

Nanosurf NaioAFM

Operating Instructions

for

**Naio Control Software
Version 3.6**

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OPERATING INSTRUCTIONS V3.6R0, BT05386-22.

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About this Manual

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

PART A: INTRODUCTION TO THE INSTRUMENT will familiarize you with the Nanosurf NaioAFM system, and will explain how to set up your system and operate it on a daily basis. Among other things, it will also describes how to set up basic experiments and how to generally improve measurement quality. Part A starts with *Chapter 1: The NaioAFM* (page 15) and ends with *Chapter 6: Finishing measurements* (page 59).

PART B: SOFTWARE REFERENCE is a reference for the software that comes with the NaioAFM system. It starts with *Chapter 7: The user interface* (page 65) and ends with *Chapter 16: Quick reference* (page 283). Its content applies to the Nanosurf Naio control software version 3.6. 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 235) and ends with *Chapter 19: Technical data* (page 251).

PART A:

**INTRODUCTION TO THE
INSTRUMENT**

CHAPTER 1:

The NaioAFM

1.1: Introduction

The Nanosurf NaioAFM system is an atomic force microscope that can measure the topography and several other properties of a sample with nanometer resolution. These measurements are performed, displayed, and evaluated using the Nanosurf Naio 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 251).

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

- NaioAFM Side View Camera.
- Naio Advanced Modes Option: package that enables Spreading Resistance Operating mode, Force Modulation Operating mode, Advanced Spectroscopy modes, 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 an NaioAFM 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:

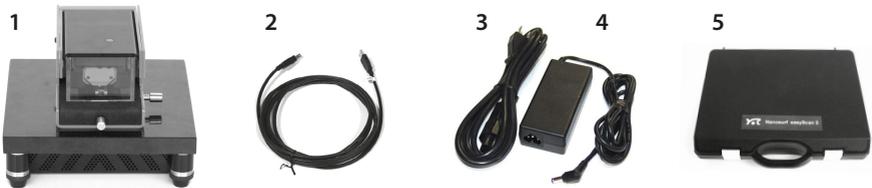


Figure 1-1: Components. The NaioAFM system

1. The NaioAFM system.
2. USB cable.
3. Mains cable (for power supply).
4. Power supply.

5. NaioAFM tool set. The items contained in the NaioAFM tool set are described in the next section.
6. NaioAFM side view camera (option; not shown).
7. The NaioAFM 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 NaioAFM Operating Instructions manual (not shown).
10. AFM extended sample kit (option; not shown): comes with a set of 10 samples and description of experiments.
11. Naio Advanced Modes Option certificate of purchase with Activation key printed on it (option;; not shown; comes with Naio Advanced Mode Option).
12. 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 61).

1.2.1: Contents of the tool set

The content of the tool set depends on the modules and options included in your order. It may contain any of the following items:



Figure 1-2: Contents of the tool set

1. Set of 4 steel sample discs.
2. Cantilever tweezers: (103A CA).
3. Cantilever insertion tool (usually mounted in the DropStop).
4. DropStop.
5. Samples (option; not shown). Possible combinations are:
 - a. AFM large scan sample kit (grid: 10 μm / 100 nm, CD ROM piece).
 - b. AFM high resolution sample kit (grid: 660 nm, graphite (HOPG) sample on sample support).

- c. Two calibration samples (grid: 10 μm / 100 nm, grid: 660 nm).
6. AFM calibration samples kit (option; not shown) with three calibration samples (grid: 10 μm / 100 nm, grid: 660 nm, flatness sample).
7. Set of 10 static mode cantilevers (option; not shown).
8. Set of 10 dynamic mode cantilevers (option; not shown).
9. USB dongle for Nanosurf Report or SPIP software (option).

1.3: Connectors, indicators and controls

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

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 NaioAFM system from mechanically transmitted vibrations.

Controller housing

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

Power LED

Lights up blue when the system is powered on.

Scan head housing

Orange, metallic housing encompassing the scan head and providing a hinge-function for the scan head cover and scanner shield.

Scan head cover

Black, metallic part underneath which the scan head is mounted. Offers a flip-over function for accessing the scan head and the sample stage. Also contains the Side View Optics.

Side view lens

Allows observation of the tip-sample distance during approach (by eye or via optional side view camera).

Sample stage

XY-positioning table that allows the sample to be positioned with respect to the cantilever. Allows selection of the measurement area of interest.

Positioning screws

Used to change the position of the sample stage (and thus of your sample).

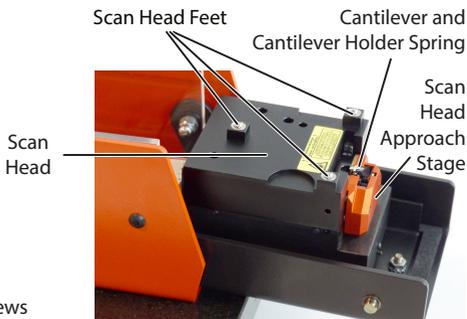
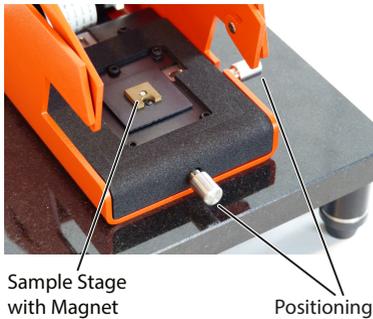
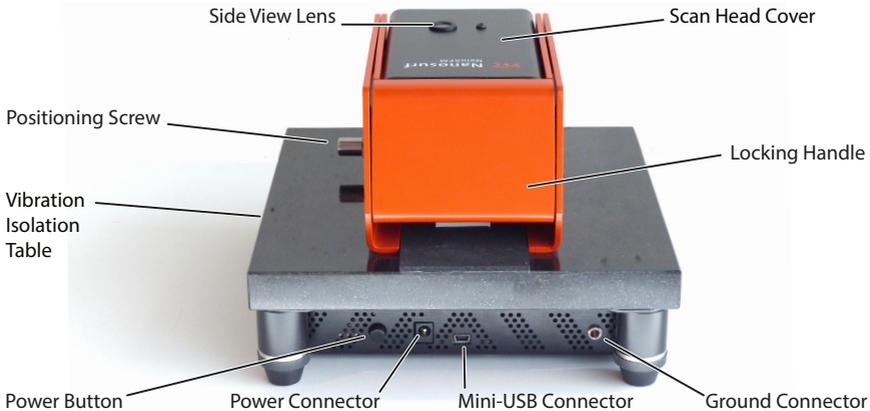
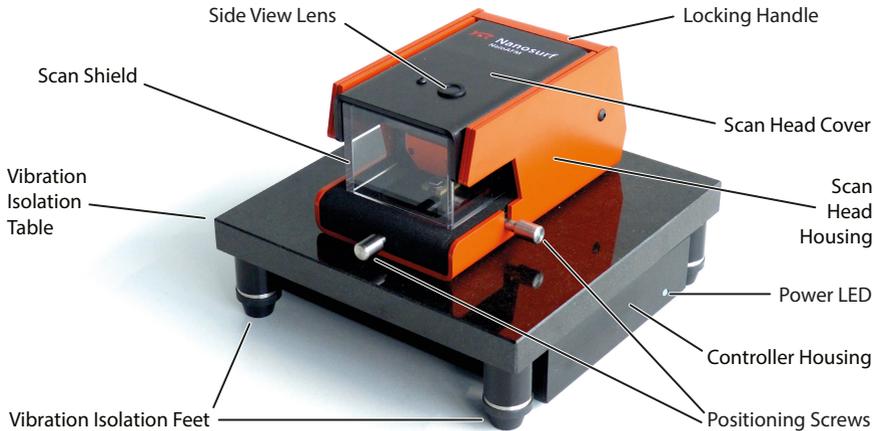


Figure 1-3: Parts of the system.

Scan shield

A partly metallic, partly plexi-glass cover that protects measurements from air flow and (to a lesser extent) acoustic disturbances.

Locking handle

Locks the NaioAFM system for Measurement. Only when the system is properly closed with the locking handle can measurements be performed.

Scan head

Contains all electronic and mechanical components necessary for scanning and cantilever deflection detection.

Scan head feet

Used to reproducibly and stably position the scan head with respect to the sample.

Approach stage

Motorized part of the scan head that brings the cantilever into contact with the sample.

Power button

Used to turn the NaioAFM system on or off.

Power connector

Used to connect the power supply.

USB connector

Used to connect the NaioAFM system to a personal computer.

Ground connector

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

CHAPTER 2:

Installing the NaioAFM

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 *Operating system/PC requirements* (page 253).
- 2 Make sure none of the NaioAFM system's hardware is connected to the computer (this includes the optional (USB) NaioAFM 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 NaioAFM 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.

In Windows Vista/7, 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:

- 1 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.
- 2 When the “Ready to install” window appears, click on the “Install” button.

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

This completes the driver and control software installation procedure. If you wish to use the Lithography features of the NaioAFM 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 advanced measurement analysis, you may also opt to install it now. Otherwise, you can exit by clicking the “Exit” button and continue with *Section 2.2: Installing the hardware*.

2.2: Installing the hardware

Important

- Make sure your mains power connection is protected against excess voltage surges.
- Place the instrument on a stable support in a location that has a low level of building vibrations, acoustic noise, electrical fields, and air currents.
- 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 Ilostage. Refer to the respective manuals for installation instructions.

- 1 Connect the NaioAFM to the power supply



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

⚠ WARNING



LASER RADIATION (650nm)
DO NOT STARE INTO THE BEAM
OR VIEW DIRECTLY WITH OPTICAL
INSTRUMENTS (MAGNIFIERS)
CLASS 2M LASER PRODUCT

Always close the DropStop before inspecting or mounting a cantilever, or before inspecting the alignment chip, especially when using optical instruments (magnifiers) for the inspection.

- 2 Connect the NaioAFM 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 2).
A popup balloon appears 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.
- 3 If you own a NaioAFM side view camera, connect it to a USB port on your computer.
On Windows 7 computers, a popup balloon may display the message “Problem installing driver”. If this happens, disconnect and reconnect the video camera once more. Hardware recognition will now complete successfully.

CHAPTER 3:

Preparing for measurement

3.1: Introduction

Once the system has been set up (see *Chapter 2: Installing the NaioAFM* (page 21)), the instrument and the sample have to be prepared for measurement. The preparation consists of three steps: *Initializing the NaioAFM system, Installing the cantilever, and Installing the sample.*

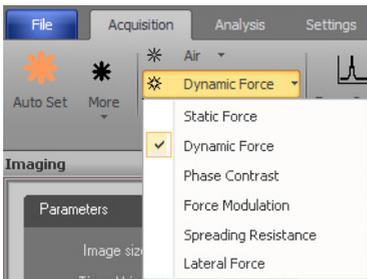
3.2: Initializing the NaioAFM system

To initialize the NaioAFM system:

- ❶ Make sure that the NaioAFM system is connected to the mains power and to the USB port of the control computer.
- ❷ Turn on the power of the NaioAFM 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.
- ❸ 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 on the computer screen.
- ❹ In the *Preparation group* of the *Acquisition tab* you will see the currently selected operating mode and cantilever type.
- ❺ Determine which operating mode you wish to use.
Refer to *Chapter 6: Operating modes* (page 66) for detailed properties of the modes available.

To change the operating mode:

- ➔ Select the desired operating mode from the *Operating mode* drop-down menu by clicking the currently selected operating mode:

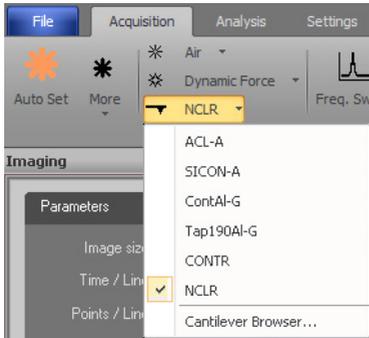


- 6 Determine which cantilever type you wish to use.

The cantilever most suited for your measurements will depend on the selected the selected operating mode, and on your sample.

To change the cantilever type:

- Select the desired cantilever type from the *Cantilever selector* drop-down menu by clicking the currently selected cantilever type:



3.3: Installing the cantilever

To maximize ease of use, the NaioAFM is designed in such a way that the cantilever can be quickly installed and removed without having to re-adjust the cantilever deflection detection system. The quick cantilever installation is possible because the scan head contains a self-alignment system. This alignment system consists of structures on the alignment chip and matching grooves in the cantilever chip. The alignment system positions the cantilever with micrometer accuracy (see *Figure 3-1: Cantilever*, left). This accuracy is only guaranteed when the cantilever and the mounting chip are absolutely clean. Installation of the cantilever should therefore still be carried out with great care. The quality of measurements depends strongly on the accuracy of the cantilever installation.



Figure 3-1: Cantilever. (Left) Alignment system. (Center) Cantilever chip viewed from the top. (Right) Cantilever, 450 μm long, 50 μm wide with integrated tip.

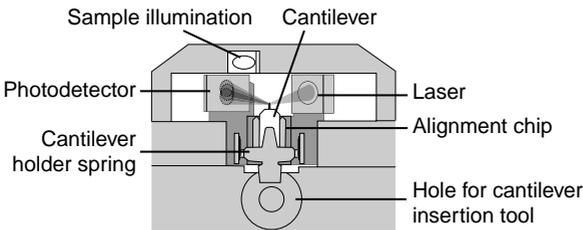


Figure 3-2: Cantilever deflection detection system

3.3.1: Selecting a cantilever

Stiffer and shorter cantilevers (e.g. NCLR [Nanoworld] or Tap190Al-G [BudgetSensors]) are generally used for the *Dynamic force mode*. More flexible and longer cantilevers (e.g. XYCONTR [Nanoworld] or ContAl-G [BudgetSensors]) are generally used for the *Static force mode*.

To change to a different cantilever type:

- ➔ In the *Preparation group* of the *Acquisition tab*, select the desired cantilever type from the *Cantilever selector* drop-down menu by clicking the currently selected cantilever type.

For each cantilever type, data is stored. This data is used to calculate:

- Force data and setpoint from cantilever deflection.
- Frequency search range for dynamic mode setup.

If the wrong cantilever type is selected, these calculations will most likely produce incorrect results.

In addition to this, the selected cantilever type is used in the *Data info panel* of a measurement to show what cantilever was used for that particular measurement.

If the cantilever type is not available in the list, select the last list entry ("Cantilever Browser...") and refer to *Section 8.9: Cantilever Browser dialog* (page 91) on how to create a new cantilever type in the software.

3.3.2: Inserting a cantilever in the scan head

WARNING



LASER RADIATION (650nm)
DO NOT STARE INTO THE BEAM
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INSTRUMENTS (MAGNIFIERS)
CLASS 2M LASER PRODUCT

Always close the DropStop before inspecting or mounting a cantilever, or before inspecting the alignment chip, especially when using optical instruments (magnifiers) for the inspection.

CAUTION

- Nothing should ever touch the cantilever. The cantilever tip may get damaged or the cantilever may break off otherwise.
- The Cantilever Holder Spring is very delicate. NEVER overstretch it! It will become bent and unusable otherwise!

If the NaioAFM is locked (i.e. closed for measurement), you have to unlock it first:

- ➔ Grab the NaioAFM's locking handle and pull it over to the other side (see *Figure 3-3: Unlocking and opening the NaioAFM scan head*, Left).

To remove the old cantilever:

- 1 Put the scan head upside-down by flipping over the scan head cover (see *Figure 3-3: Unlocking and opening the NaioAFM scan head*, Center and Right).

At this point, the sample illumination light will turn off and the approach stage of the scan head will move to its "Home" position, retracting the cantilever as far as possible. This is a safety precaution to avoid crashing of the new cantilever into the sample surface once the scan head cover is closed again. You can manually abort or shorten

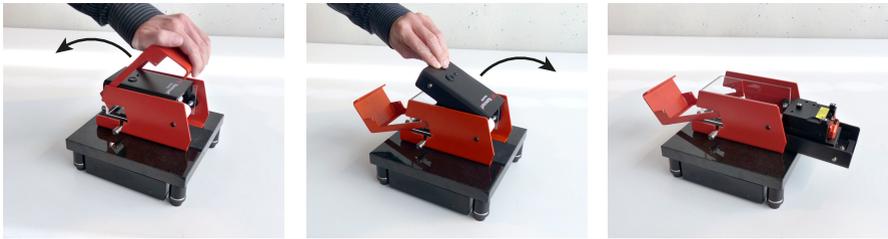


Figure 3-3: Unlocking and opening the NaioAFM scan head. (Left) Unlocking. (Middle) Opening. (Right) Ready for cantilever exchange.

the retraction process by clicking the “Stop” button in the Naio control software (see also *Home* (page 109)), although this is only recommended for experienced users.

- 2 Remove the Cantilever Insertion Tool from the DropStop.
- 3 Place the DropStop on the scan head (see *Figure 3-4: Placing the DropStop*).
The laser beam is now blocked by the DropStop. As a consequence, the Probe Status light in the Naio Control software will now blink red.
- 4 Place the cantilever insertion tool (*Figure 1-2: Contents of the tool set* (page 17), item 3) into the hole behind the alignment chip (*Figure 3-5: Mounting the cantilever*, top left).
The Cantilever Holder Spring opens.
- 5 Use the Cantilever Tweezers (figure *Figure 1-2: Contents of the tool set* (page 17), item 2) to remove the old cantilever from the instrument (*Figure 3-5: Mounting the cantilever*, top right).

CAUTION

Always store and ship the scan head with a cantilever installed. If you fail to do so, the cantilever holder spring may damage the alignment chip structure.

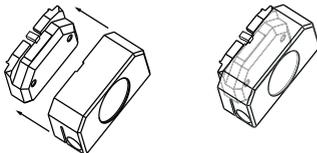


Figure 3-4: Placing the DropStop

To insert the new cantilever:

- ❶ Take the new cantilever out of its box with the cantilever tweezers.
- ❷ Place the cantilever carefully on the alignment chip in the scan head (*Figure 3-5: Mounting the cantilever, top right*).

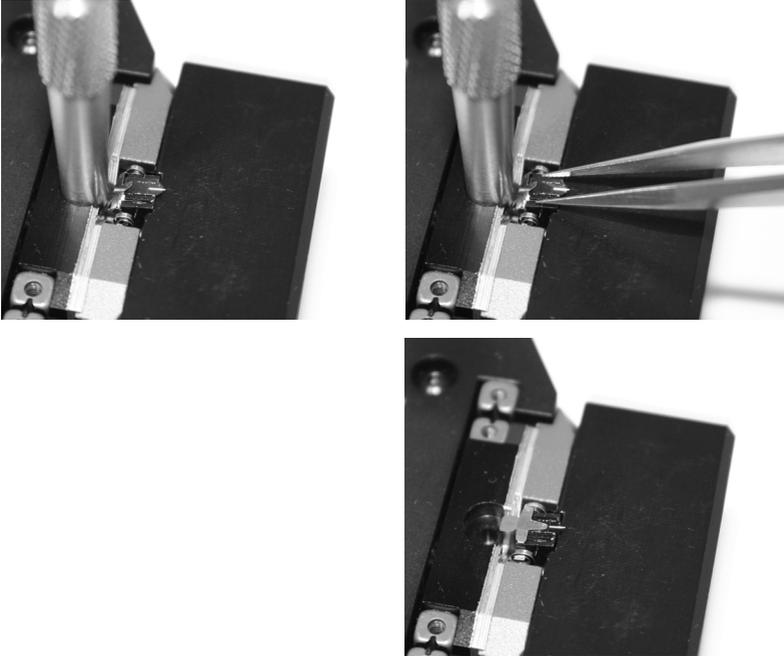


Figure 3-5: Mounting the cantilever. (top left) inserting the cantilever insertion tool, (top right) inserting/removing the cantilever, (bottom right) correctly inserted cantilever.

- ❸ Verify that the cantilever does not move with respect to the alignment chip by carefully tapping on it with the tweezers.
If the cantilever does move, it is probably not inserted correctly. Refer to *Figure 3-6: Cantilever alignment* for correct alignment and examples of incorrect alignment.
- ❹ Gently pull the cantilever insertion tool out of the hole.
The Cantilever Holder Spring closes and holds the cantilever chip tightly in position (*Figure 3-5: Mounting the cantilever, bottom right*).

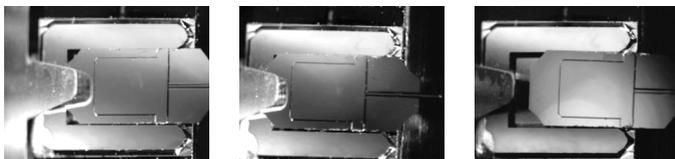


Figure 3-6: Cantilever alignment. (Left) Correct: the mirrored environment shows a reflection that is continuous over the cantilever and the alignment chip, and small triangular gaps can be seen between the edges of the alignment chip and the corners of the cantilever chip. (Center & right) Incorrect: the mirrored environment shows a reflection that is different on the cantilever and on the alignment chip, and no nice triangular gaps can be discerned.

5 Remove the DropStop.

The laser beam is now unblocked, and the Probe Status light in the Naio Control software should now stop blinking red. If this is not the case refer to *Section 17.3.1: Laser fail* (page 241).

3.4: Installing the sample

3.4.1: Preparing the sample

The NaioAFM can be used to examine any material with a surface roughness that does not exceed the height range of the scanning tip. Nevertheless, the choice and preparation of the surface can influence the surface–tip interaction. Examples of influencing factors are excess moisture, dust, grease or other contaminations of the sample surface. Because of this, some samples need special preparation to clean their surface. Generally, however, only clean your samples if this is absolutely required, and be sure to clean very carefully in order not to harm the sample surface.

If the surface is dusty, try to measure on a clean area between the dust. Although it is possible to blow away coarse particles with dry, oil-free air, small particles generally stick quite strongly to the surface and cannot be easily removed this way. Also note that bottled, pressurized air is generally dry, but pressurized air from an in-house supply is generally not. In this case an oil filter should be installed. Blowing away dust by breath is not advisable, because it too is not dry, and the risk of contaminating the sample even further is very high.

When the sample surface is contaminated with solid matter or substances that can be dissolved, the surface should be cleaned with a solvent. Suitable solvents are distilled or demineralized water, alcohol or acetone, depending on the nature of the contaminant. The solvent should always be highly pure in order to prevent accumulation of impurities contained within the solvent on the sample surface. When the sample is very dirty, it should be cleaned several times to completely remove partially dissolved and redeposited

contaminants. Delicate samples, which would suffer from such a treatment, can alternatively be cleaned in an ultrasonic bath.

3.4.2: Nanosurf samples

Nanosurf delivers optional samples, which are usually packed in the AFM tool set. These samples are briefly described here. Further samples are available in the AFM Extended Sample Kit, which contains its own sample description.

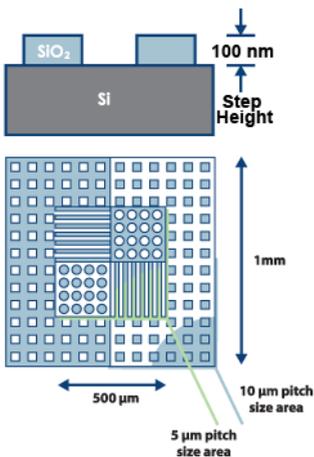
All samples should be stored in their respective boxes. This way, it should not be necessary to clean them. Cleaning of the samples is generally not advisable (unless indicated below), because their surfaces are often rather delicate.

Grid HS-100MG

The grid HS-100MG features silicon dioxide structure arrays on a 5 mm × 5 mm silicon chip. The calibration area is situated in the center of the chip. It is easy to locate this area optically. The structure step height is in the range of 100 nm. The exact value for each chip is indicated on the box label. Arrays of structures with different shape and pitch are integrated on the chip. The larger square (1 mm × 1 mm) contains square pillars and holes with a 10- μ m pitch. The smaller square (500×500 μ m) contains circular pillars and holes as well as lines in the X- and Y-direction with a 5- μ m pitch.

Aside from Z-axis calibration, this design also allows X- and Y-axis calibration for large range scanners (in the 70- to 110- μ m range).

The HS-100MG chip is glued onto a 12-mm metal disc using a high-quality electrically-conductive epoxy resin and it is ready for use as shipped.



Sample specifications:

Size: 5 mm × 5 mm

Material: Silicon

Step height: Approx. 100 nm

- Geometry:
- Square holes and pillars with a 10- μm pitch arranged in a 1 mm × 1 mm square
 - Circular pillars and holes, plus lines in the x- and y-direction, with a 5- μm pitch arranged in a 500 μm × 500 μm square

Flatness sample

The Flatness sample is a polished silicon sample. It can be used for testing the Flatness of the scanned plane.

Sample specifications:

Size: 5 mm × 5 mm

Material: Silicon

Thickness: Approx. 320 μm

CD-ROM piece

Sample for demonstrating the AFM imaging. The CD sample is a piece from a CD, without any coating applied to it.

Sample specifications:

Material: Polycarbonate

Structure: 100 nm deep pits arranged in tracks that are spaced 1.6 μm apart.

Graphite (HOPG) on sample support

This sample can be used for STM as well as AFM measurements. In high resolution AFM measurements, the atomic steps of the graphite surface can be seen. Conductivity variations can be observed in spreading resistance mode.

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 3-7: Cleaving graphite*):

- ❶ Put the sample on the table using a pair of tweezers.
- ❷ Stick a piece of adhesive tape gently to the graphite and then pull it off again. The topmost layer of the sample should stick to the tape.
- ❸ Remove any loose flakes with the tweezers.

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

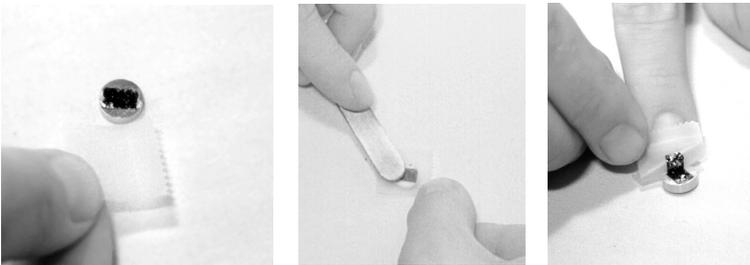


Figure 3-7: Cleaving graphite

3.4.3: Mounting a sample

Samples should be mounted on steel discs with a maximum diameter of 12 mm. They can either be attached more permanently by using glue or double-sided adhesive tape, or be mounted temporarily using the method described below. The sample disc can then be easily placed on the NaioAFM sample stage, where it is securely held in place by a magnet.

To mount a sample onto the steel disc:

- ❶ Put a double-sided adhesive tape on the frontside of a Post-it® note, so that it is on the opposite side of the sticky part.
- ❷ Cut off all parts of the note that do not have adhesive tape on it.
- ❸ Fix the tape-side of the prepared note to the steel disc.

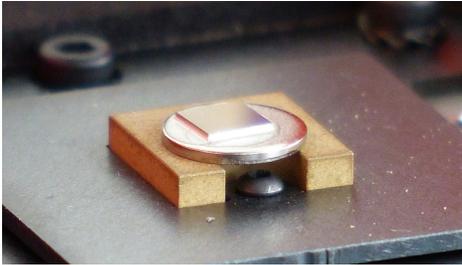


Figure 3-8: Sample mounted on a steel disc and placed on the NaioAFM sample stage.

- 4 Put the sample on the sticky side of the Post-it[®] note, and press on it lightly. The result should resemble *Figure 3-8: Sample mounted on a steel disc and placed on the NaioAFM sample stage*.
- 5 Remove the scan head and place the sample holder on top of the sample plate. It is recommended to always connect the sample holder to the ground connector on the scan head using the ground cable.
- 6 Place the scan head back onto the Sample Stage, but be sure to keep a safe distance between the cantilever and the sample surface. If necessary, adjust the tip-sample distance via the leveling screws before placing back the scan head.

To mount the sample onto the NaioAFM sample stage:

- 1 Unlock the NaioAFM by flipping over the locking handle (see *Figure 3-9: Opening the NaioAFM for full access to the sample stage, Step 1*).
- 2 Flip over the scan head cover and scan head (see *Figure 3-9, step 2*).
At this point, the sample illumination light will turn off and the approach stage of the scan head will move to its “Home” position (similar to pressing the “Home” button in the Approach section of the Naio control software’s the Acquisition tab; see *Home* (page 109)), retracting the cantilever to its upper-most position. This is a safety precaution to avoid crashing of the cantilever into the newly-placed sample’s surface once the scan head is closed again. You can manually abort or shorten the retraction process by clicking the “Stop” button in the Naio control software, although this is not recommended for the sample placement process described here.
- 3 Flip over the scan shield (see *Figure 3-9, step 3*).
- 4 Optionally flip back the locking handle to further increase accessibility of the sample stage (see *Figure 3-9, step 4*).

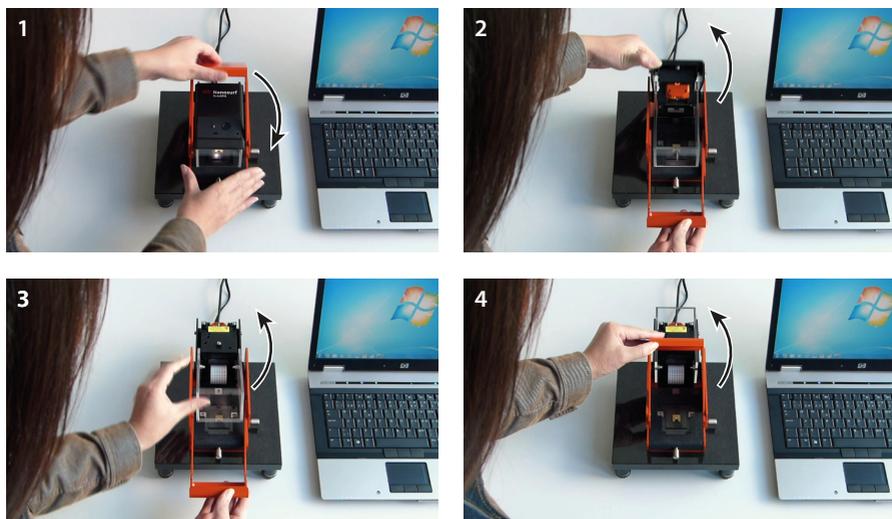


Figure 3-9: Opening the NaioAFM for full access to the sample stage. Step 1: Flip the locking handle all the way to the front. Step 2: Flip the scan head cover (and scan head) all the way to the back. Step 3: Flip the scan shield all the way to the back. Step 4: Optionally flip back the locking handle again.

- 5 Place the steel sample disc onto the sample stage using tweezers (see *Figure 3-10: Placing a sample, left*).
The sample will be held in place by the magnet that is located in the center of the sample stage (see *Figure 3-10, center*).
- 6 Close the NaioAFM system again by following all steps above in reversed order (see *Figure 3-10, right*).



