



**Operating Instructions**

**for**

**Naio Control Software**

**Version 3.8**

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NAIOSTM OPERATING INSTRUCTIONS V3.8R3, BT05387-27.

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## About this Manual

This manual describes the Nanosurf NaioSTM system. For your convenience, it has been divided into three separate parts:

**PART A: INTRODUCTION TO THE INSTRUMENT** will familiarize you with the Nanosurf NaioSTM system, and will explain how to set up your system and operate it on a daily basis. Among other things, it will also describe how to set up basic experiments and how to generally improve measurement quality. Part A starts with *Chapter 1: The NaioSTM* (page 15) and ends with *Chapter 6: Finishing measurements* (page 57).

**PART B: SOFTWARE REFERENCE** is a reference for the software that comes with the NaioSTM system. It starts with *Chapter 7: The user interface* (page 63) and ends with *Chapter 15: Quick reference* (page 205). Its content applies to the Nanosurf Naio control software version 3.8. If you are using newer software versions, download the latest manual from the Nanosurf support pages or refer to the "SPM software version history.pdf" file that came with the newer software. 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 209) and ends with *Chapter 19: Technical data* (page 225).





## **PART A:**

# **INTRODUCTION TO THE INSTRUMENT**



**CHAPTER 1:**

# **The NaioSTM**

## 1.1: Introduction

The Nanosurf NaioSTM 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 NaioSTM, 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 NaioSTM 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 225).

Several other Nanosurf products can be used in conjunction with the NaioSTM:

- Naio Advanced Modes Option: package that enables Advanced Spectroscopy and Advanced Lithography modes.
- Nanosurf Report: software for simple automatic evaluation and report generation of SPM measurements.
- Nanosurf Analysis: software for detailed analysis of SPM measurements.
- The Nanosurf IsoStage: a highly compact active vibration isolation table.

## 1.2: Components of the system

This section describes the parts that may be delivered with a Nanosurf NaioSTM 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. Verify that the package contains the following components:



**Figure 1-1: Components.** The NaioSTM system

1. The NaioSTM system.
2. Magnifying cover with 10x magnifier.
3. USB cable.
4. Mains cable.
5. Power supply:..

6. NaioSTM tool set. The items contained in the NaioSTM tool set are described in the next section.
7. The NaioSTM installation CD (not shown): contains product software and calibration files, as well as PDF files of all relevant manuals, application notes and technical notes.
8. A calibration certificate for your system (not shown).
9. This NaioSTM Operating Instructions manual (not shown).
10. Naio Advanced Modes Option certificate of purchase with Activation key printed on it (option; not shown; comes with Naio Advanced Mode Option).
11. Instrument case (not shown).

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 options included in your order. It minimally contains 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. STM Sample holder in its container.
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 (not shown).
8. USB dongle for Nanosurf Report or SPIP software (option; not shown).

## 1.3: Connectors, indicators and controls

Use this section to discover the function and location of key parts of the NaioSTM system, as referred to throughout this manual.

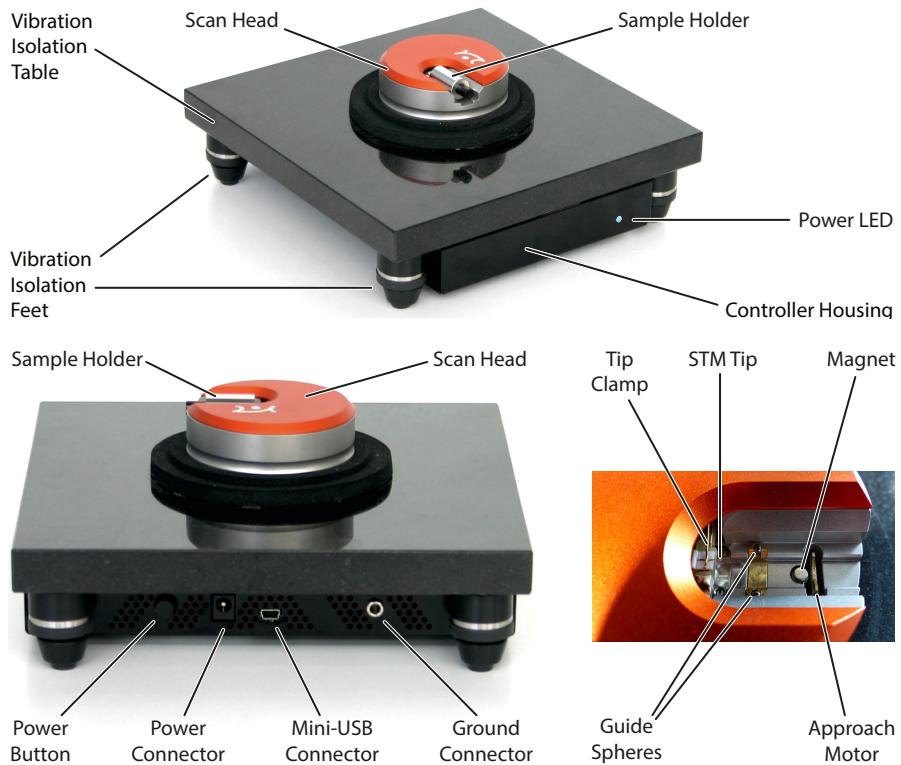


Figure 1-3: Parts of the system.

### Vibration isolation table

Granite table that (through its weight) helps eliminate environmental vibrations that would otherwise disturb sample measurements.

### Vibration isolation feet

Rubber, spring-mounted feet that further isolate the NaioSTM system from mechanically transmitted vibrations.

**Controller housing**

Black, metallic housing that shields and protects the NaioSTM control electronics mounted directly underneath the vibration isolation table.

**Power LED**

Lights up blue when the system is powered on.

**Magnifying cover**

A partly metallic, partly plexiglass cover that protects measurements from air flow and (to a lesser extent) acoustic disturbances, and that contains a 10× magnifier lens (see *Figure 1-1: Components*, item 2).

**Scan head**

Contains all electronic and mechanical components necessary for scanning.

**Sample holder**

Metallic cylinder with magnet that holds the sample disc.

**Power button**

Used to turn the NaioSTM system on or off.

**Power connector**

Used to connect the power supply.

**USB connector**

Used to connect the NaioSTM system to a personal computer.

**Ground connector**

Used to connect the electrical ground of the NaioSTM system to that of other equipment.

**Approach motor**

Motorized part of the scan head that brings the sample into tunneling distance of the tip.

**Guide spheres**

Two metal balls at the bottom inside of the scan head, along which the sample holder slides during sample approach/retraction.

**Tip Clamp**

Used to press the STM tip down onto the tip holder (white surface below the tip clamp). Holds the STM tip securely in place.

**STM tip**

Cut Pt/Ir wire with sharp tip for high-resolution scanning tunneling measurements.

**Magnet**

Pulls the sample holder down onto the approach motor for a strong friction contact between the two, resulting in reliable sample holder movements.

## CHAPTER 1: THE NAIOSTM

**CHAPTER 2:**

# **Installing the NaioSTM**

## 2.1: Installing the Naio control software

### 2.1.1: Preparation

Before installation, the following steps need to be performed:

- ① Make sure the computer to be used meets the minimal computer requirements, as described in *Chapter 19: Technical data* under.
- ② Make sure none of the NaioSTM system's hardware is connected to the computer (this includes the optional (USB) NaioSTM Side View ).
- ③ Turn on the computer and start Windows.
- ④ Log on with Administrator privileges.

#### Important

Do not run any other programs while installing the NaioSTM software.

### 2.1.2: Installation

To initiate the installation procedure:

- ① Insert the Naio 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 Naio Installation CD and start the program "CD\_Start.exe".

#### Important

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

- ② Click the "Install Naio software" button.

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

The User Account Control (UAC) dialog may pop up after clicking the "Install Naio 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 each of 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 advanced lithography features of the NaioSTM 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.

Likewise, if you wish to use the Gwyddion program for complex image analysis, you may also opt to install it now.

AtomicJ can be installed if you wish to analyze spectroscopy maps.

If not, you can exit by clicking the “Exit” button and continue with *Section 2.2: Installing the hardware*.

## 2.2: Installing the hardware

### Important

- 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.
- Make sure your mains power connection is protected against excess voltage surges.
- If the vibration isolation of your setup proves to be insufficient for your measurement purposes, you can use an active vibration isolation table such as the Nanosurf Isostage. Refer to the respective manuals for installation instructions.

- ❶ Connect the NaioSTM to the power supply

## CHAPTER 2: INSTALLING THE NAIOSTM



**Figure 2-1: Measurement setup.** Complete NaioSTM system with personal computer.

- ② Connect the NaioSTM to the computer on which the Naio control software was installed (see *Section 2.1: Installing the Naio control software*) using the supplied USB cable (*Figure 1-1: Components* (page 16), item 3).

A popup balloon may appear in the Windows notification area, stating that new hardware devices have been found and drivers are being installed. This can take quite some time (20 seconds or more). Please be patient! After successful installation, the popup balloon indicates that the installation has finished and 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 NaioSTM* (page 21)), the instrument and the sample have to be prepared for measurement. The preparation consists of three steps:

1. *Initializing the NaioSTM system*
2. *Preparing and installing the STM tip*
3. *Preparing and mounting the sample*

## 3.2: Initializing the NaioSTM system

To initialize the NaioSTM system:

- ① Make sure that the NaioSTM system is connected to the mains power and to the USB port of the control computer.
- ② Turn on the power of the NaioSTM system by pressing the power button at the back of the controller housing.  
A blue power LED on the side of the system will light up.
- ③ Start the Naio control software on the control computer.

Now a message "Controller startup in progress" is displayed on the computer screen. When initialization is completed, a message "Starting system" is briefly displayed in the status bar of the NaioSTM control software.

## 3.3: Preparing and installing the STM tip

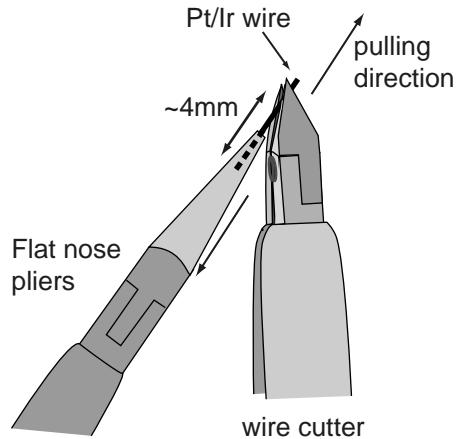
The STM tip can be prepared and installed by yourself. This is the most difficult part of your preparations. It usually needs patience and some practice to get the first good tip. Only an accurately cut tip enables optimal measurements. Therefore, cutting and installing should be carried out with great 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 a tip:

- ① Clean the cutting part of the wire cutters (*Figure 1-2: Contents of the tool set* (page 17), 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.
- ② 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.

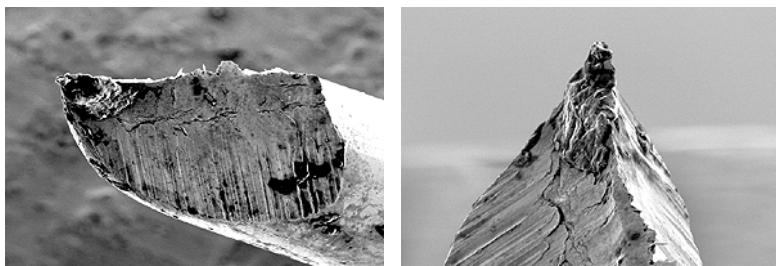
To prepare the tip:

- ① Hold the end of the wire firmly with the pliers.
- ② 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**

- ③ Close the cutters until you can feel the wire, but do not cut the wire.
- ④ 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

- ⑤ Use the pointed tweezers to hold the tip wire with just behind the tip.
- ⑥ Release the flat pliers.

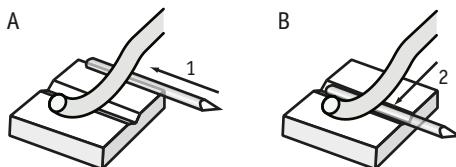
## Important

- 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 up too high.

To mount a newly prepared tip:

- ① 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 tip clamp, A*).
- ② Move the tip wire sideways until it is in the groove in the tip holder (*Figure 3-3: Mounting the tip under the tip clamp, B*).

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



**Figure 3-3: Mounting the tip under the tip clamp**

The tip is now installed.

## 3.4: Preparing and mounting 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 optional samples, which are usually packed in the NaioSTM 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 boxes. 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 3-4: Cleaving graphite*):

- ① Put the sample on the table using a pair of tweezers.
- ② 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.
- ③ 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 17), item 7). The supports are made of a magnetic steel that is 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.

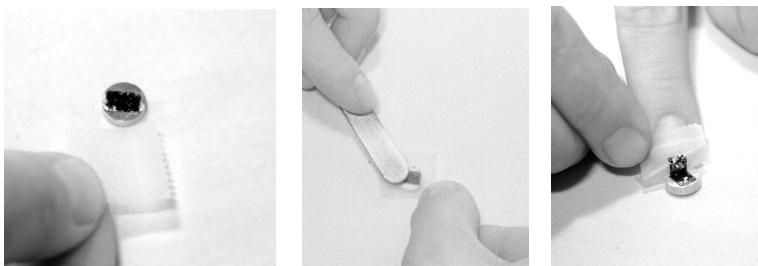


Figure 3-4: Cleaving graphite

### 3.4.3: Mounting the sample

To mount a sample:

- ① Unpack the sample holder (*Figure 1-2: Contents of the tool set* (page 17), item 5) from its plastic storage vial, touching only its black plastic handle.

#### Important

Always store the sample holder in its plastic storage vial in order to prevent corrosion (see *Chapter 16: Maintenance* (page 209)).

- ② Put the prepared sample onto the magnetic end of the sample holder using a pair of tweezers (*Figure 3-5: Putting the sample on the sample holder*).

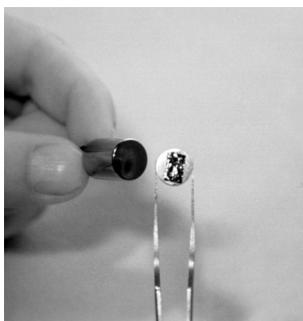


Figure 3-5: Putting the sample on the sample holder

- ③ Lower the front end of the sample holder onto the sample holder guide spheres (two metal balls on the bottom inside of the scan head) first. Then gently settle the back end onto the approach motor support.

Place the sample holder into the scan head carefully so that it does not touch the tip, and in such a way that the sample is not pulled from the sample holder by the magnet that pulls the sample holder down onto the approach motor (*Figure 3-6: Placing the Sample Holder in the scan head*).



**Figure 3-6: Placing the Sample Holder in the scan head**

## CHAPTER 3: PREPARING FOR MEASUREMENT

**CHAPTER 4:**

# **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. If you are not familiar with the Naio control software, first read *Chapter 7: The user interface* (page 63) and the chapters directly thereafter, or try using the Naio control software in microscope simulation mode (see *Section 4.7: Running the microscope simulation*).

### 4.1.1: Entering and changing parameter values

When using the Nanosurf NaioSTM and the Naio control software, you may from time to time need to change or enter numerical parameter values in various panels and dialogs.

To change a parameter or enter a value:

- Activate the parameter by clicking inside the (white) parameter edit box:



- 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 Naio controller, for example due to resolution or timing limits. In such cases, the desired value is automatically changed to the nearest possible value.

## 4.2: Preparing the instrument

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

- ① Prepare and install a Pt/Ir tip.
- ② Install the HOPG sample.

To make sure that the configuration is correct:

- Open *File menu >> Parameters >> Load parameter settings* and load the file "Default\_STM.par" from the folder that holds the default Naio configurations.  
Usually this is "C:\Program Files\Nanosurf Naio\Config".

## 4.3: 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*, *Fine approach approach motor*, and the *Automatic final approach*. The color of the Status light 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:

- ➊ Select the Acquisition tab

The controls for positioning the sample with respect to the tip are located in the *Approach group*.

### 4.3.1: Manual coarse approach

To perform a manual coarse approach:

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



Figure 4-1: Manual coarse approach

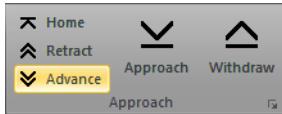
- ② If the tip is pointing toward a rough area of the sample, try turning the sample holder around its axis so that the tip points towards a flat, mirror-like area of the sample.
- ③ Put the magnifying cover (*Figure 1-1: Components* (page 16), item 2) over the scan head without touching the sample holder.
- ④ 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.

### 4.3.2: Fine approach 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.

- ① Watch the distance between tip and sample with help of the magnifier.
- ② Click the “Advance” button in the Approach group of the Acquisition tab to move the sample to within a fraction of a millimeter of the 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.



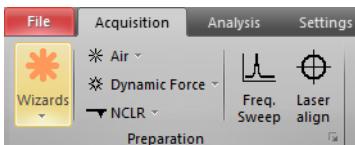
**Figure 4-2: Tip-sample position.** Position at the end of the Manual approach with the approach motor.

- ③ If you cannot see the motor moving, clean the sample holder guide spheres and the surfaces of the approach motor following the procedure described in *Chapter 16: Maintenance* (page 209).

### 4.3.3: 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:

- ① In the *Preparation group* of the *Acquisition tab*, click the *Wizards* button:



- ② 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.

- ③ Answer the questions of the imaging 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 29).

Now that the initial software settings have been given suitable values, you need to name the measurement series (see *Section 13.5.1: History file mask* (page 163)). 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 264)).

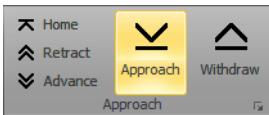
To set the measurement series name:

- ① Activate the *Gallery panel* (see *Section 13.5: Gallery panel* (page 162)) in the info pane.
- ② Click the *History* tab at the top of the *Gallery panel* with the mouse.

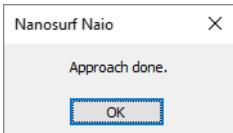
- ③ In the entry box at the top of the panel, enter a name by hand or use the *Mask editor dialog* (see *Section 13.5.4: Mask editor dialog* (page 164)) to create the name mask. If no [INDEX] attribute is explicitly added to the name mask, it will be automatically applied to the end of the file name so that individual measurements can be stored and distinguished.

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

- ① 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 in the Naio control software will blink red-green-orange/yellow in cycles (see *Section 7.7: Status bar* (page 72)). 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:



- ② Click the "OK" button.

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 *Section 17.3: STM measurement problems* (page 217) for the next steps to take.

## 4.4: Starting a measurement

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

## CHAPTER 4: FIRST MEASUREMENTS

- Start measurements manually by clicking the *Start* button in the *Imaging group* of the *Acquisition tab*:



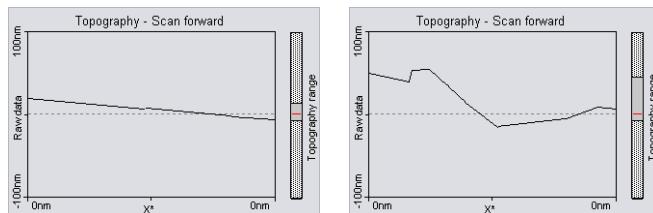
- Enter an image size (e.g. 50 µm) in the *Image size* entry field (see page 96).

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 unstable. This means that you should stop measuring and cut a new tip:

- Click the “Stop” button in the Imaging group of the Acquisition tab:
- Follow the instructions in *Section 17.3: STM measurement problems* (page 217).

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.

## 4.5: Achieving atomic resolution

### 4.5.1: 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

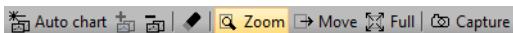
Measurements on the micrometer/nanometer scale are very sensitive to environment influences. Temperature variations near the scan head can influence and disturb the measurement. It is best to let a promising measurement run for some time in order to stabilize thermally.

To decrease the Imaging area:

- ① Click the Color map chart to make it active.

A blue square is now drawn around the Color map chart.

- ② Click the “Zoom” button in the Chart bar:

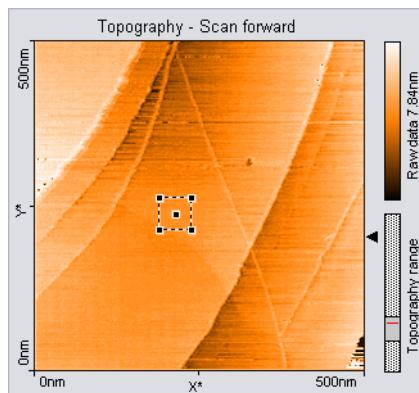


The mouse pointer becomes a pen when moving over the selected chart.

- ③ Move the mouse cursor to a “flat” region (showing a uniform color distribution) 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 measurements* (page 47) for further instructions.

- ④ 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.

## CHAPTER 4: FIRST MEASUREMENTS

- 5 Double click the chart when the scan new area is set to your liking. You can abort the zoom function by clicking with the right mouse button.

When you accept the new scan area, the new imaging settings are set to correspond to the area that was indicated by the square.

- 6 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*).

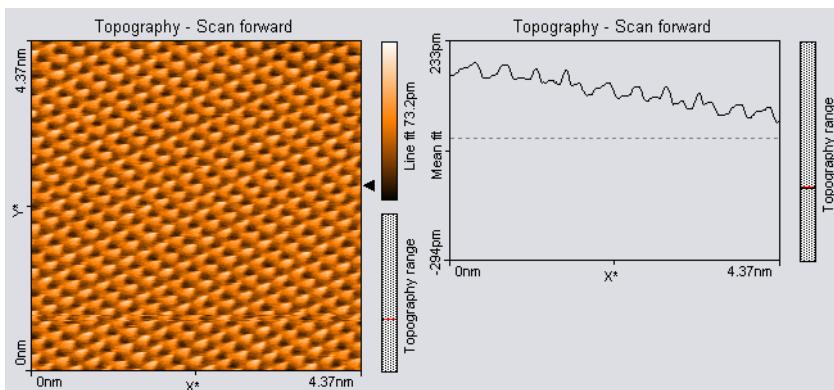


Figure 4-5: A successful graphite measurement

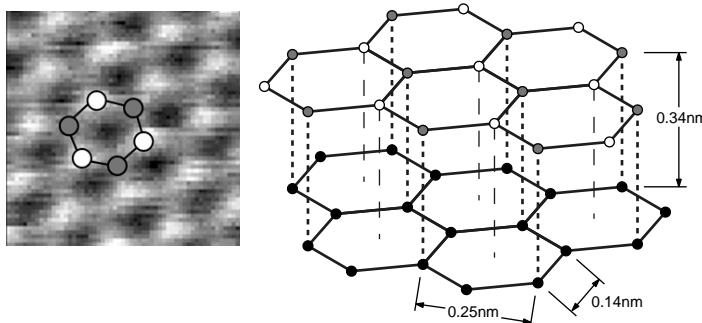
When you're satisfied with the image quality obtained, you may want to save the measurement. Refer to *Section 4.6: Storing the measurement* (page 45) for details on how to do this.

### 4.5.2: 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.

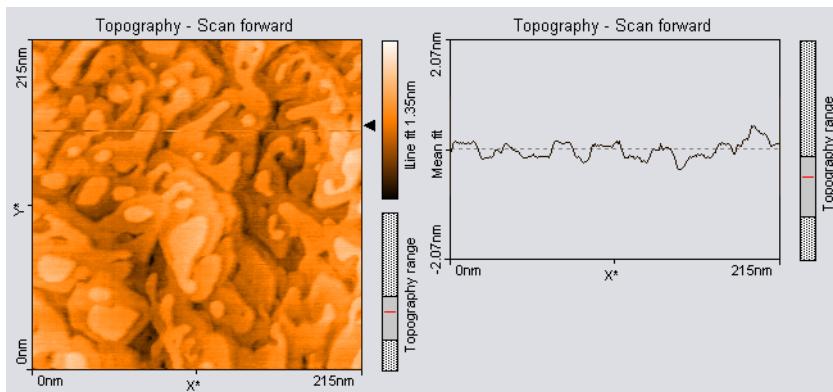


**Figure 4-6: The graphite surface.** (left) Measurement. (right) Lattice model.

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

### 4.5.3: 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

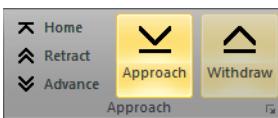
Before performing any experiments with the gold sample it is recommended to practise on the graphite sample. The graphite sample is also a good test sample to judge the quality of the installed STM tip.

To perform measurements on gold:

- Proceed as described 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.

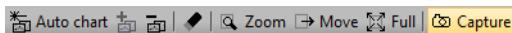
If the image reproduces stably:

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

## 4.6: Storing the measurement

By default, each completed measurement is automatically stored (temporarily) 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 :



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 13.5: Gallery panel* (page 162) for details). In addition, the captured document will remain open in the document space of the Naio control software.

Refer to *Section 13.5: Gallery panel* (page 162) for instructions on how to name entire measurement series and for information on how to handle measurement documents in general.

Measurement documents in the temporary History folder (see page 264) 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 163).

Once permanently stored in new location, measurement documents can always be loaded with the Naio control software (or with third party image processing and analysis software) for later viewing, analysis, and printing.

## 4.7: Running the microscope simulation

The Naio control software can be started without having the microscope connected to your computer in order to explore the Naio 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.

## CHAPTER 4: FIRST MEASUREMENTS

When the Naio control software is started without a microscope connected to your computer, the following dialog appears:



- ② Click "OK".

The status bar will now display the text "Simulation".

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

- ② 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:

- ② 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".

## 4.8: 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 measurements* (page 47).
- Performing a different type of measurement by choosing a different operating mode, as described in *Chapter 8: Operating modes* (page 77).
- Finishing measurements, turning off the instrument, and/or storing the instrument, as described in *Chapter 6: Finishing measurements* (page 57).

