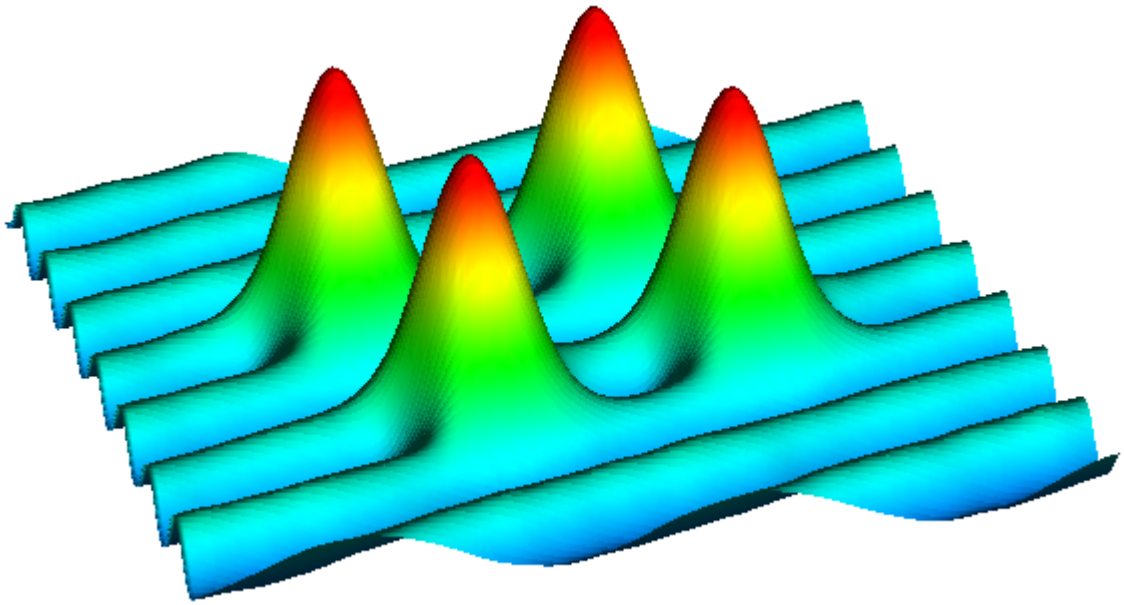

STMAFM 3.0
Manual

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Welcome

to the Manual of the SPS-Createc low temperature STM

by <Sven Zöphel>

We hope that this manual will assist you in your daily operation of the SPS-Createc low temperature scanning tunneling microscope.

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Index 0

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1 Overview STMAFM

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2 Installation

1.Installation of the STMAFM Software package and the required Hardware

The STMAFM - Software package uses the digital signal processor (DSP) board SBC6711 (150MHz/250MHz) from Innovative Integration (www.innovative-dsp.com). The SBC6711 is connected to the PC by a standard USB 1.0 cable. (Optionally a high speed USB 2.0 adapter board is available) The drivers available from Innovative Integration support Windows 2000/XP. (Windows Vista support is not available yet). A single Createc ADDA board (6ch 20bit DA, 4ch 18bit AD) is used by the software in the Standard configuration. (A second board can be optionally installed for AFM operation)

The STMAFM-Program can be operated together with the DSP-board for Data-Acquisition, but also without the board for Data Analysis. In the latter case no driver installation is needed. Several instants of the STMAFM-Program can be run simultaneoulsy on the same computer, but only one will startup in Data-Acquisition mode. The program running in Data acquisition mode will inform the other programs if new data has been acquired and saved.

1.1 How to install the hardware:
Connect the USB Cable from the Electronics to the USB input of a PC.

1.2 How to install the software:

To deinstall the software go to Settings>Control Panel>Software and remove the STMAFM Software.

To install:
Copy the Setup.exe file to a temporary directory and start the setup.exe file. Follow the instructions on the screen of the standard Installshield procedure.
If you want to compile the source code of the software you need *Codegear Delphi 2007 for Win32* and you have to install the *CreatecSTMAFM.bpl* Package.

3 First Steps

Basic Structure of the Software

The software consists of several windows. The main window STMAFM contains all necessary control elements to for data acquisition and image analysis. The software is controlled by set of parametes which can be accesses through the window called 'Parameter'. On several panels all important parameters can be adjusted. Additional windows for lateral and vertical manipulation, I/V spectroscopy, data recording, coarse approach control, 3d rendering etc are available. On startup the software tries to access the Createc DSP Electronic, which should be connected by USB. If the electronics can not be found the software starts up in analysis mode.

Several instances of the software can be run at the same time, but only one will be in Data Acqusition mode. It is usually good to start up two instances of the software. One for data acquisition, and a second for Data Analysis. This is supported by a communication channel which is setup between all instances. New acquired and saved images will be automatically communicated to other instances on the computer.

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1. First steps:
To learn about the different features of the STMAFM program load a test file A....dat. from the file menu.
Test the different kinds of image processing and analysis use this file. Most of the features are almost self explaning, but will be discussed later in this manual.

2. How to take an image
Start the STMAFM-Program. Select the image size, the scan area and scan speed on the 'SCAN' panel in the Parameter window.

Start the Scan by pressing the <Start> - Button.

When the scan is finished, click on the <QSave> - Button to save the Scan in the current directory.

4 Main Window STMAFM

The **STMAFM** form contains the main control elements of the software.Below the menu bar several control the data acquisition and analysis of the STM data.

To take a new image press the <**START**> button. To stop press the <**STOP**> button. When a new scan is started a default filename is assigned to the image. It consists of the date and time, when the scan was started. Its extension will be '.dat'. A single letter is put in the front of the name, which is used to indicate the machine name. (Example:' A020124.190937.dat'). To save the file either press the <**QSAVE**> button which saves the file in the current directory, indicated in the status line at the bottom of the window, or use the menu command <**Save *.dat**> under <File>. As long as the files has not been saved a ' * ' is attached to the file. The <**Copy**> copies the data in the left image to the second image on the right.

The basic operations to display the data are done using the following buttons:

<**DA**>: Display the image using different line by line subtraction modes
<**DX**>: Display the image using automatic plane substraction
<**DP**>: Display the image using plane substraction
<**LA**>: Display image in DA mode and perform automatic scaling

<**LP**>: Perform a low pass filter operation
<**HP**>: Perform a high pass filter operation
<**Pln**>: Input 3 points (with the mouse) to determine the plane for plane background subtraction
<**Lin**>: Calculate a linescan along a line between 2 points

Use <Disp LinePlan Quad> under <Display> in the menu subtract to perform an automatic line/plane subtraction using also quadratic terms.

The other buttons:

<**LM**> Lateral manipulation
<**VM**> Vertical manipulation of I/V spectroscopy
<**TF**> Tip forming

Below the buttons you find the **Palette** window, which displays the current 8bit palette. Use the left mouse button to switch between different standard palettes. Using the right mouse button will open

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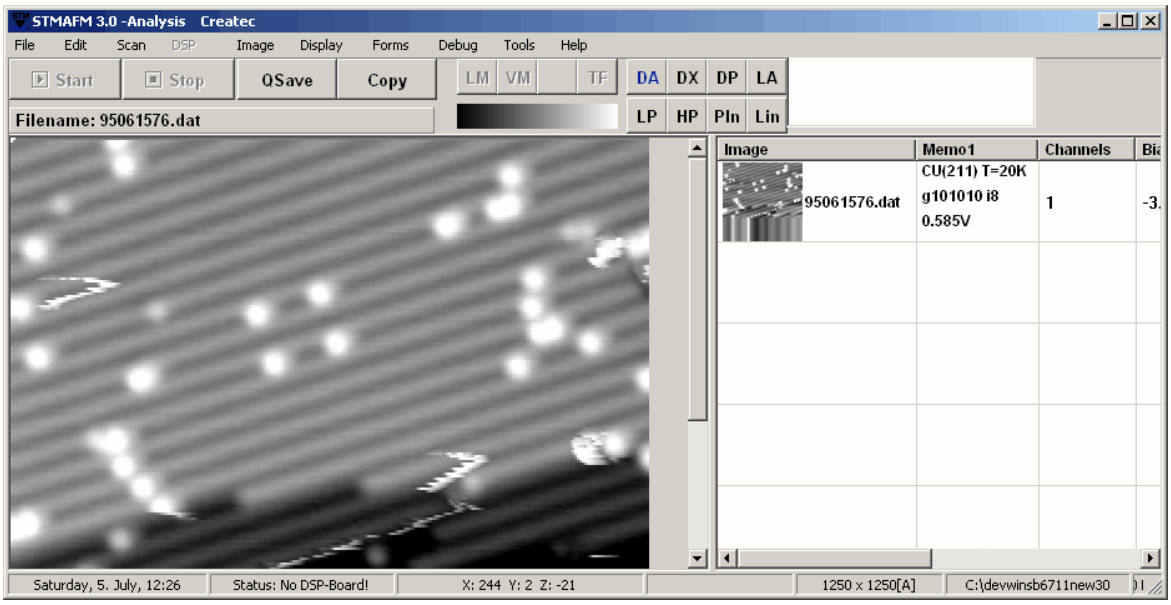
a popup menu with additional options to create a user defined palette or to load and save externally defined palettes.

The small list box on the right is used for communication between different instances of the STMAFM program. If the instance of the program which is in data acquisition mode saves a file then this filename is send to all other instances of the program running in analysis mode.

Below the buttons the screen is separated in two parts, divided by an horizontaly movable slider. On the left is always the image of the current data file displayed. All the operations like scanning and image processing are done in this part on the window. On the right usually a list of all loaded files is displayed. A small icon image and some info is shown for each file. The two modes to display these data are **'Report" and 'Icon' view**. The modes can be selected under menu item 'Display'. When in Report view pressing on the 'Image' bar will switch the way how the info is displayed. The list view can be suppressed by selecting '**Image2**' under menu item 'Display' and the second image is displayed instead.

On the bottom of the window a **status bar** is located. It shows the current date and time, some status info about the scanning status, the mouse position on the image,the size of the image, the current default directory, the available space of disk storage.



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4.1 Main Menu Structure

File

Open *.DAT	Open STMAFM DataFile
Save *.DAT	Save STMAFM DataFile
QuickSave	Save STMAFM DataFile in active directory

Export File

Save *.BMP	Save Image as BMP-File
SaveEMF *.EMF	Save Image in EMF Format

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SaveAscii *.ASC	Save Image-Data in ASCII Format
Import File	
Load *.BMP	Load BMP File
Print	
Print Image	Print the image
Print Listview	Print the Filelist in Listview
Printer Setup	Select the printer
Special	
Compress Files	All Files are saved using Data compression with Zlib
Save Listview-Files	Save List of Files in the Listview window
Autosave *.bak	Save all recorded images
DOS-CommandLine	Open a DOS-Window
Get_SRS_Lockin_Val	Get External Lockin Setup Parameters
STMAFM-Analysis	Start another copy of the STMAFM-Program
Exit	Exit the STMAFM-Program
About	About
ReOpen:	Opens the last file

Edit

Copy Clipbd	Copy the image to the clipboard
Copy Dataimage2	Copy left image to the right
Copy Clipbd EMF	Copy the image to the clipboard in EMF Format with Info
Copy New Window	Copy the image into new form
Copy Overview	Copy the image into the overview form
Copy Palette to Clipbd	Copy the palette to the Clipboard

Scan

Scan Start	Start the Scan
Scan Stop	Stop the Scan
Enable/Start RepeatTimer	Start the Repeat-Timer
Preamplifier	Select the preamplifier
Preamp_Balzers	Select for Balzers EP112
Preamp_Femto_LowNoise	Select for Femto Preamp in Low Noise Mode
Preamp_Femto_HighSpeed	Select for Femto Preamp in High Speed Mode
Preamp_Femto_100G	Select for Femto Preamp with fixed gain 10^11
Preamp_UserType	Select for User specific Preamp
Autofilesave	Save every image
Autorepeat	Start a new image automatically
Autodispreset	Clear the image window when starting a new scan
Show Scanline Marker	Display a red line at the actual scan line position
Display current Scan Profile	Display the current line as a line scan in a separate window
Scan_Y_Direction	Select the Scandirection (Top-Bottom,Bottom-Top,etc)
ScanCoarse	Check to set scanning by Coarse Piezos otherwise the main Piezo is used

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DSP

Lateral Manip.	Lateral Manipulation
Vertical Manip.	Vertical Manipulation
Tip Forming	Tip Forming
SetXYOffset - Top	Set the xy-offset for the new top site
SetXYOffset - Center	Set the xy-offset for the new center site
SetXYOffset - Zoom	Set the xy-offset for the new center site
ResetXYOffset	Set the xy-offset to (0,0)
Copy Offset from Param	Copy the xy-offset values from the scanparameterlist
1: Offsetx,y: 0 0	Select as new Offset
2: Offsetx,y 0 0	Select as new Offset
3: Offsetx,y 0 0	Select as new Offset
4: Offsetx,y 0 0	Select as new Offset
Set_Plan_Dx_Dy	Set the parameters for the plan-offset.
Set_DSP_Clock	Change the Clock-Frequency of the DSP-FeedBack-Loop

Image

Undo Filter	Undo last image operation

Filter

LowPass	Low Pass Filter the image
HighPass	High Pass Filter the image
Laplace	Laplace Filter the image
Median	Median Filter
Edge(Horz)	Edge Filter in the horizontal direction
Invert	Invert the image
Imagedata * 10	The image data is multiplied by a factor of 10
Imagedata / 10	The image data is divided by a factor of 10

Resize

Zoom_Up_Rect	Zoom up a selected rectangle
Resize / 2	Resize the image
Resize x 2	Resize the image
Interpolation / 2	Interpolate the image
Interpolation x 2	Interpolate the image

Rotate90deg

FFT

FFT2D	Fast Fourier Transform
FFT2D Invers	Inverse FFT
FFT2d Cutout	Cutout a part of the FFT
FFT Evaluate	Open FFT Evaluate window

Image Analysis

Histogram	Show the histogram of the image
Areacalculation	Calculate the size of islands
Islandsize	Calculate the size of islands

Display

Zoom

100%
200%

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300%
400%

ListView

Report	Show files as icons and info
Icon	Show files as icons only
Image2	Show Image2 and not the Listviewbox
AutoclearList	Clear the Listviewbox before new a new list is added
Largeiconsize=64-256	Icon size of the images in the listviewbox
Load Icon Plan	Load the icons using image plan subtraction
Clear Listview	Clear the ListView

