ANFATEC SCAN – THE IMAGE ACQUISITION

The Anfatec scan software is designed for various applications. It is initialization file based (description of sxm-ini in Appendix 1). All user settings are saved during work and reload when the program is opened again.

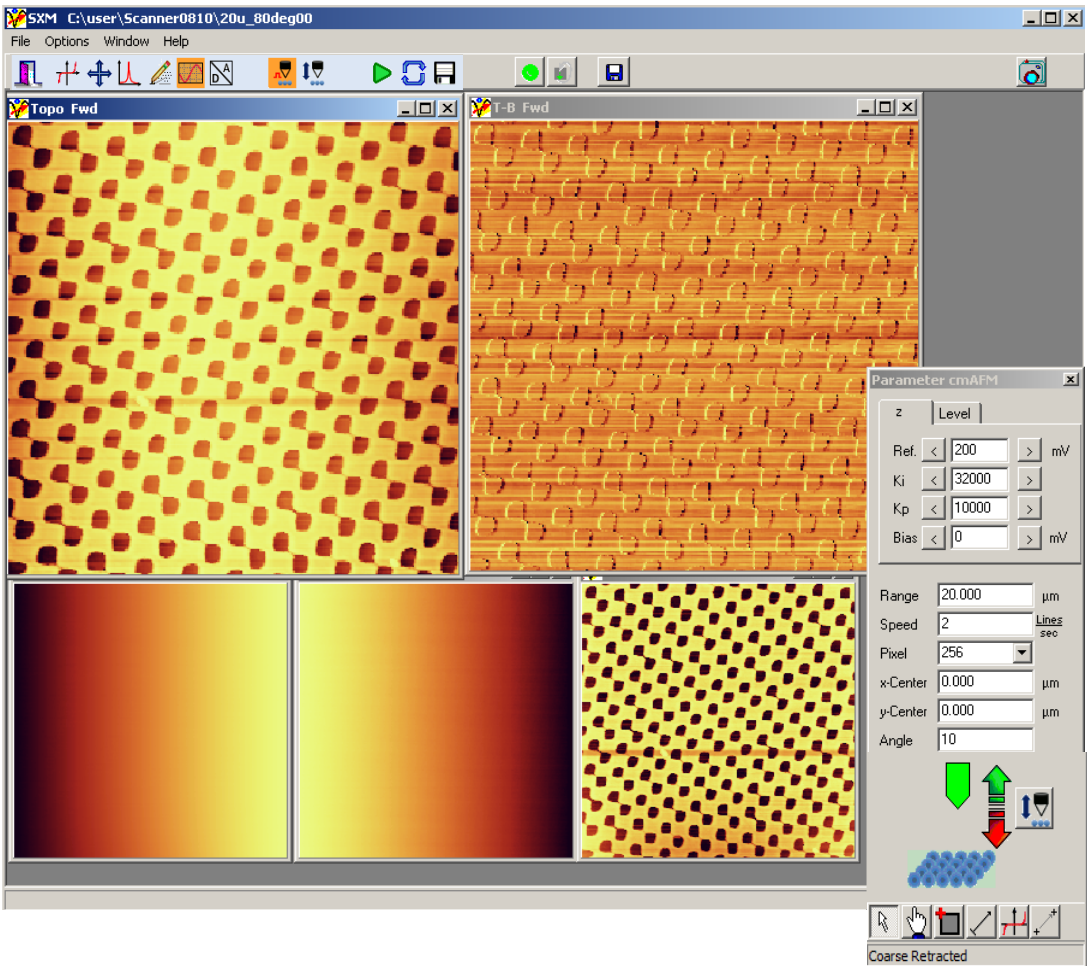
In order prepare the program for different applications (e.g. Different experiments in students education), the program can be stored in several directories with separate initialization files or ini-files can be saved to keep settings stored.

Note: all parameter inputs into the program has to be confirmed with ENTER. Wrong number, which can be detected automatically, are marked in red and comments explain what's wrong.

1 Quick-Start for Anfatec Scan

Start the program

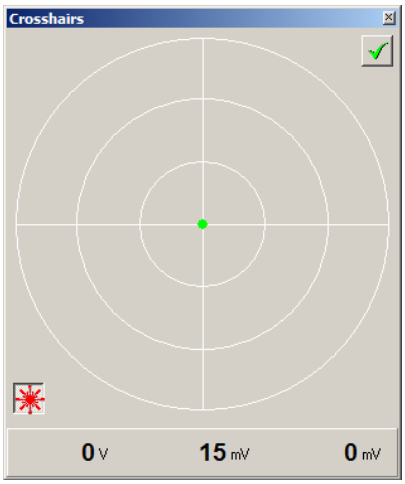
Double click on the sxm-icon. Each start of program restarts the SPM-controller. Therefore it is important, that the power supply of the controller is switched on before the program is started.



When started, the last opened scan windows and the parameter windows are shown.

For everyday use, all necessary channels are already open. For special experiments, you can store the settings (sxm.ini) in a separate file (mysetup.ini) and call the program from the desktop with the option of this filename (case sensitive!): ' "...\sxm.exe" mysetup'.

Adjust your system (AFM only)



- ✗ Adjust the laser on the cantilever
- ✗ Open the crosshairs window (see page 18)
- ✗ Adjust the laser onto the photo detector

The cross hair window shows the position of the laser beam on the photo detector. The "x-value", "y-value" and "intensity" give an idea about the real position. The displayed position can be scaled with the gain knobs.

"Laser" switches the voltage supply for the AFM laser on and off.

The colour of the dot represents the intensity. If the intensity increases, the dot gets green. If the intensity reduces, the dot gets red. Constant intensity is displayed as black dot.

Find the Cantilever resonance (Dynamic AFM only)

- ✗ Open the DNC window
- ✗ Take spectrum
- ✗ Zoom in until the resonance is clear
- ✗ Click into the spectrum to set the set-point for the feedback

Search for setpoint

- ✗ Open the oscilloscope
- ✗ Display the input channel (It for STM, T-B for contact AFM, 'Amplitude' for dynamic modes)
- ✗ Read value (mean value in the oscilloscope)
- ✗ Set the setpoint to a suitable value

For other modes see the hints on page 4.

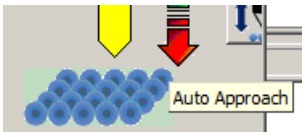
Approach

a) manual approach: (not for the Level- AFM)

- ➢ Start the approach button
- ➢ Approach while checking z-position
- ➢ If the system thinks, approach is done and a sound is given.
- ➢ Adjust the z-position in the central z-range

b) automated approach:

This function works only, if a z-translation for the coarse movement is installed. Use the AutoApproach button.



Check approach:

Check force distance curve (1 nm to 20 nm distance dependence) with Spectroscopy Window.

Set feedback parameters

Set Ki as high as possible. Ki is too high, if the tip starts to oscillate. Kp does not really matter for AFM measurements, but you might set it to a value close to Ki.

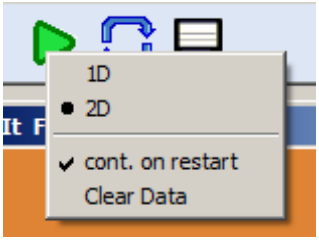
dynamic AFM:

If the tip does not stop to oscillate in dynamic AFM: increase the drive (set setpoint to maximum = soft-retract, increase drive, check free amplitude, set the setpoint to new value).

Acquire Images

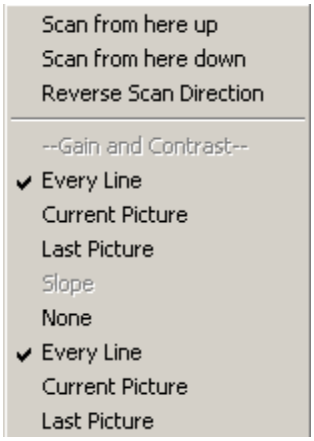
Start the image acquisition with the scan button:  (the button gets red)

You can change the scan mode when you click with the right mouse button on the scan button. The appearing window shows:



- ✗ 1D line scan at the first or current line
- ✗ 2D 2-dimensional scan
- ✗ cont. on restart: when checked and you stop the scan, the scan restarts at the line at which it was stopped.

For each window, one can set display options during the scan. Click with the right mouse button into an active window (e.g. "TopoFwd"):



Scan from here up and **Scan from here down:**
usage: during the image acquisition or in order to start image acquisition
function: uses the current mouse position to determine "here" and starts to scan from this position upwards or downwards. The function does not change or check the setting "cont. on restart".

Reverse Scan direction:

usage: during the image acquisition
function: changes the scan direction from downwards to upwards or vice versa.

Gain and Contrast: changes the gain and the contrast of the used colour range during the scan. Maximum and minimum are taken automatically in *Every Line* or from the whole *Current Picture*. In case of *Current Picture*, all values available from the 1st scanned (might be the uppermost or the lowermost line in an image) to the currently scanned line (visualized with a black or yellow line) are evaluated. In case of *Last Picture*, maximum and minimum of the last acquired image are taken to calculate the contrast.

Slope: subtracts either a linearly fitted line from each scan line (*Every Line*) or a fitted plane through the whole currently acquired image from the 1st to the currently scanned line (*Current Picture*). One can also use the calculated slope from the last image (*Last Picture*) or disable the slope correction completely (*None*).

Save images

The data are saved in two formats: Anfatec file format and bitmap, that the following files are created:

- a base file (*.txt)
- and 2*N data files (*.bmp + *.int)
  (N ... number of acquired data channels, each saved as bitmap and as integer).

The file names ('*') consist of:

- ☑ a base name provided by the user (example: “S45B”)
- ☑ an automatically generated 2-digit number (example: “00”)
- ☑ the channel name written in the image windows (example: “TopoFwd”)
- ☑ the file extension.

In the case that two channels called “TopoFwd” and “ItFwd” are acquired, the generated files are:

- S45B00.txt
- S45B00TopoFwd.int
- S45B00TopoFwd.bmp
- S45B00ItFwd.int
- S45B00ItFwd.bmp

Each click on the save button increases the 2-digit number by one (next file set: S45B01.txt, ...).

With the OpenLast function [File/OpenLast], the last saved image is opened in a new Present window. You can enable **AutoSave** with “Shift+left mouse button” on the Save button. The base name of the stored files can be given in [File/Save As].

Hints for setpoint settings

STM

If the system is scaled correctly, you can just put in the tunnel current in the parameter window.

AFM contact mode

Set the setpoint to more positive values than in large distance to the sample. Consider, that softer cantilevers need larger values.

AFM – conventional dynamic mode

Read the free amplitude in large tip-sample distance and set the value to 80 % to 90 % of it. If the

tip starts to oscillate, reduce Ki. If no stable feedback is possible, increase the drive amplitude (DNC window) to stabilize the system

`Example:`

in crosshairs	x-value :	- 500 ... 500 mV
	y-value:	-200 mV .. 200 mV
	intensity:	1000 mV ... 6500 mV
in DNC:	drive:	2 V
	gain:	1
	amplitude in resonance:	70 mV ... 600 mV
feedback parameter:	Ki = 15 ... 80	
	(reduce, if tip oscillates after approach,	
	increase, until oscillation is almost visible = 1 nm ripple)	
	Kp = 100 ... 2000	

Parameters during imaging:

- Start scan with 1 line/s.
- Increase Ki until oscillations seem to appear.
- Increase Kp to 3 * Ki.
- Increase scan speed, until edges on the sample get blunt.

Soft-Retract : set setpoint to a value higher than free amplitude, that the piezo is retracted (LED in UP-position for the HV45B amplifier in the Level AFM)

Dynamic AFM with high resolution

after laser adjustment:

in crosshairs	x-value :	- 200 ... 200 mV
	y-value:	-50 mV .. 50 mV
	intensity:	3000 mV ... 6500 mV
in DNC:	drive:	0,01 V .. 0,1 V
	gain:	10 or 100
	amplitude in resonance:	5 mV ... 150 mV

- open oscilloscope
- check amplitude (= free amplitude)
- set setpoint (parameter window) to 95 % of free amplitude

feedback parameter: Ki = 15 ... 40
(reduce, if tip oscillates after approach,
increase, until oscillation is visible = 1 nm ripple)
Kp = 100 ... 1000

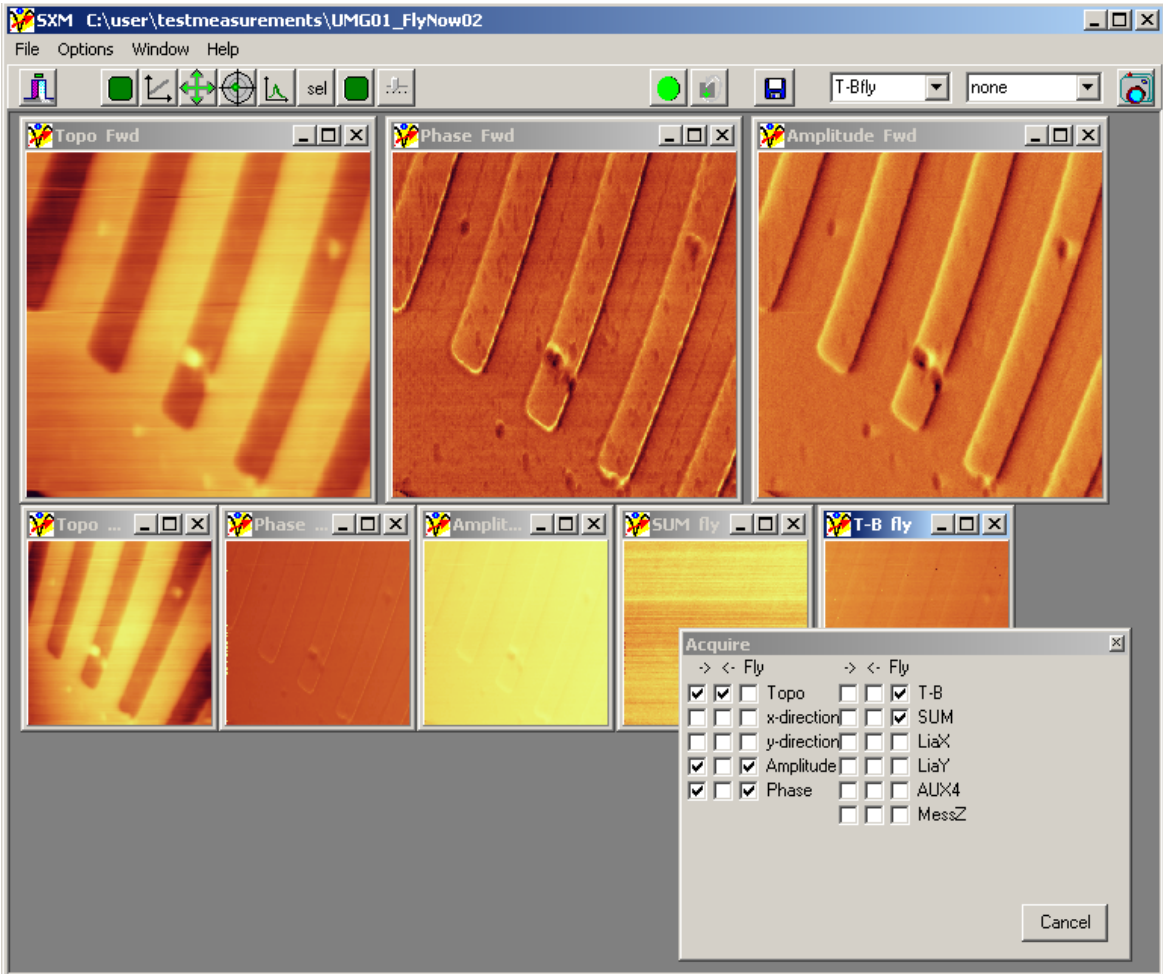
2 Explanation of the Windows / Buttons and Keys

Here, the following windows are described: 

- Main Window
- Spectroscopy Window
- Coarse move Window
- Crosshairs Window
- DNC = dynamic non-contact mode
- Scripting / Matrix&Line Spectroscopy Window
- Oscilloscope
- Slider or DAC-Control
- Tip Conditioning
- Z-Control
- Vertical Manipulation

Main Windows and Child-Window - Places and Sizes

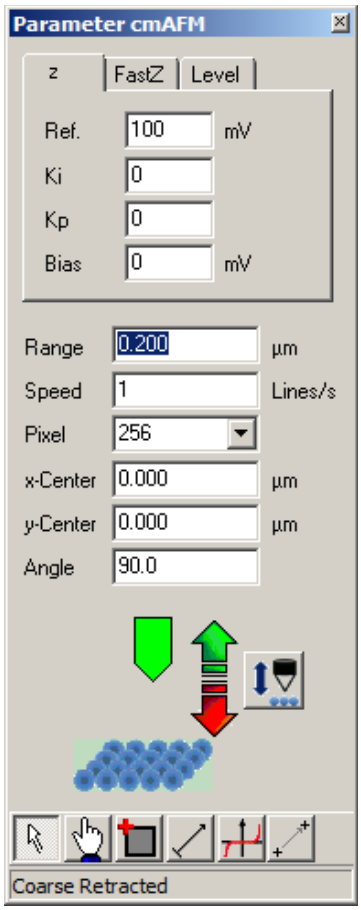
Each acquired signal checked in the **acquire menu** (Options/Acquire) is represented by an image shown as Child-Window inside the main window of the scan program. In versions older than 17h, these windows have been replaced and resized every time the program has been re-opened.