Figure 3-10: Placing a sample. Left: Use the tweezers to place the sample onto the sample stage. Center: Sample is held in place by the magnet of the sample stage. Right: NaioAFM closed for measurement.

CAUTION

Only when the system is fully closed with the locking handle pressed down should the NaioAFM be used for measurement! The locking handle makes sure that the scan head is decoupled from the scan head cover and securely positioned onto the scan head feet via a strong cover-mounted spring. Only when this is the case can a reliable sample approach and subsequent sample measurement take place.

CHAPTER 4:

A first measurement

4.1: Introduction

In this chapter, step-by-step instructions are given to operate the microscope and to perform a simple measurement. 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 65) and the chapters directly thereafter, or try using the Naio control software in microscope simulation mode (see *Section 4.8: Running the microscope simulation*).

4.1.1: Entering and changing parameter values

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

To change a parameter or enter a value:

- 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.

4.2: Preparing the instrument

Important

- Never touch the cantilever or the surface of the sample! Good results rely heavily on a correct treatment of the tip and the sample.
- Avoid exposing the system to direct light while measuring. This could influence the cantilever deflection detection system and reduce the quality of the measurement.

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

- 1 If you want to perform dynamic measurements, install an NCLR type cantilever. Otherwise install a XYCONTR type cantilever.
- 2 Install one of the samples from the Nanosurf AFM basic sample kit or calibration sample kit. Preferably, install the 10 μm calibration grid when using a 70- μm or 110- μm scan head, and the 660 nm Calibration grid when using a 10- μm scan head.
The measurement examples shown here were made with the 10 μm calibration grid.

To make sure that the configuration is correct:

- ➔ Open *File menu >> Parameters >> Load parameter settings* and load the file “Default_AFM.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 start measuring, the cantilever tip must come within a fraction of a nanometer of the sample without touching it with too much force. To achieve this, a very careful and sensitive approach of the cantilever is required. This delicate operation is carried out in two steps:

10. *Fine approach using the motorized approach stage*
11. *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 install a new cantilever again.

– **Green**

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

To prepare for the approach process:

- ➔ Select the Acquisition tab

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

During the approach steps described in the following sections, use the side view of the cantilever to judge the distance between tip and sample surface:

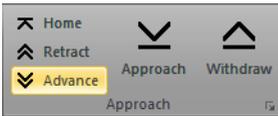
- ➔ If the NaioAFM Side View Camera is installed, select “Side view” in the Video panel located in the Info pane (see *Section 9.2: Video panel* (page 102)).
If the NaioAFM Side View Camera is not installed, use the side view lens of the scan head to observe the sample instead.

4.3.1: Fine approach using the motorized approach stage

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

1. Observe the distance between tip and sample in side view.

- While observing the tip-sample distance, click and hold the “Advance” button in the Approach group of the Acquisition tab until the tip is close enough to the sample:



The tip should not come closer to the sample than a few times the cantilever width (see *Figure 4-1: View of the cantilever and sample after fine approach*, left).

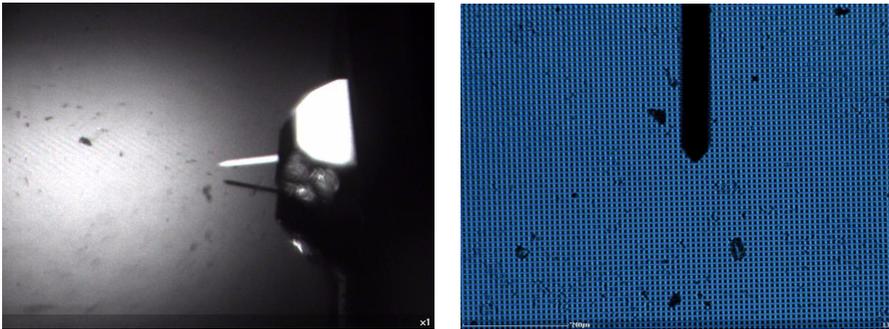


Figure 4-1: View of the cantilever and sample after fine approach. (Left) Side view, (Right) Top view.

Now that the sample is in focus, the top view image can be used to find a suitable location to measure on. In top view, the sample is seen from a direction perpendicular to its surface (see *Figure 4-1: View of the cantilever and sample after fine approach*, right).

To use the top view:

- Select Top view in the *Video panel* (see *Section 9.2: Video panel* (page 102)).
- If necessary, move the sample by turning the positioning screws of the sample stage to find a suitable location that is free of dust particles.

Important

- After turning any of the positioning screws in a certain direction to adjust the sample position, always turn it back half a turn in the opposite direction once you are satisfied with respective X- or Y-position: The position of the sample won't change before at least a full turn is made, but this “half-a-turn-back” procedure does ensure that the sample table is decoupled from the respective positioning screw, thus reducing vibrations otherwise transmitted through the positioning screws.
- Make sure to always perform this procedure for both of the positioning screws.

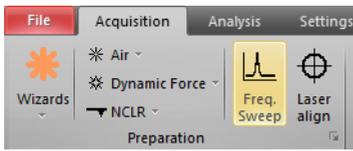
4.3.2: Automatic final approach

In this last step, the tip automatically approaches the sample until a given Setpoint is reached. Before starting the automatic approach, select the desired operating mode and cantilever type. To do this:

- ➔ In the *Preparation group* of the *Acquisition tab*, select an operating mode and cantilever type that match the cantilever installed.

In dynamic force mode, the instrument will automatically determine the vibration frequency to be used during imaging. To determine the optimal frequency, the controller performs a coarse and a fine frequency sweep in which the cantilever vibration amplitude (and — in phase contrast mode — also the phase) are recorded as a function of excitation frequency. It is instructive to see both frequency sweep measurements in all detail at least once. To do this, it is possible to manually perform the frequency sweeps:

- 1 In the *Preparation group* of the *Acquisition tab*, click the *Freq. sweep* button:



The *Vibration frequency search dialog* now opens (see *Section 8.10: Vibration frequency search dialog* (page 94) for details).

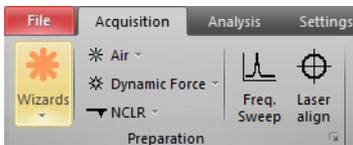
- 2 Click the *Auto frequency set* button.

The Naio control software now sets appropriate values for the coarse and fine sweeps and performs these sweeps. The fine sweep will overwrite the data of the coarse sweep in the charts displayed in the *Vibration frequency search dialog*. To see the results of the individual sweeps:

- ➔ Press the *Coarse sweep* and *Fine sweep* buttons sequentially.

Before final approach of the sample, it is necessary to set the scanning and feedback parameters of the control software to suitable initial values. 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 33).

Now that the initial software settings have been given suitable values, you need to name the measurement series (see *Section 13.4.1: History file mask* (page 187)). 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 13.4: Gallery panel* (page 186)) 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 13.4.4: Mask editor dialog* (page 188)) 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.

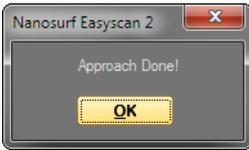
The automated final approach can now be started. To do this:

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



The cantilever is moved towards the sample via the approach stage, with the Z-controller turned on. This movement continues until the Z-controller error becomes zero. From this point onward, the distance between sample and tip is maintained

automatically by the electronics. The probe status light changes to a constant green, and a message “Approach done” appears:



- 2 Click the “OK” button.

If the automatic final approach fails, refer to *Section 17.3: AFM measurement problems* (page 241) for the further steps to take.

4.4: Starting a measurement

Now that the tip–sample interaction defined by *Setpoint* has been established 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:

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



Two representations of the ongoing measurement are now drawn in the graph area of the the *Imaging window*. One representation is a color coded height image (topography) called a *Color map*. The other is a plot of height as a function of X^* position called a *Line graph*. With the default settings, the software automatically adjusts the contrast of the *Color map*, and height range of the *Line graph* to the data that have been measured.

To judge the imaging quality, watch the displays until at least one fourth of the measurement has been completed.

Important

Measurements on the micrometer/nanometer scale are very sensitive to environment influences. Direct light or fast movements — causing air flow and temperature variations near the scan head — can influence and disturb the measurement.

When a measurement contains large disturbances, or no two scan lines are similar, stop measuring and reduce or eliminate the disturbances. To do this:

- ➔ Click the *Stop* button in the *Imaging group* of the *Acquisition tab* and follow the instructions in *Chapter 17: Problems and solutions* (page 237):

4.5: Selecting a measurement area

If you were able to prepare your measurement so that the scan line in the *Line graph* reproduces stably, the *Color map* should look similar to the one shown below when the measurement has finished.

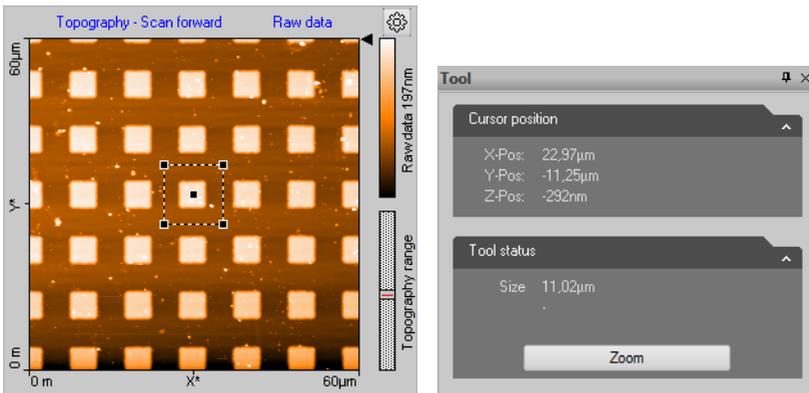
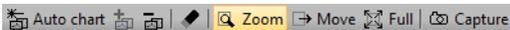


Figure 4-2: Zooming in on an overview measurement

To zoom in to an interesting part of the measurement:

- 1 Activate the *Color map* by clicking on it.
- 2 Click the *Zoom* button in the *Imaging toolbar*:



The mouse pointer becomes pen-shaped when moving over the color map.

- 3 Click on one corner of the region to be selected using the left mouse button, and keep the button pressed.
- 4 Drag the mouse to the other corner of the region.
The size and the position of the square are shown in the *Tool panel* of the info pane.
- 5 Release the mouse button when the size of the square covers approximately one period of the grid.

- 6 Confirm the selection by double clicking the color map graph using the left mouse button. Now the selection is enlarged to the whole display size. You can abort the zoom function by clicking the *Zoom* button again.

The microscope will now start measuring a single grid period. Once the measurement is completed, you should get an image such as the one in *Figure 4-3: Zoomed measurement*, left. The depression in the sample surface to the sides of the structure is due to the *Line fit* data filter used. To remove it, click on *Line fit* and select the data filter *Raw data* from the drop-down menu. The chart will now look like *Figure 4-3: Zoomed measurement*, right.

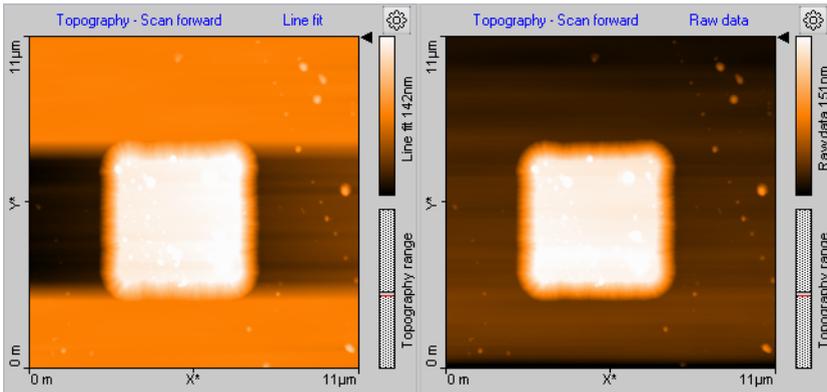


Figure 4-3: Zoomed measurement. (Left) With line subtraction. (Right) Without line subtraction.

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 *Imaging toolbar*:



The current measurement is immediately stored and will show up in the History page of the *Gallery panel*, together with all other finished/stored measurements (see *Section 13.4: Gallery panel* (page 186) for details). In addition, the captured document will remain open in the document space of the Naio control software.

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 187). Measurement documents thus permanently stored can always be loaded with the Naio control software (or with the optional Nanosurf

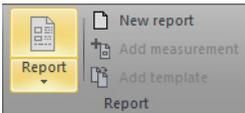
Report or Nanosurf Analysis software packages) for later viewing, analysis, and printing. A brief introduction on how to create a basic report using the Report software is given below. For more detailed information on starting and using the Report software, see *Section 22.2: Creating a report* (page 452), or refer to the Nanosurf Report online help.

4.7: Creating a basic report

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

To create a basic report of a completed measurement:

- ❶ Open a measurement from the *Gallery panel*.
- ❷ In the *Report group* of the *Analysis tab*, click the *Report* button.



The Nanosurf Report software will now launch, import the currently open measurement, and evaluate the data using the default template.

Important

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

4.8: 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 cantilever. In simulation mode, most functions of the real microscope are emulated. The sample is replaced by a mathematical description of a surface.

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



- ➔ Click "OK".

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

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

- ➔ In the *Hardware group* of the *Settings tab*, click the *Simulation* button.

The *Simulation* button will now be highlighted and the status bar will display the text "Simulation".

To exit the microscope simulation mode:

- ➔ In the *Hardware group* of the *Settings tab*, click the *Simulation* button again.

The highlighting of the *Simulation* button will now disappear, and the status bar will display the text "Online".

4.9: Further options

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

- Performing a new measurement on another sample by repeating the instructions given in *Chapter 3: Preparing for measurement* and *Chapter 4: A first measurement* with the new sample.
- Improving measurement quality, as described in *Chapter 5: Improving measurement quality* (page 51).
- Performing a different type of measurement by choosing a different operating mode, as described in *Chapter 6: Operating modes* (page 66).
- Finishing measurements, turning off the instrument, and/or storing the instrument, as described in *Chapter 6: Finishing measurements* (page 59).

CHAPTER 5:

Improving measurement quality

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*).
- Infrared and other light sources (light bulbs, sample illumination in an inverted microscope; see *Section 5.1.3: Infrared and other light sources*).

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:

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

- ❶ Connect the instrument to the mains power supply using sockets with line filters and surge protection.
- ❷ Use the Ground connector on the NaioAFM to ground the system.
- ❸ Remove interfering electromagnetic field sources, such as cathode ray tube displays, loudspeakers, etc.

5.1.3: Infrared and other light sources

Infrared and other light sources can influence the cantilever deflection detection system. This problem is especially severe when measuring in the Static Force mode. Try the following in order to reduce the influence of infrared light sources:

- ❶ Turn off the light.
- ❷ Shield the instrument from external light sources.

5.2: 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 5-1: 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 5-2: 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.
- 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.

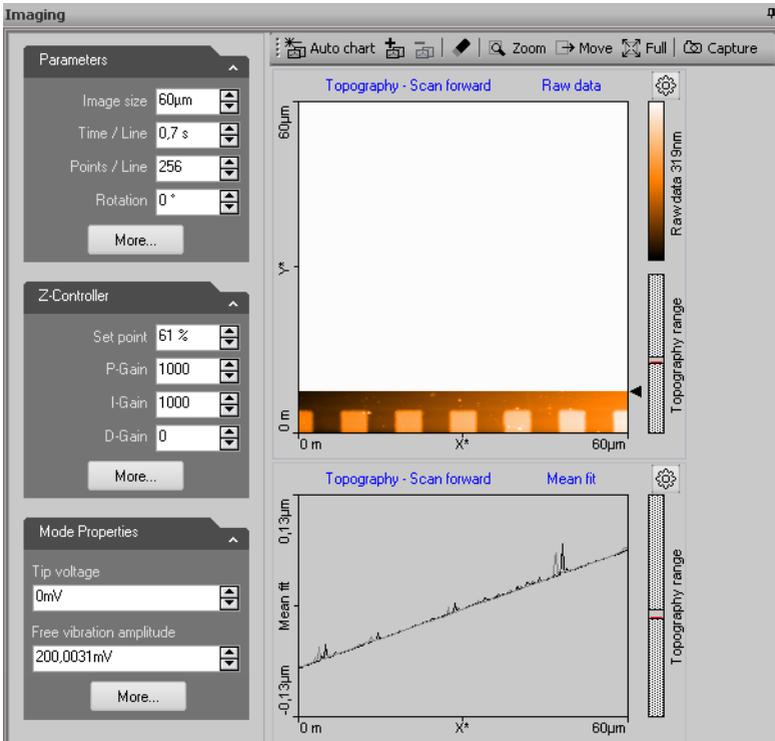


Figure 5-1: Unadjusted slope. Measurement with improperly set X*-slope.

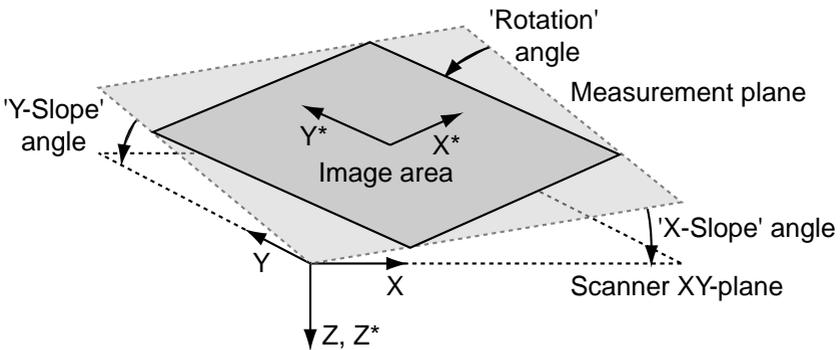


Figure 5-2: Sample and measurement orientation before slope adjustment

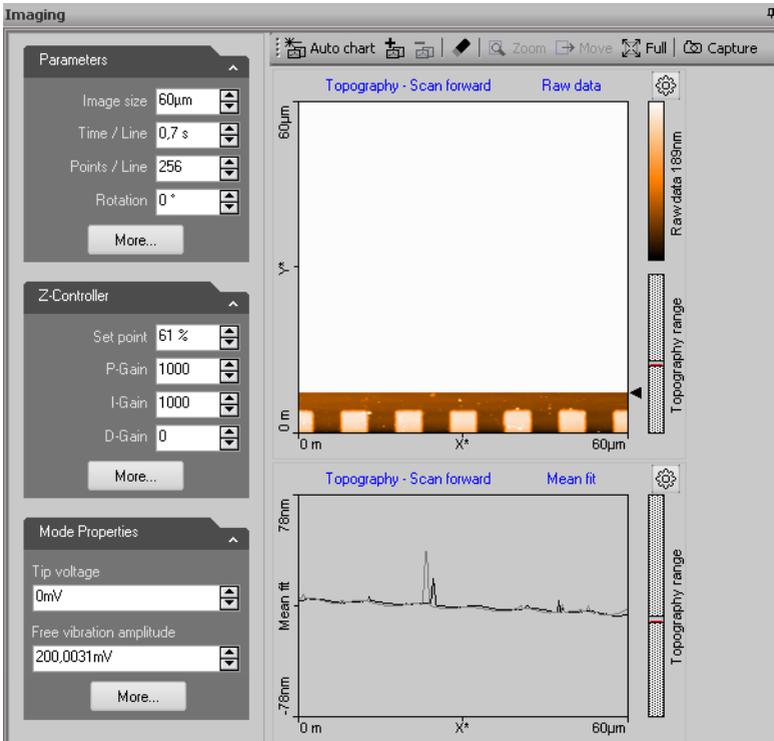
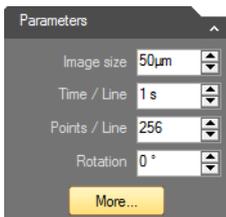


Figure 5-3: Adjusted slope. Measurement with properly set X*-slope.

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 NaioAFM system (see also *Section 7.9: SPM parameters dialog* (page 76)).

- 2 Click the *Adjust slope* button:

Adjust slope

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.

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 13.5.1: Measure group* (page 192)).
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 125)) 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.

5.3: Judging tip quality

When all prerequisites for measurement are optimal, the measurement quality mainly depends on the quality of the tip. A good tip quality is essential for high quality images and high resolution.

When the image quality deteriorates dramatically during a previously good measurement, the tip has most probably picked up some material from the sample. As a result, the image

in the color map charts consist of uncorrelated lines or the image appear blurred (see *Chapter 5: Measurement containing tip artifacts*). In such cases:

- ➔ Follow the suggestions in *Section 17.3.3: Image quality suddenly deteriorates* (page 242).
If these do not help, the cantilever should be replaced.

When all peaks in the image have the same, usually triangular shape, the sharp end of the tip may have broken off. The measured structure reflects the shape of the tip rather than that of the sample and is called a tip artefact. In such cases:

- ➔ Replace the cantilever.

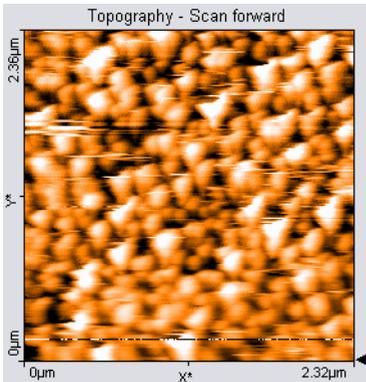


Figure 5-4: Measurement containing tip artifacts

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 If the NaioAFM Side View is installed, activate “Side view” in the *Video panel* (see *Section 9.2: Video panel* (page 102)).
If the NaioAFM Side View is not installed, use the side view lens of the scan head to observe the sample instead.
- 3 Retract the cantilever to a safe distance from the sample by clicking and holding the *Retract* button in the *Approach group* of the *Acquisition tab* until the tip-sample distance is at least as large as shown in *Figure 6-1: Side view of the cantilever after retracting* or by clicking the *Home* button and waiting for the automatic full retraction process to finish.



Figure 6-1: Side view of the cantilever after retracting. Minimal distance required for safe removal of the scan head and sample.

- 4 Open the NaioAFM as described in *Section 3.4.3: Mounting a sample* (page 35).
- 5 Remove the sample from the sample stage.
- 6 Close the NaioAFM.

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 187)).

- 3 Exit the Naio control software.
- 4 Turn off the power by pushing the power button at the back of the NaioAFM (see *Figure 1-3: Parts of the system* (page 19)).

Important

Always store the NaioAFM with a(n old) cantilever installed. This will prevent dust from gathering on the alignment chip, and will protect the alignment chip against damage.

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 Leave the cantilever in the scan head, or replace it with an old one.
- 3 Pack all components in the original Nanosurf packaging material or instrument case, as shown in *Figure 6-2: Packing*.

Important

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



Figure 6-2: Packing. The NaioAFM system packed in its instrument case. Shown here is the NaioAFM system with optional NaioAFM Side View Camera and Isostage Adapter Set.

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.

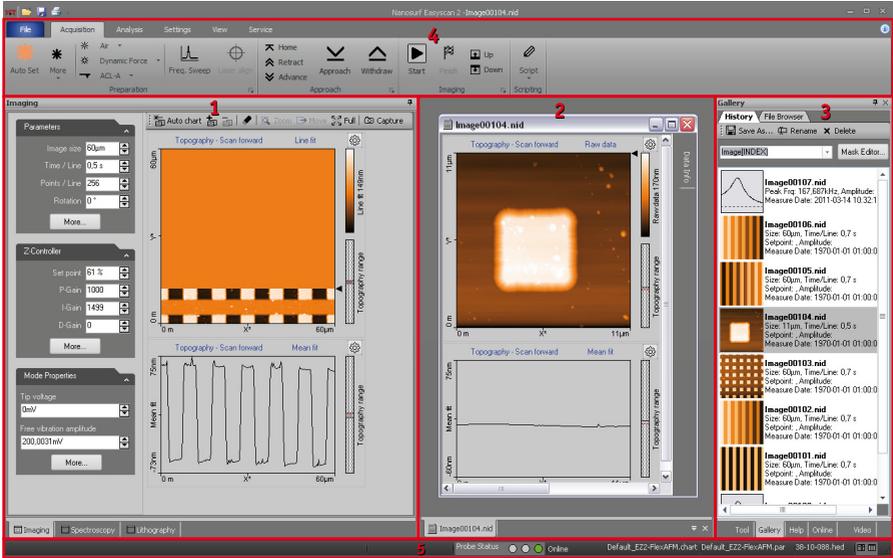


Figure 7-1: The main window in “Normal” workspace mode

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 76), 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).

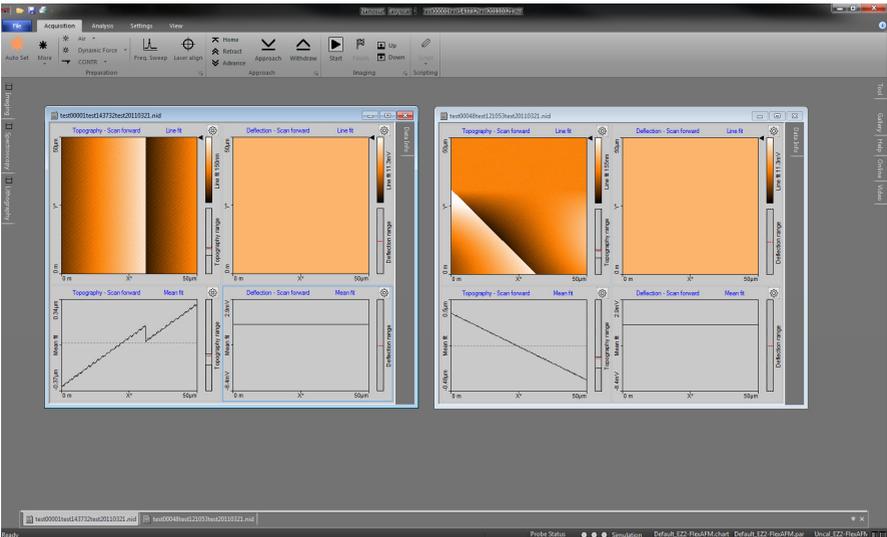


Figure 7-2: The main window in “Document” workspace mode

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*.

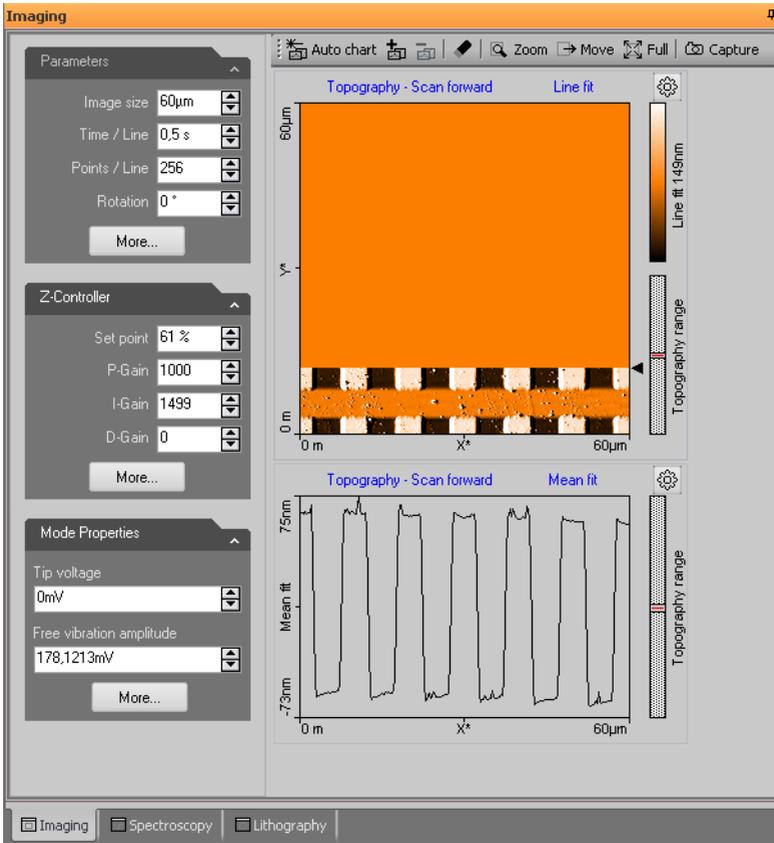


Figure 7-3: Elements of operating windows. Shown here is the imaging window, with the parameter area on the left, the chart area on the right, and the imaging toolbar on top. Clicking the tabs at the bottom of the measurement pane switches between the operating windows.

The operating windows are:

- The *Imaging window*; used for generating images of a sample (for details see *Chapter 10: Imaging* (page 113)).
- 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 129)).
- The *Lithography window*; used for performing lithography on the current scan area (for details see *Chapter 12: Lithography* (page 153)).

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 76)). 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.

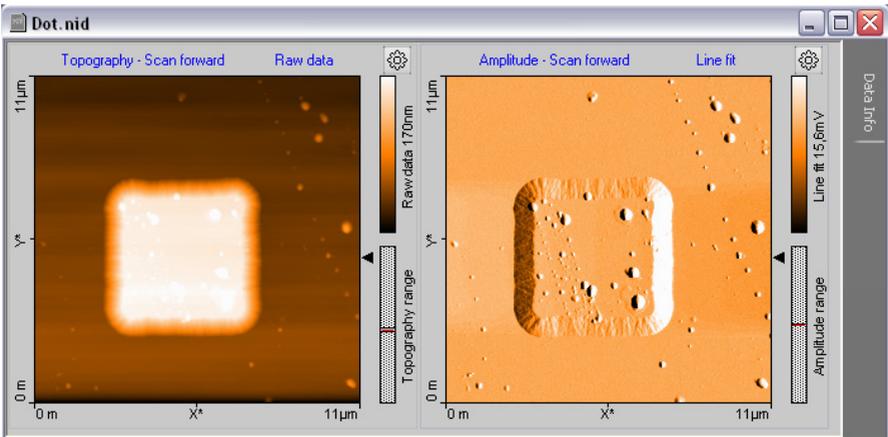


Figure 7-4: Example of a measurement document window

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 13.4: Gallery panel* (page 186)), but should be moved to a new folder for permanent storage as soon as you have finished measuring (see *Save as* (page 187)).

Everything related to documents is described in more detail in *Chapter 13: Working with documents* (page 173).

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*).

