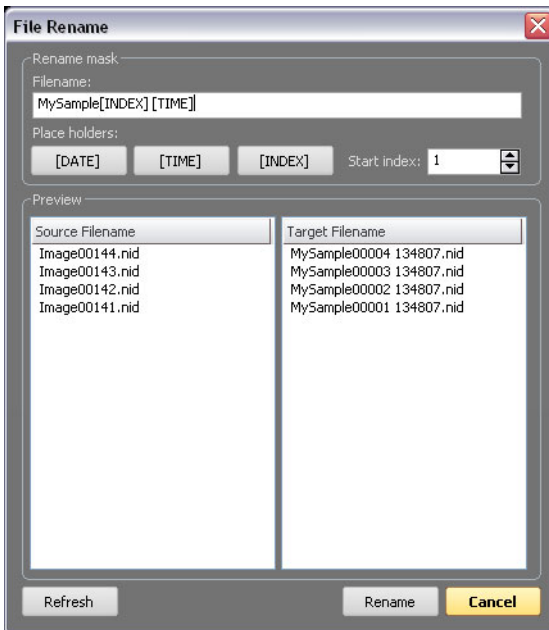
The File Rename dialog is used to rename (or move) multiple files using a Rename mask (see below). The dialog is opened by clicking the "Rename" button in the Gallery panel. To rename a file or multiple files, the Rename mask can be defined here following the same principles as for the History mask. A preview of the new filenames is shown in the preview section.

Rename mask

See *History mask* (page 191).

Preview

Source Filename
The left column of the Preview section shows the original filename(s).

Target Filename
The right column of the preview section shows what the filename(s) will be after pressing the "Rename" button.

Refresh
This button updates the preview list.

Rename
This button renames the selected files.

IMPORTANT

If no unique filename(s) would result from the specified Rename mask, an index is automatically added to the files. If this still does not result in unique filenames, the text "Copy of" is added to each filename as often as is required to make it unique.

Cancel
This button closes the dialog without renaming the files.
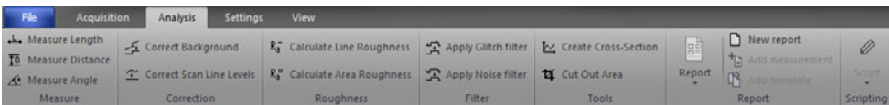
13.5: Analysis tab

Measurement data can of course not only be displayed in charts, it can be analyzed as well. The control software has several tools that allow quick numerical evaluation and modification of chart data in Operating or document windows. These tools are accessible through the various groups of the Analysis tab.

All of these tools can also be used while a measurement is still being acquired.

To use a quick evaluation tool:

❶ Click on the chart that you want to evaluate to activate it.

❷ Select the desired tool using one of the following approaches:
  • Click on one of the tool buttons in the Analysis tab.
  • Select the tool from the Chart's context menu (right-click on the chart).

❸ Define the evaluation. The procedure to define the evaluation is different for each tool. Details can be found in the tool-specific instructions below.

When a tool has been selected, the Tool panel (see *Section 13.6: Tool panel*) moves to the top of the panel stack of the Info pane.

IMPORTANT

Depending on the selected chart type, some tools may be unavailable.

To stop using a tool:

➡ Select another tool, select the same tool a second time, or select "Abort" in the Chart's context menu.

Tip

For more elaborate evaluations, the optional Nanosurf Analysis or Nanosurf Report software can be used.

13.5.1: Measure group
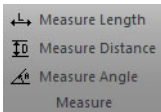
Measure Length
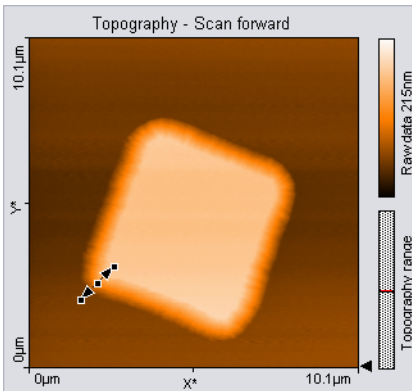
Calculates the distance and signal difference between two points. Graphically, a line with arrowheads on each end represents the selection marker. The line is defined by drawing a line on the measurement chart. The first point is positioned by moving the mouse cursor to the desired location and clicking and holding the left mouse button. The second point is positioned when the mouse button is released. When the mouse is not moved between clicking and releasing, an line parallel to the X*-axis is drawn.

The direction and length of the selection marker can be adjusted by dragging the end markers. The line can be moved as a whole by dragging the center marker.

The Tool status section of the Tool panel displays the calculated "Length", "DeltaZ", "Width" and "Height". This data will also be stored in the "Tool" data category of the Data Info panel

(see *Section 13.2: Data Info panel*) for the respective measurement document as long as the tool is active when the document is stored. For more information on the data in the Tool status section (see *Tool status section* (page 207)).

Measure Distance
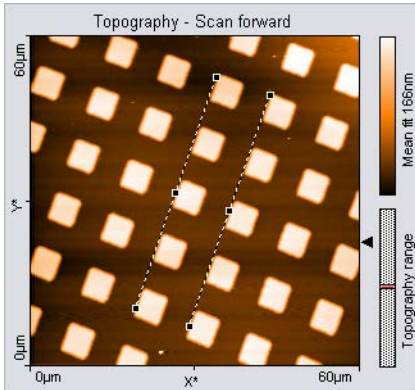
Calculates the distance between two parallel lines. The parallel lines are defined by drawing them in the chart. The first point of the first line is defined by the mouse cursor position where the left mouse button is clicked, the second point by the position where the button is released. When the mouse is not moved between clicking and releasing, a line parallel to the X*-axis is drawn. After releasing the mouse button, a second parallel line sticks to the mouse cursor, that is released by clicking its desired position. The direction of the parallel lines can be adjusted by dragging their end markers; they can be moved by dragging the center marker.

The Tool status section of the Tool panel displays the calculated distance. The distance value only depends on the cursor positions, it does not on depend the displayed data values. The distance data will also be stored in the "Tool" data category of the Data Info panel (see *Section 13.2: Data Info panel*) for the respective measurement document as long as the tool is active when the document is stored. For more information on the data in the Tool status section (see *Tool status section* (page 207)).
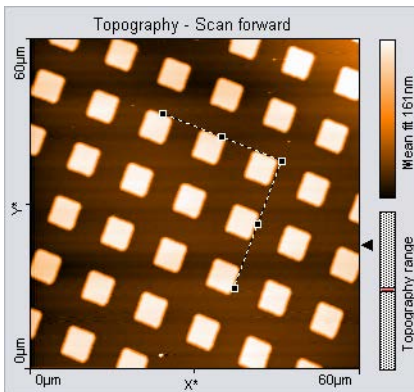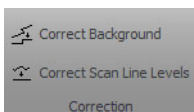
Measure Angle

Calculates the angle between two lines. In Line graph-type displays, this tool can only be used when the chart displays data that has the unit "meters".

The two lines are defined by drawing them in the chart. The first point of the first line is defined by the mouse cursor position where the left mouse button is clicked, the second point by the position where the button is released. When the mouse is not moved between clicking and releasing, a line parallel to the X*-axis is drawn. After releasing the mouse button, the end of the second line sticks to the mouse pointer. The end is released by clicking its desired position. The angle can be changed by dragging the line end point markers or the corner mark; it can be moved by dragging the line center markers.

The Tool status section of the Tool panel displays the calculated angle. This data will also be stored in the "Tool" data category of the Data Info panel (see *Section 13.2: Data Info panel*) for the respective measurement document as long as the tool is active when the document is stored. For more information on the data in the Tool status section (see *Tool status section* (page 207)).

13.5.2: Correction group

In contrast to the evaluation tools of the Measure and Roughness groups, the tools of the Correction group (and also those of the Filter group (see *Filter group* (page 201))) actually change measurement data. This is done in a copy of the original measurement document, though, so you won't lose any data and will always be able to access the original measurement data in addition to the corrected or filtered data.

Correct Background

Removes the effect of an ill-aligned scan plane when the line filter options (see *Filter* (page 184)) do not give satisfactory results. This may be the case when the scan lines in different parts of the measurement have a different average height. An example of such a measurement is shown in *Figure 13-6: Correct Background*.
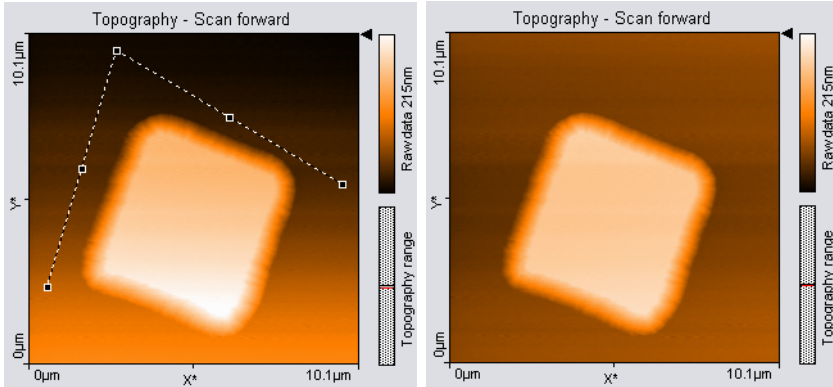

Figure 13-6: Correct Background. (Left) Uncorrected image; the end points of the selection marker have been moved to points that should have the same height. (Right) Corrected image.

To use the tool, select three points that should be on the same height. This is done in the same way as with the angle tool (see *Measure Angle* (page 339)). The selected points become the end points of the selection marker.

After clicking the "Execute" button in the Tool status section of the Tool panel, a copy of the original measurement document is made and the plane that is defined by the selection maker is subtracted from the measurement data in the newly created document. To get useful results, the Data filter option for the corrected image in the new document will be automatically set to "Raw data".

Correct scan line levels

Removes the effect of drift when the line filter options (see *Filter* (page 184)) do not give satisfactory results. This may occur when the scan lines in different parts of the measurement have a different average height. An example of such a measurement is shown in *Figure 13-7: Correct scan line levels*.

To use the tool, draw a line through points that should have the same height in the same way as with the Measure Length tool.

After clicking the "Execute" button in the Tool status section of the Tool panel, a copy of the original measurement document is made and the average level of each scan line in the newly created document is adjusted so that all points along the drawn line have the same
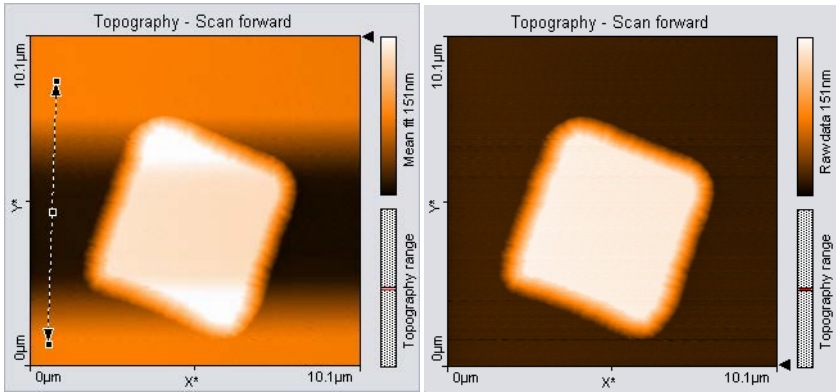
Figure 13-7: Correct scan line levels. (Left) Uncorrected image with a selection marker through points that should be at the same height. (Right) Corrected image

height. To get useful results, the Data filter option for the corrected image in the new document will be automatically set to "Raw data".

13.5.3: Roughness group
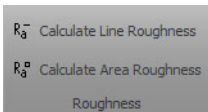
Calculate Line Roughness
Calculates several roughness parameters from the data at points along a selected line. The line is selected in the same way as with the Measure length tool (see *Measure Length* (page 195).

The Tool status section of the Tool panel displays the calculated "Length" and "DeltaZ" of the selected area.

