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. Though, the student get only the needed information.

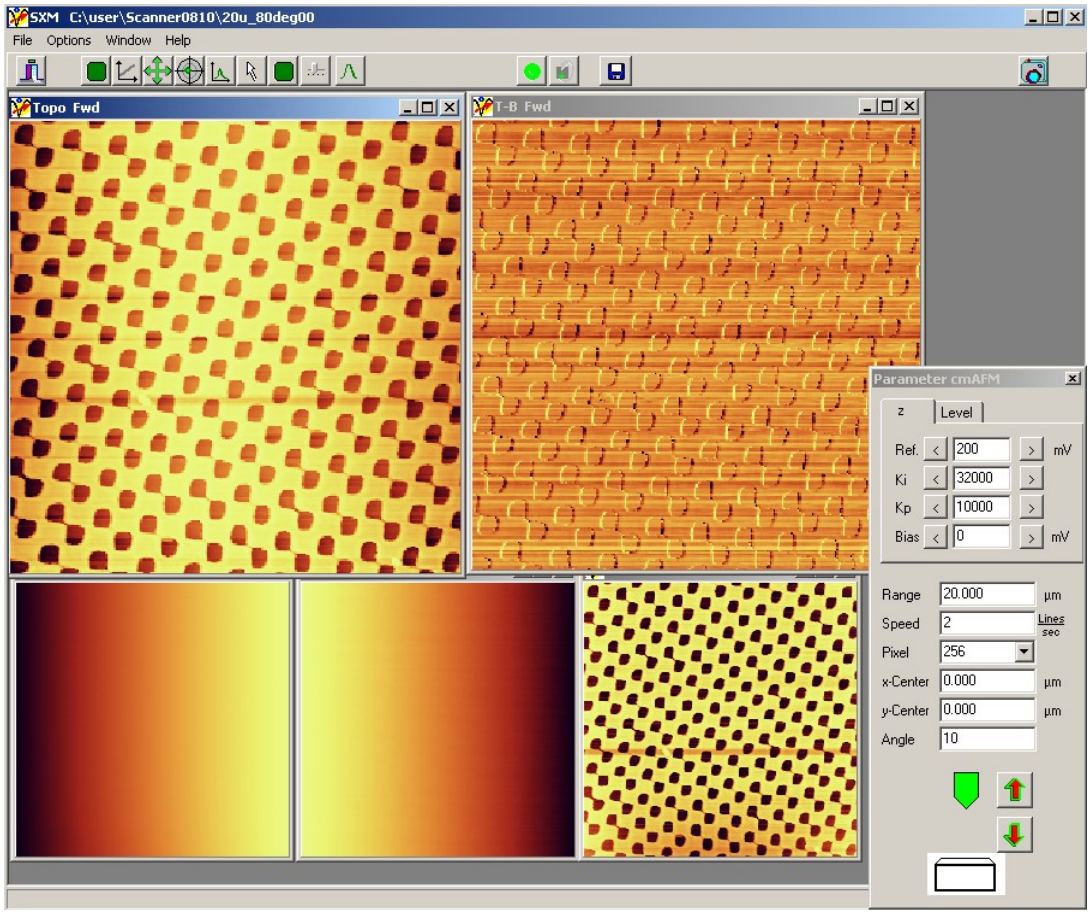
Note: all parameter inputs into the program has to be confirmed with ENTER. Wrong number, which can be detected automatically, are marked in red and comments explain what's wrong.

1 Quick-Start for Anfatec Scan

Start the program

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

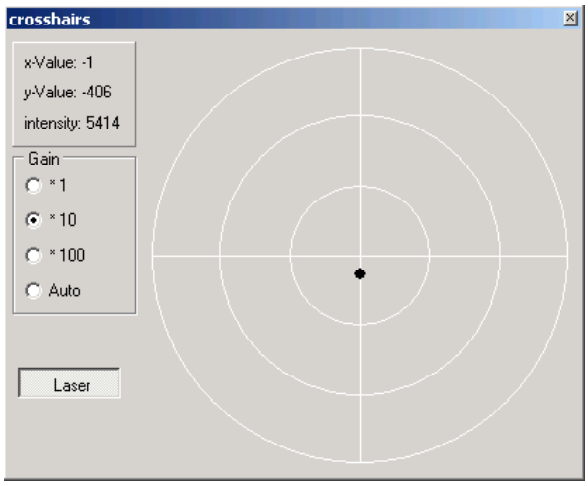
When started, the last opened scan windows and the parameter windows are shown.



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 15)
- ✗ 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 set point

- ✗ Open the oscilloscope
- ✗ display the input channel (It for STM, T-B for contact AFM, 'Ampl' 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 systems 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 set point to maximum = soft-retract, increase drive, check free amplitude, set the set-point to new value).

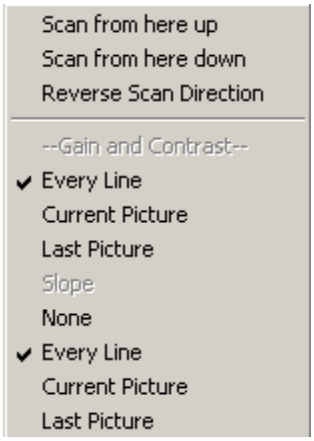
Acquire Images

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 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. "Topo Fwd"):



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 SET POINT 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 set-point 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	

Parametes during imaging:

- Start scan with 1 line/s.
- Increase Ki until oscillations seam 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 in 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

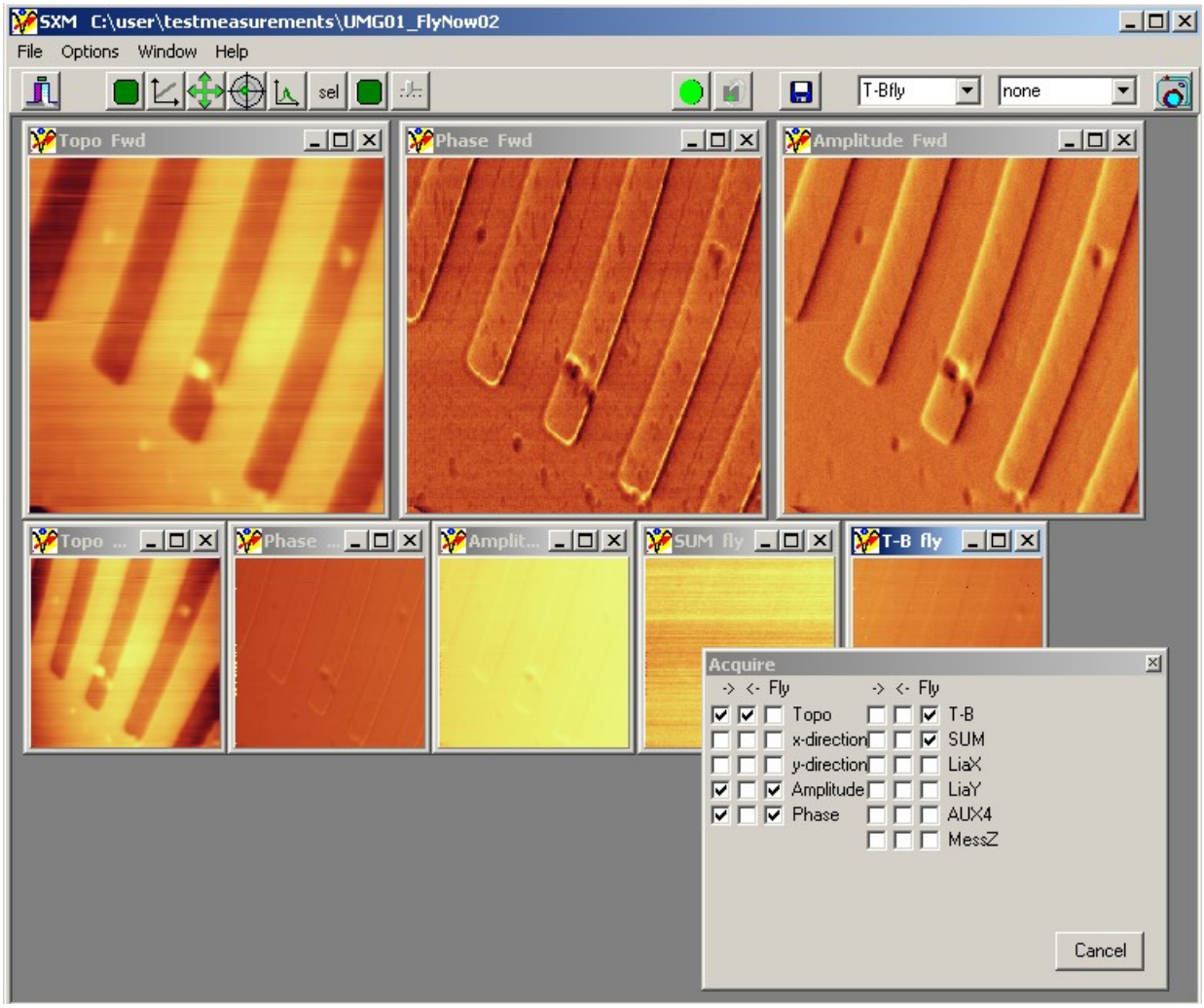
1 Explanation of the Windows / Buttons and Keys