**CHAPTER 5:**

# **Improving measurements**

## 5.1: Removing interfering signals

Interfering signals can be recognized because they have a fixed frequency 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; see *Section 5.1.1: Mechanical vibrations*).
- Electrical interference (in the electronics, or in electrical forces of the tip–sample interaction; see *Section 5.1.2: Electrical interference*).

### 5.1.1: Mechanical vibrations

Measure the frequency of the vibrations to find out if the interference is due to mechanical vibrations. You can use the optional Gwyddion software for this (see last paragraph of *Section 2.1.2: Installation* (page 22) for instructions on how to install this software). 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 vary slightly over time. Try the following to find out if the interfering signal is due to mechanical vibrations:

- ① If possible, turn off all rotating machines (i.e. pumps) in the room.
- ② Move the system to an entirely different location.

If mechanical vibrations are the cause of the interference, either improve the isolation of the vibrating machines, or improve the isolation of the instrument by using an active vibration isolation table (e.g. the optional Nanosurf Isostage or halcyonics\_i4).

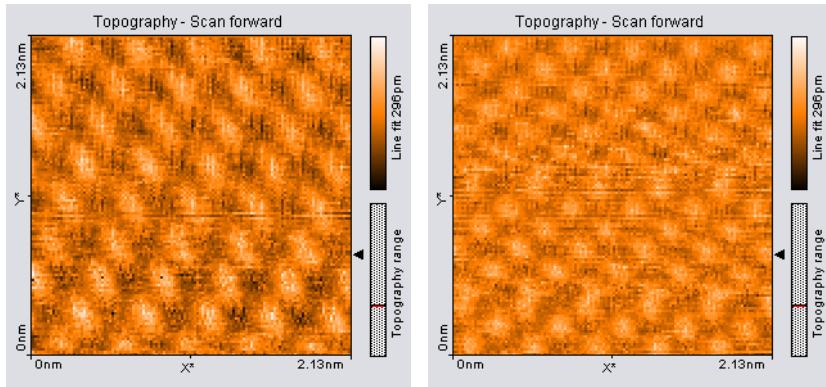
### 5.1.2: Electrical interference

Electrical interference may be caused by interference in the electronics, or by electrostatic forces acting between the tip and the sample. These interferences usually have a frequency that is a multiple of the local mains frequency (50 or 60 Hz). Try the following in order to reduce the influence of electrical interference:

- ① Connect the instrument to the mains power supply using sockets with line filters and surge protection.
- ② Use the Ground connector on the NaioSTM to ground the system.
- ③ 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  $0.1^{\circ}\text{C}$  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 (leave the Magnifying Cover on during measurements).

## 5.3: Adjusting the measurement plane

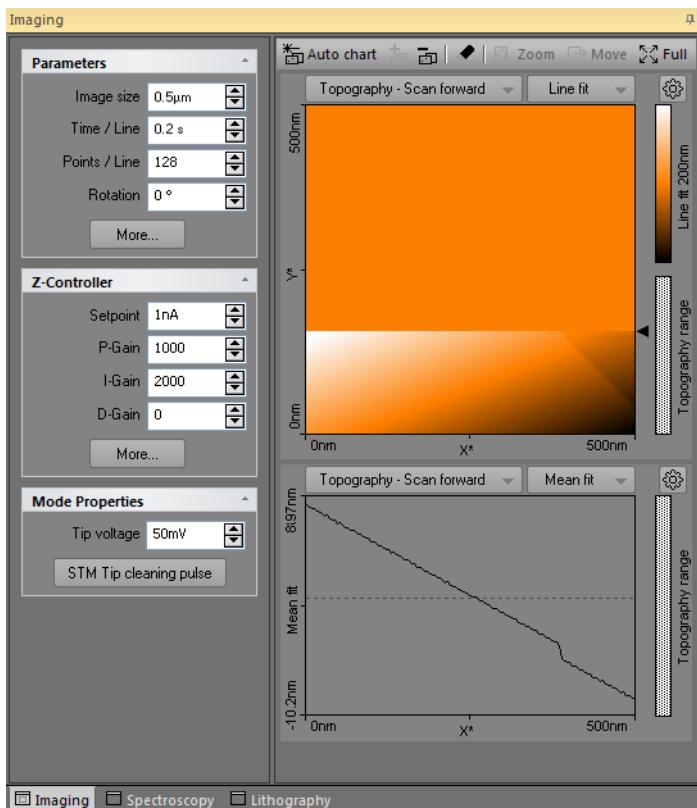
Ideally, the sample surface and the XY-plane of the scanner run parallel to each other. In most cases, however, the sample plane is tilted with respect to the XY-plane of the scanner. In this case, the sample cross section in the  $X^*$  measurement direction has a certain slope. The line graph in *Figure 5-2: Unadjusted 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 *Mean fit*, *Line fit*, or higher order filters cannot be used properly.

## CHAPTER 5: IMPROVING MEASUREMENTS



**Figure 5-2: Unadjusted slope.** Measurement with improperly set X\*-slope.

- 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 either be done automatically or manually. Both procedures are described below.

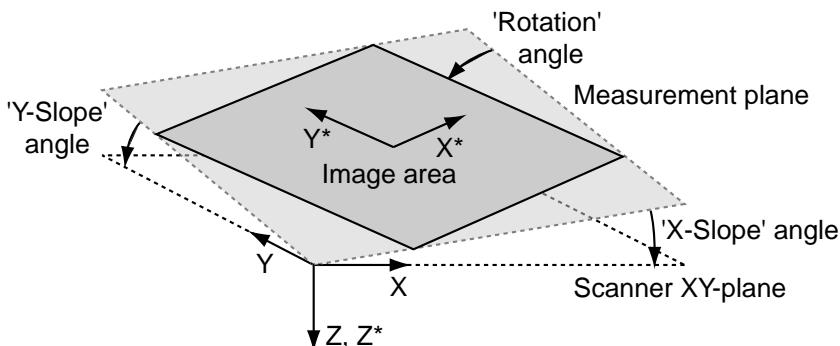
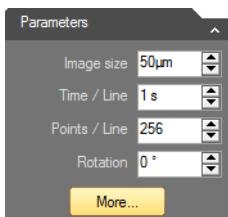


Figure 5-3: Sample and measurement orientation before slope adjustment

To automatically adjust the measurement plane once:

- ① In the *Imaging parameters section* of the *Imaging parameters area*, click the *More* button:



The *SPM parameters dialog* will now open on the *Imaging page*. This dialog contains all possible parameters and settings that influence the behavior of your Nanosurf NaioSTM system (see also *Section 7.9: SPM parameters dialog* (page 74)).

- ② Click the *Adjust slope* button:



The Naio control software will automatically perform a slope determination procedure similar to the manual procedure described below and will enter the slope angles into the *Slope X* and *Slope Y* parameters.

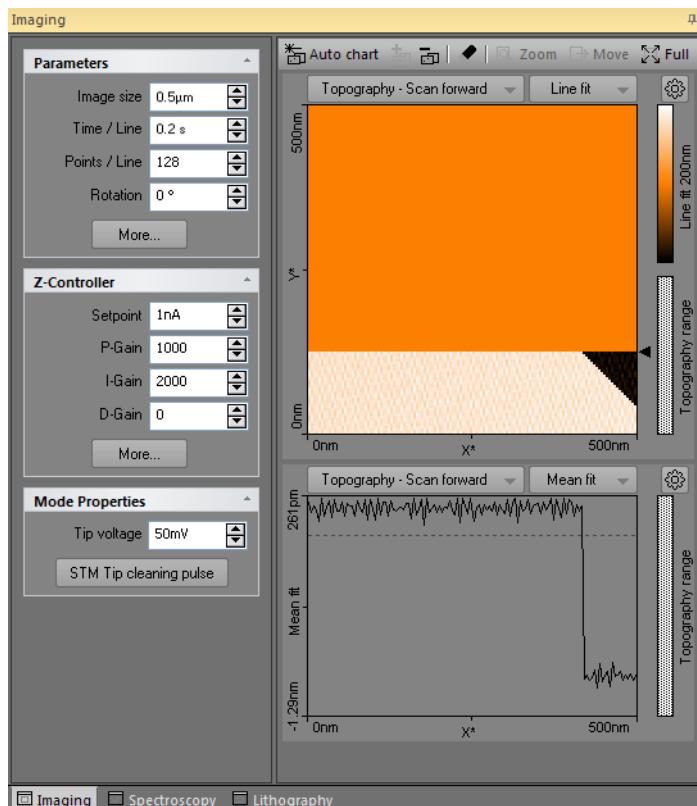


Figure 5-4: Adjusted slope. Measurement with properly set X\*-slope.

### 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 slope* checkbox next to the *Adjust slope* button.

To manually adjust the measurement plane:

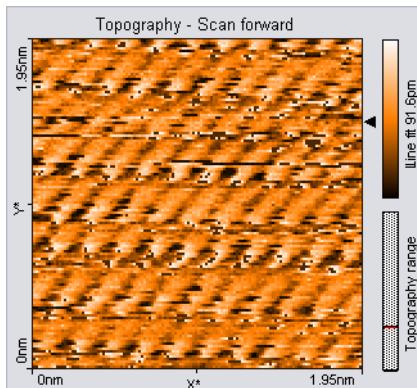
- ① Measure the slope for X in the *Line graph* using the *Measure angle* tool (see Section 13.6.1: *Measure group* (page 168)).  
Use a single click instead of dragging the first line to create a horizontal line and measure the angle relative to the X\*-Axis.
- ② Enter the result of the angle determination as *Slope X* (see *Imaging Options* (page 103)) and fine-tune its value until the X-axis of the scan line lies parallel to the X-axis of the sample.
- ③ Set *Rotation* to 90° to scan along the Y-direction of the scanner.
- ④ 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.
- ⑤ Set *Rotation* back 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.

## CHAPTER 5: IMPROVING MEASUREMENTS

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

- While measuring, open the NaioSTM 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:

- ① Follow the instructions in *Section 6.1: Finishing scanning* (page 58).
- ② Follow the instructions in section *Section 3.3: Preparing and installing the STM tip* (page 26).

### 5.4.1: Examples of images made with unusable tips

Prepare a new tip when your image looks like one of the examples below.

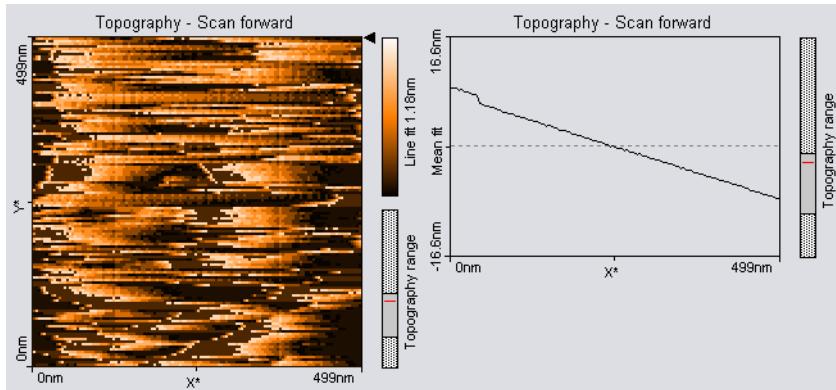


Figure 5-5: The color map image consists of uncorrelated lines.

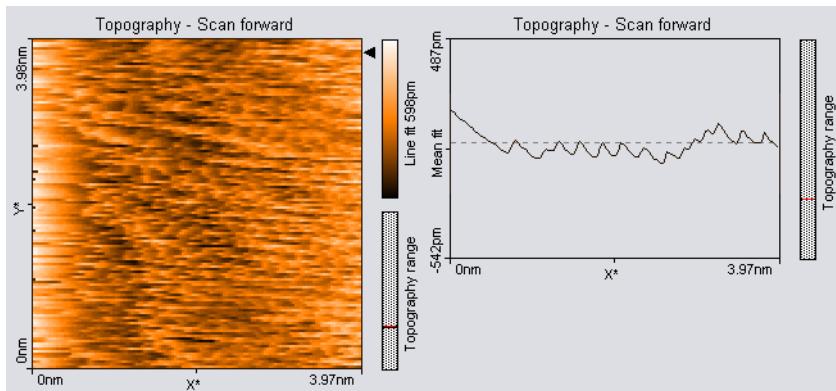


Figure 5-6: The image is “smeared out” on one border (here on the left border).

## CHAPTER 5: IMPROVING MEASUREMENTS

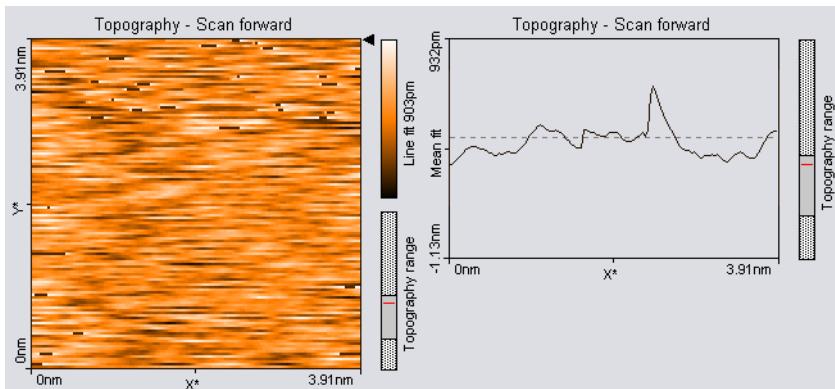


Figure 5-7: Each image looks different.

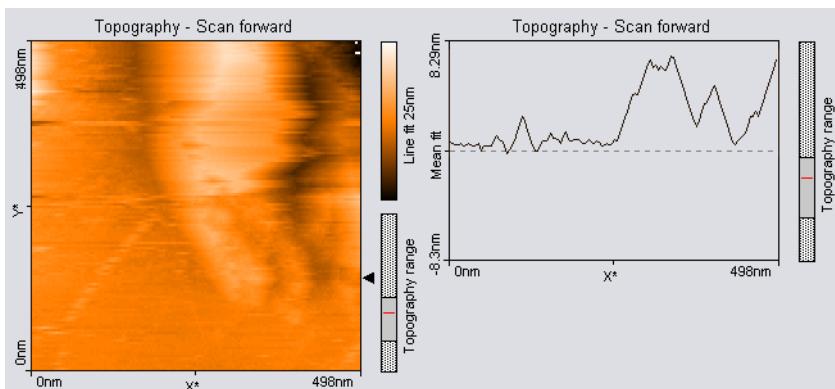


Figure 5-8: The scan lines in Line graph are unstable and the image in the Color map is blurred.

**CHAPTER 6:**

# **Finishing measurements**

## 6.1: Finishing scanning

Once you are done measuring:

- ① In the *Imaging group* of the *Acquisition tab*, click the *Stop* button to stop measuring.
- ② 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.
- ③ Remove the magnifying cover from the scan head.
- ④ Remove the sample holder with one hand.
- ⑤ Remove the sample from the sample holder and store it in its case with the other hand.
- ⑥ Store the sample holder in its container.

## 6.2: Turning off the instrument

To turn off the instrument:

- ① Finish as described in *Section 6.1: Finishing scanning*
- ② 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 163)).
- ③ Exit the Naio control software.
- ④ Turn off the power by pushing the power button at the back of the NaioSTM (see *Figure 1-3: Parts of the system* (page 18)).

If you perform measurements regularly:

- Leave the instrument on the workbench 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.

- ① Turn off the instrument as described in *Section 6.2: Turning off the instrument*, and remove all cables.
- ② Remove the Sample and Sample Holder. The tip can be left in the scanner.
- ③ Store the Sample Holder in its container.
- ④ 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 NaioSTM system packed in its instrument case. The NaioSTM itself is located underneath the accessories foam material.

## CHAPTER 6: FINISHING MEASUREMENTS

**PART B:**

**SOFTWARE REFERENCE**



**CHAPTER 7:**

# **The user interface**

## 7.1: General concept and layout

The Naio 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.

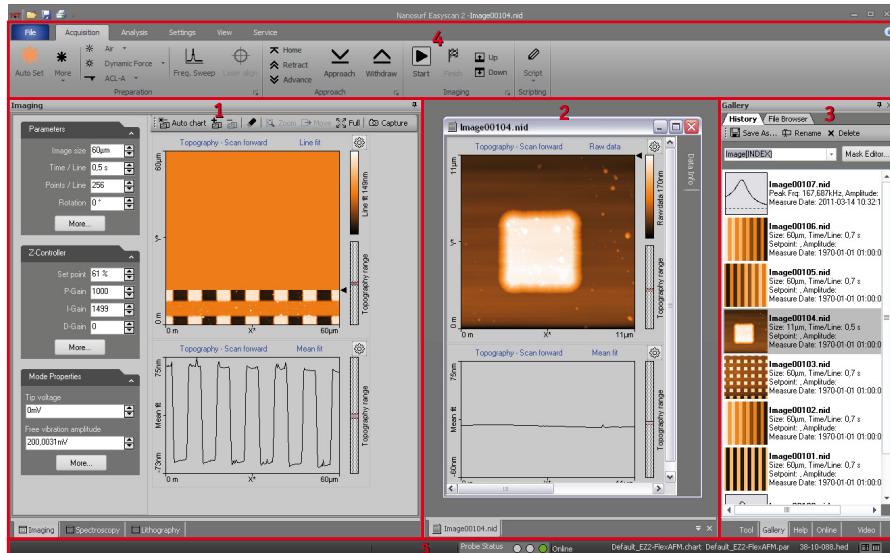


Figure 7-1: The main window in “Normal” workspace mode

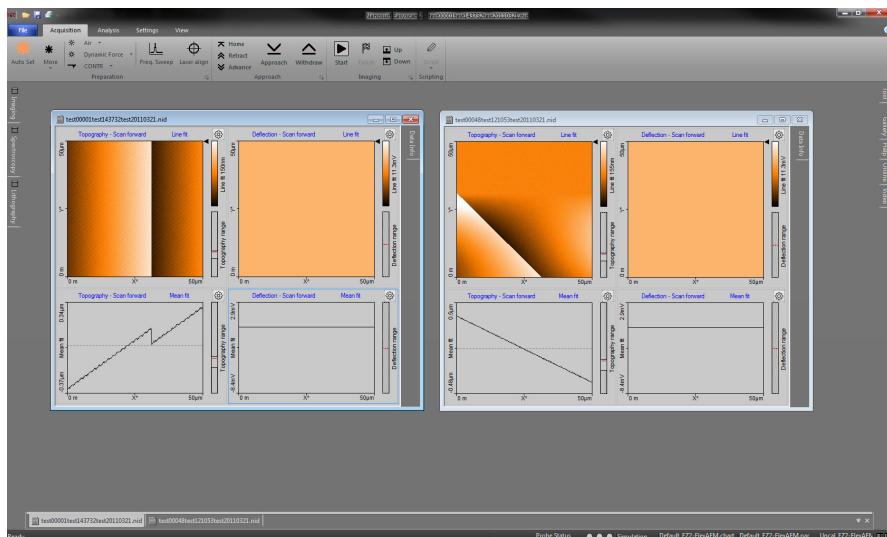
The main control software window (also referred to as *Workspace*) consists of five major areas:

1. *Acquisition pane*. contains the so-called operating windows (see *Section 7.3: Operating windows*), which are used to acquire and display ongoing measurements.
2. *Document space*; used for displaying and analyzing previously stored measurement documents.
3. *Info pane*. contains several stacked panels (see *Section 7.5: Panels*) and is used to group a diverse array of functionality and information.
4. *Ribbon*; used to access all action functions.
5. *Status bar*; used to display system status and further information.

Additionally, there is the *SPM parameters dialog* (page 74), accessed via the More buttons or launcher icons, which gives access to parameters that are not available in the ribbon or the operating windows.

## 7.2: Workspace

With the Naio control software, measurement of newly acquired data and analysis of already stored data can be performed in parallel. Since these tasks are partly performed in different workspace areas, the use of a high resolution monitor (or multiple monitors) is recommended to do this most efficiently. To offer a similar functionality on systems with limited screen resolution, the user can switch between a *Normal* (see *Figure 7-1*) and a *Documents* mode (see *Figure 7-2*).



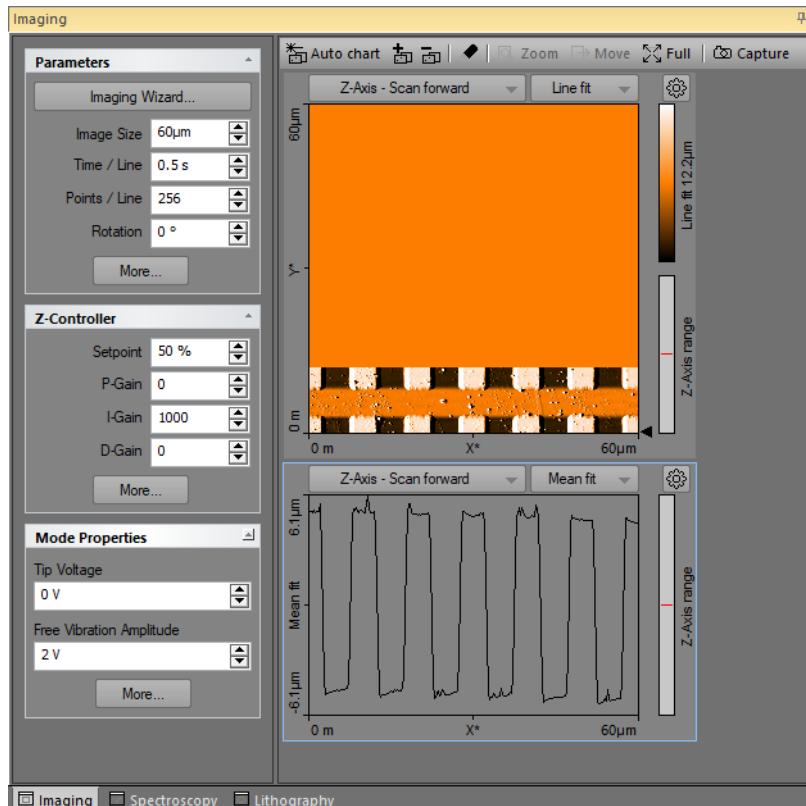
**Figure 7-2: The main window in “Document” workspace mode**

In *Normal* workspace mode, the emphasis lies on the *Acquisition pane* and the *Info pane*. The inside border of the two panes can be dragged by the mouse to adjust their individual widths to your needs. The room reserved for *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 *Documents* workspace mode, the *Document space* is maximized while the *Acquisition pane* and *Info pane* 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 *Acquisition pane* and can be accessed by clicking the respective tab at the bottom of the pane. 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 on the left, the chart area on the right, and the imaging toolbar 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 91)).
- The *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: Spectroscopy* (page 107))).
- The *Lithography window*; used for performing lithography on the current scan area (for details see *Chapter 12: Lithography* (page 127))).

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:

- ① Activate the parameter by clicking inside the (white) parameter edit box:



- ② 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 Naio 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.

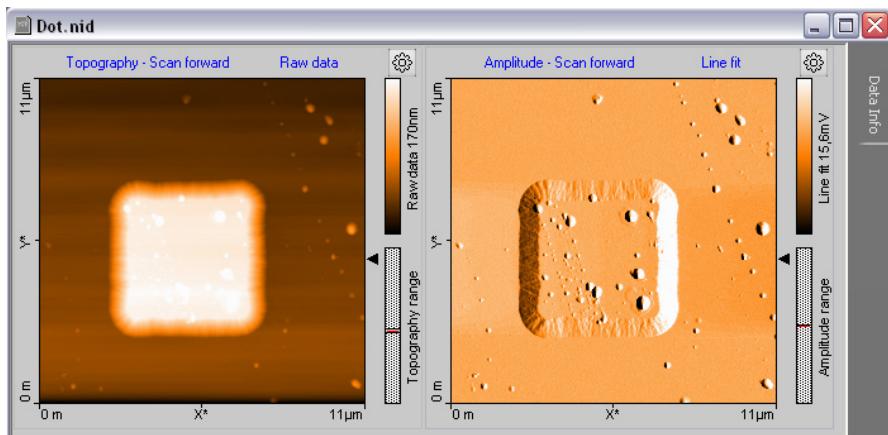


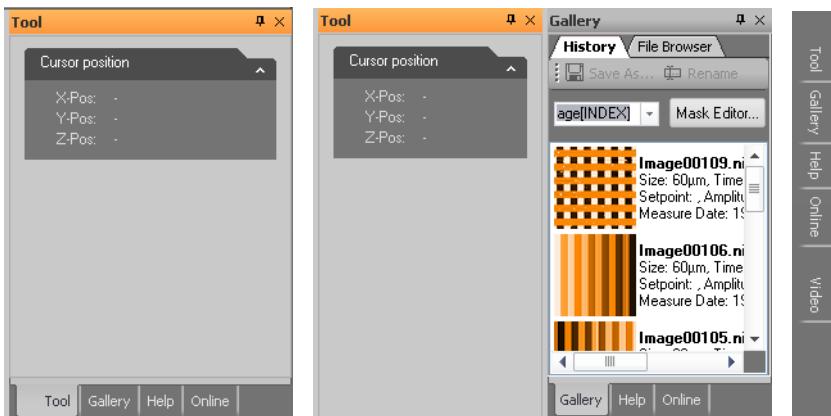
Figure 7-4: Example of a measurement document window

By default, all measurements are automatically stored (temporarily) during imaging and spectroscopy. They can be opened at all times from the *Gallery panel* (see *Section 13.5: Gallery panel* (page 162)), but should be moved to a new folder for permanent storage as soon as you have finished measuring (see *Save as* (page 163)).