The Tool result section displays the roughness values that are calculated from the data according to the following formulas:

The Roughness Average, S_a

$$S_a = \frac{1}{N} \sum_{l=0}^{N-1} |z(x_l)|$$

The Mean Value, S_m

$$S_m = \frac{1}{N} \sum_{l=0}^{N-1} z(x_l)$$

The Root Mean Square, S_q

$$S_q = \sqrt{\frac{1}{N} \sum_{l=0}^{N-1} (z(x_l))^2}$$

The Valley depth, S_v

$S_v = lowest\ value$

The Peak Height, S_p

$S_p = highest\ value$

The Peak-Valley Height, S_y

$S_y = S_p - S_v$

The roughness values depend on the line filter option (see *Filter* (page 184)) that is applied to the chart, because they are calculated from the filtered data.

Clicking the "Store" button in the Tool result section stores the roughness values in the "Roughness" data category of the Data Info panel for the active measurement document.
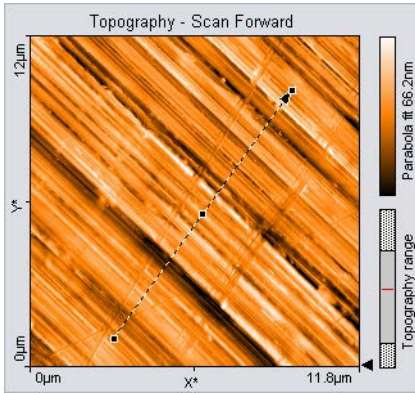
Calculate Area Roughness

Calculates several roughness parameters from the data points in a selected area.

The area is selected in the same way as with the Cut out Area tool.

The Tool status section of the Tool Results panel displays the calculated Size or Width and Height of the selected area. For more information on the Tool status section, see The Tool status section (page 207).

The Tool result section displays the roughness values that are calculated from the data according to the following formulas:

The Roughness Average, S_a

$$S_a = \frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} | z(x_k, y_l) |$$

The Mean Value, S_m

$$S_m = \frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} z(x_k, y_l)$$

The Root Mean Square, S_q

$$S_q = \sqrt{\frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} (z(x_k, y_l))^2}$$

The Valley depth, S_v
$S_v = lowest\ value$

The Peak Height, S_p
$S_p = highest\ value$

The Peak-Valley Height, S_y
$S_y = S_p - S_v$

The roughness values depend on the Data filter that is applied to the chart, because they values are calculated from the filtered data. More information on data filters is provided in Section 18.2: The Chart bar under Data filter (page 199).

Clicking the "Store" button in the Tool result section stores the roughness values in the "Roughness" data category of the Data Info panel for the active measurement document.

Tip

The Area Roughness tool can be used to determine the mean height difference between two plateaus with more accuracy than with the "Measure Distance" tool. To determine the mean height difference, select an area on each plateau, and calculate the difference between their Sm-values.

13.5.4: Filter group

Apply Glitch filter
Apply Noise filter
Filter
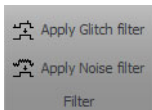
Glitch Filter
The Glitch Filter removes the effect of small defects in the image such as single short glitches in the scan. Compared to the Noise Filter (see below), it has the advantage of not reducing resolution on step edges. The glitch filter is implemented as a Median filter on a 3×3 pixel matrix.

To apply the filter, activate the color map chart that is to be filtered, then click the "Glitch Filter" button. A new Measurement document with the filtered data is created.

Noise Filter
The Noise filter removes high frequency noise from the image, but applying the filter will also decrease the resolution of the image. The Noise Filter is implemented as a convolution with a 3×3 pixel Gaussian kernel function.
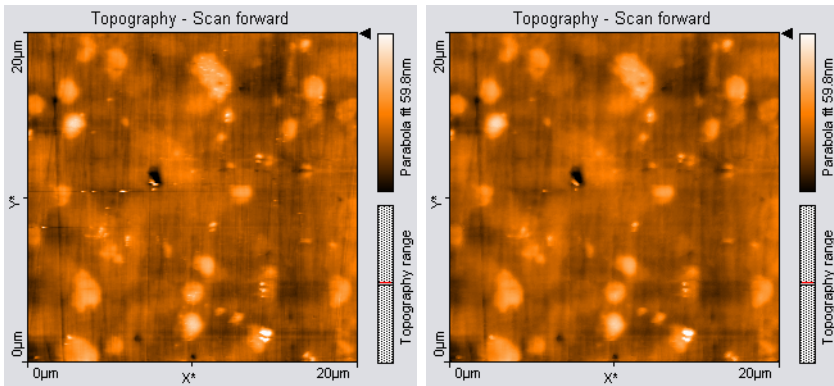
Figure 13-8: Glitch Filter. (Left) Unfiltered image with some glitches where the tip lost contact with the sample. (Right) Corrected image.
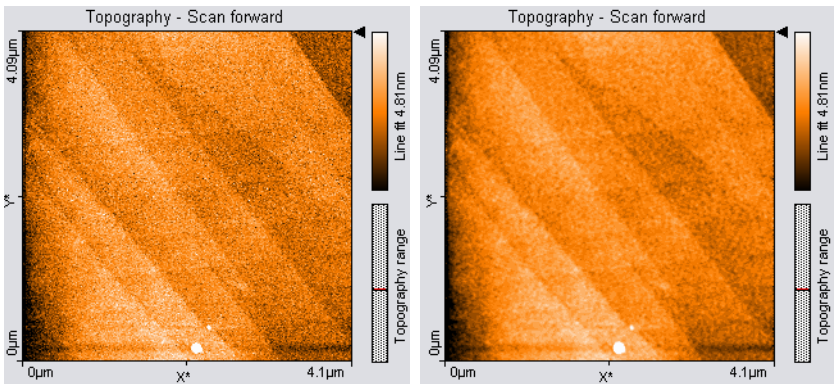
Figure 13-9: Noise Filter. (Left) Noisy (unfiltered) image of an AFM measurement on HOPG. (Right) Filtered image

To apply the filter, activate the color map chart that is to be filtered, then click the "Noise Filter" button in the Tools bar. A new measurement document with the filtered data is created.

> ## Tip
>
> - Filters are especially useful for improving the appearance of 3D views.
>
> - Applying filters may changes the result of the other tools. This may result in incorrect results, e.g. when evaluating sample roughness.

13.5.5: Tools group
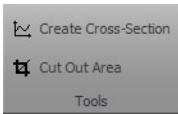
Create Cross-Section

Creates a new measurement document containing a line cross-section of a Color map or Line View display.

The line is defined by drawing a selection arrow. The arrow points toward the forward direction of the line. The start of the arrow is defined by the mouse cursor position where the left mouse button is clicked, the end of the arrow by the position where the button is released. When the mouse is not moved between clicking and releasing, an arrow ending in the center of the measurement is drawn. The direction of the arrow can be adjusted by dragging its end markers; it can be moved by dragging the center marker.
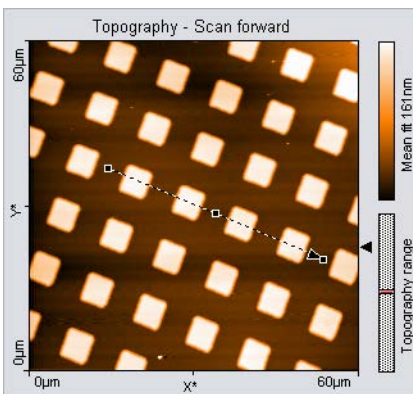
Double-clicking the graph, or clicking the "Cut out line"-button in the Tool status section of the Tool panel creates a new document that contains the line section.

The Tool chart section of the Tool Results panel displays a preview chart of the selected line.

The Tool status section of the Tool Results panel displays the calculated "Length" and "DeltaZ" of the selected line. For more information on the data in the Tool status section (see *Tool status section* (page 207)).

Cut Out Area

Creates a new measurement document containing a subsection of an existing measurement.

One corner of the area is defined by the mouse cursor position where the left mouse button is clicked, the opposite corner by the position where the button is released. When the mouse is not moved between clicking and releasing, an area is defined that has a size of 33% of the current measurement, and is centered on the clicked location.

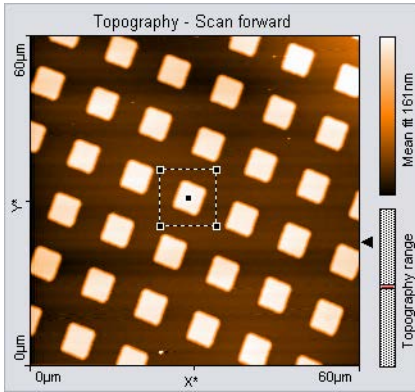Once an area is defined, it can be resized by dragging one of its corners, and moved as a whole by dragging its center point.

Pressing the "Shift" key while dragging a corner defines a non-square (i.e. rectangular) area.

Double-clicking the graph, or clicking the "Cut out area" button in the Tool Results panel creates a new measurement document that contains the selected area.

The Tool status section of the Tool Results panel displays the calculated "Size" or "Width" and "Height" of the selected area. For more information on the data in the Tool status section (see *Tool status section* (page 207)).

13.5.6: Report Group
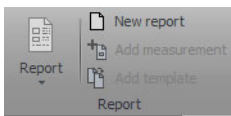
The Nanosurf Report software offers a powerful and extensive set of analysis functions. Complex analyses can be created interactively, and then displayed and printed in visually appealing reports. These reports can then be used as templates to consistently apply the same analysis to other measurements.

Report
The "Report" button starts the Report software (if installed) from within the SPM Control Software:

When a measurement is opened by the Report software, it will import all measurement channels that are displayed in the current measurement document. By default, a Basic Report is generated. Other Report styles can be chosen from the "Report" button's drop-down-menu:

This drop-down menu lists templates stored in a template folder. The Menu Item's name is equal to the template name without the extension (*.mnt) and is sorted alphabetically. This standard directory is configured by the Report Template File path (see *Reporting* (page 217)).

> **IMPORTANT**
>
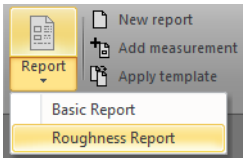> After a fresh installation of the Report software, the Report software has to be run at least one time before you can automatically start it from the SPM Control Software. To run the Report software for the first time, select it from the Windows "Start" menu.

New Report
An empty report is opened.

Add Measurement
The currently active measurement is added to the currently opened report.

Apply Template
Opens a dialog that allows you to select a template that is applied to the currently active measurement. If selected, a menu item the template is applied to the current selected measurement Document.

> **IMPORTANT**
>
> If you do not save the measurement in the control software, but only save the report, the data in measurement channels that were not displayed is lost.

IMPORTANT

A measurement document should only display those channels that are used in a template. When a template is applied to a measurement document that displays different, or a different number of measurement channels than the template uses, the results may not be correct.

13.5.7: Scripting group

Please refer to *Section 10.4.2: Scripting group* (page 127).

13.6: Tool panel
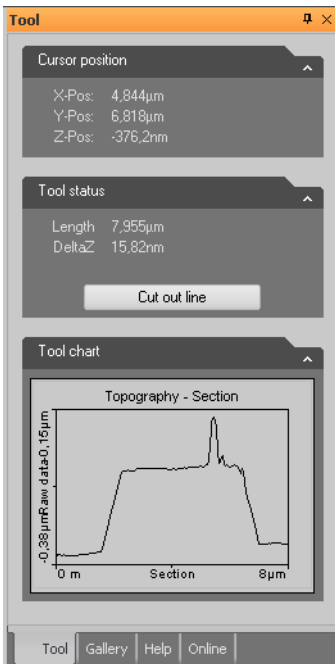
The Tool panel of the Info pane displays varying information, which depends on the tool currently selected in the Analysis tab.

Cursor Position section

This section is always visible. It displays the mouse cursor position in the physical units of the selected chart.

Tool status section

This sections appears when a tool is being used. It displays the evaluation result of the currently active tool.

The tools that require drawing a selection marker to define the evaluation have some common parameters that are described here. The other parameters are described in the sections that describe the respective tool (see above).