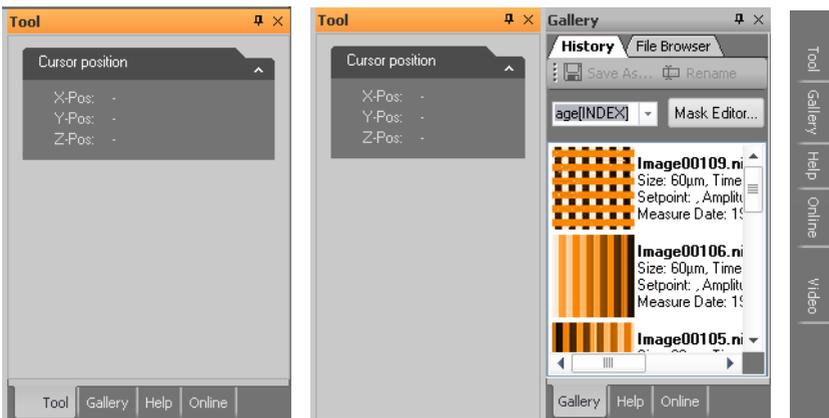


Figure 7-5: Arranging panels. (Left) Stacked panels. (Center) Separated panel that is docked to a stack. (Right) Panels that are minimized in “Document” mode.

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.

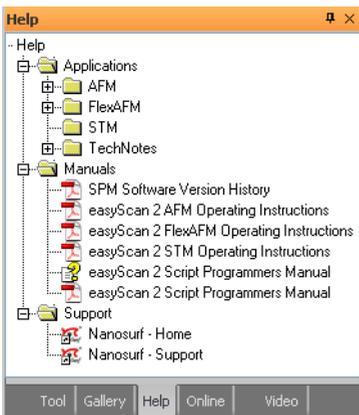
Tool

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 13.6: Tool panel* (page 203).

Gallery

The *Gallery panel* displays a list of stored measurements for quick opening (viewing and analysis). A file browser is also integrated for general file management tasks. The *Gallery panel* is described in more detail in *Section 13.4: Gallery panel* (page 186).

Help



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

Online

The *Online panel* provides you with an overview of the current scan range within the maximum range the scanner is capable of (*Scan position section*), a master image that can be used as a reference for multiple zoomed scans on different points of interest (*Master image section*) and a simple illumination control (*Illumination section*). The *Online panel* is described in more detail in *Section 9.3: Online panel* (page 107).

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* (page 42)). The elements and usage of the *Video panel* is described in *Section 9.2: Video panel* (page 102).

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.

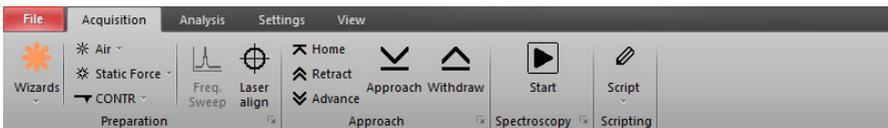


Figure 7-6: The Ribbon.

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 13.7: File menu* (page 205). 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 79) and *Chapter 9: Positioning* (page 101), 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 76).

Analysis tab

Contains measurement data functions for extracting information from your measurements (e.g. step height or roughness). It also provides functions to permanently modify your image data (e.g. backplane removal or noise filtering). All of these functions are described in *Section 13.5: Analysis tab* (page 191).

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

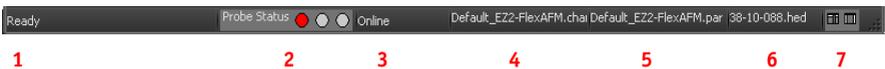
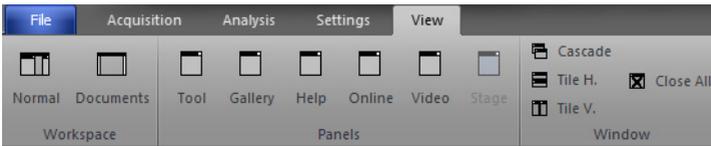


Figure 7-7: The status bar. Numbers in this figure correspond to those in the list below.

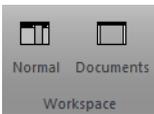
The status bar displays relevant microscope information and the loaded settings (see *Figure 7-7: The status bar*). It contains the following elements:

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 () 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.

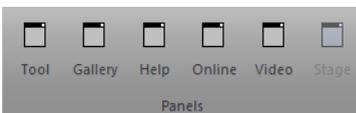
Normal

The optimal workspace choice during measurements.

Documents

The best choice for viewing or analysis of stored documents (see *Chapter 13: Working with documents* (page 173)).

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

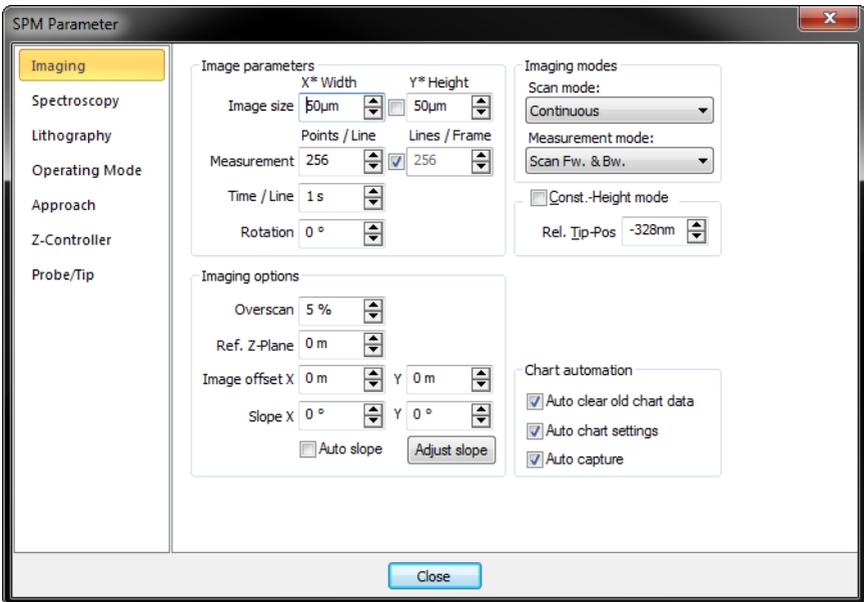
Closes all open document windows. If unsaved data exists, you will be asked to save it.

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 124))
- Spectroscopy (see *Section 11.6.1: Spectroscopy page* (page 146))
- Lithography (see *Section 12.7.1: Lithography page* (page 170))
- Operating mode (see *Section 8.8.1: Operating mode page* (page 86))
- Approach (see *Section 9.5.1: Approach page* (page 110))
- Z-Controller (see *Section 8.8.2: Z-controller page* (page 88))
- Probe/tip (see *Section 15.8.2: Probe/tip page* (page 277))
- SPM System (see *Section 8.8.3: SPM System page* (page 90))

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

CHAPTER 8:

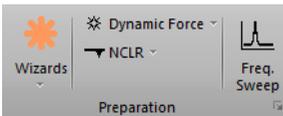
Operating modes

8.1: Introduction

This chapter instructs you on how to use the *Static force mode*, *Dynamic force mode*, *Phase contrast mode*. The latter two modes require the Naio Advanced Modes Option to be activated using the corresponding access code (see *Section Access code* (page 264)). Operating modes 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 133) for further details).

Operating mode

This drop-down box (☒) allows selection of the operating mode used for measuring (see *Section 8.4: Dynamic force mode* and onward).

Cantilever selector

This drop-down box (▼) allows the selection of the mounted cantilever in case of AFM scan heads. The last entry in the list, “Cantilever Browser...”, opens the *Cantilever Browser dialog*, which allows you to edit existing or define new cantilever types (see *Section 8.9: Cantilever Browser dialog* (page 91)).

Freq. sweep

This button opens the *Vibration frequency search dialog*. In this dialog, amplitude versus frequency plots can be measured and the operating frequency for dynamic modes can be set manually. In “Air” environment, setting of the vibration frequency is normally performed fully automatically, without user intervention. In “Liquid” environment, the *Vibration frequency search dialog* opens after the control software determined a suitable vibration frequency. You need to fine adjust and confirm the selected resonance frequency prior to approach. For more details about this dialog see *Section 8.10: Vibration frequency search dialog* (page 94).

Launcher icon

More advanced settings are available through the Dialog Launcher icon (■) at the bottom right corner of the Preparation group, which opens up the SPM parameters dialog on the Operating Mode page (see *Section 8.8.1: Operating mode page* (page 86)).

8.3: Static force mode

In the static force mode, the “static” deflection of the cantilever is used as the error signal for the Z-controller. The setpoint in Newton is calculated by multiplying the deflection with the spring constant of the selected cantilever. In order to minimize tip/sample wear, the force setpoint should be made as small as possible. In some cases, even a negative setpoint (i.e. an adhesive force) may work, but when the tip momentarily loses contact with the sample due to some disturbance, the Z-controller will always fully retract the cantilever from the sample. Moreover, working in this range may cause image artifacts due to instabilities in the tip–sample contact.

Both the force modulation mode and the spreading resistance mode are an extension of the static force mode (see *Section 8.6: Force modulation mode* and *Section 8.7: Spreading resistance mode*, respectively).

The procedure for a first static force mode measurement is almost identical to the procedure described for the dynamic force mode in *Chapter 4: A first measurement* (page 39). In contrast to the description given there, however, do the following:

- ① Select a cantilever suitable for static force mode (e.g. CONTR).
- ② Install the cantilever as described in *Section 3.3: Installing the cantilever* (page 27).
- ③ Select this cantilever type in the *Preparation group* of the *Acquisition tab*.
- ④ Select the static force mode in this group as well.
- ⑤ Set the force *Setpoint* in the *Z-controller section* of the *Imaging window*.

For a more detailed description of the parameters that can be set, refer to *Section 8.8.2: Z-controller page* (page 88).

8.4: Dynamic force mode

In the dynamic force mode, changes in the dynamic behavior of the cantilever are detected by measuring changes in its vibration amplitude when it is excited with a sinusoidal signal with a frequency close to the free resonance frequency of the cantilever. When the cantilever tip comes close to the sample surface, this vibration amplitude will generally go down. Thus the Setpoint is the percentage of the vibration amplitude that remains when the cantilever is close to the sample surface compared to the vibration amplitude when the cantilever is far away from the surface. A small percentage means a big reduction, and a large percentage means a small reduction. To minimize tip/sample wear, the Setpoint should be set as large as possible. However, when the Set-point becomes too large, the Z-controller may not be able to optimally follow the sample surface, and artifacts may occur due to instabilities in the cantilever vibration.

The procedure for a first dynamic force mode measurement is described for the dynamic force mode in *Chapter 4: A first measurement* (page 39). For more information on how the vibration amplitude and frequency are set, refer to *Section 8.8.1: Operating mode page* and *Section 8.10: Vibration frequency search dialog*.

8.5: Phase contrast mode

The phase contrast mode is an extension of the dynamic force mode. Therefore, the same cantilevers can be used as for dynamic force mode. In addition to the vibration amplitude, the phase shift between the cantilever vibration and a reference signal is measured. This phase shift changes when the resonance characteristic of the cantilever changes due to changes in the tip-sample interaction. Thus, the phase contrast mode can be used to produce material contrast when there is a significant difference in the tip sample interaction of these materials. This section gives a brief description of how to operate the NaioAFM in phase contrast mode. For a more detailed description of the parameters that can be, refer to section *Section 8.8.1: Operating mode page* (page 86).

The phase contrast mode can also be used to do Magnetic and Electrostatic Force Microscopy. For more information on how to do Magnetic Force Microscopy, refer to technical note *TN00031 – Magnetic Force Microscopy*, which can be downloaded from the support section of the Nanosurf website.

Phase measurement

In phase contrast mode, the phase of the measured cantilever vibration is compared to the phase of a reference sine wave. The phase comparison is performed by multiplying the measured vibration signal with the reference. The measured phase, $\phi_{measured}$, is the output

of this multiplication, and is related to the actual phase shift between the measured vibration and the excitation sine wave, ϕ_{actual} , according to the following equation:

$$\phi_{measured} = 90^\circ \sin(\phi_{actual} - \phi_{reference}),$$

where $\phi_{reference}$ is a reference phase that can be set by the user. This has two important consequences:

1. The measured phase shift lies between -90° and $+90^\circ$; phase shifts outside this range are folded back into the -90° to $+90^\circ$ range. The measurement does not distinguish between phase ϕ and phase $\phi + 180^\circ$.
2. The phase shift measurement becomes less sensitive when the phase approaches $+90^\circ$ and -90° .

Note that the phase of the cantilever vibration changes by 180° symmetrically around its resonance frequency. This phase shift only fits into the -90° to $+90^\circ$ range when the reference phase is set in such a way that it is zero at the resonance frequency. However, the operating frequency is generally set to be different from the resonance frequency. In such cases, the reference phase is automatically set in such a way that the phase shift is zero at the operating frequency. Thus, part of the frequency spectrum of the phase shift will be folded back into the -90° to $+90^\circ$ range (*Figure 8-1: Phase shift folded back*).

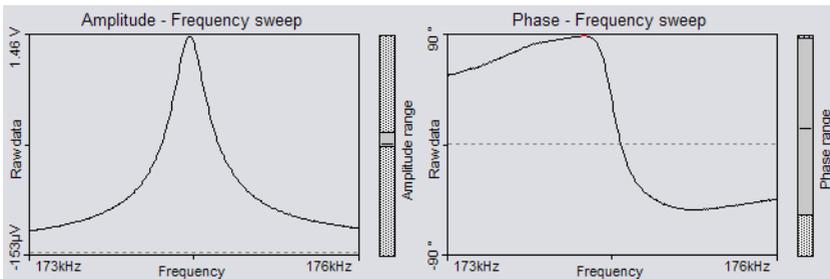


Figure 8-1: Phase shift folded back. Frequency spectrum with phase shift folded back over the $+90^\circ$ limit.

Operating the NaioAFM in phase contrast mode

To operate the NaioAFM in phase contrast mode:

- ➔ Select the *Phase contrast mode* in the *Preparation group* of the *Acquisition tab*. A new color map and line chart for the phase data will automatically be added to the chart area. If necessary, you can increase the size of the acquisition pane to make room for the new charts.

After approach, the reference phase is usually set automatically in such a way that the average phase shift lies in the center of the measurement range. To re-adjust the phase shift:

- ➔ Click the *Freq. sweep* button in the *Preparation group* of the *Acquisition tab*.

If you do not want the reference phase to be set automatically:

- 1 Open the *SPM parameters dialog* by clicking the *More* button in the *Mode properties* section of the *Imaging window*.
- 2 Uncheck the reference phase *Auto set* checkbox.
- 3 Enter the reference phase manually using the *Reference phase* input box.

8.6: Force modulation mode

The force modulation mode is an extension of the static force mode. The static force acting on the cantilever is still used to produce a topography image of the sample. Simultaneously, the cantilever is excited and the resulting vibration amplitude measured. The vibration amplitude depends on the drive amplitude, the stiffness of the cantilever and, most importantly, the stiffness of the tip-sample contact. Thus, the force modulation mode can be used to produce material contrast when there is a significant difference in the stiffness of the tip-sample contact of these materials. This section gives a brief description of how to operate the NaioAFM in force modulation mode. For a more detailed description of the parameters that you can set, refer to *Section 8.8.1: Operating mode page* (page 86).

To operate the NaioAFM in force modulation mode:

- 1 Select a cantilever that has a spring constant that is suitable for the sample stiffness that you expect.
Good results were obtained with LFMR-type cantilevers. The FMR type cantilever, which is explicitly sold for force modulation mode measurements, cannot be used due to its insufficient width.
- 2 Install the cantilever as described in *Section 3.3: Installing the cantilever* (page 27).
- 3 In the *Preparation group* of the *Acquisition tab*, select the *Force modulation operating mode*.
- 4 In the *Z-controller* section of the *Imaging window*, verify the *force Setpoint*.
- 5 In the *Preparation group* of the *Acquisition tab*, click the “*Freq. seep*” button.
- 6 Click the “*Auto frequency set*” button to measure the frequency characteristic of the cantilever.

- 7 Make a note of the cantilever resonance frequency from the sweep chart and set “Vibration frequency” to this value.
- 8 Set “Vibration amplitude” to the desired modulation amplitude.
- 9 Increase the vibration amplitude if no proper Force Modulation signal can be measured.

8.7: Spreading resistance mode

The spreading resistance mode is an extension of the static force mode. The static force acting on the cantilever is used to produce a topography image of the sample. Simultaneously, changes in the spreading resistance from the cantilever tip to a ground contact on a sample can be imaged by measuring changes in tip current while a fixed voltage is applied to the tip. This section gives a brief description of how to operate the NaioAFM in spreading resistance mode. For a more detailed description of the parameters that you can set, refer to *Section 8.8.1: Operating mode page* (page 86).

To operate the NaioAFM in the spreading resistance mode:

- 1 Electrically connect the sample to the Ground connector on the NaioAFM (*Figure 1-3: Parts of the system* (page 19)) via a 100 kOhm resistor in order to prevent damage to the tip due to an excessive current.
For best results, the sample should be electrically isolated except for the connection mentioned above.
- 2 Select a suitable cantilever:
 - CDT-NCLR should be used for samples where a high force is needed to penetrate a surface oxide layer.
 - CONT-PtIr cantilevers can be used on delicate samples. The applied voltage should be small, because high currents may cause the conducting layer on the tip to evaporate. Also, applied forces should be very small to prevent damage to the conducting layer.
 - NCL-PtIr cantilevers could be used in combination with non-contact topography measurements, but damage to the tip is likely.

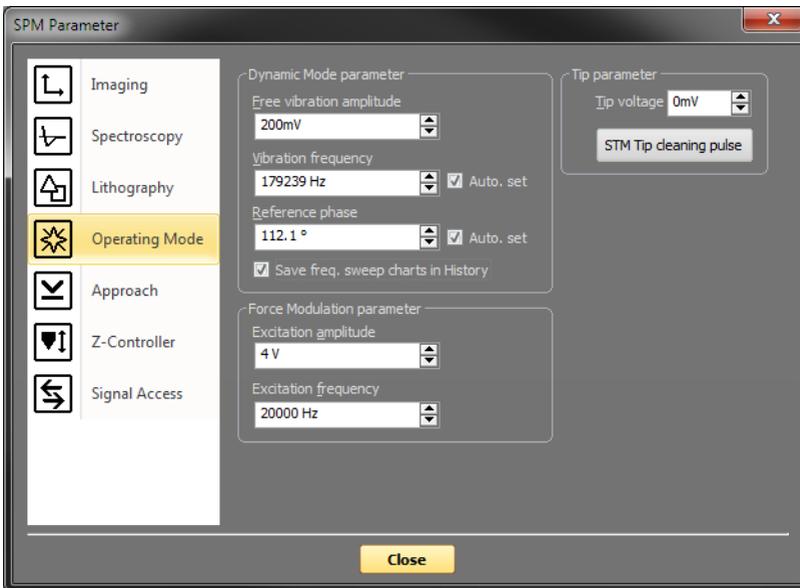
Important

- Standard XYCONTR cantilevers cannot be used due to the surface oxide on the tip, and the semiconducting contact between the tip and the sample.
- EFM cantilevers cannot be used for static force mode measurements, due to their insufficient width.

- 3 Install the cantilever as described in *Section 3.3: Installing the cantilever* (page 27).
- 4 In the preparation group of the acquisition tab, select the spreading resistance operating mode.
- 5 In the Z-controller section of the imaging window, verify the setpoint.
- 6 In the mode properties section, set the tip voltage to your requirements.

8.8: SPM parameters dialog

8.8.1: 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 AFM systems the sample has to be electrically connected to the instrument chassis ground for accurate measurements.

Dynamic mode parameters

These parameters determine the cantilever vibration measurement for dynamic mode topography and phase contrast mode.

Free vibration amplitude

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

Vibration frequency

The frequency at which the cantilever vibrates during the measurement. This frequency can be set automatically as described at the start of this section by enabling the *Auto set* check box (see below).

Auto set

When *Auto set* is enabled, the Vibration frequency is automatically set. Immediately at activation and each time an approach is started. When *Auto set* is disabled, the frequency can be set manually, either by directly changing its value in the control box, or by using the Vibration Frequency Determination dialog (see *Section 8.10: Vibration frequency search dialog* (page 94)).

Reference phase

The reference phase for the detected cantilever vibration. Changing the reference phase changes the offset of the phase signal. The phase reference can be automatically set so that the phase signal is zero by enabling the *Auto set* check box.

Auto set

When *Auto set* is enabled the phase reference is automatically set after finishing the approach.

Auto capture frequency sweep

When checked, this option will cause the software to automatically save the frequency sweep graphs as an .NID file.

Force Modulation parameters

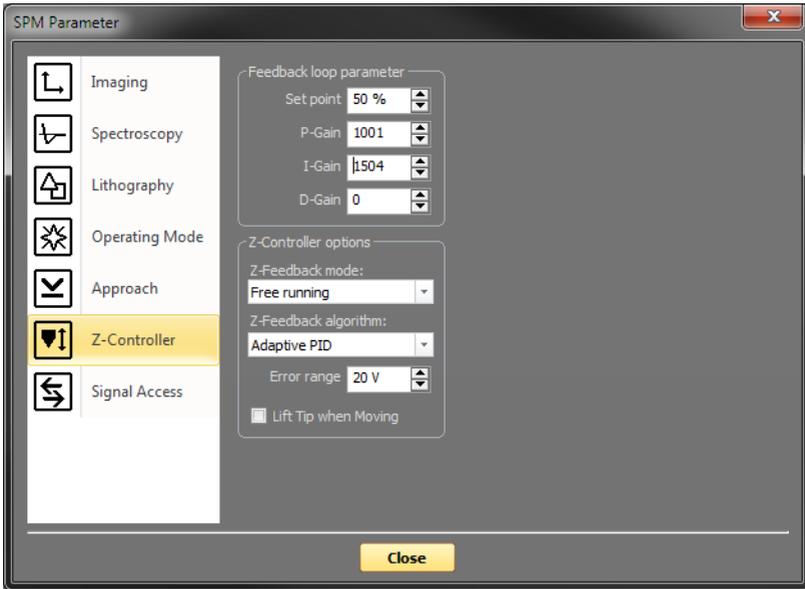
Excitation amplitude

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

Excitation frequency

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

8.8.2: Z-controller page



Feedback loop parameter

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.

I-Gain

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

D-Gain

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

Z-controller options**Z-feedback mode**

The following modes are available:

– **Free running**

The Z-controller is active.

– **Freeze**

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.

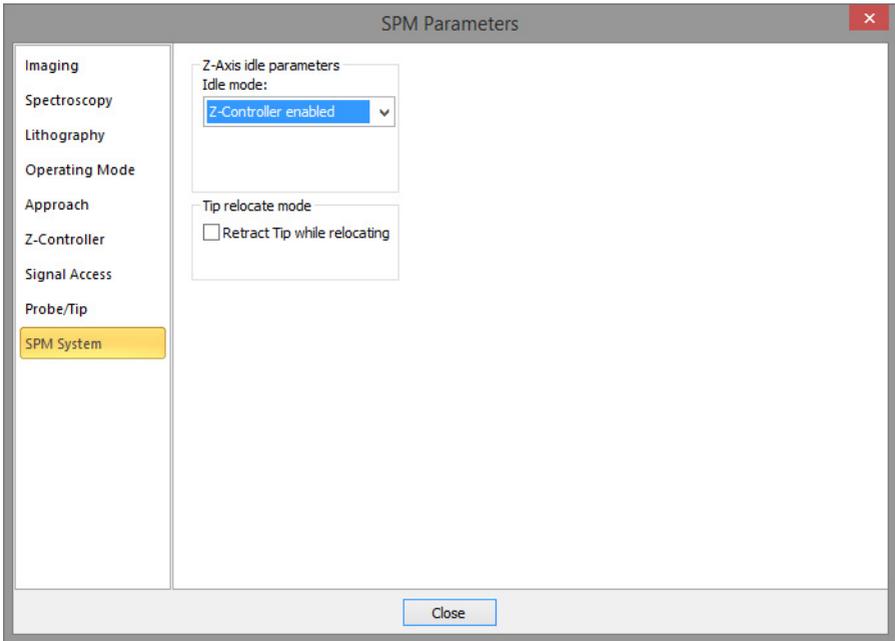
– **Adaptive PID**

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.

8.8.3: 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)

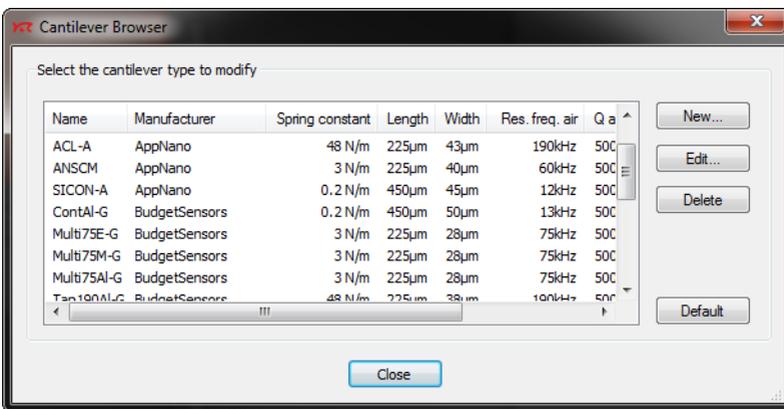
Tip Relocate mode

Retract Tip while relocating

When this check box 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.

8.9: Cantilever Browser dialog



The Cantilever Browser dialog displays the list of stored cantilever types in the database of the Naio control software. In this database, many cantilevers of different manufactures are saved with their typical physical properties. The Cantilever Browser dialog is opened via the drop-down menu entry “Cantilever browser” of the “cantilever” button in the Preparation group of the Acquisition tab.

Important

- Many commercial cantilever types are compatible with the NaioAFM scan head, but there are some requirements with regard to light reflection and alignment that must be met (see *Section 19.2.3: Cantilever requirements and considerations* (page 254)).
- Never put a grooveless cantilever in the AFM. The cantilever would damage the alignment chip. In addition, the cantilever will probably not be in the focal plane of the laser beam, thereby causing large interferences.

New

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

Edit

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

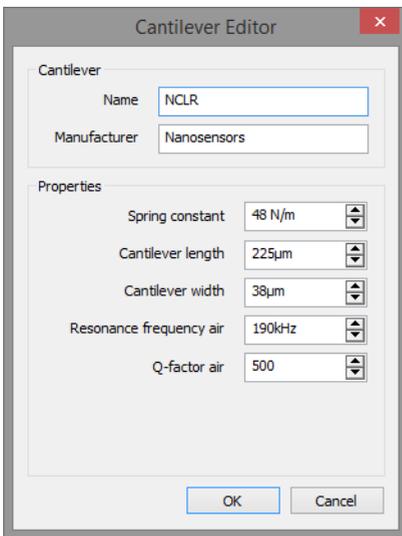
Delete

Deletes the currently selected cantilever type.

Default

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

8.9.1: Cantilever Editor dialog



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

Cantilever

Name

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

Manufacturer

Name of the cantilever manufacturer.

Properties

Spring constant

When the cantilever type in the cantilever type drop-down menu is changed, this value is entered in the respective field in the Probe/Tip page of the SPM parameters dialog (see *Section 15.8.2: Probe/tip page* (page 277)).

Important

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

$$\text{Force [N]} = \text{Spring Constant [N/m]} * \text{Deflection [m]}$$

Cantilever length

The nominal length of this cantilever type.

Cantilever width

The mean width of this cantilever type.

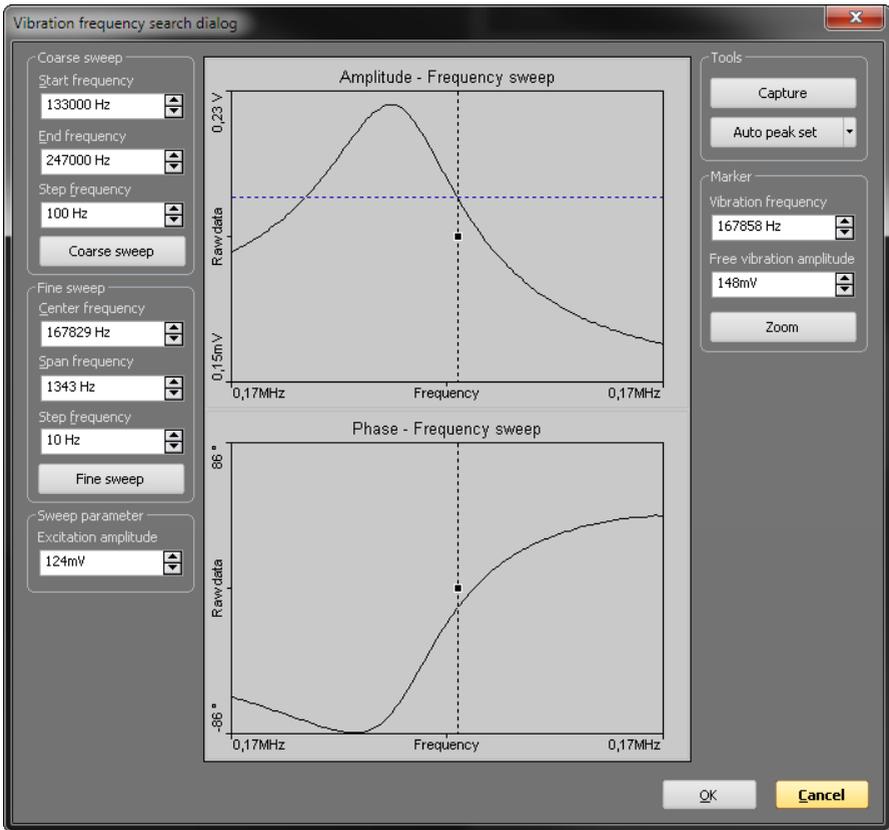
Resonance frequency air

The nominal resonance frequency of the cantilever type in air or in liquid measurement environment. This frequency is used for calculation of the automatic coarse frequency sweep search range (see *Section 8.10: Vibration frequency search dialog* (page 94)).

Q-factor air

The quality factor of the cantilever resonance in air. The higher the number, the sharper the peak. By default, this number is 500 in air and 5 in liquid. The quality factor is used for calculation of the automatic fine frequency sweep search range (see *Section 8.10: Vibration frequency search dialog* (page 94)).

8.10: Vibration frequency search dialog



8.10.1: General concept

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

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

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

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

Resonance frequencies vary greatly between cantilevers, depending on the cantilever's respective physical properties. Cantilever manufacturers provide information on the resonance frequency range of each cantilever type. The Naio control software therefore has a built-in database of commonly used cantilevers. Other cantilever can be manually added by the user (see *Section 8.9: Cantilever Browser dialog* (page 91)). Based on this database information, the control software selects the frequency sweep range.

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

Important

The Phase measurement and chart plot is performed only if a Mode Extension Module is installed in the NaioAFM controller. The Phase is always measured, independent on the selected operating mode.