Starting from Version 17h, it is possible to place the windows with additional functions:
When a window is selected, the cursor key are used to move the window inside the main window. With 'Shift+Cursor-UP' the window gets smaller, with 'Shift+Cursor-DOWN' the window gets larger.

The settings are saved as *user.ini* and reload with the next program- start.

Parameter Window – the z-Tab



Ref. Is the setpoint of the system. In dependence on the selected feedback mode, it has different meanings. In DNC, its the amplitude. In contact mode, its the set T-B signal

Ki integral part of the PI feedback (switchable)

Kp proportional part of the PI feedback

The mathematics behind the feedback procedure is shortly described in Options/Feedback.

Bias is an dc output voltage provided at the Ut output of the DS4L controller (switchable)

Range scan range in µm

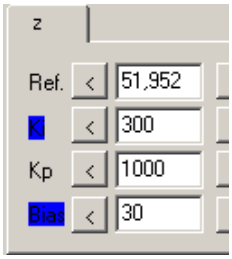
Speed scan speed in lines per second. If the speed is selected higher than 10 lines per second, the on-line visualization of the acquired images might be switched off automatically.

Pixel All images are taken square like with N by N pixels resolution. The number of pixels effects the scan achievable speed and the achievable resolution of the images.

x-Center, y-Center in relation to the scan range, are the central coordinates of the acquired images with respect to the total provided range.

Scan Angle turns the scan direction. If the scan angle is 45 degree, the maximum scan range is reduced by a factor of $\sqrt{2}$.

Switches behind the parameters:



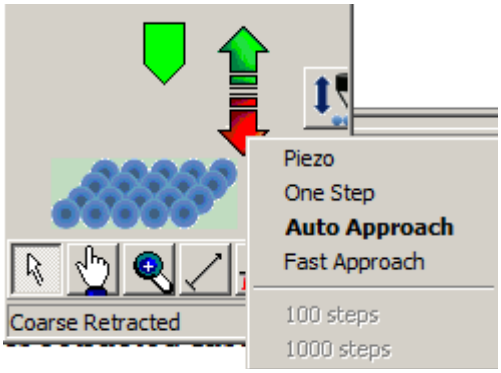
Ki (and for versions without tip conditioning also Bias) provide a switch. When you click with the left mouse button on the text "Ki" or "Bias", respectively, these values will jump between the current and a 2nd value. When the 2nd value is on, the background of the text gets blue.

For bias, this allows to switch the sample voltage and one might pulse the tunnel voltage with this option.. For Ki, this switch is used to distinguish between approach setting and scan settings. During AutoApproach, it uses automatically the 2nd value.

Automatic Approach button: click once to start automatic approach.

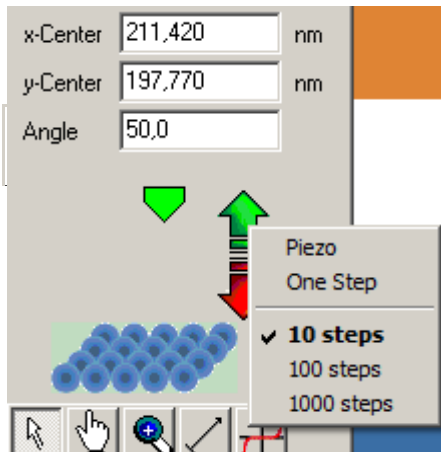
When the right mouse button is used on the approach button, it shows two options: "one step" and "Auto Approach". The fat written one is the standard option performed when the left mouse button is used on the approach knob.

The automated approach is a loop in which:



- the piezo is retracted fast
- the steppers move “Approach steps” forward (approach steps are defined in “Options/Misc”)
- the feedback approach the tip with the user defined speed until the front position – 10 % is reached

This loop stops whenever a single data point is below the given setpoint value.



Retract button: when pressed, the tip is retracted by the option chosen. In order to view the selected option, use the right mouse button on the retract knob. The picture left shows, that the retract button can be used to retract the piezo only (“piezo”). This option is used for soft-retract, if any sensitive feedback parameter or even the sample position has to be changed.

As standard, “10 µm” is selected. When the retract button is used in an approached situation, the piezo is retracted first. Then the stepper is used to retract 10 µm.

When inside the selection menu the “100 µm” is chosen, the system retract 100 µm.

Tip colour:

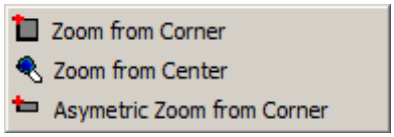
Colour	*Tip position*	*Meaning*
Red	Almost retracted	The tip is the last 10 % of the possible positions, and cannot retract further.
Green	Central positions	The tip is approached and hold in a central range between 10 % and 90 % of the possible z-values.
Yellow	Most extended position (piezo cannot extend any further)	The tip is extended more than 90 % of its maximum possible extension. If this colour occurs during scan, it is possible, that the tip does not reach the sample surface anymore.
Lime Green	Any	If the tip moves very fast in the time slot, its position is detected, the difference between its maximum and minimum extension in this time slot is shown in lime green.

Sub-Functions inside the Parameter Window

Enable this feature to Drag&Drop the current scan image into the Select Window (page 23)

With this function, the current scam area can be moved during the scan.
Note: disable this function to avoid unintended movements.

Zoom function – allows to zoom into the currently scanned image starting from the center or a corner.

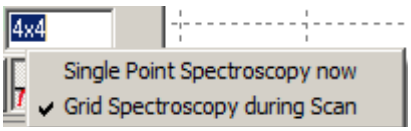


Additionally, asymmetric zoom can be chosen. After an asymmetric zoom, the parameter Image Format in [Options → Misc → Aspect Ratio] is changed.

Notes:

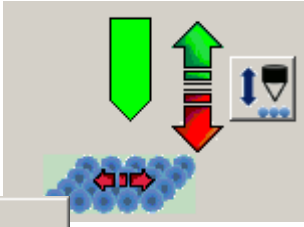
1) Zoom out (to larger image sizes) by simply dragging the cursor over the image borders.
2) Return to square-like images by selecting “Zoom from Corner” or “Zoom from Center”.
3) Asymmetric zoom will not have an effect on the pixel density setting.

Measures a distance XY inside a currently acquired image.



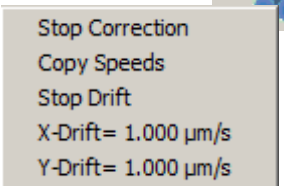
Acquire **Single Point** (one spectrum per click onto a position) or **Grid Spectroscopy** spectra inside the currently acquired scan area. The grid positions of grid spectra are shown inside the image. During image acquisition, the scan stops automatically at these positions and takes a spectrum with the current setting. For each data channel in the spectroscopy window, a data file “... _Matrix.dat” is generated.

Drift Compensation feature.



During a continuous (repeated) scan with constant scan speed, enable this button and click into an image to select a certain feature in the image. Click a 2nd time in the next image to define the drift vector.

The activation of the drift compensation is visible inside the sample structure as red horizontal arrow.



Click with the right mouse button onto this horizontal arrow to access further options like:

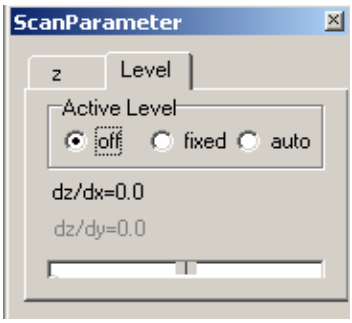
“Stop Correction” – disables the drift compensation

“Copy Speeds” – copies the drift vectors into the clipboard

“Stop Drift” – sets the drift vector to zero – bot the drift compensation remains enabled

“X-Drift = 1.000 µm/s” and “Y-Drift = 1.000 µm/s” – allow to set defined drift vectors in either X or Y-direction to check the system.

The Level-Tab – Plane Correction during Image Acquisition

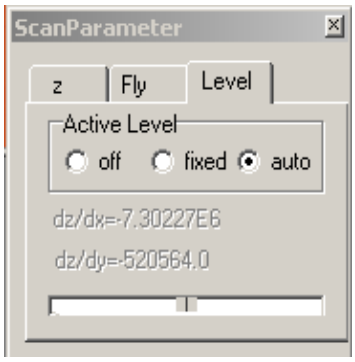


The main change is the levelling of the sample plane versus the scanning plane during image acquisition. This levelling is neutral to the z-output of the feedback. It consists of two coefficients 'dz/dx' and 'dz/dy', which describe the tilt in x- and in y-direction, respectively. During the scan, when the scan generator provides a step in x-direction, the resulting step dz calculated from 'dz/dx' is added to the z-output. The same is done for the y-direction.

Level is visible as extra tab in the parameter window. It has three different states:

Off disables the level function. Even if there are numbers available from the last scan, these values are not used for the tilt correction. One can click with the left mouse button into one of the coefficients and provide a number for later use.

Note: when the program is started, ***Off*** *shows the last used values, but does not use them. It is useful to click into the values and set them to zero before one switches to Auto.*



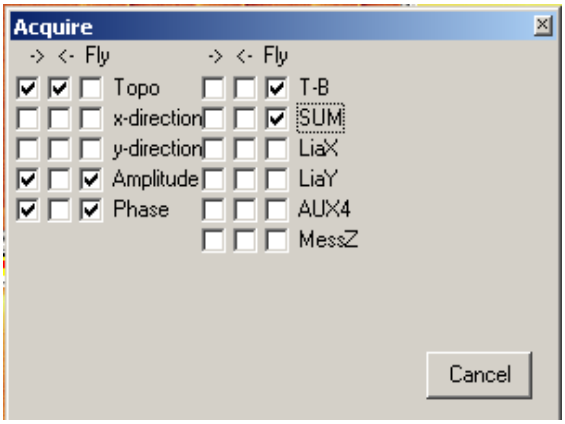
Fixed allows the manual adjustment of the sample plane. It is thought for fine adjustment or for the case, when a single line scan is used for the plane evaluation. One selects the direction bz clicking into the displayed value 'dz/dy' or 'dz/dx'. The slider allows to change the value continuously. Alternatively, the number can be printed in the edit box.

Auto reacts on "Image ready". When a picture is completed, the plane of this image is calculated based on the last (displayed) coefficients 'dz/dx' and 'dz/dy'. The new coefficients are displayed. The next image is taken with corrected plane. As long as Auto is ON, this procedure is repeated after each completed image.

The **coefficients** are calculated degree. The given number presumes that the scaling in x- , y- and z-direction correct.

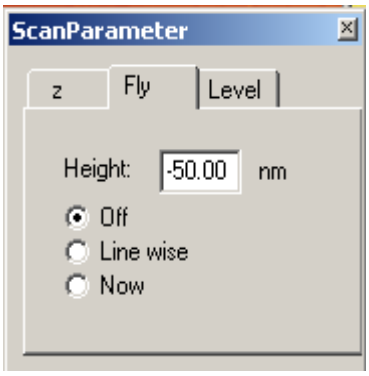
Fly-Tab – Variations of the Standard Two-Path Imaging

Fly modes are used to image the surface a 2nd time in a different height. If the flight is intended, one has to check at least one of the 3rd column check boxes in the acquire menu (Options\Acquire) with the name Fly. Then, an additional tab appears in the parameter window.



Old versions: in versions older than 17h, an Edit-Window appeared in the acquire menu, which allowed to set a flight height. This value has now to be set in the tab Parameter\Fly under"height".

This Tab allows to set a flight height as known from previous versions and provides three options:



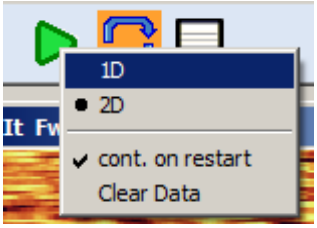
Off scans over the surface as if 'Fly' is not intended. Even, if there is a number given as height, this number is not used. (Don't get irritated: the images with the name "…. Fly"do not disappear and their last data are shown during scan. But when saved, these images are empty.)

Line wise equals the former 'Fly mode'. Each scan line is taken once as topography. After backward trace, the tip is elevated the "Height" above the surface and the same topographical line (including all detected topographical variations) is scanned a second time in this height.

Important: Negative value of Height = retract.

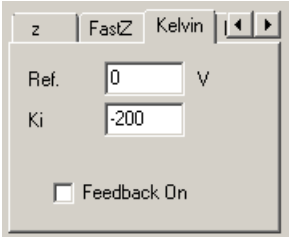
Now is intended for the scan of a complete plane above the surface without tracing the real topographical variations. It is important, that the surface has been leveled with the Level function properly, before this mode is used for scanning. When "Now" is selected, the tip is lifted immediately, and not released to feedback until Now is switched OFF again.
IMPORTANT: Don't forget to switch Now OFF, when the image is ready. Drift might cause a collision of the tip with the surface, because the feedback is OFF!!!

When a planar scan in a 'Height' is intended above the surface, but no complete picture should be taken in advance, we suggest the following procedure:



- go to "line scan" by right mouse click into the scan knob. The symbol changes from  to  . This enables a function, that scan only the first line of a picture.
- Chose the scan angle 0º (In original settings, this scans the y-direction.). Open the Level-Tab and the oscilloscope window. Chose 'Fixed' in the Level-Tab.
- Start the line scan by clicking into  . The first y-line is scanned repeatable.
- Use the slider or the Edit window to adapt the leveling coefficient 'dz/dy', until the plane vanished.
- Rotate the scan direction to 90º (x-direction is scanned). Adjust the leveling coefficient 'dz/dx'.
- Go back to 2D scan mode. Use Now to lift the tip and start to scan.

Kelvin-Tab in the Parameter Window



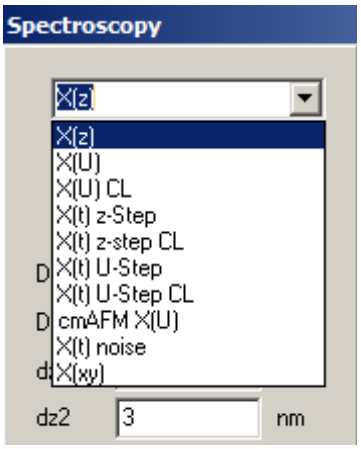
Ki – defines the feedback speed of the Kelvin Feedback

Ref. – allows to use offset compensated KPFM (correction on the input signal for the kelvin Signal to get rid of cross talk induced distance dependencies.

Feedback On – switches the feedback on (standard = off)

Spectroscopy Window

The spectroscopy allows to acquire a wide range of spectra. As there are many different possibilities to collect data, some typical spectroscopy types (data acquisition versus tip-sample distance or data acquisition versus bias voltage) are predefined.



This selector allows to switch between those predefined and a customised spectroscopy.

X_s the z-output is swept

X_U the bias or "Ut" is swept

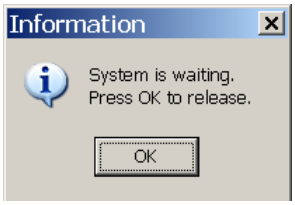
feedback_test provides a jump at the output "Z"

MassSpec this special function is implemented to retract the tip a distance **dz2** for a certain time.

SCM uses two external SRS lockin amplifiers controlled by GBIP to measure e.g. electrical forces

CM X(U) this mode is implemented conduction AFM measurements in contact mode.

When started, the piezo retracts dz2 and stays in this position. It shows the message "System is waiting". Click OK to let the system approach again.



X, Y	coordinates of the data acquisition (changed with "select")
delay 1	time before 1st data point in ms
delay 2	time between data points in ms
dz1	distance 1 to be retracted/approached (negative values for retract!!)
dz2	distance 2 to be retracted/approached (negative values for retract!!)
U1	start voltage for ½ loop
U2	stop voltage for ½ loop

starts the spectrum acquisition. The spectrum is also taken, if you zoom into a new frequency range.

Opens a options window, where data storage, view and acquisition options can be changed.

If checked, the spectrum acquisition is repeat, until this knob gets released again.

Saves the spectrum with the next valid number. The number can be reset to zero by changing the base name of the file with "Save as" or by using the entry [SpectOpt] → NextNumber = 0.

Copies the data to clipboard.

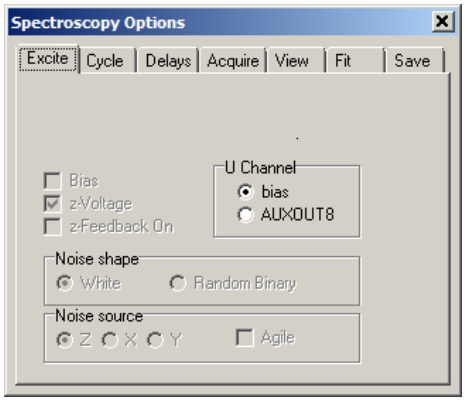
Fits a linear line to the measured data set with the aim to determine a system sensitivity. The range on the x-axis is taken from the last spectrum. Moving the end points of the line fit changes the settings for the line position.

Channel selection: Here, the channels to be acquired can be selected. For standard applications, choose T-B (normal force) in contact mode, and the amplitude (channel name might be LiaR or Amplitude) in dynamic mode.