Here, the following windows are described:

- Main Window
- Spectroscopy
- Coarse move
- Cross hair
- DNC = dynamic non-contact mode
- Select (an new image range for zoom into a picture)
- Oscilloscope
- Slider

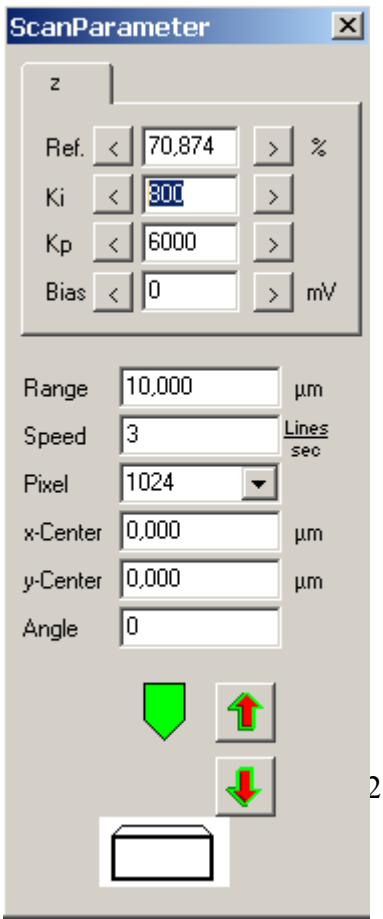
Main Windows and Child-Window - Places and Sizes

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 set point 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)

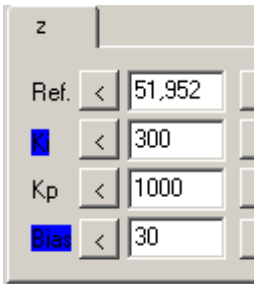
Range scan range in µm

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 $\sqrt{2}$.



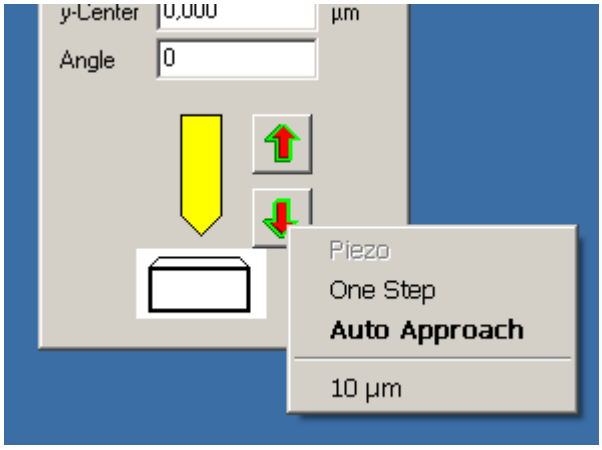
Switches behind the parameters:

Ki and 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 on the 2nd value, 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.

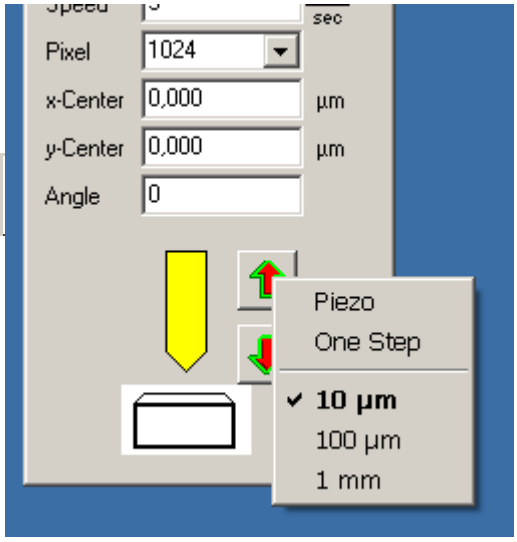
When the right mouse button is used on the approach button, it shows two options: "one step" and "Auto Approach". The fat written one is the standard option performed when the left mouse button is used on the approach knob.



The automated approach is a loop in which:

- the piezo is retracted fast
- the steppers move "Approach steps" forward (approach steps are defined in 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 set point value.



Retract button: when pressed, the tip is retracted by th 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.

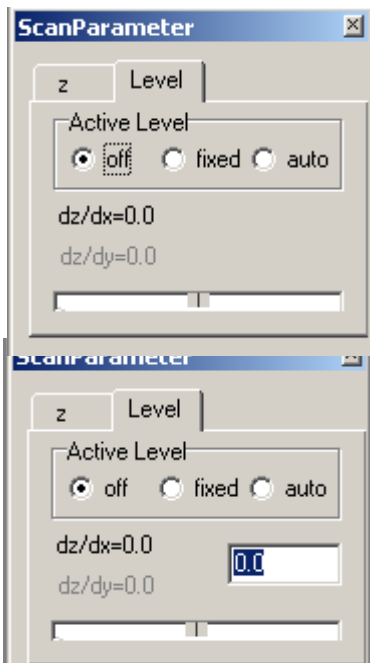
As standard, "10 µm" is selected. When the retract button is used in an approached situation, the piezo is retracted first. Then the stepper is used to retract 10 µm.

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

Tip color:

Color	*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 color 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.

The Level-Tab – Plane Correction during Image Acquisition

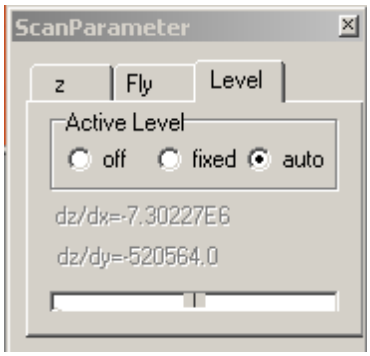


The main change is the leveling of the sample plane versus the scanning plane during image acquisition. This leveling is neutral to the z-output of the feedback. It consists of two coefficients 'dz/dx' and 'dz/dy', which describe the tilt in x- and in y-direction, respectively. During the scan, when 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.

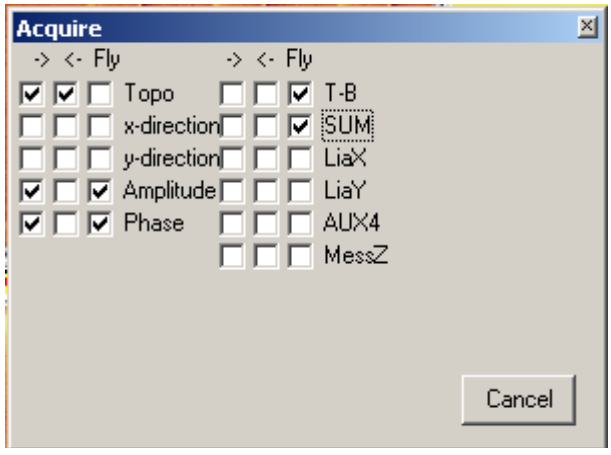
Auto reacts on "Image ready". When a picture is completed, the plane of this image is calculated based on the last (displayed) coefficients 'dz/dx' and 'dz/dy'. The new coefficients are displayed. The next image is taken with corrected plane. As long as Auto is ON, this procedure is repeated after each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

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

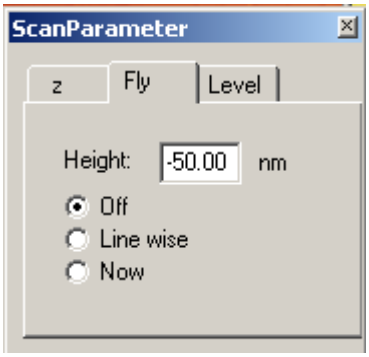
Fly-Tab – Variations of the Standard Two-Path Imaging

Fly modes are used to image the surface a 2nd time in a different height. If the flight is intended, one has o 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 und er"height".



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



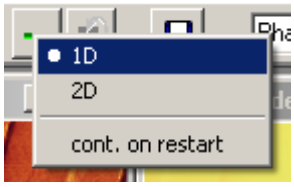
Off scans over the surface as if 'Fly' is not intended. Even, if there is a number given as height, this number is not used. (Don't get irritated: the images with the name ".... Fly"do not disappear and their last data are shown during scan. But when saved, these images are empty.)

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!!!

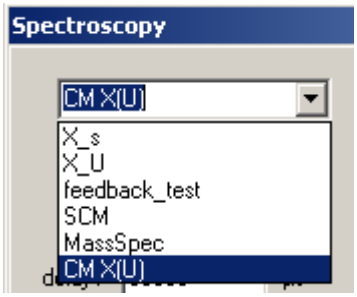
When a planar scan in a 'Height' is intended above the surface, but no complete picture should be taken in advance, we suggest the following procedure:



- 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 fist 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 repeatably.
- 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.

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

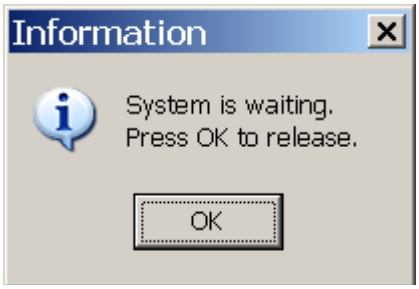
feedback_test provides a jump at the output "Z"

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 dat 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!!)
start	start voltage
stop	stop voltage

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 know gets released again.