8.10.2: Automated vibration frequency search

Tools

Auto frequency set

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

1. First a coarse frequency sweep based on the database information of the currently selected cantilever is performed. The frequency range of this sweep is shown in the coarse sweep section.
2. Based on the best frequency peak found in this coarse sweep a narrow band fine sweep is done. The frequency peak and sweep range used for the fine sweep is shown in the fine sweep section.
3. Based on the amplitude reduction settings (accessed by choosing "Config" from the "Auto frequency set" buttons drop-down menu) the optimal vibration frequency is

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

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

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

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

Capture

Stores a copy of the current Bode-plot in the History page of the Gallery panel. The data is stored as a new measurement and remains open in the Document space of the Naio control software.

Config

Selected from the “Auto frequency set” button’s drop-down menu, this menu option opens the Auto frequency config dialog (see *Section 8.10.4: Auto Frequency Config dialog* (page 98)).

8.10.3: Manual sweep controls

Marker

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

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

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

Vibration frequency

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

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

Free vibration amplitude

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

Zoom

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

Coarse sweep

Start / End Frequency

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

Step Frequency

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

$$Datapoint = (End - Start) / Step + 1.$$

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

Coarse sweep

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

Fine sweep

Center / Span Frequency

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

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

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

Step Frequency

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

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

Typical steps are 10 Hz or less.

Fine sweep

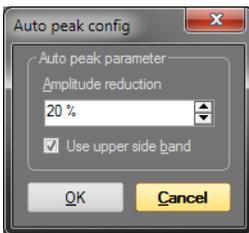
The “Fine sweep” button starts a fine frequency sweep according to the fine sweep parameters entered (see above).

Sweep parameter section

Excitation amplitude

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

8.10.4: Auto Frequency Config dialog



Auto frequency parameters

Amplitude reduction

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

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

Use upper side band

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

CHAPTER 9:

Positioning

9.1: Introduction

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

1. An area of interest has to be found and positioned directly underneath the tip before an approach and subsequent measurement can be initiated. Several panels of the *Info pane* can be of assistance here. They are explained in *Section 9.2: Video panel* and *Section 9.3: Online panel*.
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. The settings for each of these controls is stored independently for each video signal (i.e. different parameters can be set for both top and side view).

9.2.1: Digital video camera display

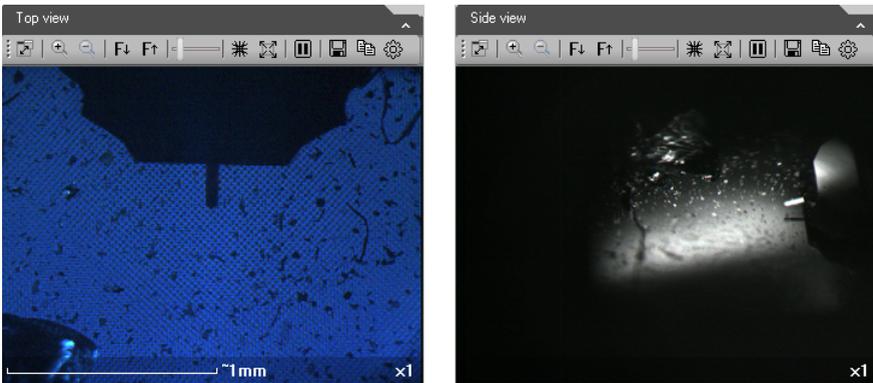


Figure 9-1: Digital video signal in the video panel. (Left) Top view. (Right) Side view.

If your system is equipped with the additional NaioAFM side view camera, the two camera views (top and side view) can be displayed simultaneously in the *Video panel*. The video signal and its display can be influenced by the controls in the *Digital video camera toolbar* (see below).

Digital video camera toolbar



Some of the buttons on the video camera toolbar described here (such as zoom, focus and properties) are only available with video sources that support these features.

Show window

This button () allows you to switch between display of the video signal in a section of the *Video panel* and display of the video signal in a separate window.

Zoom in / zoom out

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

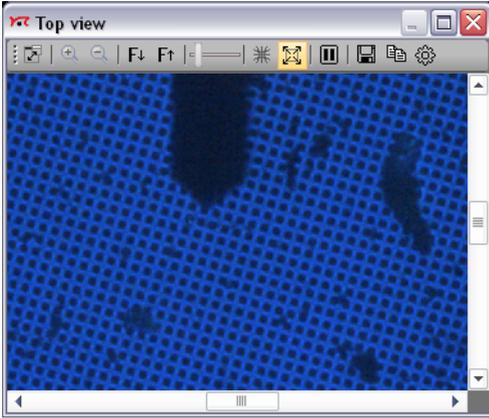
Gain

This slider () regulates the amount of gain applied to the video signal.

Anti-moiré

This button () ensures that the ratio between the number of camera pixels and video display pixels is always a whole number. This prevents moiré patterns from occurring in the video image. The moiré effect is mostly visible on samples with regular structures like grids or lines if this option is not enabled. When the anti-moiré mode is active, the button is highlighted. Clicking the highlighted button will deactivate the anti-moiré mode and will cancel the button's highlighting.

High-resolution mode



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

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

Important

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

Pause

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

Save as

This button (💾) allows you to save the current video image as a JPG file.

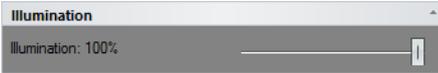
Copy

This button (📄) allows you to copy the current video image to the Windows clipboard for pasting into other applications.

Video properties

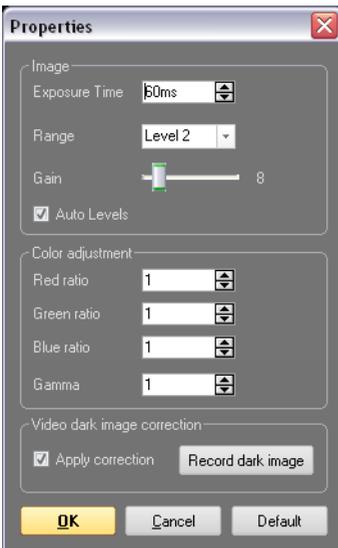
This button opens the *Digital video properties dialog*. See *Section 9.2.3: Digital video properties dialog* for details.

9.2.2: Illumination section



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

9.2.3: Digital video properties dialog



This dialog is only available with the FlexAFM camera, the NaniteAFM, camera and the NaoAFM Topview camera. Other cameras may support their own configuration dialogs, which you can access by right clicking on the video image. These dialogs are not documented here.

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

Image

Exposure time

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

Range

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

Gain

Identical to the *Gain* slider in the *Digital video camera toolbar* (page 103), which adjusts the amount of gain applied to the video signal.

Auto levels

When checked, this option automatically adjusts the camera data to fill the dynamic range of the video display (similar to the *Auto set* option for the *Chart data range* (see *Section 13.3.2: Chart Properties dialog* (page 178))). Using this option will automatically give you a good quality image. You will find that changing the other image parameters while this option is checked (within limits) hardly has an effect on the video display anymore.

Color adjustment

Red ratio

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

Green ratio

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

Blue ratio

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

Gamma

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

Video dark image correction

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

Apply correction

Applies the dark image correction.

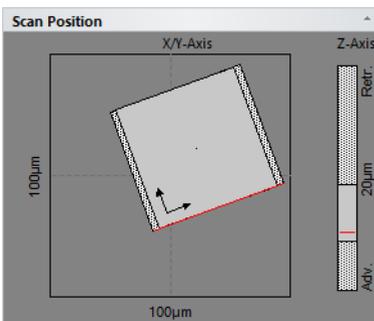
Record dark image

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

9.3: Online panel

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

9.3.1: Scan position section



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

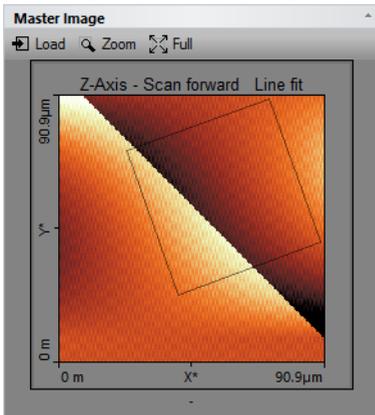
The left side of the section shows the maximum scan range of the scan head (outer square and numbers) and the currently set image size (inner square). The dotted bars to the left

and right of the inner square represent the *Overscan* area (see *Section 10.6.1: Imaging page* (page 124)).

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 124)).

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

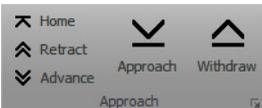
This button allows you to select a new scan area size and position inside the *Master image section* (within the loaded image). After selecting the *Zoom* button, the user draws a zoom frame in the chart area. To select the new scan area, double-click within the selection area. A right mouse click aborts 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 122)).

9.3.3: Illumination section

With the illumination slider in the *Illumination section*, the intensity of the sample illumination LED is controlled. This slider is only present in the *Online panel* when no video camera is present in your system. When a camera is present, this slider automatically moves to the *Video panel* (see also *Section 9.2.2: Illumination section*).

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 111).

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 110)). 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

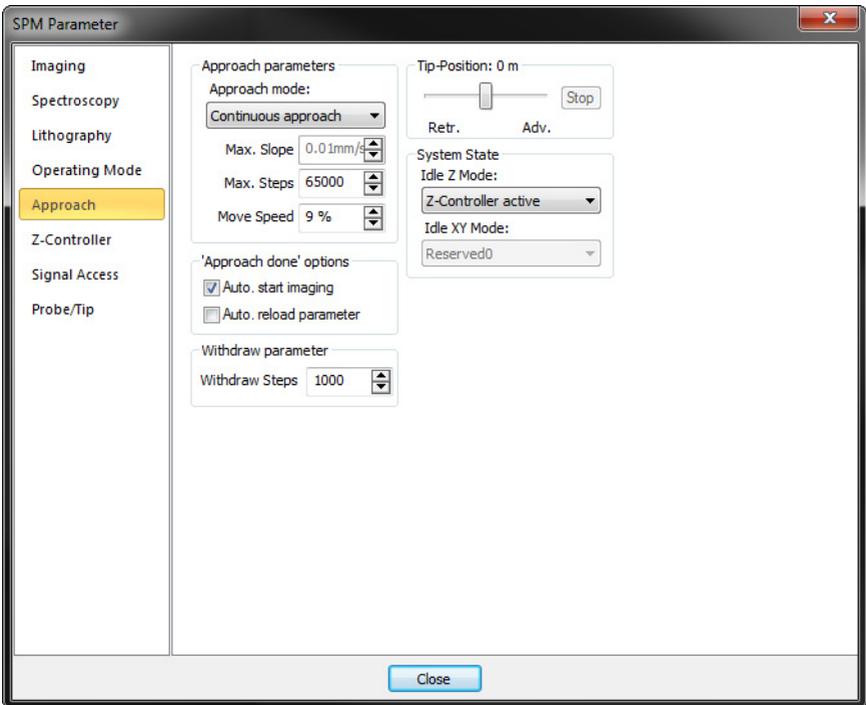
Increases the tip-sample distance with approach speed settings.

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 AFM scan heads, two approach options are available:

– Continuous approach

Approach with a continuous and slow motorized stage movement until surface contact point is reached. Z-Axis stays at *Tip-position* during approach (see page 112). This is the default approach method, and was the only method available in the Nanosurf Naio control software before version 3.

– Step-by-step approach

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

Max. slope

This parameter defines the speed of extending the Z-axis. It is only available in *Step-by-step approach* mode. Slower speeds help to preserve sharp tips.

Max. steps

This parameter defines the maximal duration of an automatic approach:

- In *Continuous approach* mode it defines the maximum time.
- In *Step-by-step approach* mode it defines the maximum number of cycles.

Move speed

This parameter defines the move speed during automatic approach and withdraw:

- In *Continuous approach* mode this value should be small. If the approach is too fast, the tip or the sample surface can be damaged. On the other hand, the motor will not move when the move speed is too small.
- In *Step-by-step approach* mode this value should be around full speed. Lower values help to stop in the Z-range of the scanner. On the other hand the approach time increases.

Approach done options

Auto start imaging

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

Withdraw parameter

Withdraw steps

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

Tip-position

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

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: A first measurement* (page 39). For details on how to use the charts see *Section 13.3: Charts* (page 175). 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 173).

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 76)).

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 102) and *Section 9.3: Online panel* (page 107). A description of the other panels is found elsewhere in this manual. Please refer to the *Chapter 16: Quick reference* (page 283) to locate them.

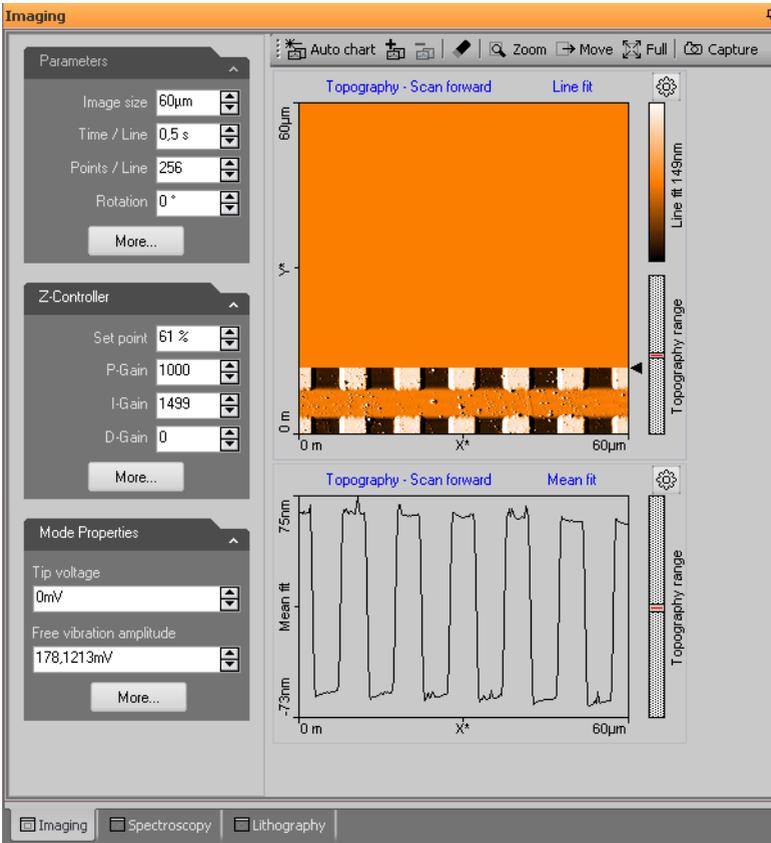


Figure 10-1: Imaging window

10.2: Imaging wizard

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

The *Imaging wizard* will display the following dialogs:

Imaging Wizard

This wizard sets imaging parameters to suitable values

The imaging parameters will be set to reasonable values based on your sample description and imaging requirements.

Describe Your Sample

Expected Sample Feature Size 50nm

Expected Feature Height 5nm

You will be able to change these settings later to better match your needs.

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< Back Next > Cancel

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.

Imaging Wizard

Please define the imaging optimization level

Imaging Optimization Level

High Scan Speed / Low Image Quality

Medium Speed / Good Image Quality

Low Scan Speed / Optimal Image Quality

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< Back Finish Cancel

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' schematical 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 107)).

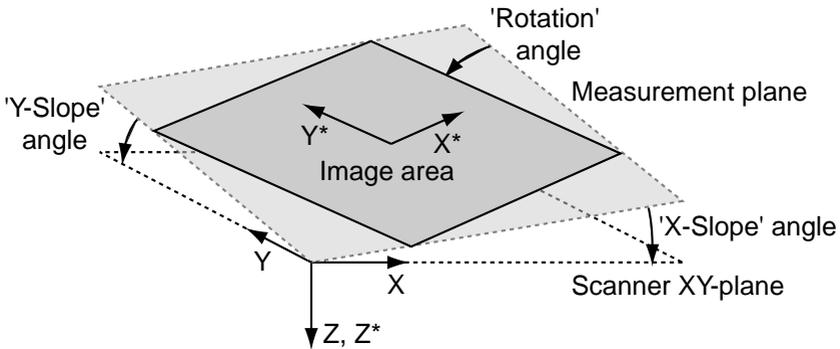
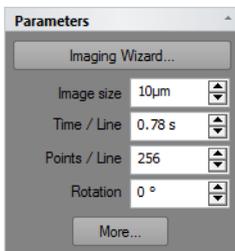


Figure 10-2: Coordinate systems

Imaging parameters section



Imaging wizard

This button starts the *Imaging wizard* that helps you set reasonable imaging parameters for your sample (see also page 115).

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.

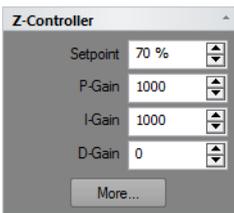
Rotation

The angle between the X-direction of the scanner and the X* direction of the measurement (Figure 15-2: Coordinate systems). Note that with the NaioAFM the maximum scan range is obtained at 45° rotation.

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.

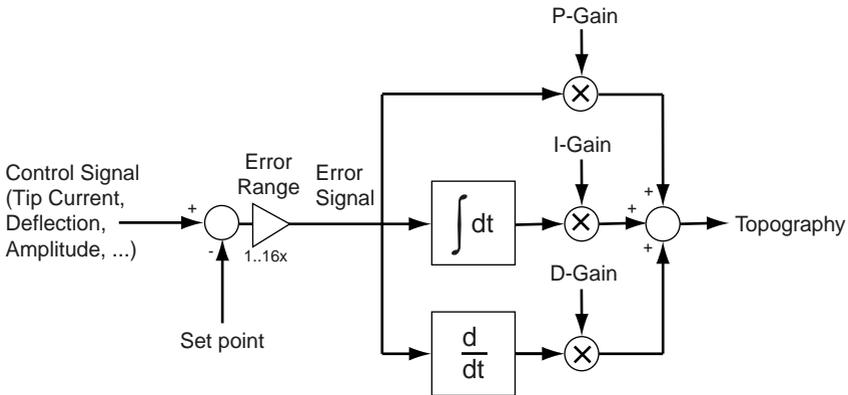


Figure 10-3: Z-controller

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.

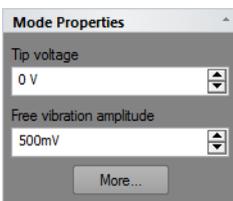
D-Gain

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 8.8.2: Z-controller page](#) (page 88)).

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 AFM scan heads the sample has to be electrically connected to the instrument's chassis ground for accurate measurements.

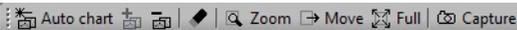
Free vibration amplitude

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

More

Opens up the SPM parameters dialog on the "Operating mode" page for more advanced parameters (see *Section 8.8.1: Operating mode page* (page 86)).

10.4: Imaging toolbar



The toolbar contains the following icons and labels from left to right: a vertical ellipsis, 'Auto chart', a plus sign, a minus sign, a diamond, a magnifying glass, 'Zoom', a right arrow, 'Move', a four-way arrow, 'Full', and a camera icon, 'Capture'.

Auto chart

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

"+" and "-"

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

Clear old chart data

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

Zoom

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

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

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

To accept the new zoom area:

- ➔ Double-click the chart with the left mouse button, or click the “Zoom” button in the Tool Results panel.

This action modifies the parameters “Image size”, “Image offset X” and “Image offset Y” in the Imaging page of the SPM parameters dialog accordingly (see *Section 10.6.1: Imaging page*).

To abort the zoom function

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

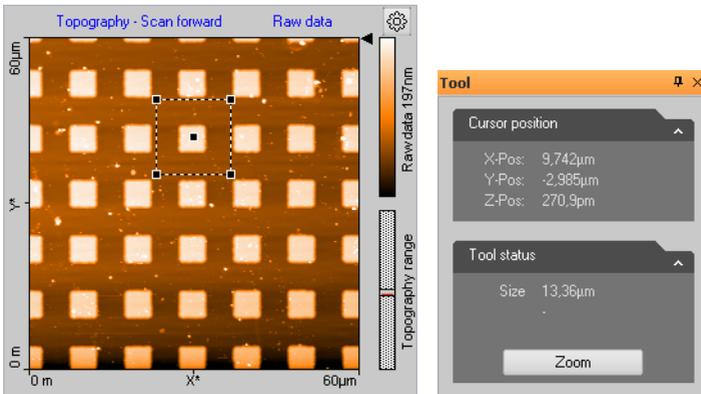


Figure 10-4: Zooming. (Left) The Zoom tool area marker. (Right) The Zoom tool information in the Tool panel of the Info pane.

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.

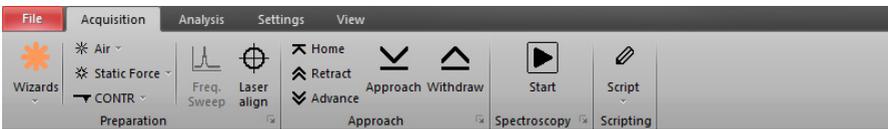
Full

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 13.4: Gallery panel* (page 186)). 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 80) and the Approach group is explained in *Section 9.4.1: Approach group* (page 109), the Imaging and Scripting groups are described here.

10.5.1: Imaging group



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

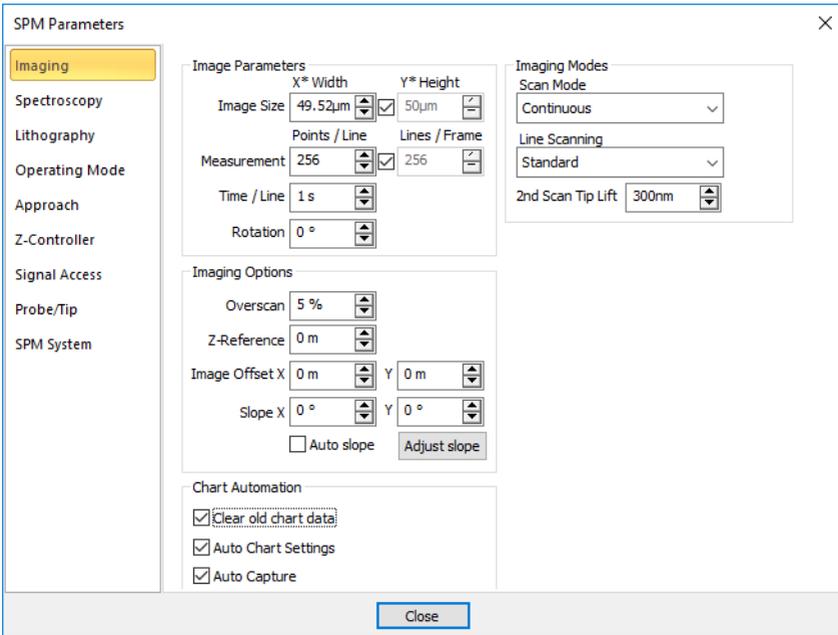


Image Parameters

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 (Figure 15-2: Coordinate systems). Note that with the NaioAFM the maximum scan range is obtained at 45° rotation.

Imaging Options**Overscan**

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

Ref. Z-Plane

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

The reference plane for the image can be aligned to the surface of the sample using the slope parameters (see *Figure 5-2: Sample and measurement orientation before slope adjustment* (page 54) or *Figure 10-2: Coordinate systems* (page 117)).

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 5.2: Adjusting the measurement plane* (page 53) 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 127) 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.
- **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

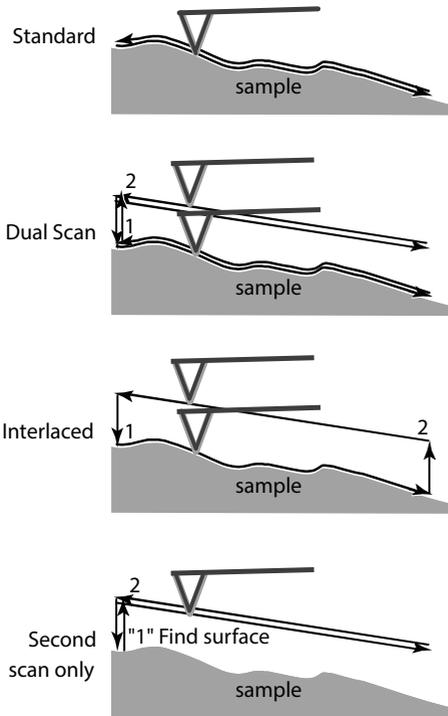


Figure 10-5: Available Line Scanning options

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 126)).

Auto chart settings

If checked, the chart arrangement is automatically updated (see also *Auto chart* (page 120)).

Auto capture

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

CHAPTER 11:

Spectroscopy

11.1: Introduction

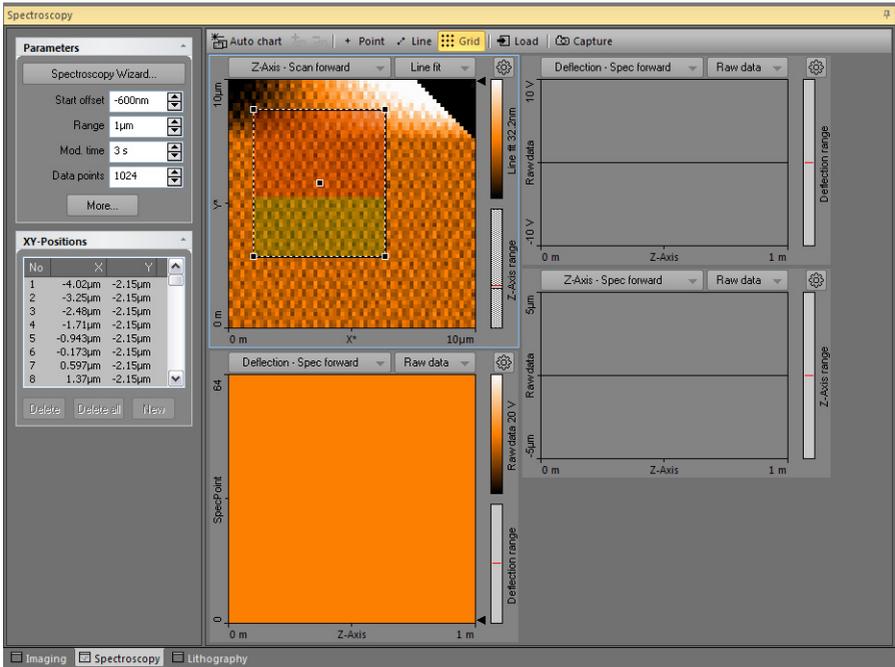


Figure 11-1: Spectroscopy window

Spectroscopic measurements are performed in the Spectroscopy window, which is opened by clicking the Spectroscopy tab in the 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.

The Spectroscopy window also contains a number of charts that display the data from a previous imaging measurement and the data from the ongoing spectroscopic measurement. The Spectroscopy window can display as many charts as the size of the window can accommodate. It is recommended to display at least two charts, one Color map of a previous Topography measurement of the area where the spectroscopy measurement is performed, and one Line graph of the current spectroscopy measurement. For more information on adding and changing charts see *Section 13.3: Charts* (page 175).

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

- Force–Distance curves in AFM static, spreading resistance, and lateral force operating modes
- Amplitude–Distance or Phase–Distance curves in AFM dynamic operating modes
- Tip Current– Tip Voltage curves in AFM and 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. Alternatively, individual positions can also be defined manually by entering their X and Y coordinates in the XY-Position dialog, opened by clicking the “New” button in the XY-Position section (also see *New* (page 143)). 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*).

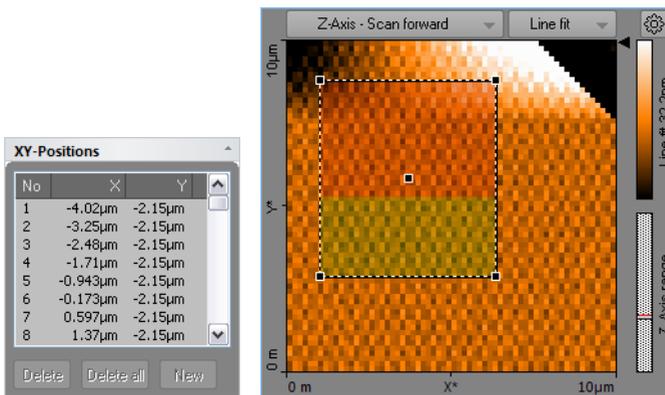


Figure 11-2: Example of a multiple position measurement using the Grid tool. ((Left) List of coordinates. (Right) Grid area as shown on the sample surface. Measured points are tinted yellow; unmeasured points are tinted red.

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:

 (also see *Section 11.4: Spectroscopy toolbar* (page 143))

Individual points created using any method 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**

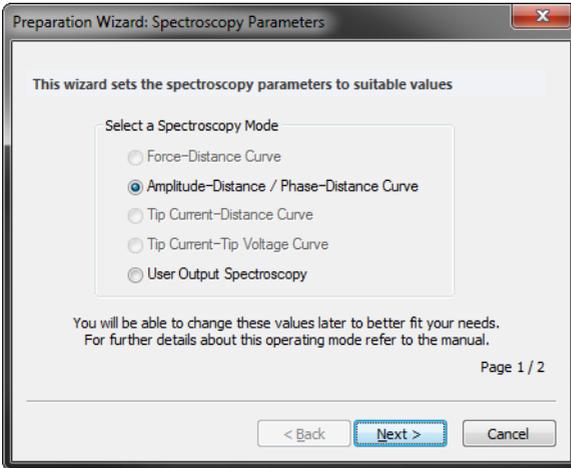
This type of modulation has a fixed start and end value. It is freely available with the Standard spectroscopy level (see *Section 11.6.2: Spectroscopy page (standard level)*).

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

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

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

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

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

Important

- A disabled spectroscopy mode means that this mode is not available for the currently selected operating mode. “Amplitude–Distance curve”, for example, is only possible in dynamic force or phase contrast operating mode and not in static force” operating mode.
- A disabled parameter means that it is only available when the advanced spectroscopy level has been activated by a correct (see *Access code* (page 264)).

11.2.1: Force–distance

The Force–Distance curve is a spectroscopy mode where the cantilever is moved while the deflection signal is measured. With Force–Distance spectroscopy, the typical snap-in and release effect of the tip–sample interaction can be measured. Additionally, the cantilever spring constant and the system’s deflection sensitivity can be precisely calibrated (see *Section 15.8.2: Probe/tip page* (page 277)).

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

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

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

1. Tip is approached (i.e. in contact with the surface).
2. Move the tip to a defined position (Range) above the surface while measuring the deflection signal (and any other input signals that the current measurement mode may allow). This is called the “Forward Modulation phase”.
3. Move the tip back to the surface while measuring deflection (and any other input signals). This is the “Backward Modulation phase”. Its duration is the same as during the forward phase. The direction is opposite to that of the forward phase.
4. Remain approached (keep Z-controller active). If more spectroscopy measurements are to be performed, move to the next measurement (XY) position (also with active Z-feedback).