DispCommands

DispAuto	Display image using linear line background subtraction
DispPlanAuto	Display image using auto plan background subtraction
DispPlan	Display image using plan subtraction
Last Disp Autoscale	Display with automatic scaling
Plan Auto Subtract	Like Displanauto + subtract plane from image data
Linescan	Linescan in the image
Plan2dinput	Input 3 points to select the background subtraction plane

Configuration

DACunits	Select DAC units
nm-Units [A]	Select Angström units
Display Image in Lines	Select to display image in line and not gray scale mode
Disp LinePlan Quad	Select to perform lin.+quad. Backgroundsubtraction
Disp Plan and Subtract	If selected Disp Plan subtracts the plane from the image data
Disp Automode Offset/Slope	DA Mode subtract offset and slope line by line
Disp Automode Offset	DA Mode subtract offset line by line
Disp Automode None	DA Mode subtract offset of first line
Disp Automode Diff	DA Mode differentiate image data lien by line

Frames

Parameter

Lat.Manip	Show the Latmanip window
Vert.Manip	Show the Vertmanip. window
Time Spectrum	Show the Time Spectrum window
Ramp-Controller	Start Ramp Controller
New Channelform	Open another Channelform
Linescan	Show the linescan window
Draw Grid	Show Grid window
3dView	Show 3d View window
Overview	Show the overview window
Slider	Show the Slider window
User Form	Show the User Form
Reset Form Positions	Position all windows at (top,left) = (0,0)
Show/Hide Old Param	Show/Hide the old Parameter window

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Debug

Reset Scanstatus	Enable all buttons again
Remote	Open Remote window
Client Server Control	Open Client Server Control
FIFO_COM USB2.0	Shows whether communication is by USB2.0 Hardware
Build Testimage	Build a new image without scanning
Debug Messages On	Show Debug messages

Tools

Tip-Etching	Open to etch STM tips
Initialization	Open Initialization wondow

Help

Show STMAFM-Manual

4.2 Main Buttons

<Start> or <F1>: Start the scan
<Stop> or <F2>: Stop the scan
<Qsave> or <F3>: Automatically saves an image in the actual directory
<Copy> or <F4>: Copy Image1 to Image2

<LM> or <F5>: Perform a lateral manipulation
<VM> or <F6>: Perform a vertical manipulation or spectroscopy
<TF> or <F8>: Perform tip forming

<DA> or <F9>: Display the image with automatic line by line background subtraction
<DX> or <F10>: Display the image with automatic plane background subtraction
<DP> or <F11>: Display the image with planar background subtraction with predefined parameters

<LP> or <Shift F9>: Low pass filter
<HP> or <Shift F10>: High pass filter
<PLN> or <Shift F11>: Input 3 points for the plane used in plane background subtraction
<LIN> or <Shift F12>: Display a linear scan between two points on the image

5 Parameter

This window gives allows the user to input the parameters controlling the STM programm.

5.1 Scan

The position of the tip (x,y,z) is controlled by three 20bit D/A converters. Range (-524288 .. +524287 corresponding to –10V to +10V).The orientation is chosen in the following way: negative X Values are located on the left side of the image, positive Y values are located at the bottom of the image. The origin of the image is without additional offset values at point (0,0). This corresponds to the point in the Y top and X-center of the image. (The origin of the image can be changed using the setxyoffset – command, which changes the OffsetX,Y values).
The size of the image is defined by the distance between the image points in DAC units (Delta X,Y) and the number of image points. The corresponding size of the image is in Angström: DeltaX*NumX/(524287)*10V* GainX*XPIEZOCONST[A/V] (similar to Y, Z). T

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Size, Speed, Pixelnumber(with certain limitations) can be changed during scanning. Top-down and Bottom-Up scanning is supported.

Scan operation is controlled by the following parameters:

Image Size(Pixel):
Input the number of pixels of the image to be acquired. X is the value of the horizontal scan direction.

I**mage Size(A)**
Input the size of the image [Å]. It is important that the Piezo-Sensitivity factors have been correctly chosen. The deflection sensitivity is temperature dependent!

Scanning Speed[A/sec]
Value of the scanning speed [Å/s]. Input values will be adjusted regarding to hardware restrictions. For higher speeds larger internal step sizes will be chosen. Also the time it takes for a single line (only forward direction time) and the time to take a complete image are displayed.

Biasvoltage[V]
Input of tunneling bias voltage [V]. The bias voltage value can be also changed with the Voltage - Slider. The Bias-Polarity can be switched by pressing the <+> or <-> Keys or by mouse clicking on the '+V' or '-V' - Label at the voltage - slider.

Rotation[Deg]
Rotation of the scanning direction in degree. Rotation is around the center point in the top image scan line (0,0 point)

Rot_center
If checked the rotation is done around the image center.

Channels
Select the channels which will be measured during a scan operation.

I-Preamp Gain
Select the gain of the gain switchable current preamplifier. The value is the base 10 logarithm of the gain in [Å/V].

Constant Current - Constant Height
Select either scanning in normal constant current or in constant height mode. In constant height mode the topography signal is automatically substituted by the current signal.

Forward - Backward Scandirection
Normally data is taken only when scanning from left to right. If forward+backward is selected then data is acquired in both directions. As an example if only one channel is active the uneven lines are taken from left to right and the even lines are taken from right to left.

Multivoltage
Another option is the multiple voltages mode. In this mode a series of images are taken in parallel line by line, while for each image a different bias voltage is applied. The different bias voltages are taken from the neighboring MultiVolt table. Only the voltages up to the first voltage which is equal to zero are used up to a maximum of 6 voltages. The individual images are saved in the same file and appear in one single image window

PlanDX, PlanDY
An average tilt of the sample can be compensated by using these parameters. The user can input these parameters manually or use the automatic feature. This is done the following way. Take an image. Use the <Pln> Button and input 3 points to subtract a plane. Then select the

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Set_Plan_DX_DY feature under the DSP item in the main menu. It is important to realize that thermal drift or piezo creep will significantly disturb the Plan_DY value. To improve that you could take an image rotated by 90deg and follow the above procedure. This will give you a better Plan_DY value, but less precise Plan_DX value. Combination of both allow you to both values with higher precision. Important: Check the new values, especially before you take a constant height image.

Offset_X,Offset_Y
The X,Y offset voltages of the origin of the image. Double Click the Offset_X Label to switch between [V] and [Å] units

Repeat Control
Use these parameters to acquire image series with precise timing.

Count: The number of images to be taken.

Interval: Select the time interval [s] when a new image scan is started. (must be larger then the time to acquire a single image)

The files are automatically saved with the file extension R.DAT

Const. Height Z-Offset, Preamp gain, Bias Voltage
In constant height mode different values for the Preamp Gain and the Biasvoltage can be applied. In constant height mode scanning Zoffset determines an additional perpendicular shift of the tip after the feedback loop has been switched off.

Piezoconstants
These are calibration constants to determine the piezo sensitivity [Å/V]. Be aware that these parameters are temperature dependant.

HV_Gain
Displays the gain of the x,y,z channels of the Createc HV Amplifier

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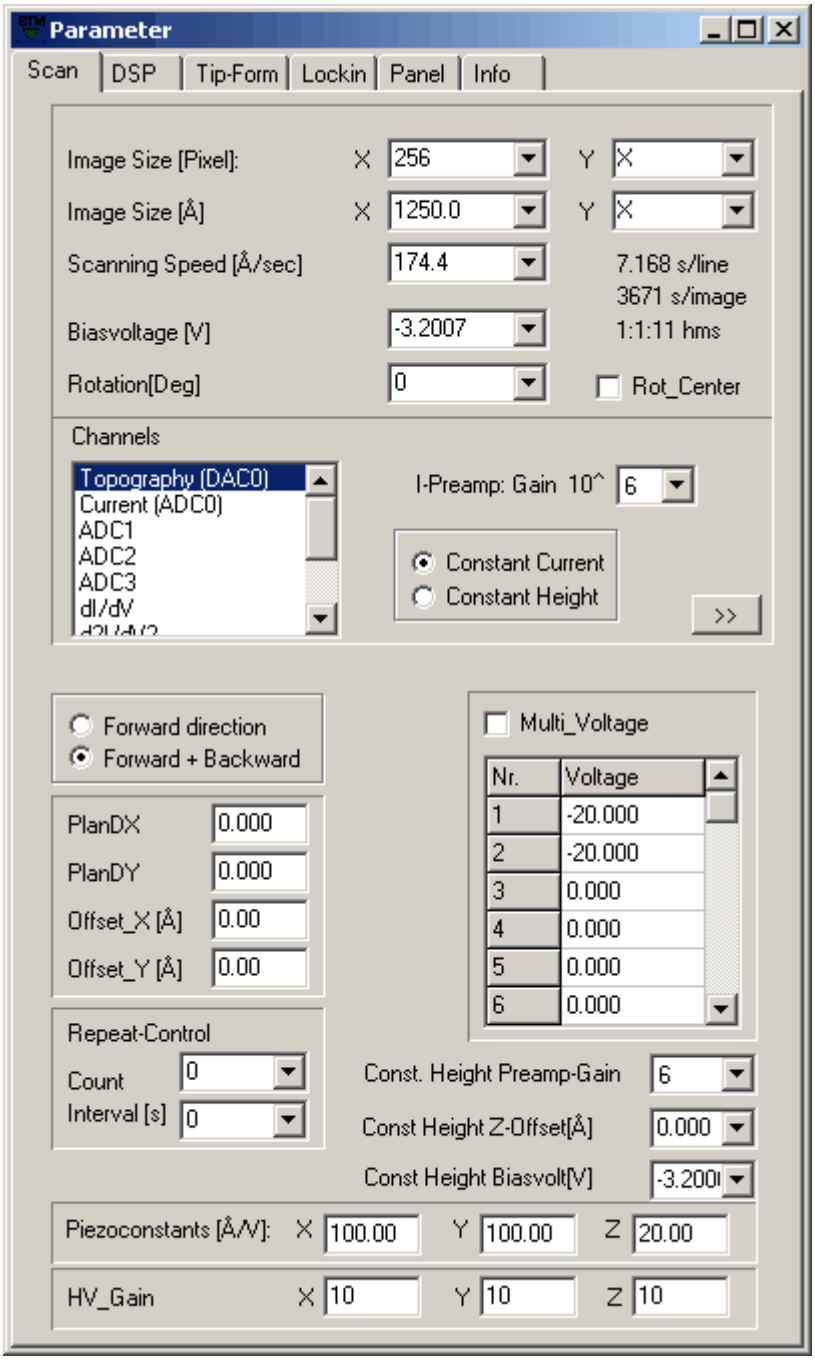

5.2 DSP

The digital feedback controller is operated by the following parameters.

FB-Mode
Select whether the current signal from the FB Channel is applied directly to the digital feedback controller (Lin(I)), or the logarithm of the signal (Log(I)) or the absolute value (Abs(I)) is calculated first.

FB-Channel

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Here the value of the channel can be selected which is used as input signal of the Feedback Loop controller.

Current[A]
Setpoint value of the current signal.

Integrator-RC
This value sets the response time of the integrator part of the PI controller. Only the integrator part is usually installed.

Current Low Pass[Hz]
The current signal from ADC0 can be recorded during scanning. Before the signal is stored on the PC the signal is low pass filtered. The edge frequency of this low pass filter can be set by this parameter.

Integrator and P-Gain Slider
The Integration and P-Gain values can be continuously modified using the two sliders. The original values input manually in the text boxes can be changed by 0.1 - 10.0 by slider movement. Both values can be changed during scan operation to optimize feedback operation.

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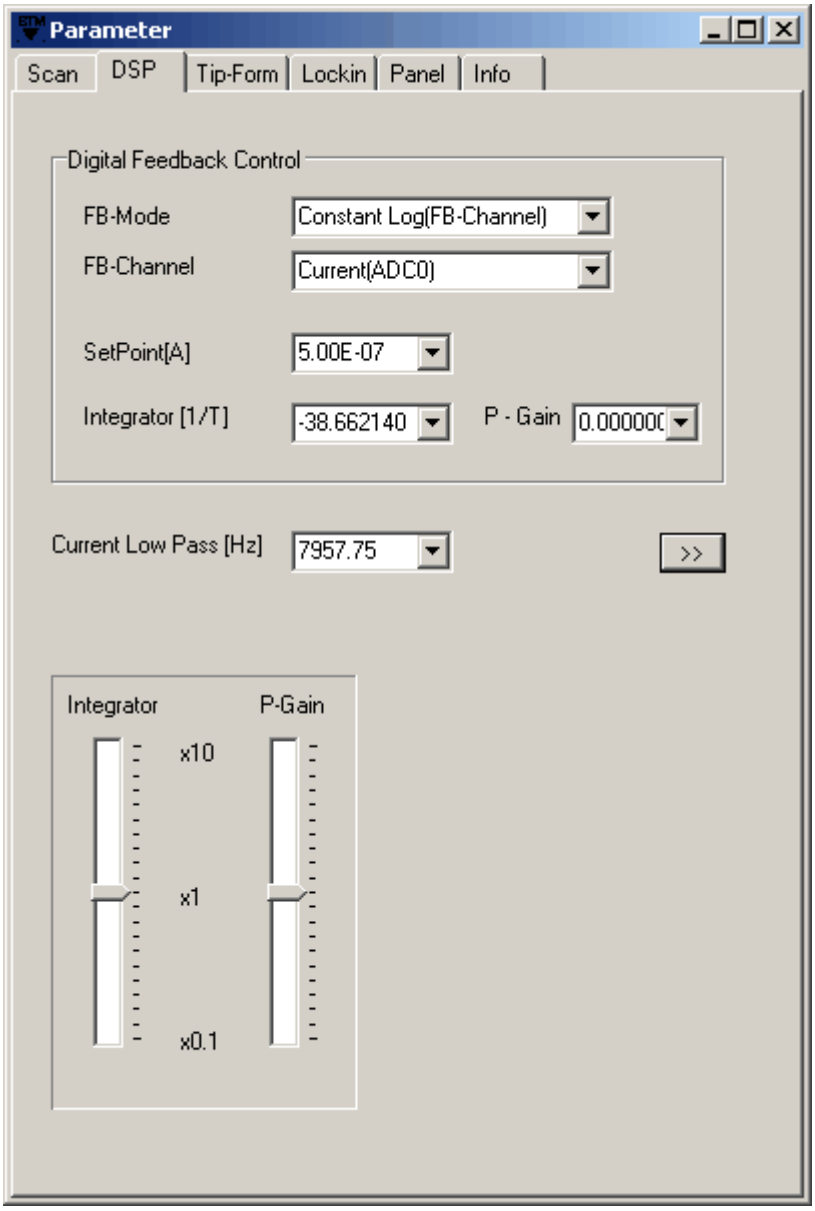

5.3 Tip Forming

Tip forming (controlled crashing of the tip) is similar to the vertical manipulation procedure, but uses independent parameters to simplify the intermittent use of tip forming and vertical manipulation/spectroscopy. Tip forming is performed by first pressing on the tip forming button <TF> and then marking a particular point in the image by clicking with the left mouse button. Similar to vertical manipulation the data taken during the tip formation are displayed in the vertical manipulation form. The parameters used are TipForm_Vol, which is the voltage applied to the sample during the tip forming process. Then TipForm_Z [mV] , which means that the tip is moved towards the sample by Z x Zpiezoconst for the tip forming. (The gain of the z - HV amplifier is automatically included). The preamplifier gain is always set to gain 10^6.