Length

The length of the selection marker in the plane of the chart. "Length" is related to the evaluation results "Width" and "Height" (see below) according to the formula:

$$Length = \sqrt{Width^2 + Height^2}$$
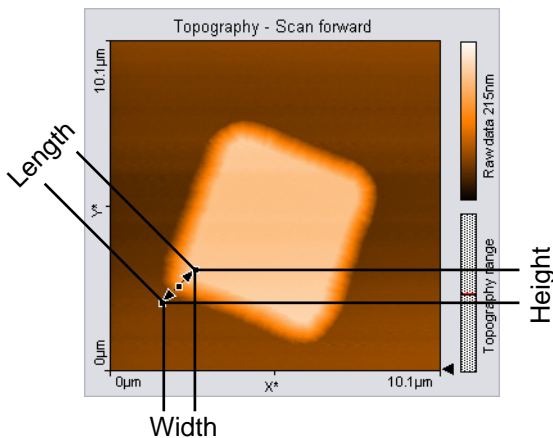
In a Color map chart, length is calculated in the XY-Plane. In a Line graph chart, length is calculated in the XZ-Plane.

"Length" is not displayed when "Width" and "Height" are of different physical units (e.g. in Amplitude Spectroscopy, where the X-Axis is given in [m] and the Z-Axis in [V]).

Width, Height

The "Width" and "Height" of the measurement tool in the chart, calculated in the chart plane.

DeltaZ

The difference between the "Z-Pos" values at both ends of the selection marker.

In a Color map chart, "DeltaZ" is the difference in the (filtered) sample height between the start and the end point.

IMPORTANT

The calculated values of "Length", "Width" and "Height" only depend on the cursor positions, they do not depend on the displayed data values.

13.7: File menu
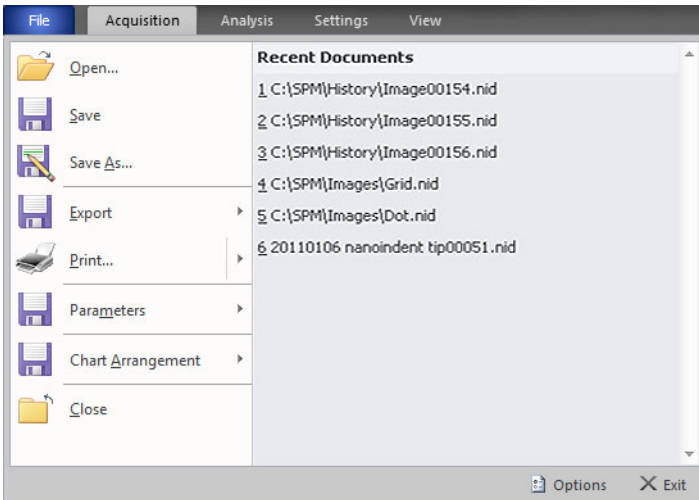
The File menu is accessed by clicking the File tab at the left side of the Ribbon. It provides access to software related settings and options (see *Section 14.1.1: Options dialog* (page 213)), but also to basic file operations such as such as opening, storing and printing of measurements (explained below). The latter functions can also be performed using the Quick Access toolbar, in which these commands are present by default:

Open

Launches a system "File open" dialog for opening Nanosurf ".nid" or ".ezd" (Easyscan 1) files. It is possible to select more than one file at the same time by using the "Shift" and/or "Ctrl" keys.

Selected files will open in document windows, which contains a chart area and a data info panel. There is no Imaging toolbar like there is for ongoing measurements in the Imaging window. You can however still customize the charts through a context menu, which opens through a right-click. The data info Panel displays all significant parameters were used for the measurement. For more information on Measurement document functionality, see *Section 13.1: Introduction*.

Save / Save as...

Save a measurement document in Nanosurf image data format (file extension ".nid"). The same dialog is opened for both menu items.

Close

Closes the currently active document, but not the SPM control software. If you have unsaved data in the current document, you will be asked to save it.

Export

Exports either the active chart or the whole active measurement document for use in other programs or image-processing software. Available data types for documents are tagged image file format (.tif), portable network graphics (.png), Windows bitmap (.bmp), 16 bit data file (.dat), and plot file (.plt). For Charts, additional available data types are comma separated z values (.csv), and (X,Y,Z)-points (.csv).

When the data is exported using the function "Export" >> "Current document as...", every Chart in the measurement document is stored in the export file consecutively. In the binary format, the blocks of data from each Chart are stored directly one behind the other. In the "ASCII" text format the blocks of data for each Chart are separated by two empty lines.

Tagged image file format (.tif), portable network graphics (.png), and Windows bitmap (.bmp)
All of these image file formats are suitable for inclusion of images in electronic documents, e.g. in Word, PowerPoint or image-processing software. The exact image as seen on the computer screen will be saved in the exported file (similar to a screenshot of the respective chart).

Data file 16Bit (.dat)
A binary data file that can be processed in data processing software. This "binary" data format only contains the measured data. The data is stored consecutively, line by line upwards, as 16-bit values (−32768 to +32767). Before being stored, the data is processed using the settings chosen in the Correction and Filter groups of the Analysis tab (see *Section 13.5: Analysis tab* for details).

Plotfile ASCII (.plt)
This is an "ASCII" text format which contains the measured data as well as a small header with a description of the scan. A plotfile can be used for detailed data analysis by various mathematical software packages such as MathLab, or for plotting by software such as GnuPlot. Before being stored, the data is processed using the settings chosen in the Correction and Filter groups of the Analysis tab (see *Section 13.5: Analysis tab* for details).

If "Line graph" is selected as "Display" in the "Chart bar", only the visualized lines will be stored. Each data point is stored as a pair of floating point numbers on a separate line. The number pairs are separated by a blank character (SPACE).

If any other chart type is selected, all measured values are stored. All values in a data line are stored on a separate line in the text file. An empty line is inserted after every data line. The data lines are stored from the bottom to the top. A small header at the beginning of the first data line contains the names of the channel and frame, as well as X-, Y-, and Z-ranges with their physical units.

Comma separated z values (.csv)
This format stores all the measured data in a chart, as a matrix of floating point numbers in ASCII format separated by a "comma" and "SPACE" character. This enables easy data exchange with commonly used spread sheet and database applications.

(X, Y, Z)-Points (.csv)
This format stores the coordinates of all measured points in a chart as a list of floating point number pairs. For Line graphs, only X and Z points are exported.

Print / Print preview...

Prints the currently selected measurement document together with the values shown in the Data Info panel.
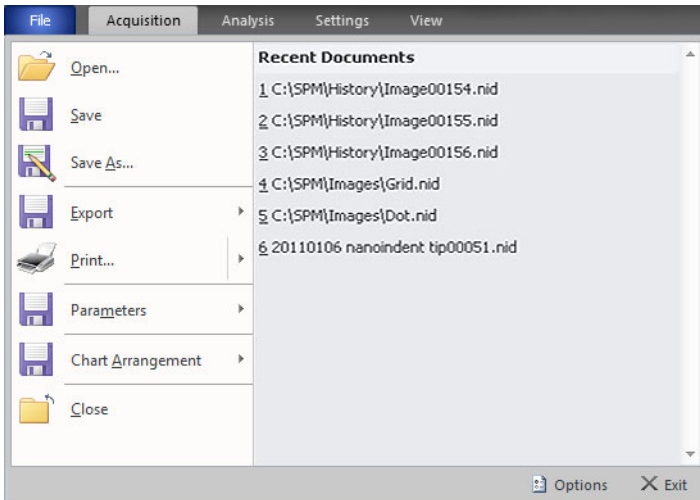
Exit

With exit you can close the SPM Control Software. If you exit the program while still having unsaved data, you will be asked to save it.

CHAPTER 14:

Options and settings

14.1: File menu

The File menu is accessed by clicking the File tab at the left side of the Ribbon. It provides access to basic file operations such as such as opening, storing and printing of measurements (explained in *Section 13.7: File menu* (page 208)), but also to some software related settings and options (explained below).

Parameters

All measurement parameters are stored in a configuration file with the extension ".par". When the SPM Control Software is started, default values are loaded from a file that is selected in the Controller Configuration dialog (*Section 14.7: Controller Configuration dialog*). Functions for storing and retrieving parameters are accessed via the application button.

Save

Saves the parameters to the currently selected parameter file. The name of this file is indicated in the status bar at the bottom of the main window.

Save as...

Saves the parameters under a new file name.

Load

Loads a previously saved parameter file.

Chart Arrangement

The chart arrangement of the Imaging and Spectroscopy windows is stored in a configuration file with the extension ".chart". When the SPM Control Software is started, a default arrangement is loaded from a file that is selected in the Controller Configuration dialog (*Section 14.7: Controller Configuration dialog*). Functions for storing and retrieving the chart arrangement are accessed via the application button.

Save

Saves the chart arrangement to the currently selected chart file. The name of this file is indicated in the status bar at the bottom of the main window.

Save as...

Saves the chart arrangement under a new file name.

Load

Loads a previously saved chart file.

Options

The "Options" button opens the Options dialog (see *Section 14.1.1: Options dialog*), which configures various general control software settings.

14.1.1: Options dialog

Customize
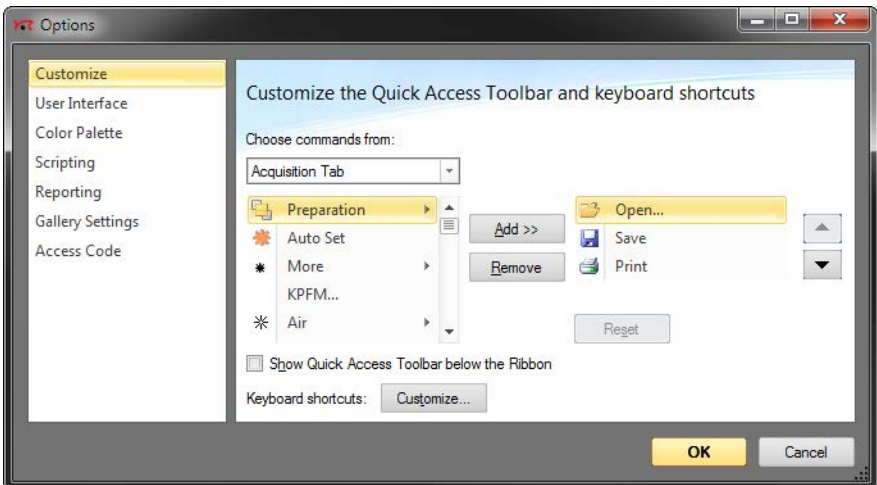
Allows changes to the content of the Quick Access toolbar (see *File menu* (page 212)). This process is very similar to that in the Microsoft Office applications and is therefore not explained in this manual. You are free to try it out and can always use the "Reset" button to reload standard settings.

User Interface
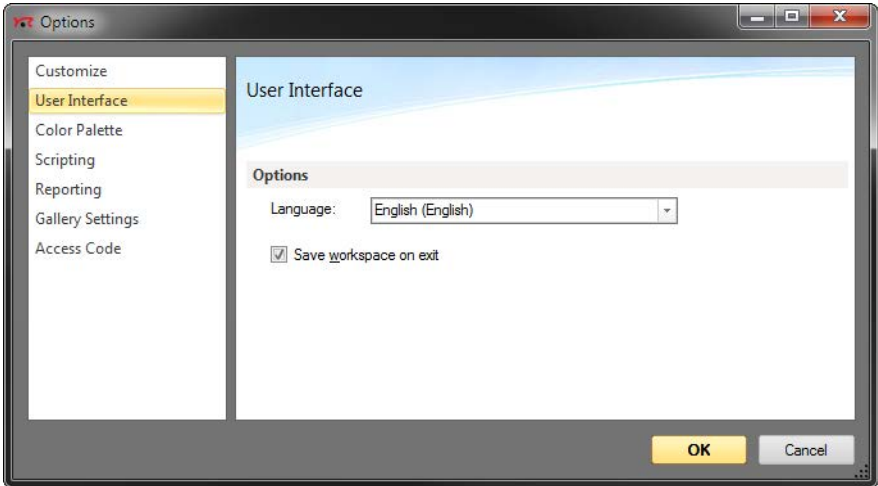
Language
Specifies the SPM Control Software language.