Spectroscopy Options 

The options window for the spectroscopy consists of five parts:

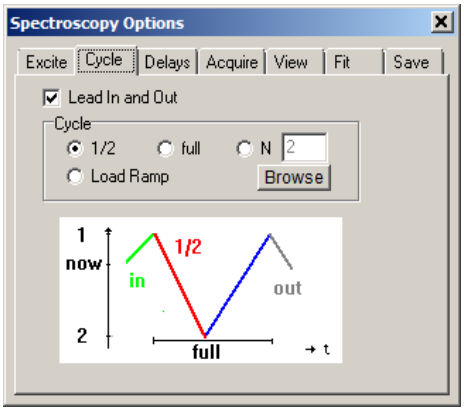
Excite	selects the spectroscopy type
Cycle	defines the start and end points of the variable to be swept with respect to the actual position
Acquire	
View	
Save	enables the user to set the file parameters for the ASCII export of the data



Excite

When a pre-defined spectroscopy is chosen (e.g. Distance spectroscopy), this window shows, which variable is swept during spectroscopy.

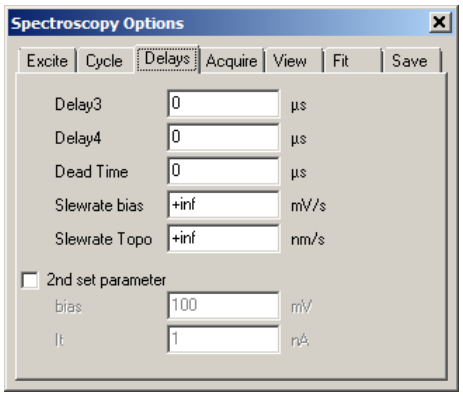
When the customised spectroscopy is selected, the user can choose the variable to be swept, here.



Cycle

Lead In an Out if "On", the sweep starts at the value set or detected at this moment

Cycle ½ cycle measures from value 1 to value 2. The full cycle measures from value 1 to value 2 and back. N cycle repeat the full cycle N times. With "Load Ramp" a user dined ACSII ramp can be loaded (see APPENDIX 9).



Delays

Delay3 Time after reaching Position and 2nd parameter set

Delay4 Time after Spectrum

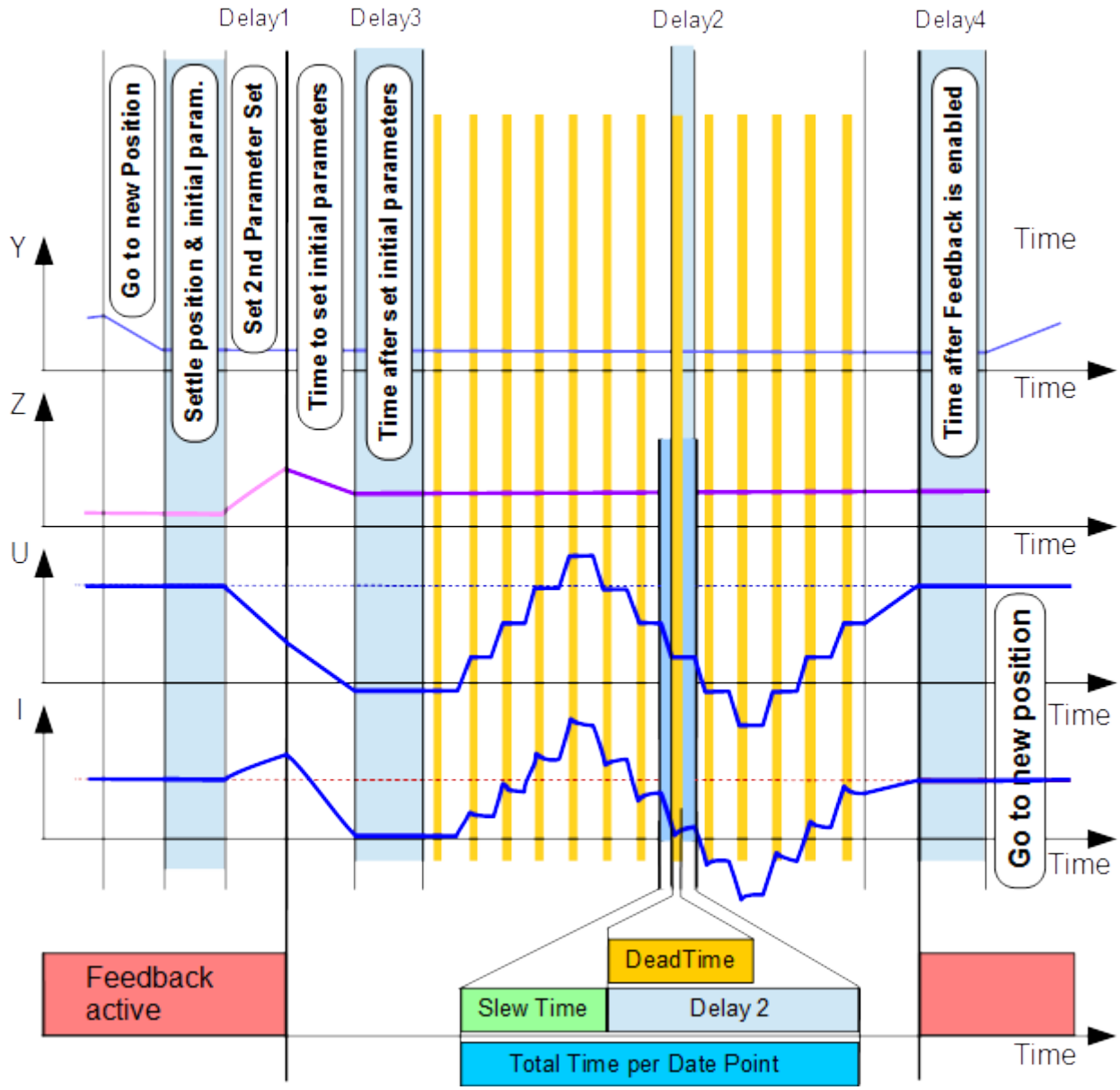
Dead Time Time in between data points, that is not taken into account for averaging

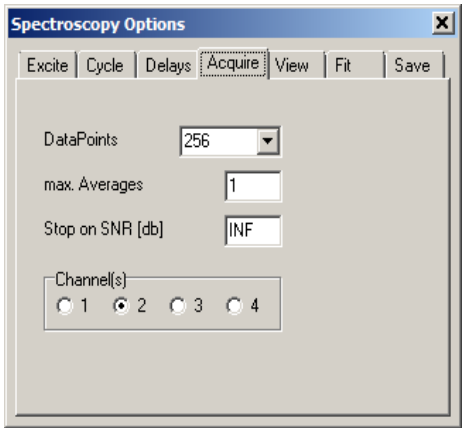
Slew Rate Bias maximum rate the output Bias is changed during spectroscopy

Slew Rate Topo maximum rate the output Z is changed during spectroscopy

2nd Parameter Set Before spectroscopy is started and the feedback is switched off, the system might set different feedback parameters

The full *time scheme in spectroscopy* is realized as follows:

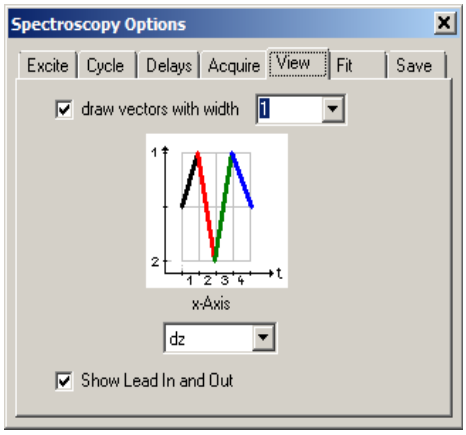




Acquire

Data Points is the amount of points in a half-cycle.

Channel(s) defines the number of acquired channels. Which of the available signals is displayed in the channels, can be chosen in the Acquire-part of the spectroscopy window.

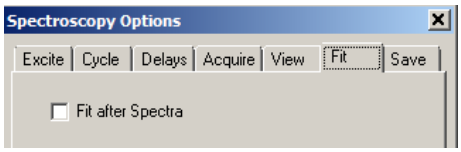


View

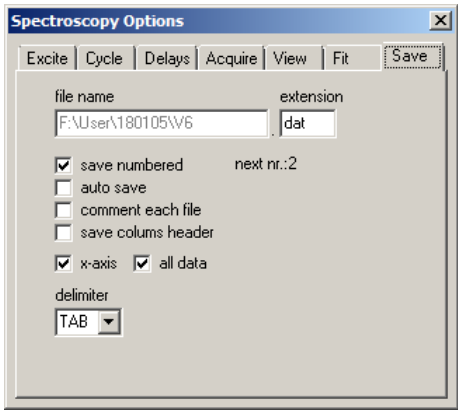
defines the way the data are displayed on the screen.

With "**Draw vectors**" enabled, the data points are connected with lines of the provided width. Otherwise, each data point is drawn as dot **with** the **width** as size/diameter.

drop down selection at x-axis allows to chose which data are used as x-axis



Fit enabled, automatically uses the function behind  after each spectrum is acquired.



Path and file name shown here a defined in the function [File → Set Save Path …] or with the function [File → Save Spectroscopy As …].
All other settings define the extension, delimiter and structure of the ASCII file. Numbered saving is recommended for al kind of automated data acquisition and for the use of Line, multiple Point and Matrix spectroscopy.

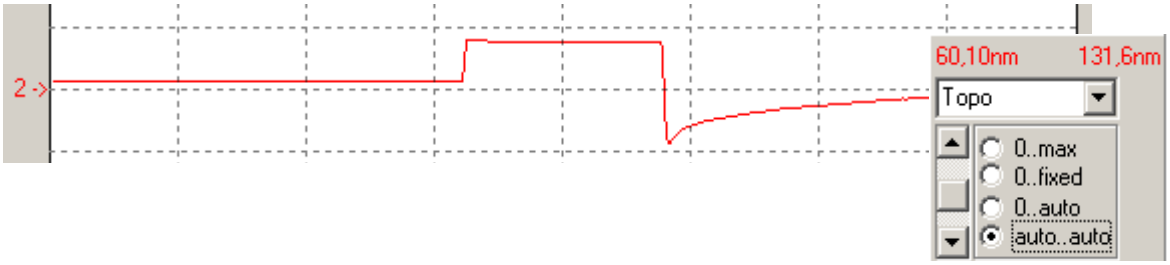
Short Explanation of the Spectroscopy Types

Type	Description
X(z)	Retracts the tip or moves the tip in z-direction, while the feedback is off
X(U)	Sweeps the output voltage at “Bias”, Feedback is OFF
X(U)CL	Sweeps the output voltage at “Bias”, Feedback is ON
X(t)z-Step	Applies a step output to Z, Feedback is OFF
X(t)z-Step CL	Applies a step output to Z, Feedback is ON
X(t)U-Step	Applies a step output to Bias, Feedback is OFF
X(t)U-Step CL	Applies a step output to Bias, Feedback is ON
cmAFM X(U)	Switches feedback mode from “AmplitudeR” to “ContactMode” after reaching position. Sweeps the output voltage at “Bias” in contact mode. Switches back to dynamic mode feedback.
X(t) Noise	Analyses the system response of the CL system in X, Y or Z direction
X(xy)	Lateral manipulation

Contact Mode Conduction Measurements in dynamic Mode set-up “cmAFM X(U)”

- ✗ the tip moves with the scan speed to the acquisition point in the current feedback mode
- ✗ wait “delay1”
- ✗ the feedback is switched to Contact Mode based on the last settings in contact mode
- ✗ wait “delay1”
- ✗ data acquisition with “delay 2” as point delay (voltage is swept according to settings)
- ✗ the feedback mode is switched back to the former feedback mode

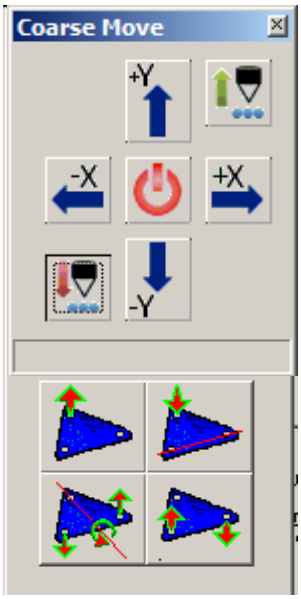
When the signals “Amplitude”, “Normal Force” = “T-B” and “Bias” are observed on the oscilloscope during the spectra acquisition, one finds the following picture:



When the x-y-position is reached, the amplitude drops to zero (drive is switched off, feedback mode is changed to Contact Mode) and T-B jumps to it's setpoint (here: 100 mV). The system waits “delay1”, until the voltage is swept (here: from 0V to -0.5V and back). After a further “delay1”, the feedback mode is switched back to dynamic mode. As the amplitude is zero (from the Contact Mode), the DNC feedback retracts the tip slightly, while the cantilever starts to oscillate (this takes

some ms). Typically, the system retracts before it re-approaches to the former distance in NC mode.

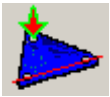
Coarse Move Window



Retracts the tip from the sample by moving all three stepper motors simultaneously

Approaches tip and sample with all three stepper motors simultaneously

The back motor is moved upwards. The head angle towards the sample increases. As side effect, the tip retracts from the sample.



The back motor is moved downwards.

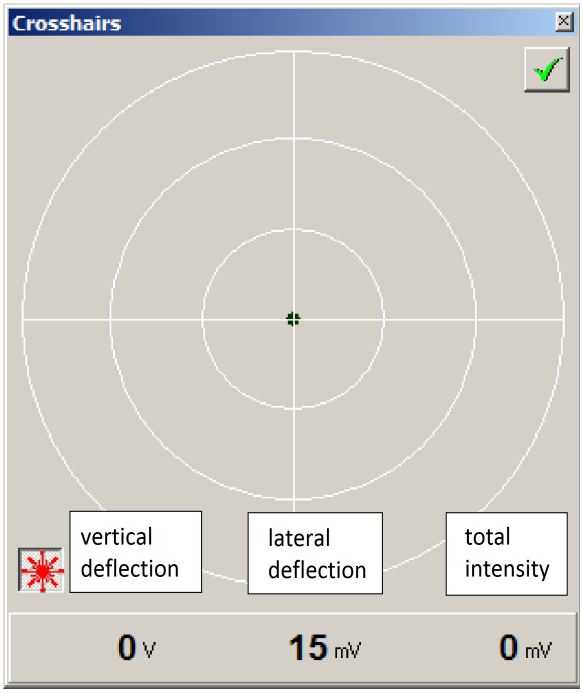
The left motor moves down and the right motor moves upwards. The head is tilted along its y-axis. On multi-tip chips, the left tip touches the sample first.

The motors are switched off. **Please use this button after each manual movement!**

Single steps: it's not possible to move only single steps. When you click once on the knobs, the motors move in dependence on the time you press.

Fast movement: Use "SHIFT" + left mouse click onto a button to move the motors constantly.

Crosshairs Window



X-value (= lateral defelection)**, Y-value** (= vertical deflection)**:**
positions on the photo diode shown in mV. The maximum numbers here are about 7000 mV.

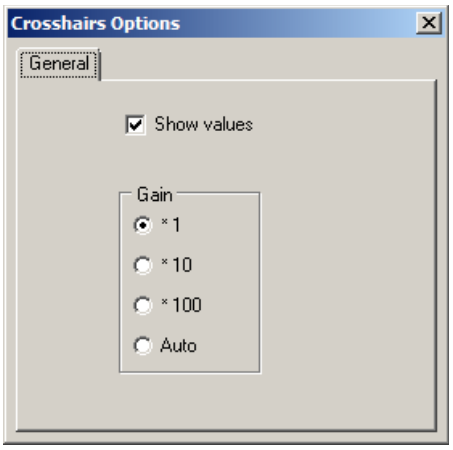
Total Intensity: SUM signal of the light intensity of all four photo diode elements. Maximum number here is 7000 mV, too. It can be scaled in mW or µW.

The displayed channel can be chosen in the ini-file under [crosshairs].

Dot colour: A black dot indicates a constant SUM signal. If the intensity increases, the dot gets green. A red dot means, the intensity decreases.

Laser: switches the laser power on and off.

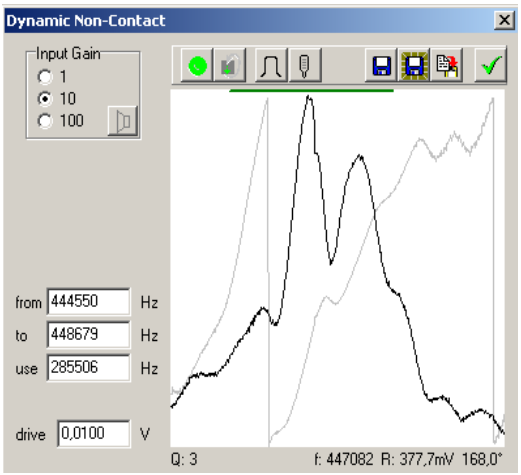
This icon opens an options window →



With "**Show Values**" , the visualization of the numbers for TB, LR or Sum is enabled/disabled.

Gain – switches the magnification of the data visualization (not the hardware input gain – which is switch in DNC window – see page 19)

DNC – THE DYNAMIC NON-CONTACT MODE



Input gain: is a hardware switch for the input amplification on the PCI lockin amplifier. It affects the available range for the T-B signal:

gain = 1: - 7 V ... 7 V

gain = 10: - 700 mV ... 700 mV

gain = 100: - 70 mV ... 70 mV

from: start frequency

to: stop frequency

use: selected frequency

drive: excitation amplitude

starts the spectrum acquisition. The spectrum is also taken, if you zoom into a new frequency range.

Zoom in: click with the left mouse button into the spectrum and move the mouse to the right with pressed button. A red line at the top edge of the window indicates the selected frequency range. When the mouse button is released, the spectrum in the new range is acquired automatically.