Voltage[V]
Volatge applied during the tip forming manipulation process.

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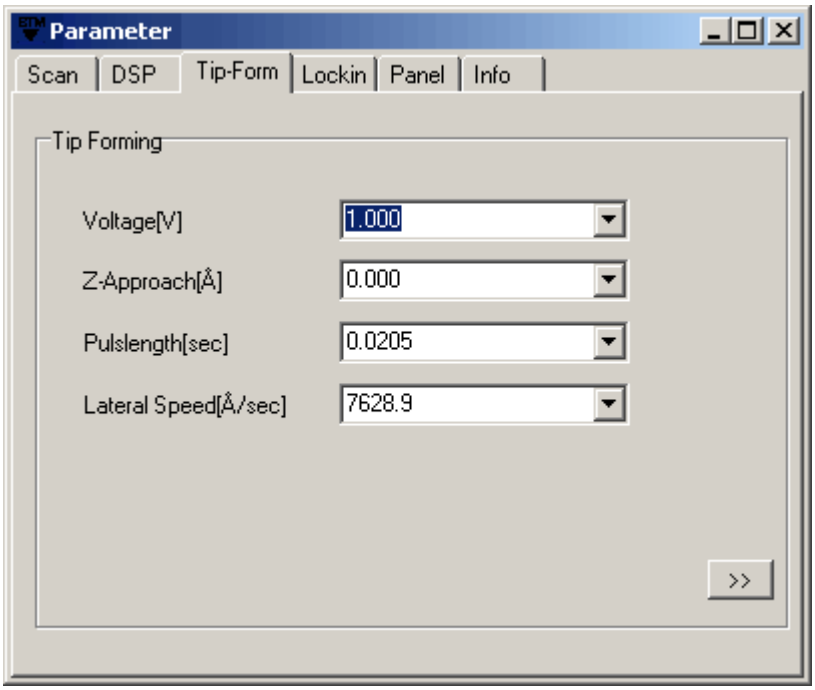
Z-Approach
Defines how far the tip moves towards the sample during a tip forming process

Pulslength[sec]
Defines how long a complete tip forming approach takes.

Lateral Speed[A/sec]
Defines how fast the tip moves to the selected tip contact position



5.4 LockIn

The new version of STMAFM has an internal lockin integrated in the DSP software. The internal lockin modulates the bias voltage directly and measures the modulated current signal on ADC0. No extra cabling has to be installed. It is still possible to switch between the internal lockin and an external one whose output has to be connected to ADC1(ADC2).

The internal lockin measures both the signal at the modulation frequency and the second harmonic.

The parameters:

Frequency:
Modulation frequency

Amplitude:
Peak to Peak modulation amplitude

Ref. Amplitude:
Peak to Peak amplitude of the external reference signal supplied by DAC4. (Discontinued under AFM Operation)

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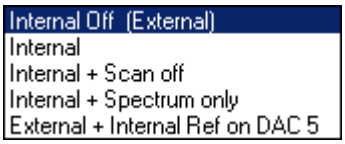
RC:
Time constant of the lock-in low pass filter

Phase1,Phase2:
Phase value for first and second harmonic

Lockin-Mode:



Internal Off (External): The internal lockin is switched off. The modulation has to be taken from an external lockin. Connect the dI/dV signal to channel ADC1 and the d2I/dV2 to ADC2.

Internal: Modulation and Signal detection done by the internal lockin. The signal is extracted from the current signal (ADC0).

Internal + Scan off: Internal Lockin Mode but the modulation is switched off during scanning

Internal + Spectrum only: The modulation is applied only during spectroscopy

External + Internal Ref.on DAC 5: The modulation is done by the internal lockin, but lockin detection is performed by the external lockin. A reference signal for the external lockin is supplied by DAC 5. Connect the dI/dV signal to channel ADC1 and the d2I/dV2 to ADC2.

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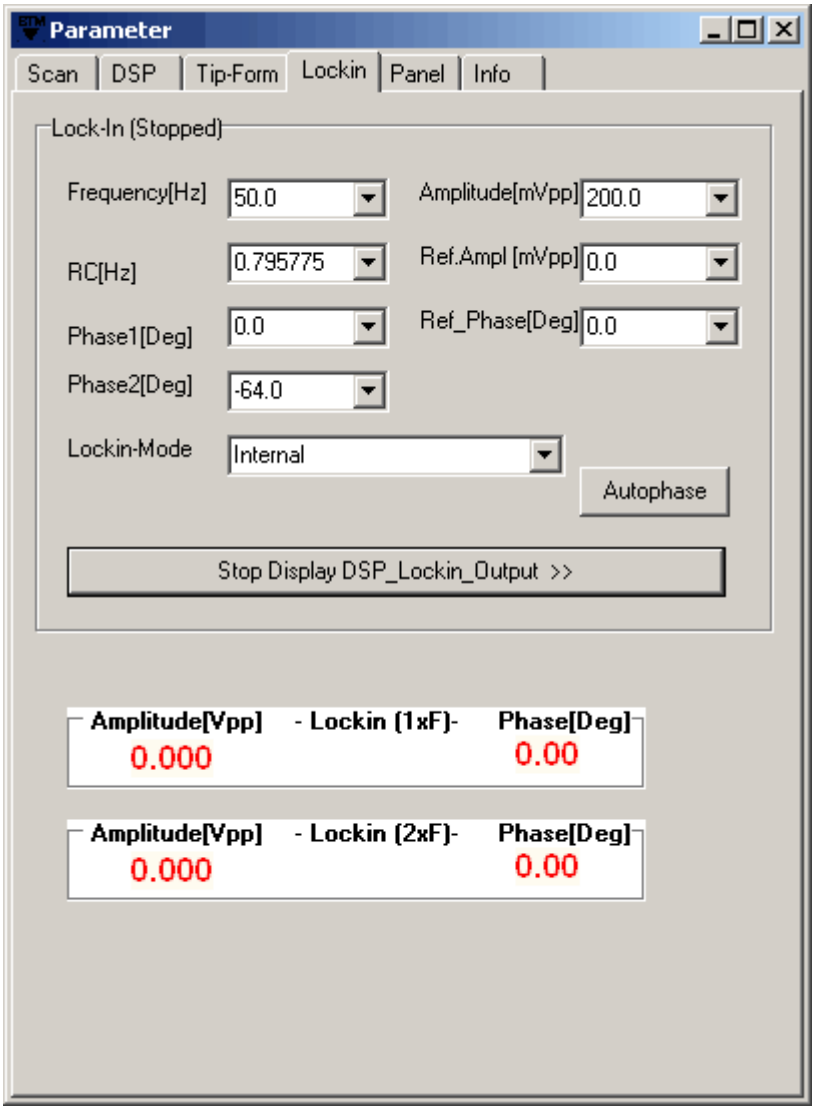

5.5 Panel

Sensors
On Panel additional information is available, regarding the temperature sensors etc.

Memo
The memo field is used to input extra information about the current image. The memo info is stored with the image.

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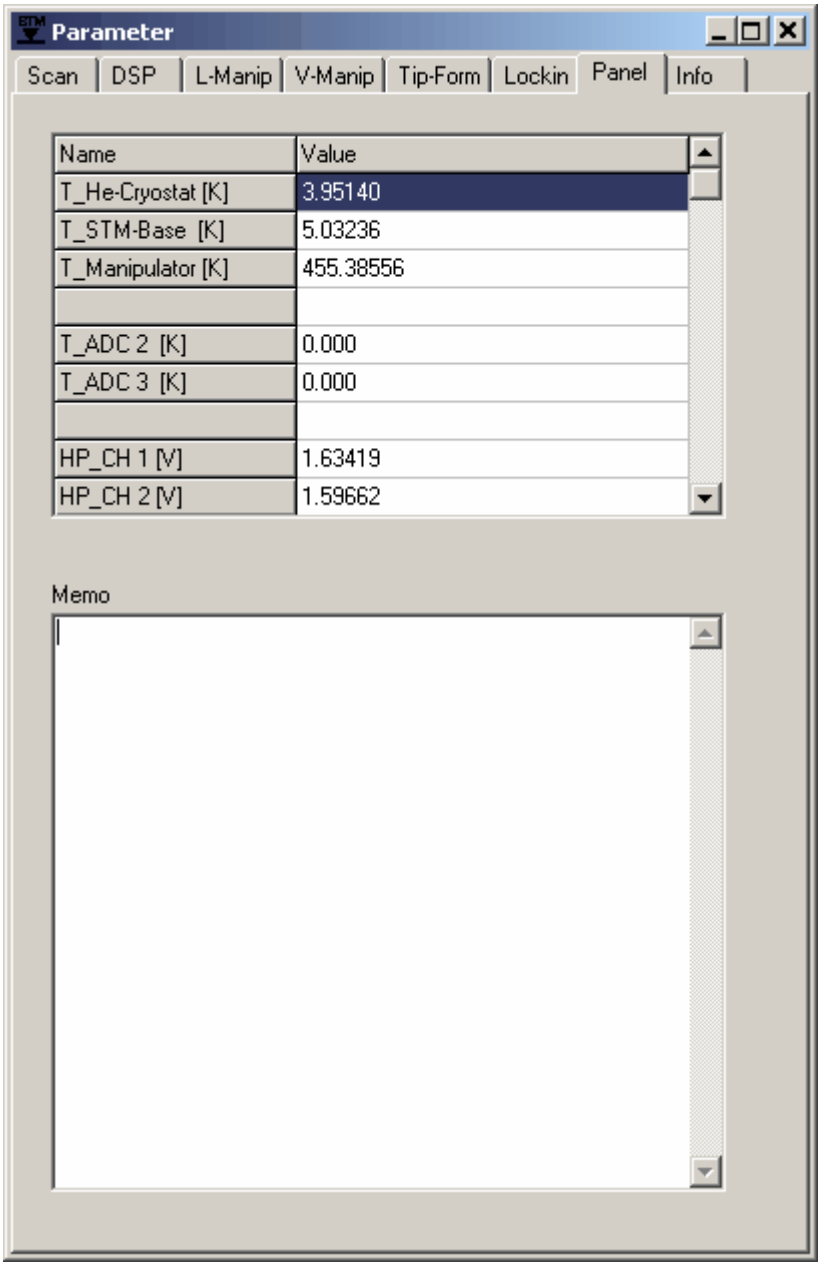

5.6 Info

Lists all paramter sets.

Load,Save
Press to load or save the selected parameter set.

Info
Use the info field to input information which should be later available, but not contained in any other datafile etc.
The contents of the info field is saved in info.cfg. Double clicking in the info field, will insert an actual time stamp.

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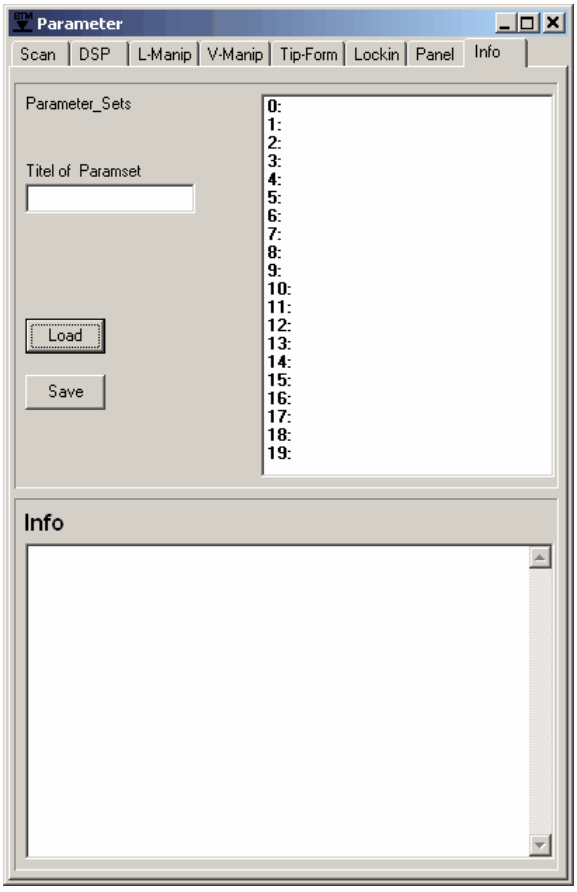

6 Windows

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6.1 LineScan

Press the Lin Button to take a line scan of the image. First select two points of the image by pressing the left mouse button. The linescan
is displayed in the upper linegraph of the linescanform-window. To perform measurements on the linescan press the <Measure> button.

Use the left mouse button to select a new point. With the right mouse button you can switch between points. Pressing the Shift button allows to move a whole line. Pressing the right mouse button together with the Shift button will switch to the prependicular averaging mode.

Important: If the linescan form is opened through the menue selection first, all linescan data will be displayed always in the this particular window. Otherwise pressing the LIN button will always open a new window.