Saves the spectrum with the next valid number.

Allows to save under a new name or directory.

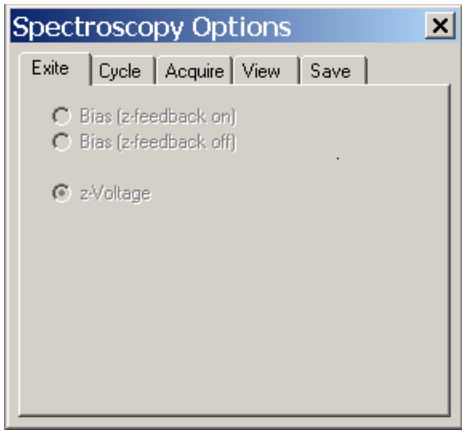
Copies the data to clipboard.

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:

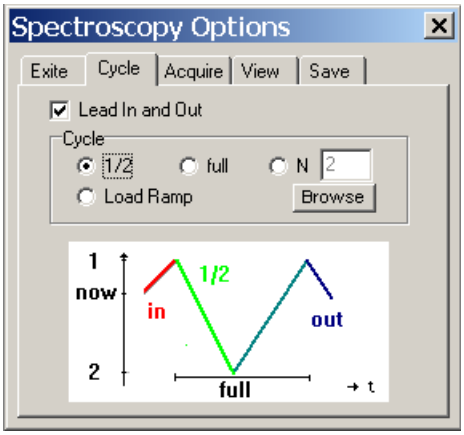
Exite selects the spectroscopy type
Cycle defines the start and end points of the variable to be swept with respect to the actual position
Acquire
View
Save enables the user to set the file the parameters for the ASCII export of the data



Excite

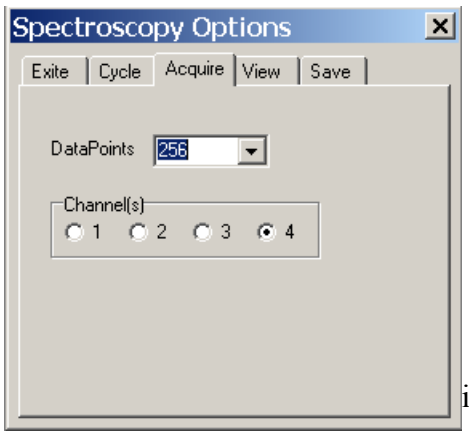
When a pre-defined spectroscopy is chosen (e.g. Distance spectroscopy), this windows shows, which variable is swept during spectroscopy.

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



Cycle

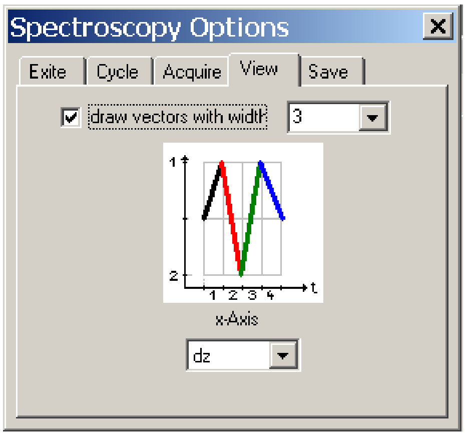
Lead In an Out if "On", the sweep starts at the value set or detected at this moment
Cycle ½ cycle measures from value 1 to value 2. The full cycle measures from value 1 to value 2 and back. N cycle repeat the full cycle N times. With "load ramp" a user dined ACSII ramp can be loaded.



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.

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

Distance spectroscopy (X_s)

- ✗ the tip moves with scan speed to the acquisition point.
- ✗ wait “delay 1”
- ✗ the feedback is switched off
- ✗ z-movement over dz
- ✗ data acquisition with “delay 2” between the single data
- ✗ feedback is switched on

I-U-Spectroscopy (X_U)

- ✗ the tip moves with scan speed to the acquisition point.
- ✗ wait “delay1”
- ✗ the feedback is switched off
- ✗ z-movement over dz
- ✗ data acquisition with “delay2” between single points
- ✗ feedback is switched on

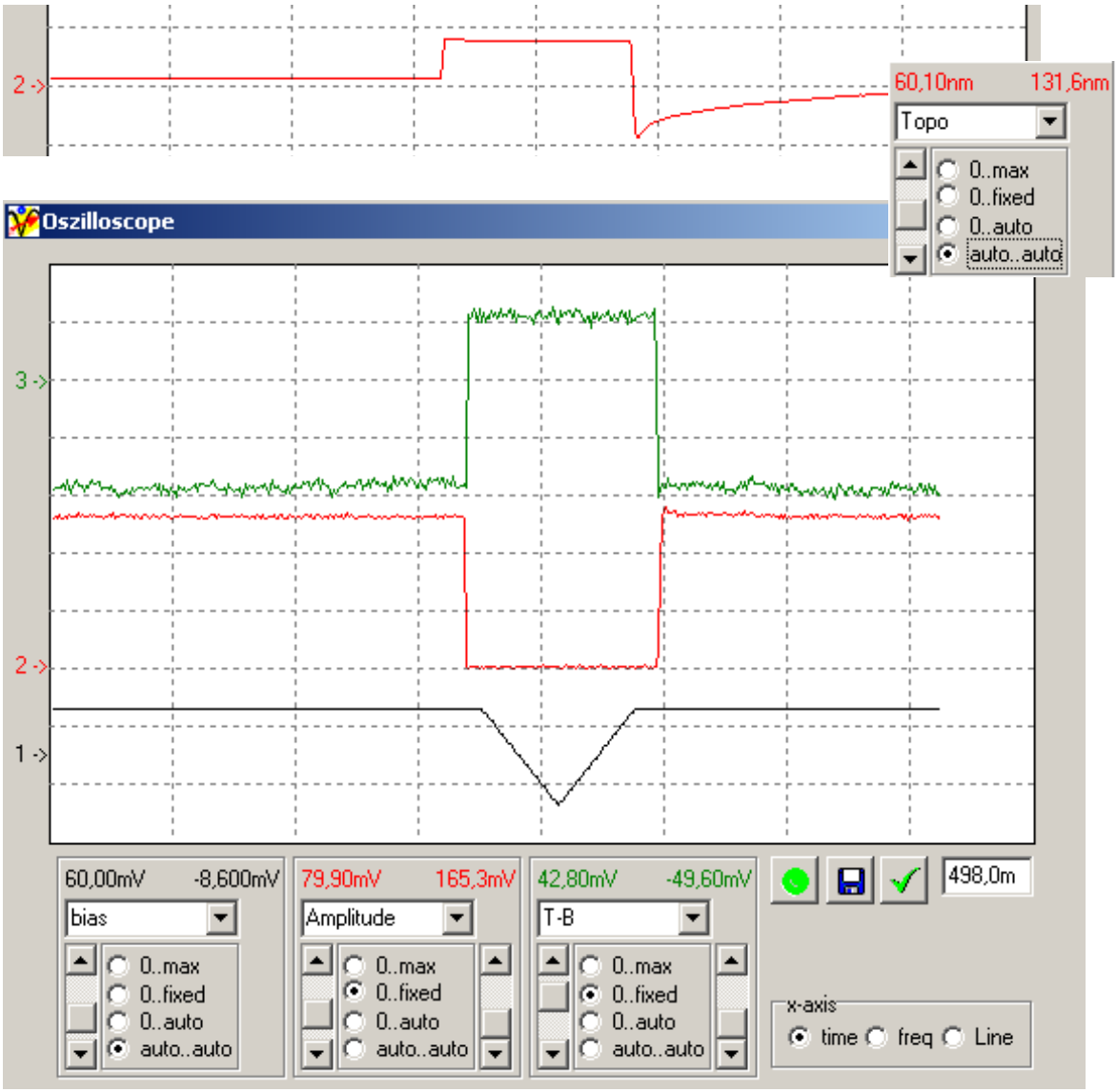
Mass-Spectrometry (Mass Spec)

- ✗ the tip moves with scan speed to the acquisition point.
- ✗ wait “delay1”
- ✗ the feedback is switched off
- ✗ z-movement over dz
- ✗ a message window appears and waits, until the user confirms with “OK” that the external measurement is finished ***(Attention: the feedback is OFF!)***
- ✗ when “OK” is pressed the feedback is switched on

Contact Mode Conduction Measurements in dynamic Mode set-up (CM X(U))

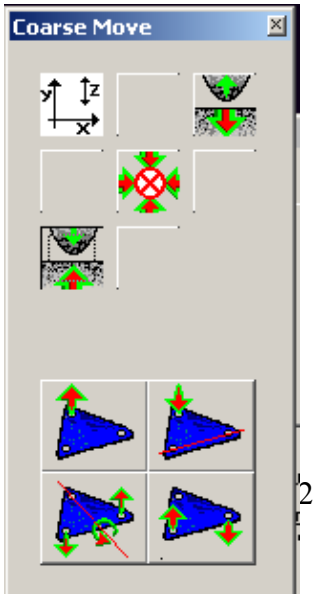
- ✗ the tip moves with the scan speed to the acquisition point in the current feedback mode
- ✗ wait “delay1”
- ✗ the feedback is switched to Contact Mode based on the last settings in contact mode
- ✗ wait “delay1”
- ✗ data acquisition with “delay 2” as point delay (voltage is swept according to settings)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



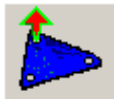
When the x-y-position is reached, the amplitude drops to zero (drive is switched off, feedback mode is changed to Contact Mode) and T-B jumps to it's set-point (here: 100 mV). The system waits “delay1”, until the voltage is swept (here: from 0V to -0.5V and back). After a further “delay1”, the feedback 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

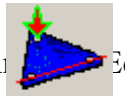


Retracts the tip from the sample by moving all three stepper motors simultaneously

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.