Frequency selection: click once with the left mouse button. The lateral mouse position is used as "use" frequency, the vertical mouse position is used as new setpoint.

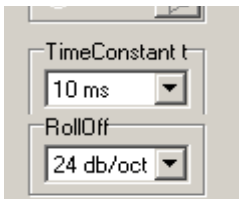
Inside the spectrum, a vertical grey line appears which visualizes the chosen position and a red cross on this line shows the selected setpoint for the feedback. If the user changes the setpoint now manually, this cross moves along the line to the new position.

Use the right mouse button to display former frequency selections and a default range over the full spectrum.

Repeated spectrum acquisition. When the "continuous" feature is enabled in the "Acquire" tab of the DNC options window, all spectra are integrated. Otherwise, this feature allows to use the spectrum acquisition as spectrum analyser.

 ↔ 

toggles the **bandwidth feature** for this lockin amplifier input. For standard DNC with resonance frequencies above 20 kHz, this feature should be disabled. If the cantilever resonance is below 20 kHz or the DNC window is used for the force modulation technique in contact mode at lower frequencies (e.g. 3 kHz), then this feature allows to select an integration time t and a low pass filter grade as "RollOff" for the evaluation of the amplitude and the phase of the DNC signal.



When this feature is selected, an additional setting appears below the Gain-entries (see image to the right). Please note that these time constants are independent of the time constants of the multi-lockin for EFM and KPFM applications.

 ↔ 

The **"Thermal Noise Spectroscopy"** is used to determine the thermal noise spectra of the cantilevers and can be used to determine the force constant based on the method of Mr. Sader. When the feature is selected, the excitation of the cantilever is switched off automatically. The displayed

data are a Fourier transform of the input signal acquired vs. time. The best result is obtained, if many of these Fourier transforms are integrated. The integration is enabled with the "continuous" feature in the "Acquire" tab of the DNC options window and automatically repeated spectrum acquisition.


Opens a options window, where data storage, view and acquisition options can be changed.


Saves the spectrum with the next valid number.

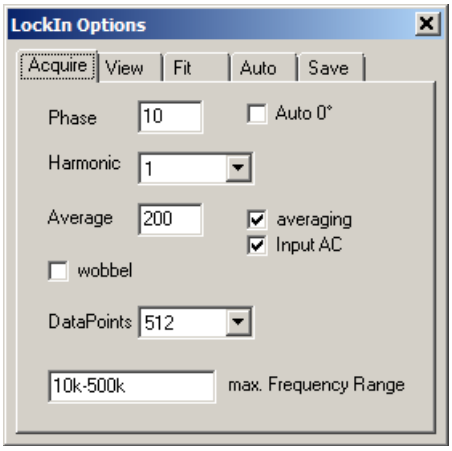

Allows to save under a new name or directory.


Copies the data to clipboard.

DNC options Window

With certain options the DNC window can configured with customer specific settings. The DNC-options window is opened with this knob: 

When the spectrum of the cantilever oscillation is acquired, the frequency is swept in N steps (N = **DataPoints**), while the amplitude is measured. As the SPM lockin has always 25 µs time constant, a better filtering or an adjustment of the bandwidth can be achieved by averaging a certain amount (given in **Average**) of subsequently acquired values at the same frequency.



Another possibility to improve the signal to noise ratio is to average subsequently acquired spectra. If "**Continue Acquire**" (auto repeat spectra) is selected, spectra are acquired continuously and averaged automatically. 

It is possible to adjust the **Phase** offset between outgoing excitation (red cable → Dither) and measurement signal (blue cable → TB or Fast TB). In case "**Auto 0°**" is selected, the phase offset will be automatically set to zero when the working frequency is selected in the DNC window.

For some applications, an other than the 1st **harmonic** might be used as feedback input.

If the expected peak is so small, that the single frequencies might not exactly meet its values, it is possible, that one does not find the peak in a large range spectrum. For this case, the function "**Wobble**" allows to sweep the excitation between the values of neighboured data points so that every excitation frequency is used during acquisition.

If the vertical adjustment position on the photo detector is more than 30..50 mV away from zero, it is useful to switch to ac coupling. "**Input AC**" coupling works for all frequencies above 1 Hz, which means for all cantilevers. This ac coupling is available when the hardware version of the AMU2.x board is higher than 2.3 or equals "2.3". For the version 2.3, one needs to set the ac coupling option manually in the *sxm.ini*. The AMU2.9 card does not support AC coupling.

"Sync Filter" is a special feature available from PROM-Code version 26h in the AMU2.6 cards as well as on the AMU2.9 card. The feature enables a faster evaluation of the amplitude signal related to the operations frequency. The amplitude is taken after 1/f, already. This feature increases

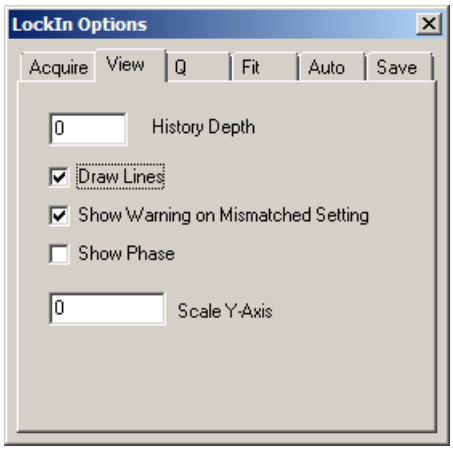
feedback speed. For cantilevers with high resonances, the noise is increased. The reaction time of the feedback system reduces from 100 µs down to 50 µs. The sync filter is enabled with the entry [scanner] SyncFilter=1 in the sxm.ini.

Starting with software version 26.22, the number of sync cycles can be entered below the sync.filter checkbox.

Note: larger numbers of sync cycles are useful for cantilevers with larger Q-factor and higher resonance frequency. Estimate a good value for the sync-cycles

- to measure the Q-factor Q (e.g. 300) and center frequency f (e.g. 300 kHz) in DNC window
- take Q/10 as amount of sync-cycles S (e.g. 30)
- check that S/f (e.g. 30/300 kHz = 0.1 ms) is much shorter than 100 µs – otherwise reduce the amount of sync-cycles

The default value for the spectrum (right mouse button click inside the white area of the spectrum + topmost line in the "**max. Frequency Range"** listing) can be changed here as well.

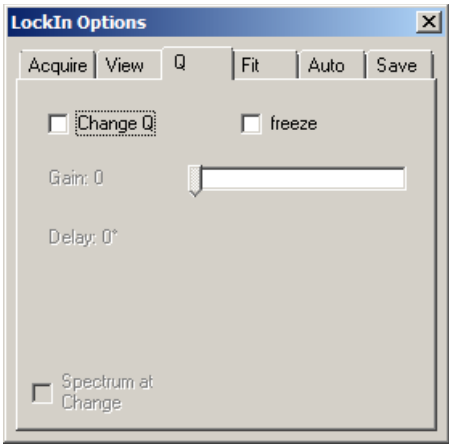


The spectra data might be drawn as single points or **vectors**. One can set the input gain of the lockin in a range that leads automatically to wrong amplitude values (too high internal amplification). This is detected in the hardware by an overflow. When **"Show Warning on Mismatched Setting"** is selected, the field around the *input gain* gets red on overflow.

"Show Phase" enables the display of the phase signal during spectrum acquisition.

It is possible to show the current and a certain number of previous spectra in the same screen. When the **History Depth** is set to zero, only the current spectrum is shown. When "1", the current plus the last spectrum are shown.

As default, the y-axis of the spectrum is scaled automatically to the last acquired spectrum. If one likes to change this, one has to put a vertical scaling factor into **Scale Y-Axis**.



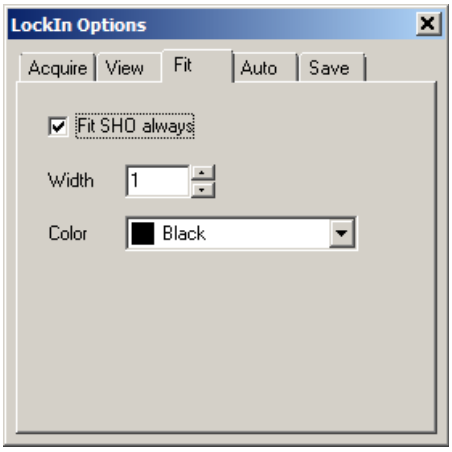
The tab "Q" gives access to the implemented Q-control feature. With "**Change Q**", Q control is enabled/disabled.

Delay is always related to to the actively chosen working frequency and given in degree (0...360°).

Gain defines the amplification of the input signal, which is added onto the reference output.

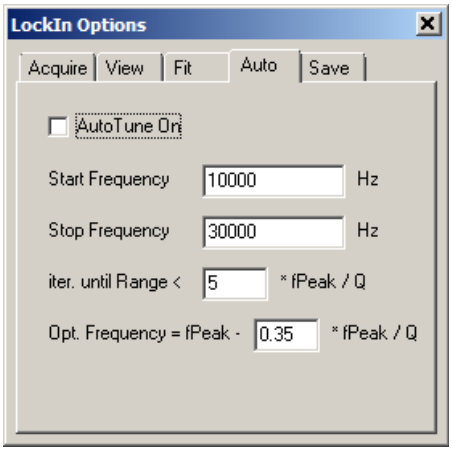
With "**freeze**", the Gain is kept.

"**Spectrum at Change**" forces the system to acquire a new frequency sweep with the last settings as soon as Gain for Delay are changed and thus makes the effect of these parameters visible instantly.



The function “Fit SHO” fits a simple harmonic oscillator into the acquired spectrum. From the fit data, the central frequency and the Q-factor are derived, so that a time constant for the cantilever can be calculated.

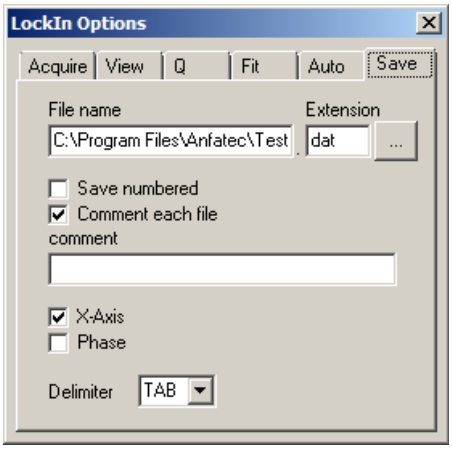
Based on this time constant one can estimate the maximum pixel clock that this cantilever be operated with.



This function enables an automatic tuning of the cantilever in dynamic mode. When “AutoTuneOn” is active, the image in the icon for starting a spectrum changes.

Pressing “Start” results in an automated sweep between **Start Frequency** and **Stop Frequency**. The peak frequency and Q-factor are determined. The sweep range is constantly reduced, until the range is close enough around the cantilever's resonance. This value is calculated by … ***fPeak/Q**.

The setpoint for dynamic mode operation is chosen with the entry **Opt.Frequency = fPeak -** …



The Save tab gives access to data storage settings.

The **file name** shown here is the complete path and file name of the last saved file.

The file **extension** can be chosen here costumer specifically.

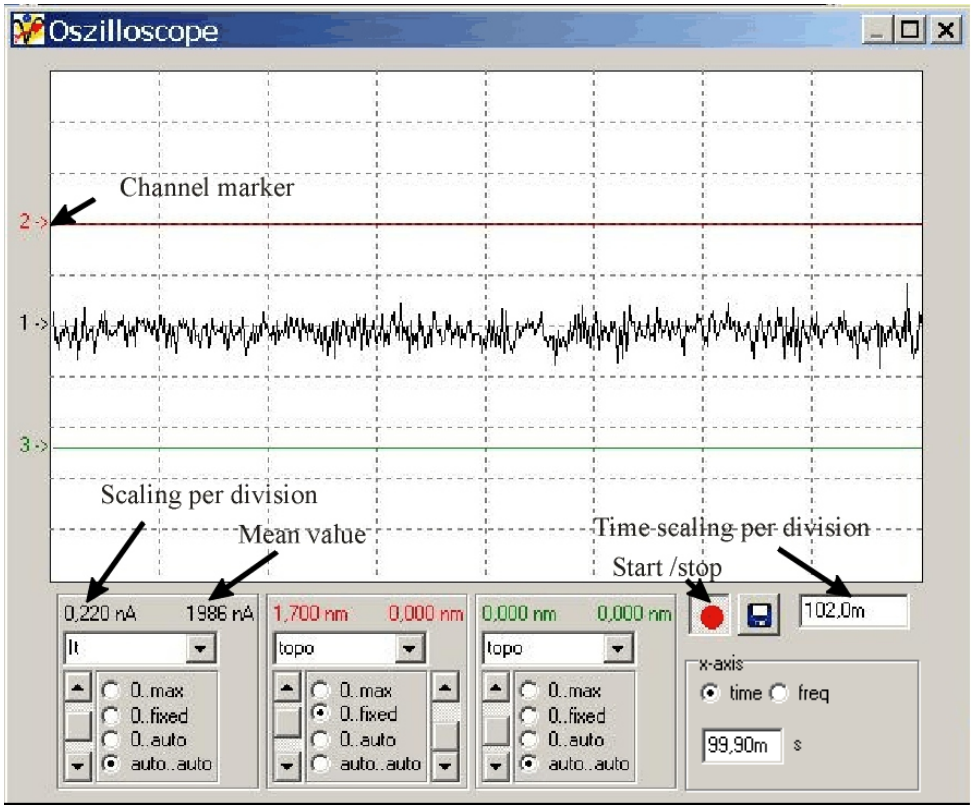
If **save numbered** is ON, one click on the *save button* will save the current data with the same name but count the last number of the file name upwards. The number of the next file is shown behind.

If comment each file is ON, the comment providable in the edit line below.

The **x-axis** and the **Phase** are stored only in the data set, if selected here. Single rows are delimited by the character provided as **delimiter**.

Oscilloscope Window

The oscilloscope works like a real 3-channel-oscilloscope. Content, scaling type and offset of the three channels are selectable.



Channel selection: is done from a drop down list, which shows only the available channels. The numbers above the channel selection are the scaling factor per vertical unit and the mean value

Vertical scaling types:

- **0..max** the scaling is set to maximum value of the channel
- **0..fixed** the maximum value can be changed by a slider appearing on the right sight of the scaling type selection
- **0..auto** the program calculates the the optimum, but takes always "0" as minimum
- **auto..auto** automatically scaled

Time scaling is done with the edit window (right sight) in seconds.

"Save Pic" saves the oscilloscope screen in a bitmap file.

"Draw mode" selects whether the data are drawn as dots or lines.

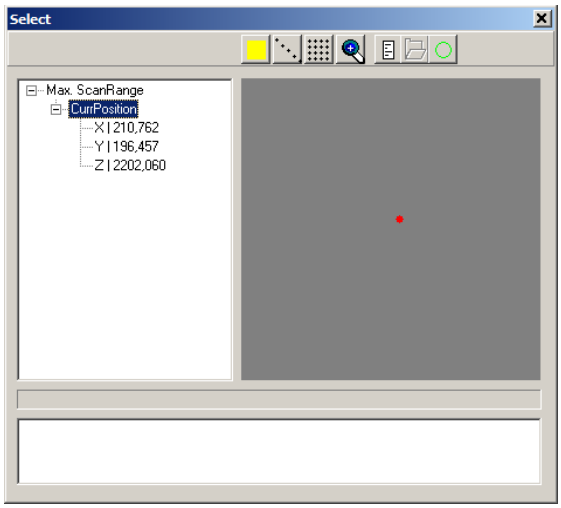
Select Window

The select window covers the following functions:

- Choose a point position for the point-spectroscopy
- Zoom into the current scan area
- Reset scan range and centre position to formerly stored values
- Run user defined scripts in the currently selected scan area

- Observe the current tip position in the totally available scan area
- Move the tip in the total scan area with the joystick (see: settings)
- Move the tip to a former point spectroscopy position

When the select window is opened, it shows an entry "Max.ScanRange" (maximum scan range). The grey screen represents the totally available scan area. The current tip position inside this scan area is displayed as red dot.



Click in any data channel window and 'drag&drop' the image into the image part (right) of the select window. Then, this window is shown there (as bitmap in the same way, it was displayed on the screen before) and its scan range as well as its centre position are stored with the image. On the left side below the entry "Max.ScanRange" appears an additional entry in the list. So, a list of former images is generated.

Move the tip in the scan area with the joystick

To access the function, which moves the tip (scanner) with the joystick based on the settings for the joystick, one has to activate the entry "CurrPosition" (see image).

Additional requirement: Feedback-Mode = Off

It is possible to limit the scanner movement to one of the three directions, only. Open the tree entry "CurrPosition"with a click on "+" and select for instance "X| *value*" to limit the movement to the x-direction.

Observe the tip position

If the entry "Max.ScanRange", "CurrPosition" or one of its sub-entries is activated (selected), the red spot shows the current tip position inside the total scan area during the scan or any kind of spectroscopy.

Open the entry "Curr.Position" to display the numbers behind each sub-entry X, Y and Z (example: "X| *2.355*"). These numbers are the value of the current position in the currently selected physical units (here: µm). They are updated during each scanner movement.

Select a point to perform spectroscopy experiments:

Requirement: one of the data channel windows needs to be "draged&droped" inside the select window.