Autosize
Selects automatic scaling of the linegraph

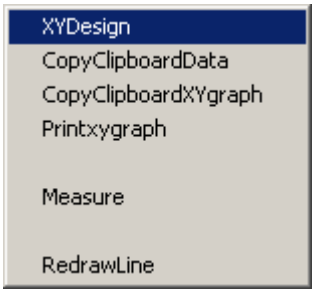
Autolinebacksub
Selects automatic subtraction of linear background

Line Display Trackbar
Move to show a line scan of a particular image line. A FFT of the selected line is shown in the lower line graph.(The number of points/line has to be a power of 2)

Popup menu of upper linegraph
xydesign: Select to adjust the appearance of the line graph
CopyClipboardData: The line scan data are copied to the ClipBoard
CopyClipboardXYGraph: The line scan graph is copied to the ClipBoard
Printxygraph: The line scan graph is send to the printer
Measure: Do measurements of the plot data.
Redrawline: The line in the image is redrawn

Popup menu of lower linegraph
has the same items as the upper popup menu and one additional entry:
Show Frequency: Gives the FFT in frequency [Hz] instead of inverse distance [1/Å] (updated when the Line Display Trackbar is moved)

Channels
Select the channels which are displayed



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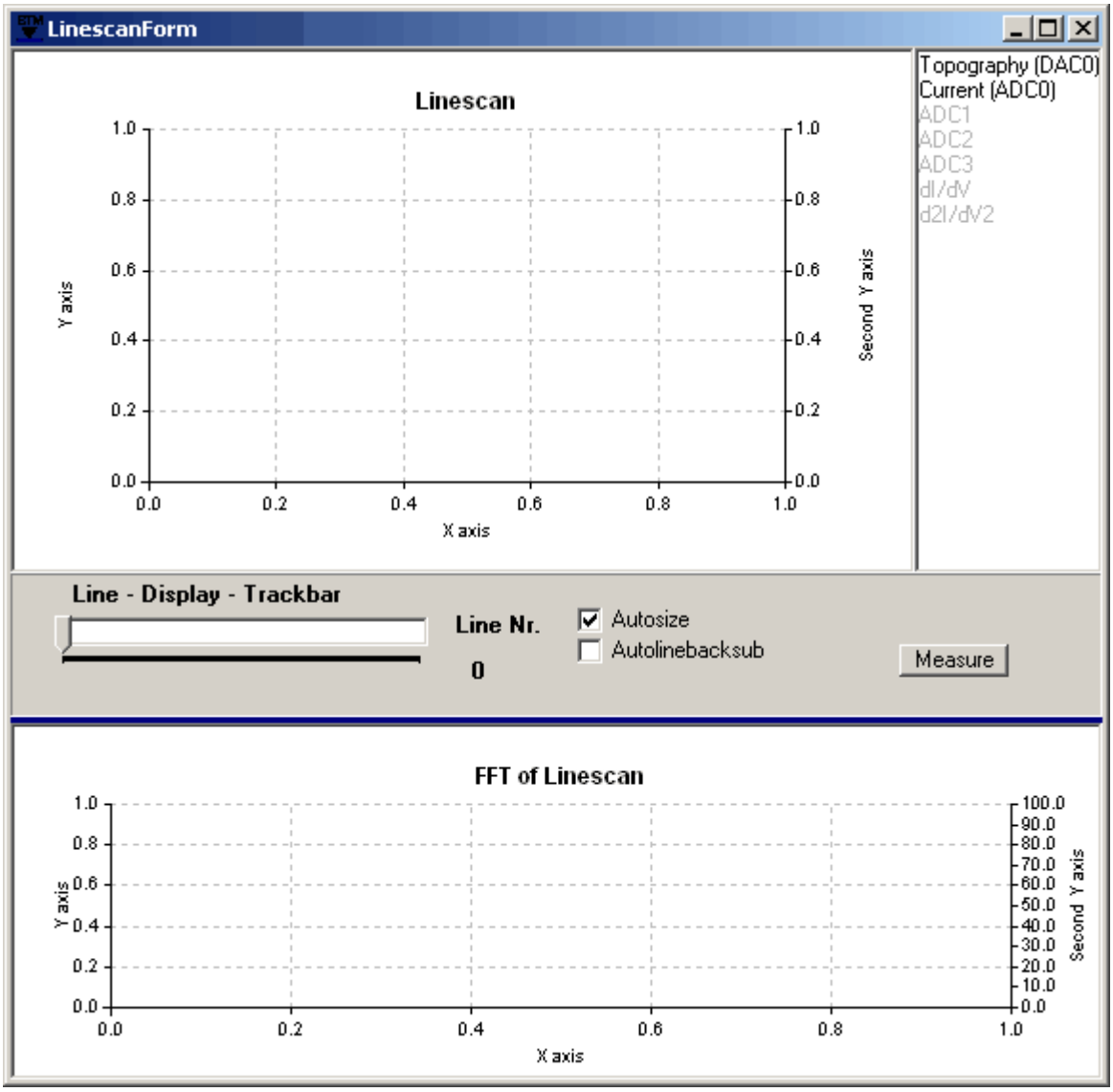

6.2 Ramp-Controller

Click on the <Ramp> button. This opens the 'Rampcontroller'-window with control elements necessary to perform the coarse approach. The 6 buttons with arrows in the top of the form correspond to moving the tip in respect to the sample surface. Moving in x/y direction can also be done using the x/y cursor keys on the keyboard. The page up and page down keys are used correspondingly for rotation up and down. Selecting the burst mode in x/y or rotation will result in a series of steps corresponding to the number of burst steps displayed in the ramp parameter list. When the <Crash Protection> is switched on, the program checks before each step, whether it can detect a tunneling current. If this is the case it will cancel the step. Usually the crash protection should be switched on, but in cases where the tip is already crashed, the protection has to be switched off. The program issues some warnings when the ramp windows opens to inform the user to do necessary changes for a successful ramping. These are: First retract the tip, reset the x- and y-offset in the STM-program, select the appropriate gain (1-10, depending on the temperature) in the x- and y- channel of the HV-amplifier and set the external offset voltages to zero.
The usual coarse approach is done by controlling the approach with an optical microscope. When the tip is close enough, the automatic tip approach can be switched on, by pressing the

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<Approach> button. It will start a combination of single coarse approach rotation steps combined with tip approach testing until the tip can reach the sample. The <Approach> stops when a tunneling current is detected. The value of this threshold current is set by the current slider.
Important: When the approach stops, the tip is automatically retracted, by setting the current to zero. Before leaving the coarse approach by pressing the <Quit> button, you have to select the mode for scanning. When the <Main/Coarse> button displays 'Coarse' mode, then the outer 3 piezos are used for scanning, otherwise the center piezo is used. In the normal operation of the microscope the 'Coarse' mode should be selected. Select the required set point current to see if the approach was successful. Now the tip should be retracted manually by using the external HV-amplifier z-offset voltage to go out of tunneling. Select the required gains and re-approach the tip again.

See also: Approach Tips

The Coarse Approach operation is controlled by the following parameters:

Puls Height[V]
Input the peak to peak height (in V) of the sawtooth pulse used for moving the inertial slider. Two different values are used for the lateral XY motion and the rotational motion.

Puls-Duration[sec]
Input the duration of a single sawtooth pulse in seconds.

Burst-Count
Determines the number of sawtooth pulses applied when operating the coarse control in burst mode.

Approach Period[sec]
Determines the time for a single approach cycle including approach and retraction of the tip to find the sample surface.

Approach Burst Count
This is the number of coarse pulses applied between two approach cycles.

Approach Retry Count
This is the number of retry operations done before the approach is stopped.

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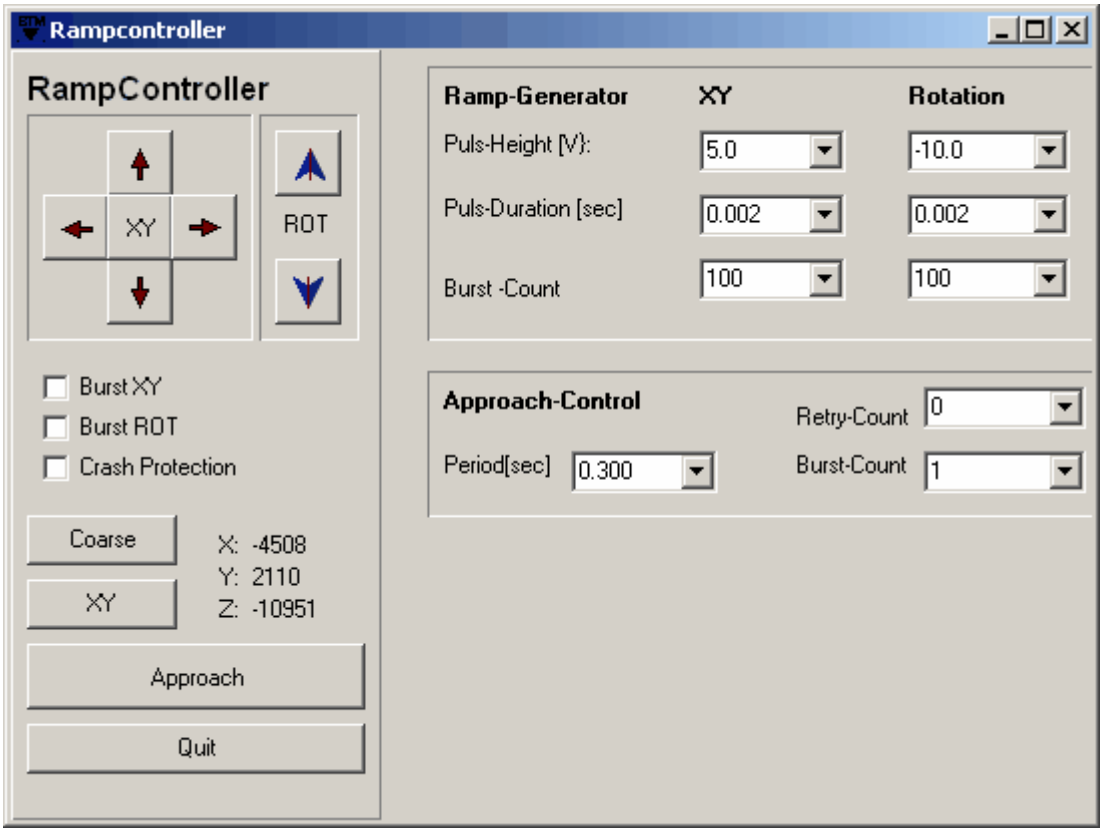

6.3 Grid

The form 'Grid-Image- Transformation' contains several functions for different kinds of image transformations. A suitable combination of the procedures below will allow transformations useful for drift correction, superstructure analysis, extraction of registry information. To open the form press on the grid button in the STMAFM form. With the 6 slider controls a grid can be overlayed on the image. The lateral position, the angles of the grid and the distance between the grid lines can be adjusted. An alternative way to input the grid is pressing the <Mouse> button and to mark 3 points (the first one is the center, the other two determine the direction of the two lines). Pressing the <Rotation> button will rotate the image in such a way that one set of the grid lines (X-Axis) is parallel to the horizontal direction. Pressing the <Zoom> button will zoom the image by the value set in the edit control positioned next to the right of the button. The image is zoomed around the center point of the grid. By pressing on the <X..,Y..> button the actual center position of the grid is stored and displayed on the button. Selecting a new center position with the mouse, as described above, and pressing the <Move grid to Center> button will move the new defined center to the stored center position. The <Transform> button will transform the image according to the 2 Parameters in the edit controls below. The first is the new angle between the lines in the image and the second is the new ratio the grid line distances. Selecting the <HexGrid> check box will draw a grid suitable for hexagonal unit cells. If draw inverted is selected the grid is drawn by a inversion process. Otherwise you can select with <Grid Color> the line color of the grid.

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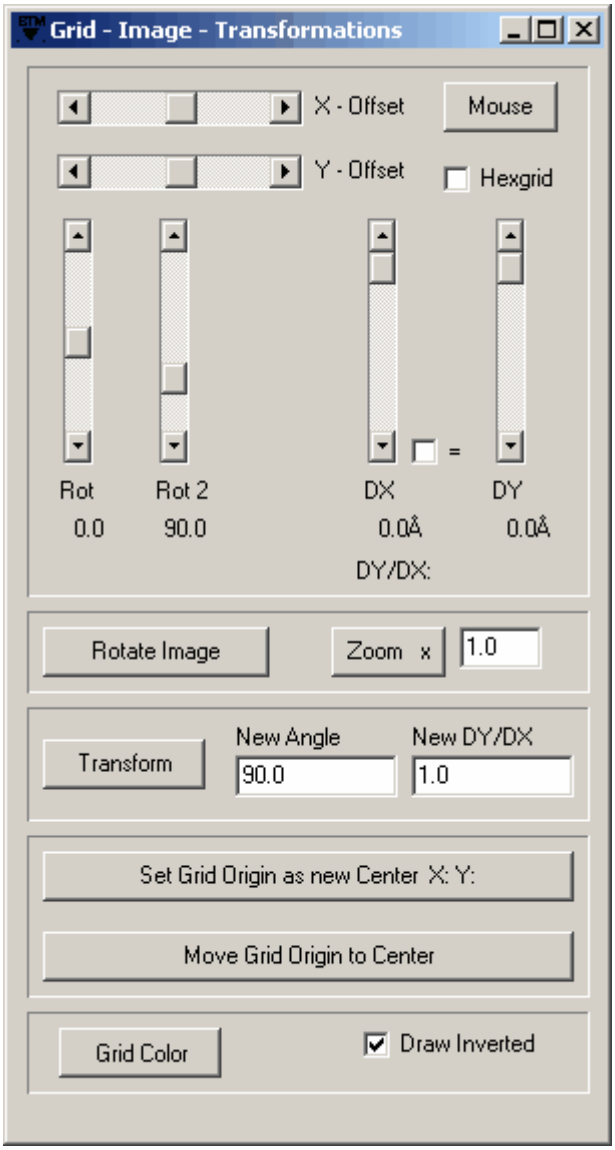

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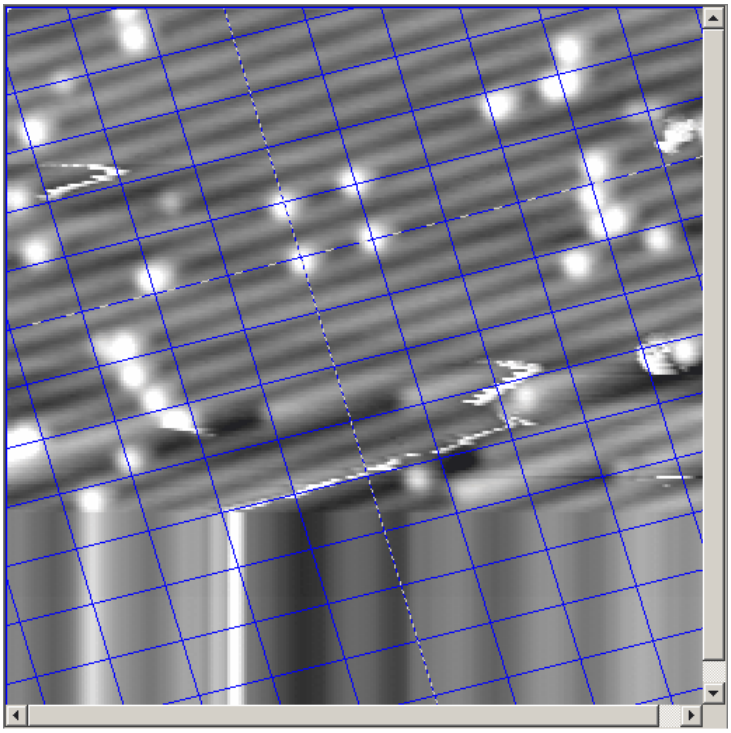

6.4 Time Spectrum

It is very often useful to take a time record of the A/D input channels, without scanning or changing the biasvoltage. This is for example a convenient way to characterize the noise performance of the STM. To take a time record just press the <Start> Button on the Time-Spectrum window or press the <TS> button on the main window. Five channels are recorded simultaneously. The A/D channels 0 and 3 (ADC0 is called current I) and the topography signal output from the feedback loop, called Z. The displayed channel is selected by the corresponding channel button. Three parameters control the data acquisition:

Spec_Points
The number of data points taken for a single spectrum. This must be a power of 2, to allow FFT of the data.
(Maximum is 4096)

Spec_Freq[Hz]
The sampling frequency. (Limited by the DSP_Clock value)

Spec_Avrg_Count
The number of spectra averaged. Averaging is done only for the spectrum, i.e. the FFT data.