Save workspace on exit
When checked, the workspace settings are automatically saved to the system registry when the control software is closed (see also *Parameters* and *Chart Arrangement* (page 213)).

Color Palette
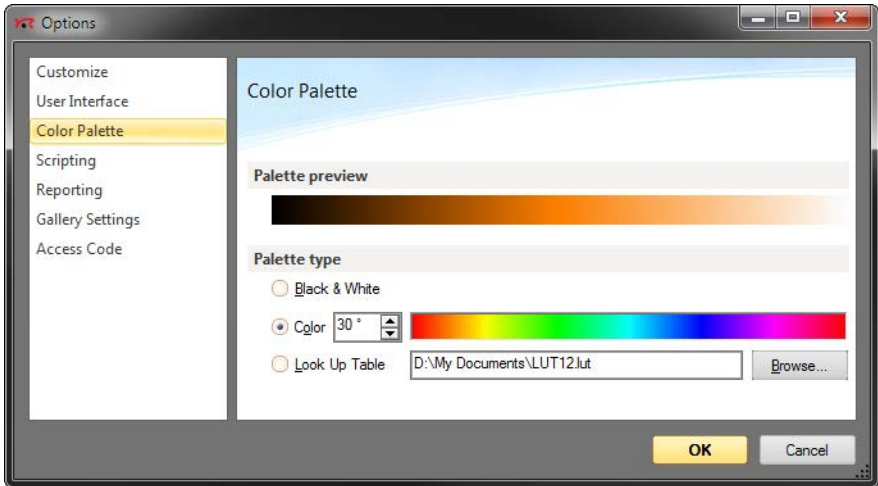
The color palette dialog is reached via the menu item "Options" >> "Config Color palette...".
The color palette is used to map the display range of the measured values to a color. Three
different palette types are available:

– Black&White
   The color map is a linear gray scale.

– Color
   The color selection uses the HSB-color model where the color (H) is set in ° value. The
   color is selected by entering a number or by clicking a color in the color bar.

– Look Up Table
   A user definable palette (with max 256 color entries) can be selected. This palette is
   stored in a ".lut" file that contains an ASCII table with RGB color values. A different look up
   table can be selected by clicking the "Browse..." button.

Scripting
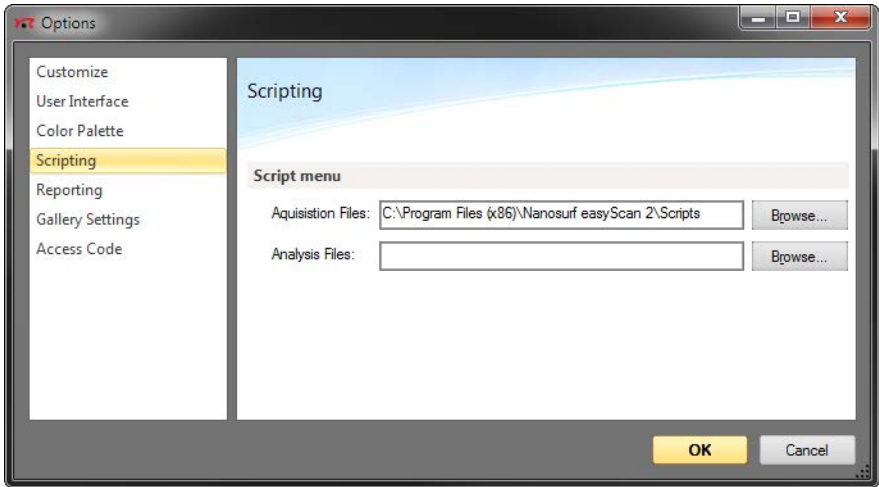
Allows you to set the search paths for the Acquisition and Analysis scripts that are displayed in the Scripting group of the Acquisition tab and Analysis tab, respectively.

Scripts can be organized in subdirectories inside each of the "Script" directories, which are displayed as submenus in the control software. These submenus are displayed before individual scripts in the Script drop-down menu.

Reporting
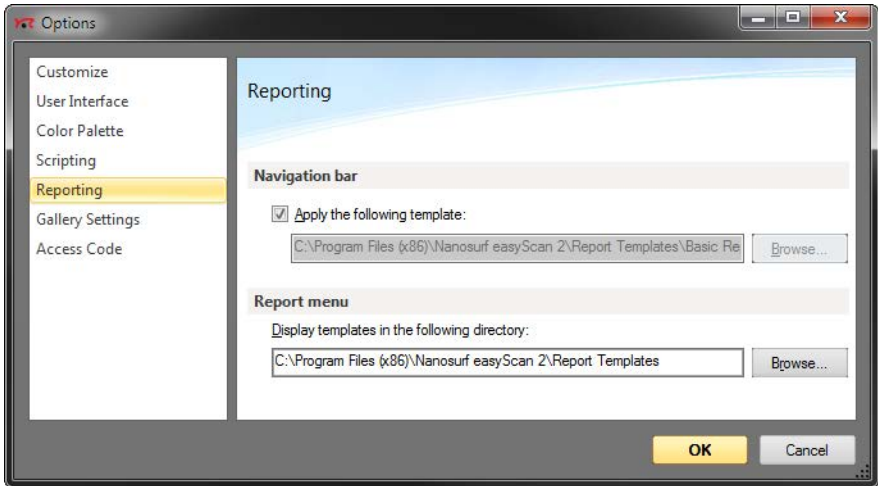
Used to configure the behavior of the "Report" button in the Report group of the Analysis tab.

Apply the following template
When enabled, automatically applies the template specified in the box below. You can search for a template using the "Browse" button.

Display templates in the following directory
As with the Stridulating paths (see *Scripting* (page 216)), the content of the specified directory is displayed as choices in the Report drop-down menu.

Gallery Settings
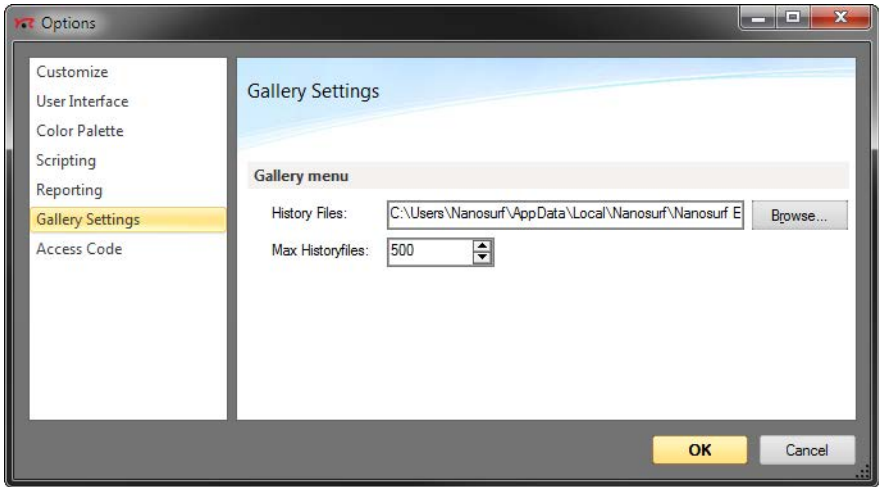
History files

Sets the directory where the temporarily (automatically) stored measurements (which are listed in the Gallery panel of the Info pane) are stored.

Max History Files

Sets the maximum number of files to keep in the above directory. When the maximum is reached, the oldest measurement is deleted from disk to allow the latest measurement to be saved.

Access Code
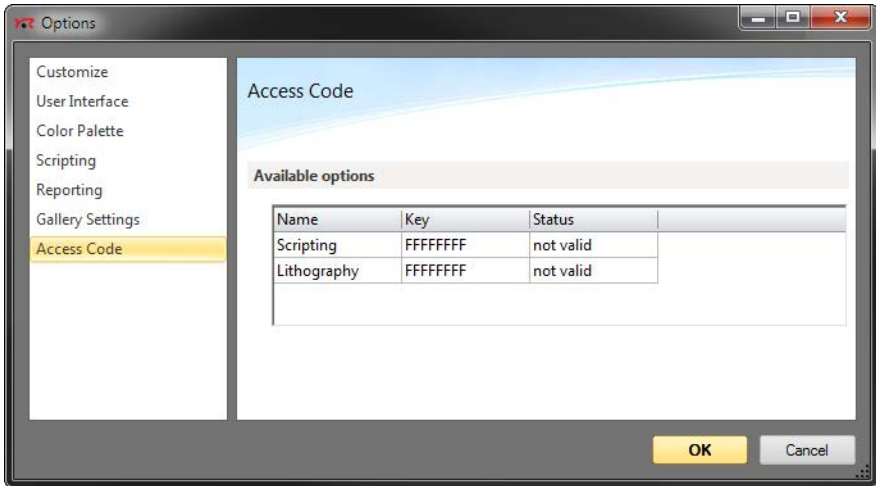
Used to enter the access code for software modules, such as the Scripting Interface and the Lithography Option..."

IMPORTANT

If you receive the warning "To change access codes you need Windows administrator rights", please restart the control software with the "Run as Administrator..." option from the Windows Explorer context menu.

14.2: Settings tab
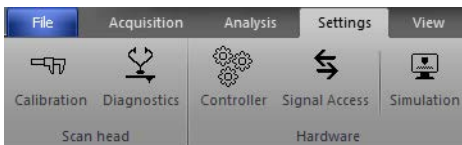
Provides access to many hardware related settings.

14.2.1: Scan Head group
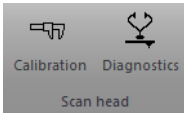
Calibration
This button opens the Scan Head Selector dialog to load, save or edit a scan head calibration file. For more details, see *Section 14.3: Scan Head Selector dialog* (page 221).

Diagnosis
This button opens the Scan Head Diagnosis dialog where the actual health state of the scan head can be seen. For more details, see *Section 14.6: Scan Head Diagnostics dialog* (page 225).

14.2.2: Hardware group
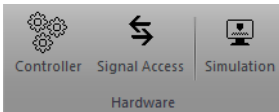
Controller
Opens the Controller Configuration dialog where different hardware related settings can be defined. It defines communications port, video driver settings, start up parameter and others. For more details, see *Section 14.7: Controller Configuration dialog* (page 227).

Signal Access
Opens the SPM Parameters dialog on the Signal Access page (see *Section 14.8.1: Signal Access page* (page 229)).

Simulation
Check or uncheck the Simulation button to enter or exit the control software's microscope simulation mode. Once the simulation mode is active, the status bar of the control software displays the text "Simulation". Otherwise, this field displays the text "Online".

In microscope simulation mode, many functions of the microscope are performed on a mathematically generated surface. Thus, software functionality and acquisition procedures can be practised without danger of harming the instrument.

14.3: Scan Head Selector dialog
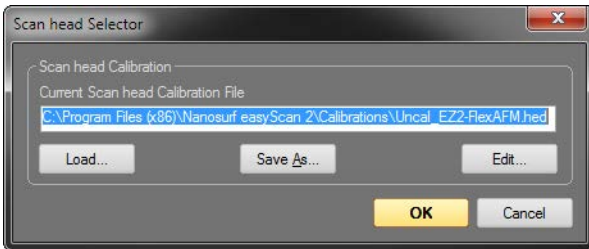
The Scan Head Selector dialog is used to load, save or edit scan head calibration files. These files store all calibration values specific to a certain scan head. The Scan Head selector dialog is opened via the "Calibration" button in the Scan Head group of the Settings tab.

The configuration of each scan head is stored in a file with a filename that corresponds to the serial-number of that particular scan head and with the extension ".hed" (e.g. "10-11-584.hed" for an Easyscan 2 AFM scan head). The currently loaded scan head calibration file is displayed in the status bar.

Tip:

The specific scan head calibration file(s) for each customer is automatically copied and selected as default during the installation of the control software from the installation CD. It can be found in the "Calibrations" sub directory of your installation path.