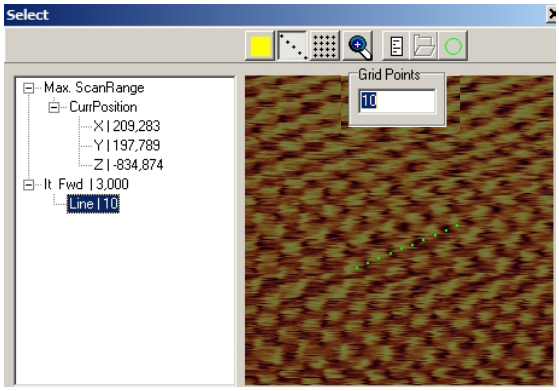
Click on the icon  . The image is darkened. A sub-entry "Point" appears below the image entry. It contains again sub-entries for the three coordinates X, Y and Z.

If one chooses this point selection for the first time on an image, the current tip position is used to generate new values for x, y, and z for this point. If one clicks inside the image with the left mouse button, one can choose a new point for the point spectroscopy. A green cross appears at the selected point. This point is entered immediately in the X and Y coordinates of the spectroscopy window.

To **move the tip to a former spectroscopy point**, select this point in the list (the entry "Point" gets blue) and click with the right mouse button onto it.

Choose “Go in X and Y”. The tip moves to this position with the currently selected scan speed. It is also possible to move the tip in x-direction and y-direction separately: Choose the related sub-entry (example: X|0,703) and click with the right mouse button on it. Choose “Go in X” and the tip moves in x-direction with the scan speed.

Spectroscopy along a line

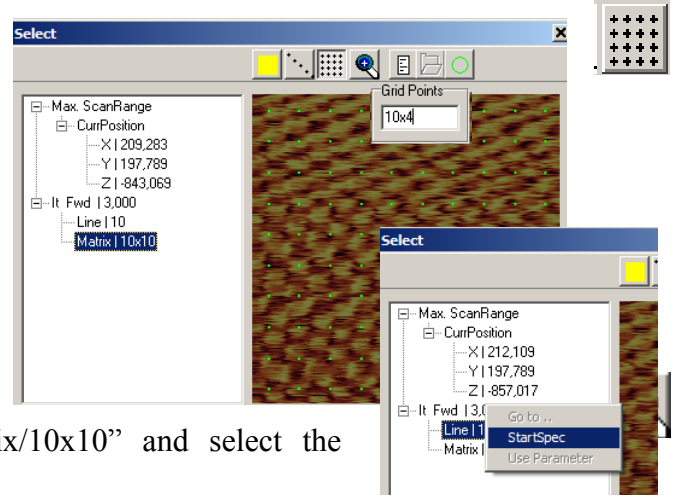


allows to place a line inside an image that was drag&dropped into the Scripting window beforehand.

By clicking onto the text “Line/10”, an Edit window is opened that allows to correct a amount of data points to be taken along this line.

In order to move the position of the line, one simpy draws a new line, by clicking with the left mouse button onto the start position and keeping the left mouse buttom pressed while moving to the end position.

Matrix Spectroscopy

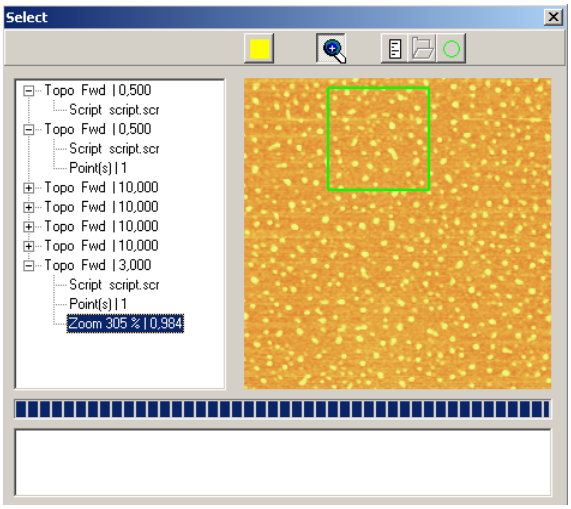


would acquire spectra all over the current imaging area. The locations are equally distributed over the whole image.

By clicking onto the text “Matrix/10x10”, an Edit window is opened that allows to enter a new amount of points in X and Y direction.

In order to start either line- or Matrix spectroscopy, click with the right mouse button onto the text “Line/10” or “Matrix/10x10” and select the “StartSpect” line.

Zoom into the current image with the icon

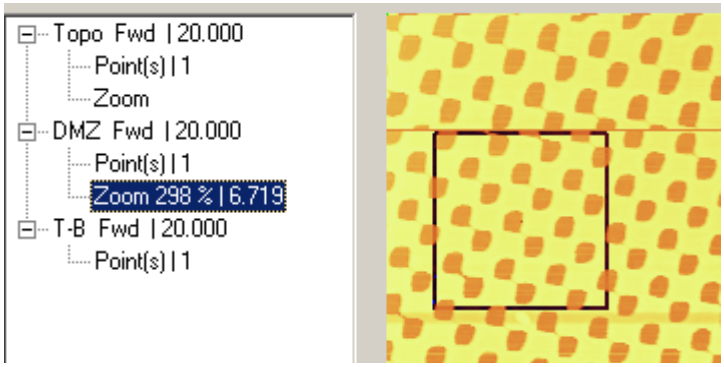


Click with the left mouse to define the centre of the zoom area and keep the mouse button down while you drag to define the size of the new window. When the mouse button is released, a green square shows the selected new area and the list on the left side shows the zoom factor (here: 298 %) and the new scan range size (here: 6.791 µm), which is directly overtaken into the ParameterWindow.

At any time later, one can go back to the old scan ranges by selecting their images from the list on the left side (here, the image “TopoFwd” with 20 µm range is re-selected) and might repeat the zoom at a different position.

Reset scan range to former parameters

After a zoom into an image and a new scan, one can go back to the old scan range selection. One selects the related entry (example: “DMZ Fwd | 20.000”) so that it gets blue and clicks with the right mouse button on it. Choose “Use Parameter” to reset the values of *Range*, *x-Center* and *y-Center* in the parameter window.

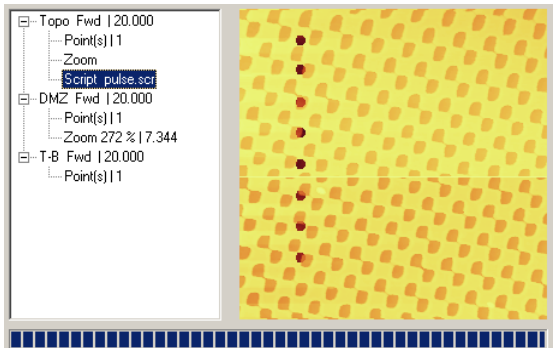


Run user-defined scripts

The select window allows to run user-defined scripts. A script is loaded with the button 

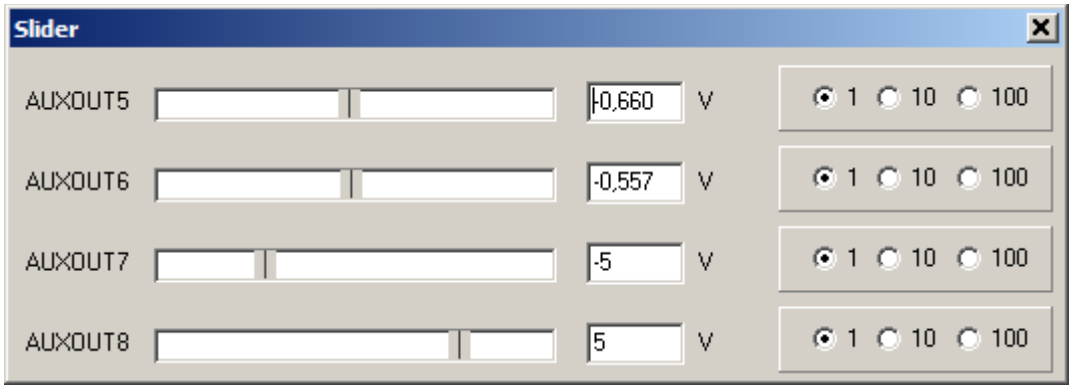
The program loads automatically the last used script. Below the selected image appears an additional menu entry “Script” with the script name (pulse.scr) as parameter.

Position defined in the script as “GoXY” are shown in the image as points. With a double click onto the script file name, an editor window with the script opens.



With  a new script can be opened in a dialogue box. With  the currently selected script is started. The horizontal bar shows the progress of the script execution. The white screen displays messages during the script execution. For available commands, please refer to page Fehler: Referenz nicht gefunden.

Sliders For auxiliary DAC-Channels



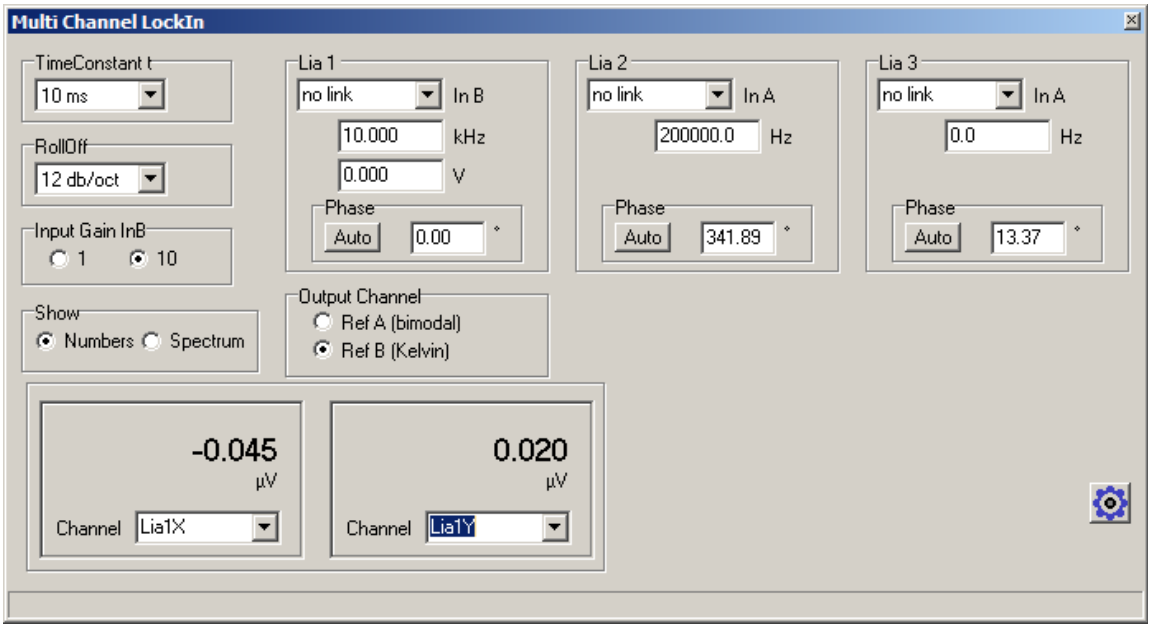
Here, you can change the output data of the AUX output channels 5-8. The number shows the valid value in V. When amplification "1" is selected, the slider moves from -10 V to + 10 V. When "10" or "100" is selected, the slider is always in central position and the movement of the slider is more sensitive.

One can also give some values here by simply typing them into the related Edit-Window.

Multiple Lockin Amplifier Window

This window appears only, if a 2nd lockin board is installed. Then, a new selection knob appears directly beside the Slider-knob:

It opens the following window:

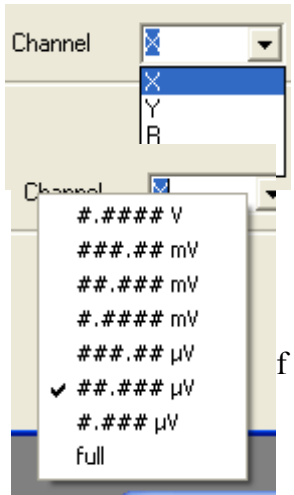


This is a complete lockin amplifier with selectable **time constant** and **roll-off**'s for the selection of the band width.

In **dynamic**, the input gain is switched between three amplifications (comparable with the input gain in the DNC window).

Frequency, Amplitude, Phase and Harmonic are self-explaining output parameters and settings of a lockin amplifier.

In the two meters, one can choose between the displayed channels:

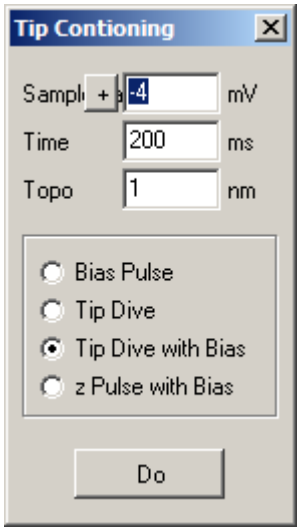


Besides real (X) and imaginary part (Y), amplitude [R] and phase (Phi) are available

In order to visualize the detected values for X, Y, and R inside the meters in a suitable way, one can click with the right mouse button inside the meter. A selection list is opened which shows the possible scaling setting inside the meters.

TAKE CARE THAT THE AMPLITUDE IN THIS WINDOW IS SET TO ZERO, IF EFM IS NOT USED!

Tip Conditioning Window



Tip Conditioning is done with defined vertical movements of the tip versus sample and the application of dc voltage between tip and sample.

This window offers four different (self-explaining) regimes for independent or simultaneous movement and bias.

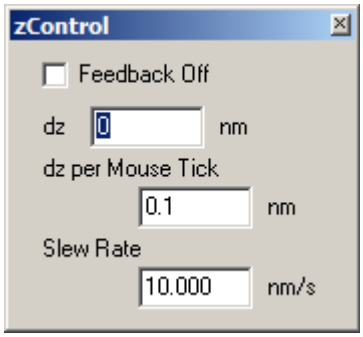
"**Bias**" - defines the maximum applied DC voltage.

"**Time**" - defines the duration of the whole tip conditioning procedure.

"**Topo**" - defines the distance the tip is retracted/approached.

The **Do** knob tarts the tip conditioning with the chosen settings.

Z-Control Windows



Z-Control gives access to a manually controlled vertical movement of the tip.

With "**Feedback Off**", the tip is frozen at a vertical position which is the (current vertical position + **dz**). Here, the movement to the height **dz** is done with the vertical speed defined in "**Slew Rate**"

One can move the mouse wheel to manually do vertical steps. "**dz per Mouse Tick**" defines the distance that is done on each mouse wheel tick.

Notes:

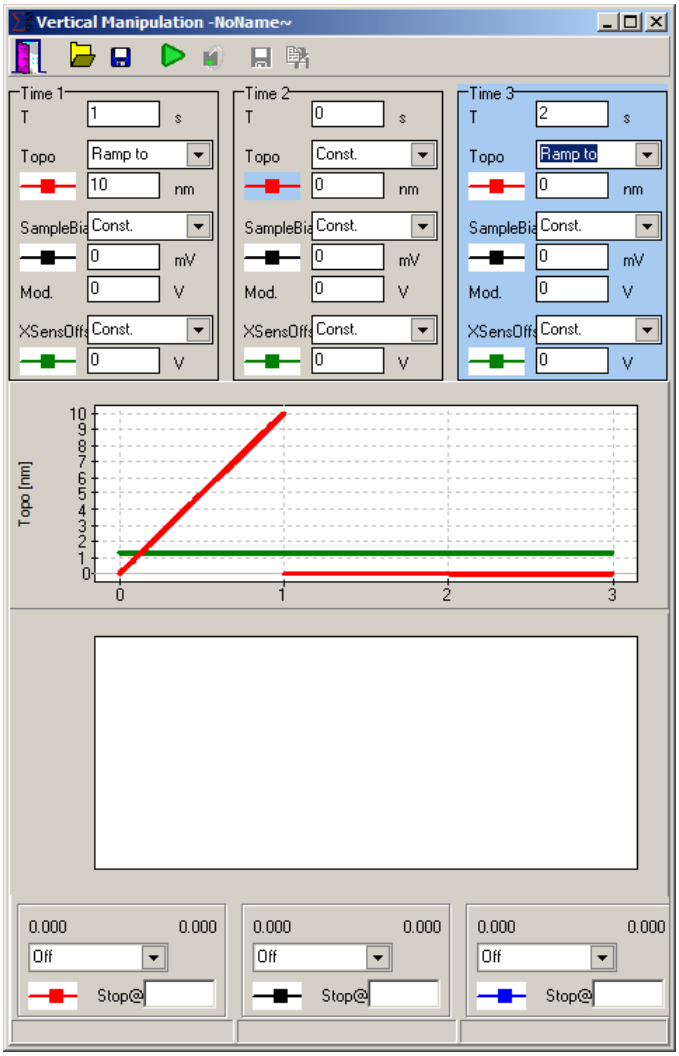
1) Mouse wheels can behave different from mouse to mouse. The ini-entry

[ZControl] → MouseWheelSense=0,00416666666666667

defines how one tick of the mouse wheel is understood by Windows. Use multiples of the given number to adapt your system to your mouse.

2) Each vertical movement is performed with **Slew Rate** in this window.

Vertical Manipulation Windows



Allows to "program" sequences for vertical manipulation.