Channels
First select the check boxes to determine the channels which are acquired during data acquisition Part of these channels can be further selected to be displayed.

The results are displayed in two line graphs.
The upper one shows the time behaviour. (The vertical scale is always in V)
The lower one shows the frequency spectrum. (The vertical scale on the left shows the peak to peak value of a pure sine component,
the right scale the rms amplitude for non correlated signals)

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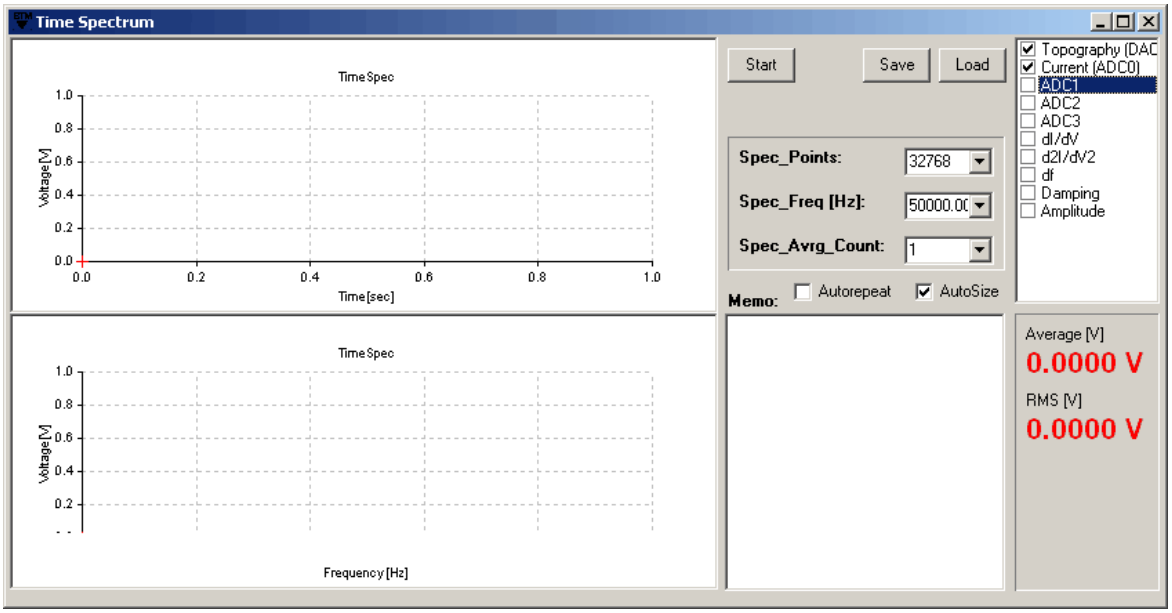
!!!!!!!!!!!!!!!!!!!!!!!!!!!!Has to be checked!!!!!!!!!!!!!!!!!!!!

The frequency resolution depends on the number of points and the sampling frequency.
Important: The current signal and the ADC1 signal are filtered by a first order digital filter, which is controlled by the same CurrentRC Parameter.
The contents of the memo field is saved together with the file.

Save
The data is saved in ASCII Format



6.5 3d-View

This part of the program allows the display of 3d views of selected parts of the images. To start, open the window by clicking the <3d view> button. Then click on <New Data> in the main menue and select a rectangular region on the image displayed in the STMAFM program. A new form will be opened, where the rendered image is displayed. The sliders in the 3d-view form allow to change the orientation, size, offset and lighting of the 3d object. The 3d image can be displayed in different ways, depending on which check boxes are checked. So the lights can be switched on or off, the 3d image can be shown using lines, hidden lines, or in the normal surface view. Checking the save box will start saving of each images displayed. With this feature a series of BMP images for movies can be created. Checking the <Box> box will draw a 3d box with x,y,z axes in the 3dimage.In the light sources field the angle of the light source can be changed. Apart from a directed diffuse light source ambient lighting can be added.

Under the menue item Color the color of the background and of the lines can be changed. Morover the image can be copied to the clipboard (in BMP format), to a new window or the data can be exported in PoVRay format.
(New List means that a new imagedisplaylist is created for the underlying OPENGL rendering program. This usually done automatically)

Selected views can be saved and are saved with the program.

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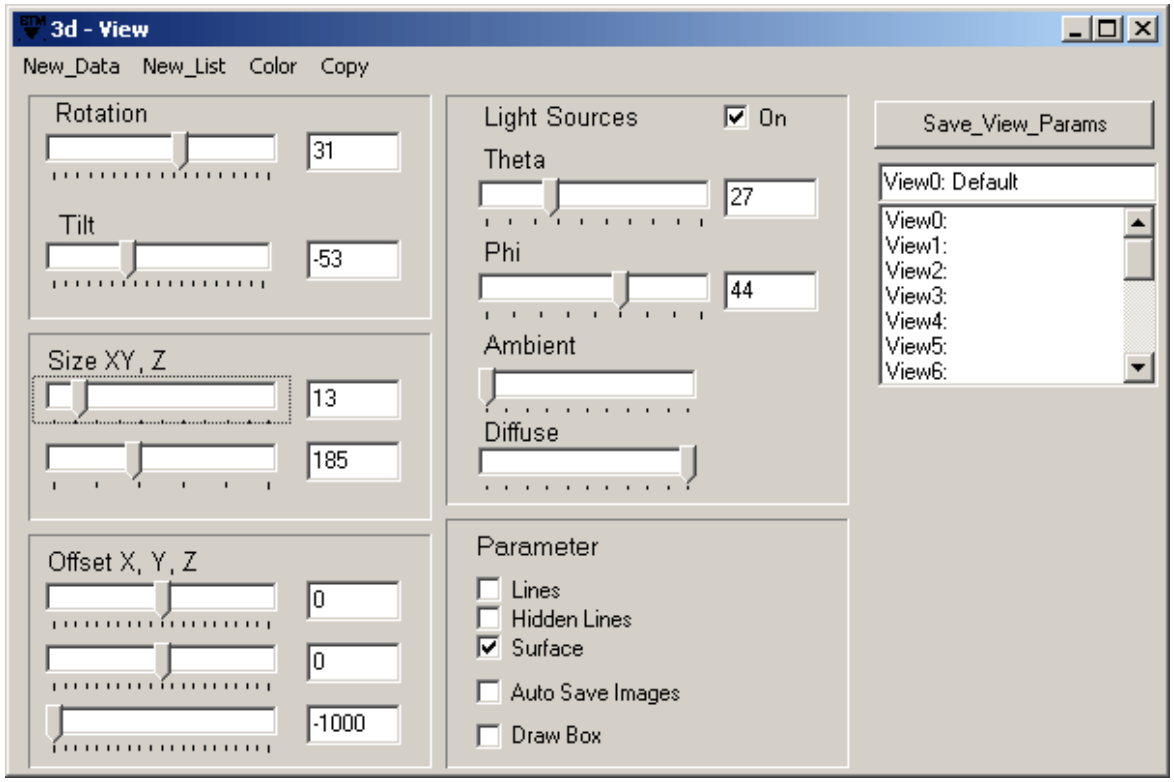

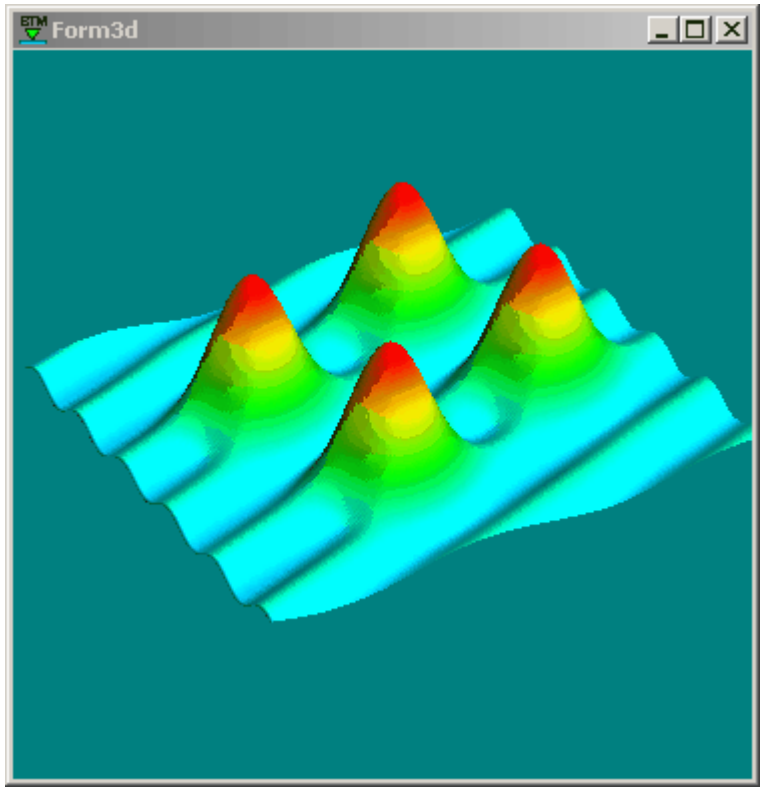

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6.6 Lateral Manipulation

o perform a lateral manipulation with the tip one has first to press the Button <LM> and then to select the starting and the final position of the manipulation path by selecting these points in the image with the left mouse button. A thin line is drawn on the screen between these points. After the manipulation is completed a separate window opens up where the tip height and current during the manipulation is displayed. By pressing the save button this data set can be saved in a *.LAT File.

Different kinds of manipulation procedures can be performed. They are selected by choosing a certain manipulation mode number in the manipulation parameter field. These different modes are described in the following. The speed of the tip is controlled by the parameters latmandelay and latmanddx, which are used throughout the whole process and not only when the tip is manipulating.

Mode 1: This is the simplest constant current mode manipulation. Starting from the top of the image the tip moves in a straight line to the starting point of the manipulation using the standard feedback parameters used for imaging. Then the feedback parameters are switched to the ones selected in the lateral manipulation parameter set . These are current, voltage and gain of the preamplifier. Then the tip moves using these manipulation parameters to the final position. There the parameters are set back to their original imaging values and the tip moves back to top of the image.

Mode 2: Similar to mode 1, but the tip moves first to the final position, then starts the manipulation to the starting position and goes back to final position. It switches back to imaging parameters and moves to the top of the image.

Mode3: Similar to mode 1: The tip first moves to the starting point. Then it moves to final position and back to the starting position using the normal imaging parameters, but the tip height and current are recorded during these two scans. Then the parameters are switched to the manipulation parameters and the tip moves to the final position. Then the parameters are changed back to the imaging parameters and the tip moves back to the starting position while again recording the tip height and current. Finally the tip moves to the top of the image.

Mode 4: This is a constant height manipulation mode. The tip moves first to the starting position. Then it moves from the starting to the final position and back taking data in normal imaging mode. Then the feedback is switched off and the tip moves from the starting to the final position in constant height mode. The height used is given by the height of the tip when the feedbackloop is switched off plus the additional offset given by latmanccdz. This means that the height depends on the imaging parameters. Then the tip moves back from the final position to the starting position in imaging mode, but taking data again. Finally the tip moves to the top of the image. With the extension factor the manipulation path can be extended at the final position by the factor given by latmanextlextension. The starting point is not affected by the extension factor.

Mode 5: Similar to mode 4. In this mode the extension affects also the starting position. The extension positions are first calculated. The tip moves in imaging mode to extended starting position. Then moves to the final extended position and backward and takes data in imaging mode. Then the tip moves to the starting position, while taking data in imaging mode. Then the tip moves from the starting position to the final position in constant height manipulation mode. Then it moves back to the starting position in imaging mode and takes data. Finally it moves back to the top of the image.

Mode 6: Similar to mode 5. The only difference is that the tip moves from the starting to the final position and backward in constant height mode and not only in the forward direction, as done in mode 5.

Mode 0: This mode is different from the other modes. In mode 0 the tip follows always the mouse position immediately. The height of the tip is displayed on rate meter appearing on the left. By pressing the upper case L key the imaging parameters are switched to the manipulation

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parameters and back again. (By pressing the upper case S a small 64 pixel * 64 pixel scan is performed.) Clicking with the mouse button will stop the continuous following of the tip. After additional clicking the tip moves to the new mouse position in a straight line and tracks the mouse position again.

These parameters control the lateral manipulation processes.

Mode
Select one of several different manipulation modes. There are constant current and constant height modes. For example P0 is the origin of the image. Then the tip moves to P1, the first point selected with the mouse. The tunneling parameters are changed to manipulation parameters and the tip moves from P1 to P2. There the normal tunneling parameters, used for imaging, are selected again and the tip moves to the origin P0.