Everything related to documents is described in more detail in *Chapter 13: Working with documents* (page 147).

## 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 *Acquisition pane*). 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.

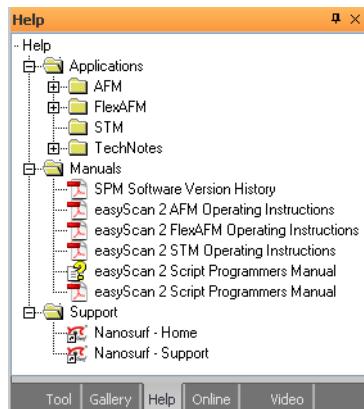
## Tool

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 13.7: Tool panel* (page 179).

## 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 13.5: Gallery panel* (page 162).

## 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*) and a master image that can be used as a reference for multiple zoomed scans on different points of interest (*Master image section*). The *Online panel* is described in more detail in *Section 9.3: Online panel* (page 86).

## 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 4.3: 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 86).

## 7.6: Ribbon

The *Ribbon* provides quick access to all major actions and commands by organizing them in tabs according to their usage. Each tab is further divided into several functionally relevant groups.

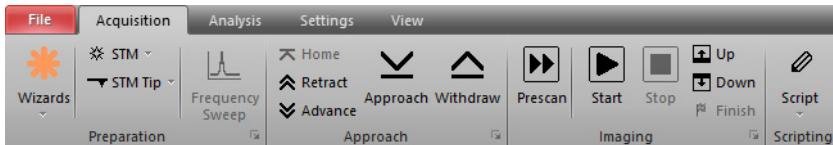


Figure 7-6: The Ribbon.

## 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 basic functions of the *File menu* are described in *Section 13.8: File menu* (page 181). Its more advanced functions are explained in *Section 15.1: File menu* (page 258).

## Acquisition tab

Guides you through the measurement process. There are groups of buttons for measurement preparation, sample approach and the measurement itself. The *Preparation group* and the *Approach group* have a fixed content and are described in *Chapter 8: Operating modes* (page 77) and *Chapter 9: Positioning* (page 85), respectively. The content of the other groups varies with the selected measurement window (*Imaging*, *Spectroscopy*

or *Lithography*) and is therefore described in the respective chapters. At the bottom right of some of the Acquisition tab groups, the Dialog Launcher icon ( ) can be found. It provides access to the *SPM parameters dialog* (page 74).

## 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 13.6: Analysis tab* (page 167).

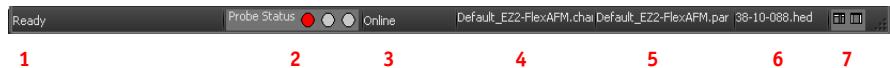
## Settings tab

Contains functions to configure the microscope controller hardware and calibrating the scan head. It is described in *Section 15.2: Settings tab* (page 265)

## 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 Naio control software, it is described in this chapter (see *Section 7.8: View tab*).

## 7.7: Status bar

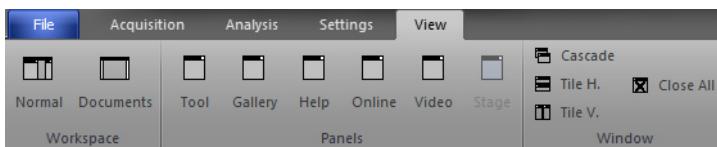


**Figure 7-7: The status bar.** Numbers in this figure correspond to those in the list below.

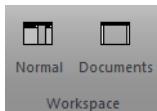
The status bar displays relevant microscope information and the loaded settings (see *Figure 7-7: The status bar*). It contains the following elements:

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, and/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 *Normal* and *Documents* workspace view.

## 7.8: View tab



### 7.8.1: Workspace group



The *Workspace group* of 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 ((toolbar)) on the right-hand side of the status bar (see also *Section 7.7: Status bar*). With these smaller buttons you don't even need to switch to the *View tab* while measuring.

#### Normal

The optimal workspace choice during measurements.

#### Documents

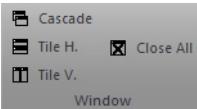
The best choice for viewing or analysis of stored documents (see *Chapter 13: Working with documents* (page 147)).

### 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 the *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*.

### 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**

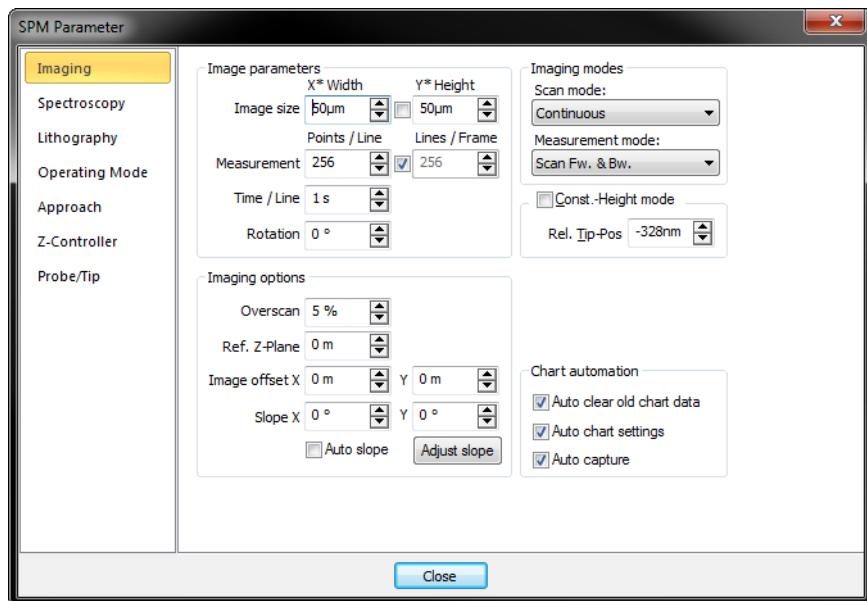
Closes all open document windows. If unsaved data exists, you will be asked to save it.

#### **Windows**

Allows you to directly select an open document window from a drop-down list, or to create a new windows for the currently active document.

### 7.9: SPM parameters dialog

While not directly visible upon starting the Nanosurf Naio 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 acquisition 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* contains several (sub)pages:

- Imaging (see *Section 10.6.1: Imaging page* (page 102))
- Spectroscopy (see *Section 11.6.1: Spectroscopy page* (page 120))
- Lithography (see *Section 12.7.1: Lithography page* (page 144))
- Operating mode (see *Section 8.5.1: Operating mode page* (page 80))
- Approach (see *Section 9.5.1: Approach page* (page 89))
- Z-Controller (see *Section 8.5.2: Z-controller page* (page 81))
- Probe/tip (see *Section 14.8.1: Probe/tip page* (page 204))
- SPM System (see *Section 8.5.3: SPM System page* (page 83))

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

## CHAPTER 7: THE USER INTERFACE

**CHAPTER 8:**

# **Operating modes**

## 8.1: Introduction

Operating modes determine how a sample is measured. They can be selected in the *Preparation group* of the *Acquisition tab*. Appropriate parameters can either be set manually or via one of the 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 111) for further details).

#### Operating mode

This drop-down box (STM) allows selection of the operating mode used for measuring). For STM systems, the only available operating mode is "STM". It is however possible to modify the STM measurement mode to measure in Constant Current or in Constant Height mode (see *Section 8.3: Constant Current mode* and *Section 8.4: Constant Height mode*).

#### Tip selector

This drop-down box (STM Tip) allows the selection of the mounted tip. For STM systems, the only available option is "STM Tip".

#### Launcher icon

More advanced settings are available through the Dialog Launcher icon (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 80)).

## 8.3: Constant Current mode

In Constant Current mode (the default STM operating 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, 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 NaioSTM is normally configured to measure in the Constant current mode. To switch to the Constant height mode, you could theoretically just move the sample to a certain distance away from the tip and then turn off the Z-Controller. This can be accomplished by selecting either the *Dual scan*, *Interlaced*, or *Second scan only* option in the *Line Scanning* section of the *Imaging page* of the *SPM parameters dialog* (see page 104). For STM measurements, however, several problems will arise:

- The tip would crash into the slightest unevenness of the surface.
- The scan plane of the scanner must be very well-aligned (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.

Therefore, to perform STM measurements in Constant height mode:

- ① Find a flat area of the sample by imaging it in Constant current mode, and zoom in on this area.
- ② In the Z-Controller section of the Imaging tab, set I-Gain to 4.
- ③ Set P-Gain to 0.

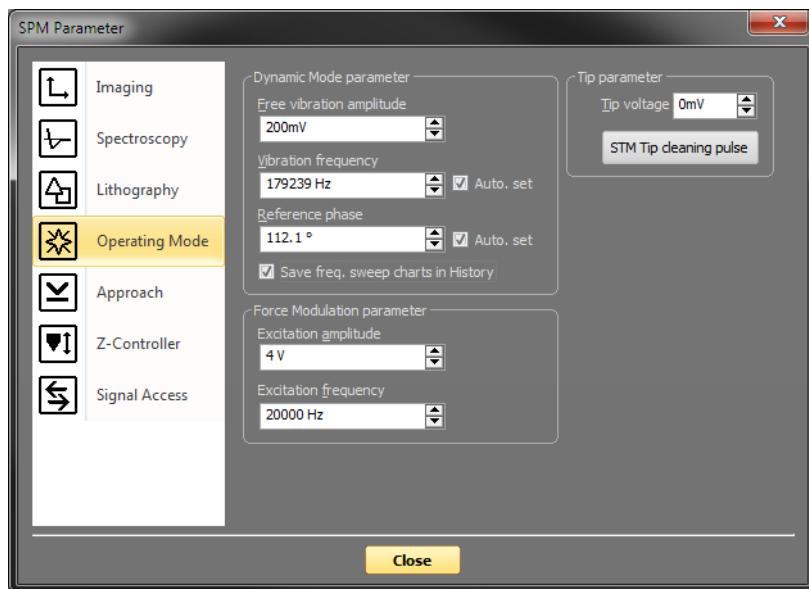
To visualize the current:

- 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



### Tip Parameter

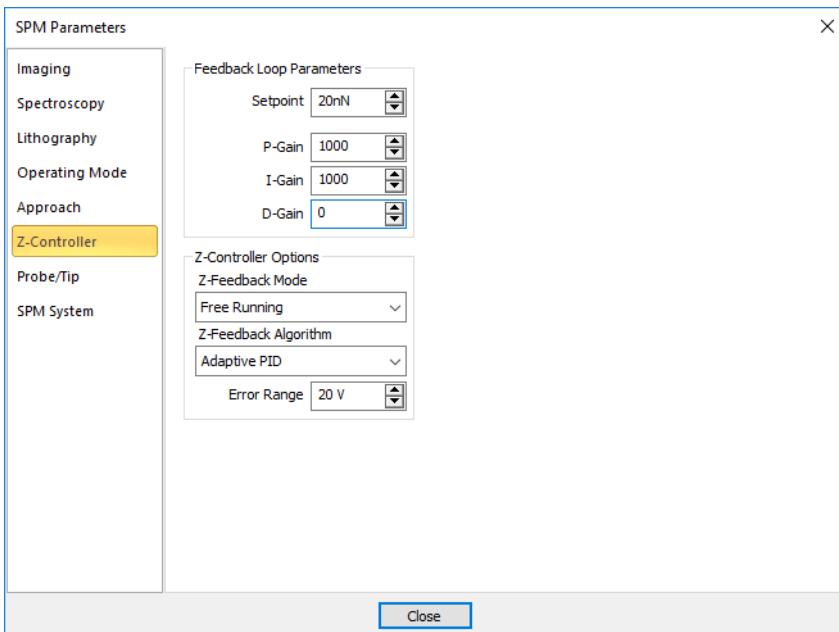
#### Tip Voltage

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

#### Important

With all Nanosurf STM systems the sample is automatically connected to the ground of the instrument.

## 8.5.2: Z-controller page



### Feedback Loop Parameters

#### **Setpoint**

The working point for the Z-controller. For STM systems, this is the tunneling current (in pA or nA).

#### **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.

## External Z-Stage Parameters

You can connect an external Z-stage to user Output C, and if the Stage has a Z-sensor, you can connect this to user Input B. You can then use this stage for Z-Feedback.

### Activate User Out C feedback

When selected, Z-feedback is performed with the External Z-Stage.

## Z-Closed-Loop Parameters

If the scan head has a Z-sensor, the controller can adjust the Z-Axis output to maintain a constant Z-sensor signal.

### Activate Z-Closed-Loop

When selected, the Z-Closed-Loop operation will be activated when the Z-feedback is in a "Keep Last" state (see *Z-axis idle parameters* (page 84) and *Z-Axis Pause Mode* (page 126)).

### Speed

Speed of the Z-closed-loop feedback. Too high values will result in oscillations. Too low values will result in slow response times.

## Z-controller options

### Z-feedback mode

The following modes are available:

- **Free running**  
The Z-controller is active.
- **Freeze**  
The Z-controller is not active, the scanner remains in its current Z-position.
- **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.

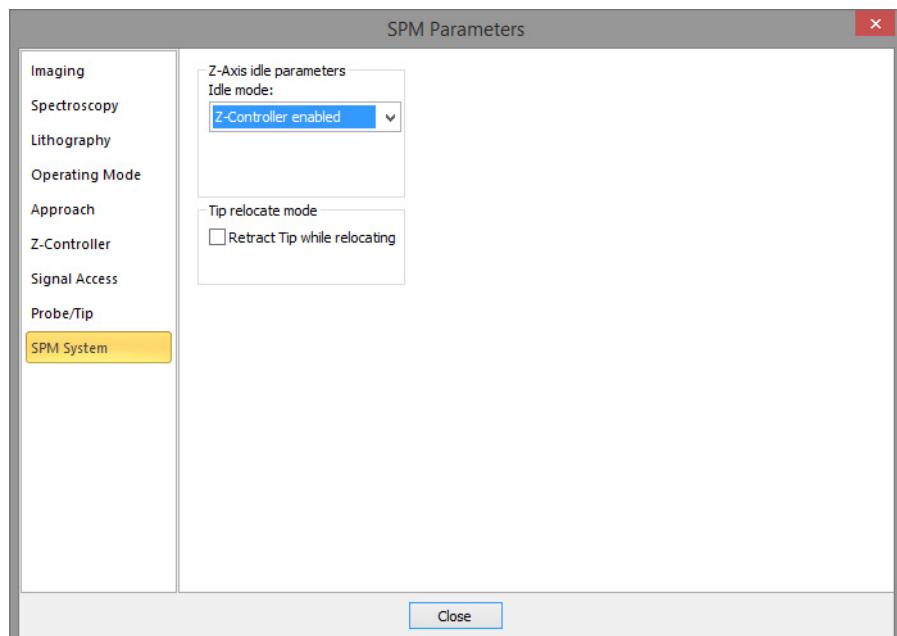
### - Adaptive PID

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.

### 8.5.3: SPM System page



Various settings that control the general behavior of the scanning system, independent of operating mode and measurement mode, are set here. One important setting is the system behavior when it is when it is idle (not performing any measurement or approaching).

## Z-axis idle parameters

### Idle mode

Determines what the Z-controller does when not busy with Imaging, Spectroscopy, Lithography or Approach.

- **Z-Controller enabled**

The tip stays at the surface

- **Retract tip**

The tip is fully retracted

- **Keep last Z-pos**

The tip does not move (better not used when the tip is on the surface, but can be used when a spectroscopy measurement ends away from the surface)

## Tip Relocate mode

### Retract Tip while relocating

When this checkbox is activated, the tip moves to the fully retracted state when moving in XY. Activate this checkbox when there is danger of damaging the tip or sample when moving

Do not activate this checkbox when measuring very flat samples; moving the full Z-range may cause some drift or creep that could disturb the sample surface.

**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. A suitable distance between tip and sample needs to be established before an approach and subsequent measurement can be initiated.
2. The tip has to approach the sample until a given setpoint is reached. The approach process is controlled through the Approach group of the Ribbon's Acquisition tab (see *Section 9.4.1: Approach group*).

## 9.2: Video panel

The *Video panel* displays the available video signals. Each of the graphical sections used for video display contains a toolbar with control options to adjust the display properties of the respective video signal.

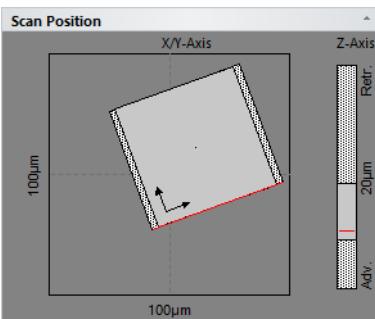
### Important

If your system is not equipped with a video camera, the *Video panel* will not be available. This is normally the case for STM systems.

## 9.3: Online panel

The *Online panel* displays scan area information and various other data.

### 9.3.1: Scan position section



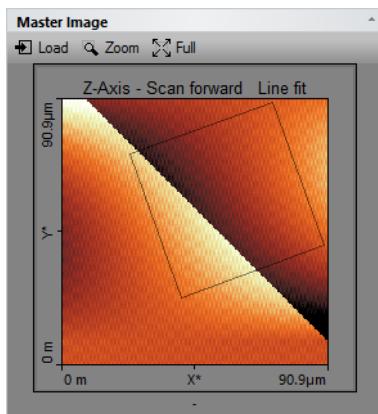
The *Scan position section* displays information about the maximum scan area (scan head range), the current measurement area, and the tip position.

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 *Section 10.6.1: Imaging page* (page 102)).

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 *Image offset X/Y* and *Rotation point* (see *Section 10.6.1: Imaging page* (page 102)).

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

This button loads the current topography image of the active operating window into the *Master image section*.

#### Zoom

This button allows you to select a new scan area size and position inside the *Master image section* (within the loaded image). After selecting the *Zoom* button, the user draws a zoom

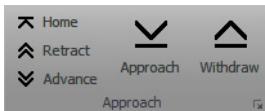
frame in the chart area. To select the new scan area, double-click within the selection area. A right mouse click aborts the zoom operation.

## Full

This button sets the current scan size back to the full scan range, similar to the *Full* button in the *Imaging toolbar* of the *Imaging window* (see *Full* (page 100)).

## 9.4: Acquisition tab

### 9.4.1: Approach group



The buttons of the *Approach group* control the position of the approach stage that has been selected by the *Approach mode* setting (page 89).

#### Home

Increases the tip–sample distance to its maximum value to ensure that the maximum motorized approach range is available during final automatic approach. When the *Home* button has been pressed, it changes to a *Stop* button that can be used to abort the full retraction process.

#### Stop

Aborts the full retraction process and changes the *Stop* button back to the *Home* button.

#### 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 9.5.1: Approach page* (page 89)). During the approach process, the *Approach* button changes to a *Stop* button that can be used to abort the approach process.

#### Stop

Aborts the approach process and changes the *Stop* button back to the *Approach* button.

#### Withdraw

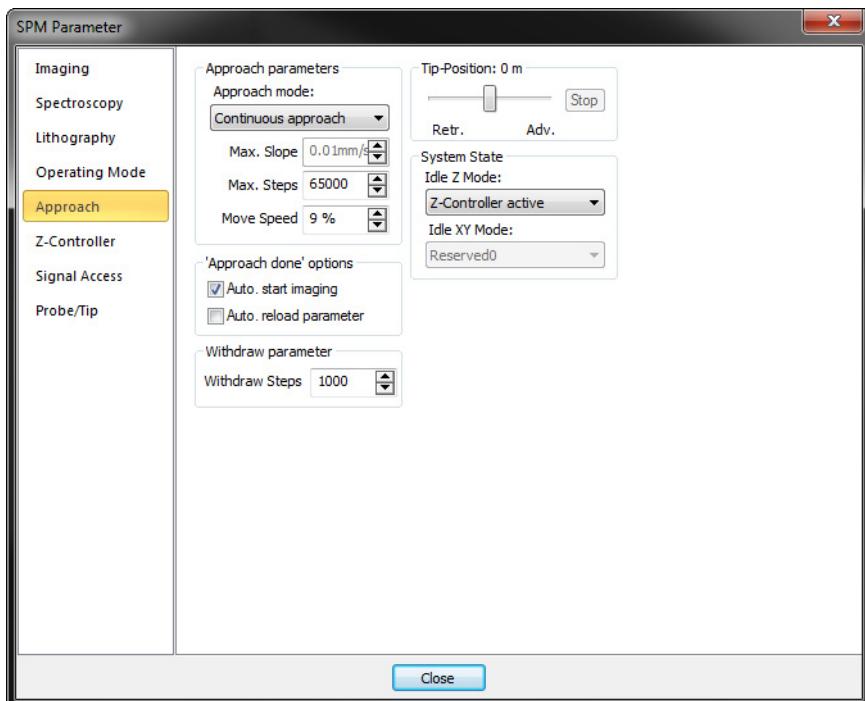
Increases the tip–sample distance with approach speed settings.

**Launcher icon**

More advanced settings are available through the “dialog launcher” icon ( at the bottom right corner of the *Approach group*), which opens up the *SPM parameters dialog* on the *Approach page* (see *Section 9.5.1: Approach page*).

## 9.5: SPM parameters dialog

### 9.5.1: Approach page



## Approach parameters

### Approach mode

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

### Max. slope

This parameter defines the speed of extending the Z-axis. Slower speeds help to preserve sharp tips.

### **Max. steps**

- This parameter defines the maximal duration of an automatic approach.

### **Move speed**

- This parameter defines the move speed during automatic approach and withdraw.

## **Approach done options**

### **Auto start imaging**

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

## **Withdraw parameter**

### **Withdraw steps**

The number of steps to use for withdrawing the tip from the sample (see *Withdraw* (page 88)).

### **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.

# **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 13.4: Charts* (page 150). For advanced imaging settings see *Section 10.6.1: Imaging page*.

The *Imaging window* is contained within the *Acquisition pane* and can be opened by clicking the *Imaging* tab at the bottom of the *Acquisition pane*. 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 measurement documents, see *Chapter 13: Working with documents* (page 147).

The parameter area on the left side of the *Imaging window*, the so-called *Imaging parameters area*, is organized in 3 sections: the *Imaging parameters section*, *Z-controller section* and the *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 10.3: Imaging parameters area*. 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 10.4: 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 10.5: Acquisition tab*.

Before and during imaging, several panels of the info pane provide additional information for your reference. The relevant panels for positioning and imaging are explained in *Section 9.2: Video panel* (page 86) and *Section 9.3: Online panel* (page 86). A description of the other panels is found elsewhere in this manual. Please refer to the *Chapter 15: Quick reference* (page 205) to locate them.

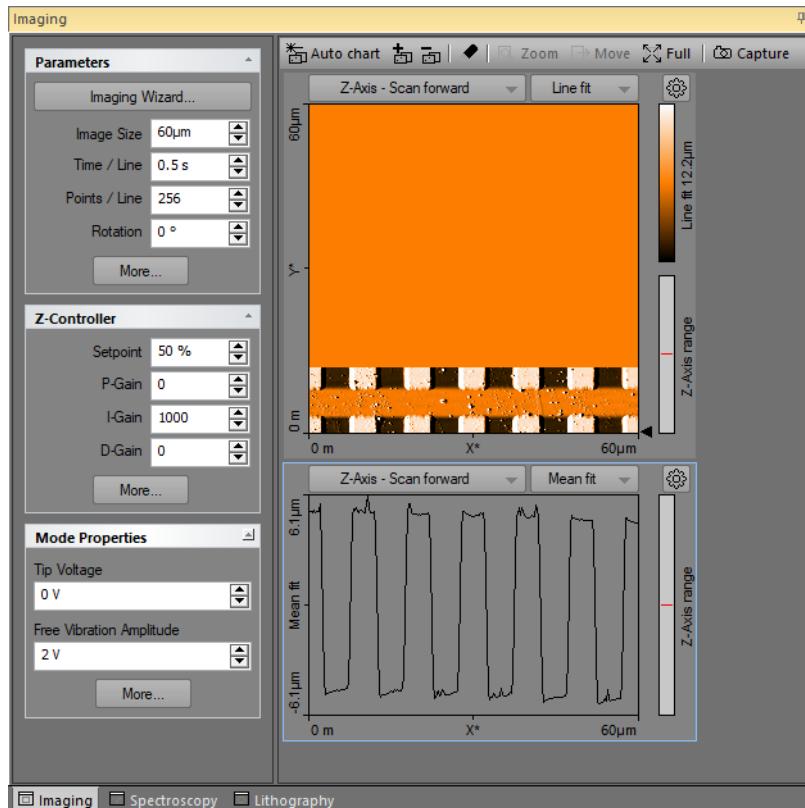


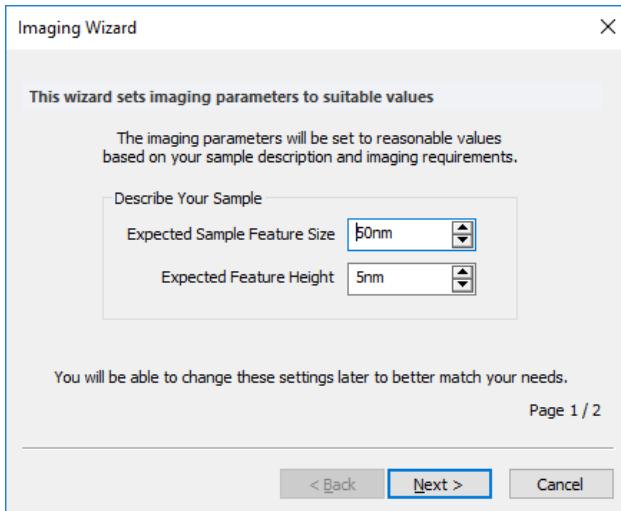
Figure 10-1: Imaging window

## 10.2: Imaging wizard

The *Imaging wizard* helps you to quickly setup the imaging parameters for an imaging experiment, based on your sample description and imaging requirements. It can be activated by clicking the *Imaging wizard* button of the *Imaging parameters* area (see below).