The sequences can be stored and reload with 

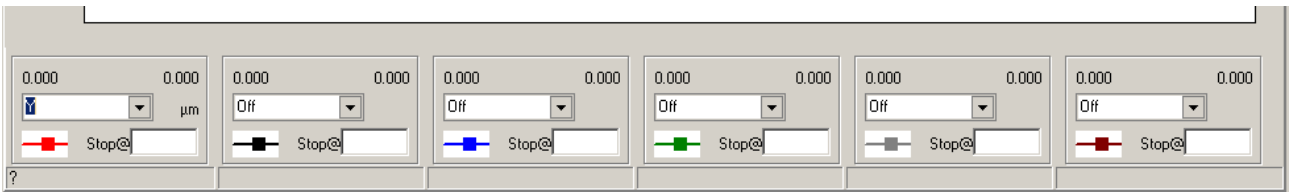
The sequence is started with 

A new time slot can be inserted with the "Ins" key. Time slots that are not required any more can be deleted with the "Del" key.

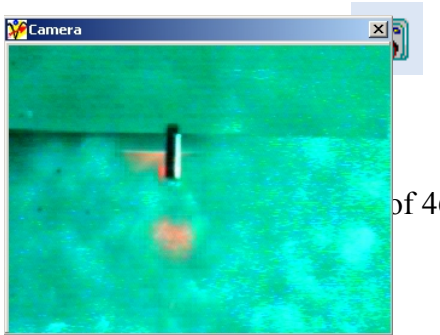
The upper graph shows what has been programmed with the time slot entries.

The lower graph shows up to **six** data channels that can be selected from all available channels from the drop-down channel list.

Enlarge the window to make more channels visible:



Camera Windows & LED adjustment

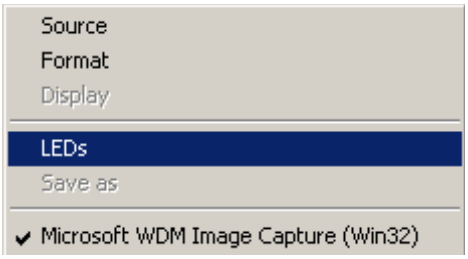


Starting from SXM-software version 18u, this application is

connected to the sxm-application, opens and closes together with the sxm software.

The camera usually is adjusted in a way, that it looks directly onto the cantilever.

With the "right mouse button" inside the camera window, settings for the camera are available:



Source: allows to change the camera format.

Format: allows to change the size of the appearance on the screen

LEDs: opens a small windows, which allows to adjust the brightness of the two LEDs independently:

The lowest position of the sliders darkens the LEDs as much as possible.

Note: the LEDs are not completely OFF in this position.

The highest position makes them as bight as possible.

ATTENTION: do not keep the LED light in bright position for a long time, if it is not required for your application, because they consume up to 50 mA and, thus, heat of the inner part of the AFM head.

The switch "Camera Off during Scan" is a safety for the user. The camera might consume a lot of the PCs time and reduce the performance during image acquisition. It is saver to switch the camera off during image acquisition. This switch realizes an automated "switch off", when the scan is started.

3 Channels and their meaning

Visible Channels

As the hardware provides many version of channels with various scaling and meanings, the huge amount of hardware channels is provided. To limit the "visible" channels for students, the channels can switched off in the scale window (see page 33).

If a channel is visible, the user can:

- use it in spectroscopy
- acquire its data as image in all three scan types
- select the channel in the oscilloscope for visualization

Acquired Channels

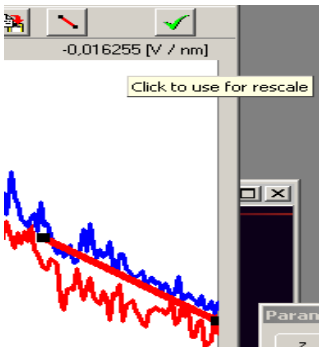
These are channels taken as picture data. They are selected in the Acquire Menu (see pages 6 and Fehler: Referenz nicht gefunden).

4 Required System Calibration for Quantitative Measurements

While the whole system is calibrated for every application, there is one thing, which cannot be

assumed to be constant, because it depends on the user's abilities: the sensitivity of the laser deflection system. It depends on the cantilever reflectivity, of the mounting of the cantilever and on the cantilever adjustment. While the laser intensity can vary between 1000 mV and 5000 mV, the sensitivity can vary between 0.1 mV/nm and 20 mV/nm (typical values, only).

Therefore, **quantitative measurements require a system calibration** after each change of the tip or the tip adjustment.



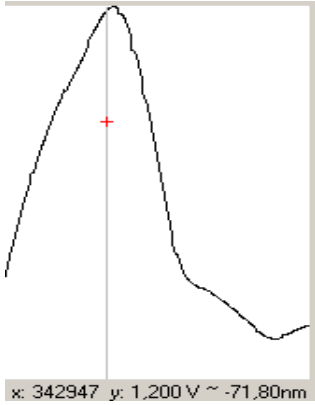
This system calibration is done by distance curves.

In dynamic mode, one detects the amplitude versus the distance. The linear fit allows to fit automatically the first 30 % of the curve. One can manually adjust the fit result, if necessary. After this, a number is displayed above the distance curve and a hint on the number tells: 'Click to use for rescale'. When used, the number changes its colour to 'green on black'.

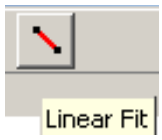
After this procedure, one might open the DNC windows. In dependence on the mouse position in the white screen, it displays now three numbers:

x: frequency in Hz y: amplitude in V ~ **amplitude in nm**

as shown in the image.



In case of **contact mode**, one case to measure the normal force versus distance (T-B). Afterwards, the same linear fit allows to find the coefficient for the contact mode. Usually, these two coefficients are close to each other, but do not equal completely. Therefore, they are stored as two independent parameters.



By clicking into the provided number (colour change), it is overtaken. After this, one finds the calculated contact force as hint behind the reference entry:

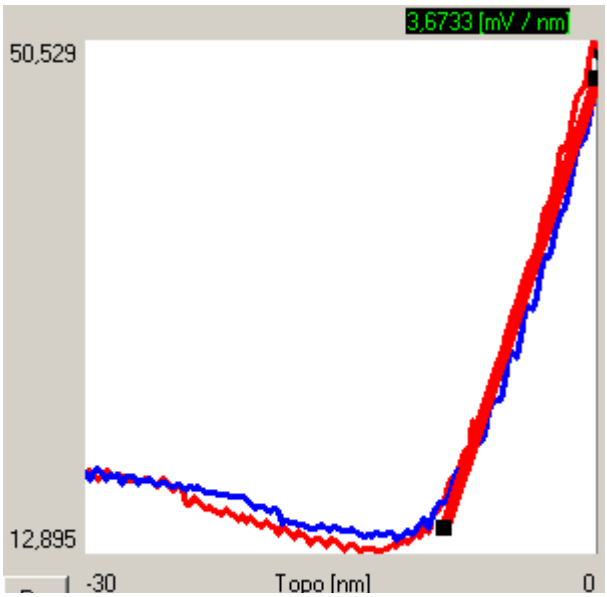
The force constant was k = 40 N/m in the example.

The formula used is:

Force = k / Sensitivity * Reference Value

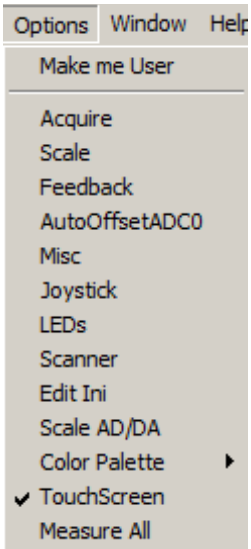
F = 40 nN/nm / 3.67 mV/nm * 50 mV

<u>F = 544,5 nN</u>



5 Software Set-Up and Functions found in "Options"

The most usual setup functions are in the option menu:



Make me User / Make me Admin allows to switch between an administrator mode (all parameters can be set without restrictions) and a user mode with limited access to scaling entries and settings.

Acquire select, which channels are acquired in which direction and saved

Scale select, which channels are active (can be acquired) and how is their physical scaling

Feedback selects the feedback mode

AutoOffset corrects the Offset of the feedback related input channel

Misc scan, image save and coarse move settings

DDE Server program allows/forbids exchange of data with other applications

Joystick allows to select the joystick and to check ist functions

LEDs opens a window to change the brightness of available LED controls (I2C or PWR)

Scanner allows to select a scanner file and to change the scaling of the scanner

Edit Ini opens the active ini-file in an editor window

Edit Ini opens the active ini-file in an editor window

Scale AD/DA is thought for installation, only. Gives access to digital channels. Allows to change scaling settings of the system

Touch Screen if active, icons are displayed larger.

Some additional setup procedures based on direct changes in the sxm.ini file are found here.

Make me User / Admin

Admin-mode: all settings can be set without restrictions. The Options appear completely.

User-Mode: the Options show only the Acquire menu.

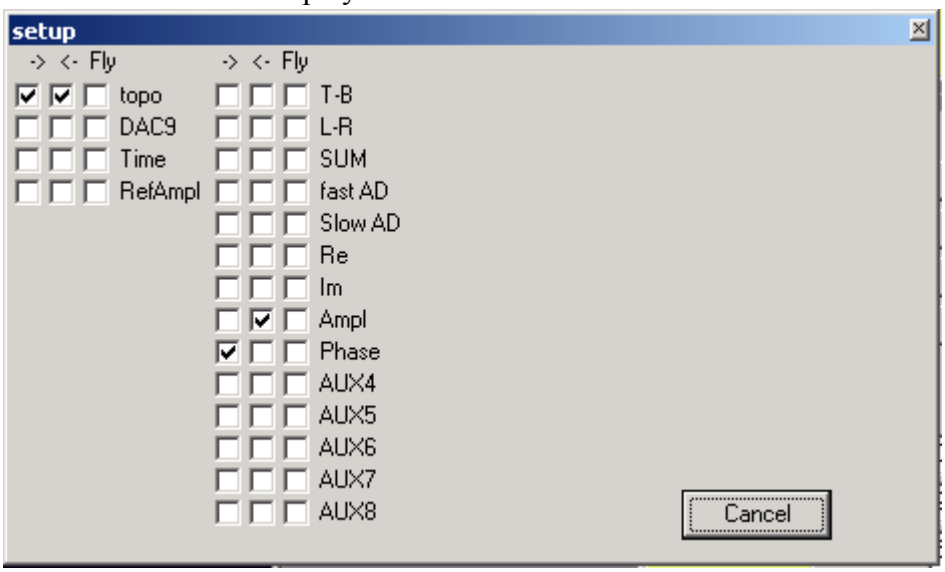
Switch from User to Admin: this requires a password. This password is stored in the user.ini located in the same directory as the running program:

```
[Admin]
CurrentMode=0
WordPass=CETAFNA
```

CurrentMode= 0 equals "User mode". CurrentMode= 1 equals "Admin mode". The password is spelled right to left.

Acquire

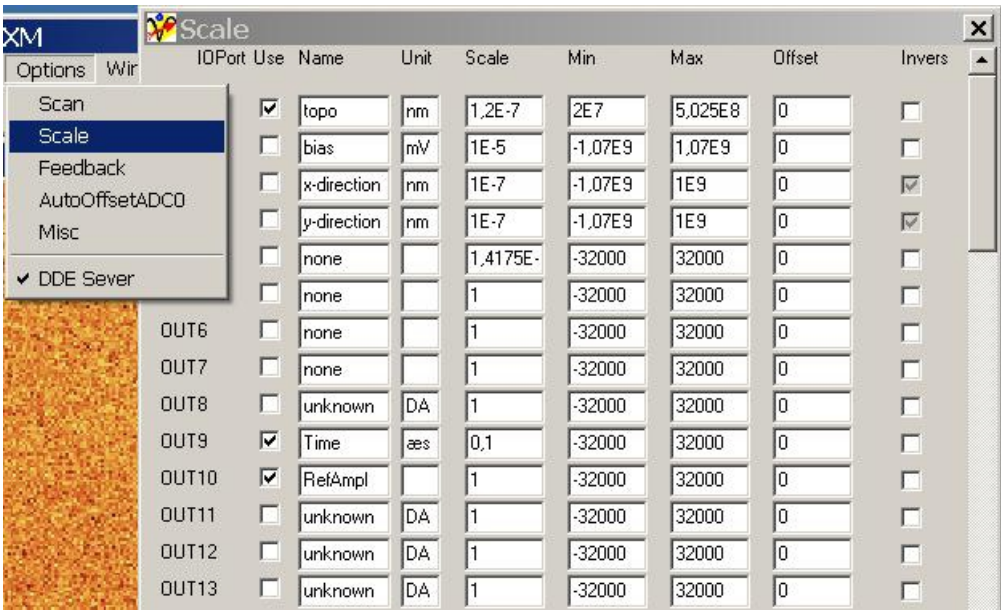
The “Options/Scan” opens a menu called “Acquire” which is a setup of the scan. This menu displays all channels that are selected as “used” in the Scale-Window (page 33). Each channel provides three selection which are displayed in rows.



If you select a channel in the 1st row, the data of this channel are acquired in forward scan direction as picture. The 2nd row allows to acquire pictures in backward scan direction. If one channel is selected in the 3rd row, each line is scanned twice: once as usual with the feedback on and a second time in a certain height adjustable as parameter in this setup window.
In the example shown here, the topography is acquired in forward and backward direction. Two identical pictures are expected. The amplitude is acquired in backward direction only, while the phase is taken in forward direction. All together, you obtain four pictures.

Scale

This window selects, which channels are active and can be taken as picture by the sxm-software, on which hardware channel is which program channel and it makes the relation between the numerical units of the digital SPM controller and physical units of interest for the user.



Use if checked, this channel can be acquired with the software

Name name displayed in the head line of the windows and used for file names

Unit physical unit displayed at related positions in the program

Scale scaling factor between numerical units and physical units. This factor can be negative or positive. If the topographical image, for instance, appears inverted, one can place a negative scaling factor in order to invert its **visualization** in the SXM-program and the Present-program.

num. values numerical values used in the back round of the sxm software

Min /Max minimal num. value, for 16-bit signed integer variables, these values are +/- 32000. For the 32-bit integer variables, +/- 1e9 is chosen. Set to "0", the output of the channels can be reduced to -10 V.. 0 V or 0 V ... 10 V. Even -2 V ... 10 V as needed for PI HV amplifiers is possible.

Max maximal num. value

Offset For certain uses the offset correction can be done here.

Invers especially for z, it can be useful to have an "invers" option. If checked, the channel is inverted at the interface between hardware and software. This allows to define the operation direction of the piezo actuator in z-direction.

Calculation of scaling factors:

As all input channels and all output channels (except the lockin channels) are inverted, the equation for the scale factor is:

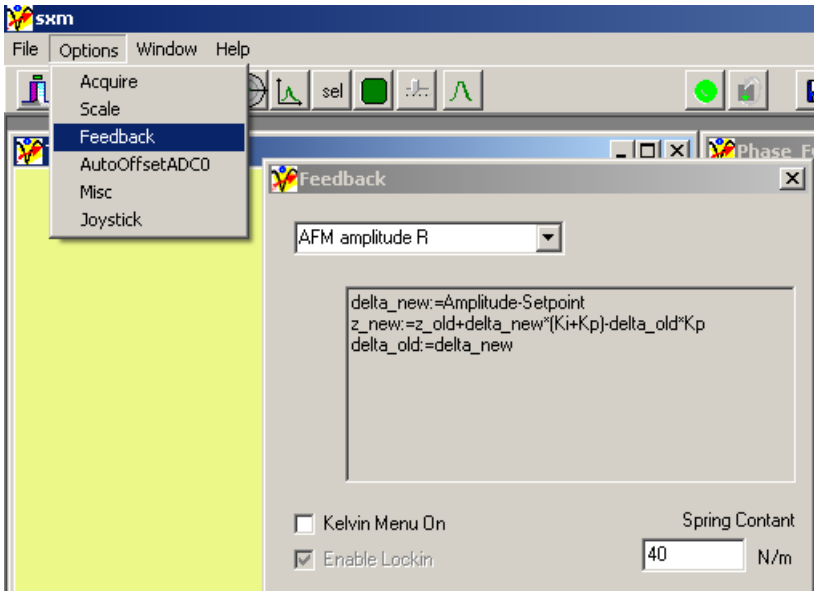
Phys. value = - scale factor * num. value

`Example 1:` The maximum voltage output of the DAC is 10 V and the related maximum num. value is 32000. Then, the scale factor is 0,3052 to obtain an output display in mV.

`Example 2:` The maximum voltage output of the DAC is 10 V and the related maximum num. value is 1e9. Then, the scale factor is 1,07e-5 to obtain an output display in mV.

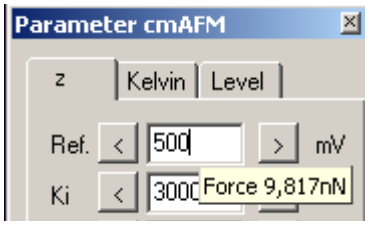
FEEDBACK

The feedback window allows to select the feedback mode and so the mathematical description of the feedback and the input channel used for the feedback input.



The following table shows, how the modes are connected to the used channels:

Mode	**description**	**feedback input**
Off	no distance feedback	→ this mode is used to control the piezo scanner with the Joystick
STM general	standard STM mode	It = AD channel 1
STM supp. Ic	STM mode with suppressed displacement current	It = AD channel 1
STM adapt. Ki&Kp	STM mode with adapted feedback constants	It = AD channel 1
AFM contact mode	contact mode AFM	T-B = AD channel 1
AFM amplitude R	dynamic mode AFM	Amplitude (from LockIn, Channel Out12)
AFM amplitude X	dynamic mode AFM	LiaX (from LockIn, Channel In9)
AFM PLL	dynamic mode feedback for vacuum applications	
	with separate feedback circuits for	
	the frequency	Phase (from LockIn, Channel Out13)
	the amplitude	Amplitude (LockIn,Channel Out12)
	the distance	from frequency feedback output.



