

Abbreviated AFM manual

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1. Atomic force microscopy

The AFM microscopy technique works 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 (figure 1). The force acting on the tip can then be determined by detecting the deflection of this cantilever.



Figure 1: Cantilever. 228 μm long 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, nanometre-range flattening of the tip, and friction and stiction between the tip and the sample.

To circumvent the aforementioned problems, we will use the AFM in so-called dynamic mode. In this mode, the cantilever vibrates during the operation. Changes in the free resonance frequency and the damping of the cantilever vibration caused by the forces between the tip and the cantilever are measured and used to regulate the tip–sample distance.

In dynamic mode, 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 (figure 2).

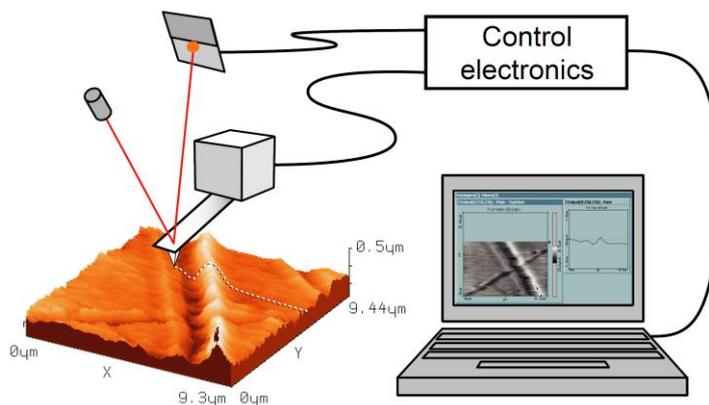


Figure 2: SPM system. Cantilever with deflection detection system scanning the sample. The sample is visualized on a computer with installed scan software, which also directs the scan itself.

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.

2. Mounting a sample

To mount a sample onto the Sample Holder:

1. Put a double-sided adhesive tape on the front side of a Post-it note, so that it is on the opposite side of the sticky part.
2. Cut off all parts of the note that do not have adhesive tape on it.
3. Fix the tape-side of the prepared note to the Sample Holder.
4. Put the sample on the sticky side of the Post-it note, and press on it lightly.

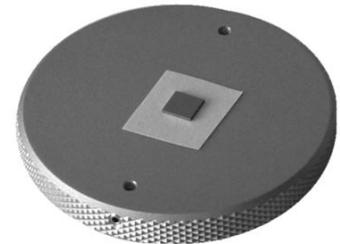


Figure 3: Sample mounted onto the Sample Holder

The result should resemble figure 3.

3. Initializing the easyScan 2 Controller

To initialize the easyScan 2 controller:

1. Make sure that the easyScan 2 controller is connected to the mains power, to the scan head and to the USB port of the control computer.
2. Turn on the power of the easyScan 2 controller.
First all status lights on top of the controller briefly light up. Then the Scan Head lights and the lights of the detected modules will start blinking, and all other status lights turn off.
3. Start the Nanosurf easyScan 2 Control Software on the control computer.
The main program window appears, and all status lights are turned off. Now a Message “Controller Startup in progress” is displayed on the computer screen, and the module lights are turned on one after the other. When initialization is completed, a Message “Starting System” is briefly displayed on the computer screen, and the Probe Status light, the Scan Head status light of the detected scan head, and the Module lights of the detected modules will light up. If no scan head is detected, both Scan Head Status lights blink

4. Positioning the sample under the AFM

IMPORTANT

Never touch the cantilever! The cantilever and the tip are made of silicon which is extremely brittle. The slightest touch will break it. Tips are expensive and it might cost half an hour to replace one. Be extremely careful when you move the sample holder under the tip. Make sure the tip is at least 1.5 mm above the sample when you move the sample holder.

See figure 4.

- Place the Sample Holder on the Sample Stage. The Sample Holder is magnetic so it will stick onto the Sample Stage.

- Use the three levelling screws to raise the Scan head so that the cantilever is at least 5 mm above the sample on the Sample Holder.
- Position the sample under the tip of the AFM by sliding the Sample Holder over the Sample Stage.

5. Loading parameter values

1. Open the menu item File >> Parameters >> Load..., and load the file AFM ST222.par from the directory D:\Nanosurf\Configuration.
2. Open the menu item File >> Chart Arrangement >> Load..., and load the file AFM ST222.chart from the directory D:\Nanosurf\Configuration.



Figure 4: The easyScan 2 AFM Scan Head on its Sample Stage

6. Approaching the sample

To start measuring, the cantilever tip must come within a fraction of a nanometre 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 three steps: Manual coarse approach, Manual approach using the motorized approach stage, and the Automatic final approach.

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 lens of the scan head to judge the distance between tip and sample surface.

6.1. Manual course approach

In this step, the sample surface is brought within the range of the motorized approach stage of the Scan Head. To perform a manual coarse approach:

- Use the three levelling screws to lower the Scan head so that the cantilever is within 1–2 mm of the sample. Take care that the Scan head remains parallel to the sample surface by approximately turning all screws equally and using the accompanying level.
- The side view should now look as shown in figure 5. When the sample is reflective, the mirror image of the cantilever should be visible. When the sample is not reflective, the shadow of the cantilever may be visible. If neither a mirror image nor a shadow is visible, change the environment light until it is. You can use the cantilever as a ruler to judge distances in the views of the integrated optics.



Figure 5: Side view of sample and cantilever after manual coarse approach.