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

1. Start from a (fully) retracted Z-position.

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

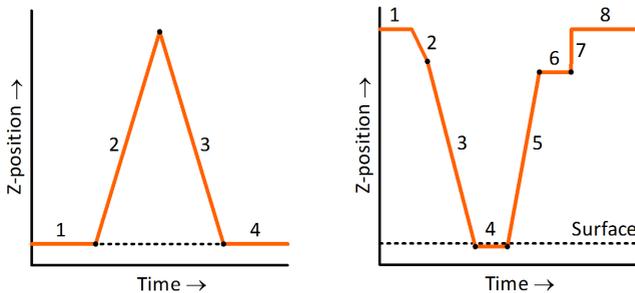
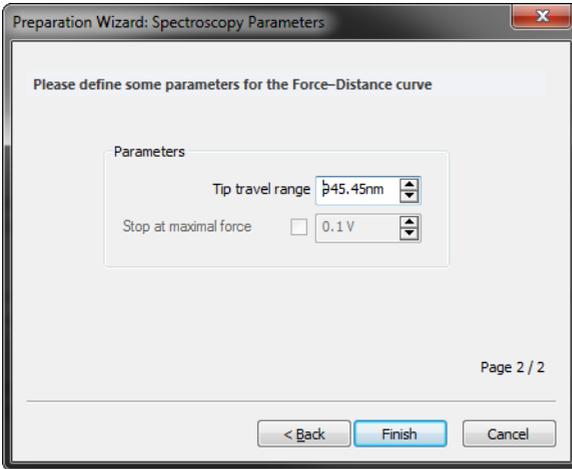


Figure 11-3: Typical phases of Force-Distance curves. (Left) Fixed length (standard) modulation. (Right) Stop by value (advanced) modulation.

Important

- Force-Distance Curve is available in all Static force operating modes.
- Cantilevers with low spring constants are typically used.



Parameters

Tip travel range

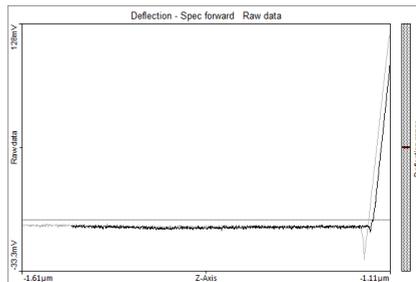
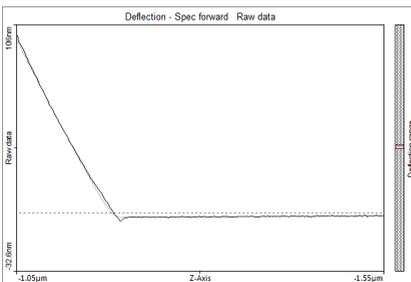
Defines the range of the desired tip movement toward/away from the sample during measurement. In fixed length modulation, this parameter sets the actual forward and backward travel ranges. In stop by value modulation, this parameter sets the maximum travel ranges (if not shortened by the respective stop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

Stop value

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

Results

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



Usage

Force–Distance curves can be easily analyzed in the Nanosurf Naio control software to reveal the system’s deflection sensitivity (see below). These can then be entered into the respective fields on the Probe/Tip page of the SPM parameters dialog (see *Section 15.8.2: Probe/tip page* (page 277)) and allow the software to correctly express measurement data (voltage) as height information (e.g. in nm). If the cantilever spring constant has been determined and entered in the corresponding field on the Probe/Tip page as well, the software can also accurately express measurement data as Force (in Newton).

To perform a calibration:

- ❶ Record a Force—Distance curve as described above.
- ❷ Use the Measure Length tool (see *Measure length* (page 192)) on the Ribbon’s Analysis and draw a line on the descending or ascending part of the force curve (see *Figure 11-4: Deflection sensitivity calibration, Left*).
- ❸ From the numbers shown in the Tool status area of the Tool panel of the Info pane (*Figure 11-4: Deflection sensitivity calibration, Top right*), divide Height by Width to obtain the slope in V/m. In the example shown in *Figure 11-4*, the slope calculates to $303 \text{ mV} / 127.9 \text{ nm} = 2369038 \text{ V/m}$.
- ❹ To obtain the Deflection sensitivity, divide 10 V (the scale of the AFM detector) by the slope. In the example shown in *Figure 11-4*, this corresponds to $4.221 \times 10^{-6} \text{ m}$.
- ❺ Enter this number in the Detector Sensitivity field of the Probe/Tip page of the SPM parameters dialog. In the example shown, $4.221 \text{ }\mu\text{m}$ has to be entered (see *Figure 11-4: Deflection sensitivity calibration, Bottom right*).

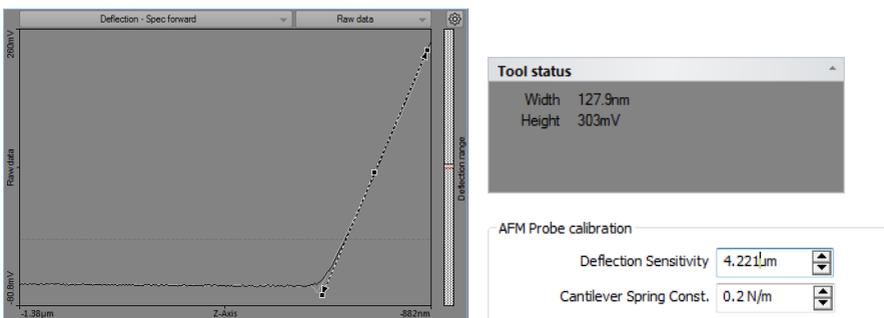
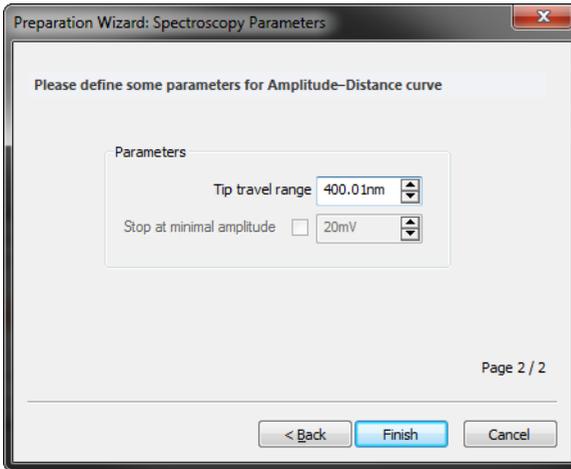


Figure 11-4: Deflection sensitivity calibration.

11.2.2: Amplitude–Distance / Phase–Distance

The Amplitude–Distance / Phase Distance curve is a spectroscopy mode where the cantilever is moved while the amplitude or phase signal is being recorded. With this modulation, the typical amplitude reduction or phase shift effect due to the increasing tip–sample interaction can be measured (see *Results* (page 139)). Note that while both amplitude and phase signal can be recorded simultaneously, only the amplitude signal can be used as Stop value in Advanced Spectroscopy mode.



Important

- Amplitude–distance / phase–distance curve is only available in dynamic force or phase contrast operating mode.
- Cantilevers with high spring constants are typically used.

Parameters

Tip travel range

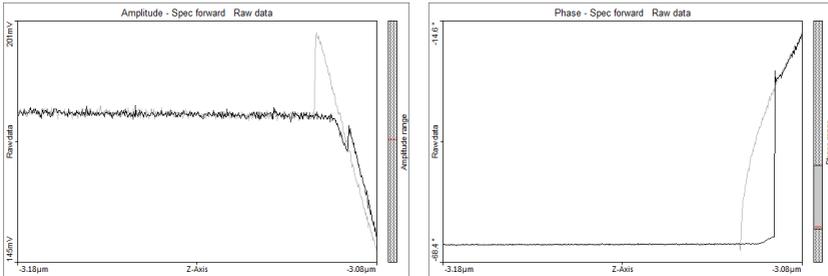
Defines the range of the tip movement during the forward and backward phases of the spectroscopy measurement.

Stop value

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

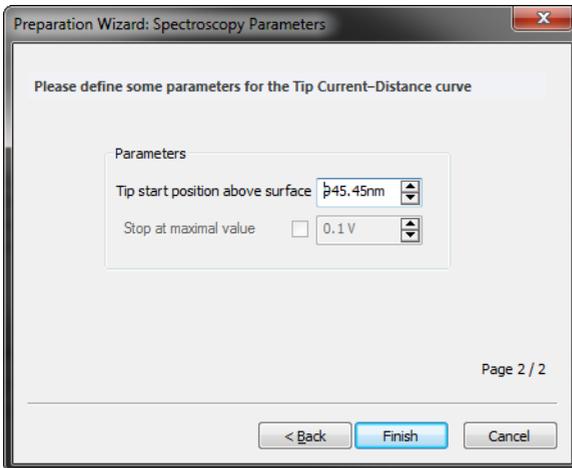
Results

Typical measurement results will look as follows (Left: Amplitude; Right: Phase):



11.2.3: Tip current–Distance

The Tip current–Distance curve is a spectroscopy mode where tip current is measured while the tip is moved.



Important

- The Tip current–Distance curve is only available in in the AFM “Spreading resistance” operating mode.
- AFM users must electrically connect the sample to the ground connector on the scan head to apply a tip–sample voltage difference.

Parameters

Tip travel range

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

Stop value

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

11.2.4: Tip current–Tip voltage

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

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

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

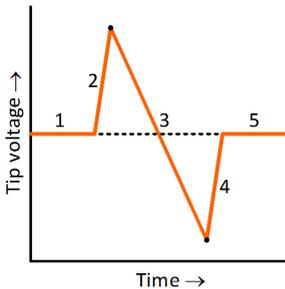
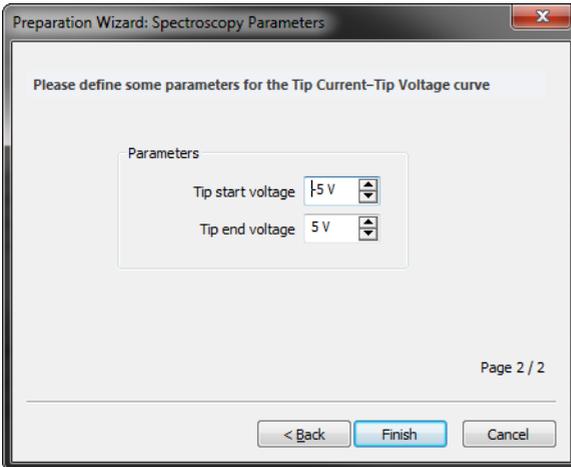


Figure 11-5: Typical Tip Current–Tip Voltage curve. Dotted line represents resting potential.

Important

- The Tip current–Tip voltage curve is only available in the AFM “Spreading resistance” operating mode.
- AFM users must electrically connect the sample to the ground connector on the scan head to apply a tip–sample voltage difference.



Parameters

Tip start voltage

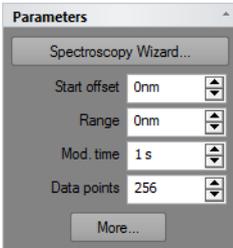
Defines the start point of the voltage scan.

Tip end voltage

Defines the end point of the voltage scan.

11.3: Spectroscopy parameters area

Parameters section



Spectroscopy wizard

This button starts the spectroscopy wizard (see *Section 11.2: Spectroscopy wizard* (page 133) for details).

Start offset

The starting point for the spectroscopy modulation

Range

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

Mod. time

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

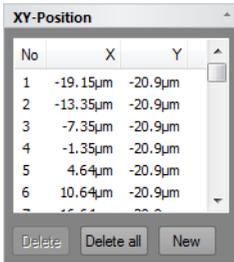
Data points

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

“More” button

Opens up the SPM parameters dialog on the Spectroscopy page for more advanced parameter settings (see *Section 11.6.1: Spectroscopy page* (page 146)).

XY-Position section



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

Delete

Removes the currently selected measurement position from the list.

Delete all

Removes all measurement positions from the list.

New

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

11.4: Spectroscopy toolbar



Auto chart

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

“+” and “-”

With these buttons you can add or remove chart groups, respectively, but not more than what minimally makes sense. There will always be a chart group left. Conversely, you can't add more chart groups than the Auto tool would display. You can however still remove or add charts manually (See *Section 13.3.1: Working with multiple charts* (page 177)).

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.

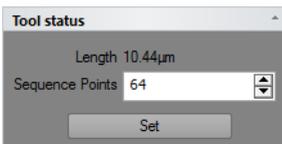
Load

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.

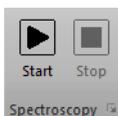
Points, Lines

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:

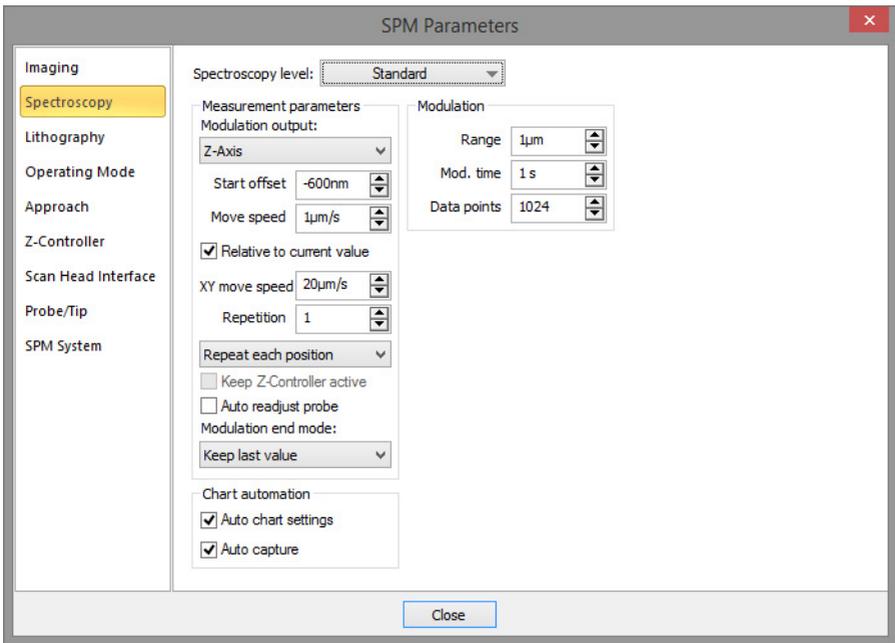
– Standard Spectroscopy

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 current value

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

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

Auto readjust probe

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

Modulation End Mode

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

Modulation**Range**

This value defines the range over which the output value is changed during the forward modulation phase, starting from Start Offset. The range can be positive or negative (also see *Important* (page 147)). The backward modulation automatically follows the reverse direction range. After both (fwd/bwd) modulation phases, the modulation output will be at the Start offset value again.

Mod. time

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

Data points

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

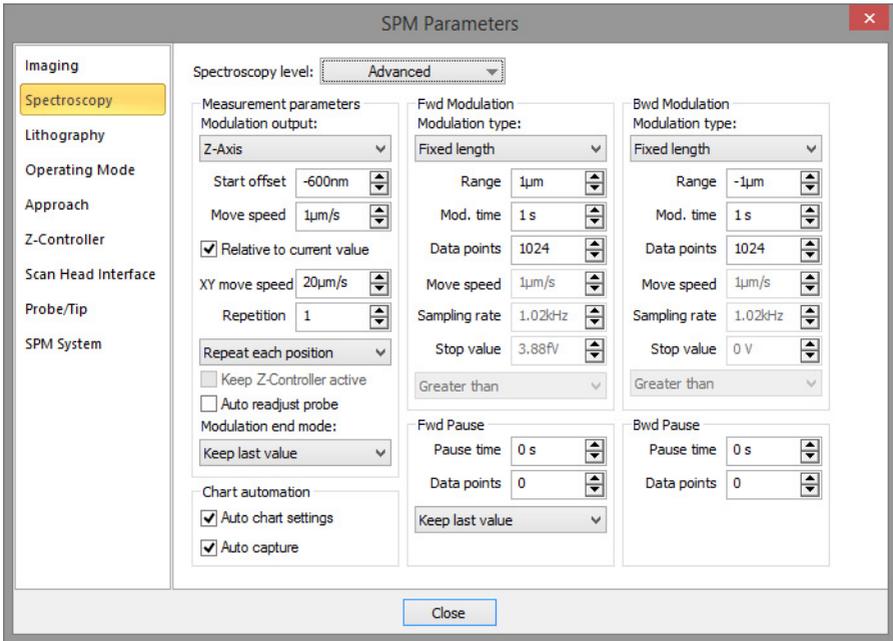
Chart automation**Auto chart settings**

If checked, the chart arrangement is automatically updated (see also *Auto chart* (page 143)).

Auto Capture

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

11.6.3: Spectroscopy page (advanced level)



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

Fwd Modulation / Bwd Modulation

Modulation Type

In “Fixed Length” the modulation phase is exactly defined by Range, Mod. Time and Data points. All measurements (repetitions, different positions) will have the same length. In “Stop by value” this is not the case; only maximum values are given. Since the input channel used for feedback during imaging (e.g. deflection or amplitude) is used to stop each modulation phase at a preset point (see *Stop Value* (page 151)), the lengths of each modulation phase (for each repetition, different position) will most likely be different.

Range

In “Fixed length” modulation, this value defines the change of the output value during the modulation phase. For forward modulation it starts from Start offset. The range can be

positive or negative (also see *Important* (page 147)). For the backward modulation it starts from the last value of the forward pause phase and with its own Range settings. Therefore, the modulation output value at the end of the backward modulation phase can be different from the start value of the forward phase. In "Stop by value" modulation, this field shows a maximum value, calculated from the Data points, Move speed, and Sampling rate parameters (see below).

Mod. time

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

Data points

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

Move speed

In "Stop by value" modulation, this value defines the speed at which the modulation output is changed. The move speed can be positive or negative (also see *Important* (page 147)). For the backward modulation it can have a different value than for the forward modulation. Therefore the modulation output value at the end of the backward modulation phase can be different from the start value (Start offset). In "Fixed length" modulation mode, this value is calculated from the Range and Mod. time parameters (see above).

Sampling rate

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

Stop Value

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

Stop Mode

If "Greater than" is selected the modulation is stopped if the measured value is more positive than "Stop value". If "Less than" is selected the measured value has to be more

negative. For Z-Axis modulations, "Greater than" should be selected for Static operating modes and "Less than" for Dynamic operating modes.

Fwd Pause / Bwd Pause

Pause time

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

Data Points

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

Z-Axis Pause Mode

In "Z-Axis Modulation" Mode (see *Modulation Output* (page 147)), it is possible to select the Pause-Phase behavior via this selector. With "Keep last Z-Pos" it maintains the final value of the modulation phase. With "Z-controller active" it activates Z-controller feedback during the pause; the surface is tracked.

CHAPTER 12:

Lithography

12.1: Introduction

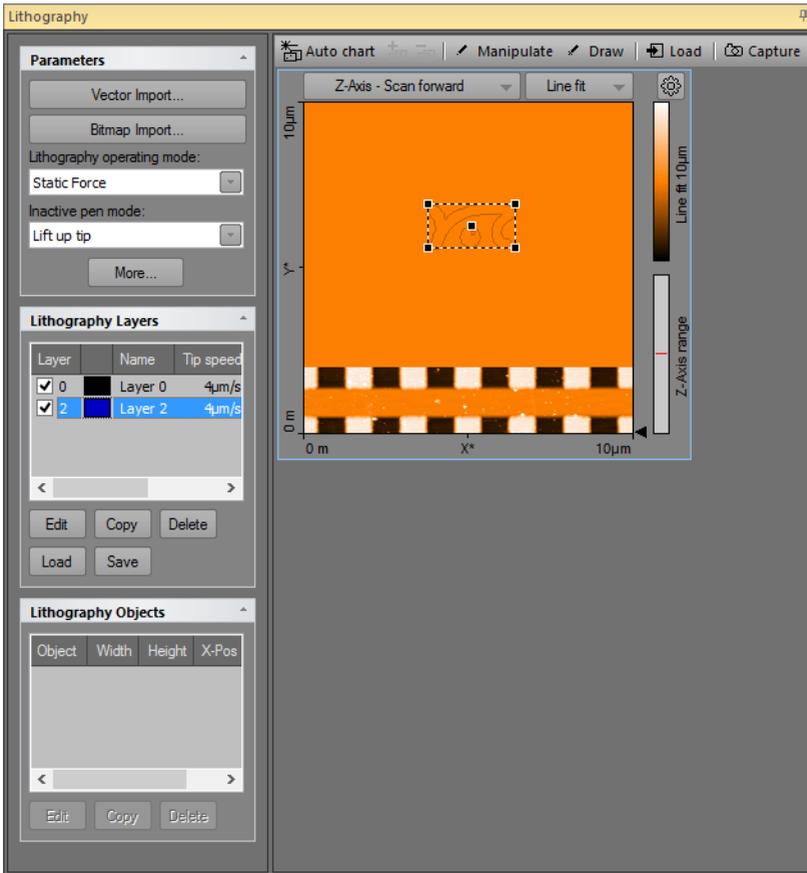


Figure 12-1: Lithography window

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 169)) and a Color map chart of the current Topography measurement. The Lithography window can however display more charts, should this be desirable. For more information on adding and changing charts, see *Section 13.3.1: Working with multiple charts* (page 177).

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.

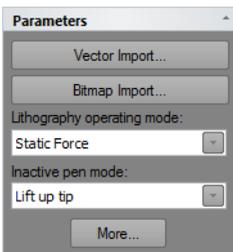
4. The imported object is positioned and scaled to fit the target area.
5. The Lithography sequence is executed.
6. The sample surface is re-imaged to view the Lithography results.

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 159).

Bitmap import

Opens the *Pixel Graphic Import dialog* for importing bitmap graphics based lithography data (see page 161).

Lithography operating mode

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

- **Static force**
- **Dynamic force**

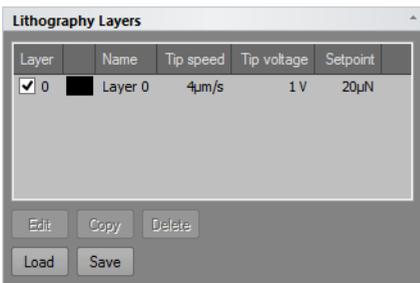
Inactive pen mode

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 162) 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.

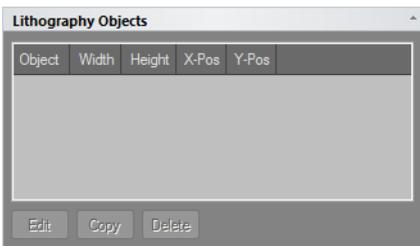
Load

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 unchecked it will not be used for a lithography session.

Edit

Edit will open the Object Editor dialog to edit the selected object (see *Section 12.3.4: Object Editor dialog* (page 166)).

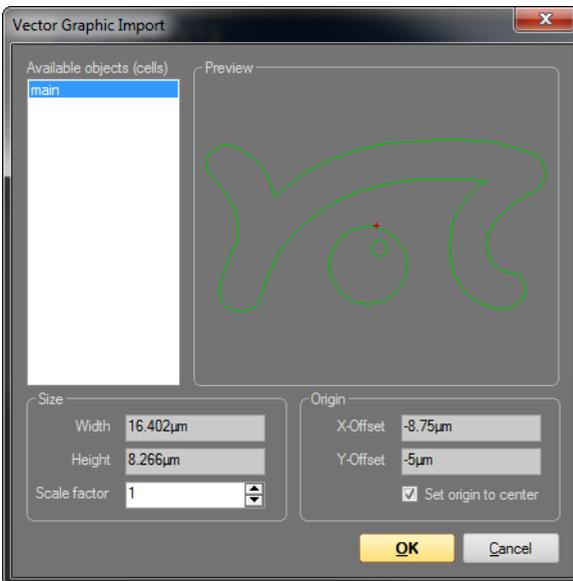
Copy

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

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

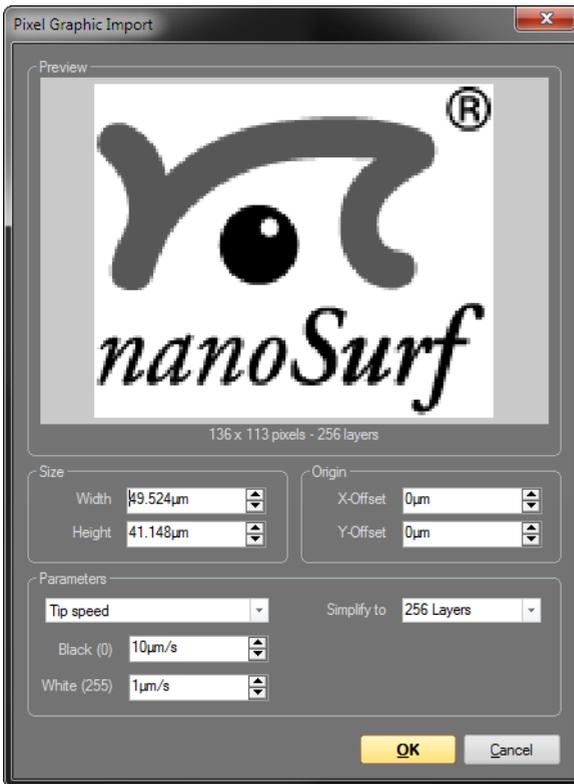
X-Offset / Y-Offset

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 maintain its aspect ratio. It is at this point however possible to change the automatically calculated size manually. If the width is changed manually, the height is recalculated to keep the aspect ratio. If the height is changed manually, the width is not recalculated.

Origin

X-Offset / Y-Offset

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

Parameters

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

Important

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

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

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

- **Tip speed**
- **Tip voltage**
- **Static force setpoint**

- **Dynamic force setpoint**
- **Dynamic force amplitude**

Black / White

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

Example

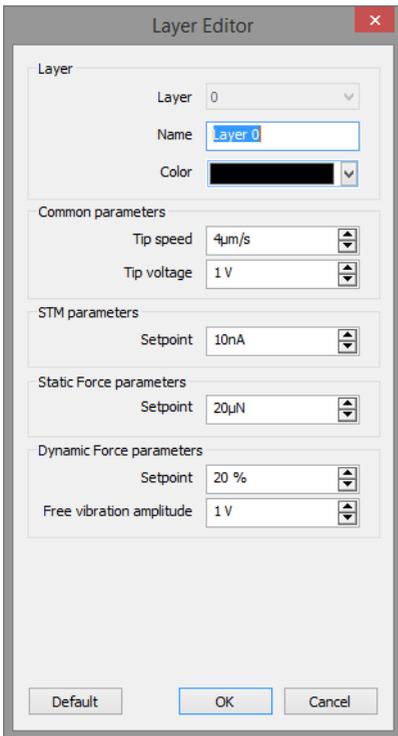
Setting the automatically adjusted Lithography parameter to “Static Force Setpoint”, and Black (layer 0) and White (layer 3) to 25 μN and 10 μN , respectively, will result in:

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

Simplify to

Select the number of layers the imported pixel graphics file should be simplified to. Selecting the number of layers to be identical to the number of grayscale values in the pixel graphics file will 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. This setting has no effect during AFM Lithography.

Static force parameters

Setpoint

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

Dynamic force parameters

Setpoint

Used to set the amplitude Setpoint of a lithography sequence performed in dynamic force AFM mode.

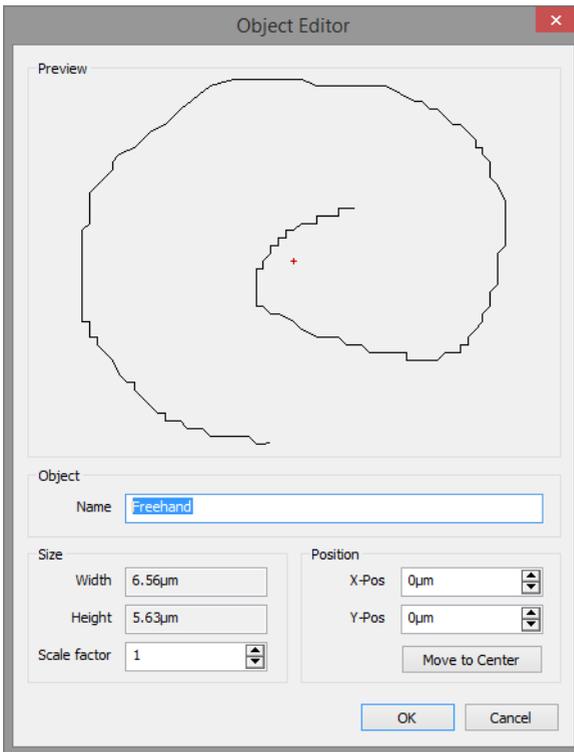
Free vibration amplitude

Used to set the Free vibration amplitude of a lithography sequence performed in dynamic mode.

“Default” button

Loads the default Lithography parameter values.

12.3.4: 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.

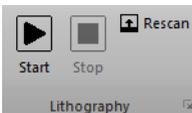
Move to Center

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.

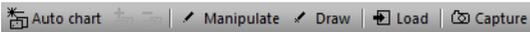
Important

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

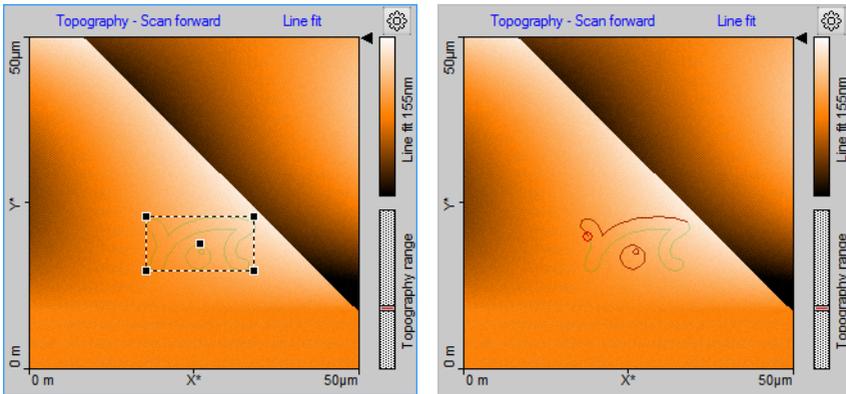


Figure 12-2: Lithography preview. (Left) Before the Lithography sequence has been started. (Right) While the Lithography sequence is running.

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 158)) and the superimposed preview images of the Lithography objects (when these have been loaded and selected; see *Vector import* or *Bitmap import* (page 157)).