## CHAPTER 10: IMAGING

The *Imaging wizard* will display the following dialogs:

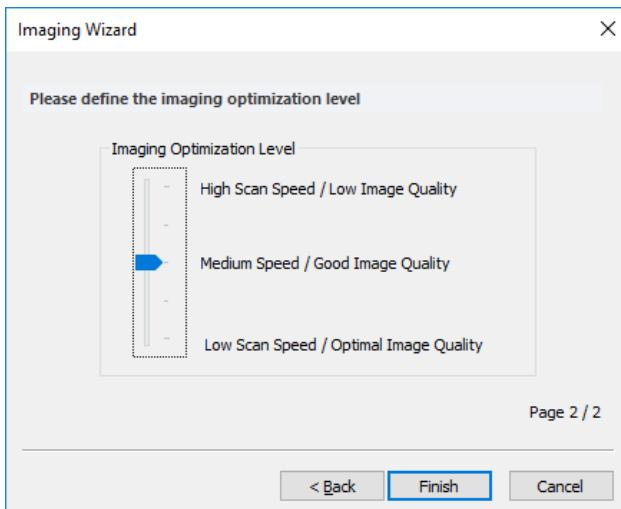


### Expected Sample Feature Size

Provide a rough estimate of the sample structure dimensions.

### Expected Feature Height

Provide a rough estimate of the sample structure height.



**Image Optimization level**

Select the kind of imaging you want to perform.

## 10.3: Imaging parameters area

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 parameters area. The effect of these parameters is illustrated in *Figure 10-2: Coordinate systems*. In the Naio control software, a 'live' schematic 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 86)).

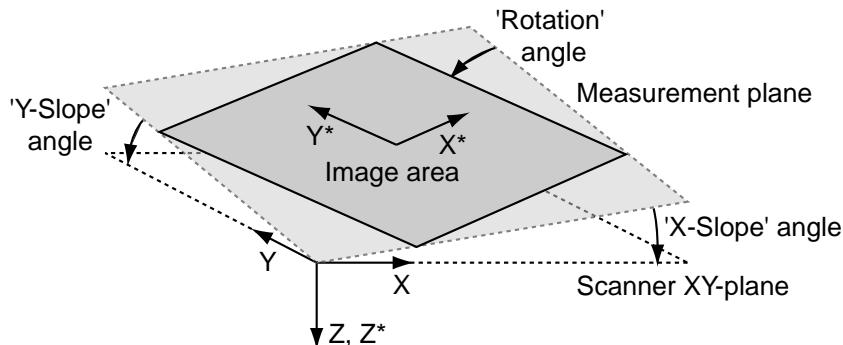
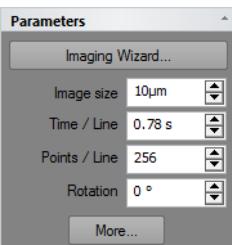


Figure 10-2: Coordinate systems

## Imaging parameters section



### Imaging wizard

This button starts the *Imaging wizard* that helps you set reasonable imaging parameters for your sample (see also page 93).

**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**

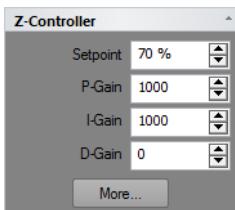
The number of measured data points per line. It also sets the number of lines to the same value.

**Rotation**

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

**More**

Opens up the *SPM parameters dialog* on the *Imaging page* for more advanced parameters (see *Section 10.6.1: 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*.

**Setpoint**

The working point for the Z-controller. Depending on the operating mode, this is the 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.

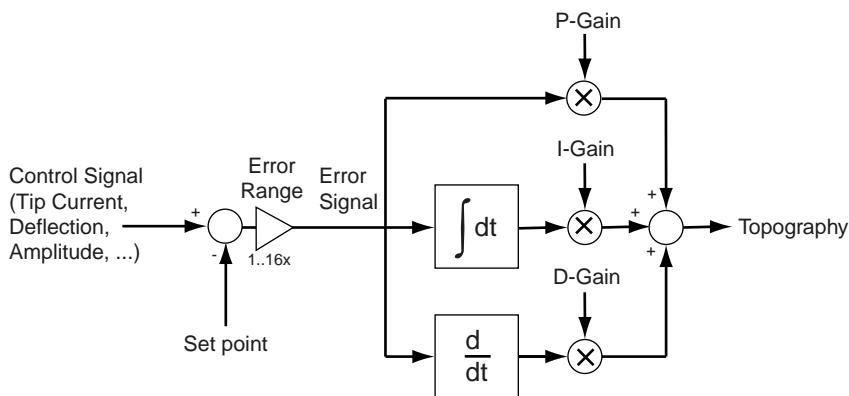


Figure 10-3: Z-controller

### 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.

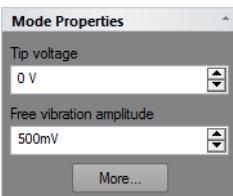
### D-Gain

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

Opens the SPM parameters dialog on the “Z-controller” page for more advanced parameters (see [Section 8.5.2: Z-controller page](#) (page 81)).

## 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.

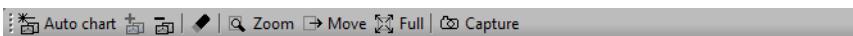
### Free vibration amplitude

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

Opens up the SPM parameters dialog on the “Operating mode” page for more advanced parameters (see *Section 8.5.1: Operating mode page* (page 80)).

## 10.4: Imaging 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 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.

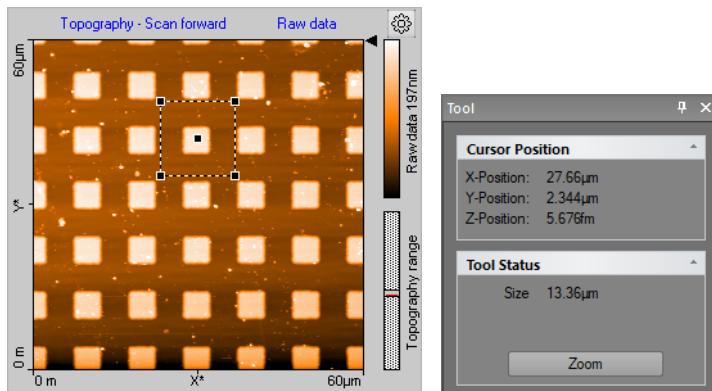
To accept the new zoom area:

- ➊ 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 10.6.1: Imaging page*).

To abort the zoom function

- ➋ Click Zoom again, or use the right mouse button to select “Abort” in the context menu.



**Figure 10-4: Zooming.** (Left) The Zoom tool area marker. (Right) The Zoom tool information in the Tool panel of the Info pane.

## 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.

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.

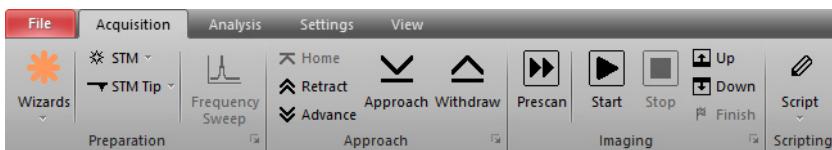
**Full**

The Full button returns the parameters Scan range to the largest possible values, and "X-Offset" and "Y-Offset" to zero (see *Section 10.6.1: Imaging page*).

**Capture**

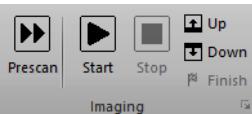
With the "Capture" button, you can immediately copy the current measurement to the History page of the Gallery panel without waiting for the scan to be completed (see also *Section 13.5: Gallery panel* (page 162)). It is stored as a new document and remains open in the Document space of the Naio control software.

## 10.5: 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 9.4.1: Approach group* (page 88), the Imaging and Scripting groups are described here.

### 10.5.1: Imaging group

**Prescan**

Clicking this button starts a prescan of the sample. Prescan only measures every  $n^{\text{th}}$  line of an image and fills in missing data via interpolation. The amount of scan lines skipped is adjusted automatically in such a way that the final image prescan time is always below one minute. During operation, this button changes to a *Stop* button.

**Start**

Clicking this button starts a measurement and changes the button to a *Pause* button.

**Pause**

Clicking this button pauses the measurement and changes the button to a *Resume* button. Z-controller feedback remains active during the pause phase.

**Resume**

Clicking this button will resume the measurement and changes the button back to the *Pause* button again.

**Stop**

Clicking this button stops a measurement as soon as the current scan line is finished. It can be clicked during measurement as well as during a pause phase.

**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.

**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.

**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 10.6.1: Imaging page*).

## 10.5.2: 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 *s* page (see *Access code* (page 264) of the Options dialog.

**Script**

This button opens the Script editor dialog. In this dialog, a script source code can be loaded, edited, saved and run directly.

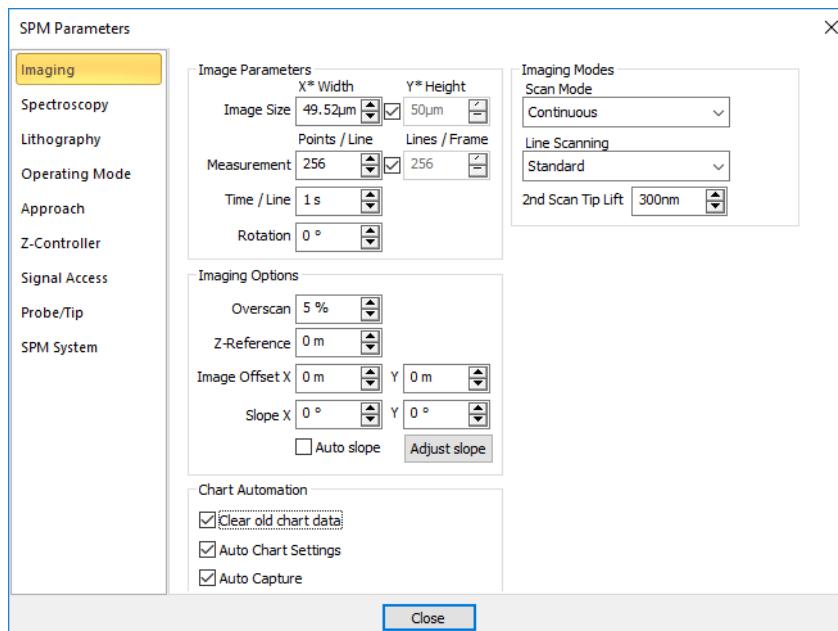
### The script button drop-down menu

Accessed by clicking the arrow head at the bottom part of the *Script* button. In this drop-down list, scripts from the standard scripting folder 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 folder is configured through the Scripting acquisition and Analysis file paths (accessed via "File" >> "Options" >> "Scripting" (see *Scripting* (page 262)).

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.

## 10.6: SPM parameters dialog

### 10.6.1: Imaging page



## Image Parameters

### 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 (see *Figure 10-2: Coordinate systems* (page 95)).

## 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 (for details, see *Section 5.3: Adjusting the measurement plane* (page 49)).

### 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.

### **Line Scanning**

This parameter defines how each imaging line is acquired and stored (for details see *Figure 10-5: Available Line Scanning options* (page 105) and a description of the available options below):

- **Standard**

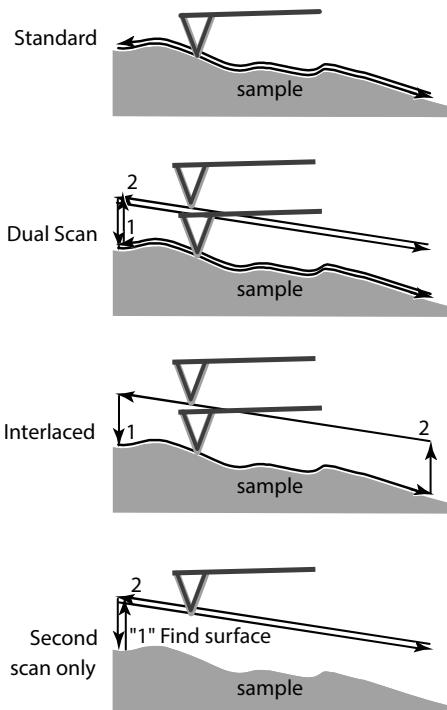
The Z-controller is enabled during both forward and backward scan.

- **Dual scan**

The first (forward and backward) scan is made as in the standard setting, but then a second scan is made with the Z-controller disabled. This setting is the most precise, and gives the largest amount of information, but it is also half as fast as the other dual modes.

- **Interlaced**

The Z-controller is enabled in the forward scan, and disabled in the backward scan. Thus the data acquisition time is reduced compared to Dual scan but forward scan data cannot be compared to backward scan data to judge controller performance. This setting is twice as fast as Dual scan, but it is not possible to compare forward and backward scan to optimize feedback settings.



**Figure 10-5: Available *Line Scanning* options**

**- Second scan only**

The Z-controller is only enabled before the start of each scan using the standard settings. During the scan, the 2nd Scan Parameters are used. This setting is the fastest, and has the lowest tip wear, because the measurement can be made faster as the tip does not need to follow topography. However, correlation of second scan data with topography is much less precise.

**2nd Scan Tip Lift**

This parameter sets the height of the start of the second scan compared to the height of the start of the first scan. Positive values move the tip further away from the sample. For a procedure on how to determine the tip lift, please refer to technote "TN00031 – Operating Nanosurf AFMs in MFM mode", which can be found in the "Technote" section of the Help panel.

## 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 104)).

### Auto chart settings

If selected, the chart arrangement is automatically updated (see also *Auto chart* (page 98)).

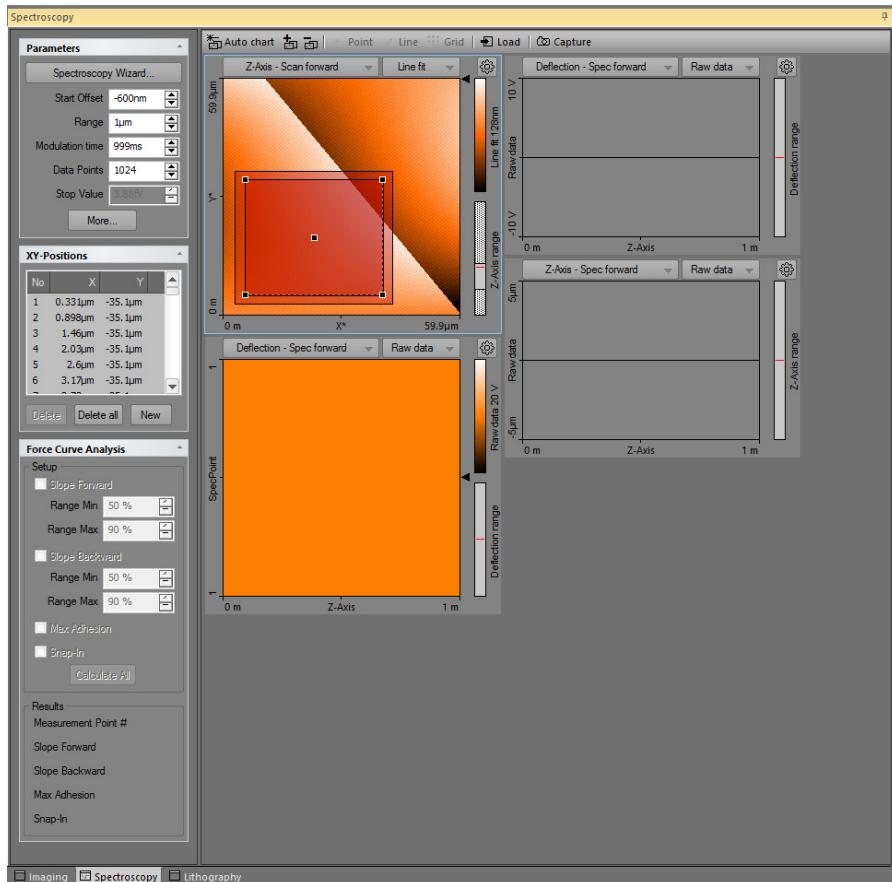
### Auto capture

If selected, all measurements are automatically stored in the history Gallery. If deselected, 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 Acquisition pane. The Spectroscopy window contains the Spectroscopy toolbar, with commands that control the spectroscopy processes, and the spectroscopy parameters area, with parameters that determine how the spectroscopy measurement is performed and evaluated.

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 13.4: Charts* (page 150).

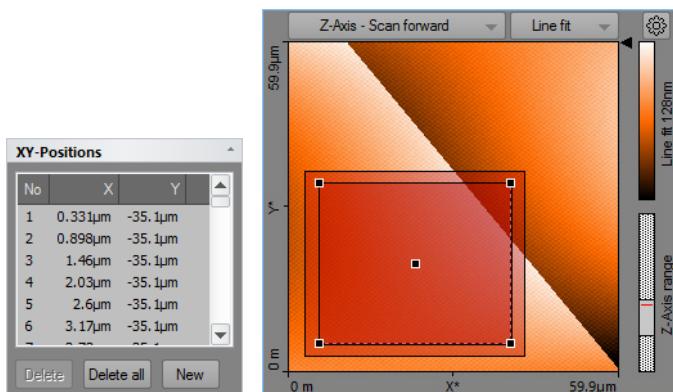
In general, a spectroscopic measurement is a measurement of an input signal as a function of a modulated output. Common spectroscopic measurement types are:

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

### 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 parameters area 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. In case of Point and Line measurements, 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 116)). The positions in the list are also shown 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) Grid area as shown on the sample surface. Measured points are tinted bright red, measured points are tinted darker red, or according to the force curve analysis result (see Force Curve Analysis section of the Spectroscopy parameters area (see page 116).

## Important

In the spectroscopy toolbar, the Naio 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 117))

Individual points created using the point and line methods can be easily repositioned by dragging the respective circle to its new position in the Topography overview chart.

When using the graphical tools Line and Grid to define the measurement positions, the Tool status field in the Tool results panel needs to be used to define the number of measurement positions.

For any spectroscopy measurement, two basic modulation method types exist:

- **“Fixed length” modulation**

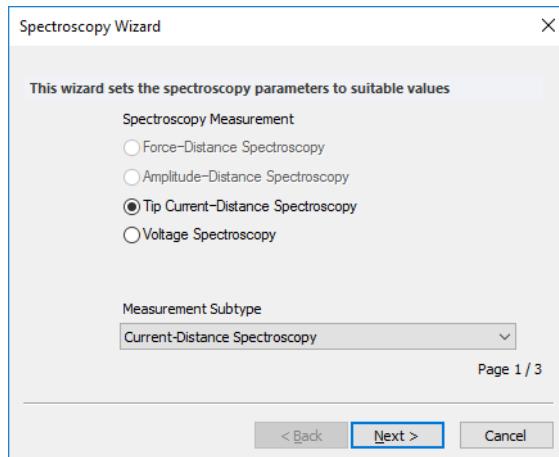
This type of modulation has a fixed start and end value. It is freely available with the Standard spectroscopy level (see *Section 11.6.2: Spectroscopy page (standard level)*).

- **“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 helps you to quickly set up a spectroscopy measurement of a certain type, without accessing the SPM Parameters page.

The Spectroscopy wizard takes you through a three or four step process:

1. Select the spectroscopy measurement type and subtype.
2. Set the most relevant parameters for the spectroscopy modulation.
3. When appropriate: set parameters for the spectroscopy pause
4. Apply these settings to the SPM Parameters page.

After clicking the “Finish” button, the Wizard sets all parameters. For more control over the spectroscopy experiment, you can adjust the settings in the SPM parameters dialog (see [Section 11.6.1: Spectroscopy page](#)).

If you want to do grid or line spectroscopy, you can select the grid now.

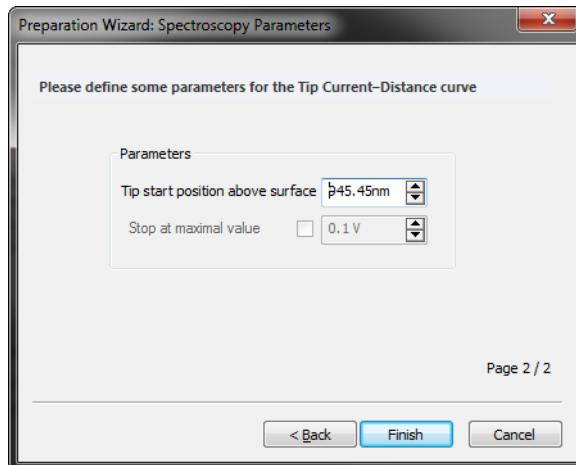
If already approached to the surface, you are ready to start the Spectroscopy by clicking the “Start” button in the Spectroscopy group of the Acquisition ribbon (see [Section 11.5.1: Spectroscopy group](#)). If no X/Y-Position is defined, spectroscopy will be performed in the center of the image, respecting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

**Important**

- A disabled parameter means that it is only available when the advanced spectroscopy level has been activated by a correct *Access code* (see page 194).

**11.2.1: Tip Current-Distance Spectroscopy**

In the Tip Current-Distance Measurement procedure, the 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.

**Parameters**

The behavior of the Z-Axis is the same as for Fixed Length and Stop-by-Value Force-Distance Spectroscopy measurements.

**Stop value**

If selected, the forward spectroscopy stops its forward movement as soon as a defined force is reached. In STM mode, the stop value corresponds to a defined tip tunneling current.

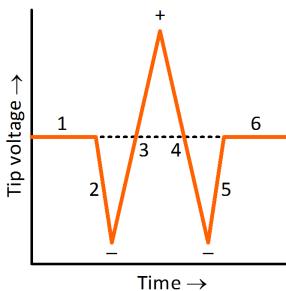
## 11.2.2: Voltage Spectroscopy

### Current-Voltage Spectroscopy

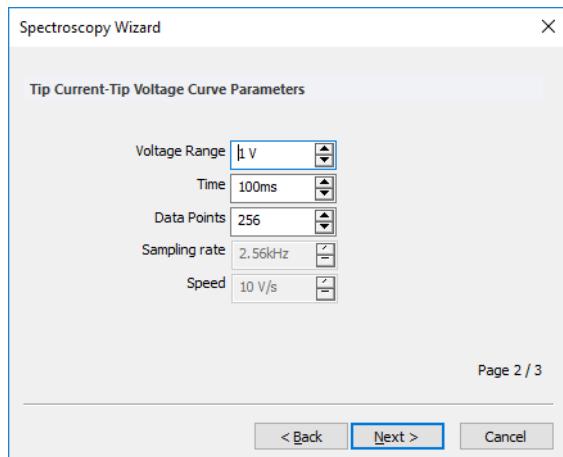
In the Current–Voltage Spectroscopy measurement the tip is not moved, but where the tip voltage is changed instead. During this voltage change, the tip current signal is measured.

A Current–Voltage spectroscopy experiment is typically divided into 6 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 negative value (e.g. -5 V).
3. Tip voltage is changed to a positive voltage (e.g. +5 V) while the Tip current is being measured.
4. Tip voltage is changed back to the starting negative voltage while the Tip current is being measured (Spec Backward).
5. Tip voltage is returned to its resting potential.
6. Tip voltage remains at this potential. If more spectroscopy measurements are to be performed, move to the next measurement (XY) position.



**Figure 11-3: Typical Tip Current–Tip Voltage curve.** Dotted line represents 0 V.

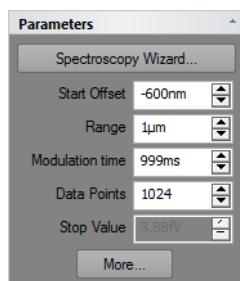


### Voltage Range

The Voltage is modulated from  $-\text{Voltage Range}/2$  to  $+\text{Voltage Range}/2$ .

## 11.3: Spectroscopy parameters area

### Parameters section



### Spectroscopy wizard

This button starts the spectroscopy wizard (see *Section 11.2: Spectroscopy wizard* (page 111) for details).

### Start offset

The offset applied at the start of each modulation cycle.

## Important

When the Z-axis is modulated relative to the current surface, and the tip does not return to the surface between modulations then the start offset is only applied at the start of the first modulation cycle.

### 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.

### Stop value

Sets the Stop value of the Forward modulation.

### “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 120)).

## XY-Positions section

XY-Positions		
No	X	Y
1	0.331µm	-35.1µm
2	0.898µm	-35.1µm
3	1.46µm	-35.1µm
4	2.03µm	-35.1µm
5	2.6µm	-35.1µm
6	3.17µm	-35.1µm
7	3.73µm	-35.1µm

The XY-Positions section lists the positions to be used for spectroscopy measurements. The list can be populated using tools from the *Spectroscopy toolbar* (page 117) 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.

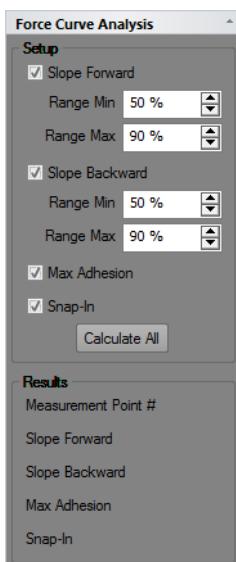
**Delete all**

Removes all measurement positions from the list.

**New**

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

## Force Curve Analysis section



The *Force Curve Analysis section* allows setting up force curve analysis functions that produce results as each force curve is measured. This allows:

- Immediate inspection of numerical analysis results.
- Graphical representation of the analyzed parameters in a Force Curve graph.
- Producing a color map of analyzed parameters during the measurement.

These features are only available when Advanced Spectroscopy has been unlocked with a valid access key (see *Access code* (page 194)).