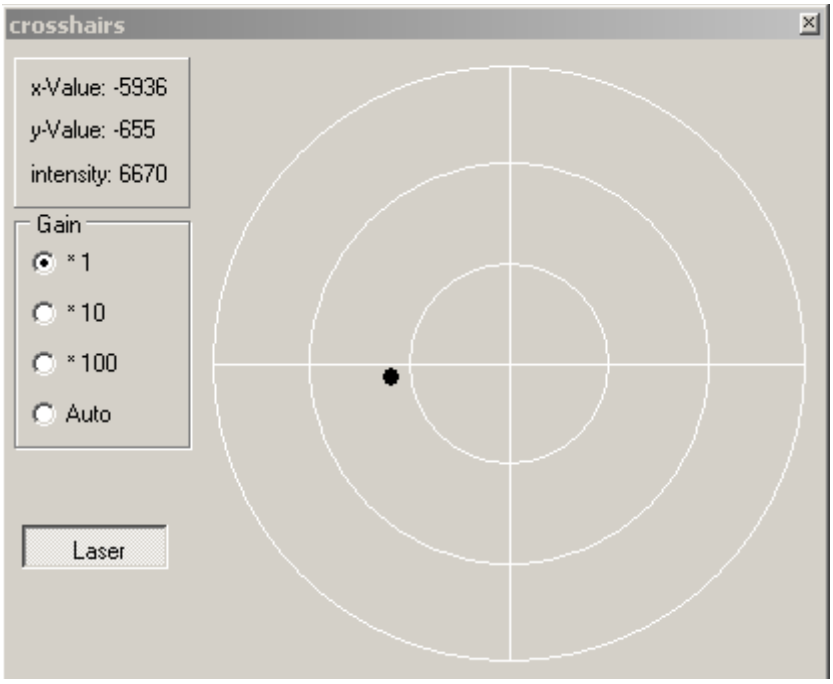
The left motor moves down and the right motor moves upwards. The head is tilted along its Y-axis. On multi-tip chips, the left tip touches the sample first.

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, Y-value: positions on the photo diode shown in mV. The maximum numbers here are about 7000 mV.

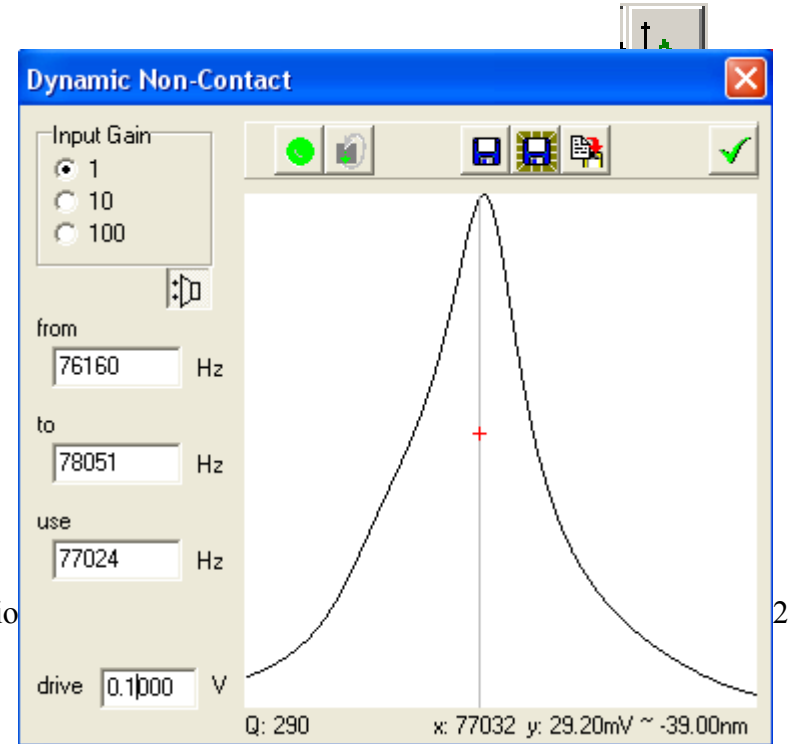
Intensity: SUM signal of the light intensity of all four photo diode elements. Maximum number here is 7000 mV, too. It can be scaled in mW or µW.

Gain: This has no effect on any hardware. It's used for visualization purposes only. Gain = 100 scales the crosshairs screen a hundred times wider than gain = 1. If the signal is then outside the scaling, the dot moves along the outer circle.

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.

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 set-point.

Inside the spectrum, a vertical grey line appears which visualises the chosen position and a red cross on this line shows the selected set-point for the feedback. If the user changes the set-point 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.

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

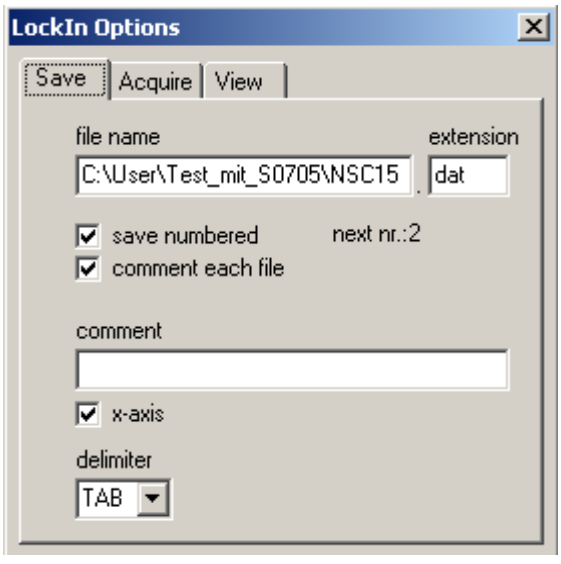
Saves the spectrum with the next valid number.

Allows to save under a new name or directory.

Copies the data to clipboard.

DNC OPTIONS WINDOW

The Options window is opened with this knob  and allows to store the data in an ASCII file



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.

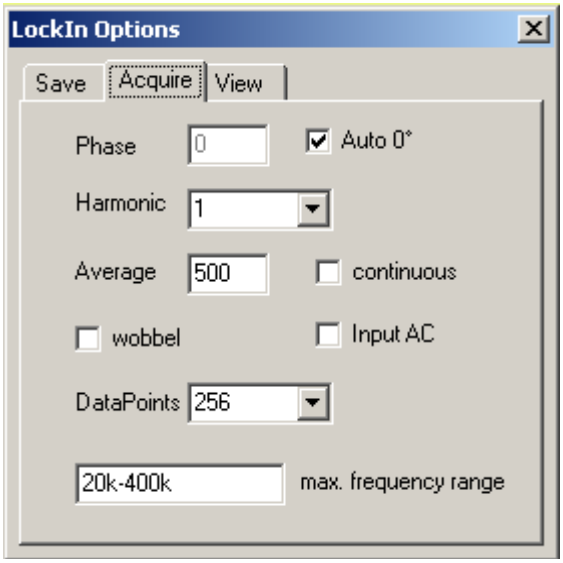
If **save numbered** is ON, one click on the *save button* will save the current data with the same name but count the last number of the file name upwards. The number of the next file is shown behind.

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

The **x-axis** is only stored in the data set, if selected here. Single rows are delimited by the character

provided as **delimiter**.

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 **Continuous** is selected in the *Acquire* tab and the repeat knob is ON, spectra are acquired continuously and averaged automatically.

It is possible to adjust the **phase** offset between outgoing excitation (REF-OUT) and measurement signal (T-B or IN). In case **Auto Zero** 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 **Wobbel** allows to sweep the excitation between the values of neighboured data point 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. **Ac input** 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 default value for the spectrum (right mouse button click inside the white area of the spectrum + topmost line in the **frequency range** listing) can be changed here as well.