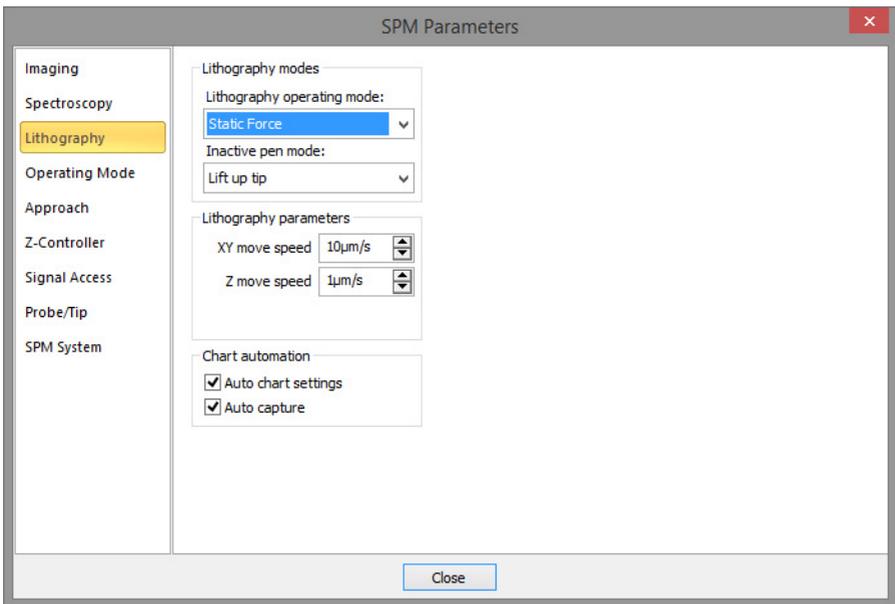
Before running a lithography sequence, a box with the size and content of the selected lithography object is superimposed on the surface map. When selecting the center of the box with the mouse, the corresponding object can be moved around the scan area to reposition it. The new object location (X-Pos 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 166)).

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 169), 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**

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 checked, the chart arrangement is automatically updated (see also *Auto chart settings* (page 171)).

Auto Capture

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

CHAPTER 13:

Working with documents

13.1: Introduction

When working with the Nanosurf 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 13.4: 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 66) and *Section 7.4: Document space* (page 70)). It is strongly recommended to permanently store relevant documents to a new folder (see *Save as* (page 187) in *Section 13.4.3: Gallery toolbar*).

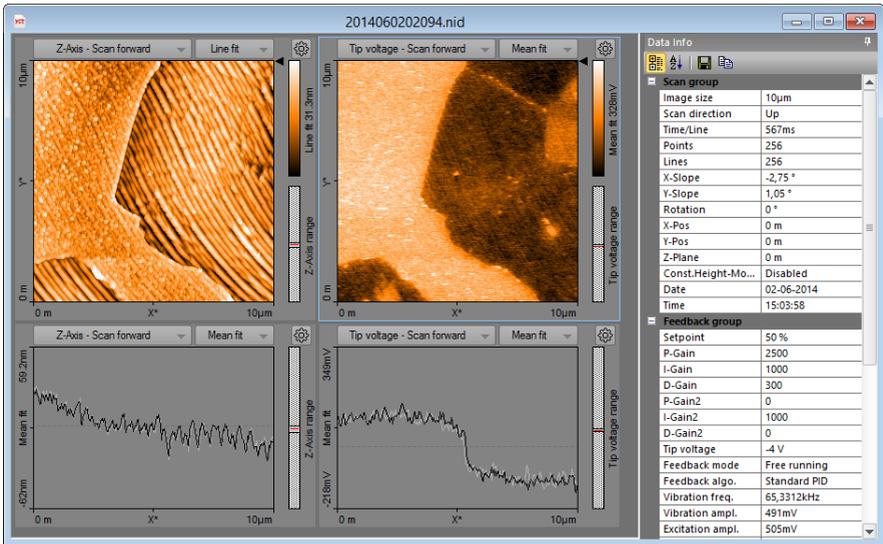


Figure 13-1: Measurement document. Typical measurement window with the Data Info panel expanded (see *Figure 7-4: Example of a measurement document window* (page 70) for a window with a minimized Data Info panel).

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

Alphabetical

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

Save

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

Copy to Clipboard

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

13.3: Charts

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

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

Chart titles

The title elements of each chart display the signal name and the background line filtering type that are used. A click on each of these titles opens a drop-down menu with other possible signals or filters:

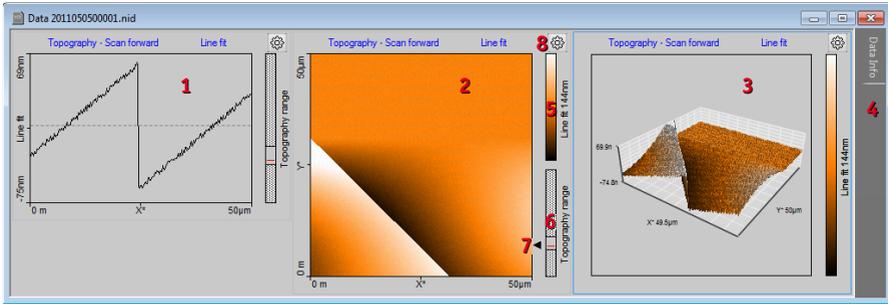
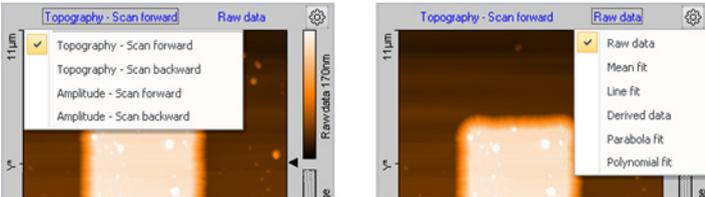


Figure 13-2: Elements of a chart. (1) Line graph. (2) Color map. (3) 3D view. (4) Data Info panel (see Section 13.2: Data info panel). (5) Color scale for data Z-range. (6) Data range indicator, with scan head Z-range as dotted box, data Z-range as solid gray box and current scan line height as red line.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



Changing the titles will change the content of the chart.

Color scales

The Color scale (Figure 13-2: Elements of a chart, item 5) shows which measured signal level is mapped to which color. The color mapping can be changed using the Color Palette dialog (see Section Color Palette (page 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 13.3.2: Chart Properties dialog*) and immediately updates the color display of the data in the chart.

Line selection arrow

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

Chart properties

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

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

13.3.1: Working with multiple charts

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

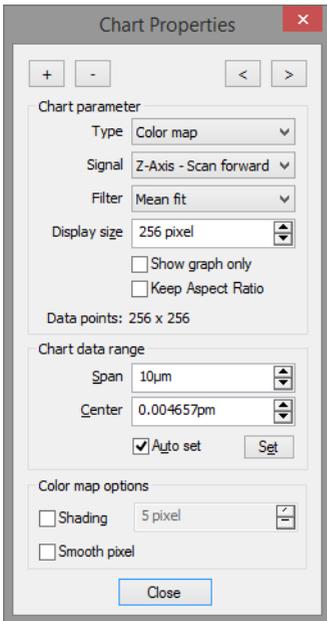
Adding or removing a chart, or setting chart parameters is all performed in the Chart Properties dialog (see *Section 13.3.2: Chart Properties dialog*). When opened, the settings displayed in the Chart Properties dialog refer to the currently selected chart. This (active)

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 too small to display all charts, scrollbars are displayed at the border of the window.

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

13.3.2: Chart Properties dialog



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

Some parameters are chart type specific. They are therefore displayed at the bottom of the Chart Properties dialog in a separate group.

Add chart

The “Add Chart” button () creates a copy of the currently selected or active chart and adds it to the active window in last position.

Remove chart

The “Remove Chart” button () removes the currently active chart.

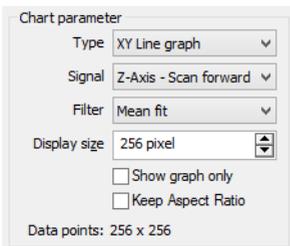
Previous chart

The “Previous Chart” button () activates the previous chart and updates the parameters displayed in the Chart Properties dialog to those of that chart.

Next chart

The “Next Chart” button () activates the next chart and updates the parameters displayed in the Chart Properties dialog to those of that chart.

Chart parameters



Type

Selects the chart type to be used for display of the measurement data:

– Line graph

Data is displayed as a Line 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 177)). 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.

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.

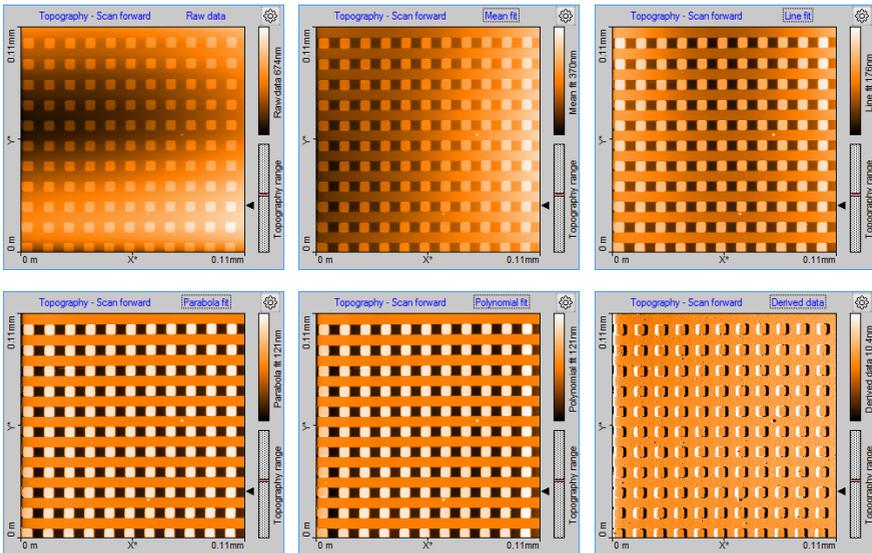


Figure 13-3: Data filter types. The same measurement data displayed using the available filters. A defective area on a calibration grid is shown here to illustrate the effect of the filters.

Display size

The size of the chart in pixels.

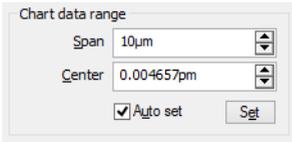
Show graph only

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

Keep Aspect ratio

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

Chart data range



Span

The span that corresponds to the chart's displayed Z-range. Increasing Span decreases feature contrast and vice-versa. The current span is displayed next to the color scale in color maps, or can be inferred from the Z-axis labels in Line graphs and 3D views.

Center

The signal value that corresponds to the center of the "Span" parameter.

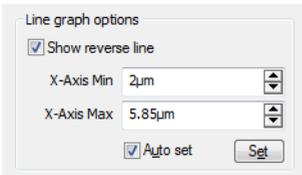
Set button

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 checked, the software will set the Min and Max values each time the chart is automatically scaled.

Line graph options



Show reverse line

When checked, the reverse scan data is drawn in gray (see *Figure 13-4: Show reverse line option*). It allows comparison of the forward and reverse measurements data. Whether or not this data is available depends on the measurement mode used during the acquisition of the data (see *Line Scanning* (page 126).

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 or out to a specific data range.

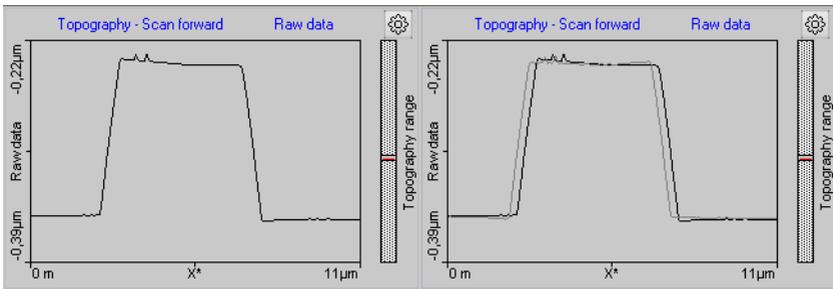


Figure 13-4: Show reverse line option. (Left) Reverse line disabled. (Right) Reverse line enabled.

XY line graph options

Line graph options

Show reverse line

X-Axis Min

X-Axis Max

Auto set

Signal

The signal that determines the horizontal position of the plotted points.

All other parameters are identical to the ones described for the *Line graph options* (page 182).

Color map options

Color map options

Shading

Smooth pixel

Shading

When checked, the color map creates the impression of a 3-dimensional surface which is lighted from the left. This is achieved by combining the topography with its derivative. The number of pixels in the edit box defines the amplification of the derivative add on.

Smooth pixel

When checked, the screen edge rendering of individual data pixels is smoothed with their neighboring pixels. Alternative data pixels are drawn as individual squares. This smoothing shows the most effect when the display size is larger than the number of measured data points (e.g. a 256×256 measurement displayed at 512×512 pixels).

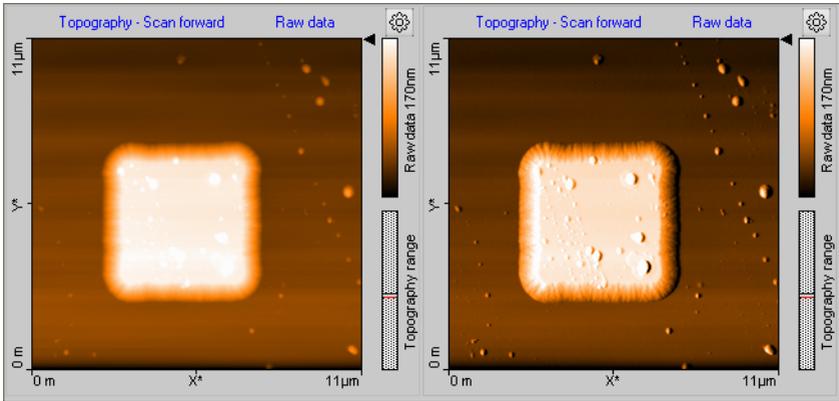
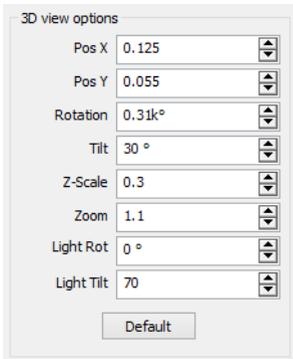


Figure 13-5: Shading option. (Left) Shading disabled. (Right) Five-pixel shading enabled.

3D View options



Pos X, Pos Y

Defines the center position of the 3D plot inside the chart area.

Rotation

Defines the z-axis rotation of the 3D plot relative to the view point.

Tilt

Defines the off-plane angle of the 3D plot.

Z-Scale

Defines a Z-axis 'stretch' factor. Use this e.g. to enlarge surface details.

Zoom

Defines the magnification of the 3D plot.

Light Rot

Defines the rotation angle of the light source relative to the Z-axis (360°)

Light Tilt

Defines the off-plane angle of the light source. The lowest value (0°) corresponds to "sunset" lighting, the highest value (90°) corresponds to mid-day lighting at the equator.

Default

The "Default" button resets all 3D parameters to their default values.

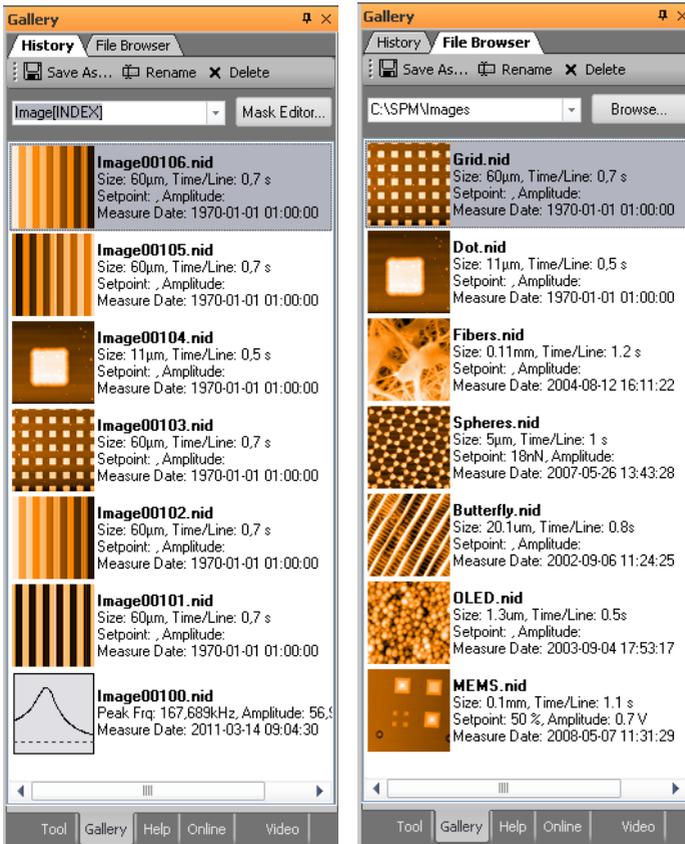
Keyboard and Mouse short cuts

Always click and hold the left mouse button on the 3D view chart while moving around the mouse to change the 3D view. The surface is reduced in feature complexity once the left mouse button is pressed to speed up redrawing on the screen. The surface will return to full detail once the mouse button is released.

Press the following additional keys/buttons to determine which chart property is changed:

- **Surface rotation**
Mouse left/right
- **Surface tilt**
Mouse up/down.
- **Size displayed surface**
"Ctrl"- key + mouse up/down
- **Surface position**
"Shift"-key + mouse up/down/left/right
- **Z-scale magnification**
Left mouse button + right mouse button + mouse up/down
- **Light source direction**
"Shift" + "Ctrl"-key + mouse left/right
- **Light source height**
"Shift" + "Ctrl"-key + mouse up/down

13.4: Gallery panel



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

13.4.1: 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 13.4.4: Mask editor dialog*), which is opened by clicking the “Mask Editor” button next to the edit box.

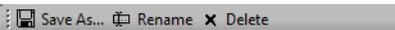
13.4.2: Image list

In the image list the stored measurement are shown. Each measurement is displayed as a thumbnail image of the measurement, together with some information about the measurement and measurement document.

The following mouse operations are possible inside the image list:

- **Double-click**
Opens the respective measurement in the document space.
- **Single left mouse click**
Selects the respective measurement and removes all other selections.
- **“Ctrl” key + left mouse click**
Adds individual selections to the current selections.
- **“Shift” key + left mouse click**
Selects all measurements from the last selection to the new selection.

13.4.3: Gallery toolbar



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))

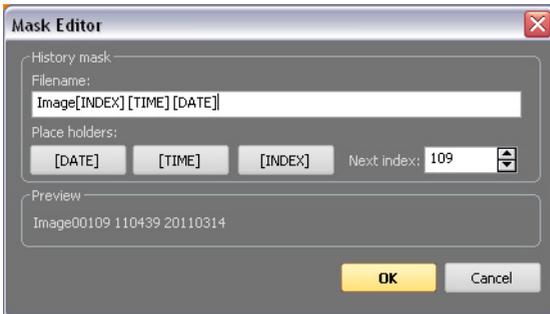
Rename

Single or multiple measurements can be renamed by clicking the “Rename” button. It will open the File Rename dialog (see *Section 13.4.5: File Rename dialog*), which allows you to specify a mask for the new file names.

Delete

Single or multiple measurements can be deleted by clicking this button.

13.4.4: Mask editor dialog



The Mask Editor dialog assists you in the creation of file name masks.

History mask

Filename

A file name mask is the template that is used to generate the file names for documents that are 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.

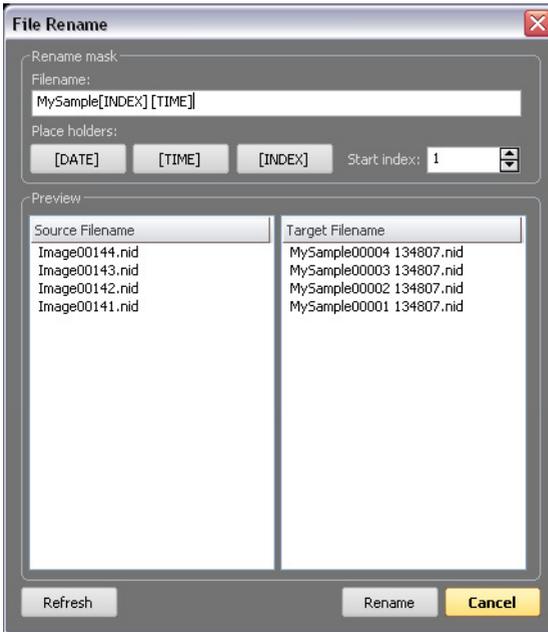
Important

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.

13.4.5: File Rename dialog



The File Rename dialog is used to rename (or move) multiple files using a Rename mask (see below). The dialog is opened by clicking the “Rename” button in the Gallery panel. To rename a file or multiple files, the Rename mask can be defined here following the same principles as for the History mask. A preview of the new filenames is shown in the preview section.

Rename mask

See *History mask* (page 188).

Preview

Source Filename

The left column of the Preview section shows the original filename(s).

Target Filename

The right column of the preview section shows what the filename(s) will be after pressing the “Rename” button.

Refresh

This button updates the preview list.

Rename

This button renames the selected files.

Important

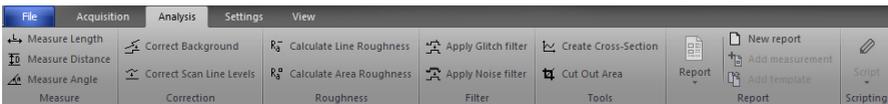
If no unique filename(s) would result from the specified Rename mask, an index is automatically added to the files. If this still does not result in unique filenames, the text "Copy of" is added to each filename as often as is required to make it unique.

Cancel

This button closes the dialog without renaming the files.

13.5: Analysis tab

Measurement data can of course not only be displayed in charts, it can be analyzed as well. The control software has several tools that allow quick numerical evaluation and modification of chart data in Operating or document windows. These tools are accessible through the various groups of the Analysis tab.



All of these tools can also be used while a measurement is still being acquired.

To use a quick evaluation tool:

- 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 13.6: Tool panel*) moves to the top of the panel stack of the Info pane.

Important

Depending on the selected chart type, some tools may be unavailable.

To stop using a tool:

- ➔ Select another tool, select the same tool a second time, or select "Abort" in the Chart's context menu.

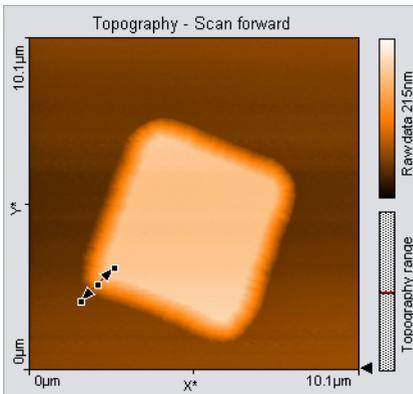
Tip

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

13.5.1: Measure group



Measure length



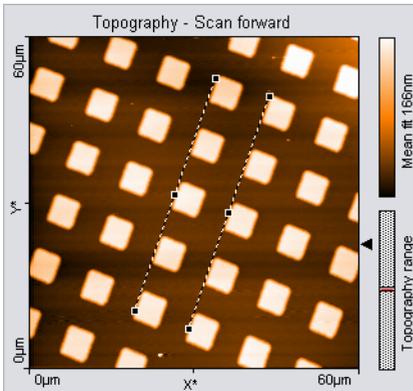
Calculates the distance and signal difference between two points. Graphically, a line with arrowheads on each end represents the selection marker. The line is defined by drawing a line on the measurement chart. The first point is positioned by moving the mouse cursor to the desired location and clicking and holding the left mouse button. The second point is positioned when the mouse button is released. When the mouse is not moved between clicking and releasing, an line parallel to the X*-axis is drawn.

The direction and length of the selection marker can be adjusted by dragging the end markers. The line can be moved as a whole by dragging the center marker.

The Tool status section of the Tool panel displays the calculated "Length", "DeltaZ", "Width" and "Height". This data will also be stored in the "Tool" data category of the Data Info panel

(see *Section 13.2: Data info panel*) for the respective measurement document as long as the tool is active when the document is stored. For more information on the data in the Tool status section (see *Tool status section* (page 203)).

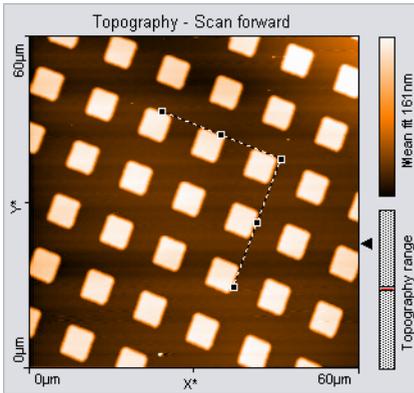
Measure distance



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 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 203)).

Measure angle

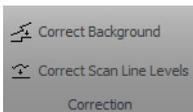


Calculates the angle between two lines. In Line graph-type displays, this tool can only be used when the chart displays data that has the unit “meters”.

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 203)).

13.5.2: Correction group



In contrast to the evaluation tools of the Measure and Roughness groups, the tools of the Correction group (and also those of the Filter group (see *Filter group* (page 198)) 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 180)) do not give satisfactory results. This may be the case when the scan lines in different parts of the measurement have a different average height. An example of such a measurement is shown in *Figure 13-6: Correct Background*.

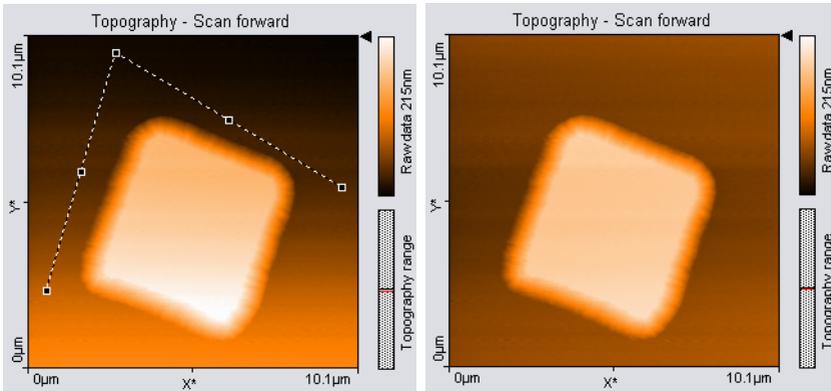


Figure 13-6: Correct Background. (Left) Uncorrected image; the end points of the selection marker have been moved to points that should have the same height. (Right) Corrected image.

To use the tool, select three points that should be on the same height. This is done in the same way as with the angle tool (see *Measure Angle* (page 339)). The selected points become the end points of the selection marker.

After clicking the “Execute” button in the Tool status section of the Tool panel, a copy of the original measurement document is made and the plane that is defined by the selection maker is subtracted from the measurement data in the newly created document. To get useful results, the Data filter option for the corrected image in the new document will be automatically set to “Raw data”.

Correct scan line levels

Removes the effect of drift when the line filter options (see *Filter* (page 180)) do not give satisfactory results. This may occur when the scan lines in different parts of the measurement have a different average height. An example of such a measurement is shown in *Figure 13-7: Correct scan line levels*.

To use the tool, draw a line through points that should have the same height in the same way as with the Measure Length tool.

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

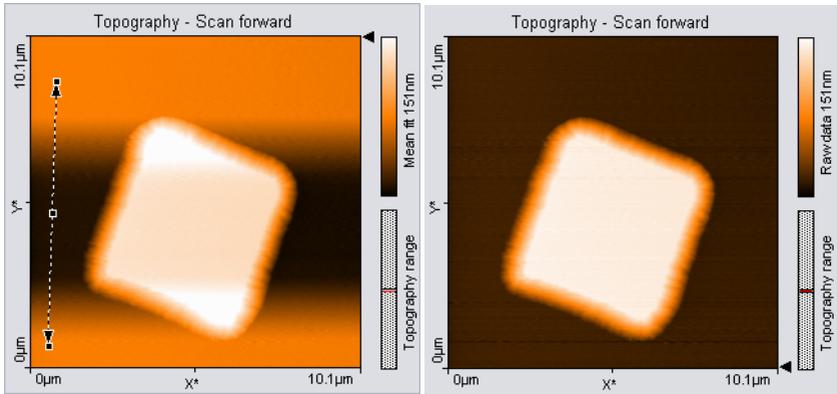


Figure 13-7: Correct scan line levels. (Left) Uncorrected image with a selection marker through points that should be at the same height. (Right) Corrected image

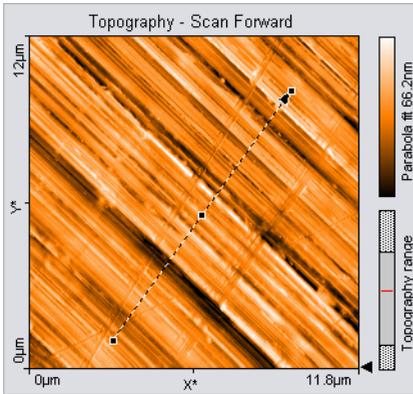
height. To get useful results, the Data filter option for the corrected image in the new document will be automatically set to “Raw data”.

13.5.3: Roughness group

R_a^- Calculate Line Roughness
 R_a^a Calculate Area Roughness
Roughness

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 192)).



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 180)) 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_d

$$S_d = \frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} |z(x_k, y_l)|$$

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_g

$$S_g = \sqrt{\frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} (z(x_k, y_l))^2}$$

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

$$S_y = S_p - S_v$$

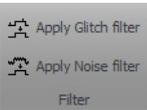
The roughness values depend on the Data filter that is applied to the chart, because they values are calculated from the filtered data. More information on data filters is provided in Section 18.2: The Chart bar under Data filter (page 199).

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.

13.5.4: 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 3x3 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 3x3 pixel Gaussian kernel function.

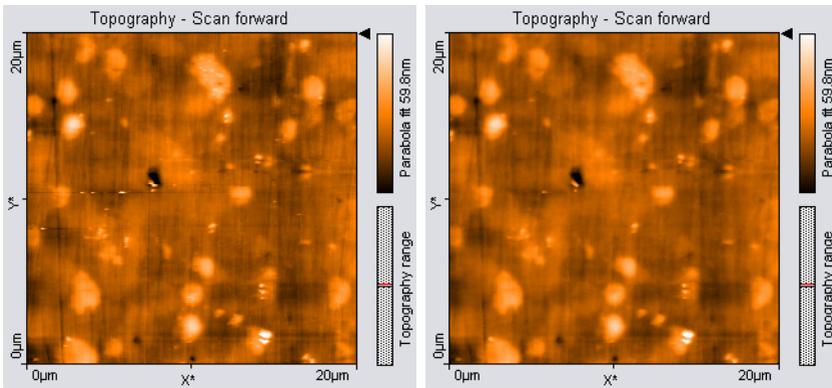


Figure 13-8: Glitch Filter. (Left) Unfiltered image with some glitches where the tip lost contact with the sample. (Right) Corrected image.