Under the selected modes, their mathematical description is written.

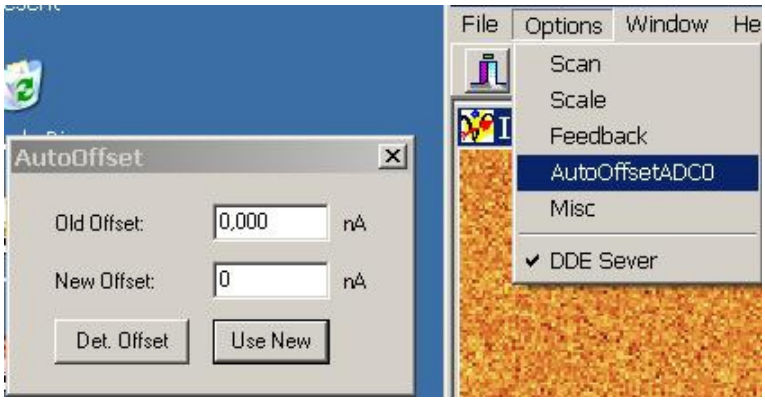
In case the 2nd lockin amplifier is installed, the Kelvin Feedback can be switched on here.

In Contact Mode, the DNC window vanishes. It can be enabled for certain applications (Force Modulation Mode – see chapter Operation Instruction) by ' Enable LockIn'. A message warning is shown, when the frequency is swept in contact mode.

The entry for the force constant is used to give an estimate of the **contact force** in contact mode. In order to display the contact force as hint, move with the mouse over the entered reference value. The system assumes that the T-B signal has been zero in a far distance between tip and sample. Also, it takes the last calibration of the sensitivity from the force distance curves.

AutoOffset

This function is used to correct the offset of the feedback input channel. It shows the valid offset and allows to determine the current offset automatically. With "Use New", the detected offset is overtaken in the program and this window is closed. With "Esc" the window can be left without changing the offset.



Misc

The “Miscellaneous” allows to set the save path for images and to select the AutoSave function. The stepper steps for approach and retract have only an effect, if the stepper is installed. Then they provide the number of steps done when the 'AutoApproach' button or the 'Retract' button are used.

Autocorrect z Violation uses the function "One Step" at the end of each image, if the z-position of the tip is in a vilent region (as close as 10 % of the total z-range).

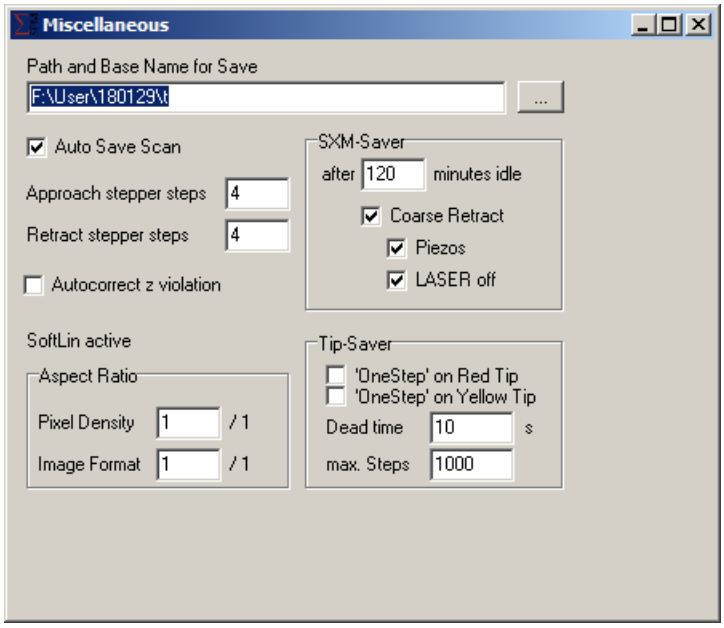
The activation of scanner linearization features of the software is also visualized here.

SXM-Saver Funktion:

allows an automated 'Coarse Retract' of the system after a certain time given in minutes and the conservation of the LASER diode and the HV-amplifiers (Piezo output voltage set to moderate values).

Tip-Saver Funktion:
The Tip-Saver function is activated only, if the system is in the state “Approached” (see message line of the parameters window). If the system is in the state “Coarse Retracted”, the function is deactivated and the counted number of single 'One step' functions already performed is reset to zero.

Settings for the Tip-Saver are available in [Options/Misc]:



“ 'OneStep' on Red Tip” … enables, that the most retracted position of the tip is monitored during approached state.

“ 'OneStep' on Yellow Tip” … enables, that the most extended position of the tip is monitored during approached state.

If one or the other case gets true, the function behind “OneStep” in the parameter window is carried out.

Aspect Ratio Function
“Pixel Density” – sets the ratio of the pixel densities in X-direction vs. Y-direction
“Image Format” – allows to scan non-quadratic images.

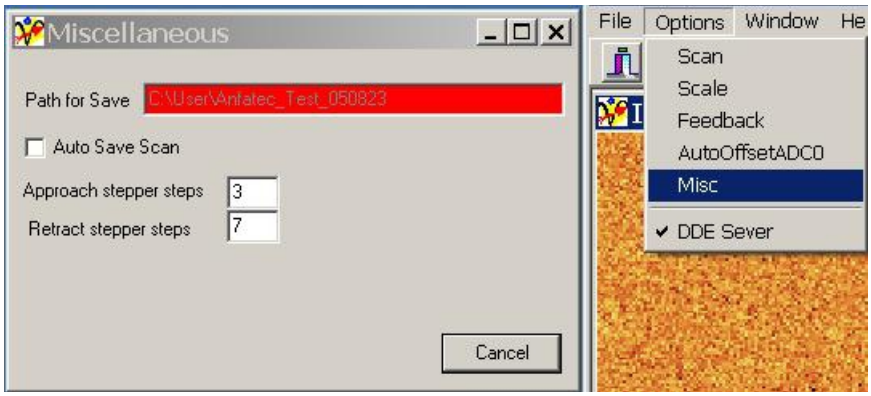
Dead time … during “One Step”, the piezo in z-direction is automatically and fully retracted and the feedback is disabled. After the step, the feedback is enabled again and the tip automatically approaches to the sample with the speed defined by the feedback settings. In dependence on the systems parameters, this approach movement in feedback can take some time and the tip might (for instance) be found in the “red” position for some time after “OneStep” was carried out. In order to avoid that the “OneStep” function is repeated without giving the tip a chance to re-approach again

to the surface, a "**Dead time**" can be defined. It is a minimum time in which the Tip-Saver function is not active and thus the minimum time between two calls of this function.

In order to define this "**Dead time**" correctly, release the tip once from Piezo retract position and estimate the time the tip requires to move trough the available z-range.

As there are other reasons (for instance a completely broken tip in dynamic mode AFM that results in a constantly retracted tip), **"max. Steps"** defines a maximum number of single steps that are performed.
The number of already performed steps is a hint shown when the mouse is moved over the edit field behind "max. Steps". The number of performed steps itself is shown as hint in the bottom line (where all hints are shown) of the whole sxm-program.
Negative number equal steps towards the sample (after yellow tip colour) and positive number are shown after steps away from the sample (after red tip colour). If backwards and forward steps occur subsequently, this counter counts up and down until the absolute value equals "max. Steps". Then, the function shown I bold letters behind the retract knob is called.

The red circle shows where the mouse should be to activate this hint.



Scanner

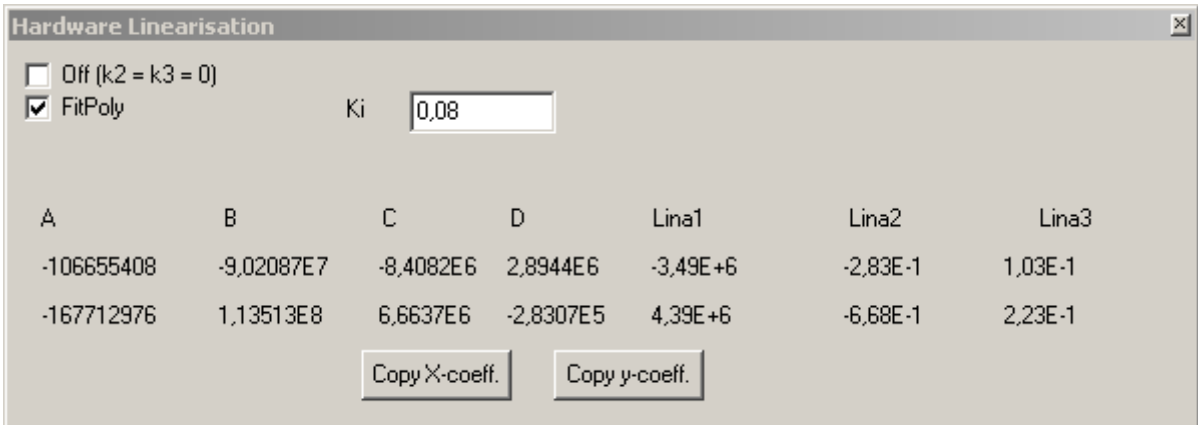
Setting for the scanner.

Linearisation with the feed forward mechanism is described in:

B. Graffel, A.-D. Mueller, F. Mueller, M. Hietschold, Rev Sci Instrum.

Online-Hardware-Linearisation

When the voltage ramp applied to the x- and y-piezo is linearly (k2 and k3 are zero), the lateral movement usually is not linearly (piezo hysteresis, scanner construction, greep, ...). In online mode (FitPoly is checked), the hardware needs to provide two signals from two input channels. In the Level-AFM, these are two strain gauge outputs called “DMX” and “DMY”, which are connected to the AD-converter channels AUX5 and AUX6 and linked to the input channels In14 and In15 (see the description of the scale window on page 33). With the entry [hardlin]:InX=14 and [hardlin]:InY=15 these two channels are provided as input channels for the online-hardware linearisation.



Now, based on these measured values, the system approximates the detected movement with a polynomial of 3rd order and displays the coefficients A (offset) to D (3rd order). Based on the knowledge of the last coefficients and this new approximation, it calculates a 2nd order polynomial for the voltage ramp to be applied to the x- and the y-piezo for the next scan line. The coefficients of this voltage polynomial are displayed here as 'Lina1' to 'Lina3' in two lines for the two directions.

As this is a feedback, it does not react with the full strength to a requested change in the coefficients (this avoids jumps and overreaction on wrong or noisy signals). Moreover, it allows the user to set a **Ki** in order to choose, how fast the system reacts on changed linearity parameters.

The required coefficients depend on scan speed, scan window size, scan window position. Therefore, they might change when the central position (x-Center, y-Center) are changed or the scan range is changed. In dependence on Ki, it might take some scan lines, until the right coefficients of the new range are found.

Take care: Do not choose Ki too large, because this might lead to unexpected artefacts.

Offline Scanner Linearisation

One can use this Hardlin-Option to correct non-linearities with a fixed parameter set. Set Ki = 0 and do not check FitPoly. Enter suitable parameters in the sxm.ini under the topic [hardlin], for example
LinXa2=-0,24
LinYa2=-0,64
LinXa3=0,091
LinYa3=0,222

and check the correction with a scan on the chess patterned grating.

Scan Range correction – SoftLin

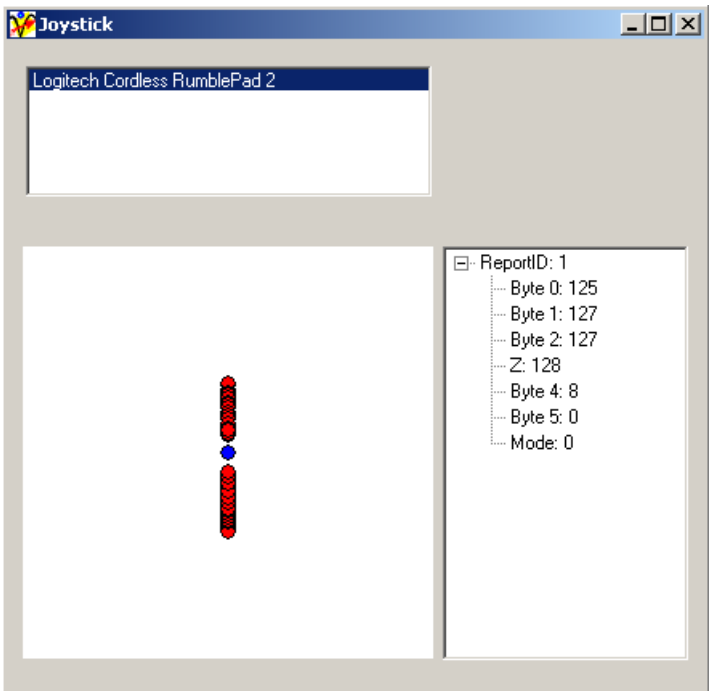
For typical piezo scanners, the scan range does not depend linearly on the voltage ramp height. Anfatec's Scan software allows to correct this dependence by using an external scanner file to be

placed in the same directory like the sxm.exe. These files can be produced and stored with the software SoftLin.exe. Usually, such a file is provided with the AFM (e.g. S0703.ini).

The entry " Name='S0803' " under the topic [Scanner] together with "SoftLinOn=1" allows to enable this function.

JOYSTICK

Starting from Version 18, it is possible to use a joystick as help for the Coarse Control of the microscope. The Window 'Options/Joystick' allows to check the functionality of the joystick (it shows the bits of the single handles and of the knobs on the joystick).



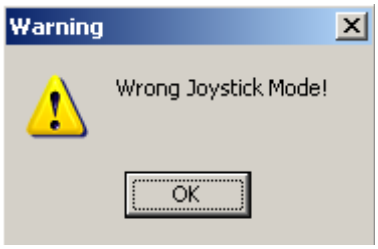
In the left upper window, it shows a list of found Human Interface Devices (HID devices). One can select the one to be used. In the left lower window, it shows the position of the handles (left/right handle as blue dots, up/down handle as red dots).

When the text in the report shows "X: ..." or "Z: ...", this direction is connected to the related coarse movement. The correlation is done in the sxm.ini with the entries under the topic [Joystick]:

JoyItemX=0
JoyItemY=1
JoyItemZ=3

Here, "-1" stands for 'not used'. "JoyItemZ=3" means, that the 4th entry in the list is used for z-movement.

In the Level-AFM, the x-movement and the y-movement is disabled, because there is no automated x-y-tablet available. Then, the entries "JoyItemX=0" and "JoyItemY=1" have no effect, except for the feedback mode "Off".



When the system does not react on the joystick, it might be in sleep mode. Press any knob to awake it. Some joysticks use two modes, between whom one might switch with a special knob on the joystick (mode-knob). If the system finds the joystick in the wring mode, it will display a message as warning:

Also, if the tip is approached by automated approach, it will not react on a use of the joystick (in order to avoid a crash of the tip). Moreover, it will display another warning:

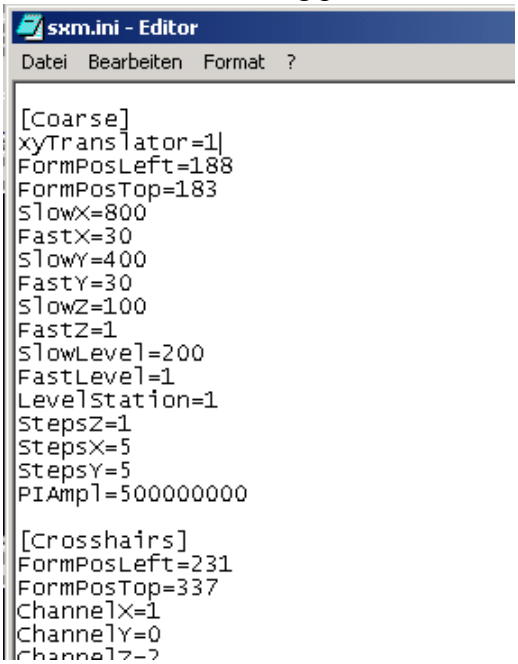
For the speed adjustment of the joystick refer to page 41.

Move the scanner with the Joystick:
One can move the scanner (outputs X, Y, and Z at the controller) from the software with the joystick, if the Feedback-Mode "Off" is enabled. This mode works only in all three scanner directions, if the ini-entry [Joystick] JoyItemX=0, JoyItemY=1 and JoyItemZ=3 is set. With JoyItemX=-1, the direction x would be disabled.
This function is used in combination with the "CurrentPosition"-display in the Select-Window.

6 Advanced Set-Up Procedures

Set-Up of the Coarse Movement in X-Y-Direction

Open the sxm.ini in an editor. Search for the strings "coarse" and "stepper". In the coarse-section of the ini-file, the following parameters affect the lateral movement:

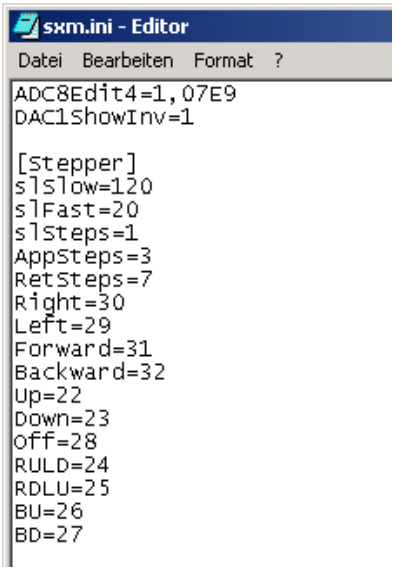


- xyTranslator=1... switches the buttons for the lateral movement in the coarse window on
- SlowX, ... time between two bursts in ms used if the position buttons are pressed – *can be changed in the "Anfatec Scan"*
- FastX, ... time between two bursts in ms used if the position buttons are pressed together with the Shift - *can be changed in "Anfatec Scan"*
- StepsX=**xn** ... means, that with each click on button or , the X-output gets **xn** ramps
  StepsY=**yn** ... like StepsX, but for Y
- PIAmpl=**xx** defines the amplitude of the ramps in Y and X direction. The output voltage is **xx** / 1e8 in V.