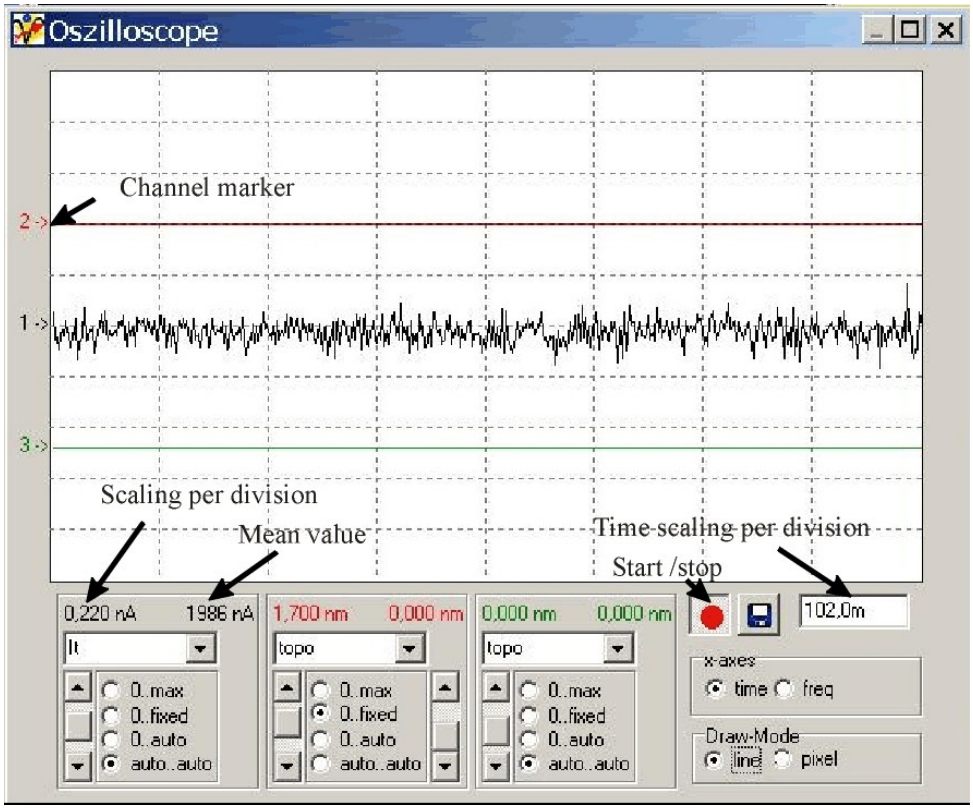
The spectra data might be drawn as single points or **vectors**. One can set the input gain of the lockin in a range that leads automatically to wrong amplitude values (too high internal amplification). This is detected in the hardware by an overflow. When **"Show Warning on Mismatched Setting"** is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

It is possibile to shows 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**.

Oscilloscope Window

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

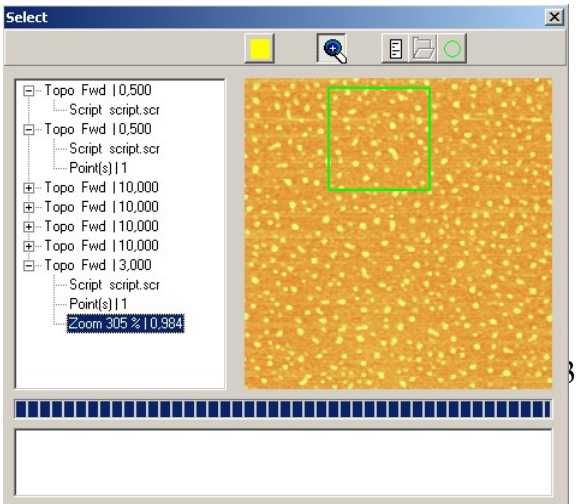
- **0..max** the scaling is set to maximum value of the channel
- **0..fixed** the maximum value can be changed by a slider appearing on the right sight of the scaling type selection
- **0..auto** the program calculates the th e optimum, but takes always “0” as minimum
- **auto..auto** automatically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



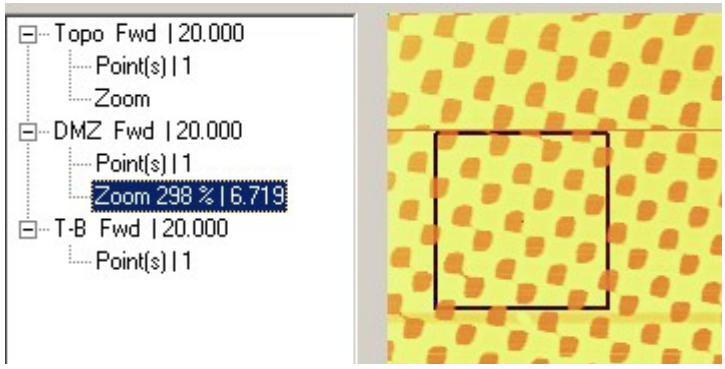
Click in any data channel window and drag&drop the image into the image part (right) of the select window. Left, a list of former images is shown.

Select a point to perform spectroscopy experiments:
Use the icon: 

Click left into the image. A black cross appears at

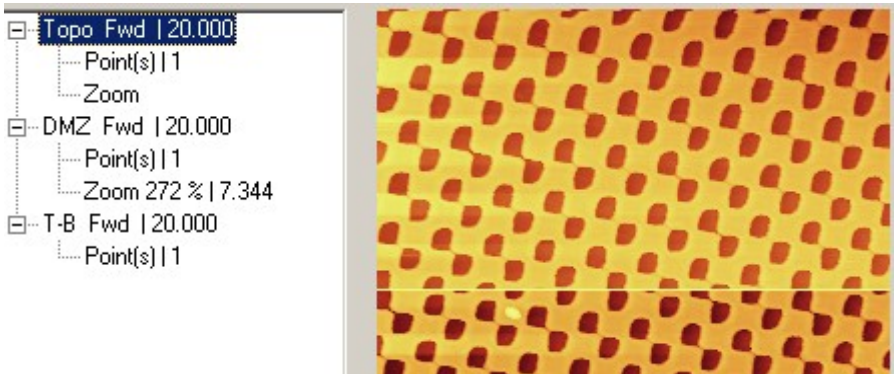
the selected point.

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.

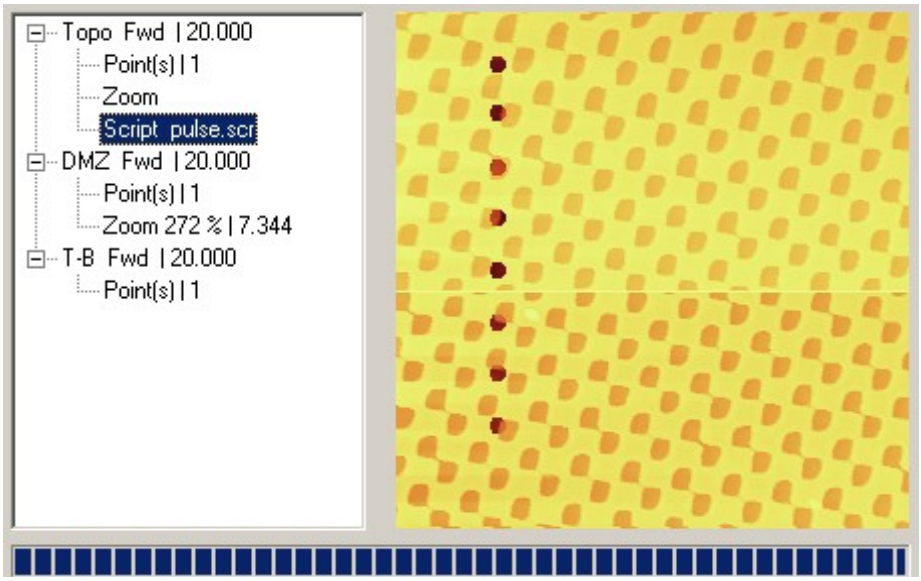
At any time later, one can go back to the old scan ranges by selecting their images from the list on the left side (here, the image "TopoFwd" with 20 µm range is re-selected) and might repeat the zoom at a different position.



RUN USER-DEFINED SCRIPTS

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

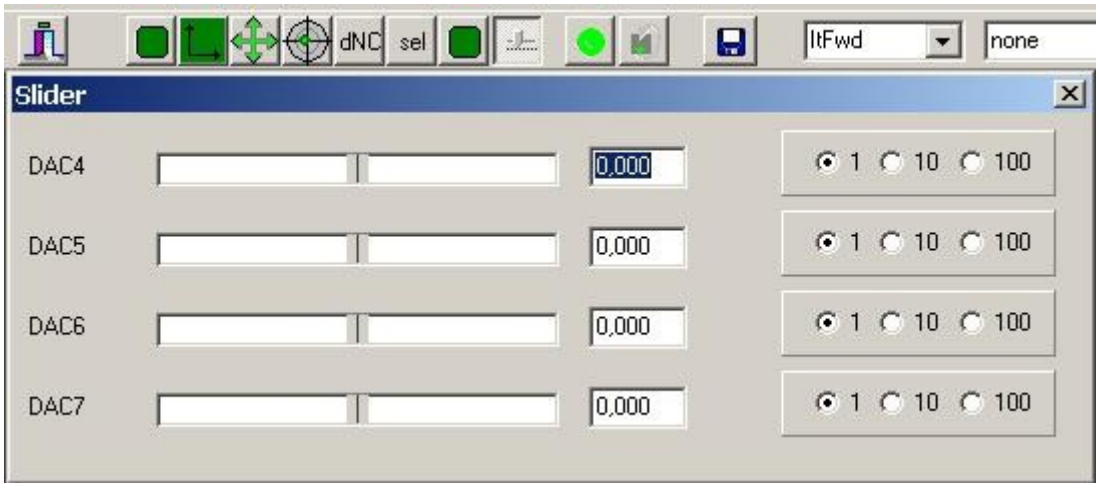
The program loads automatically the last used script. Below the selected image appears an additional menu entry "Script" with the script name (pulse.scr) as parameter.