Voltage[V]
The tunneling voltage applied during the manipulation phase.

Current[nA]
The current used during manipulation

Gain preamplifier
The gain used during manipulation

Manip. Speed[A/sec]
The speed of the tip for lateral movements. Used for all movements. Step Size determines the number points measured during a lat. manip. scan.

Extension
Extension value for manipulation modes 4-6

Const. Height Z-Offset
In constant height mode the tip sample distance can be varied by this parameters. Positive values [Å} correspond to a closer approach to the surface.

Channels
Select the channels acquired during data acquisition

LatChannelForm
Press to open a new Form to display the manipulation data.

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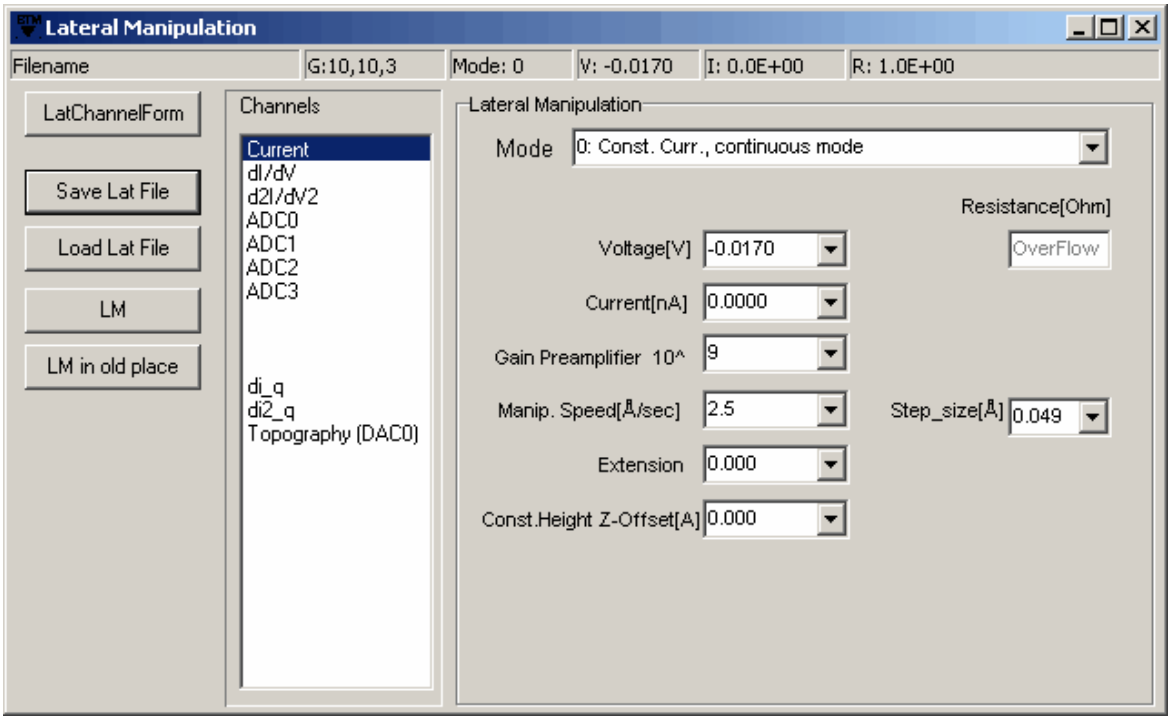
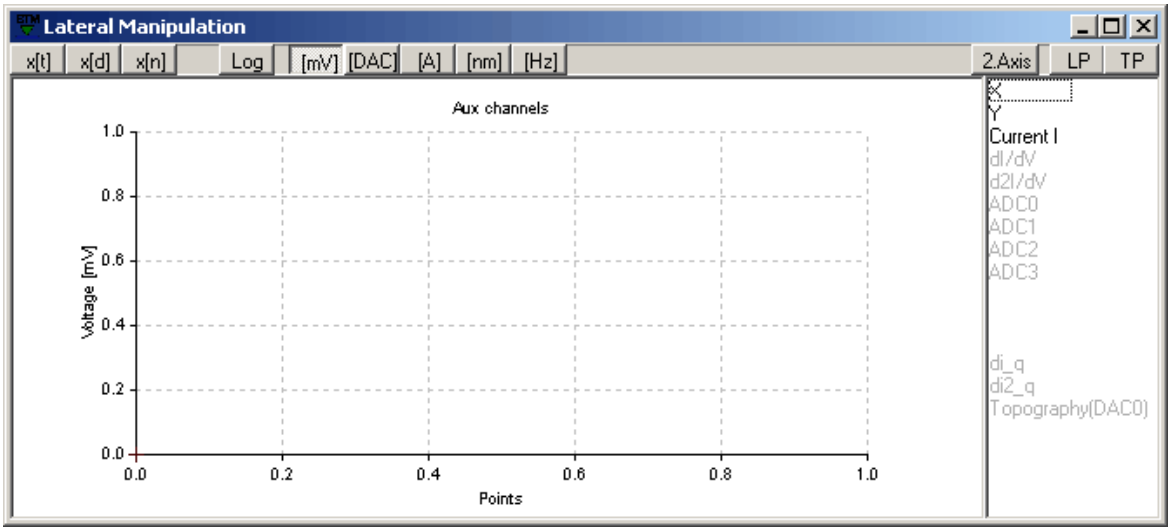


The measured data is displayed in separate windows. X and Y scaling can be adjusted by the user. Two independent axis can be displayed. (Press <2.Axis>)
<LP> Low Pass Filter
<TP> Makes the Windows transparent to put it on top of another window.



Right click to open the Popupmenu.
XYDesign, XY Series Edit allows to change the appearance of the Data
Copyclipboard.. copies the Plot or the Data into the clipboard
PrintXYGraph prints the XY Plot
Measure allows measuring the distance between points in the plot
AutoUpdate: The Plot is updated every second during Data Acquisition.
Lowpass filters the data (very simple just nearest neighbor average)

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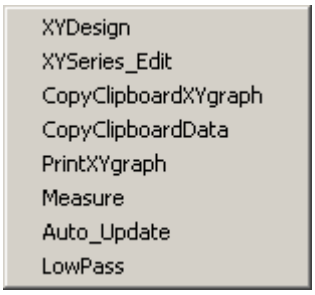

6.7 Vertical Manipulation and I/V spectroscopy

Vertical manipulation (spectroscopy) is started by pressing on the <VM> button and selecting a point in the image by clicking with the left mouse button. The tip uses the lateral speed value to move to the vertical manipulation position. When the manipulation is finished the measured data appears in a separate window and can be saved with the Save button. Different channels can be selected to be recorded. Usually an external Lockin will be connected to ADC1. The internal Lockin supplies the signals dI/dV, d2I/dV2, di_q,d2_q. The form of the voltage and the z-height ramp is controlled by 8 points in time. In the case of the voltage one can define 8 time points and their corresponding voltage value. For example (0,1000), (256,0), (512,2000),(1024,-1000) define a ramp starting with 1000mV at time 0. Then it will be linear interpolated to time 256 with 0 Volt. Then it goes up again to 2000mV at time 512 and finally reaches -1000mV at time 1024. The time values correspond to the number of points taken. In this case these are 1024 points. A maximum of 100000 points is possible. The z-height values already include the gain of the z-amplifier. This means, that changing the HV gain will not change the z-height ramp, because this will be automatically corrected. Vertspecback = 1 will apply the ramp in forward and backward direction. Vertspecback=n will apply the ramp in forward and backward direction n-times (n>=1). The shape of the ramps is shown in the lower graph in the vertical manipulation window.

Vertical spectroscopy can be done during scanning. Press the VM Button and select a point in the unscanned image area.

These parameters control the vertical manipulation and spectroscopy

Gain preamplifier
Gain of the preamplifier during data acquisition

Speclenght[sec]
Select the recording total time of the spectrum.

Spectrum backward
0: The Spectrum defined in the V,Z table is taken only once.
1: The spectrum defined in the V,Z table is taken once in forward and once in backward direction
>1: Defines how often a forward and backward spectrum is taken

Z- Offset
Defines an additonal offset which is added to the z values in the table

Z-Drift
Defines an increment which is added to the values in the table to compensate drift effects

Repeat Count
Defines how many separate spectra are taken and stored.

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Spectra/Line
Defines the number of spectra equally spaced along a line between a start and endpoint,selected by mouse input.
The first spectrum is taken at the startpoint of the line the last one at the endpoint of the line.

V,Z table
4 points can be defined to create a voltage and z table used for vertical manipulation and spectroscopy. The data values are plotted in the graph below. The first Time Value should be set to 1 (not 0, still allowed for compatibility), otherwise the first value might not be displayed. (Voltage(green), Z-Position(blue))

Spec_X_Grid
Spec_Y_Grid
Determine the spacing of the spectroscopy grid. First spectrum position is (spec_x_grid,spec_y_grid) in pixel coordinates.

SGrid_Channel
Number of channels recorded during the grid spectroscopy mode

SpecGrid_Delay
Delay in DSP cycle units added before/after a vertical spectrum is started/finished.

SpecAvrgCount
Number of Spectra acquired and averaged directly on the DSP board. For Count>1 be aware that the current preamplifier gain for vertical spectroscopy will be set the same to the normal preamplifer gain. Between the spectra the feedback loop will be switched on to readjust the sample tip distance.

SpecAvrgFBDelay
On Time of the Feedback loop in DSP cycle units between spectra in Averaging mode.

Save File
Save the present Vert. Spektrum

Single_Spectrum
Take one single spectrum. Select the position with a left mouse button click on the image. Same like pressing <VM> button

Spectra along Line
Take a series of spectra equally spaced a long a line defined by two mouse clicks.

Spec in old Place
Take a spectrum at the X,Y position of the previous scan.

Multiple Spectra
Select several spectra taken one after the other. Left Mouse button select another spectrum, right mosue button stop selection and start data acquisition.

MultSpec from File
Use an external file (Ascii) to define a series of spectra.
Only 256*256 pixel images allowed. No zoom. First line contains number of spectra. Each following line contains the x y image coordinates(integer) of each spectrum.

Spectra on Grid
Spectra taken at each grid position. (Analysis of the Grid data is done in another program)

SaveSpecgrid

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Save the Grid File. Two files are saved. One *.specgrid.dat File with all the parameters and the *.specgrid File with the grid data

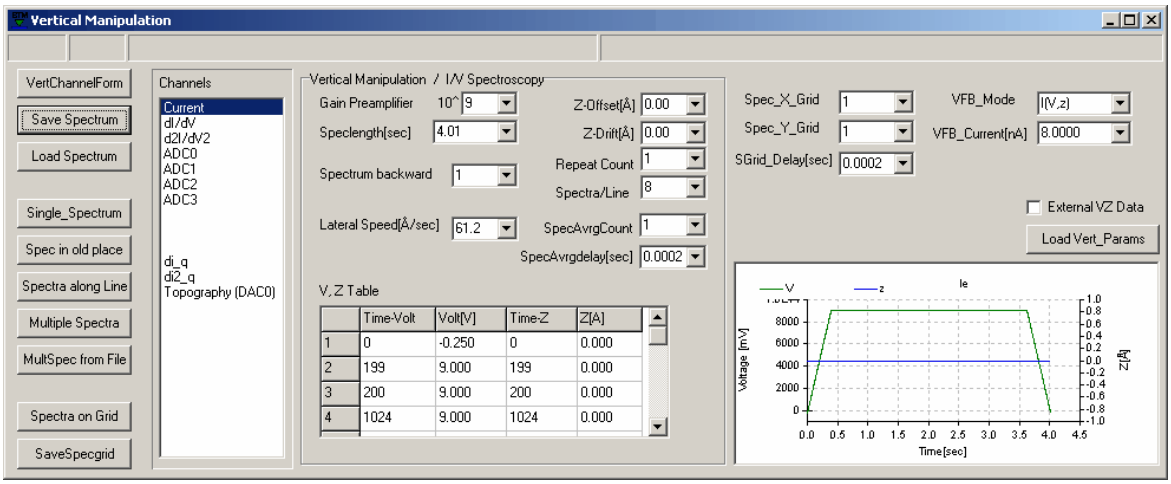
VFB_Mode
Select the VoltageFeedbackMode
I(V,z): Normal Operation feedback loop is OFF
z(V): Constant current operation

VFB_Current[nA]
Current setpoint used in z(V) Mode. FB_Channel has to be current.

Load Vert_Params
Load only the parameter of a spectrum and not the data

External VZ Data
If not checked the VZ Data for a spectrum are taken from the VZ-Table parameter.
If checked the VZData is taken from a different source table, which can be loaded from an external file.
This allows the user defined design of arbitrary VZ arrays of up to 100000 points. File format see below.

Filenames:
First Letter is the machinename, in case you have more than one LTSTM or you want to assign different users.
Followed by DATE.TIME.VERT. VERT is the standard fileextension.
In case you take repeated spectra in a point or take spectra along a line an additional "L<Number>.R<Number>." indicator is added before
the VERT file extension. L indicates line position and R indicates the numbering in repeat mode.



The measured data is displayed in separate windows. X and Y scaling can be adjusted by the user. Two independent axis can be displayed. (Press <2.Axis>)
<LP> Low Pass Filter
<TP> Makes the Windows transparent to put it on top of another window.