**Slope Forward / Backward**

The slope of the part of the forward/backward force curve in the part where the tip touches the sample (force is positive).

### Range Min /Max

Defines the deflection signal range of the contact area that is evaluated. Min defines the smallest force that is evaluated, Max the largest force. The 0% value corresponds to 0 N deflection signal; 100% corresponds to the maximum repulsive Deflection signal in the curve. Usually, Min is larger than 0% for the curve moving in contact with the surface, to ignore effects that occur when the contact is made. Max can be chosen smaller than 100% for the curve moving out of contact of the sample, to ignore effects caused by turning around the motion direction while in contact with the sample.

### Max Adhesion

The smallest deflection value of the force curve on moving away from the sample.

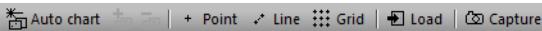
### Snap-In

The smallest deflection value of the force curve on moving closer to the sample. This is usually the force when the tip snaps into contact with the sample.

### Calculate All

Forces recalculation of all force curve analysis results: pressing this button may be necessary when changing parameters in the *Force Curve Analysis section*, because previously calculated force curve analysis results are not recalculated automatically. The results of the analysis are shown numerically in the Results section below the *Calculate All* button, and graphically (as red circles and lines) in the corresponding line graph:

## 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 13.4.1: Working with multiple charts* (page 152)).

### 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 parameters area.

**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. Press and hold the "Shift"-key while dragging to produce a square grid.

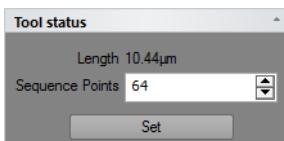
**Load**

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 Naio control software.

### 11.4.1: Tools Status for Line spectroscopy

**Length**

The length of the selected line.

**Sequence Points**

Allows setting the number of data points in the line. The total number of positions is limited to 64 in the basic spectroscopy version.

**Set**

Updates the XY positions according to the new settings.

## 11.4.2: Tools Status for Grid spectroscopy

### Start X, Y

The coordinate of the first point.

### Width

The size of the grid in the fast scan direction.

### Height

The size of the grid in the slow scan direction.

### Placement

Available options are:

- **At point:**

The corners of the drawn grid are the measurement locations. The distance between points along a line equals  $\text{Width}/(\text{Points}-1)$ . Choose this setting when the measurement result for each point should represent the results at exactly that location.

- **Cell center:**

The grid is divided in  $\text{Points} \times \text{Line}$  rectangles, the measurement position is in the center of the rectangle. The distance between points along a line is  $\text{Width} / \text{Points}$ . Choose this setting when the measurement result is seen as representative for the area around the measurement location.

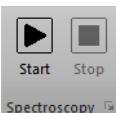
### Points, Lines

The number of points (in the fast direction) and lines (in the slow direction) of the grid. The total number of positions is limited to 64 in the basic spectroscopy version.

## 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.

## Stop

Clicking *Stop* aborts the measurement sequence as soon as the current modulation period is finished.

## Launcher icon

More advanced settings are available through the *Launcher icon* ( at the bottom right corner of the Spectroscopy group), which opens up the *SPM parameters dialog* on the *Spectroscopy page* (see below).

## 11.6: SPM parameters dialog

### 11.6.1: Spectroscopy page

The Spectroscopy page of the SPM parameters 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:

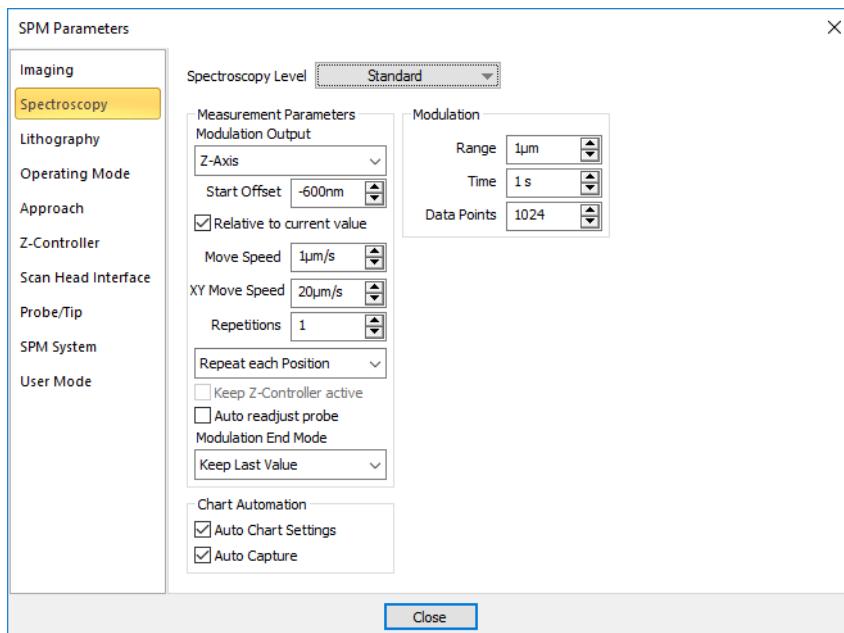
#### - Standard Spectroscopy

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 264)).

## 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 surface**

If checked, the start offset value is used as a value relative to the last known sample surface position. If deselected the Start Offset is used as an absolute value for the start of a new modulation. If "Relative to current value" is enabled and Modulation end mode is "Keep Z-position", the start offset is only applied at the first modulation.

### **XY move speed**

The speed at which the scanner moves from one point to the next during line and grid spectroscopy measurements.

### **Repetition**

This value defines the number of times a modulation measurement is repeated. Each measurement is stored individually.

### **Measurement order**

Determines in what order data is acquired and what data is contained in a single file.

Available options are:

#### **- Repeat position list**

This first measures each position of the grid/line, saves the results to a file, and then repeats this process *Repetition* times. This setting is useful when you want to measure repetitions of a whole grid.

#### **- Repeat each position**

This repeats the measurement on the first point *Repetition* times, saves the results to a file, and then goes on to the next point. This setting is useful when you want to measure single positions multiple times, for example for statistics.

### **Repeat position list / Repeat each position**

Determines how the repetitions are performed: either the entire XY-position list is repeated as a whole, or each position within the list is repeated before going to the next measurement position within the list.

### **Keep Z-controller active**

When selected, 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 deselected, the Z-Axis is kept at its last value prior to the start of the modulation.

### **Auto readjust probe**

If selected, 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 121)). 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

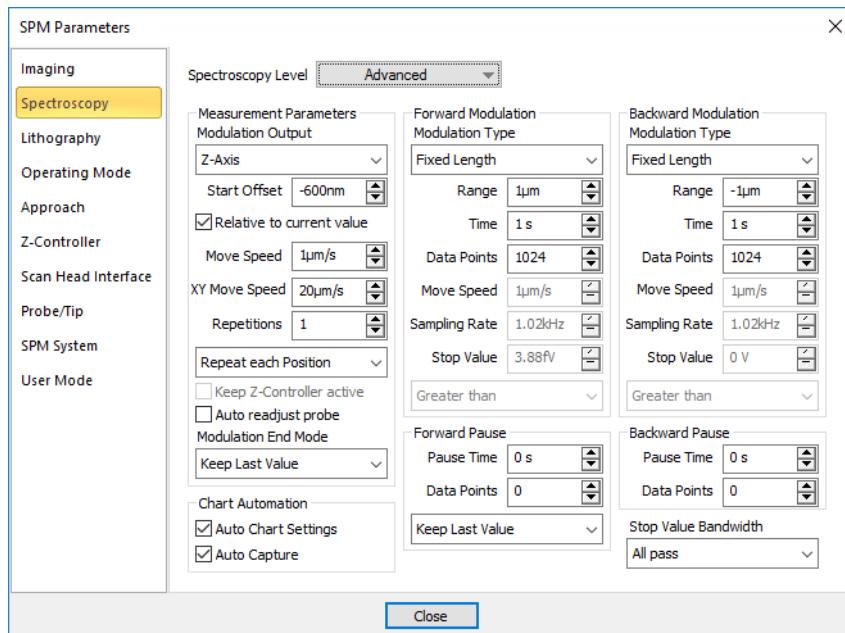
### Auto chart settings

If selected, the chart arrangement is automatically updated (see also *Auto chart* (page 117)).

### Auto Capture

If selected, all spectroscopy measurements are automatically stored in the history Gallery. If deselected, 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:

#### Forward Modulation / Backward 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 125)), 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. The range can be positive or negative (also see *Important* (page 121)).

In "Stop by value" modulation, this is the maximum change of the output value for which data is acquired.

### 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

Shows the speed at which the modulation output is changed. The move speed can be positive or negative (also see *Important* (page 121)). This value is calculated from the modulation *Range* and *Time* parameters (see above).

### Sampling Rate

Shows the number of data points measured per second during the respective modulation phase. This value is calculated form the *Data Points* and *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.

## Forward Pause / Backward 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 121)), 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.

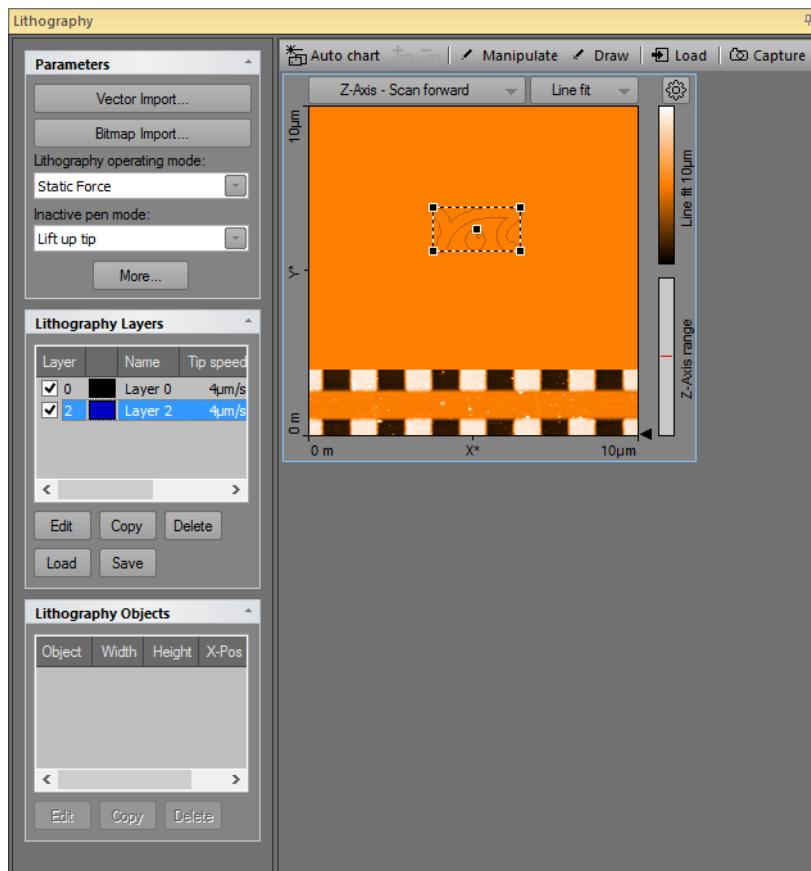
### **Stop Value Bandwidth**

The signal used for the stop condition can be low-pass filtered. Using a smaller bandwidth reduces early stops due to noise; setting the bandwidth too low produces too late stops due to a too slow reaction of the filtered signal. Set this value to approximately half the Sampling Rate.

**CHAPTER 12:**

# **Lithography**

## 12.1: Introduction



**Figure 12-1: 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 Naio control software, this is accomplished in the Lithography window. The Lithography window is opened by clicking the Lithography tab in the Acquisition pane.

The Lithography window contains the Lithography toolbar, with commands that control lithography-related processes, and the lithography parameters area, 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 143)) 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 13.4.1: Working with multiple charts* (page 152).

## Important

Lithography of objects drawn by hand and direct manipulation of the tip is available as standard functionality. Import of vector or pixel graphics files to be used as patterns in the lithography process requires the licensed Naio Advanced Modes Option. For information on how to activate the Naio Advanced Modes Option, refer to *Access code* (page 264).

## 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 than 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:

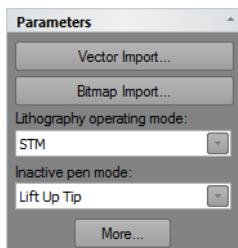
1. The sample surface is imaged to identify an area that is suitable for transfer of a pattern. Suitable areas should preferentially be flat and dust-free.
2. The Lithography window is opened and the “Load” button of the Lithography toolbar is clicked to import the imaged sample surface.
3. A pattern 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 parameters area****Parameters section****Vector import**

Opens the *Vector Graphic Import dialog* for importing vector graphics based lithography data (see page 133).

**Bitmap import**

Opens the *Pixel Graphic Import dialog* for importing bitmap graphics based lithography data (see page 135).

**Lithography operating mode**

Used to select the operating mode during lithography operation. For the NaioSTM, the only mode available is:

- **STM**

**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**

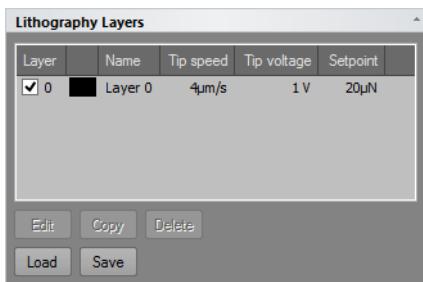
Only lift the tip (upper position of the Z-actuator of the scan head). No feedback will be performed by the Z-controller during travel to the new start point.

- **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 change 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 136) in *Section 12.3.2: 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 12.3.3: 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.

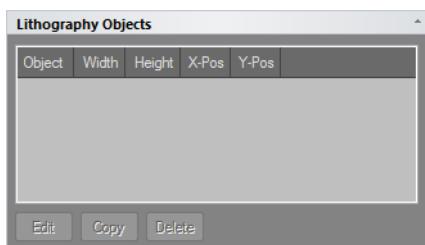
### Load

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 deselected it will not be used for a lithography session.

**Edit**

Edit will open the Object Editor dialog to edit the selected object (see *Section 12.3.4: Object Editor dialog* (page 140)).

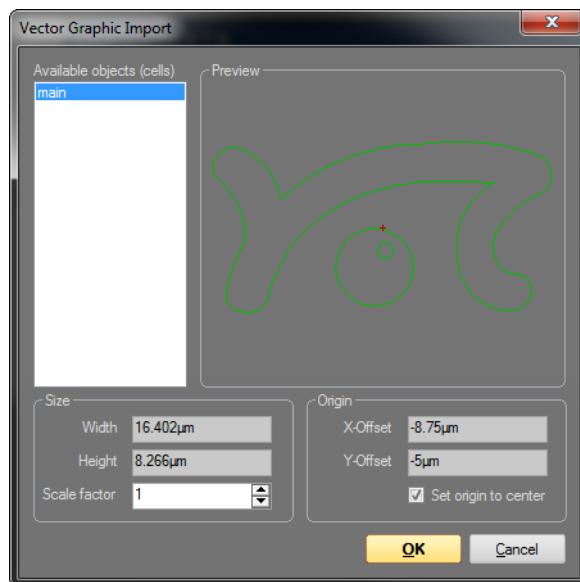
**Copy**

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: 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 result in the respective object being displayed in the preview area of the Vector Graphic

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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

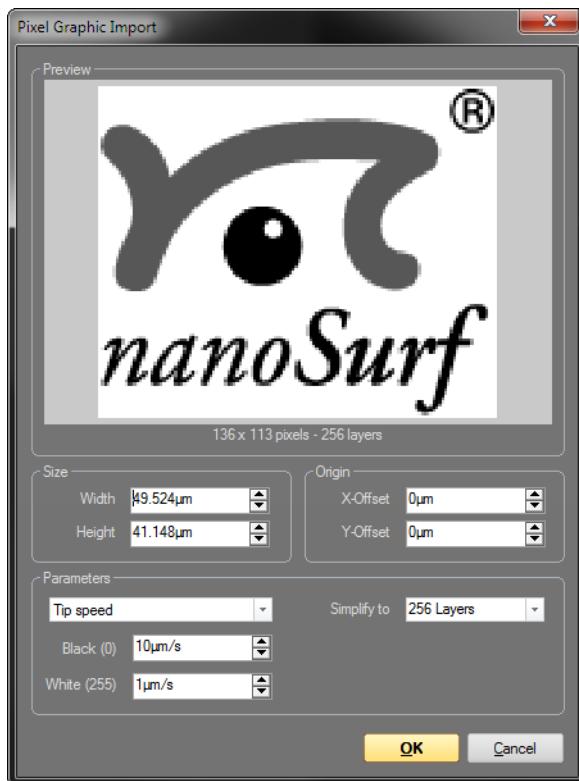
#### **X-Offset / Y-Offset**

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.

### 12.3.2: 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 maintaining 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  $\mu\text{N}$  and 10  $\mu\text{N}$ , respectively, will result in:

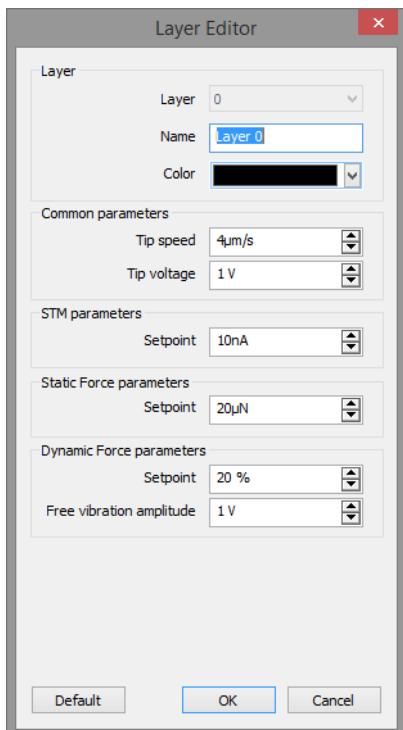
- Layer 0 (black pixel layer) having a Static Force Setpoint of 25  $\mu\text{N}$
- Layer 1 (gray pixel layer 1) having a Static Force Setpoint of 20  $\mu\text{N}$
- Layer 2 (gray pixel layer 2) having a Static Force Setpoint of 15  $\mu\text{N}$
- Layer 3 (white pixel layer) having a Static Force Setpoint of 10  $\mu\text{N}$ .

#### 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 result in no simplification taking place. In all other cases, simplifications are performed through binning of layers.

### 12.3.3: 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. This setting has no effect during STM Lithography.

## Dynamic force parameters

### Setpoint

Used to set the amplitude Setpoint of a lithography sequence performed in dynamic force AFM mode. This setting has no effect during STM Lithography.

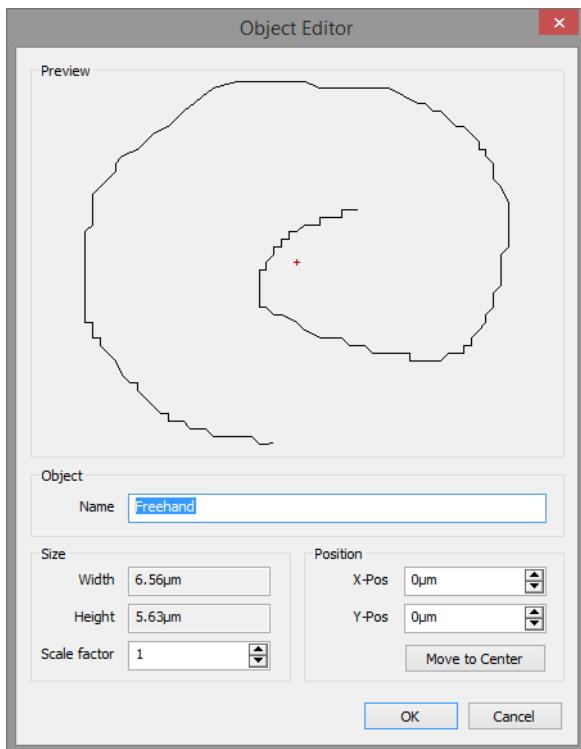
### Free vibration amplitude

Used to set the Free vibration amplitude of a lithography sequence performed in dynamic mode. This setting has no effect during STM Lithography.

### “Default” button

Loads the default Lithography parameter values.

### 12.3.4: 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.

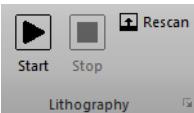
### Move to Center

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 "Measuring" until the lithography sequence is finished.

#### Stop

Aborts the lithography 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.

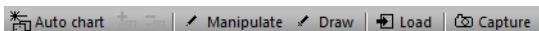
## Important

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 parameters area.

### 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



### 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 chart* tool would display. You can however still remove or add charts manually (See 13.7 Working with charts).

### 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 the lithography parameters section, 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 parameters section 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.

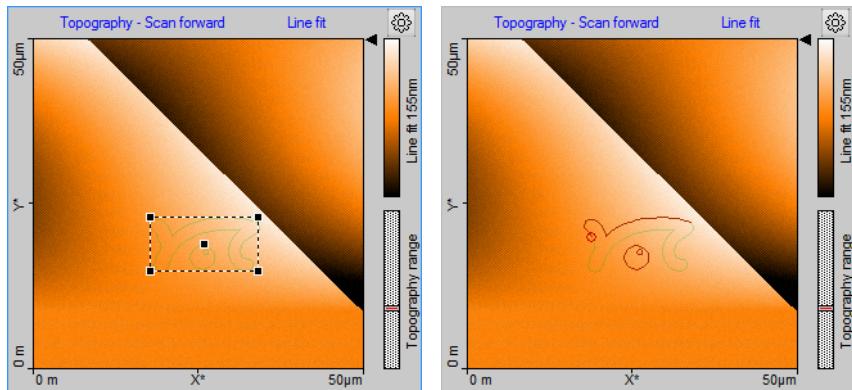
**Load**

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 Naio control software.

## 12.6: Lithography preview



**Figure 12-2: 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 12-2: 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 132)) and the superimposed preview images of the Lithography objects (when these have been loaded and selected; see *Vector import* or *Bitmap import* (page 131)).

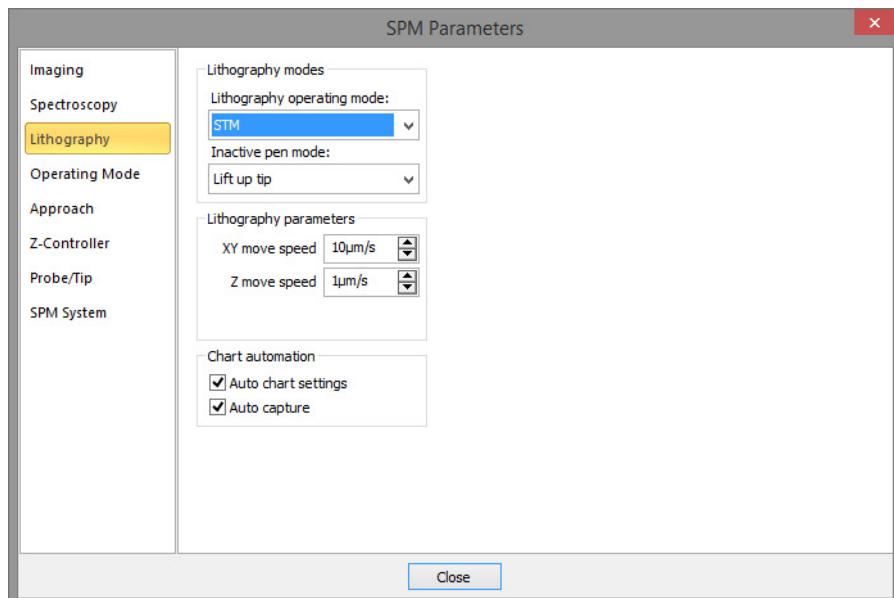
Before running a lithography sequence, a box with the size and content of the selected lithography object is superimposed on the surface map. When selecting the center of the box with the mouse, the corresponding object can be moved around the scan area to reposition it. The new object location (X-Pos 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 12.3.4: Object Editor dialog* (page 140)).

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 12-2: Lithography preview* (page 143), 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 change back to the values used for imaging. The Z-controller will be active during travel to the new start point.

## **Lithography parameters**

### **XY move speed**

The speed at which the tip moves laterally.

### **Z move speed**

The speed at which the tip moves in the Z-direction.

### **Lift tip abs. Z pos**

The Z-position the tip lifts up to during Z modulation lithography.

## **Chart automation**

### **Auto chart settings**

If selected, the chart arrangement is automatically updated (see also *Auto chart settings* (page 145)).

### **Auto Capture**

If selected, all Lithography measurements are automatically stored in the history Gallery. If deselected, you have to click the “Capture” button in the Lithography tool bar to manually save your measurement data.

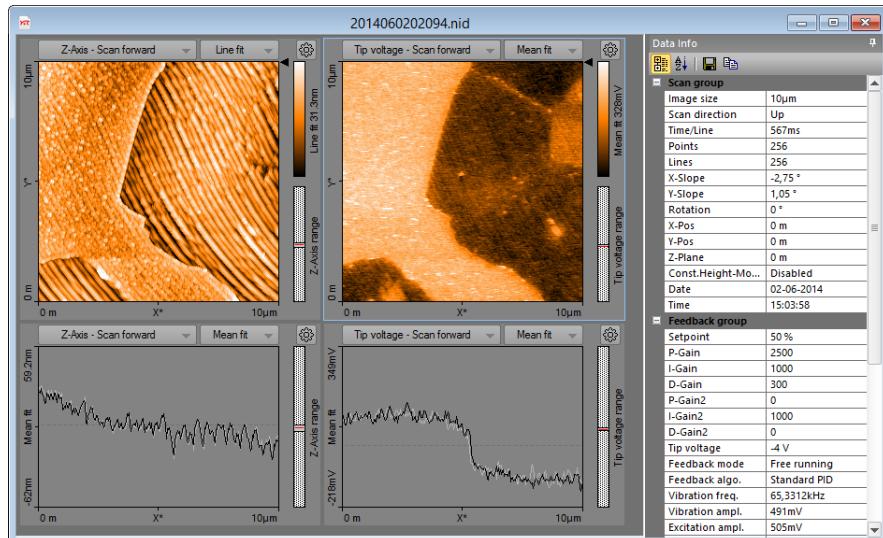
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**CHAPTER 13:**

# **Working with documents**

## 13.1: Introduction

When working with the Nanosurf Naio 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 13.5: Gallery panel*). These measurement documents can be opened and displayed in the document area of the Naio 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 163) in *Section 13.5.3: 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 (see *Section 13.2.1: Data info 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 (grid icon) 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 (A-Z icon) will sort the data entries for the measurement document alphabetically.