IMPORTANT:

When you change a scan head, you have to load the correct configuration file too. If you do not, scan ranges and other important calibration settings are incorrect and the scan head may not operate properly.

Load...
Loads a different scan head calibration file.

Save as...
Saves the current scan head calibration file with a different name.

Edit...
Edit the currently loaded scan head calibration file using the Scan Head Calibration Editor dialog (see *Section 14.4: Scan Head Calibration Editor dialog*). Always save a backup copy of the original scan head calibration files by clicking 'Save As...' first.

14.4: Scan Head Calibration Editor dialog

Through this dialog, the calibration of all standard Inputs and Outputs can be configured individually for a particular Scan Head. The configuration of the User Inputs and User Outputs is located in a different dialog (*Section 14.9: User Signal Editor dialog* (page 233).

> **CAUTION!**
>
> Changes to these settings should be performed with great care. False settings can lead to false interpretation of the data and incorrect operation of the controller.

14.4.1: Scan Axis
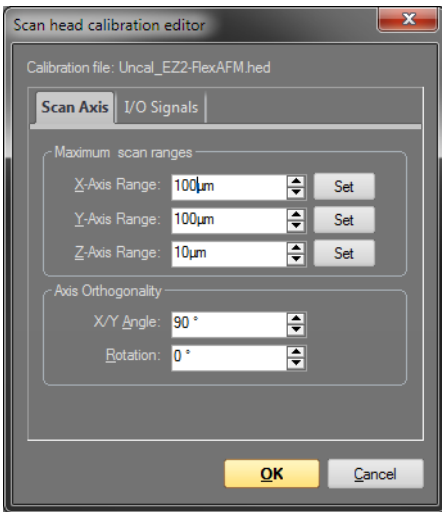
Maximum scan ranges

X/Y/Z-Axis Range
The calibration values of each of the scanner axes. The calibration values are given as the maximum motion range of the scanner (Overscan is set to 0% and X/Y Angle set to 90° and the Axis Orthogonality Rotation of 0° [or a multiply of 90°]).

Set
The "Set" buttons open the Scan Axis Correction dialog (see next section).

Axis Orthogonality

The X- and Y-Axes of the scanner are generally not perfectly orthogonal, and their orientation with respect to the AFM housing may vary. The controller corrects these errors by adding/subtracting some of the X scanner command signal to the Y scanner command signal and vice versa.

X/Y Angle

The angle between then the X- and Y-axis of the scanner hardware. The control software uses this value to correct the scan command signals such that the scan axes are orthogonal.

Rotation

The angle between the X-axis of the scanner and the X-axis of the microscope body. The control software uses this value to correct the scan command signals in such a way that the scan axis is parallel to the X-axis of the microscope body.

Tip

With this value, the alignment of the scanner's 0° Rotation and another system's coordinate system may be calibrated (e.g. images scanned with the LensAFM or Nanite AFM and optical images by external video cameras of optical profilometers or Nano-Indenters).

14.4.2: I/O Signals
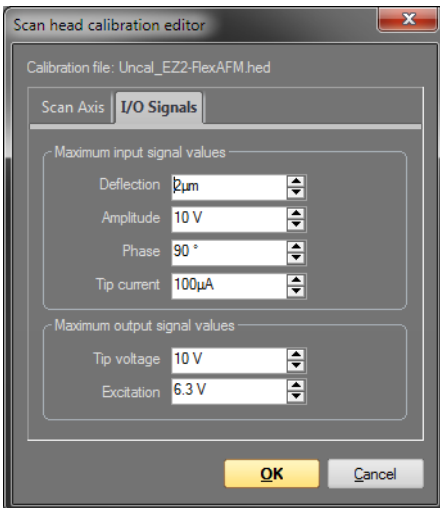
Maximum input signal values

Deflection
The calibration of the cantilever deflection signal. This calibration value is used to convert the AFM Detector Signal or the STM preamplifier signal (both in Volts) to physical units.

> ### IMPORTANT
>
> This value has been pre-configured by Nanosurf for Static Force Mode operating mode with CONTR Cantilever and a Laser Spot at 225 µm. If other Cantilevers are used, or if the laser spot has been adjusted manually in case of a FlexAFM scan head, a recalibration of this value has to be performed. If not, the Set Point in [N] may be incorrect.

Amplitude (AFM only)
The calibration value of the cantilever vibration amplitude signal.

Phase (AFM only)
The calibration value of the cantilever vibration phase shift signal.

Tip current (AFM only)
The calibration value of the controllers internal Tip current preamplifier sensitivity.

Maximum output signal values

Tip Potential
The calibration value of the Tip voltage setting.

Excitation (AFM only)
The calibration value of the Amplitude of the signal that is used to excite the cantilever in dynamic force operating modes.

14.5: Scan Axis Correction dialog
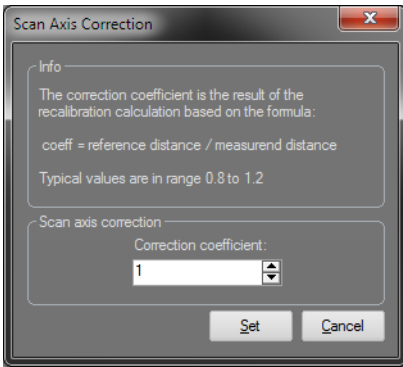
This dialog can be used to correct the scan range by entering a correction factor based on a measured distance and a known real distance.

This correction factor could for example be determined by evaluating the height information in a measurement of a calibration grid with known properties.

Scan axis correction

Correction coefficient
The scan range is multiplied with this number when the "Set" button is clicked.

14.6: Scan Head Diagnostics dialog

The Scan Head Diagnostics dialog displays the current status of the scan head. It is opened by clicking the "Diagnostics" button in Scan Head group of the Settings tab.

Tip
The Scan Head Diagnostics dialog cannot be accessed once the tip has been approached to the sample. In this case, retract the tip first.

14.6.1: Dialog for AFM scan heads
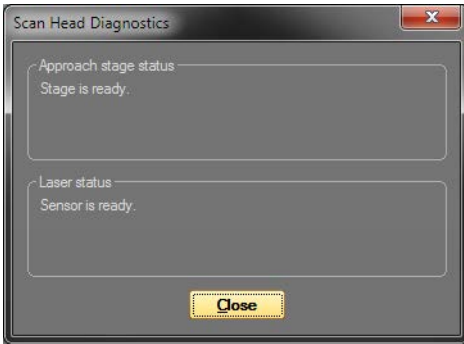
Approach stage status

Status about the motorized approach stage is shown here.

Laser Status

Status about the laser / detector system is shown here.

If the Status light on the SPM controller is blinking red, more detailed information about the failure is displayed here.

14.6.2: Dialog for STM scan head
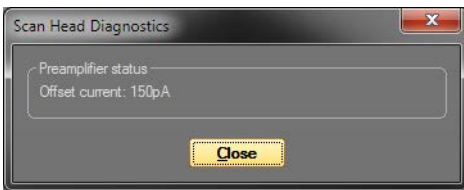
Information about the preamplifier that is present in the STM scan head is displayed here.

The offset current is a leakage current that is measured by the preamplifier when it is not in contact with the sample.

Note

The offset current is not only a measured value, but is also used as a compensating value during measurement. Therefore, even high values are not problematic for measuring at low tunnelling current.

14.7: Controller Configuration dialog
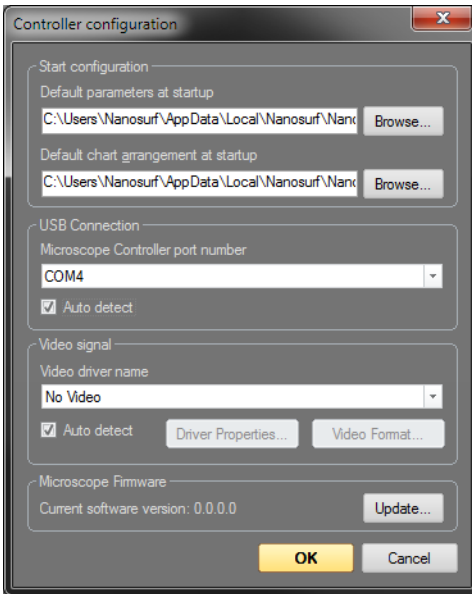
With this dialog some controller hardware related settings can be configured. On a correctly installed system, it should not be necessary to change these settings manually. The Controller configuration dialog is opened via the "Controller" button in the Hardware group of the Settings tab.

Start configuration

The parameter and chart arrangement files that are loaded when the SPM Control Software starts. Each Windows user has his/her own set of these two files a personal "Local Settings" directory. Therefore, each windows user can configure the control software to his/her own personal preferences without any consequences for other users.

USB Connection

The SPM controller uses a virtual serial port that is connected to the USB port. The number of this virtual serial port should be the same as the one shown in your the windows device manager dialog. Activate "Auto detect" to let the control software search for the right COM port at each program start. This is highly recommended, because Windows assigns individual COM port numbers to different USB connectors. With auto detect, you will be able to plug in the USB cable to different ports.

Tip
If the port number is set to "No Controller (Simulation only)" and "Auto Detect" is switched off, the control software will always start in Simulation mode. This could be useful if the software will be used mainly for analysis and is installed on a PC without microscope hardware.

Video Signal

Allows the selection of the video device driver used to handle the video camera of the SPM controller or scan head. Activate "Auto detect" to let the control software search for the right device driver. The control software then automatically selects the correct device driver for different scan heads if available. If a video device is found, the Video Panel will automatically be present in the Info pane.

Select "No video" in the list if you wish to completely suppress the video display.

Microscope Firmware

Here the currently used firmware version of the controller is shown.

In case of a standard software update (downloaded from the Nanosurf homepage) manual update of new firmware is normally not necessary since it is performed automatically at the start of the updated SPM Control Software. Automatic firmware update is always performed each time a different (older or newer!) software version is started since last time.

Click the "Update" button to install individual firmware updates you received from Nanosurf support.

14.8: SPM Parameters dialog

14.8.1: Signal Access page
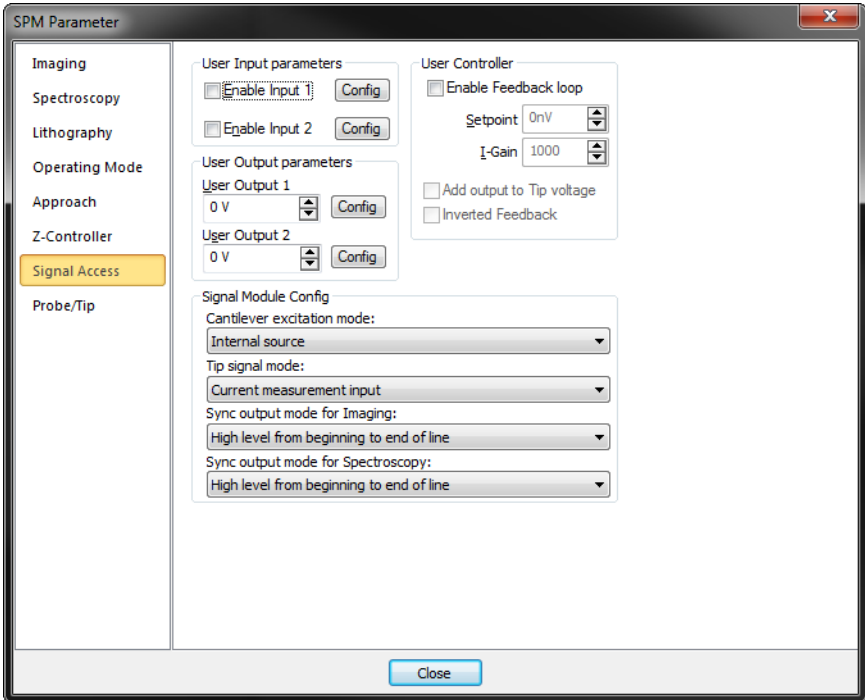
When the Signal Module A is installed, the Signal Access page allows several parameters to be configured.