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 30.

Sliders For AUX-DA-Channels



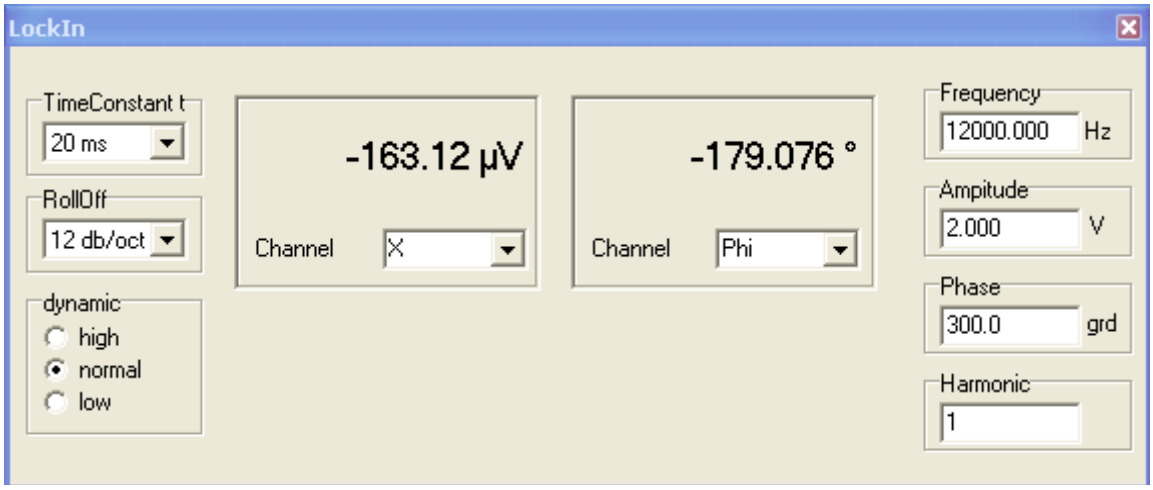
Here, you can change the output data of the AUX output channels 5-8. The number shows the valid value in V. When amplification "1" is selected, the slider moves from -10 V to + 10 V. When "10" or "100" is selected, the slider is always in central position and the movement of the slider is more sensitive.

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

2nd Lock-In Window for EFM and KPFM

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

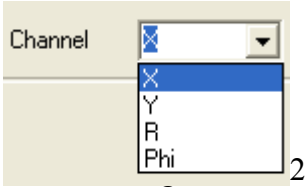
It opens the following window:



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

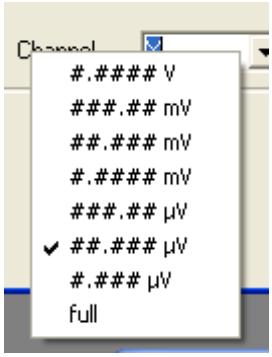
In **dynamic**, the input gain is switched between three amplifications (comparable with the input gain in the DNC window).

Frequency, Amplitude, Phase and Harmonic are self-explaining output parameters and settings of a lock-in 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 visualise 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!

1 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 23).

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

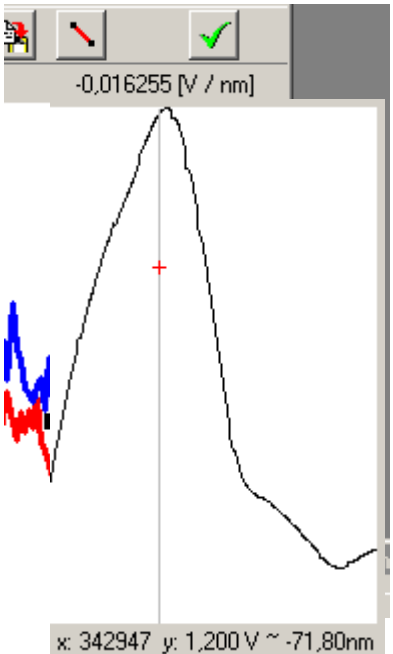
These are channels taken as picture data. They are selected in the Acquire Menu (see pages 5 and 23).

1 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'.

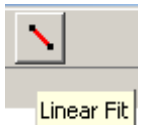
After this procedure, one might open the DNC windows. In

dependence on the mouse position in the white screen, it displays now three numbers:

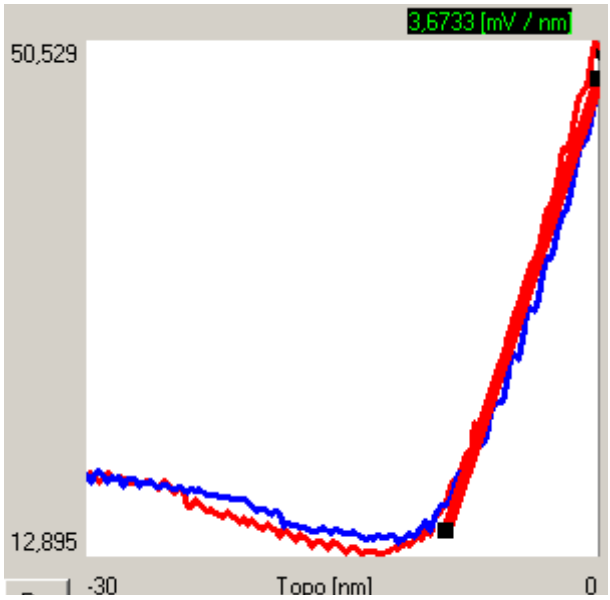
x: frequency in Hz y: Amplitude in V ~ **Amplitude in nm**

as shown in the image.

In case of **contact mode**, one ase 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

F = 544,5 nN

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

The most usual set-up functions are in the option menu:

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

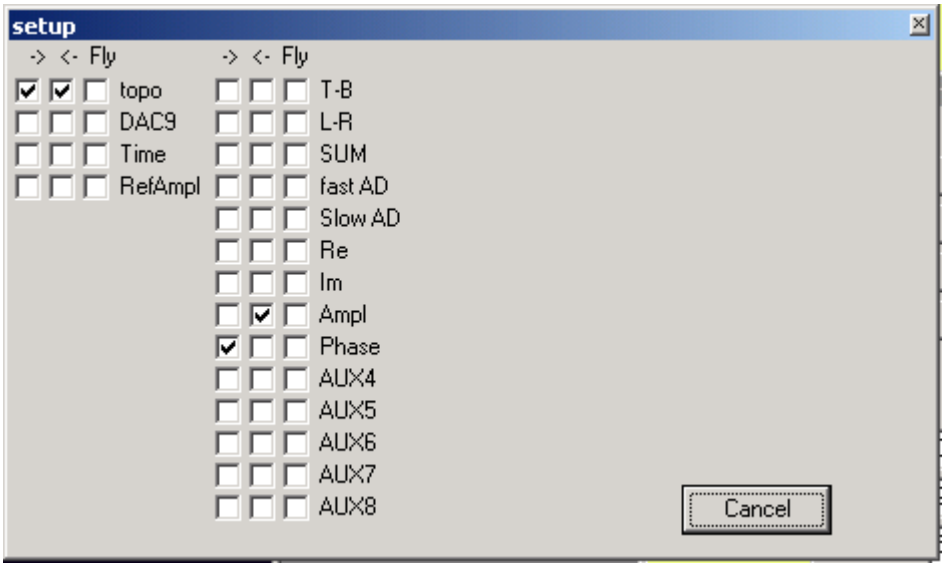
DDE Server program allows/forbids exchange of data with other applications

HardLin is for hardware linearisation (disabled, if hardlin=0 in the sxm.ini)

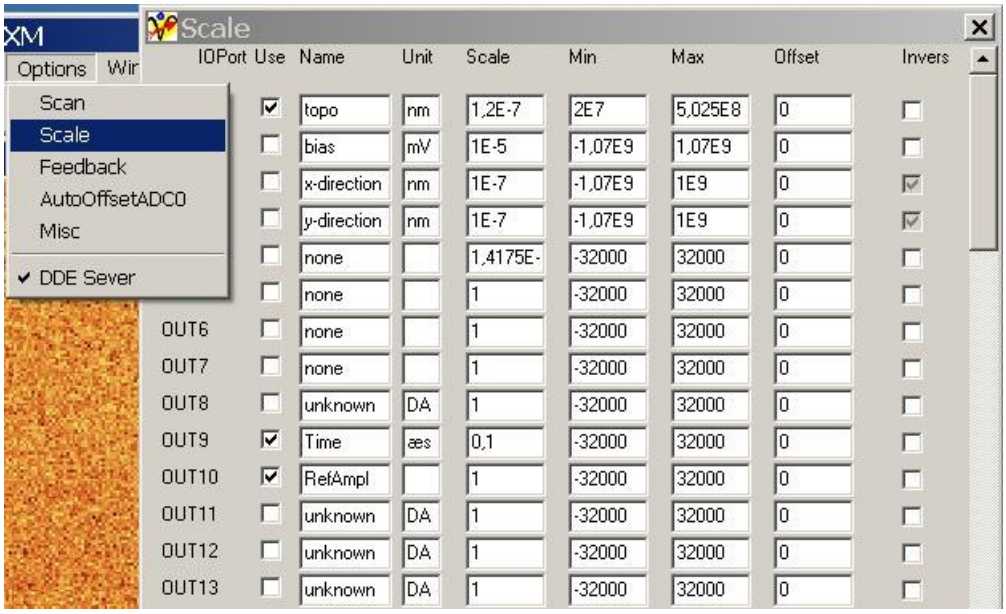
Some additional set-up procedures based on direct changes in the sxm.ini file are described on page 36.