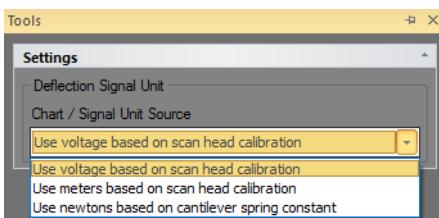
#### Save

The “Save” button (disk icon) 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 (copy icon) will copy the entries of the Data Info panel to the Windows clipboard for easy pasting into other applications.

### 13.3: Tools panel



The *Tools panel* in the measurement document contains general settings for displaying and analyzing documents.

### Settings

#### Force Curve Analysis

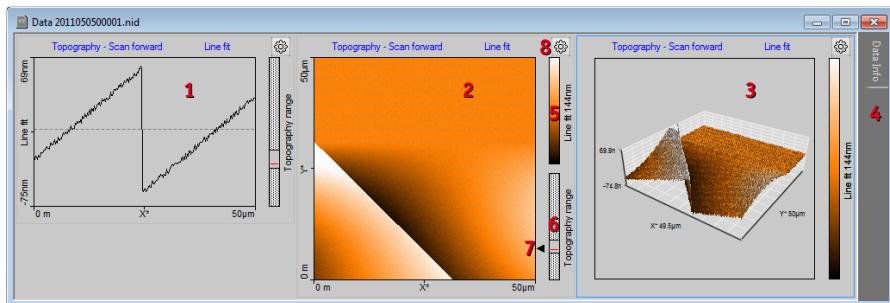
These parameters have the same function as the settings in the Force Curve Analysis section of the Spectroscopy panel.

## Deflection Chart Unit Source

Allows changing the data unit in charts that show the Deflection signal, if the measurement file contains the deflection and cantilever spring constant calibration.

### 13.4: 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*).

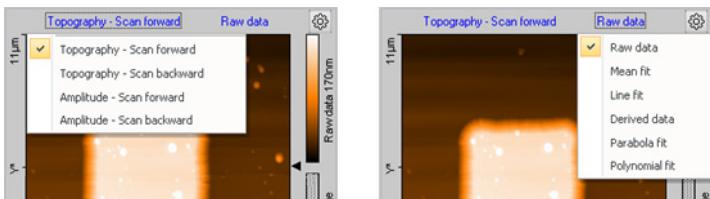


**Figure 13-2: Elements of a chart.** (1) Line graph. (2) Color map. (3) 3D view. (4) Data Info panel (see Section 13.2: *Data info panel*). (5) Color scale for data Z-range. (6) Data range indicator, with scan head Z-range as dotted box, data Z-range as solid gray box and current scan line height as red line. (7) Line selection arrow. (8) “Chart Properties” button.

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:



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 261)).

## 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 13.4.2: 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 13.4.2: Chart Properties dialog*.

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

### 13.4.1: Working with multiple charts

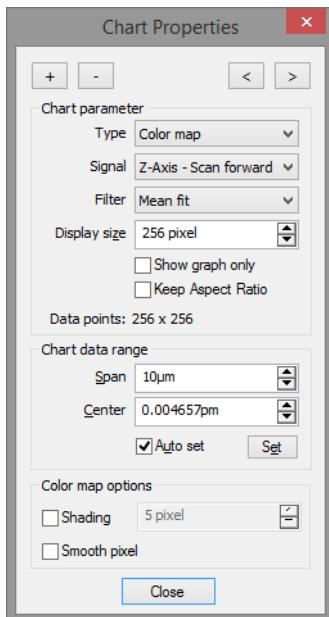
In some windows, multiple charts can be displayed and configured by the user at anytime (e.g. in the Imaging window or a Document window). The same signal can be displayed in different styles (e.g Line Graph and Color map) and / or multiple signals can be shown side by side (e.g. Topography and Phase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

Adding or removing a chart, or setting chart parameters is all performed in the Chart Properties dialog (see *Section 13.4.2: Chart Properties dialog*). When opened, the settings displayed in the Chart Properties dialog refer to the currently selected chart. This (active) 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.

### 13.4.2: 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.

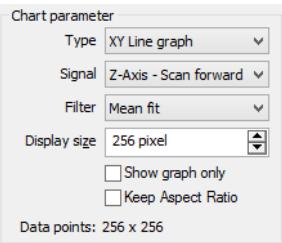
### Previous chart

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 graph where the signal channel is plotted as a function of the modulated signal (Scanner X\*-position Z-Axis out, time). 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 152)). 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.

- **XY Line Graph**

Data is displayed as a Line graph where the vertical plot position is determined by the signal channel and the horizontal plot position is determined by a second signal that was measured at the same time, with the modulated signal as invisible, independent parameter. This graph is mainly used to display spectroscopy data. It can for example show how the measured signals depend on the position measured by a Z-sensor. Mathematically, the XY Line graph is a parametric curve where the modulated signal (Scanner X\*-position Z-Axis out, time, point number) is the independent parameter and two dependent signals determine the X and the Y coordinates of the plotted points.

### - Force Curve graph

Deflection data is displayed as a function of Tip-Sample Separation in an XY Line Graph, with the possibility to overlay Force Curve Analysis results.

### Signal

Selects the dependent signal that is plotted in the chart (in line charts in the vertical direction). 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 data selected in *Signal* (see directly above) before displaying it (see *Figure 13-3: Data filter types*). No modification of the original measurement data occurs (selecting another filter is always possible). It is possible to use a filter with an XY Line graph, but the filter will only fit the Signal channel as a function of the modulated parameter; the second, X-data channel is not used for the fit. 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**

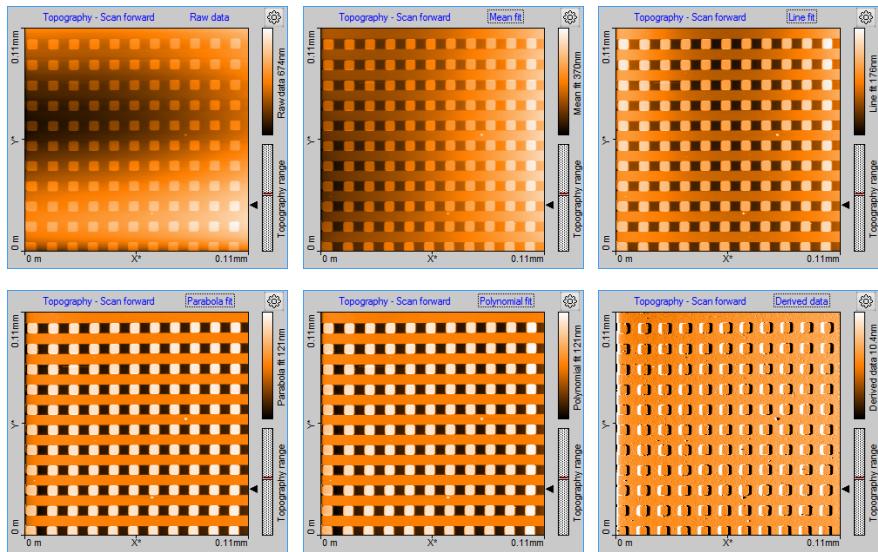
Calculates the fourth order least squares fit for each line of data points and subtracts the fitted values from the raw measurement data for each data point of that line.

### Display size

The size of the chart in pixels.

### Show graph only

When deselected (default), the axis labels, color and range scales, and titles are displayed alongside the graph. When selected, they are hidden.



**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.

### Keep Aspect ratio

When selected, the axis in the color map are drawn in their correct size-relation (according to their value and unit). When deselected (default), the size of the display is always a square and data pixels are stretched if necessary.

## Chart Data Range

Chart data range	
Span	10µm
Center	0.004657pm
<input checked="" type="checkbox"/> Auto set	
Set	

### 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.

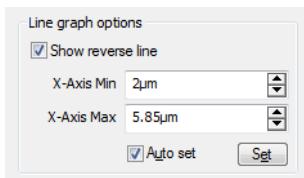
### Set button

Sets the Min and Max value so that all signal values of the current line graph fit in the Horizontal range. Mostly used when “Auto set” is off.

### Auto set

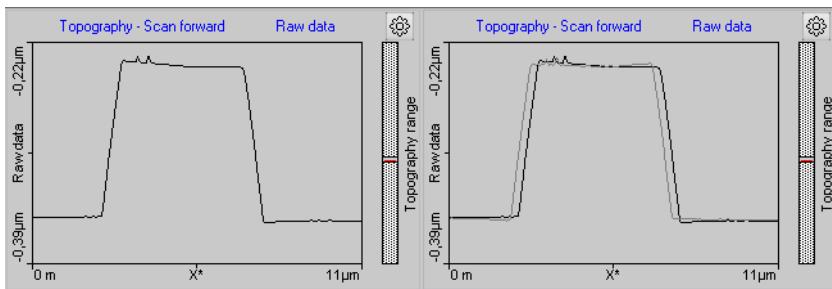
The set function is performed every time when the line graph data changes. When selected, the software will set the Min and Max values each time the chart is automatically scaled.

## Line Graph Options



### Show reverse line

When selected, 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 *Line Scanning* (page 104)).



**Figure 13-4: Show reverse line option.** (Left) Reverse line disabled. (Right) Reverse line enabled.

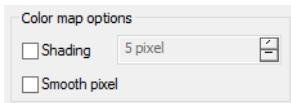
### X-Axis Min

Defines at what value the horizontal axis starts. Can be used to zoom in or out to a specific data range.

### X-Axis Max

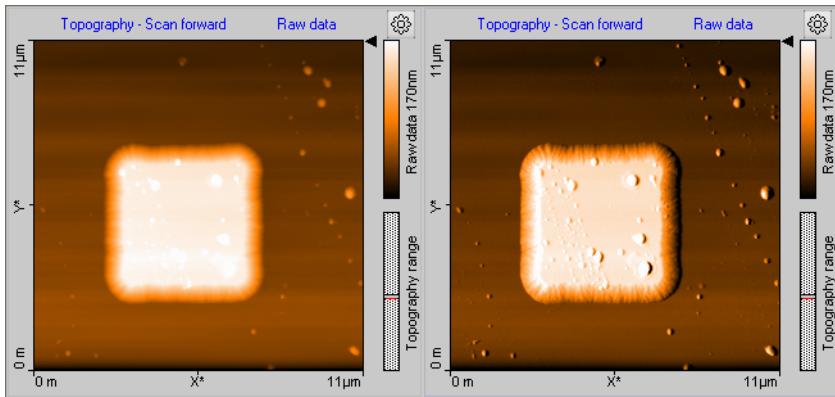
Defines at what value the horizontal axis ends. Can be used to zoom in or out to a specific data range.

## Color Map Options



### Shading

When selected, 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.



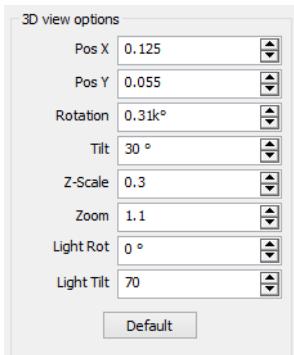
**Figure 13-5: Shading option.** (Left) Shading disabled. (Right) Five-pixel shading enabled.

### Smooth pixel

When selected, 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 than the number of measured data points (e.g. a 256×256 measurement displayed at 512×512 pixels).

In addition to the options above, *Color map* charts have the *Force Curve Overlay Options* (page 160).

## 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

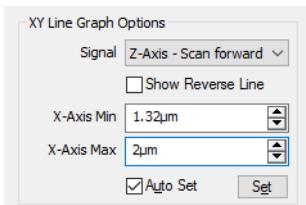
- **Light source direction**

"Shift" + "Ctrl"-key + mouse left/right

- **Light source height**

"Shift" + "Ctrl"-key + mouse up/down

## XY Line Graph Options



### Signal

The signal that determines the horizontal position of the plotted points. With the exception of the Signal parameters, the XY line graph options are the same as the *Line Graph Options* (page 157).

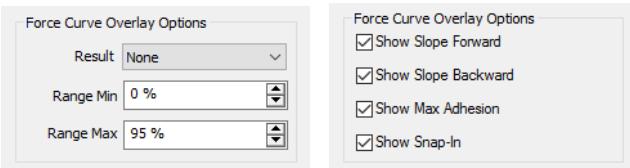
## Force Curve Graph Options

The Force Curve Graph Options are the same as the *XY Line Graph Options*. In addition, Force Curve graphs have the *Force Curve Overlay Options* (see directly below).

## Force Curve Overlay Options

Allows displaying an evaluation result of the Force Curve Analysis as a colormap overlayed over the normal color map.

Different *Force Curve Overlay Options* are available for the *Color map* and *Force Curve graph* chart types (see left and right image below, respectively):



## **Result**

Sets which analysis result determines the brightness of the overlay pixels.

## **Range Min**

Sets which percentage of the result values has the color black.

## **Range Max**

Sets which percentage of the result values has the color bright red.

All other result values have a red brightness proportional to their value.

## **Show Slope Forward**

Shows the fitted slope of the forward spectroscopy data as an overlaid red line.

## **Show Slope Backward**

Shows the fitted slope of the backward spectroscopy data as an overlaid red line.

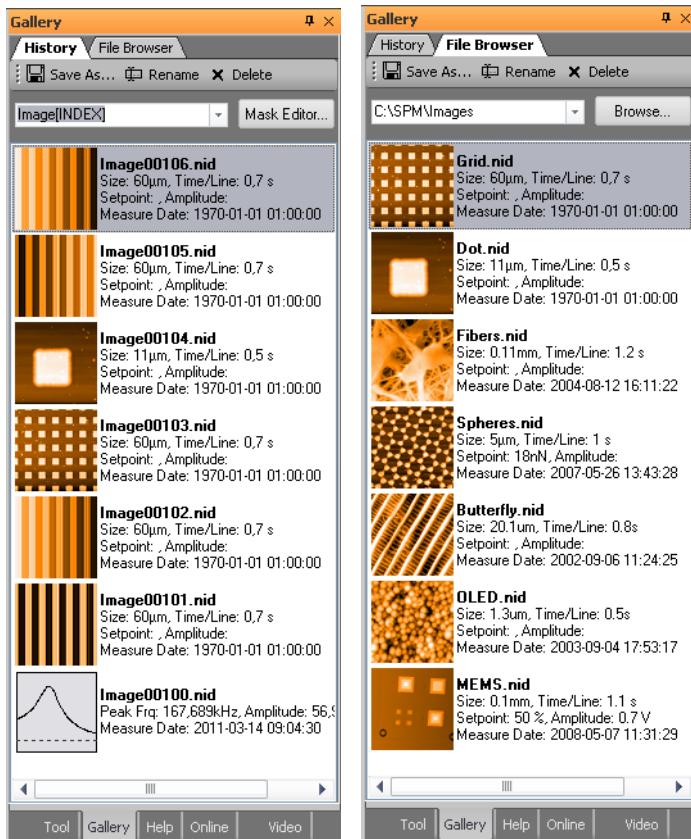
## **Show Max Adhesion**

Shows the fitted maximum adhesion as an overlaid red circle on the backward spectroscopy data.

## **Show Snap-In**

Shows the fitted maximum adhesion as an overlaid red circle on the forward spectroscopy data.

## 13.5: Gallery panel



The Gallery Panel displays lists of thumbnails representing previous measurements for quick access to those documents. It contains two pages (accessed via tabs):

1. History
2. File browser

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 264)). The *File browser* page contains measurements from a user-selected folder (e.g. containing older measurements that were previously moved there). The various elements of the Gallery panel are described in the next sections.

### 13.5.1: History file mask



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 13.5.4: Mask editor dialog*), which is opened by clicking the “Mask Editor” button next to the edit box.

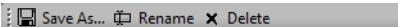
### 13.5.2: Image list

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.

### 13.5.3: Gallery toolbar



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 264))

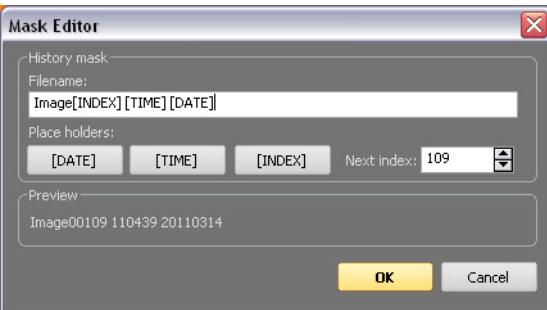
### **Rename**

Single or multiple measurements can be renamed by clicking the “Rename” button. It will open the File Rename dialog (see *Section 13.5.5: 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.

## **13.5.4: 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 automatically stored (temporarily) 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 Naio 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.

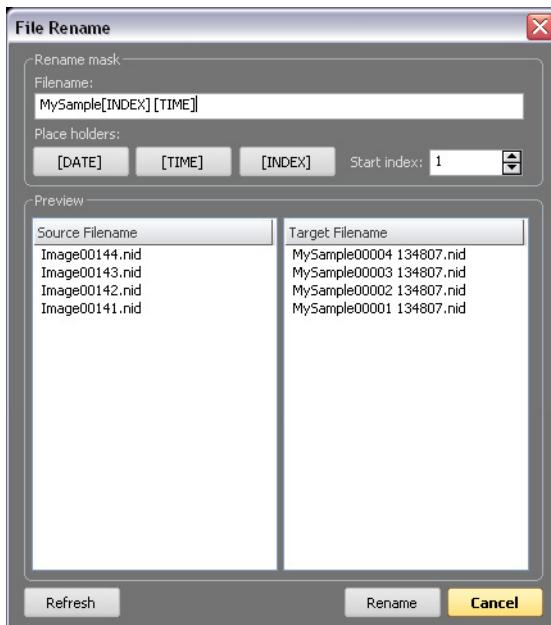
**Important**

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.

### 13.5.5: 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 164).

#### 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**

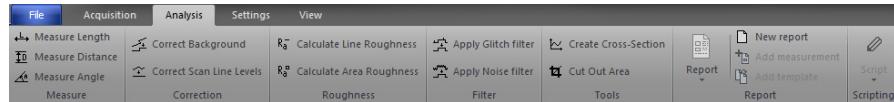
If no unique filename(s) would result from the specified Rename mask, an index is automatically added to the files. If this still does not result in unique filenames, the text "Copy of" is added to each filename as often as is required to make it unique.

**Cancel**

This button closes the dialog without renaming the files.

## 13.6: 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:

- ① Click on the chart that you want to evaluate to activate it.
- ② 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).
- ③ 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 13.7: 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.

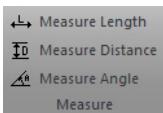
To stop using a tool:

- ➊ Select another tool, select the same tool a second time, or select “Abort” in the Chart’s context menu.

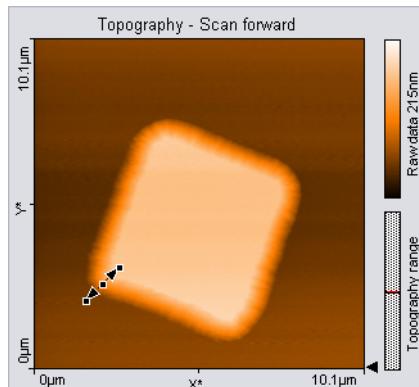
### Tip

For more elaborate evaluations, the optional Nanosurf Analysis or Nanosurf Report software can be used.

#### 13.6.1: Measure group



##### Measure length



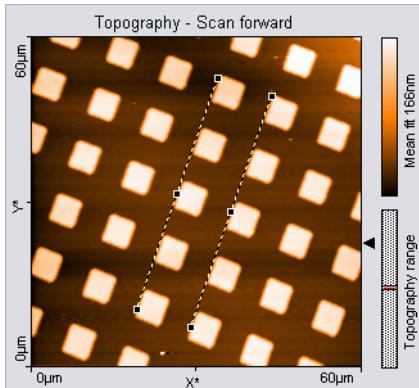
Calculates the distance and signal difference between two points. Graphically, a line with arrowheads on each end represents the selection marker. The line is defined by drawing a line on the measurement chart. The first point is positioned by moving the mouse cursor to the desired location and clicking 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, a 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 179)).

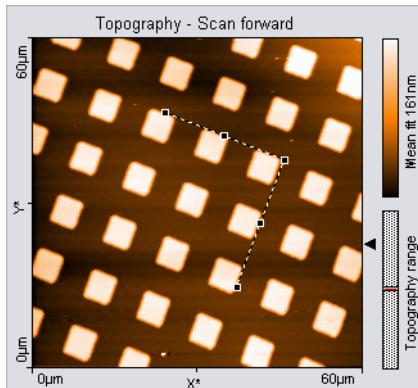
## Measure distance



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 depend on 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 179)).

## Measure angle

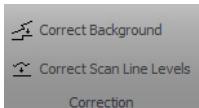


Calculates the angle between two lines. In Line graph-type displays, this tool can only be used when the chart displays data that has the unit "meters".

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 179)).

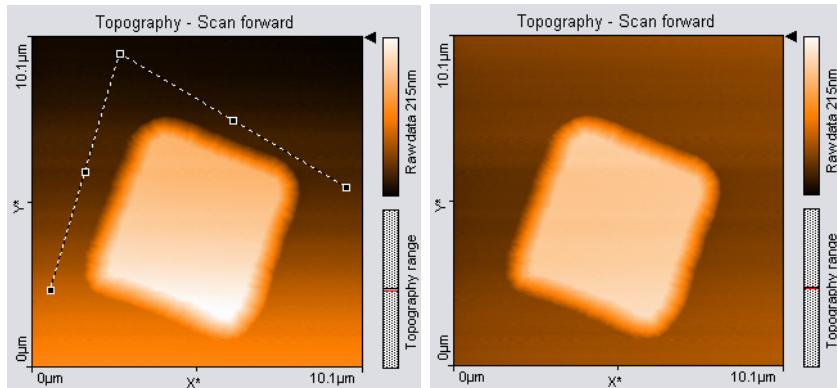
### 13.6.2: Correction group



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 174))) 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 155)) 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.

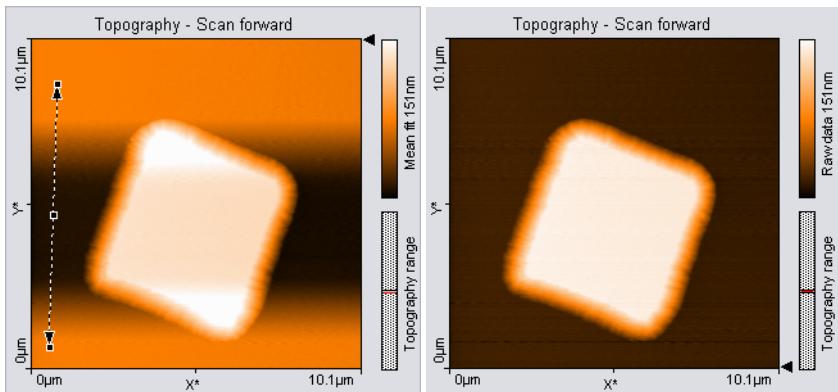
After clicking the “Execute” button in the Tool status section of the Tool panel, a copy of the original measurement document is made and the plane that is defined by the selection marker is subtracted from the measurement data in the newly created document. To get useful results, the Data filter option 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 155)) 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.

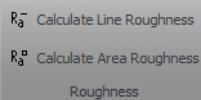
After clicking the “Execute” button in the Tool status section of the Tool panel, a copy of the original measurement document is made and the average level of each scan line in the newly created document is adjusted so that all points along the drawn line have the same



**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

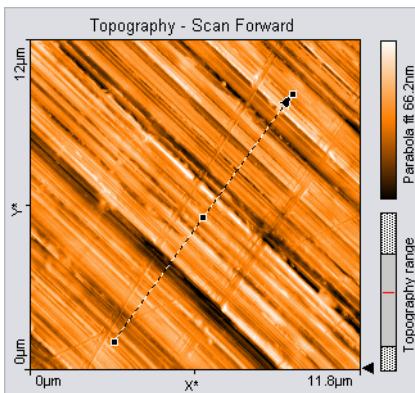
height. To get useful results, the Data filter option for the corrected image in the new document will be automatically set to “Raw data”.

### 13.6.3: 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 168)).



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 Mean Value,  $R_m$

$$R_m = \frac{1}{N} \sum_{l=0}^{N-1} z(x_l)$$

The Roughness Average,  $R_a$

$$R_a = \frac{1}{N} \sum_{l=0}^{N-1} |z(x_l - R_m)|$$

The Root Mean Square,  $R_q$

$$R_q = \sqrt{\frac{1}{N} \sum_{l=0}^{N-1} (z(x_l - R_m))^2}$$

The Valley depth,  $R_v$

$$R_v = \text{lowest value} - R_m$$

The Peak Height,  $R_p$

$$R_p = \text{highest value} - R_m$$

The Peak-Valley Height,  $R_y$

$$S_y = S_p - S_v$$

The roughness values depend on the line filter option (see *Filter* (page 155)) 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,  $S_v$  $S_v = \text{lowest value}$ The Peak Height,  $S_p$  $S_p = \text{highest value}$ The Peak-Valley Height,  $S_y$  $S_y = S_p - S_v$ 

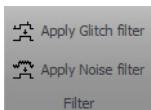
The roughness values depend on the Data filter that is applied to the chart, because they values are calculated from the filtered data. More information on data filters is provided in Section 18.2: The Chart bar under Data filter (page 199).