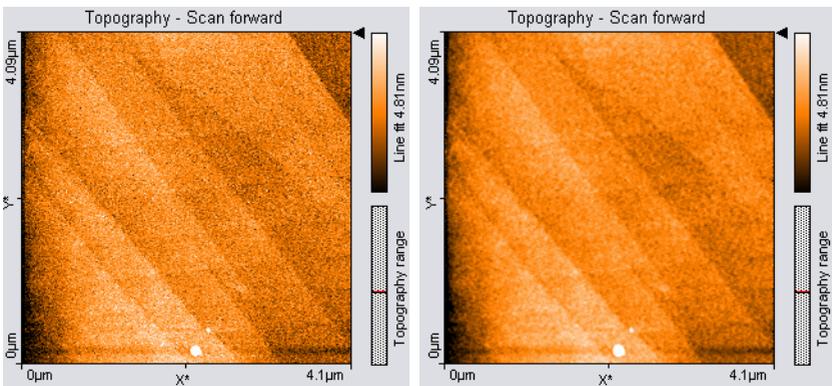


Figure 13-9: Noise Filter. (Left) Noisy (unfiltered) image of a measurement on HOPG. (Right) Filtered image

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.

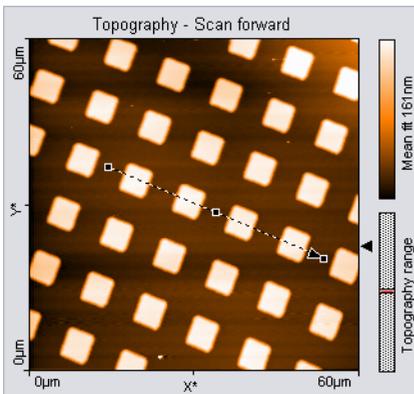
13.5.5: Tools group



Create cross-section

Creates a new measurement document containing a line cross-section of a Color map or Line View display.

The line is defined by drawing a selection arrow. The arrow points toward the forward direction of the line. The start of the arrow is defined by the mouse cursor position where the left mouse button is clicked, the end of the arrow by the position where the button is released. When the mouse is not moved between clicking and releasing, an arrow ending in the center of the measurement is drawn. The direction of the arrow can be adjusted by dragging its end markers; it can be moved by dragging the center marker.



Double-clicking the graph, or clicking the “Cut out line”-button in the Tool status section of the Tool panel creates a new document that contains the line section.

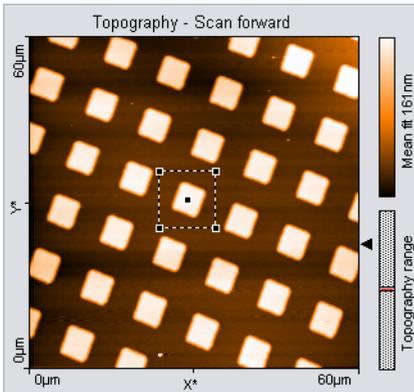
The Tool chart section of the Tool Results panel displays a preview chart of the selected line.

The Tool status section of the Tool Results panel displays the calculated “Length” and “DeltaZ” of the selected line. For more information on the data in the Tool status section (see *Tool status section* (page 203)).

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 203)).

13.5.6: Report group

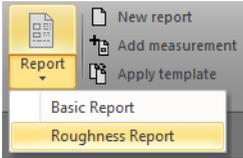


The Nanosurf Report software offers a powerful and extensive set of analysis functions. Complex analyses can be created interactively, and then displayed and printed in visually appealing reports. These reports can then be used as templates to consistently apply the same analysis to other measurements.

Report

The “Report” button starts the Report software (if installed) from within the 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

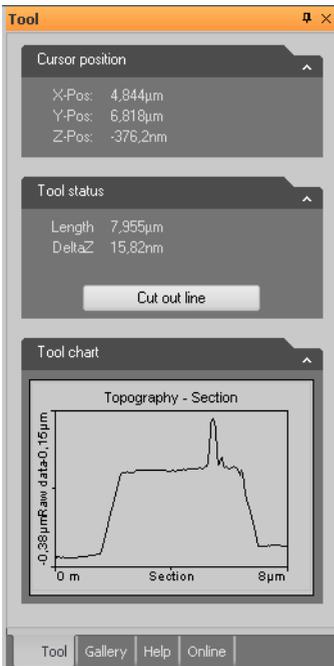
If you do not save the measurement in the control software, but only save the report, the data in measurement channels that were not displayed is lost.

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.

13.5.7: Scripting group

Please refer to *Section 10.5.2: Scripting group* (page 123).

13.6: Tool panel



The Tool panel of the Info pane displays varying information, which depends on the tool currently selected in the Analysis tab.

Cursor Position section

This section is always visible. It displays the mouse cursor position in the physical units of the selected chart.

Tool status section

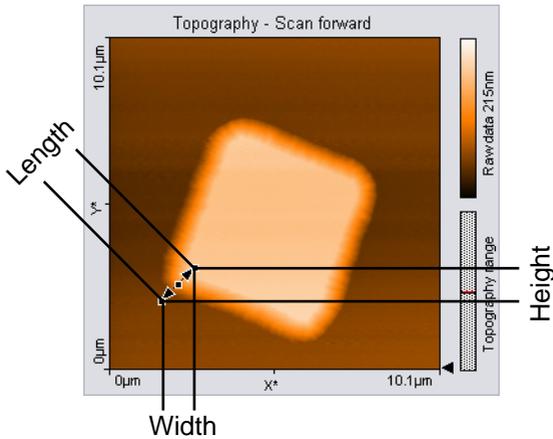
This sections appears when a tool is being used. It displays the evaluation result of the currently active tool.

The tools that require drawing a selection marker to define the evaluation have some common parameters that are described here. The other parameters are described in the sections that describe the respective tool (see above).

Length

The length of the selection marker in the plane of the chart. “Length” is related to the evaluation results “Width” and “Height” (see below) according to the formula:

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



In a Color map chart, length is calculated in the XY-Plane. In a Line graph chart, length is calculated in the XZ-Plane.

“Length” is not displayed when “Width” and “Height” are of different physical units (e.g. in Amplitude Spectroscopy, where the X-Axis is given in [m] and the Z-Axis in [V]).

Width, Height

The “Width” and “Height” of the measurement tool in the chart, calculated in the chart plane.

DeltaZ

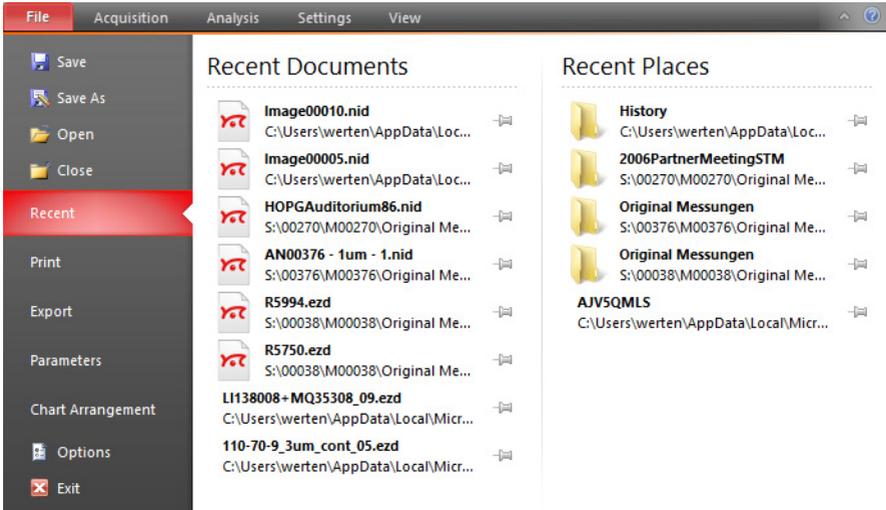
The difference between the “Z-Pos” values at both ends of the selection marker.

In a Color map chart, “DeltaZ” is the difference in the (filtered) sample height between the start and the end point.

Important

The calculated values of “Length”, “Width” and “Height” only depend on the cursor positions, they do not depend on the displayed data values.

13.7: File menu



The *File menu* is accessed by clicking the “File” tab at the left side of the Ribbon. It provides access to software related settings and options (see *Section 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 212).

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 13.5: Analysis tab* for details).

Plotfile ASCII (.plt)

This is an "ASCII" text format which contains the measured data as well as a small header with a description of the scan. A plotfile can be used for detailed data analysis by various mathematical software packages such as MathLab, or for plotting by software such as GnuPlot. Before being stored, the data is processed using the settings chosen in the Correction and Filter groups of the Analysis tab (see *Section 13.5: Analysis tab* for details).

If "Line graph" is selected as "Display" in the "Chart bar", only the visualized lines will be stored. Each data point is stored as a pair of floating point numbers on a separate line. The number pairs are separated by a blank character (SPACE).

If any other chart type is selected, all measured values are stored. All values in a data line are stored on a separate line in the text file. An empty line is inserted after every data line. The data lines are stored from the bottom to the top. A small header at the beginning of the first data line contains the names of the channel and frame, as well as X-, Y-, and Z-ranges with their physical units.

Comma separated z values (.csv)

This format stores all the measured data in a chart, as a matrix of floating point numbers in ASCII format separated by a "comma" and "SPACE" character. This enables easy data exchange with commonly used spread sheet and database applications.

(X, Y, Z)-Points (.csv)

This format stores the coordinates of all measured points in a chart as a list of floating point number pairs. For Line graphs, only X and Z points are exported.

Print

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.

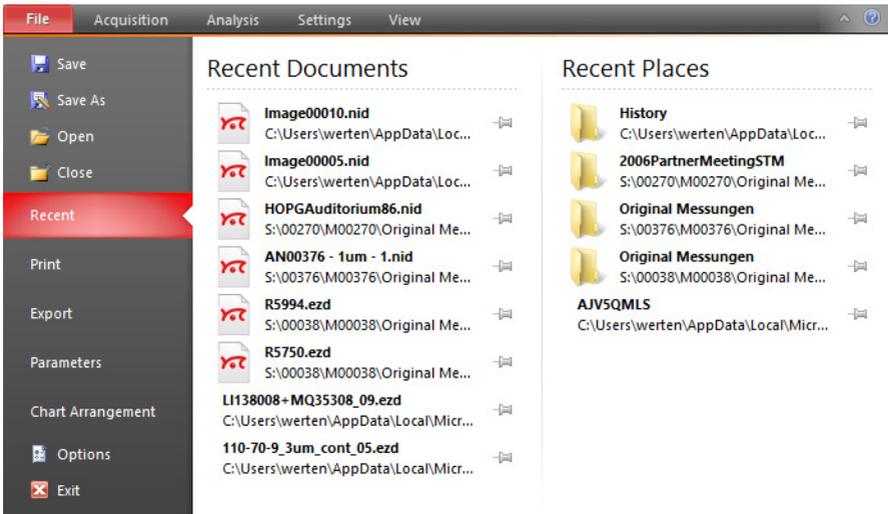
Exit

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 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 opening, storing and printing of measurements (explained in *Section 13.7: File menu* (page 205)), 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

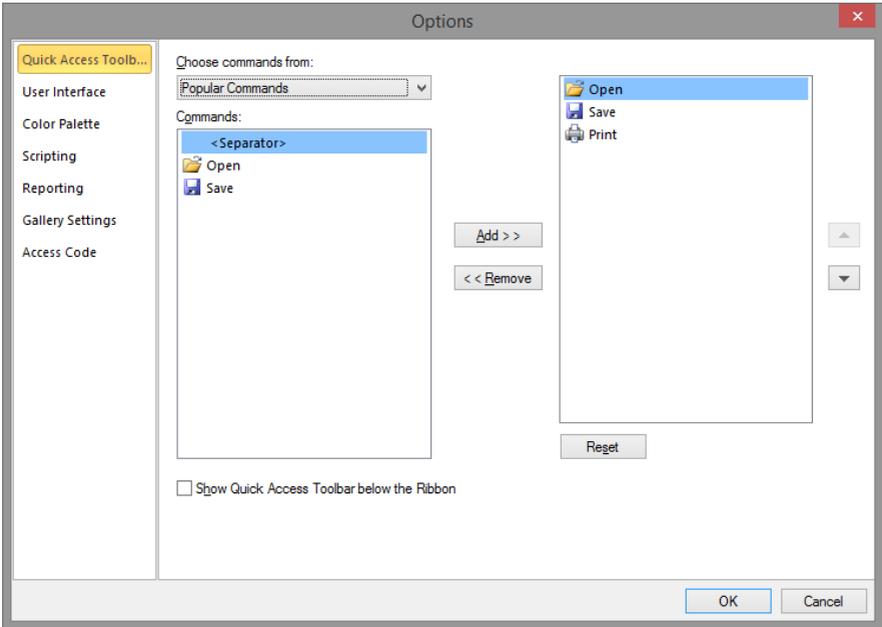
Saves the chart arrangement under a new file name.

Options

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

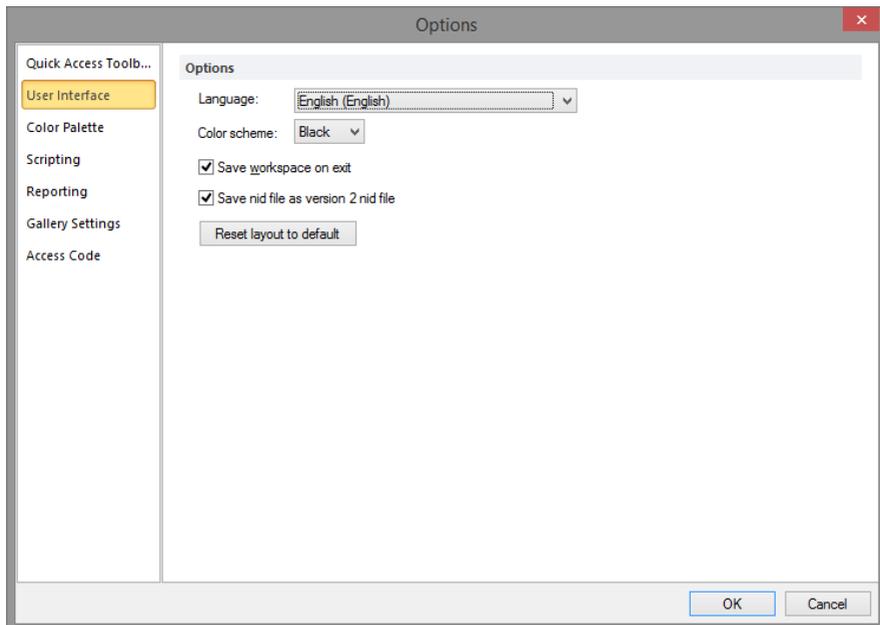
14.1.1: Options dialog

Quick access toolbar



Allows changes to the content of the Quick Access toolbar (see *Quick access toolbar* (page 205)). 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.

Save workspace on exit

When checked, the workspace settings are automatically saved to the system registry when the control software is closed (see also *Parameters* and *Chart arrangement* (page 211)).

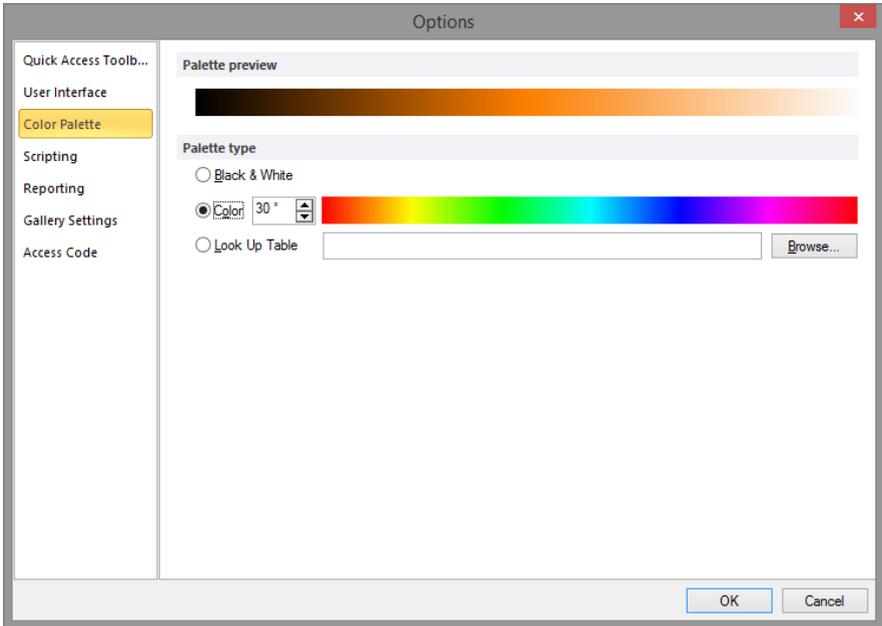
Save nid file as version 2 nid file

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.

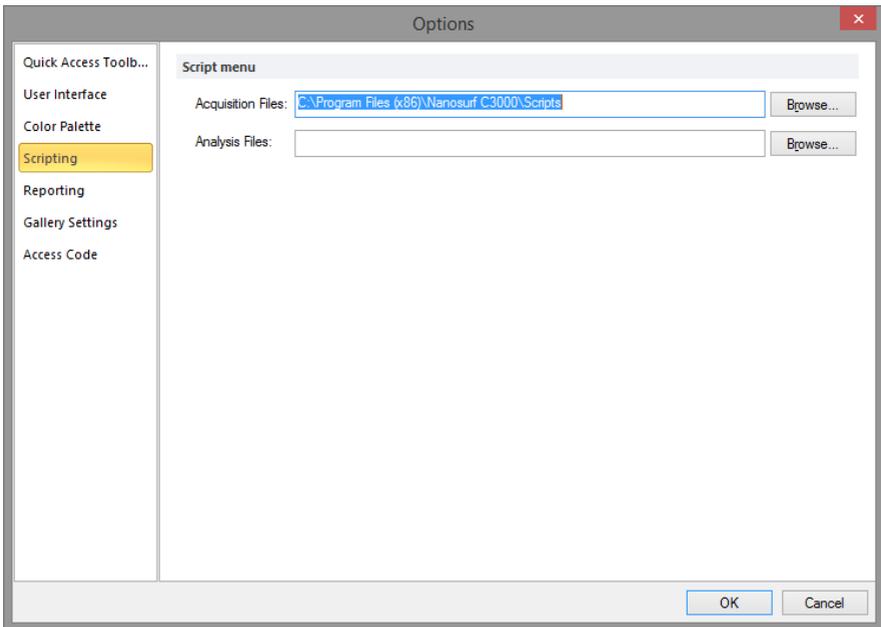
Color Palette



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.

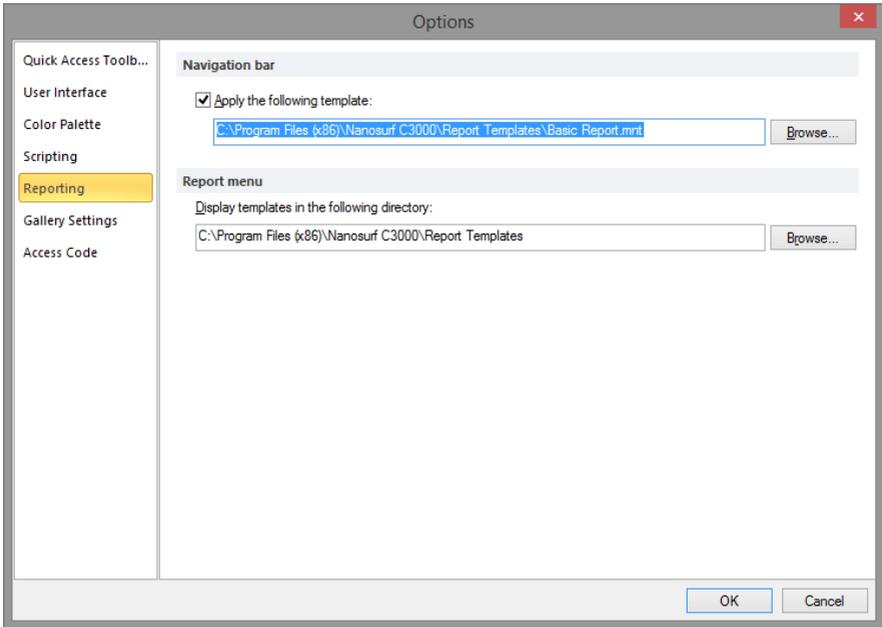
Scripting



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 191).

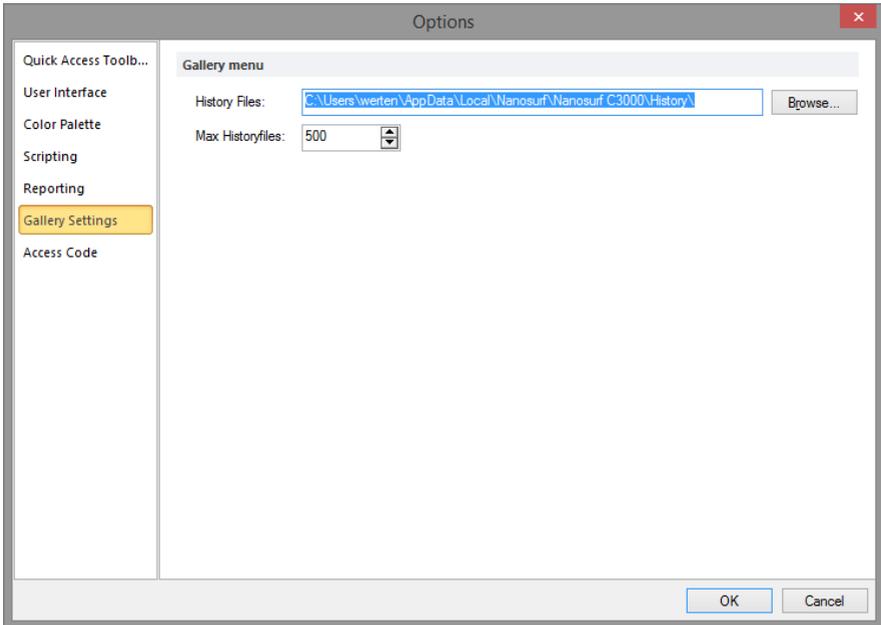
Apply the following template

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 215)), the content of the specified folder is displayed as choices in the Report drop-down menu.

Gallery settings



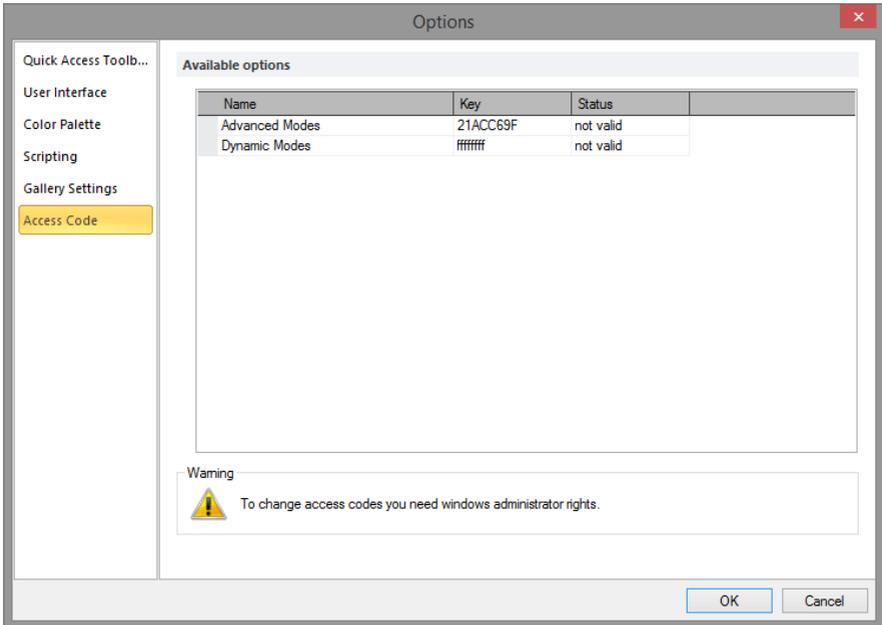
History folder

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 226).

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 practised 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.

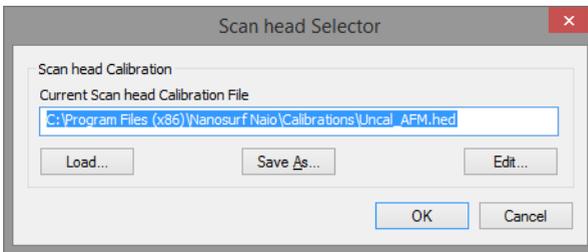
Show Log in Explorer

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.

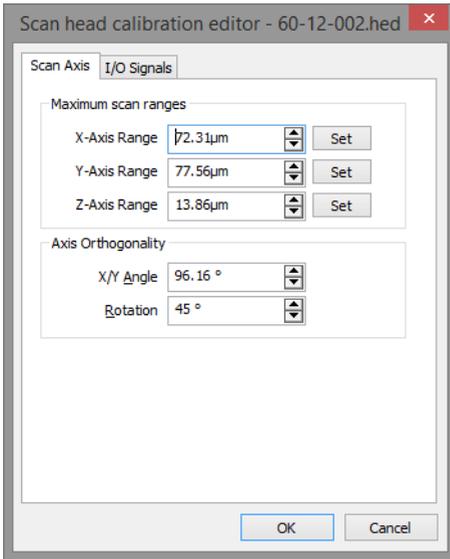
14.4: Scan head calibration editor dialog

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 225).

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.

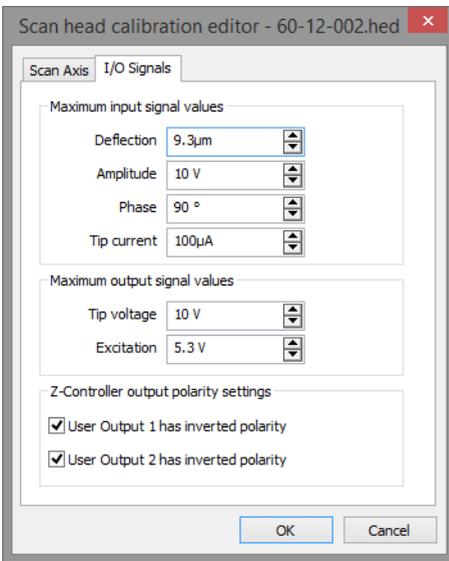
X/Y Angle

The angle between then the X- and Y-axis of the scanner hardware. The control software uses this value to correct the scan command signals such that the scan axes are orthogonal.

Rotation

The angle between the X-axis of the scanner and the X-axis of the microscope body (see *Figure 18-3: Scanner coordinate system* (page 250)). 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

Deflection

The calibration of the cantilever deflection signal. This calibration value is used to convert the AFM Detector Signal or the STM preamplifier signal (both in Volts) to physical units.

Important

Deflection sensitivity depends on laser alignment and cantilever length. Since 2013, this deflection sensitivity calibration is by definition the deflection sensitivity of a static mode, 440- μm long, 50- μm wide cantilever with the laser aligned at the end of the cantilever (measured with an XYCONTR cantilever). When using other cantilevers or older scan heads, the deflection in m and the force in N will not be correct, and should be calibrated.

Amplitude

The calibration value of the cantilever vibration amplitude signal.

Phase

The calibration value of the cantilever vibration phase shift signal.

Tip current

The calibration value of the controllers internal Tip current preamplifier sensitivity.

Maximum output signal values

Tip voltage

The calibration value of the Tip voltage setting.

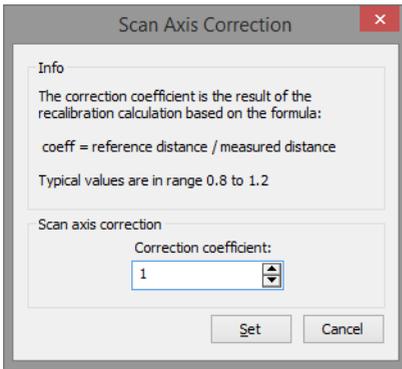
Excitation

The calibration value of the Amplitude of the signal that is used to excite the cantilever in dynamic force operating modes.

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.

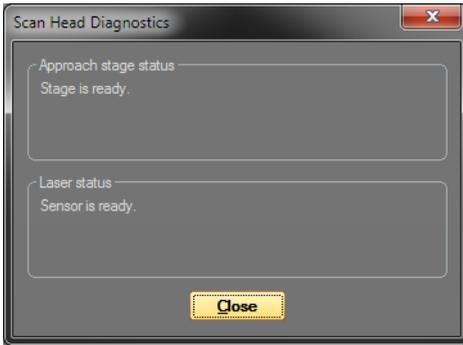
14.6: Scan Head Diagnostics dialog

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 AFM scan heads



Approach stage status

Status about the motorized approach stage is shown here.

Laser Status

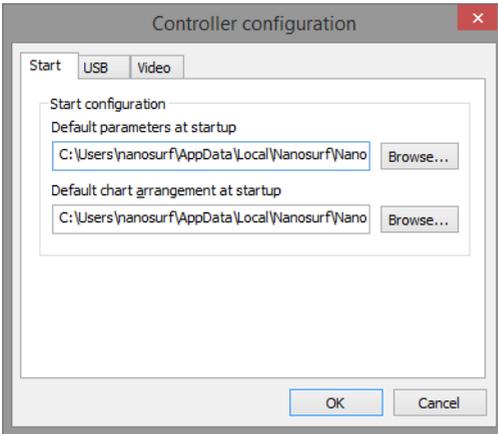
Status about the laser / detector system is shown here.

If the Status light on the NaioAFM controller in the Naio control software is blinking red, more detailed information about the failure is displayed here (see also *Section 17.3.1: Laser fail* (page 241)).

14.7: Controller configuration dialog

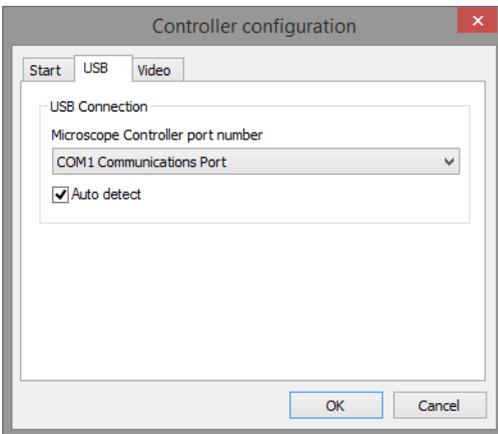
With this dialog some controller hardware related settings can be configured. On a correctly installed system, it should not be necessary to change these settings manually. The Controller configuration dialog is opened via the "Controller" button in the Hardware group of the Settings tab.