User Input Parameter

Enable User Input 1 / 2
When checked, the data from the selected User Input(s) is measured and stored during all acquisition processes (e.g imaging or spectroscopy). See also *Section 19.4.1: Signal Module A* (page 261).

Config
The "Config" button opens the User Signal Editor dialog (see *Section 14.9: User Signal Editor dialog* (page 233)) to set the signal's name, range and unit.

User Output Parameter

User Output 1 / 2
Sets the static output value of the selected user output(s).

Config
The "Config" button opens the User Signal Editor dialog (see *Section 14.9: User Signal Editor dialog* (page 233)) to set the signal's name, range and unit.

User Controller

Enable Feedback loop
Activates an auxiliary feedback loop controller. This feedback loop controller uses the User Input 1 as its signal input and drives the User Output 1 with it control value. It can be used for custom measurements in all modes; Static as well as Dynamic mode (See "Help panel" >> "AppNotes" >> "AN00031 — KPFM Operating Mode").

Setpoint
Defines the Setpoint of the feedback controller. The controller keeps the User Input Signal 1 at this value.

I-Gain
Defines the I-Gain of the feedback controller.

Add output to Tip voltage
When checked, adds the feedback controller's output voltage to the Tip voltage output.

Inverted Feedback
Inverts the direction of the feedback response. Depending on the experiment to be controlled, the feedback may have to increase or decrease its output value to force the User Input signal to reach the Set Point.

Tip

If the overall gain of the experimental setup from its input to its output is positive, feedback has to be non-inverted. If it has a negative gain, feedback has to be inverted.

Signal Module Config

Cantilever Excitation Mode
The following options are available:

– **Internal source**
  Cantilever excitation is controlled by the Easyscan 2 controller itself.

– **External source**
  Cantilever excitation is controlled by an external source.

Tip Signal Mode

The following options are available:

– **Current measurement input**
   Sets the tip signal to the input current measurement level.

– **Voltage source output**
   Sets the tip signal to the measured output voltage.

– **Direct feed through with "Tip Voltage" Input-BNC**
   Establishes a direct connection between the "Tip-Voltage" Input-BNC connector and the cantilever.

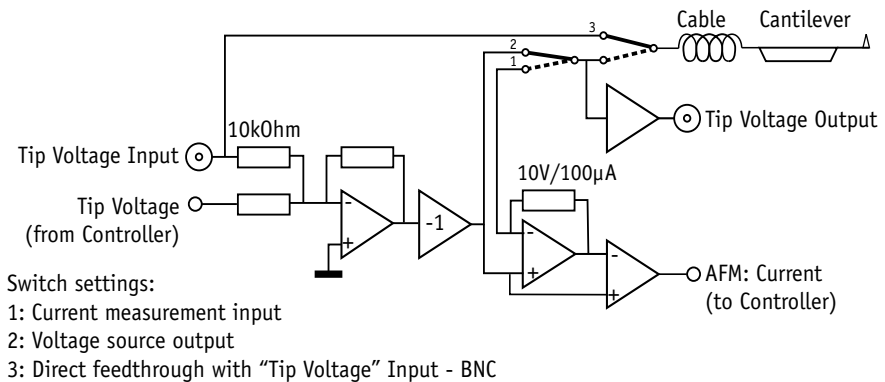These options are summarized in *Figure 14-1: Tip Signal Mode schematic.*

Figure 14-1: Tip Signal Mode schematic. Describes the electronics behind the three Tip Signal modes.

Sync output mode for Imaging / Spectroscopy

Allows configuration of the "Sync" output that can be used to synchronize external equipment with the SPM controller. Different options can be used for the Imaging and Spectroscopy modes.

14.8.2: Probe/Tip page
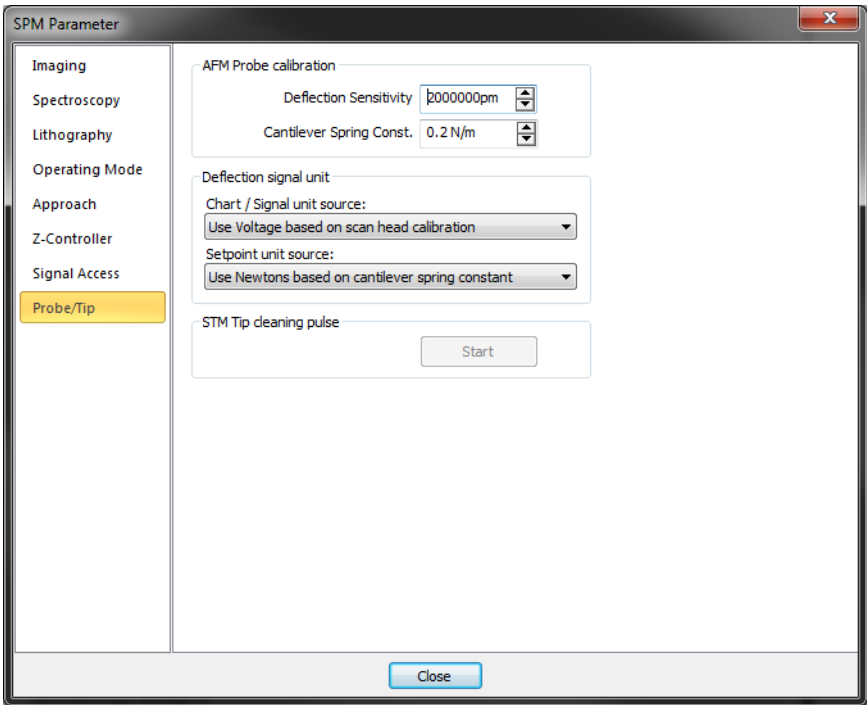
When the Signal Module A is installed, the Signal Access Page allows several parameters to be configured.

AFM Probe Calibration

Deflection Sensitivity
This value defines the scan head's deflection sensitivity as used by the SPM control software for internal calculations. Its default value is taken from the deflection value stored in the scan head calibration file. For each new calibration file loaded, this value will be set according to the new calibration file's deflection value. This default value may be not precise enough for very accurate force measurements. In such cases, you may overwrite it by a value as measured from a Force–Distance spectroscopy curve.

Cantilever Spring Const.
This value defines the spring constant of the selected cantilever, as used by the SPM control software for internal calculations. Its default value is taken from the currently selected

cantilever's database entry (see *Section 8.6: Cantilever Browser dialog* (page 86)). Each time a new cantilever is selected, this value is overwritten to the default value of the newly selected cantilever. This default value may be not precise enough for very accurate force measurements. In such cases, you may overwrite it by a measured value (e.g. a calculated spring constant, based on a mechanical cantilever model and the resonance of the cantilever).

Deflection signal unit

For all Static Force operating modes, it is possible to select different deflection signal units to be used for display in Charts/Signal values, and as used for the Setpoint. Three choices are available for each:

– **Use meters based on head calibration**
The deflection of the cantilever is displayed in meters. This is the default setting for Chart.
– **Use Newtons based on mounted cantilever's spring constant**
The deflection of the cantilever is displayed in Newtons in all charts. This is particularly useful for recording Force–Distance curves with the Spectroscopy Window. This is the default settings for SetPoint.
– **Use meters based on head calibration**
The deflection of the cantilever is displayed in Volt.

STM Tip Cleaning Pulse

Start
Applies a short voltage pulse to the STM tip to remove material picked up by the tip during measurements. The voltage pulse is approximately 5 V in height and 100 ms in duration. It can be used to clean a dirty STM tip.

14.9: User Signal Editor dialog
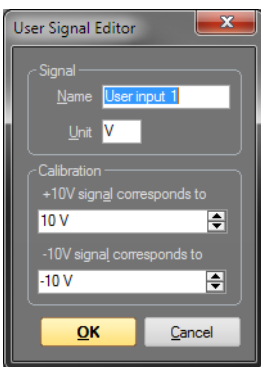
The User Signal Editor dialog is used for editing the calibration of the User Input/Output signals. The settings made in this dialog are stored in the active Scan Head calibration file.

Name
The name of the user signal. The entered name is used throughout the control software.

Unit
The base unit of the physical signal, without prefix (i.e. 'm', not 'nm' or 'μm').

Calibration
The physical signal values that correspond to the maximum and minimum signal voltages should be entered here. Prefixes can be used.

CHAPTER 15:
Quick reference

Quick reference

PART C:
APPENDICES

CHAPTER 16:
Maintenance

16.1: Introduction

To ensure fault-free operation of the microscope, the maintenance instructions below have to be observed.

16.2: The Easyscan 2 STM scan head

It is important to keep the Sample Holder and the open parts of the scanner clean. Therefore, always store the Sample Holder and scanner in a dust-free and dry environment when it is not in use. If exposed to moisture (high humidity) over a prolonged period, corrosion will occur.

16.2.1: Protecting the sample holder against corrosion

The sample holder is made of magnetic steel and therefore suffers from corrosion in a humid environment. The approach motor will not run well if the sample holder is dirty or corroded. To reduce corrosion and increase life expectancy, the sample holder must be stored in its container together with the moisture absorbing silica container. The container is waterproof but not airtight. The silica contains a blue indicator which turns pink when saturated.

Figure 16-1: STM Sample Holder Container. (from left to right) Screw cap, Sample holder, Silica container, Sample Holder Container.

 To regenerate the silica:

➲   Heat the silica container at 100°C for at least two hours until it turns completely blue again.

16.2.2: Cleaning parts of the approach motor

If you have touched the metal part of the sample holder or it has otherwise become dirty, or if the approach motor does not move, the Sample Holder should be cleaned. To do this:

❶   Take a soft cloth, if necessary moistened with alcohol.

❷ Clean the sample holder by moving the cloth along the sample holder in the axial direction.
Do not move it around its circumference!

❸ Let the parts dry before operating the motor again.

If the approach motor still does not move:

❶ Take a cotton swab, if necessary lightly moistened with alcohol.

Figure 16-2: Cleaning the sample holder guide bars

❷ Clean the sample holder guide bars (*Figure 16-2: Cleaning the sample holder guide bars*).

❸ Clean the surfaces of the approach motor that touch the sample holder.

❹ Clean the tip holder (remove the tip when doing this).

❺ Let the parts dry before operating the motor again.

16.3: The Easyscan 2 controller

To clean the case and the controls of the controller:

➡ Use a soft cloth, lightly moistened with a mild detergent solution. Do not use any abrasive pads or solvents like alcohol or spirits.

CHAPTER 17:

Problems and solutions

17.1: Introduction

The problems described here can occur during normal operation of the microscope. If the suggested course of action does not solve the problem, or the problem is not described here, refer to *Section 17.4: Nanosurf support* (page 249).

17.2: Software and driver problems

17.2.1: No connection to microscope
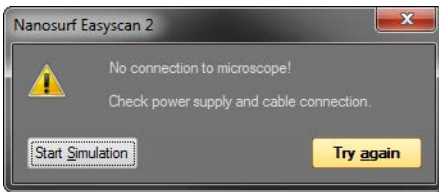
This error message appears when the Easyscan 2 software is waiting for an answer from the controller. Most likely, the Easyscan 2 is not connected to the mains power, or it is not turned on. In this case the status lights on the top of the controller are off. To fix this problem:

➥ Check the connections and the power switch.

17.2.2: USB Port error
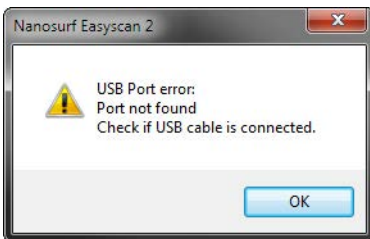
The USB serial converter is not available. The USB cable is not properly connected. In this case the USB power light on the Easyscan 2 controller rear panel) does not light up (*Figure 1-4: The Easyscan 2 controller* (page 18)). To fix this problem:

❶ Check if the a second copy of the Easyscan 2 is already running and occupying the USB port.

❷ Check that the USB cable is properly connected.

If this does not solve the problem, check if there is a driver problem with the USB Serial port/USB Serial converter drivers, as described in the next section.