In the stepper-section, the channel numbers for the lateral movement buttons have to be entered as shown in the picture:

Right = 30 Left = 29
Forward = 31 Backward = 32

If you like to switch the directions (for example left to right and vice versa), simply give the channel Right the number 29 and the channel Left the number 30.
You can check the functionality with an oscilloscope.



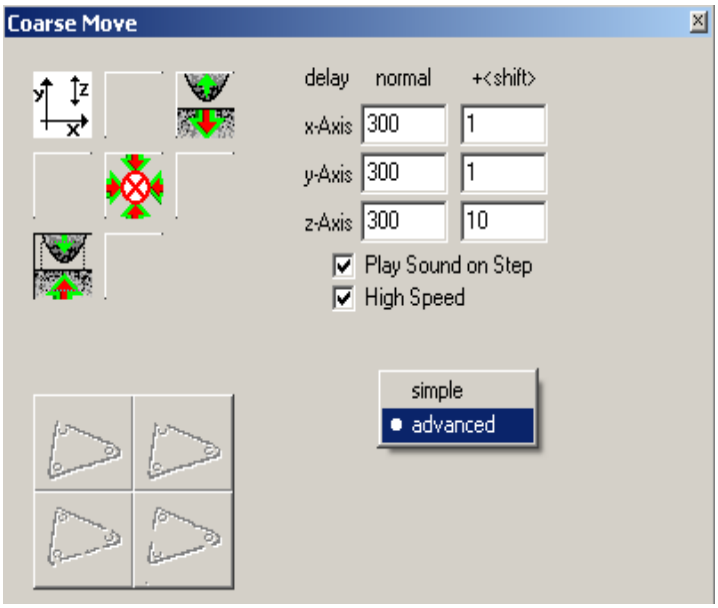
Usage of the coarse positioning

After the changes in the sxm.ini, the sidewards buttons in the coarse window should be activated. With the **right mouse** button in the coarse window, you can open the

'advanced' setup for additional settings.

The displayed parameter x-Axis/normal = 800 equals the SlowX parameter in the sxm.ini and the parameter x-Axis/+<Shift> = 30 equals the FastX parameter in the sxm.ini.

The number of steps for each click and the amplitude of the ramp can only be changed in the sxm.ini directly.



If you press uninterrupted and SlowX=800, every 800 ms an amount of **xn** pulses with the amplitude **xx** is sent to the x-channel output. After each usage of the lateral positioning, the output voltages X and Y are set to zero. If the time given in SlowX is shorter than the time needed for the given number of pulses, an uninterrupted press of the X-button results in an uninterrupted ramp output. The same is valid for the FastX and FastY parameters.

When the **Joystick** is installed, the current speed achieved with the joystick is calculated from the interpolation between the delays 'min' and 'max', as well. When used very softly, the delay 'max' allows to translate the sample in single steps. When fully extended, delay 'min' determines the maximum achievable speed.

Attention: the delay is connected to the *Direct-X-Timer* of the PC. If some other software (for example the *USB-camera*) uses the same timer extensively, it is possible, that the timer for the coarse movement (fast movements) is changed (can cause very fast movement of the motors)!!.

Play Sound on Step – enables a sound generator. This function gives a short sound, when the coarse movement is used. The number of sounds does not equal the steps, especially not, when a large number of steps is done in a short time.

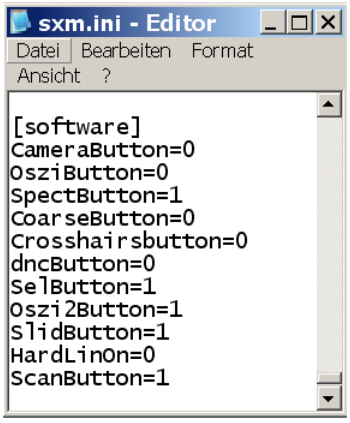
High Speed – is a switch for some special hardware (UHV slip stick), which allows to switch between different ramp voltages. It is not used for standard setups.

Switch back to “simple” to hide the right part of the enhanced coarse move window.

Switches for hidden Program Parts

Open the sxm.ini in an editor. Search for the string “software”. You find the lines shown here to switch parts on or off.

Check Appendix 1 (description of the ini-files) for explanation.



Joystick Setup

```
[Joystick]
Use=1
FormPosLeft=164
FormPosTop=242
JoyName="Logitech Cordless RumblePad 2"
JoyItemX=0
JoyItemY=1
JoyItemZ=3
Tolerance=10
JoyModeByte=6
JoyModeBit=3
SelectPoint=6
```

If the joystick does not work properly, one should check that the ini-entries in the currently used sxm.ini (the file can have a different name) are as shown in the screen shot. The entry [Tolerance] allows to make the joystick less sensitive against small deviations from the central position. The entry [SelectPoint] is the number of the button used to save the current x-y-z-position together with the data in channel AD4 in the select window.

With use=0, the joystick can be disabled.

An entry JoyItemX=-1 disables the movement

Setup of HVA and Scanner Gains (from vers. 21B)

This procedure should be done by authorized personal, only! It requires a login in Main-Admin mode for the software.

The usual chain of stages towards the scanner's movement consists of

- low voltage output of a D/A-channel (e.g. channel 0 for Z) with -10 V to 10 V output
- High voltage amplifiers (with a certain HVA gain, e.g. 7.5 for 75 V)
- Piezo gain provided by the piezo producer typically is given in units of nm/V

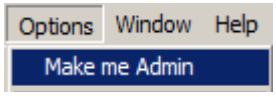
The D/A-Channel gains are usually already set. If not, one can use the AD/DA-Window to do it.

The output then is calculated as:

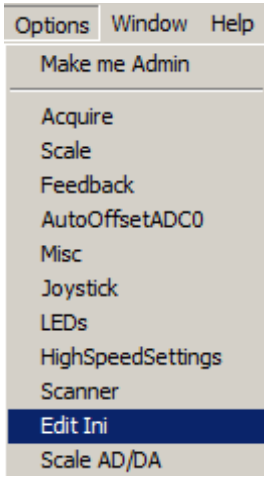
digital number [digits] * DA-Gain [V/digit] * HVA-Gain [V/V] * Piezo-Gain [nm/V] → nm

The **HVA gains** are saved in the sxm.ini file, because they are basic parameters of the microscope.

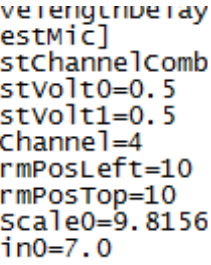
Make yourself a high-level administrator by selecting and entering the password "anfatec"



Open the used ini-file from the software:



Search for the string "TestMic" in the ini file:



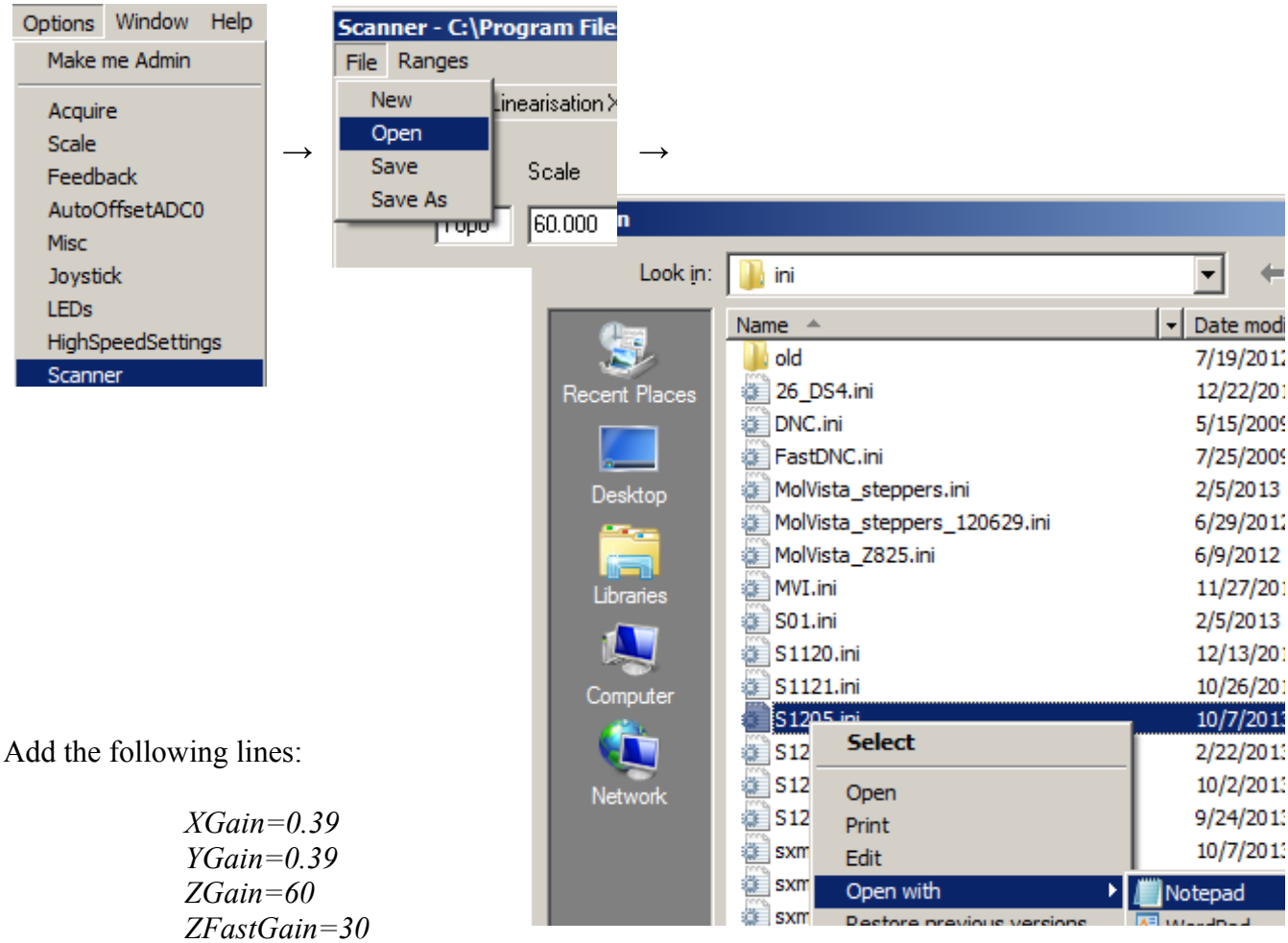
Add entries for the DA-channels 0 (this channel equals “Topo”, the entry is: “Gain0”), 2 and 3 (these channels equal x and y, the gain entries are “Gain2” and “Gain3”) as follows:

Gain0=15
Gain2=15
Gain3=15
GainzFast=15 *// this is for the fast Z-channel in high-speed systems*

These gains are the amplifications of the high-voltage amplifiers. I your case, these numbers should be 15.

The **Piezo Gains** are saved in the scanner file, because they might be different for each scanner.

- Open the used scanner file from the software in Notepad with three steps:



Add the following lines:

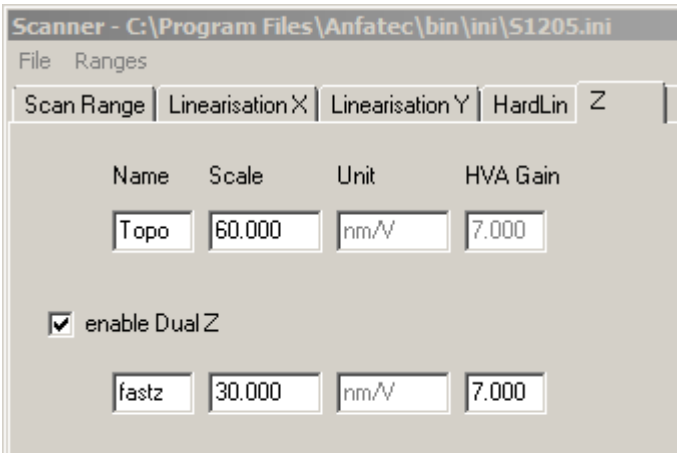
XGain=0.39
YGain=0.39
ZGain=60
ZFastGain=30

The numbers behind these entries are the piezo constants in units like “nm/V” for z-directions and “µm/V” for x- and y-direction. The volts are the volts of the HV amplifier.

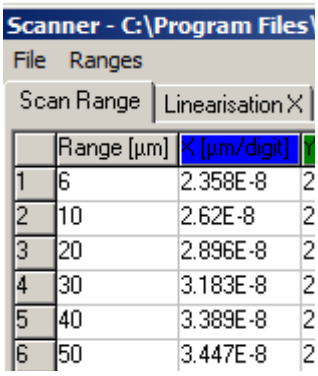
Calculation example: A piezo stack with 150 V maximum voltage supply and 9 µm maximum movement range has a piezo gain of 9 µm / 150 V = 60 nm/V.

How to check the settings:

For the two possible z-channels, the piezo gain and HVA gain are displayed in the Z-tab of the scanner window:

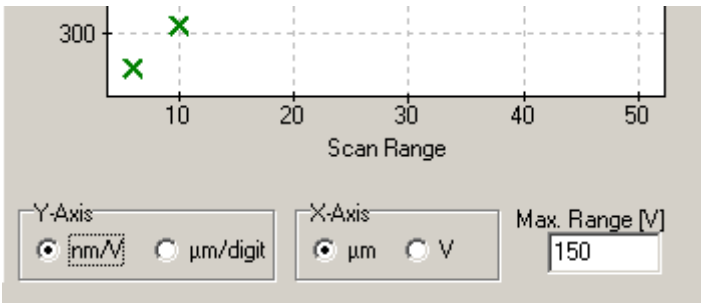


For the X-Y-direction, the gains are used to display the scan range calibration coefficients in units of "nm/V" as typically provided by the piezo supplier:



Goto to the tab "Scan Range" I the scanner window.

Enter the correct maximum voltage that the HV amplifier output can supply I the field below "Max. Range [V]". For a -150 V to 150 V amplifier, this voltage is 300 V. For the 0 V to 150 V amplifier, this voltage is 150V.



Chose the tick "nm/V" instead of "µm/digit", and the entries I the scan range table are recalculated in nm/V and displayed in this unit. The vertical axis should be approximately the value that was entered as "XGain" in the scanner file.

1 7 Revision History

From 15 to 16

- Move the channel LiaR and Phase from the input channels to the output channels -> allows the acquisition of the Amplitude in Fly mode.
- Change the numbering of the output channels and extend the width of Amplitude and Phase to 32 Bit

From 16 to 17

- Visualization of the tip-position vs. sample
- Single Step and automated Stepper Off function

From 17i to 17 j/17h

- Add the function "Level" in the Parameter Window in order to subtract the sample plane from the current z-position during scan and thus to improve the feedback control during scan
- Transfer of the function "Fly" from the menu "Options/Acquire" to the "Parameter Window" as new tab.
- Extend Fly-function by adding a planar scan in a height and to allow to switch it off.

From 17h to 18d

- Add a Game Pad function ("Options/Joystick"), which allows to control the coarse movement by a game pad.
- Extension of the Coarse Move functions to adapt the Omicron Slip-Stick Control

From 18d to 18e

- Removal of an incompatibility between the SPIP Software dongle and the Game Pad

From 18e to 18k

- Scanner movement with joystick in Select-Window
- Switch between Admin and User mode
- System hints for image time and system status

From 18k to 18u

- Implementation of a complete script language (replaces the old script)
- Light adjustment from program + camera On/Off

From 18u to 18w

- Implementation of new script language
- Removal of KP feedback bug

From 18u to 19a

- New driver version 0.7.0 – check of driver compatibility
- Unused channels for the Multi-Channel lockin are not acquired, if they are disabled in scale
- Display of phase in DNC

From 19a to 19c

- Sync filter implemented for the AMU2.6 board
- ApproachDeadTime implemented (waiting time between steps for coarse approach)
- Command 'SETLASER' in the script language

From 19 to 20

- Compatibility to Windows 7

From 20 to 21

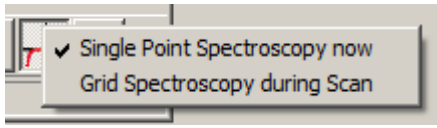
- Implementations for the Fast Scan controller and a Multiple-Channel USB-SPM-Controller
- accessibility from LabView, SciLab and MatLat
- new script functions (e.g. GETCHANNEL)
- dynamic scanner linearisation

From 21 to 23

- Visualization of Piezo voltages in [Options → Scanner → Z]

New in Version 26.xx

- Convention for where and how to safe data [File → Set Save Path ...]
- Matrix-Spectroscopy / Line Spectroscopy accessible inside acquired image



- Z-Control (page 28)

- New *Time Scheme for Spectroscopy* (see page 14)
- Vertical Manipulation Tab (see page 29)
- Present version that relates spectroscopy data to the image data
- Asymmetric Images and Pixels (page 9)