Acquire

The "Options/Scan" opens a menu called "Acquire" which is a set-up of the scan. This menu displays all channels that are selected as "used" in the Scale-Window (page 23). 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 set-up 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 lock-in channels) are inverted, the equation for the scale factor is:

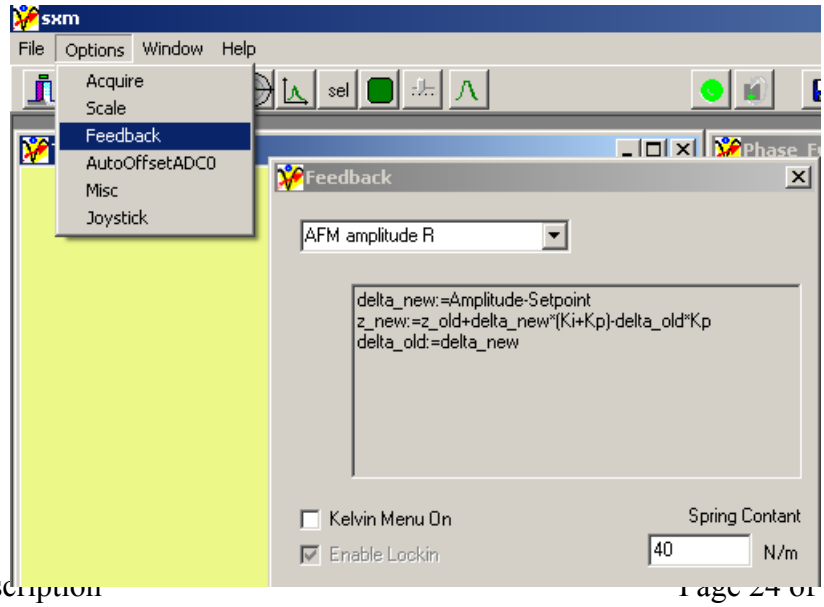
Phys. value = - scale factor * num. value

`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.



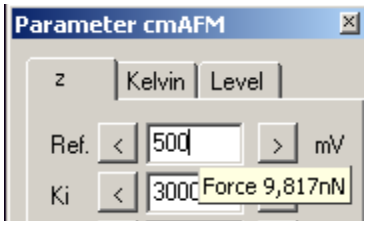
The following table shows, how the modes are connected to the used channels:

Mode	**description**	**feedback input**
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.

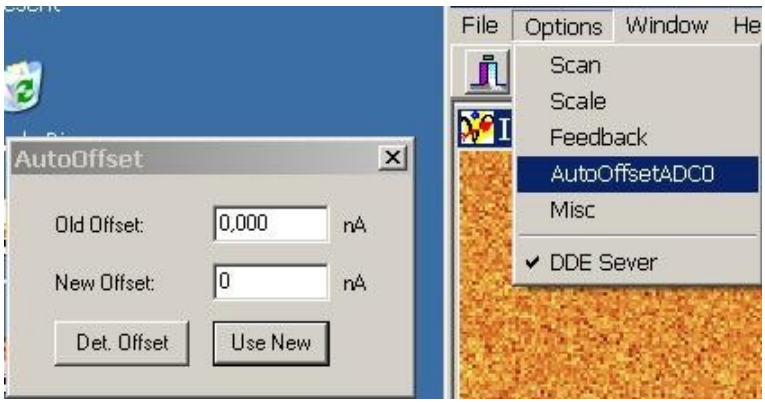
In Contact Mode, the DNC window vanishes. It can be enabled for certain applications (Force Modulation Mode – see chapter Operation Instruction) by ' Enable LockIn'. A message warning is shown, when the frequency is swept in contact mode.



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.

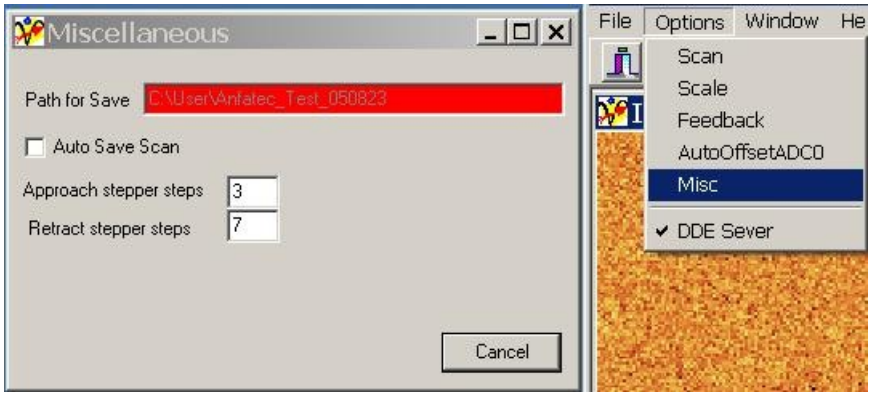
AutoOffset

This function is used to correct the offset of the feedback input channel. It shows the valid offset and allows the 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.

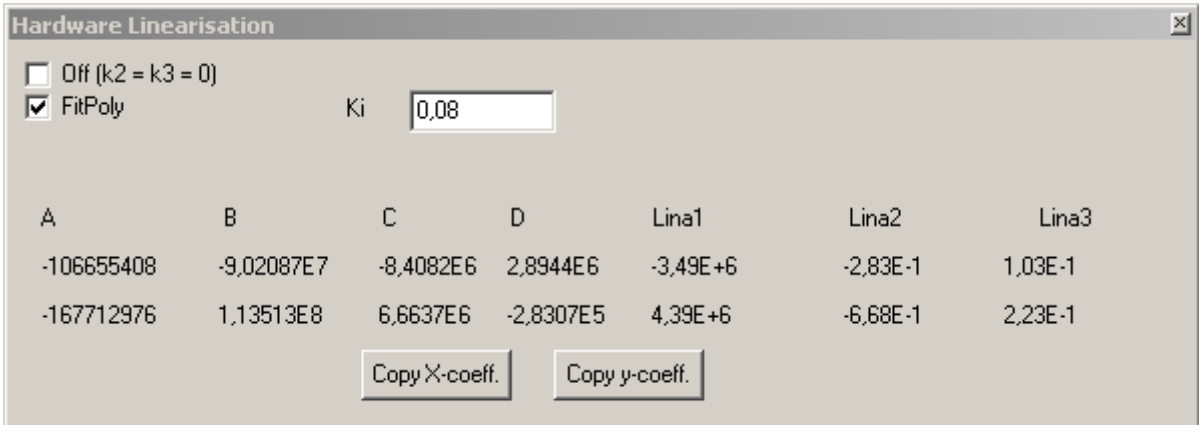


Hardlin

The “Hardlin”-windows shows the current state of the hardware linearisation. It is visible only if the sxm.ini contains the entry hardlin=1 under the section [scanner]. The mathematics behind this option is based on the publication B. Graffel, A.-D. Mueller, F. Mueller, M. Hietschold: , hwoever, it cam be used as offline linearisation with fixed non-linear coefficients as well.

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 23). 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 chose, 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 chose 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

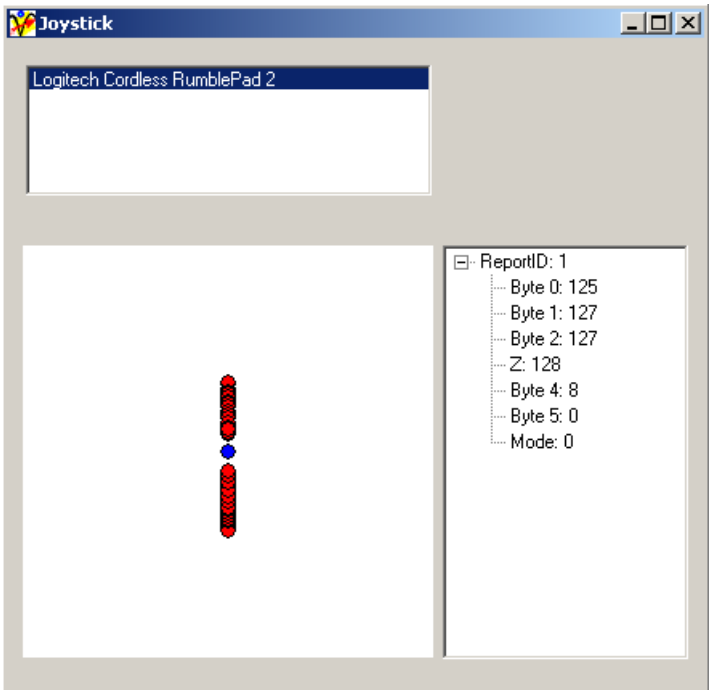
and check the correction with a scan on the chess patterned grating.