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



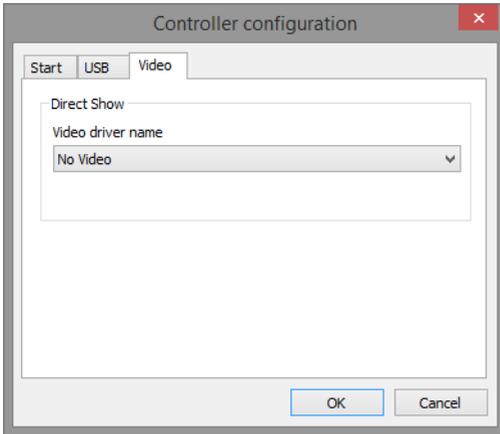
The NaioAFM controller uses a virtual serial port that is connected to the USB port. The number of this virtual serial port should be the same as the one shown in your the windows device manager dialog.

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

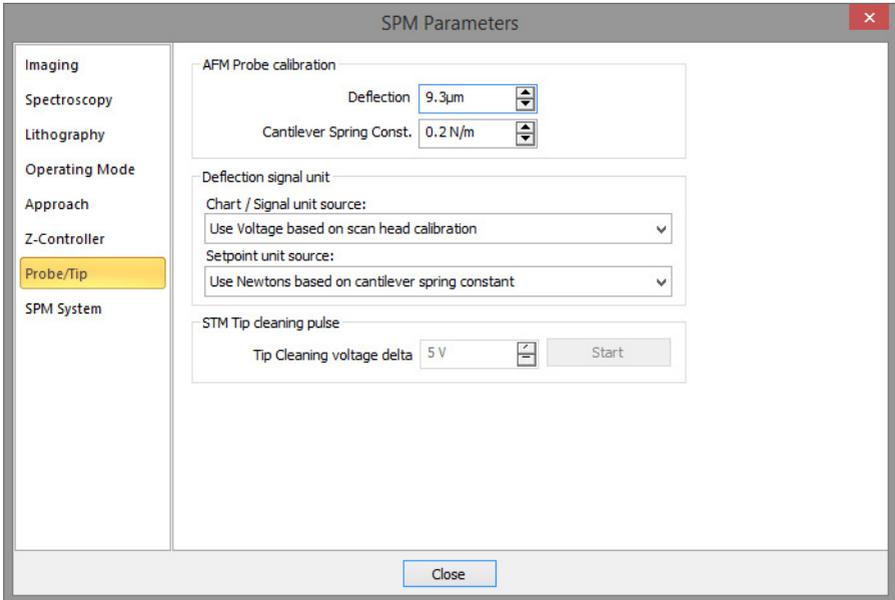


Allows selection of an additional video source to be shown in the video panel. The driver of the optional sideview camera is selected here.

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



AFM probe calibration

Deflection

This parameter should be set to the maximum cantilever deflection that can be acquired. The Sensitivity in m/V is equal to maximum Deflection / 10.V. The maximum deflection depends on the cantilever type and the position of the laser on the cantilever. The maximum deflection decrease (sensitivity increases) with cantilever length and with the distance between the laser spot and the fixed end of the cantilever.

A default value of Deflection is loaded when the scan head calibration file is loaded. This value is only correct for CONTR or XYCONTR cantilevers, depending on when the scan head was calibrated.

If you use a different cantilever than the default calibration (C3000 , or a different laser alignment), you should re-determine this value using deflection versus distance spectroscopy.

Cantilever spring const.

This value defines the spring constant of the selected cantilever, as used by the Naio control software for internal calculations. Its default value is taken from the currently selected cantilever's database entry (see *Section 8.9: Cantilever Browser dialog* (page 91)). Each time a new cantilever is selected, this value is overwritten to the default value of the newly selected cantilever. This default value may be not precise enough for very accurate force measurements. In such cases, you may overwrite it by a measured value (e.g. a calculated spring constant, based on a mechanical cantilever model and the resonance of the cantilever; refer to technical note TN00865 Determining the Cantilever Spring Constant from its Spectrum for other options to calibrate the spring constant).

Deflection signal unit

For all Static Force operating modes, it is possible to select different deflection signal units to be used for display in Charts/Signal values, and as used for the Setpoint. Three choices are available for each:

- **Use meters based on head calibration**
The deflection of the cantilever is displayed in meters. This is the default setting for Chart.
- **Use Newtons based on mounted cantilever's spring constant**
The deflection of the cantilever is displayed in Newtons in all charts. This is particularly useful for recording Force–Distance curves with the Spectroscopy Window. This is the default settings for SetPoint.
- **Use meters based on head calibration**
The deflection of the cantilever is displayed in Volt.

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 NaioAFM scan head

It is important to keep the open parts of the scan head clean. Therefore, always close the NaioAFM system and store it 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.

To clean the alignment chip when it has become dirty:

- ➔ Blow away dust using dry, oil-free air or use a soft brush.

CAUTION

When using a (compressed gas) air duster to clean the alignment chip on the NaioAFM scan head, be sure to place the DropStop and to only gently blow over the alignment chip rather than fully onto it. A failure to do so will result in strong air currents inside the scan head that could damage sensitive wires belonging to the scan head electronics!

16.3: The NaioAFM exterior

To clean the exterior of the NaioAFM 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 17:

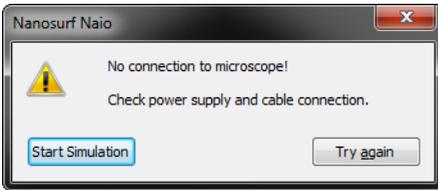
Problems and solutions

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 243).

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 NaioAFM is not connected to the mains power, or it is not turned on. In this case the power LED on the side of the NaioAFM 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 the 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 NaioAFM. In order to solve driver problems:

- ❶ Check for driver updates on the Nanosurf Support web site.
- ❷ Insert the installation CD for your instrument.
- ❸ Log in with Administrator privileges.

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

- ❶ Open the windows menu "Start" >> "Control Panel".
The control panel now opens.
- ❷ Select "Large icons" or "Small icons" if "View by" is set to "Categories".
- ❸ Double-click the "Device Manager" icon.
The device manager now opens.

When the device manager opens and your controller is connected to your computer, you may see the drivers shown in *Figure 17-1: Device manager* (information may vary depending on the configuration of your system).

If there are problems with any of these drivers, or a wrong driver is installed, you can try to do the following to fix this:

- ❶ Double click on the driver.
Properties dialog for the device now opens.
- ❷ Select the "Driver"-tab.
- ❸ Click the "Update Driver"-button
Windows will now ask you where to look for the driver.
- ❹ Instruct windows to manually search for the driver files on the Installation CD.

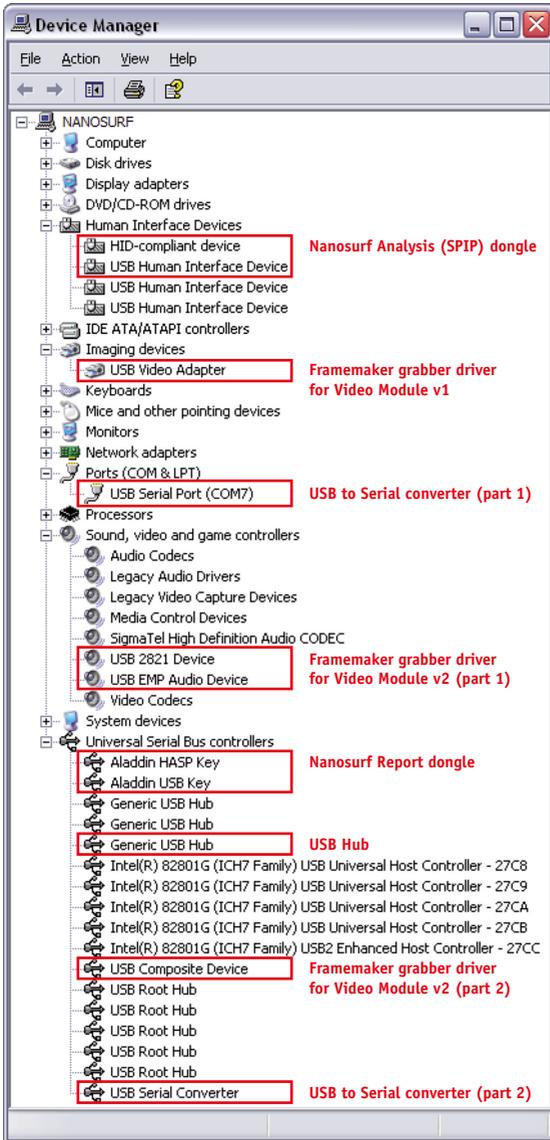


Figure 17-1: Device manager. The drivers that may be installed on your system when your controller is connected to the computer.

17.3: AFM measurement problems

17.3.1: Laser fail

Laser fail will occur when an insufficient amount of light reaches the detector of the cantilever deflection detection system. This can either be due to the DropStop still being closed or to a misaligned cantilever.

If the dropStop is still present:

- ➔ Remove it.

To check for a misaligned cantilever:

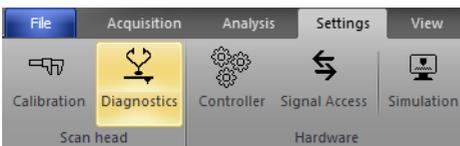
- 1 Open the scan compartment.
- 2 Make sure that the cantilever is lying perfectly in the alignment chip (for details, see *Figure 3-6: Cantilever alignment* (page 32)).

If the cantilever is not well-aligned, there may be dust between the cantilever and alignment chip. To correct this:

- A Remove the cantilever as described in *Section 3.3: Installing the cantilever* (page 27).
- B Blow away dust from the alignment chip and the back side of the cantilever using dry, oil-free air. Mount the cantilever again.

For further details on the status of the laser detection system, open the Scan Head Diagnostics dialog:

- 1 In the Scan Head group of the Settings tab, click the “Diagnostics” button:



The Scan Head Diagnostics dialog now opens.

- 2 Check the laser efficiency and position on the photodiode detector.

In some rare cases, the blinking of the Probe Status light may be caused by light from external sources reaching the photodiode detector. If this is the case:

- ➔ Turn off/down the external light source, or shield the scan head from its influence.

17.3.2: Automatic final approach fails

If the automatic approach fails, the Setpoint may either be too high, or the distance between tip and sample is larger than the maximum automatic approach range of the scan head. To solve these issues, try the procedures below (if necessary, try each and/or both procedures repeatedly until the automatic final approach is successful).

To check for a low Setpoint, repeat the approach as follows:

- ❶ In the Approach group of the Acquisition tab, click the “Home” button to fully retract the cantilever.
- ❷ Decrease the Setpoint by 5-10% (see *Z-controller section* (page 118)) and *Section 4.1.1: Entering and changing parameter values* (page 40) for details on how to do this).
- ❸ Repeat the automatic final approach as described in *Section 4.3.2: Automatic final approach* (page 44).

To check for a large tip-sample distance, repeat the approach as follows:

- ❶ In the Approach group of the Acquisition tab, click the “Home” button to fully retract the cantilever.
- ❷ While watching the side view of the cantilever, manually approach a bit further by pressing the “Advance” button.
- ❸ Repeat the automatic final approach as described in *Section 4.3.2: Automatic final approach* (page 44).

If both of these procedures do not solve the problem, check the status of the cantilever deflection detection system (*Section 15.6: Scan Head Diagnostics dialog* (page 270)) or try installing another cantilever.

17.3.3: Image quality suddenly deteriorates

Tip picks up material

When a scan line suddenly starts reproducing badly, the tip may have picked up some particles.

To get rid of these particles, follow the procedure below until the image quality improves:

- ❶ Continue measuring for a while (1–2 images), as the tip may eventually lose these particles again.
- ❷ In the Approach group of the Acquisition tab, click the “Withdraw” button to retract the cantilever, and then perform a new approach.

- ③ Try to induce changes in the tip end:
 - Ⓐ While measuring, increase the force “Setpoint”, or decrease the amplitude “Setpoint” in the Z-Controller section of the Imaging window.
 - Ⓑ Restore the Setpoint to its old value when the contrast improves, or if nothing happens after scanning several lines.
- ④ Change the cantilever if no improvement occurs after following the steps above.

Setpoint drift

When part of the scan line in the Line graph is drawn red, the tip has moved to its maximum or minimum Z-position. This should also be visible in the range display on the right hand side of the graph. The tip will move to its maximum Z-position when it has lost contact with the sample. To correct this:

- ① In the Static Force based modes, increase the force Setpoint, in the dynamic force based modes, reduce the amplitude Setpoint.
- ② If this does not help, retract and re-approach the tip.

17.4: Nanosurf support

17.4.1: Self help

The fastest way to solve a problem is often to solve it yourself. If the previously suggested actions did not help, or the problem is not described here, refer to the Nanosurf support pages:

- ① Open www.Nanosurf.com.
- ② Click on “Company” and “Support”.
- ③ Enter the login and password combination that you received upon registering.
- ④ Select the NaioAFM link.
- ⑤ If the problem is software related, try to upgrade to the latest version and/or read the “SPM software version history.pdf” file to see if the problem was solved. For the solution to other problems, refer to the frequently asked questions (FAQ).

If your instrument has not been registered yet, you will first have to register to receive a password.

17.4.2: Assistance

If the standard solutions are not sufficient, contact your local distributor for help. In order to resolve the problem as fast as possible, please provide as much information as possible, such as:

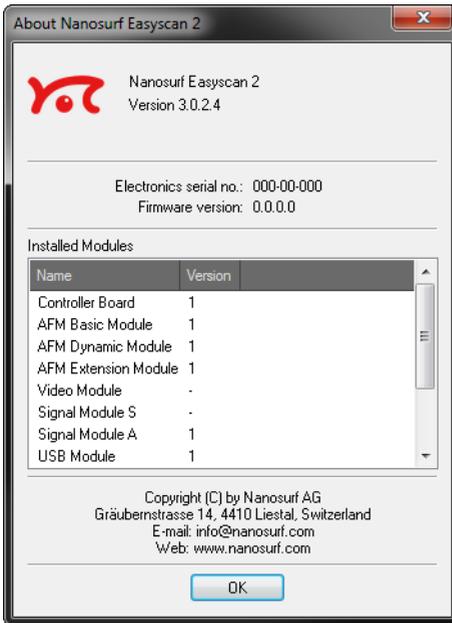
- A detailed description of what happened before the problem occurred. For example: “When I click the ‘Approach’ button, then quickly click abort, the controller will not react to anything I do anymore. This only happens when measuring in dynamic force mode.”
- If an error message was displayed: The exact text of the message, or at least the start of the message.
- The serial number of your scan head and/or controller.
- A description of the computer hardware and software on which the control software is running: computer brand, type (laptop or desktop), operating system, software version etc.
- Original Nanosurf image data (.nid) files that show the problem, rather than bitmap screen shots, because these files contain all the settings that were used to make them.
- Parameter (.par) files with the instrument settings that were used when the problem occurred.
- Script files, if the problem occurs during the operation of a script.

IMPORANT

Sending “.vbs” scripts by e-mail often does not work, because these files are usually blocked as a security measure. To successfully e-mail a script, you may either:

- Add the script text to the body of the e-mail.
- Change the extension of the script file to “.txt” and attach it to the e-mail.
- Compress the script file to a “.zip” archive and attach it to the e-mail.

17.5: About dialog



The About dialog displays information that may be useful for diagnostics when you have problems with your instrument. The About dialog is opened by clicking the “Information” button on the upper right corner of the program window, just below the “close window” button:



The About dialog contains the following information:

- The version number of the control software.
- The serial number of the controller (when the microscope simulation is active, the serial number “0xx-00-000” is displayed).
- The version number of the firmware that is running on the controller.
- The version number of all modules built into the controller.
- The version number of all installed software options.
- Contact information for getting more support.

CHAPTER 18:

AFM theory

18.1: Scanning probe microscopy

The NaioAFM is an atomic force microscope, which is part of the family of scanning probe microscopes. With the first scanning probe microscope, the scanning tunneling microscope (STM), it became possible to look into the fascinating world of atoms. The STM was developed by Gerd Binnig and Heinrich Rohrer in the early '80s at the IBM research laboratory in R schlikon, Switzerland. For this revolutionary innovation, Binnig and Rohrer were awarded the Nobel prize in Physics in 1986.

However, the STM technique is restricted to electrically conducting surfaces. An extension of this technique, called the Atomic Force Microscopy (AFM), was developed by Gerd Binnig, Calvin Quate and Christoph Gerber. The AFM also allowed insulating materials to be analyzed. Both the AFM and the STM microscopy techniques work without optical focusing elements. Instead, a small sharp probing tip is scanned very closely across the sample surface. The distance between the tip and the sample surface is so small that atomic-range forces act between them. In an AFM, a tip is attached to the end of a cantilever in order to measure these forces. The force acting on the tip can then be determined by detecting the deflection of this cantilever (see *Figure 18-1: Cantilever*).

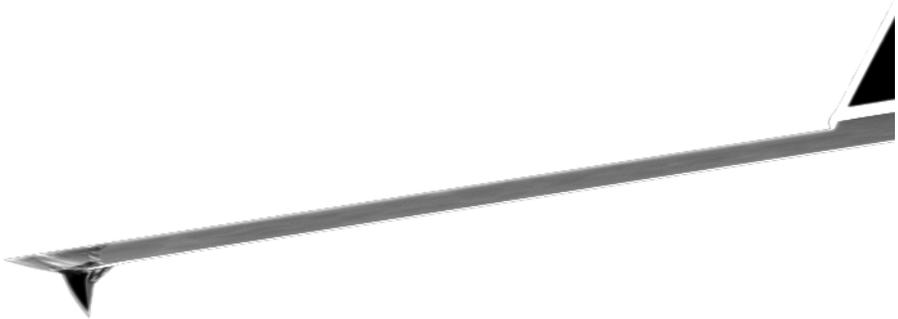


Figure 18-1: Cantilever. 228 μm long micro-fabricated silicon cantilever with integrated tip.

The measurement of the cantilever deflection can be used to control the tip–surface distance on an atomic scale. Thus, enormous resolution can be achieved, so that even the atomic arrangement of surfaces can be probed. This measurement is a so-called static operating mode, in which the static deflection of the cantilever is used. Generally, the forces acting on the tip will cause it to snap onto the sample, which result in an effective, nanometer-range flattening of the tip, and friction and stiction between the tip and the sample.

To circumvent the aforementioned problems, the so-called dynamic force microscopy modes can be used, as was pointed out by the AFM inventors. In these modes, the cantilever vibrates during the operation. In the dynamic modes, changes in the free

resonance frequency and the damping of the cantilever vibration caused by the forces between the tip and the cantilever can be measured and used to regulate the tip-sample distance.

To achieve atomic resolution, ultra-clean and flat surfaces prepared in highly sophisticated vacuum systems are needed. Nevertheless, measurements in air can give useful results for many technically relevant surfaces. In this manual, the use of the dynamic modes in air on such surfaces is described.

18.2: The NaioAFM

The NaioAFM is an AFM that can be used in both static and dynamic operating modes. The AFM cantilever is a microfabricated cantilever with an integrated tip mounted on a cantilever holder chip.

When the sensor tip comes in contact with the sample, a repulsive force that increases with decreasing tip-sample distance acts on it. In the static force operating mode, the bend of the cantilever, due to the force acting on its tip, is measured using a cantilever deflection detection system.

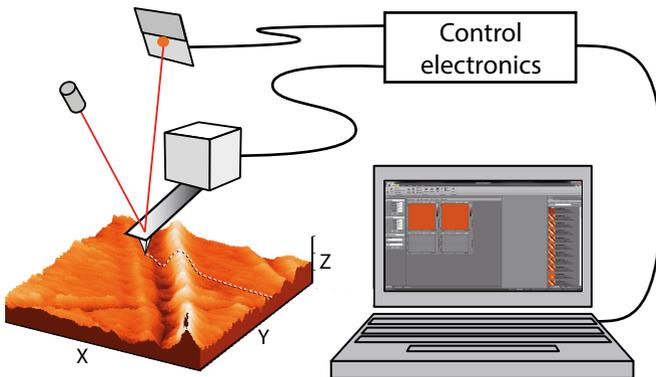


Figure 18-2: SPM system. Cantilever with deflection detection system scanning the sample. The sample is visualized on a computer with installed scan software, which also directs the scan itself.

In dynamic operating modes, the cantilever is excited using a piezo element. This piezo is oscillated with a fixed amplitude at an operating frequency close to the free resonance frequency of the cantilever. The repulsive force acting on the tip will increase the resonance frequency of the cantilever. This will cause the vibration amplitude of the cantilever to decrease. The vibration of the cantilever is also detected using the cantilever deflection detection system.

The measured laser beam deflection or cantilever vibration amplitude can now be used as an input for a feedback loop that keeps the tip-sample interaction constant by changing the tip height. The output of this feedback loop thus corresponds to the local sample height.

An image of the surface is made by scanning over the sample surface in the X and Y direction. The sample structure image is now obtained by recording the output of the height control loop as a function of the tip position. The direction of the X- and Y-axes of the scanner is shown in *Figure 18-3: Scanner coordinate system*. The scanner axes may not be the same as the measurement axes, when the measurement is rotated, or the measurement plane is tilted. Therefore, the image X- and Y-axes are denoted by an asterisk (i.e. X*, Y*).

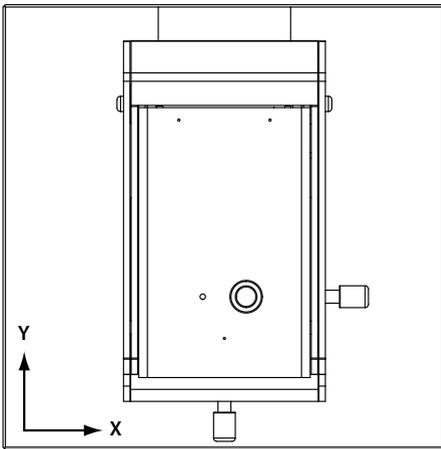


Figure 18-3: Scanner coordinate system

CHAPTER 19:

Technical data

19.1: Introduction

The specifications given in this chapter represent typical values of the Nanosurf NaioAFM system. The exact specifications of all components belonging to your system are given on the calibration certificate delivered with the instrument.

19.2: The NaioAFM

19.2.1: Specifications and features

NaioAFM Specifications and Features	
Max. scan range / scan height (resolution) ⁽¹⁾	70 μm (1.0 nm) / 14 μm (0.2 nm)
Static / Dynamic RMS Z-noise	typ. 0.4 nm (max. 0.8 nm) / typ. 0.3 nm (max. 0.8 nm)
Max. sample size / height	12 mm / 3.5 mm
Max. sample stage positioning range	12 mm travel in each direction (6 mm from center to all sides)
Top view camera	3×3 mm FOV, 4× digital zoom, 2 μm optical resolution, 2048×1536 pixels, in-axis LED illumination
Side view observation	5×5 mm FOV, variable LED illumination (with optional side view camera: 2×2 mm FOV, 1280×1024 pixels)
Approach	4 mm linear motor, continuous or step-by-step approach
Imaging modes	Static Force, Dynamic Force, Phase Contrast, MFM, EFM
Advanced imaging modes ⁽²⁾	Spreading Resistance, Force Modulation
Spectroscopy modes	Force–Distance, Amplitude–Distance, Voltage–Distance
Advanced spectroscopy modes ⁽²⁾	Current–Voltage, Stop by end value, Fwd & Bwd pause

(1) Manufacturing tolerances are $\pm 10\%$

(2) Naio Advanced Modes Option required

Cantilevers used in conjunction with the NaioAFM should have the following properties: (i) Grooves that are compatible with the alignment chip used by Applied Nanostructures, BudgetSensors, NanoSensors, NanoWorld, and VISTAprobes, (ii) a nominal length of 225 μm or more, and a width of 40 μm or more, (iii) a coating on the backside of the cantilever that reflects (infra)red light.

NaioAFM Specifications and Features (Forts.)	
Lithography modes	Static Force, Dynamic Force, Oxidation
Advanced lithography modes ⁽²⁾	Draw and load CAD vector graphics, Bitmap images
Remote control/add-ons ⁽²⁾	Windows scripting interface: compatible with LabView, C#, Visual Basic, MatLab, and other software...
Operating system/PC requirements	Windows XP/Vista/7 (32/64-bit), 1280x1024 pixels screen resolution, Core2 CPU, 4 GB RAM, 1 free USB 2.0 port
Tip voltage	± 10 V (in 5 mV steps)
Tip current measurement ⁽²⁾	± 100 μ A (3 nA resolution)
Dynamic frequency range	15–500 kHz (0.1 Hz resolution)
Phase contrast range	$\pm 90^\circ$ (0.05° resolution)
Phase reference range	0–360°
Size (LWH) / Weight / Power	204x204x160 mm / 6.5 kg / 100–240 VAC (30 W)

(1) Manufacturing tolerances are $\pm 10\%$

(2) Naio Advanced Modes Option required

Cantilevers used in conjunction with the NaioAFM should have the following properties: (i) Grooves that are compatible with the alignment chip used by Applied Nanostructures, BudgetSensors, NanoSensors, NanoWorld, and VISTAprobes, (ii) a nominal length of 225 μ m or more, and a width of 40 μ m or more, (iii) a coating on the backside of the cantilever that reflects (infra)red light.

19.2.2: Dimensions

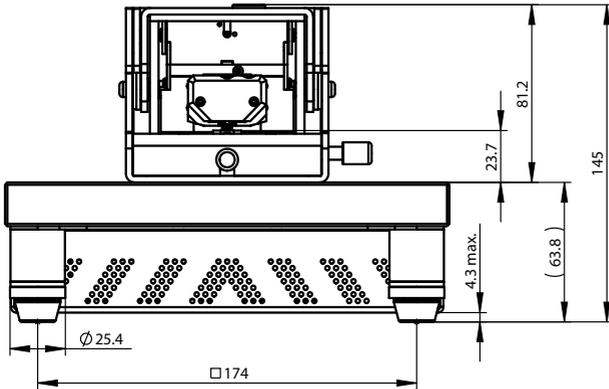


Figure 19-1: The Nanosurf NaioAFM. Front view. All dimensions in mm.

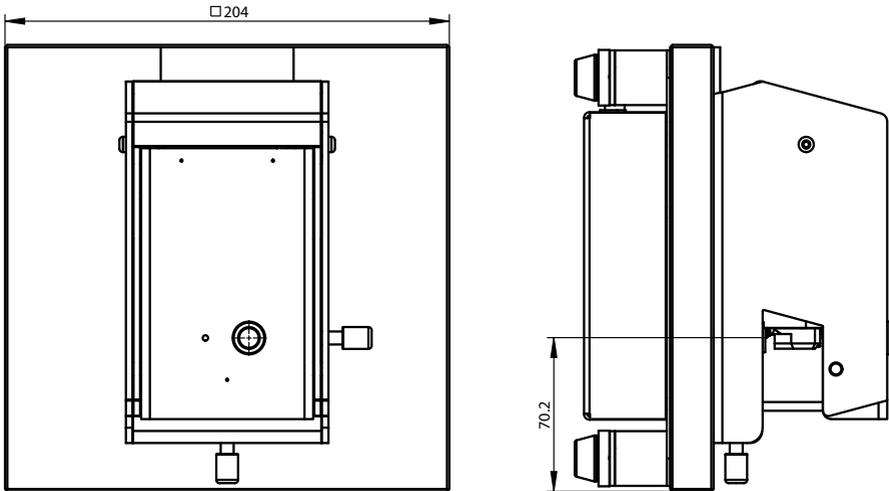


Figure 19-2: The Nanosurf NaioAFM. Top and side view. All dimensions in mm.

19.2.3: Cantilever requirements and considerations

Many commercial cantilever types are compatible with the NaioAFM scan head, but there are some requirements with regard to *Light reflection* and *Alignment* that must be met (see

below). If the cantilever type that you wish to use does not meet these requirements, please contact your local distributor or Nanosurf Support to see if a similar, compatible cantilever can be found.

Light reflection

Reflective coating

The cantilever should have reflective coating to prevent optical interference between light reflected from the cantilever and light reflected from the sample.

Width

The top width should be 40 μm or more (please distinguish between mean width specified by most manufacturers and the actual top width of trapezoid-shaped cantilevers).

Alignment

Alignment grooves

The used cantilever must have alignment grooves (available from Applied Nanostructures, Budgetsensors NanoSensors, NanoWorld, TeamNanotec Aspire, VISTAprobes)

Tip position

The scan head should always have the tip aligned to the same position. Cantilever manufacturers have used two alignment strategies: to keep the tip-end of the cantilever aligned or to keep the fixed end of the cantilever aligned. For 220- μm long cantilevers, both strategies will work. Applied Nanostructures (and Team Nanotec Aspire) cantilevers always have tip-alignment. Nanosensors and Nanoworld cantilevers only have tip alignment for XY-type series.

Without XY alignment, cantilevers longer than 220 μm will work, but with the deflection range increased by a factor 1.5. Shorter cantilever will not work, because the laser will not hit the cantilever.

Important

Never put a grooveless cantilever in the AFM. The cantilever would damage the alignment chip. In addition, the cantilever will probably not be in the focal plane of the laser beam, thereby causing large interferences.

Resonance frequency

Scan head sensitivity slowly decreases at frequencies above 100 kHz, thus the use of cantilevers with resonance frequencies above 200 kHz becomes impractical.

C3000 signal I/O option	
Clock input	<ul style="list-style-type: none"> • Input for an external digital clock (10 MHz, ± 1 V) • Synchronization of internal Lock-In, PLL, function generators
Analog inputs	<ul style="list-style-type: none"> • 2 user inputs for imaging and spectroscopy
Analog outputs	<ul style="list-style-type: none"> • 2 user outputs for spectroscopy modulation, Z-control, etc.
Digital sync	<ul style="list-style-type: none"> • 2 digital outputs for synchronization

Table 19-1: C3000 signal I/O option

C3000 stage control option	
Drivers	<ul style="list-style-type: none"> • Direct control for all supported stage controllers
Manual move	<ul style="list-style-type: none"> • Via buttons in the C3000 control software
Batch manager	<ul style="list-style-type: none"> • Automated movement via position list and scripts

Table 19-2: C3000 stage control option

C3000 PFM work package
<p>Extends the advanced modes option with the Piezoresponse force microscopy (PFM) mode through a special user interface. In addition to the standard signals, amplitude and phase of the piezo response signal can be measured during imaging and spectroscopy</p>

Table 19-3: C3000 PFM work package

19.2.4: Compatible Options and Accessories

NaioAFM Side View Camera

Allows convenient display of the side view in the Naio control software, alongside the already integrated top view.

Naio Advanced Modes Option

Adds advanced imaging modes, advanced spectroscopy modes, advanced lithography modes, and remote controls/add-ons to your NaioAFM system (see *Section 19.2.1: Specifications and features*).

Isostage Adapters for Naio

Allow the NaioAFM to be effectively mounted onto the Nanosurf Isostage, thus providing optimal vibration isolation.

AFM Extended Sample Kit

Provides 10 samples from various disciplines for AFM courses and classes.