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.

### 13.6.4: Filter group



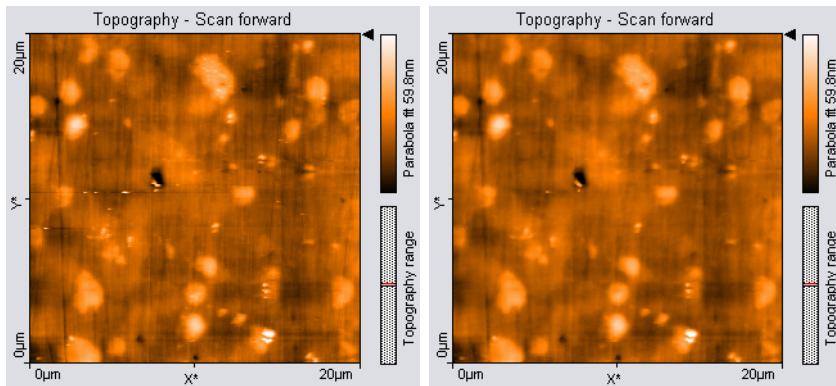
#### Glitch filter

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  $3 \times 3$  pixel matrix.

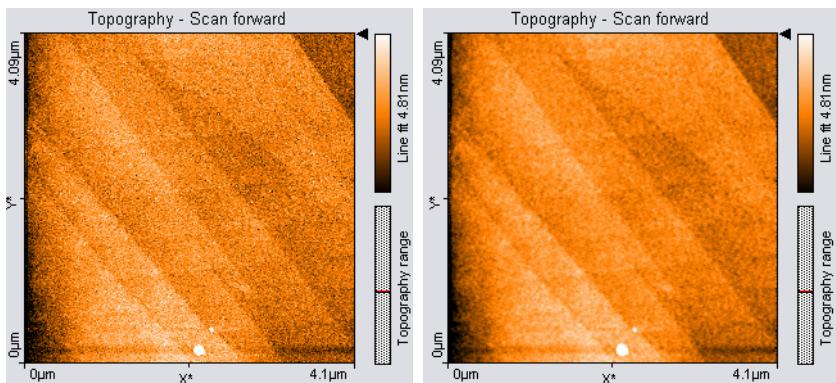
To apply the filter, activate the color map chart that is to be filtered, then click the “Glitch Filter” button. A new Measurement document with the filtered data is created.

#### 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  $3 \times 3$  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 a 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 change the result of the other tools. This may result in incorrect results, e.g. when evaluating sample roughness.

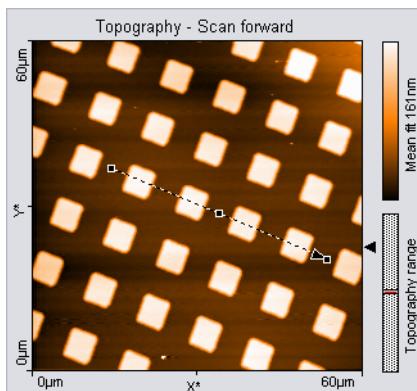
### 13.6.5: Tools group



#### 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.

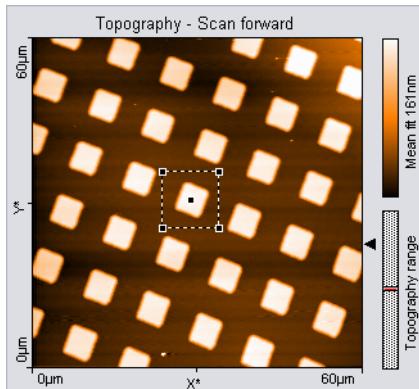
The Tool chart section of the Tool Results panel displays a preview chart of the selected line.

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 179)).

#### 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 179)).

### 13.6.6: Report group

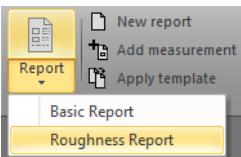


The Nanosurf Report software offers a powerful and extensive set of analysis functions. Complex analyses can be created interactively, and then displayed and printed in visually appealing reports. These reports can then be used as templates to consistently apply the same analysis to other measurements.

## Report

The “Report” button starts the Report software (if installed) from within the Naio 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 folder is configured by the Report Template File path (see *Reporting* (page 263)).

### 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 Naio 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

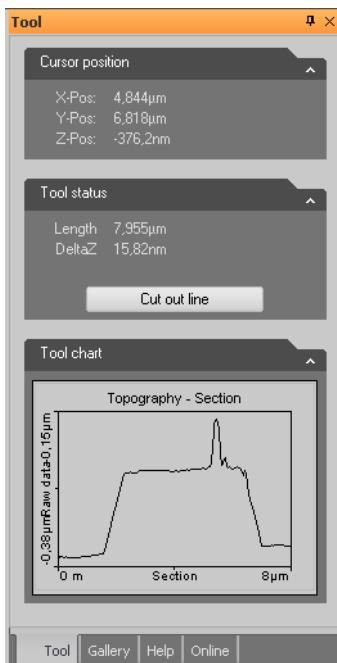
If you do not save the measurement in the control software, but only save the report, the data in measurement channels that were not displayed is lost.

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.

## 13.6.7: Scripting group

Please refer to *Section 10.5.2: Scripting group* (page 101).

## 13.7: 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

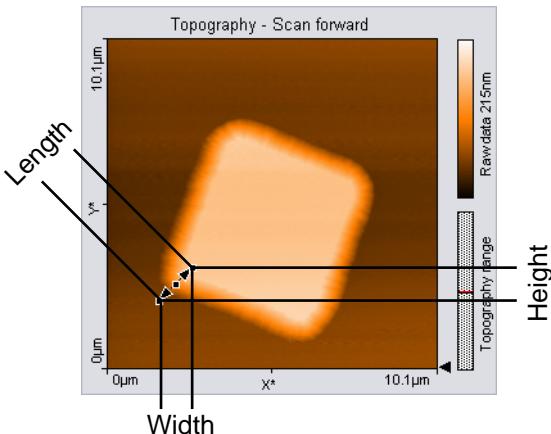
This section appears when a tool is being used. It displays the evaluation result of the currently active tool.

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:

$$\text{Length} = \sqrt{\text{Width}^2 + \text{Height}^2}$$



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

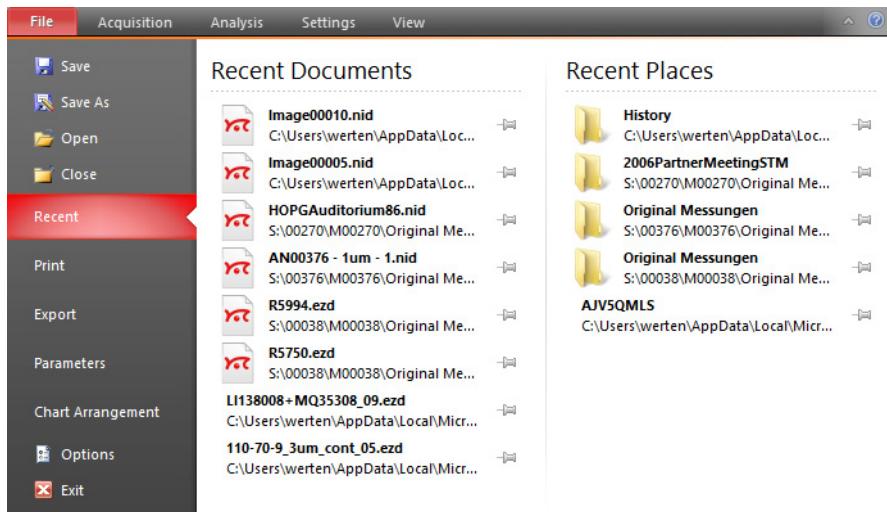
The difference between the "Z-Pos" values at both ends of the selection marker.

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.

### 13.8: 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 15.1.1: Options dialog* (page 259)), but also to basic file operations such as opening, storing and printing of measurements (explained below). The latter functions can also be performed using the *Quick access toolbar* (see below) that is located directly above the file menu.

### Quick access toolbar



By default, this customizable toolbar contains small icons to *Open*, *Save* and *Print* documents. The content of the quick access toolbar can be changed via the *Quick access toolbar* page of the *Options dialog* (see page 188).

### 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 once 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**

Saves the currently open measurement document in Nanosurf image data format (file extension ".nid") under its current name.

## **Save as**

Save the currently open measurement document under a new name.

## **Close**

Closes the currently active document, but not the Naio 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 13.6: 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 13.6: 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**

Prints the currently selected measurement document together with the values shown in the Data Info panel. The *Print* option also provides a graphical preview of document that will be printed.

## **Exit**

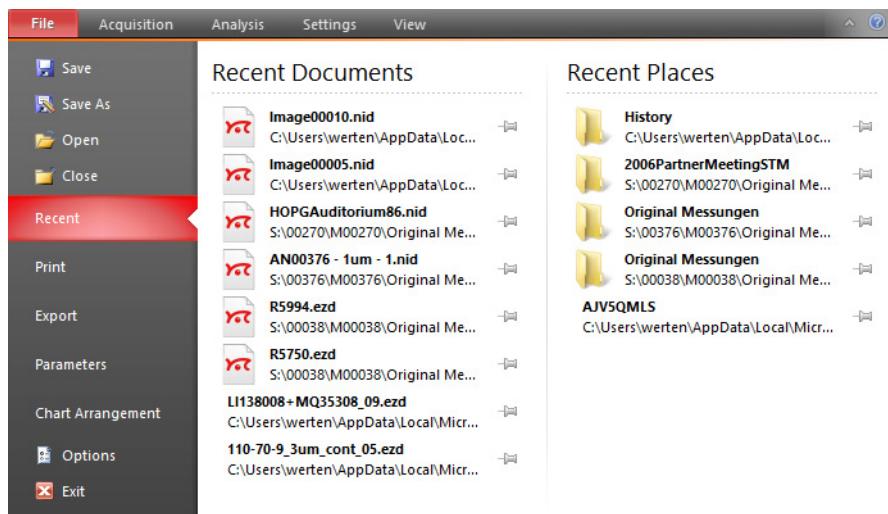
With exit you can close the Naio control software. If you exit the program while still having unsaved data, you will be asked to save it.

CHAPTER 13: WORKING WITH DOCUMENTS

**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 13.8: File menu* (page 181)), 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 Naio 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.

#### **Load parameter settings**

Loads a previously saved parameter file.

#### **Save parameter settings**

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 parameter settings**

Saves the parameters under a new file name.

## Chart arrangement

The chart arrangement of the Imaging and Spectroscopy windows is stored in a configuration file with the extension ".chart". When the Naio 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.

### Load chart arrangements

Loads a previously saved chart file.

### Save chart arrangements

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 chart arrangements

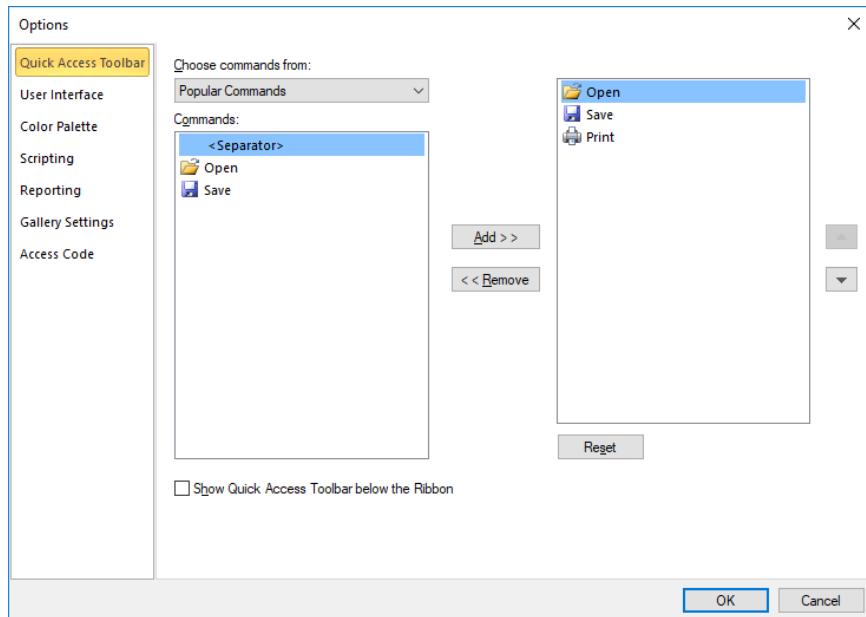
Saves the chart arrangement under a new file name.

## Options

The *Options* button opens the *Options dialog* (see below), which configures various general control software settings.

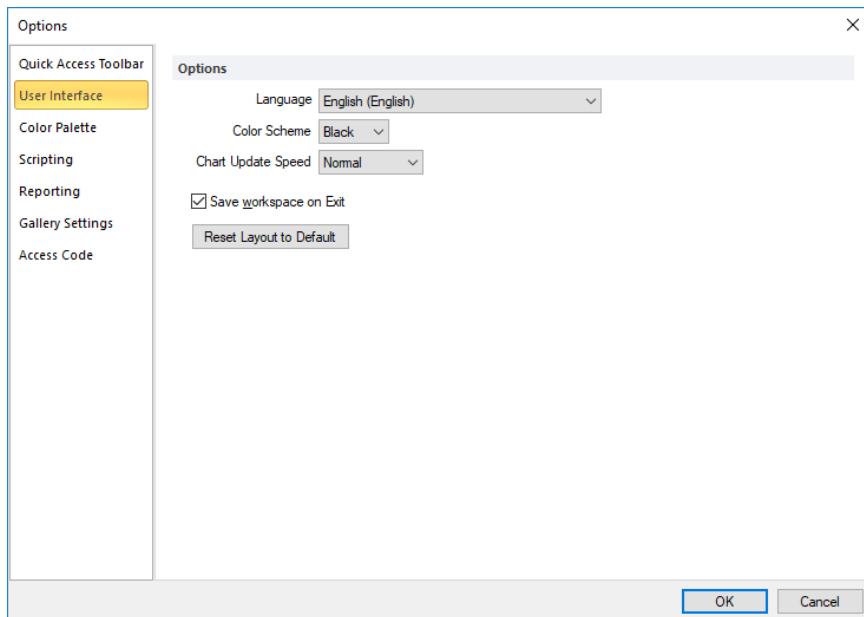
### 14.1.1: Options dialog

#### Quick access toolbar



Allows changes to the content of the Quick Access toolbar (see *Quick access toolbar* (page 181)). 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 Naio control software language.

### Color scheme

Select between black (default), silver, and blue coloring of the user interface.

### Chart Update Speed

This feature enables you to define the frequency of updating/redrawing of the data charts while scanning and doing spectroscopy. The update rate is independent from changes of the currently visualized data (e.g. spectroscopy modulation time). Intermediate changes are tracked and corresponding actions are executed during the next update call.

The following options are available from the drop-down menu:

- **Slow**  
1 Hz
- **Normal**  
5 Hz (default)
- **Fast**  
20 Hz

On slower CPUs with few cores (like Intel Core 2 Duo) we recommend selecting *Slow*.

**Save workspace on exit**

When selected, the workspace settings are automatically saved to the system registry when the control software is closed (see also *Parameters* and *Chart arrangement* (page 187)).

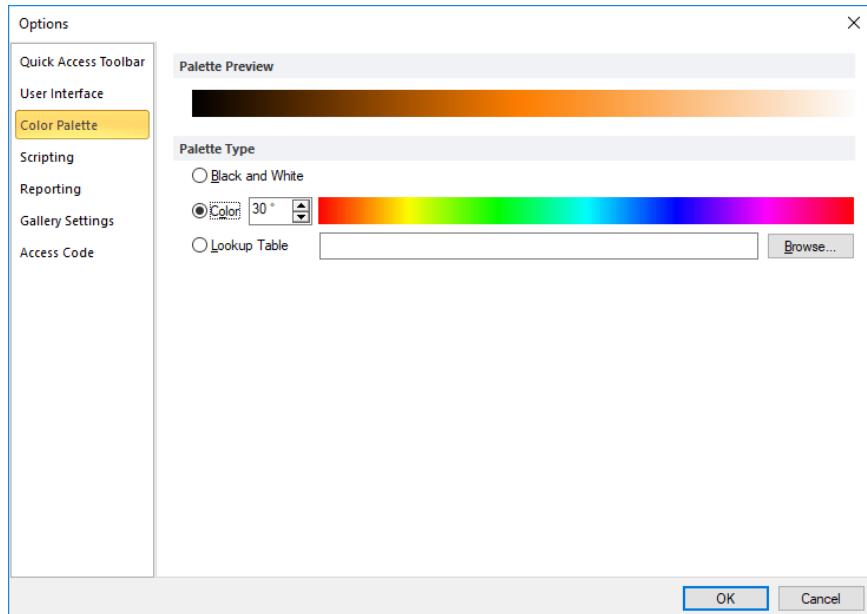
**Save nid file as version 2 nid file**

Saves a document in the older version 2 file format. Activate this option when you need to be able to import .NID files in older data evaluation software packages such as Nanosurf Report version 5 and older or SPIP 5 and older. Users of report version 6 and newer or SPIP 6 and newer should update to the latest version of their software package, if there is any trouble to read new files. This setting has no effect on most spectroscopy measurements, as they must be saved in a newer file format version.

**Reset layout to default**

Sets the layout to default settings. Especially when changing the monitor configuration, it may happen that some dialogs and panels are "displayed" off-screen. In this case, you cannot see the dialog, and it may seem that the software stopped working. If this happens, press the "Esc" key to exit the invisible dialog, and activate this button.

## 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.

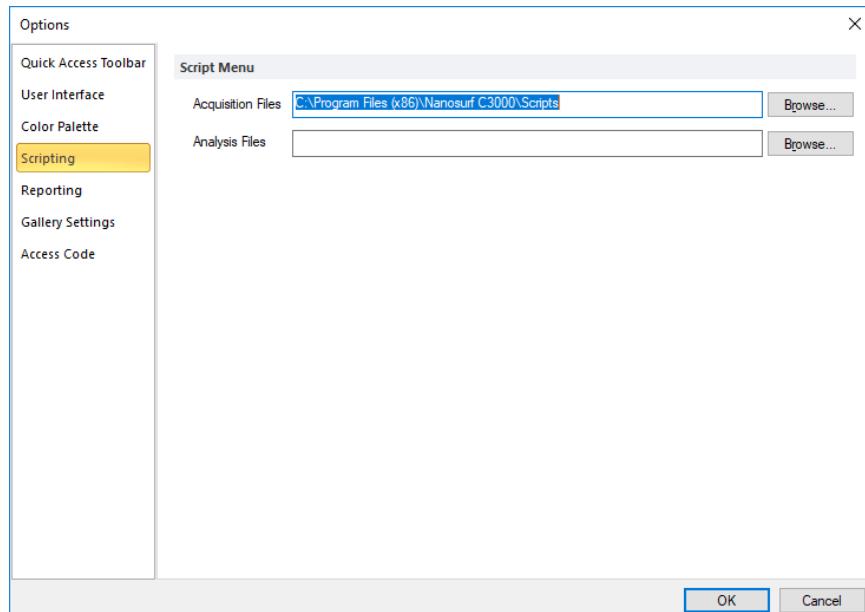
- **Color**

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.

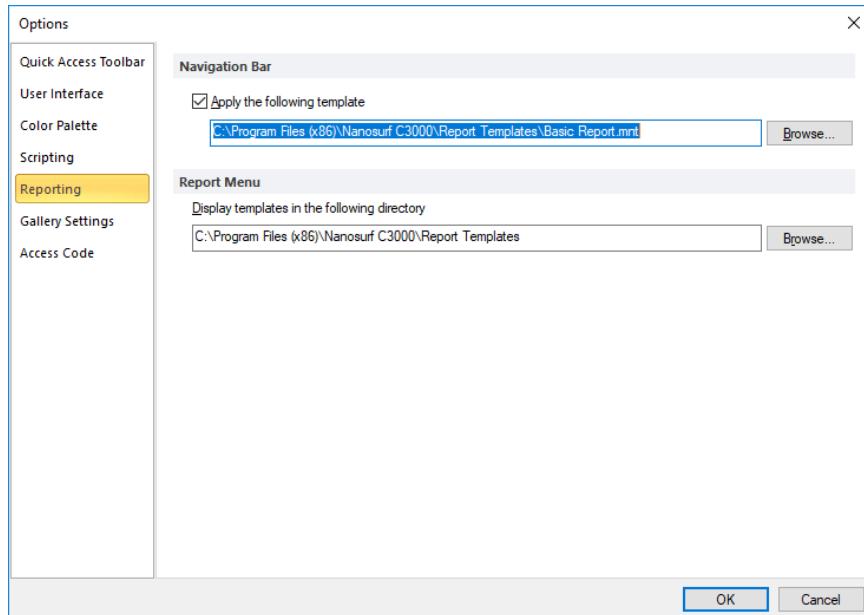
## Scripting



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 subfolders inside each of the “Script” folders, 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* (page 167).

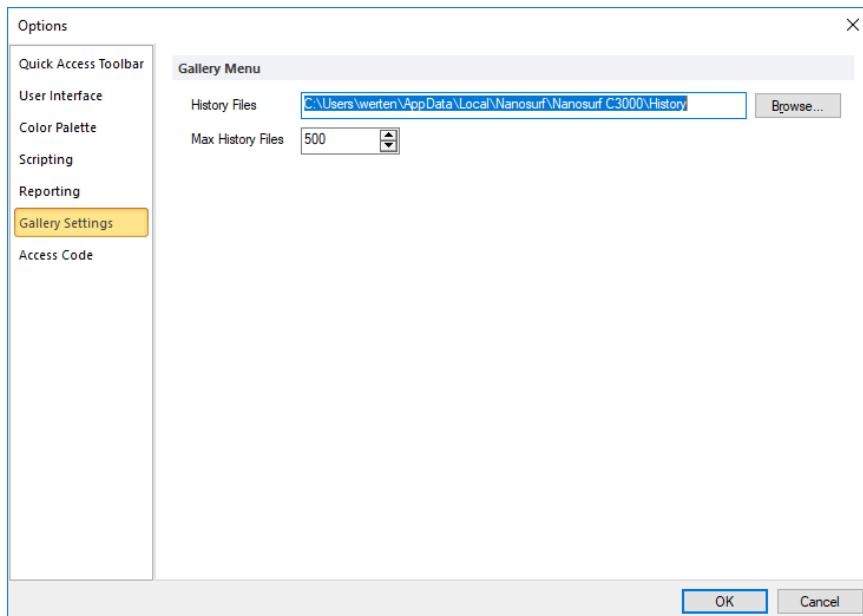
### Apply the following template

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 folder

As with the locations of the scripting files (see *Scripting* (page 191)), the content of the specified folder is displayed as choices in the Report drop-down menu.

## Gallery settings



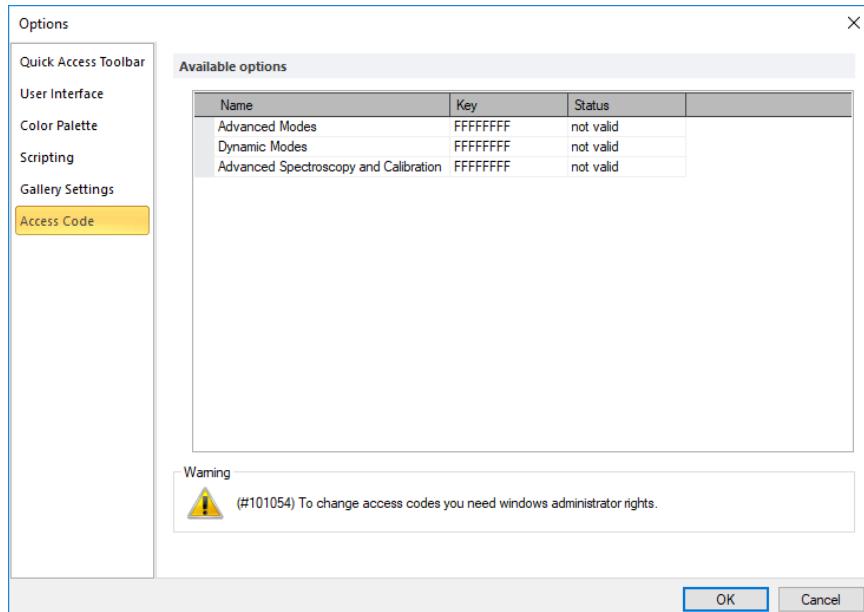
### History folder

Sets the folder 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 folder. When the maximum is reached, the oldest measurement will be deleted from the *History folder* to allow the latest measurement to be saved.

## Access code

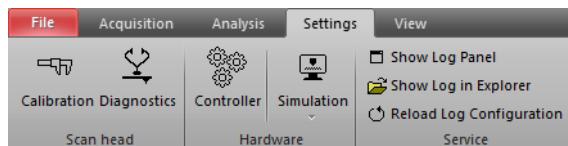


Used to enter the access codes for additional (optional) software modules.

### Important

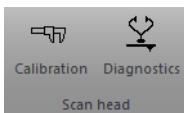
If you receive the warning "To change access codes you need Windows administrator rights", please restart the control software with the "Run as Administrator" option from the Windows Explorer context menu.