6.2. Manual 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 the side view of the integrated optics.

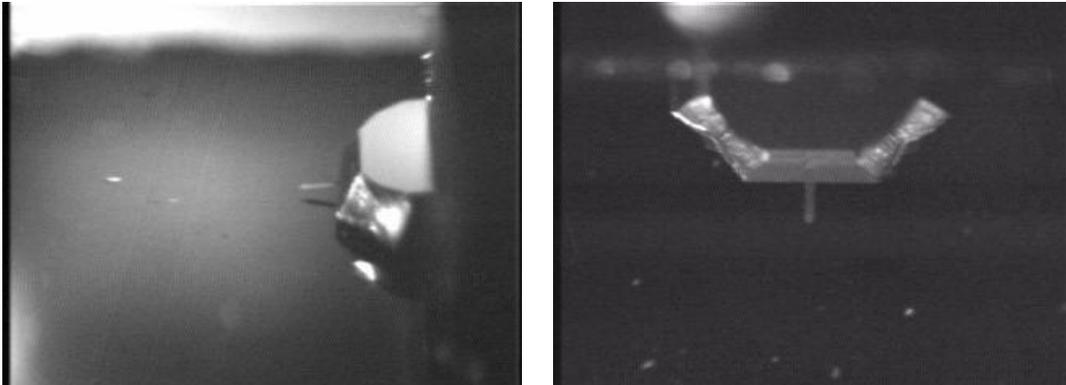
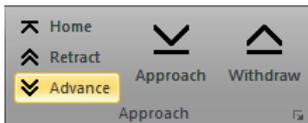


Figure 6: View of sample and cantilever after manual approach using the motorized approach stage. (Left) side view, (Right) top view.

2. 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 (figure 6, left).

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 9, right).

- Use the top view lens to observe the sample. If necessary, move the Sample Holder to find a suitable location that is free of dust particles. **Note that if the sample touches the tip while repositioning, the tip will be destroyed.** Therefore, because a sample is never completely level, only small corrections of the position are allowed. Before larger corrections, first raise the tip at least 1.5 mm above the surface of the sample.

6.3. Automatic final approach

In this last step, the tip automatically approaches the sample until a given Setpoint is reached.

Once the automatic final approach is started, the colour of the Status light on the controller shows the current status of the approach:

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

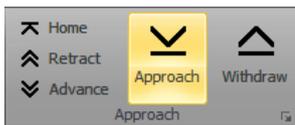
– **Red**

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

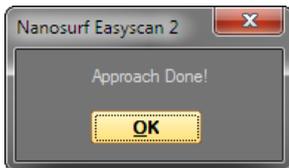
– **Green**

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

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.

7. Starting a measurement

Now that the tip–sample interaction defined by Setpoint is established between tip and sample, measurements can start. By default, the instrument is set to automatically start measuring after the automatic approach. If this is not the case start measurements manually by clicking the “Start” button in the Imaging group of the Acquisition tab.

Two representations of the on-going measurement are drawn in the Imaging panel. One representation is a colour coded height image (Topography) called a Colour map. The other is a plot of height as a function of X position called a Line graph. With the current settings, the software automatically adjusts the contrast of the Colour 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 micrometre/nanometre 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.

The parameters of the scan may be changed during scanning. Scanning will automatically restart with the new parameters.

- With the loaded parameters, the time per line is 0.5 s and the number of points is 128. This is suitable for a fast exploratory scan. For a final scan, adjust these parameters to 1 s per line and 256 points per line.

8. Image quality deteriorates

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:

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

If no improvement occurs after following the steps above, refer to the instructions in the easyScan 2 AFM Operating Instructions manual (Chapter 9: Problems and solutions, page 99).

9. Storing a measurement

By default, each completed measurement is temporarily stored (automatically) in the directory D:\Nanosurf so that it can be used later. Additionally, you can also take snapshots of measurements still in progress. To do this click the “Capture” button in the Chart bar.

Stored measurements will show up in the History page of the Gallery panel. Measurement documents in the temporary History folder should always be moved to a new location (and preferably renamed) for permanent storage when you are done measuring.

10. Finishing measurements

Once you are done measuring:

1. In the Imaging group of the Acquisition tab, click the “Stop” button to stop measuring.
2. Retract the cantilever to a safe distance from the sample by clicking the “Home” button and waiting for the automatic full withdraw process to finish.
3. Remove the sample holder from the sample stage while taking care that you don't touch the cantilever.
4. Remove the sample from the sample holder.

11. Turning off the instrument

To turn off the instrument:

1. Exit the Nanosurf easyScan 2 Control Software.
2. Turn off the power switch on the controller.
3. Remove the cable from the Scan head.
4. Store the Scan head in the Scan head case.

12. Using the Gwyddion software for visualization and processing of images

1. Start the Gwyddion program.
2. Open a measurement file (.nid file extension).

3. Display a 3D view of the data by clicking the corresponding icon in the View pane of the main window.
4. Use the controls in the window of the 3D view to adapt the view: rotation, scaling, colours, labels etc.
5. Process the data by clicking the function icon in the Data Process pane of the main window. Two much used functions are:
 - Level data by mean plain subtraction
 - Correct lines by matching height median.Use Ctrl+Z and Ctrl+Y to undo or redo applied functions.
6. The 3D image can be saved by clicking the Save icon in the window of the 3D view. The file extension you enter determines the file format: .png, .gif, .jpg or .bmp.
7. Height differences and distances can be measured in the window of the 2D view by clicking the corresponding icon in the Tools pane of the main window:
 - Read value under mouse cursor
 - Measure distances and directions between points.
8. The 2D image can be saved by clicking File >> Save As... in the main window. The file extension you enter determines the file format: .png, .jpg or .bmp.