17.2.3: Driver problems

If you have trouble connecting to the controller, or if the video image in the positioning window is not available, it is possible that one of the drivers of your instrument is causing problems, for example because the installation did not work, or the installation of some other hardware is in conflict with the drivers of the Easyscan 2. In order to solve driver problems:

❶ Check for driver updates on the Nanosurf Support web site.

❷ Insert the installation CD for your instrument.

❸ Log in with Administrator privileges.

The device manager can then be opened to view and correct any driver problems:

❶ Open the windows menu "Start" >> "Control Panel".
The control panel now opens.

❷ Select "Large icons" or "Small icons" if "View by" is set to "Categories".

❸ Double-click the "Device Manager" icon.
The device manager now opens.

When the device manager opens and your controller is connected to your computer, you may see the drivers shown in *Figure 17-1: Device manager* (information may vary depending on the configuration of your system).

If there are problems with any of these drivers, or a wrong driver is installed, you can try to do the following to fix this:

❶ Double click on the driver.
Properties dialog for the device now opens.

❷ Select the "Driver"-tab.

❸ Click the "Update Driver"-button
Windows will now ask you where to look for the driver.

❹ Instruct windows to manually search for the driver files on the Installation CD.
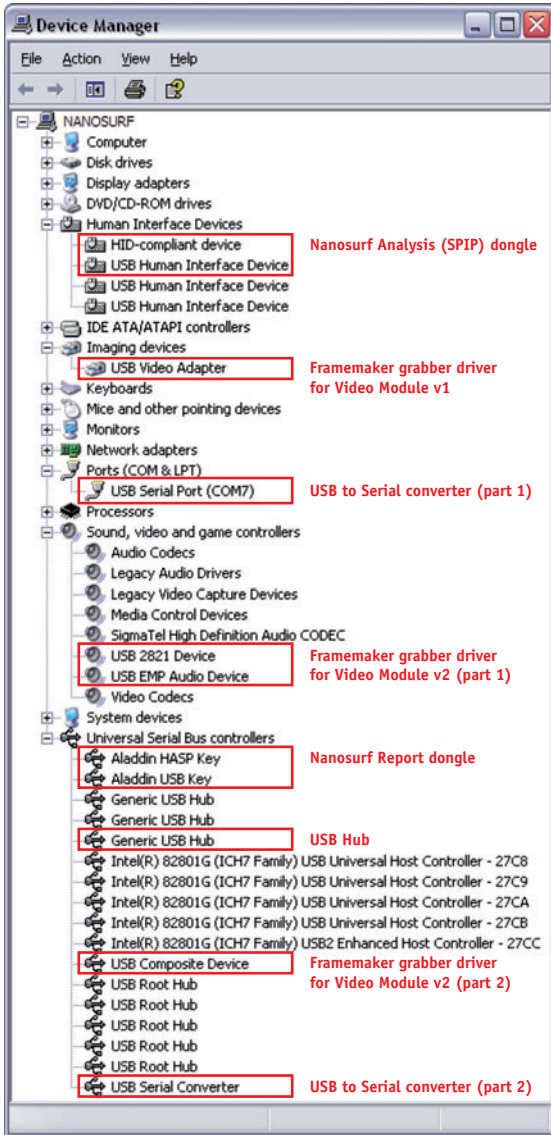
Figure 17-1: Device manager. The drivers that may be installed on your system when your controller is connected to the computer.

17.3: STM measurement problems

17.3.1: Manual approach is too slow / stops sometimes

If the manual approach using the approach motor (see *Section 4.4.2: Manual approach using the approach motor* (page 37)) is affected:

➡ Clean the sample holder guide bars and the surfaces of the approach motor, following the procedure described in *Chapter 16: Maintenance* (page 239).

17.3.2: Automatic final approach is too slow / stops sometimes

Even if the manual approach works, the automatic final approach (*Section 4.4.3: Automatic final approach* (page 38)) may not work.

➡ Clean the sample holder guide bars and the surfaces following the procedure described in *Chapter 16: Maintenance* (page 239).

If cleaning does not help, the step size may be too small. To solve this problem:

❶ Open the SPM Parameters dialog (see *Section 7.9: SPM Parameters dialog* (page 74)).

❷ In the Approach page of the dialog, increase the value of "Move Speed" by a few percent until the approach works.

Now the motor moves the sample holder with larger steps during automatic approach.

❸ Save the new value using "File menu" >> "Parameters" >> "Save".

17.3.3: Automatic final approach crashes the tip into the sample

In this case the motor moves the sample holder towards the tip with too large steps:

❶ Open the SPM Parameters dialog (see *Section 7.9: SPM Parameters dialog* (page 74)).

❷ In the Approach page of the dialog, decrease the value of "Move Speed" by 10%.

❸ Repeat the approach with a new tip. If the approach fails again, reduce "Move Speed" further.

❹ Save the best value using "File menu" >> "Parameters" >> "Save".

17.3.4: Image quality suddenly deteriorates

There are several possible causes for this phenomenon. These are described in the following sections.

Z-Drift

The tip drifted outside the Z-range of the scanner. In this case, the Probe Status light (see *Figure 1-4: The Easyscan 2 controller* (page 18)) will either light up orange/yellow or red.

If the light is orange/yellow, the tip has lost contact with the sample:

➡ In the Approach group of the Acquisition tab, first click the "Approach" button, then repeat the steps in *Chapter 4: First measurements* (page 33).

If the light is red, the tip has drifted into the sample. You can try to move the sample surface within the Z-range of the scanner, although the tip may already have been damaged:

❶ In the Approach group of the Acquisition tab, first click the "Withdraw" button.

If the light is still red after withdrawing, prepare a new tip (*Section 3.3: Preparing and installing the STM tip* (page 26)).

❷ Click the "Approach" button.

XY-Drift

The scanner may have drifted close to a deformity in the sample surface. Try to find a different measurement position:

❶ Increase the scan range.

❷ Zoom into a flat area.

Tip modification

The tip may have picked up some particles or other material from the sample surface. If this is the case:

➡ Follow the instructions given in *Chapter 5: Improving measurement quality* (page 47).

17.4: Nanosurf support

17.4.1: Self help

The fastest way to solve a problem is often to solve it yourself. If the previously suggested actions did not help, or the problem is not described here, refer to the Nanosurf support pages:

❶ Open *www.nanosurf.com*.

❷ Click on "Support".

❸ Enter the login and password combination that you received upon registering.

❹ Select the Easyscan 2 link.

❺ If the problem is software related, try to upgrade to the latest version and/or read the "SPM Software Version History" to see if the problem was solved. For the solution to other problems, refer to the Frequently Asked Questions (FAQ).

If your instrument has not been registered yet, you will first have to register to receive a password.

17.4.2: Assistance

If the standard solutions are not sufficient, contact your local distributor for help. In order to resolve the problem as fast as possible, please provide as much information as possible, such as:

• A detailed description of what happened before the problem occurred. For example: "When I click the 'Approach' button, then quickly click abort, the controller will not react to anything I do anymore. This only happens when measuring in Dynamic Force Mode."

• If an error message was displayed: The exact text of the message, or at least the start of the message.

• The serial number of your scan head and/or controller.

• A description of the computer hardware and software on which the control software is running: computer brand, type (laptop or desktop), operating system, software version etc.

• Original Nanosurf image data (.nid) files that show the problem, rather than bitmap screen shots, because these files contain all the settings that were used to make them.

• Parameter (.par) files with the instrument settings that were used when the problem occurred.

• Script files, if the problem occurs during the operation of a script.

> **IMPORANT**
>
> Sending ".vbs" scripts by e-mail often does not work, because these files are usually blocked as a security measure. To successfully e-mail a script, you may either:
> - Add the script text to the body of the e-mail.
> - Change the extension of the script file to ".txt" and attach it to the e-mail.
> - Compress the script file to a ".zip" archive and attach it to the e-mail.

17.5: About dialog
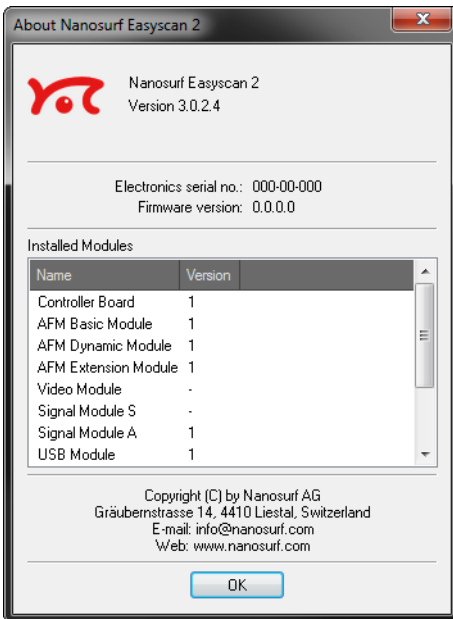
The About dialog displays information that may be useful for diagnostics when you have problems with your instrument. The About dialog is opened by clicking the "Information" button on the upper right corner of the program window, just below the "close window" button:

The About dialog contains the following information:
- The version number of the control software.

- The serial number of the controller (when the microscope simulation is active, the serial number "0xx-00-000" is displayed).
- The version number of the firmware that is running on the controller.
- The version number of all modules built into the controller.
- The version number of all installed software options.
- Contact information for getting more support.

CHAPTER 18:
# STM theory

18.1: What is STM?

Microscopy is one of the most exciting scientific techniques. The insight into small dimensions has led to a new understanding of the structure of materials and forms of life.

With the help of the scanning tunneling microscope (STM) it is possible to look into the fascinating world of the atoms. This completely new microscopy technique works without focusing elements and features atomic resolution (laterally and vertically).

The Scanning Tunneling Microscope was developed by Gerd Binnig and Heinrich Rohrer in the early 80's at the IBM research laboratory in Rüschlikon, Switzerland. For this revolutionary innovation Binnig and Rohrer were awarded the Nobel prize in Physics in 1986.

In the STM, a small sharp conducting tip is scanned across the sample's surface, so close that the so-called "tunneling current" can flow. With the help of that current the tip–sample distance can be controlled very precisely. Therefore an enormous resolution is achieved so that the atomic arrangement of metallic surfaces can be "probed".

To be able to get such excellent pictures of atomic resolution is almost incredible, considering that the size of the atom in relation to the tip is that of a golf ball to a mountain.
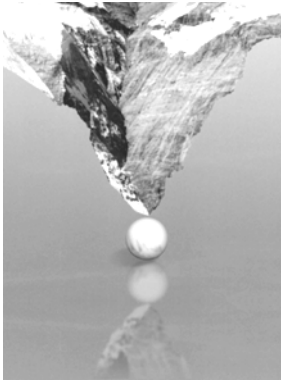
18.2: Scanning with the Easyscan 2 STM

In the Easyscan 2 STM, a platinum-iridium tip is moved in three dimensions using piezo-crystal translators that are driven with sub-nanometer precision.

The sample to be examined approaches the tip within a distance of 1 nanometer (1 nm= 1 / 1 000 000 000 m). Classical physics would prohibit the appearance of electrons in the small gap between a tip and a sample, but if a sharp tip and a conducting surface are put

under a low voltage (U~0.1V), a very small tunneling current (I~1nA) may nevertheless flow between tip and sample. This tunneling current is due to a quantum physics effect.
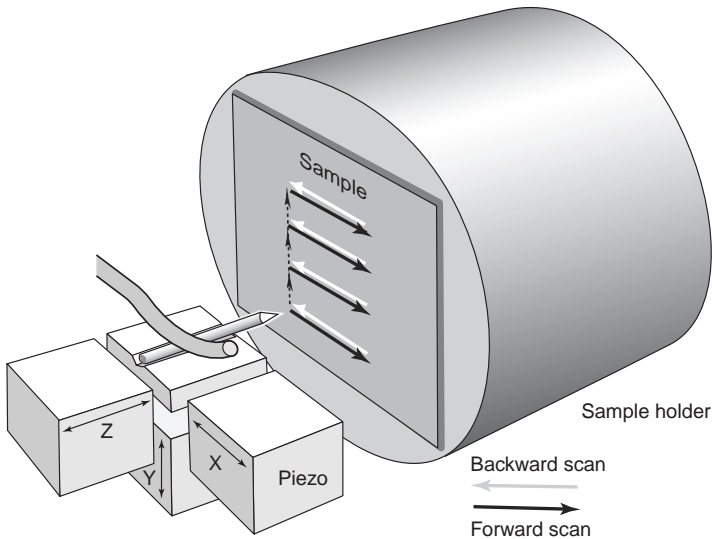
The strength of the tunneling current depends exponentially on the distance between the tip and the sample (usually referred to as Z–Distance). This extreme dependence on the Z–Distance makes it possible to measure the tip–sample movement very precisely. One of the three piezo crystals, the Z-piezo, can now be used in a feedback loop that keeps the tunneling current constant by appropriately changing the Z–Distance.