## 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](#).

### Diagnosis

This button opens the *Scan Head Diagnostics dialog* where the actual health state of the scan head can be seen. For more details, see [Section 14.6: Scan Head Diagnostics dialog](#).

## 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 201).

### 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".

The drop-down menu selects the scan heads to simulate:

- **NaioSTM**
- **NaioAFM**

In microscope simulation mode, many functions of the microscope are performed on a mathematically generated surface. Thus, software functionality and acquisition procedures can be practiced without danger of harming the instrument.

### 14.2.3: Service group

#### Show Log panel

Opens the log panel to show detailed messages about what the control software is doing. This information will be helpful for service personnel. Use the *Marker* button to mark a specific action or event in the log.

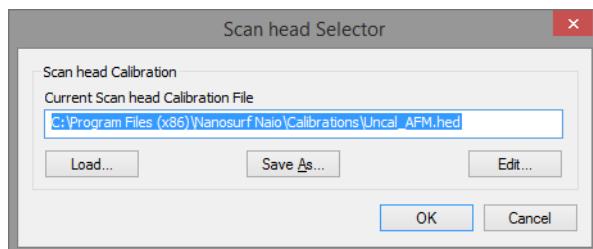
#### Show Log in Explorer

Opens the directory where the log files are stored. If the system had a problem, you can send the newest files from this directory to your local sales partner, together with an error description and — if applicable — a measurement that shows the problems.

#### Reload log configuration

Restarts the log system with the current configuration from file.

### 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 exact configuration of each scan head is stored in a file with a filename that corresponds to the serial number of that particular scan head, with the extension ".hed". 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" subfolder 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.

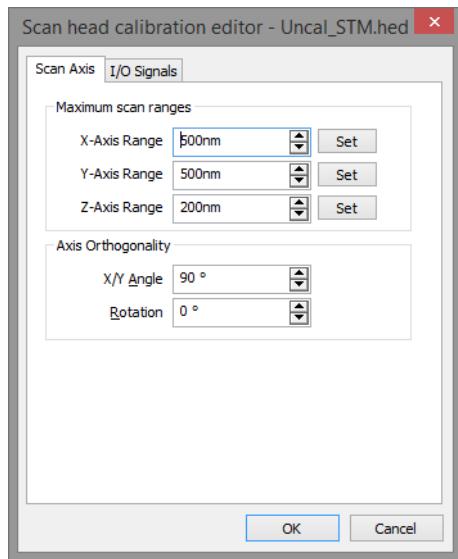
## 14.4: Scan head calibration editor dialog

Through this dialog, the calibration of all standard Inputs and Outputs can be configured individually for a particular scan head.

**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* (page 200).

### X/Y/Z-Axis Sensor

If the scan head has position sensors to measure the absolute axis positions, the calibration values are set here.

## Axis Orthogonality

The X- and Y-Axes of the scanner are generally not perfectly orthogonal, and their orientation with respect to the scanner 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.

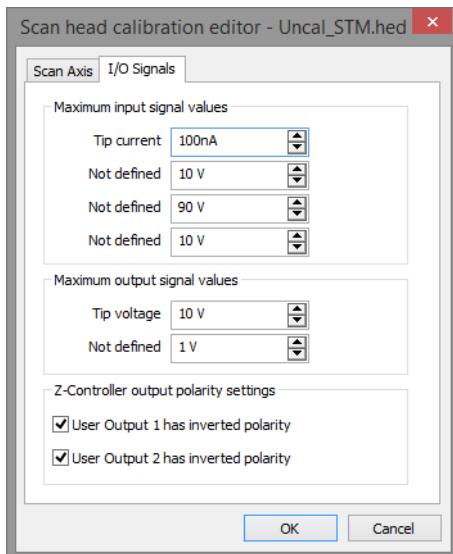
## X/Y Angle

The angle between 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.

### 14.4.2: I/O Signals



## Maximum input signal values

### Tip current

This calibration value is used to convert the STM preamplifier signal to physical units.

## Maximum output signal values

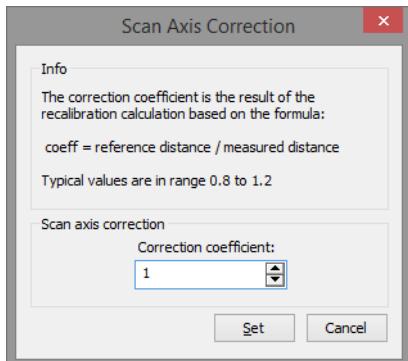
### Tip voltage

The calibration value of the Tip voltage setting.

## Z-controller output polarity settings

Determines the output of User outputs 1 and 2. These values should normally not be changed.

### 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.

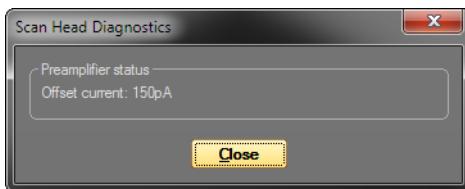
### 14.6: Scan Head Diagnostics dialog

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 STM scan head



Information about the preamplifier that is present in the STM scan head is displayed here.

#### Offset current

This is a leakage current that is measured by the preamplifier when it is not in contact with the sample.

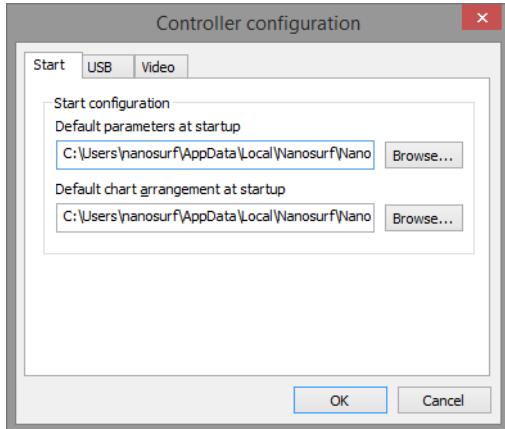
#### Important

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

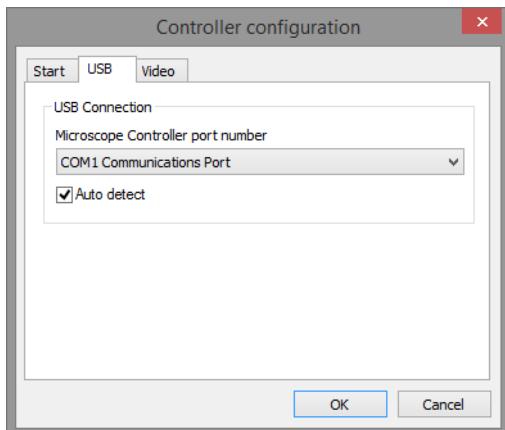
With this dialog some controller hardware related settings can be configured. On a correctly installed system, it should not be necessary to change these settings manually. The Controller configuration dialog is opened via the "Controller" button in the Hardware group of the Settings tab.

## Start configuration



The parameter and chart arrangement files that are loaded when the Naio control software starts. Each Windows user has his/her own set of these two files a personal “Local Settings” folder. Therefore, each windows user can configure the control software to his/her own personal preferences without any consequences for other users.

## USB Connection



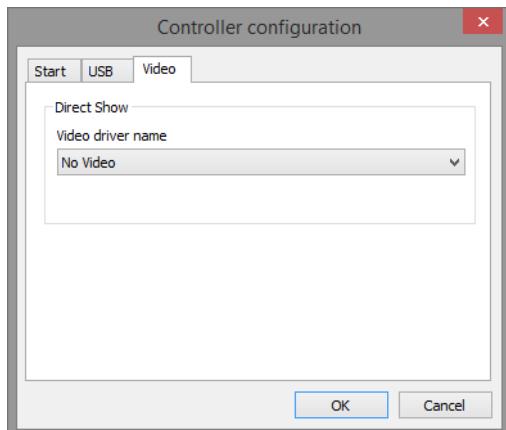
The NaioSTM controller uses a virtual serial port that is connected to the USB port. The number of this virtual serial port should be the same as the one shown in your the windows device manager dialog.

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

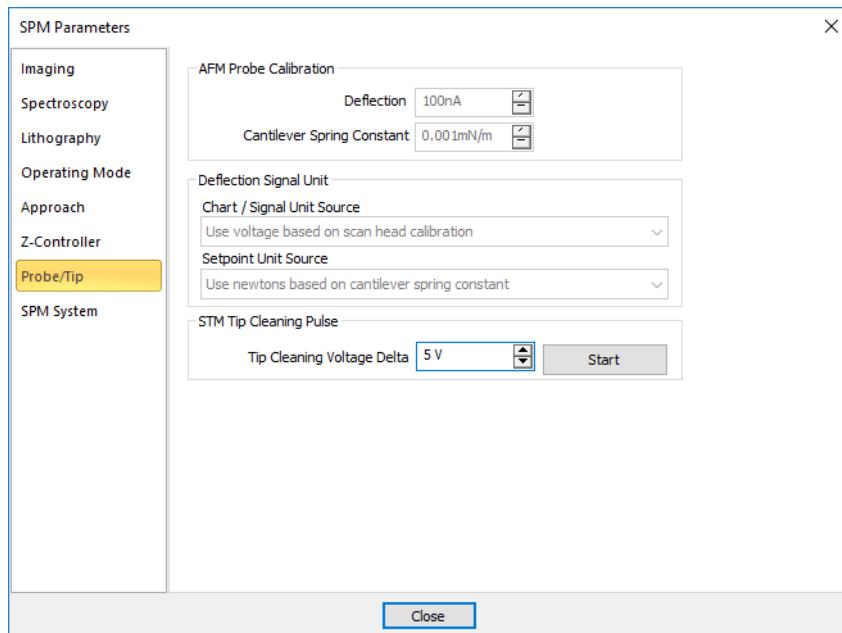


Allows selection of an additional video source to be shown in the video panel. This option is not needed for STM systems.

Select “No video” in the list if you wish to completely suppress the video display.

## 14.8: SPM parameters dialog

### 14.8.1: Probe/tip page



### 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.

**CHAPTER 15:**

# **Quick reference**

## Quick reference

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# **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 NaioSTM scan head

It is important to keep the Sample Holder and the open parts of the scanner clean. Therefore, always store 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.

If you have touched the metal part of the sample holder or it has otherwise become dirty, or in case sample approach does not seem to work, the surfaces of the sample holder, the approach motor, and the fixed support for the sample holder in the scan head should be cleaned. It is important to always clean all of these parts, because otherwise contaminations from one part will be transferred to the others, and in the end everything will be dirty. Even exchanging the sample holder will not help if the motor is not clean.

To perform a proper cleaning:

- ① Put on acetone-proof gloves (powder-free latex gloves are suitable).
- ② Take a clean, lint-free tissue and moisten it with acetone.
- ③ Clean the sample holder by moving the cloth along the sample holder in the axial direction only.  
Do not move it around its circumference!
- ④ Take a cotton swab and also moisten it with acetone.
- ⑤ Clean all surfaces inside the scan head that the sample holder lies on.
- ⑥ Let all parts dry before operating the motor again.

If the sample holder is still visibly dirty, you have to clean it at least a second time with fresh acetone, because part of the contamination will be redeposited when the acetone dries after the first cleaning.



Figure 16-1: Cleaning the sample holder support surfaces of the scan head

### 16.3: The NaioSTM exterior

To clean the exterior of the NaioSTM system:

- Use a soft cloth, lightly moistened with a mild detergent solution. Do not use any abrasive pads or solvents like alcohol or spirits.

## CHAPTER 16: MAINTENANCE

**CHAPTER 17:**

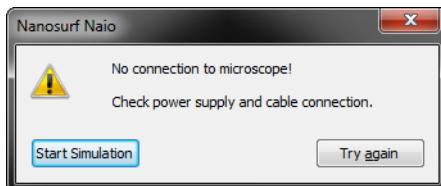
# **Problems and solutions**

## 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 219).

## 17.2: Software and driver problems

### 17.2.1: No connection to microscope



This error message appears when the Naio software is waiting for an answer from the controller. Most likely, the NaioSTM is not connected to the mains power, or it is not turned on. In this case the power LED on the side of the NaioSTM is 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. To fix this problem:

- ① Check if a second copy of the Naio control software is already running and occupying the USB port.
- ② 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 NaioSTM. In order to solve driver problems:

- ① Check for driver updates on the Nanosurf Support web site.
- ② Insert the installation CD for your instrument.
- ③ Log in with Administrator privileges.

The device manager can then be opened to view and correct any driver problems:

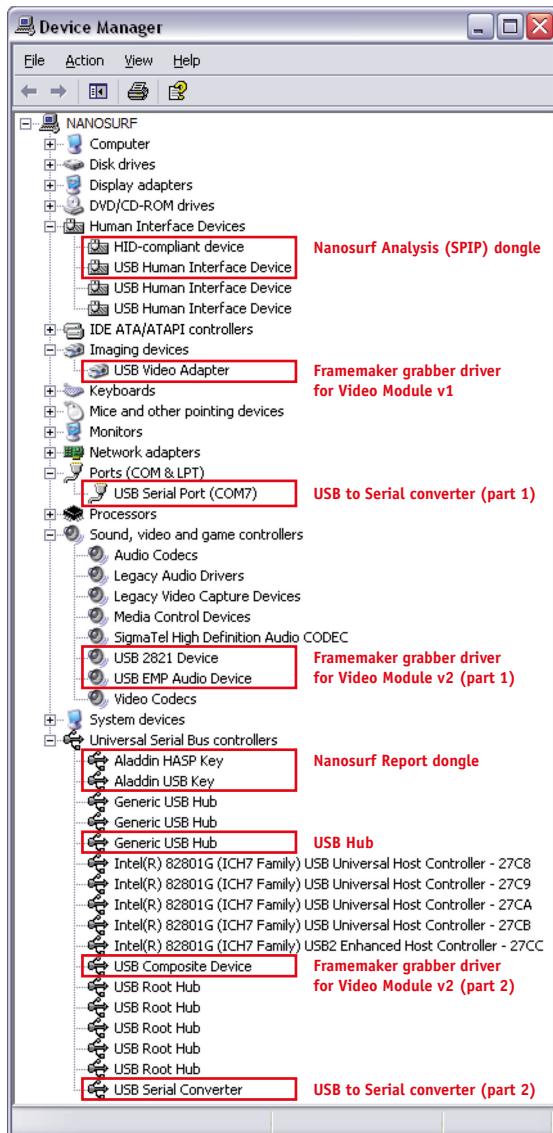
- ① Open the windows menu “Start”>> “Control Panel”.  
The control panel now opens.
- ② Select “Large icons” or “Small icons” if “View by” is set to “Categories”.
- ③ Double-click the “Device Manager” icon.  
The device manager now opens.

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:

- ① Double click on the driver.  
Properties dialog for the device now opens.
- ② Select the “Driver”-tab.
- ③ Click the “Update Driver”-button  
Windows will now ask you where to look for the driver.
- ④ Instruct windows to manually search for the driver files on the Installation CD.

## CHAPTER 17: PROBLEMS AND SOLUTIONS



**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 4.3.2: Fine approach 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 209).

### 17.3.2: Automatic final approach is too slow / stops sometimes

Even if the manual approach works, the automatic final approach (*Section 4.3.3: 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 209).

If cleaning does not help, the step size may be too small. To solve this problem:

- ① Open the SPM Parameters dialog (see *Section 7.9: SPM parameters dialog* (page 74)).
- ② 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.
- ③ 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 either moves the sample holder towards the tip with too large steps, or there is a leakage current around the tip clamp area.

To check/resolve the former:

- ① Open the SPM Parameters dialog (see *Section 7.9: SPM parameters dialog* (page 74)).
- ② In the Approach page of the dialog, decrease the value of "Move Speed" by 10%.
- ③ Repeat the approach with a new tip. If the approach fails again, reduce "Move Speed" further.
- ④ Save the best value using "File menu" >> "Parameters" >> "Save".

To check/resolve the latter:

- ① Open the *Scan Head Diagnostics dialog* (see page 200 for details).
- ② If the *Offset current* shows a higher than usual value, even when there is no sample installed in the system, remove the STM tip and clean the area below and around the tip clamp (see *Figure 17-2: Leakage current* below) with an applicator stick, wetted with ethanol or propanol (not too wet) and let it dry completely.
- ③ Install a new tip and compare the *Offset current* before and after cleaning.



**Figure 17-2: Leakage current.** Cleaning the area below and around the tip clamp prevents leakage current, which would otherwise disturb STM measurement and approach.

#### 17.3.4: Image quality suddenly deteriorates

Possible causes for this phenomenon 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 *Section 7.7: Status bar* (page 72)) 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:

- ① 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)).
- ② 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:

- ① Increase the scan range.
- ② 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 measurements* (page 47).

## 17.4: Nanosurf support

If the standard solutions in this chapter are not sufficient, please 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:

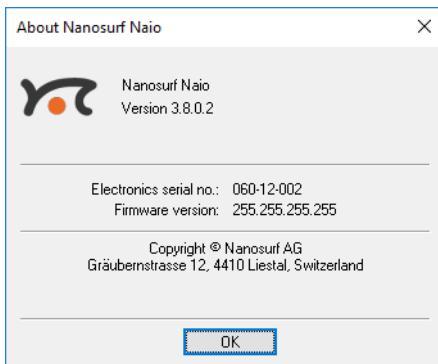
- A detailed description of what happened before the problem occurred. For example: "When I click the 'Approach' button, then quickly click abort, the controller will not react to anything I do anymore. This only happens when measuring in dynamic force mode."
- If an error message was displayed: The 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.

## IMPORTANT

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?

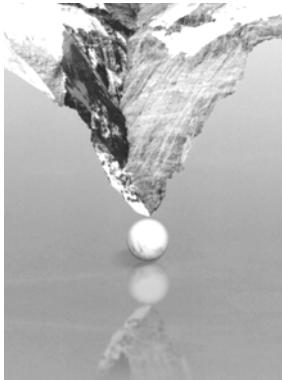
Microscopy is one of the most exciting scientific techniques. The insight into small dimensions has led to a new understanding of the structure of materials and forms of life.

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.

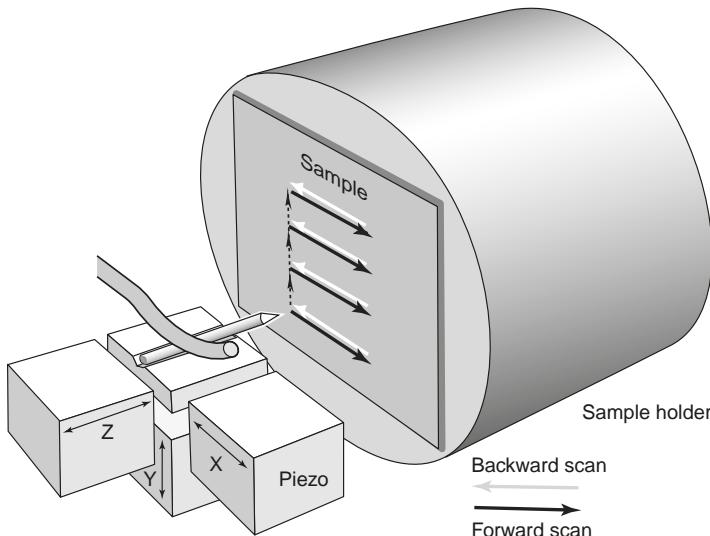


## 18.2: Scanning with the NaioSTM

In the NaioSTM, 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 ( $1 \text{ nm} = 1 / 1\,000\,000\,000 \text{ m}$ ). 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 ( $U \sim 0.1\text{V}$ ), a very small tunneling current ( $I \sim 1\text{nA}$ ) may nevertheless flow between tip and sample. This tunneling current is due to a quantum physics effect.

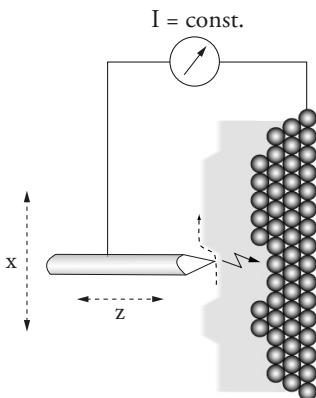


The strength of the tunneling current depends exponentially on the distance between the tip and the sample (usually referred to as Z-Distance). This extreme dependence on the Z-Distance makes it possible to measure the tip–sample movement very precisely. One of the three piezo crystals, the Z-piezo, can now be used in a feedback loop that keeps the tunneling current constant by appropriately changing the Z-Distance.

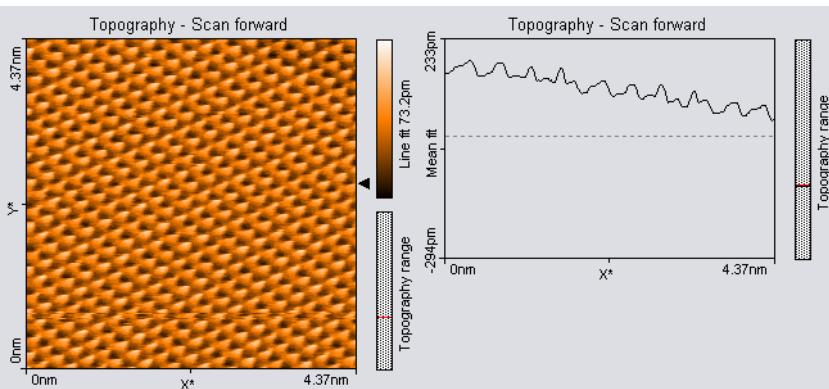
To obtain an image of the sample, the tip is scanned using the X- and Y-piezo crystals. The feedback loop will now let the tip follow the structure of the sample's surface. A height image can now be made by recording the position of the Z-feedback loop as a function of the XY-piezo position. This "landscape" (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.

## CHAPTER 18: STM THEORY



**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 (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 NaioSTM system. The exact specifications of all components belonging to your system are given on the calibration certificate delivered with the instrument.

## 19.2: The NaioSTM

### 19.2.1: Specifications and features

<b>NaioSTM Specifications and Features</b>	
Scan range (XYZ) <sup>(1)</sup>	500 nm × 500 nm × 200 nm
Scan resolution (XYZ) <sup>(2)</sup>	7.6 pm × 7.6 pm × 3.1 pm
Current amplifier	0.1–100 nA in 25 pA steps
Imaging modes	Constant Current (Topography) Constant Height (Current)
Spectroscopy modes	Current–Voltage, Current–Distance
Lithography modes	Patterning, Modification
Sample approach	Stick-slip motor
Sample size	Max. 10 mm diameter, Max. 3 mm thickness
Data points	Imaging: up to 2048×2048 Spectroscopy: up to 65535
Imaging speed	Up to 10 Hz
Computer requirements	USB 2.0, Windows XP/Vista/7 (32- or 64-bit)
Power supply	90–240 V AC, 50/60 Hz, 30 W
Size (LWH) / Weight	204 × 204 × 104 mm, 3.45 kg

(1) Typical values

(2) Calculated by dividing the maximum range by 16 bits

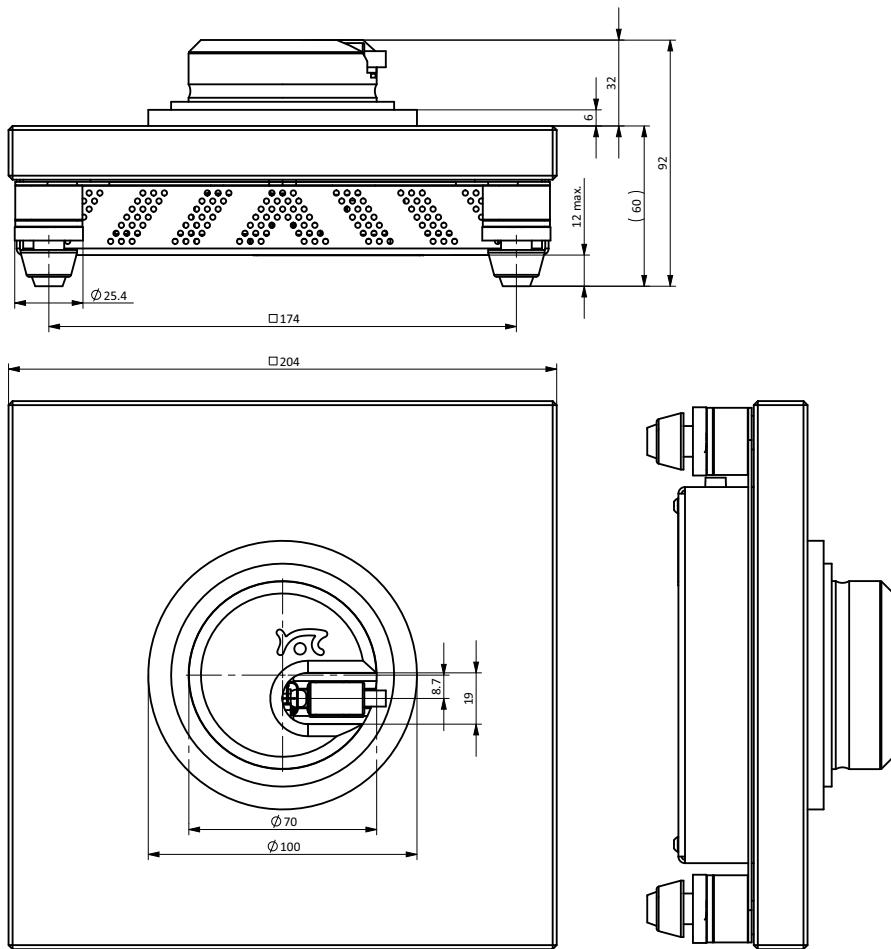
**19.2.2: Dimensions**

Figure 19-1: The Nanosurf NaioSTM. All dimensions in mm.

CHAPTER 19: TECHNICAL DATA