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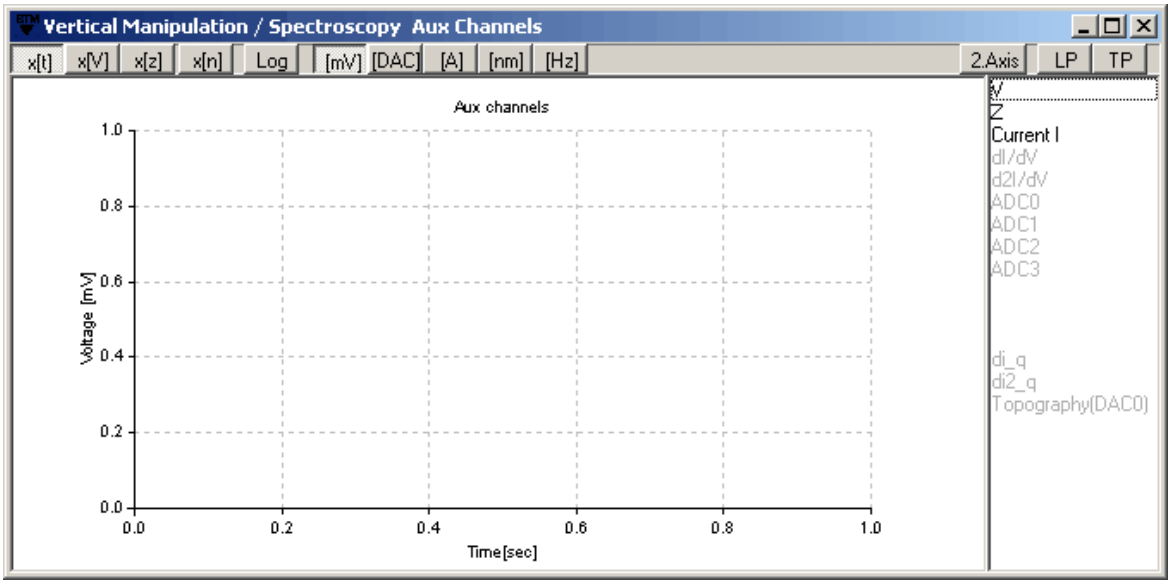
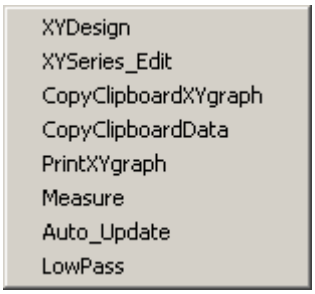


Right click to open the Popupmenu.
XYDesign, XY Series Edit allows to change the appearance of the Data
Copyclipboard.. copies the Plot or the Data into the clipboard
PrintXYGraph prints the XY Plot
Measure allows measuring the distance between points in the plot
AutoUpdate: The Plot is updated every second during Data Acquisition.
Lowpass filters the data (very simple just nearest neighbor average)



6.8 Slider

Brightness and Contrast
Use the slider window to control the brightness and contrast of the image. The slider marked B adjusts the brightness of the image. The slider marked Z controls the contrast. Above both sliders the corresponding height range in (+/-)Angstroem is displayed.So total height difference between black and white for example is two times the displayed value. On the right for multichannel images the channel, which is displayed can be selected.

Biasvoltage
The polarity of the biasvoltage can be changed by pressing with the mouse on 'V' label, or by pressing the <+>/ <-> keys.

Press the right mouse button on the 'V' label to open a Popupmenu for the biasvoltage.
Three options exist:
SetBiasMinvolt: If selected sets the current biasvoltage as the minimum biasvoltage.

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SetBiasMaxvolt: If selected sets the current biasvoltage as the maximum biasvoltage.
This feature can be used to avoid tunneling outside a specific bias voltange range. i.e for example to limit the maximum biasvoltage to protect the tip, when using the silder.

ResetBiasMinMax: If selected deletes the Min/Max values again.

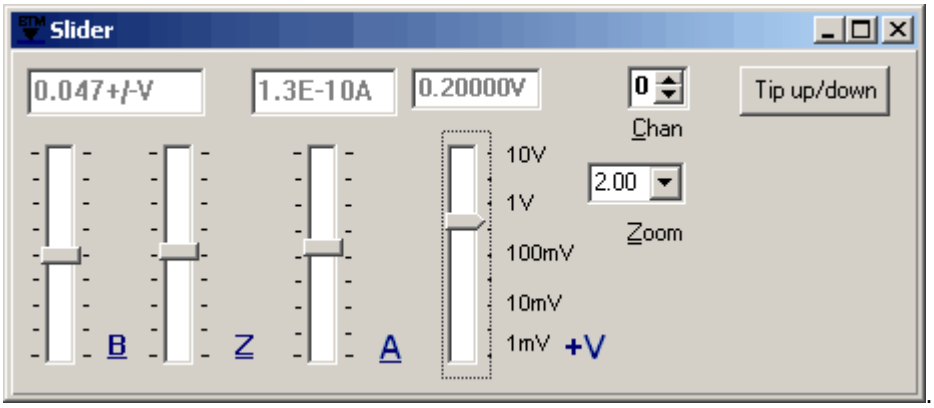
Current
Press the right mouse button on the 'A' label to open a Popupmenu for the current.

Log: logarithmic scaling of the current slider
Lin: linear scaling of the current slider

Channels
Select the displayed channel. For Channel Nr.= 0 all channels are displayed.

Zoom
Allowed zoom factors are x1, x2, x3, x4.

Tip up/down
Press this button to fully retract or to approach the tip.



The height of the slider window can be adjusted. This changes the height of the sliders simultaneously.

6.9 Tip Etching

Under the tools menu you can select this part of the program to etch STM tips. Press the <Start Tipetch> Button to start the tip etching. A voltage is applied to the tip and simultaneously the current is recorded. Etching will be stopped when the measured current is below a given treshold current. Pressing the <Stop Tipetch> button will immediately stop etching. During etching the current is recorded and displayed in the I(t) plot.

DAC Voltage
Voltage applied to the tipetching setup. A positive voltage of about 5-6V has to be applied to the tip wire.

Etch On/OFF Time
For DC etching set Etch Off Time to 0 msec. In case of pulsed etching the parameters determine the period and on/off ratio of the applied square wave signal.

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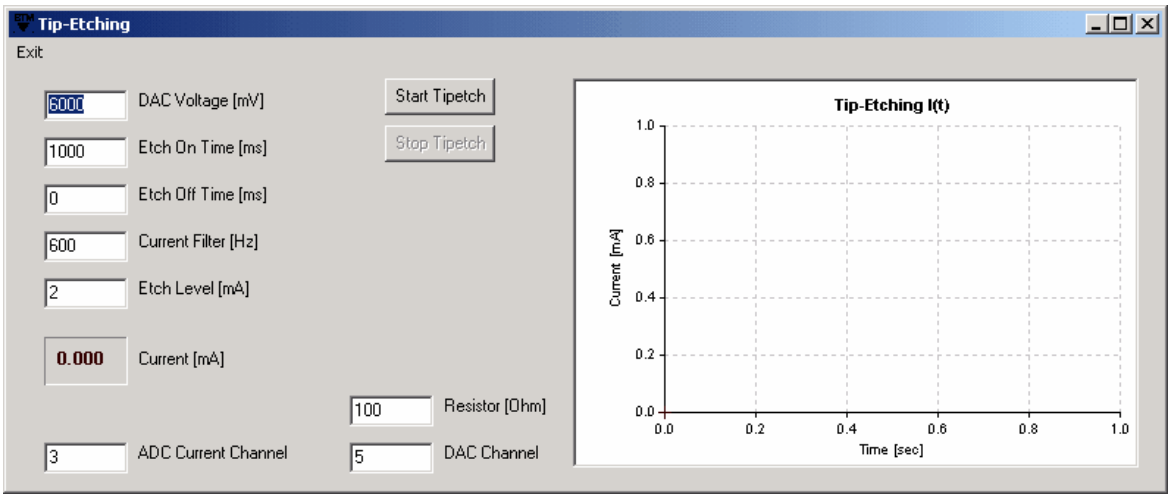
Current Filter
Filters the measured current signal to avoid stopping of the etching due to noise.

Etch Level
If the measured current is below this treshold current level, the voltage will be switched off.

ADC, DAC Channels
Selection of the ADC, DAC channel used for tip etching. ADC [1-3], DAC [1-5]

Resistor
Value of the series resistor to measure the current



6.10 Init

While most of the configuration information is saved in the Windows registry, some important initialization data is saved in the file stmafm.ini.
These data can be accessed and modified within the tool window Form_Init.

It includes the calibration data of the ADCs and DACs of the Createc ADDA board.
Machine Name: This is one letter which will be put in front of all the filenames.
Invert_Biasvoltage: Set to true to invert the biasvoltage if necessary. Will be set during installation
TakeInternalHVGainvalues: Usually false.

Press the <Calibrate_ADCs> Button to transfer the calibration data on the ADDA board.

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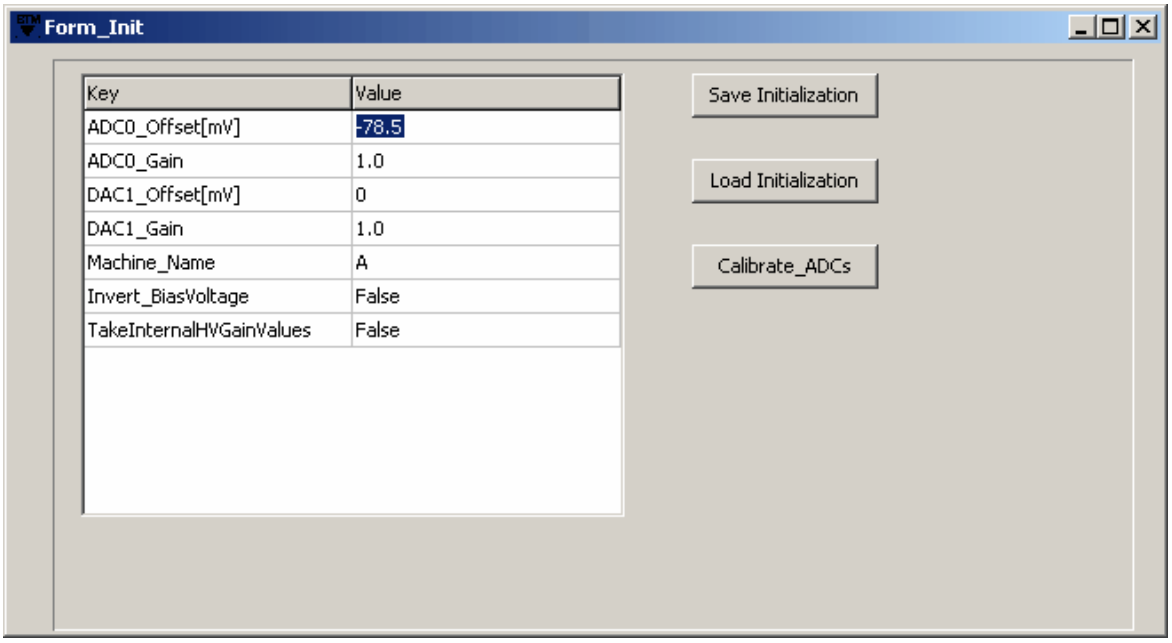
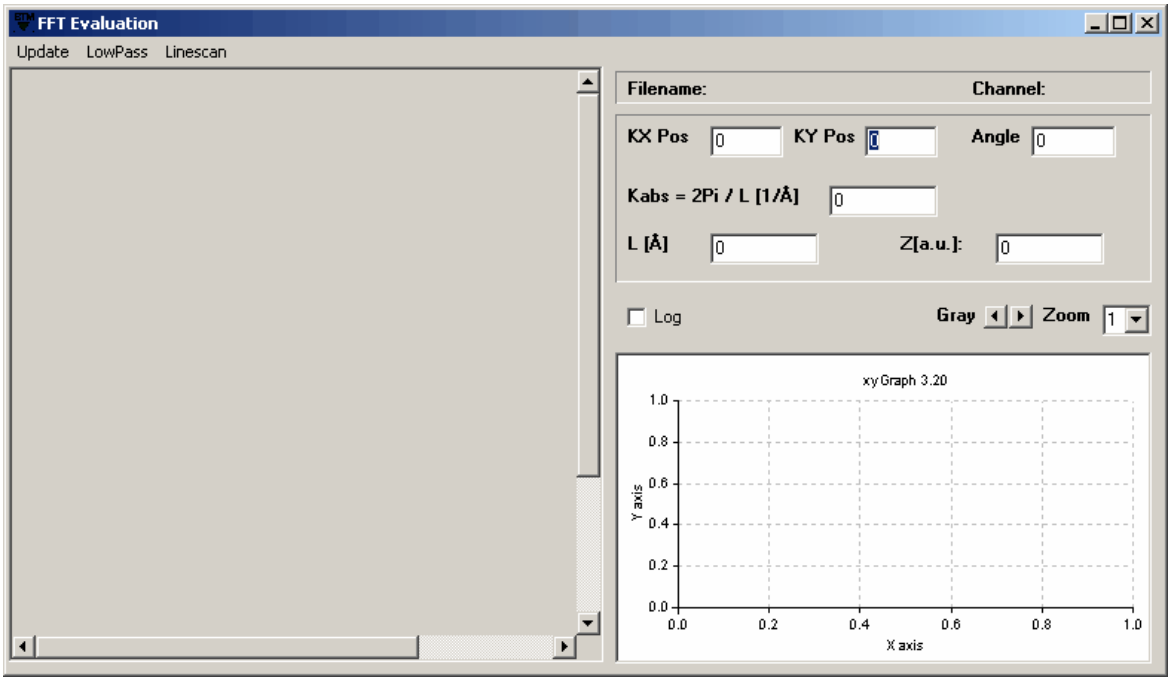


6.11 FFT Evaluation

This part of the software allows use to analyse FFT transforms of the images. (Always crosscheck the results)



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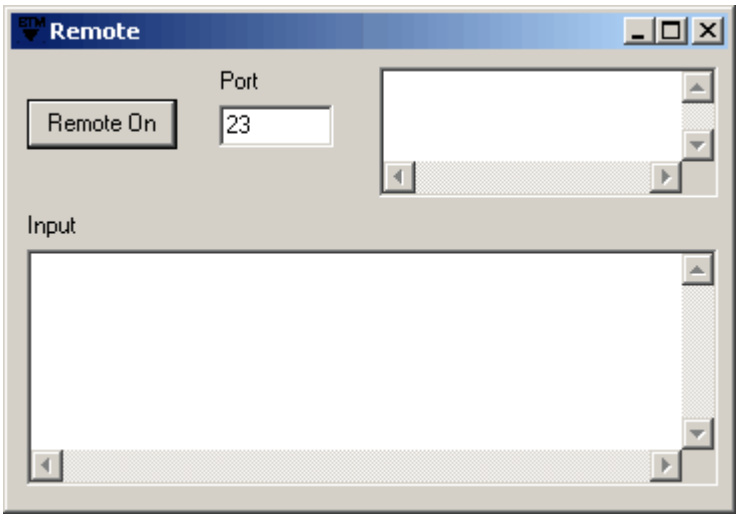
6.12 Remote

The STMAFM program accepts external commands through remote operation. Communication is via a TCPIP connection through the port given by the port pumber. To enable remote access press the <Remote On> button. When enabled remote commands are allowed at any time, i.e. it is the users responsibility that the remote operation does not interfere with the normal operation. Status information is permanently updated.