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).

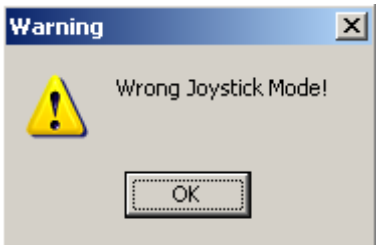
In the left upper window, it shows a list of found Human Interface Devices (HID devices). One can select the one to be used. In the left lower window, it shows the position of the handles (left/right handle as blue dots, up/down handle as red dots).

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=-1
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.

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:



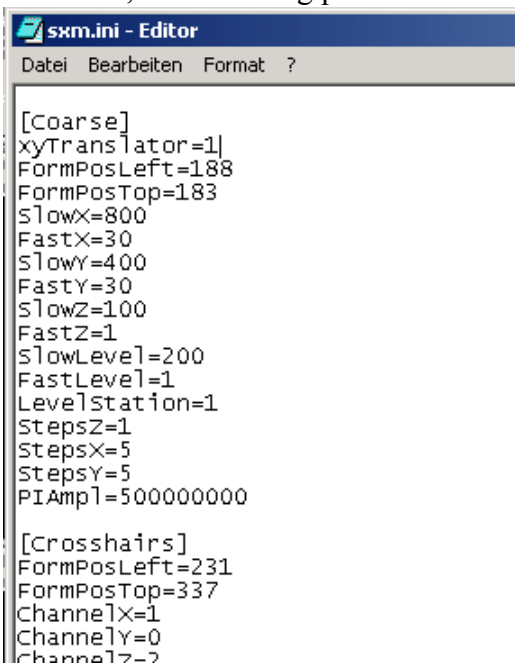
Also, if the tip is approached by automated approach, it will not react on a use of the joystick (in order to avoid a crash of the tip). Moreover, it will display another warning:

For the speed adjustment of the joystick refer to page 29.

1 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:



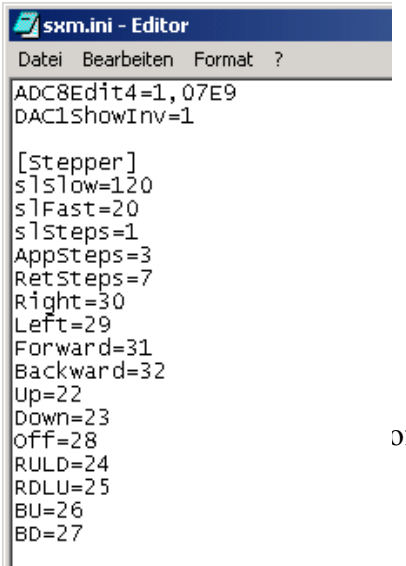
- xyTranslator=1 ... switches the buttons for the lateral movement in the coarse window on
- SlowX, ... time between two bursts in ms used if the position buttons are pressed – *can be changed in the "Anfatec Scan"*
- FastX, ... time between two bursts in ms used if the position buttons are pressed together with the Shift - *can be changed in "Anfatec Scan"*
- StepsX=**xn** ... means, that with each click on the 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:

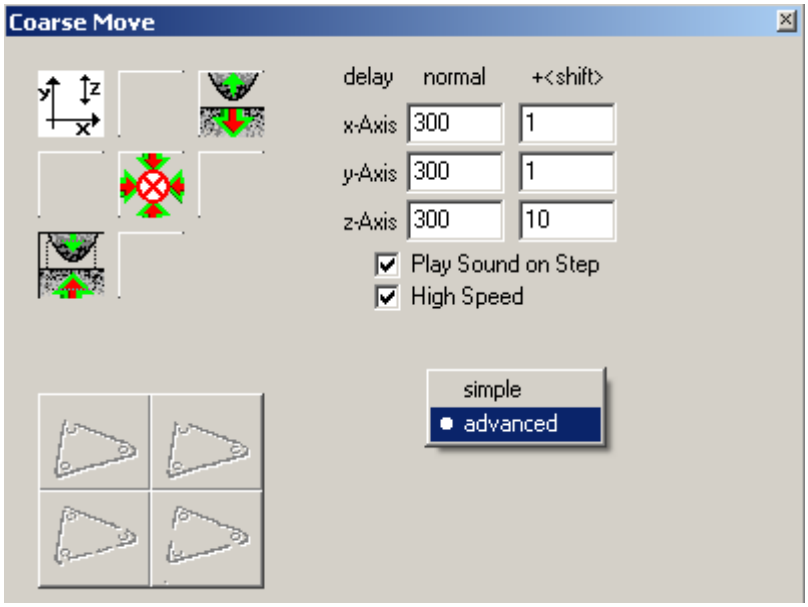
Right = 30 Left = 29



Forward = 31 Backward = 32
If you like to switch the directions (for example left to right and vise 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.

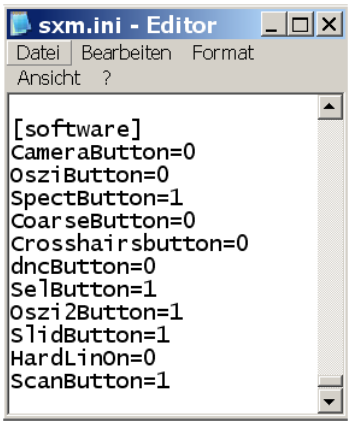
When the **Joystick** is installed, the current speed achieved with the joystick is calculated from the interpolation between the delays 'min' and 'max', as well. When used very softly, the delay 'max' allows to translate the sample in single steps. When fully extended, delay 'min' determines the maximum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



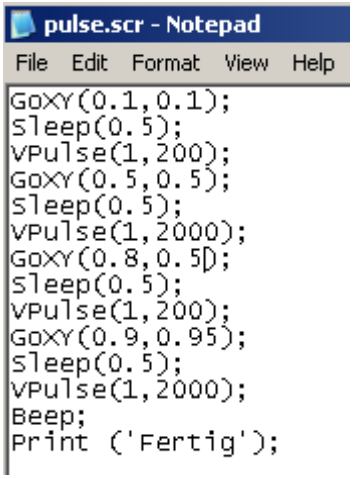
Switches for hidden Program Parts

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 for explanation.

Script Commands

Scripts are executed line wise using the SelectWindow (see page 18). Each line should contain one command and be finished with ';'. Parameters are given in round brackets '(' and ')'. The standard file extension for the script files is 'scr'. During script execution, a bar shows the progress and the start-knob changes its colour from  to  . The script can be stopped at any time by a 2nd click onto the start-knob.



In case of syntactic errors, the message window displays the line number containing the error and the error type (e.g.: “Error in Line 2: Unknown Token!”) followed by a message that the script execution was stopped. After successful script execution, a message 'succeeded' appears in the message screen.

Currently, the following scripting commands are currently available:

Sleep(Time)

Sleep allows to pause the script execution for a *Time* given in seconds.

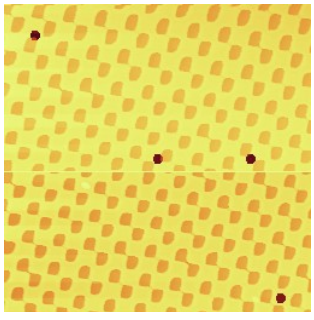
VPulse(Duration, Voltage)

The command *VPulse* allows to apply a constant *Voltage* at the output Bias. The value *Voltage* equals the pulse height and is given in the same physical units as the channel *Bias* is scaled (typically: mV). The pulse length is given as *Duration* in seconds.

If *Duration = 0*, this command can be used to set the Bias to a new value.

GoXY(X, Y)

This command moves the tip to a relative position inside the selected image range. X and Y are relative coordinates ranging from 0 to +1. The position (0,0) is the upper left corner of the image, while (1,1) is the lower right corner.



In the shown example, the function GoXY is used with the parameters (0.1,0.1), (0.5, 0.5) = centre position, (0.8, 0.5) and (0.9,

0.95).

BEEP

Gives a sound.

PRINT('MYTEXT')

Allows to display user defined text output during the script execution.

SETREF(REF)

Sets the reference value in the window “Parameter” directly in the currently used units to the value *Ref*.

```
Example: SETREF(40) sets the set-point to 40 % in dynamic mode
(Feedback type: AFM Amplitude R) or to 40 mV in Contact Mode
(Feedback type: AFM Contact Mode).
```

SETKI(KI)

Sets the feedback parameter “Ki” to the value *Ki*.

```
The system is approached and the current Ki is 200. SETKI(1200)
sets the Ki to 1200.
```

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 Ampliude 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