To obtain an image of the sample, the tip is scanned using the X- and Y-piezo crystals. The feedback loop will now let the tip follow the structure of the sample's surface. A height image can now be made by recording the position of the Z-feedback loop as a function of the XY-piezo position. This "landscape" (or topography) of the atomic surface is then drawn line by line on the computer screen.

The sample can also be scanned in a second mode: When the feedback loop is slowed down very much, the tip scans at a fixed distance from the sample (constant height mode). This time the variations in the tunneling current are measured and drawn line by line on the computer screen. However, this mode only works when the sample is atomically flat, because the tip would otherwise "crash" into the sample.
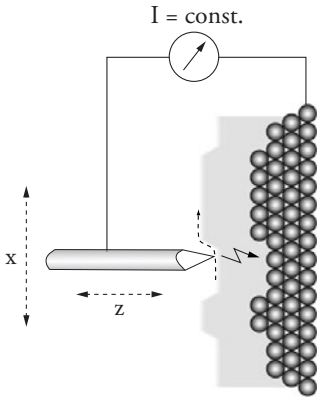
Figure 18-1: Feedback loop. The feedback loop maintains a constant tunneling current between the tip and the sample during motion in the X-direction by changing the Z-direction (viewed from top)
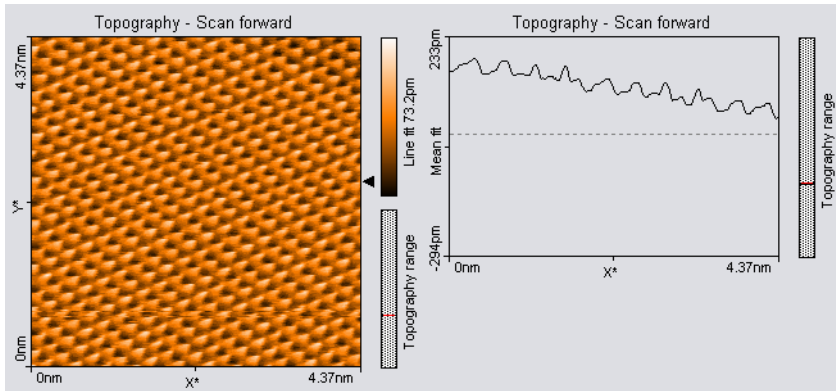

Figure 18-2: STM image of graphite

CHAPTER 19:

Technical data

19.1: Introduction

The specifications given in this chapter represent typical values of the Nanosurf Easyscan 2 STM system. The exact specifications of all components belonging to your system are given on the calibration certificate delivered with the instrument.

19.2: The Easyscan 2 STM Scan Heads

19.2.1: Specifications and features

STM Scan Head:	500 nm	1 µm	500 nm LC	1 µm LC
Maximum Scan range[1]	500 nm	1.0 µm	500 nm	1.0 µm
Maximum Z-range[1]	200 nm	200 nm	200 nm	200 nm
Drive resolution Z[2]	3 pm	3 pm	3 pm	3 pm
Drive resolution XY[2]	7.6 pm	15 pm	7.6 pm	15 pm
Current Setpoint	0.1-100 nA in 25 pA steps		0.02-20 nA in 5 pA steps	
Imaging modes:	Constant Current (Topography), Constant Height (Current)			
Spectroscopy modes:	Current-Voltage, Current–Distance			
Tip voltage:	±10 V in 5 mV steps			
Tip–sample approach:	Stick-slip piezo motor			
Sample size:	Max. 10 mm diameter			

(1) These are typical values, the exact values are given on the calibration certificate that is delivered with the instrument.

(2) Calculated by dividing the maximum range by 16 bits; atomic resolution on HOPG can be obtained with all STMs
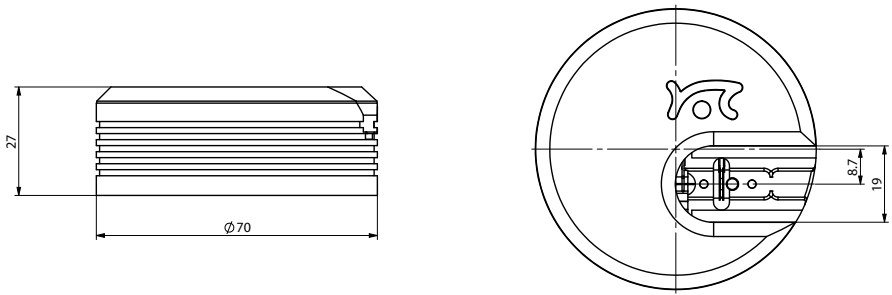
19.2.2: Dimensions

Figure 19-1: The Nanosurf Easyscan 2 STM Scan Head. All dimensions in mm.

19.3: The Easyscan 2 Controller

19.3.1: Hardware features and specifications

The Easyscan 2 Controller electronics	
Controller size / weight:	470×120×80 mm / 2.4 kg
Power supply:	90–240 V AC, 50/60 Hz, 100 W
Computer interface:	USB 2.0 (Appr. controller serial number 23-06-030 and higher)
Integrated USB hub:	2 Ports (100 mA max)
Scan generator:	16 bit D/A converter for all axes
Scan drive signals:	±10 V, no high voltage
Scan speed:	Up to 60 ms/line at 128 data points/line
Measurement channels:	16 bit A/D converters, up to five signals depending on mode.
Scan area and data points:	Individual width/height, up to 2048×2048
Scan image rotation:	0–360°
Sample tilt compensation:	Hardware X/Y-slope compensation
Spectroscopy modes:	Single point measurement or multiple measurements along a vector
Spectroscopy data points:	Up to 65535
Spectroscopy averaging:	Up to 1024 times

Table 19-1: General features and specifications of the Easyscan 2 controller electronics.

19.3.2: Software features and computer requirements

Nanosurf SPM Control Software

Simultaneous display of data in charts types:	Line graph, Color map, 3D view, …
User profiles:	Customizable display and parameter settings
Online processing functions:	Mean fit, Polynomial fit, Derived data, …
Quick evaluation functions:	distance, angle, cross section, roughness, …
Data export:	TIFF, PNG, BMP, ASCII, CSV, …

Nanosurf Scripting Interface

Applications:	Automating measurement tasks, custom evaluation functions, using third party measurement equipment, …
Included control software:	Windows Scripting Host: Visual Basic Script, Java Script, …
Remote control by:	COM compatible languages: LabView, MathLab, Visual Basic, Delphi, C++, …

The Scripting Interface has to be purchased separately for Easyscan 2 systems.

Lithography can also be performed via the scripting interface, but is more easily performed via the Lithography Window of the control software, or (when more advanced options are required) by purchasing the Lithography Option.

Computer requirements

For a detailed description of computer hardware requirements and supported operating systems, see *Nanosurf technical note "TN00477 — Computer requirements for Nanosurf Products"*. The technical note can be downloaded from the Support section of the Nanosurf website by all registered users.

19.4: Hardware modules and options

19.4.1: Signal Module A

Signal Module A can be used to monitor microscope signals and add functionality (custom operating modes) to the Easyscan 2 system. It consists of electronic modules that are built into the Easyscan 2 controller as well as of a Connector Box that is externally attached to the controller. For information on installing Signal Module A, refer to *Section 2.2: Installing the hardware* (page 21).

The signals are available on twenty-one BNC connectors that are labelled with their signal names. The signal names and their function are listed in *Table 19-2: Monitor signals* and *Table 19-3: Custom operating mode signals*.

Signal name	Function
X-Axis	X-Position command of the Scanner. Is affected by Image X-Pos and the Imaging Area Rotation.

Table 19-2: Monitor signals

Signal name	Function
Y-Axis	Y-Position command of the Scanner. Is affected by Image X-Pos and the Imaging Area Rotation.
Z-Axis	Z-Position command of the Scanner. Is affected by the Z-Controller output, Ref. Z-Plane, X- and Y-Slope.
Tip Voltage	The voltage applied to the tip.
Approach	The voltage ramp that drives the approach motor.
Excitation	No signal (for AFM only).
Deflection	The tip current (see below).
Amplitude	No signal (for AFM only).
Phase	No signal (for AFM only).

Table 19-2: Monitor signals

The calibration of the monitor signals can be found by looking up the signal calibration in the Scan Head Calibration Dialog, reached via the menu "Options" >> "Config Scan Head...". The magnitude of the physical signal can be calculated from the Monitor Signal voltage using the formula:

$$PhysicalSignal[Unit] \ = \ \frac{MonitorSignalVoltage}{10[V]} \cdot Maximum + Offset$$

The sum of the modulation inputs and the output value (for example of X-Axis) should not exceed the −10V to +10V range. The Excitation signal should not exceed the −5V to +5V range.

In addition, −15V and +15V voltage sources are available for driving small home-made electronics. The pin-out of this connector is shown in *Figure 19-2: Voltage source connector*.

Signal name	Function
Sync	An output that can be used to synchronize external equipment with the Easyscan 2 controller. This feature can be controlled with the scripting interface. For more information, refer to the Script Programmers Manual, topic "Object Reference" >> "Class Scan" >> "SyncOutMode" and "Object Reference" >> "Class Spec" >> "SyncOutMode"
User 1 Output	An analog output that can be used to drive external instruments using the controller. The User output can be used for special spectroscopy measurements.

Table 19-3: Custom operating mode signals.

| Signal name	Function
User 2 Output	An analog output that can be used to drive external instruments using the controller. The User output can be used for special spectroscopy measurements.
X-Axis Input	The Input voltage is added to the X-Position command of the scanner.
Y-Axis Input	The Input voltage is added to the Y-Position command of the scanner.
Z-Axis Input	The Input voltage is added to the Z-Position command of the scanner. If the Z-Controller is turned on, it will try to compensate this voltage, as a result of which the Input voltage will be added to the topography measurement.
Tip Voltage	The input voltage is added to the Tip-voltage set in the control software.
Excitation Input	No function (for AFM only).
User 1 Input	An analog input that can be used to record the signal from external instruments in Imaging and Spectroscopy measurements.
User 2 Input	An analog input that can be used to record the signal from external instruments in Imaging and Spectroscopy measurements.
Aux 1	A connector that can be used for accessing signals that are not otherwise available. Contact your local distributor if you need to use this connector.
Aux 2	A connector that can be used for accessing signals that are not otherwise available. Contact your local distributor if you need to use this connector.

Table 19-3: Custom operating mode signals.
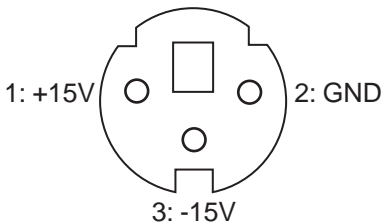
Figure 19-2: Voltage source connector. Connector as seen from outside.

Using the User Inputs and Outputs

The User Inputs and Outputs can be accessed through the Operating mode panel. Each signal can be calibrated with the User Signal Editor, which is accessed by clicking the corresponding "Config" button. This Section is only available in the Advanced user interface level. Refer to *Section 14.9: User Signal Editor dialog* (page 233) for a more detailed explanation.

Various other User Input and Output settings can be configured in the Signal Access page of the SPM Parameters dialog. Refer to *Section 14.8.1: Signal Access page* (page 229) for details on how to change them.