The remote commands are simple Ascii commands. A suitable Scripting program is available through Createc.

STMAFM Remote Commands (Further commands will be added on user request)

The Commands and Parameters are send as Strings. The Strings have to be separated by ',' or CR LF. Only one Command can be send at a time. Parameters are returned as Strings separated by CR LF The first String returned is READY or an ErrorCode.

stmbeep : For testing: STM beeps

setparam : Set Parameter // Param[1]: key Name in Param Field, Param[2]: new value (See old parameter menu)

getparam : Get Parameter // Param[1]: key name in Param Field

scanstart : Start Scan

scanstop : Stop Scan

scanwaitfinished : Wait until Scan is finished

quicksave : Save the Scanfile

btn_vertspec : Take a single Vert. Spektrum in point: //param[1], Param[2]]=imagepixelx,y,coordin

btn_vertspec_mult: Take multiple Vert. Spectra in points // param[n],param[n+1] in imagepixel coordinates

btn_vertspec_line: Take several spectra along a line / start point: param[1],param[2], end point param[2], param[3]

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vertsave : Save the Vertfile

move_tip_imagecoord: move tip to new position: startpoint: param[1],param[2], endpoint param[3], param[4], number of steps: param[5], delay in dsp cycles: param[6]

getscanstatus: get the present scanstatus; Scanstatus returned as String and as Number

6.13 Client Server Control

The STMAFM program allows remote control operation through a TCPIP connection. The program connected directly to the DSP board has to be switched into Server Mode first. Then another instant of the STMAFM program can connect to the Server program, switching from analysis mode into client mode. The client STMAFM program can be located on the same or another computer having TCPIP access to the Server machine. Apart from running the STMAFM from a remote place, the client server mode also allows more than one client program. A useful application is to control the DSP board directly without using the STMAFM program. For example you want to write a specialized spectroscopy software which
should run in parallel with the STMAFM program. Then you use an STMAFM client to do all the other operations, and your own software to send additonal control commands to the DSP directly, bypassing the STMAFM client. A detailed description of the DSP command format, will be given below.

Server-Client operations are operated through FormPC32, which is accessible under Menu option DEBUG.
If the program is in Data Acquisition mode, it can be put into Server-Mode by selecting the Server Mode check box. Communication is done using a specific port number, which has to be the same for the server and the client and should not be in conflict with other software running on the host system. Moreover take care that access is not blocked by a wrongly configured Firewall on either the server and the client machine. Once the program is in server mode the program windows are disabled. To go out of server mode simply deselect the server mode checkbox.

To switch the STMAFM program into client mode input the hostname or host address of the server machine. Use the server port number. Then press the 'Connect to Server' button. The client will automatically connect to the server. The successful connection will be displayed in the Comm-Info box, otherwise an error message will appear. To go out of Client mode press the button again. When the Client connects the server will send the server parameters to the client, so that the client will resemble the same configuration as the server. During Client operation the server parameters will not be updated by the client. Only when the client finishes the connection the client will update the server parameters with the actual client parameters.

The speed of the Client-Server operation will depend on the network performance.

Files are always stored on the computer which is operated by the user.

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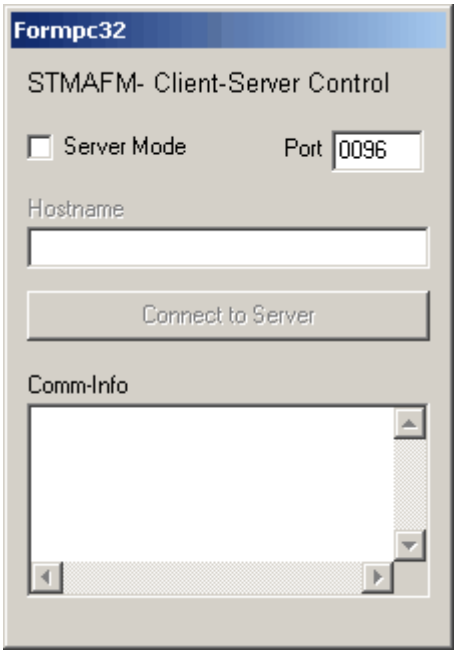

An alternative way to operate the STM from a different computer is to use a **Remote Desktop Connection** for example available directly in the Windows XP operating system. If the network is fast enough Createc recommends remote operation in this mode. In particular if the optional high speed USB2.0 adapter is installed.

7 Programming Interface

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7.1 How to start

To simplify the way to add new features to the STM-Program and to allow an easy way for later upgrades all changes should done in the special unit **'Uparamuser.pas'** and the related form **'Formuser'**. In this unit parameters an be inserted, which are displayed in the parameter list. New components like button etc can be put into the related form.

The software was developed with *Codegear Delphi 2007 for Win32*. It is necessary to install first the Createc Package in Delphi.

7.2 The unit Uparamuser

```
// Standard user unit. Put here all the additonal variables and procedures to
// customize the STMAFM program.

unit Uparamuser;

interface

uses
  Windows, Messages, SysUtils, Classes, Graphics, Controls, Forms, Dialogs,
  Menus, StdCtrls;

procedure paramassignfromcells_user;
procedure paramassigntocells_user;
procedure paraminit_user;
procedure MouseDownext(Button: TMouseButton;Shift: TShiftState; X, Y: Integer);
procedure MouseMoveext(Shift: TShiftState;  X, Y: Integer);

type
  TFormuser = class(TForm)
    MainMenu1: TMainMenu;
    User1: TMenuItem;
    AutoButton: TButton;
    Button6: TButton;
    ShowUserForm1: TMenuItem;
    procedure AutoButtonClick(Sender: TObject);
    procedure Button6Click(Sender: TObject);
    procedure ShowUserForm1Click(Sender: TObject);
  private
    { Private-Deklarationen }
  public
    { Public-Deklarationen }
  end;

var
  Formuser: TFormuser;


implementation

{$R *.DFM}

uses ustmafm, ufileio, uscandsp, uparam, upc32, ulatman, uvertman, Ugrid, usicl32;

// Assign values from the user stringgrid to the parameter variables
procedure paramassignfromcells_user;
var code:integer;
begin
with formparam do begin
    with userparamgrid do begin
      val(cells[1, 1], imageautolevel, code);
   end;
end;
end;

// Assign the values of the parameter variables to the cells of the stringgrid
```

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```
procedure paramassigntocells_user;
var i:integer;
begin
with formparam do begin
    with userparamgrid do begin
      for i := 0 to rowcount do cells[1, i] := ' ';
      cells[1, 1] := inttostr(imageautolevel);
    end;
end;
end;

// Define the name of the parameters in the stringgrid
procedure paraminit_user;
var i:integer;
begin
with formparam do begin
  with userparamgrid do
  begin
    for i := 0 to rowcount do cells[0, i] := ' ';
    cells[0, 1] := 'Autolevel';
    end;
end;
end;

// Check on mousemovement in the image
procedure MouseMoveext(Shift: TShiftState;  X, Y: Integer);
begin
end;

// Check on pressing of mousebuttons in the image
procedure MouseDownext(Button: TMouseButton;Shift: TShiftState; X, Y: Integer);
begin
end;

////////////////////////////////////////////////////////////////////////////////
///User Functions
////////////////////////////////////////////////////////////////////////////////


//Example: Several functions can be combined and executed by pressing one button
procedure TFormuser.AutoButtonClick(Sender: TObject);
begin
  if scanstatus <> scanstatreset then exit;
  stmafm.resizex2click(stmafm);
  paramassignfromcells;
  imagegrayfactor := 0.23;
  imagezoom := 1;
  paramassigntocells;
  paramassignfromcells;
  stmafm.lowpass1click(stmafm);
  stmafm.dispplan1click(stmafm);
  formgrid.BugridimagcenterClick(stmafm);
  stmafm.dispplan1click(stmafm);
  stmafm.quicksaveclick(stmafm);
end;

// Example: To substract dataimage2 (the image on the right) from dataimage1 (the image
// on the left).
procedure TFormuser.Button6Click(Sender: TObject);
var i:integer;
begin
for i:=0 to stmafm.dataimage2.nx*stmafm.dataimage2.ny do
stmafm.dataimage1.work2buffer[i]:=stmafm.dataimage1.scan2buffer[i]-
stmafm.dataimage2.scan2buffer[i];
stmafm.dataimage1.swapscanfiles;
stmafm.dataimage1.display2dauto(imageautolevel);

end;

procedure TFormuser.ShowUserForm1Click(Sender: TObject);
begin
formuser.show;
```

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```
end;


initialization

end.
```

7.3 The dataimage component

The following information shows the procedures and variables which can be accessed externally from the dataimage component.

7.3.1 Type - definitions

```
type
  tscan2buffer = array[-1..1] of single;
  tscan2bufferi = array[-1..1] of smallint;
  realarray = array[0..1024] of single;
  tpalcol = record red, green, blue, flag: integer; end;
  tpalcolarray = array[0..255] of tpalcol;
  thistrec= record  h,number,intnum:integer;  end;
  tproc=procedure;

type
  TDataimage = class(TPaintBox)
```

7.3.2 Procedures

```
    procedure display2dauto(aimageautolevel: integer);
//  Display the image using normal line by line linear backgroundsubtraction. use
imageautolevel=1

    procedure display2dautoquad;
//  Display the image using normal line by line linear + quadratic backgroundsubtraction.

    procedure display2dautoplan;
//  Display the image using auto plane backgroundsubtraction.

    procedure display2dautoplanquad;

    procedure display2dplan(aimageplanx, aimageplany, aimageplanoff, aimageplany2,
      aimageplanoff2:single; aimageplanoff2pos, aimageavergnr, aimageautolevel,
aimagebackoffset: integer);
//  Display the image using normal plan subtraction, the parameters define the plan and
are usually taken
//  form the global parameters imageplanx, ..... (without the a)

    procedure display2dstat(imagesdsdfac, imagesdorgfac, imagesdoffset, imagesdbeta:
integer);
//  Display an image using statistical differencing

    procedure displayicon(iconsize: integer);
//  Display the actual image in icon size format using line by line subtraction

    procedure displayiconplan(iconsize:integer);
//  Display the actual image in icon size format using plan subtraction
    procedure filter16bit(filtertype: integer);
//  Filter the image. Filtertype determines the kind of filtering

    procedure fft2d;
//  Perform a 2dFFT on the image

    procedure fft2dinv;
```

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```
//  Perform an inverse 2dFFT on the image

    procedure filter50Hz(fft50Hzx, dfft50hz: integer);
//  Filter the image with a 50Hz line filter

    procedure swapscanfiles;
//  Swap scan2buffer against workbuffer
    procedure displayinit;
//  init the display

    procedure showscanline(ichannel, nypos, dispmodex : integer);
//  display one line of the image at linepos ny

    procedure makestmpalette(palnr: integer);
//  make a new STM palette

    procedure initnewscan(anx, any, achannels, adx, ady, againx, againy, againz,arotation:
integer;
                          arotoffx,arotoffy:single;adacrange,aadcrange:integer);
//  Initialize the dataimage component for recording a new scan

    procedure resizeimage(factor: single; interpolate:boolean);
//  Resize the image

    procedure getplansub(aimageavergnr: integer);
//  get the parameters for the plansubtraction

    procedure getlinescan(aimagelinebacksub: integer);
//  get the two points for the linescan

    procedure getzoomuprect;
//  get the rectangle which is zoomed up

    procedure getgrid;
//  get the gridparameters

    procedure getfft2dcutout;
//  get the rectangle of the fft2dcutout

    procedure gethistogram;
//  get the rectangle of the histogram

    procedure getrect;
//  get a rectangle


    procedure imagegrid(xoffset, yoffset, angle1, angle2, xdist, ydist: single;
gridtype:integer);
//  daw a grid

    procedure imagetransformmatrix(mxa, mxb, mxc, mxd, xorg, yorg, xneworg, yneworg:
single);
//  transfrom th image using the 2d matrix and the new origin points

    procedure imagerotatezero;
//  rotate the image

    procedure imagecenter;
//  center the image

    procedure imagetransform(newlratio, newangle: single);
//  transform the image

    procedure filesave(filename: ansistring);
//  save the data in the dataimage component in a dat file

    procedure filesavebmp(filename: ansistring);
//  save the dataimage.bitmap in a BMP file

    procedure fileloadbmp(filename: ansistring);
//  Load a BMP File in the dataimage.bitmap
```

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```
    procedure fileloadraw(filename: ansistring);
//  Load a Ascii File in the dataimage.bitmap

    function fileload(filename: ansistring):boolean;
//  Load a DAT file

    procedure scan2bufferx10;
//  Multiply scan2buffer times 10

    procedure scan2bufferdiv10;
//  Divide scan2buffer by 10

    procedure assignx(d:tdataimage);
//  Assign one dataimage to another

    procedure saveemf(filename:ansistring;gridon:boolean;titelstr:ansistring);
//  save the bitmap and other graphic information in an EMF File

    procedure histogramcalc;
//  calculate the histogram

    procedure linescan;
//  calculate a linecan

    procedure plan2dparaminp;
//  calculate the plansub parameters from in the input points

    procedure ascdatout(ascfilename:ansistring);
//  save the image data in Ascii format

    procedure calcislandsize(x, y: integer);
//  calculate size of an island

    procedure savefiletiff16bit(savefilename: ansistring);
//  save the image data in 16bit Tiff format

    procedure zoomuprect;
```

7.3.3 Public variables

phandle: integer;
pactive: boolean;
bitmap: tbitmap;
bitmappal: tbitmap;
scan2buffer: ^tscan2buffer;
work2buffer: ^tscan2buffer;
strbuffer: ansistring;
dispstop: boolean;
xpiezoconst, ypiezoconst, zpiezoconst: single;
nx, ny: integer;
dx, dy: integer;
gainx, gainy, gainz: integer;
channels: integer;
imagezoom: integer;
imagegrayfactor: single;
imagebackoffset:integer;
imageframepointer: integer;
imagedispmode: integer;
imageautodispreset: boolean;
linelength: single;
linebuffer: array[0..1024] of single;
mousex, mousey: array[1..3] of integer;
loadfilename: ansistring;

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```
    palcol: array[0..5] of tpalcol;
    pal: tpalcolarray;
    gridshow: boolean;
    centerx,centery:integer;
    scan2buffersize: integer;
    work2buffersize: integer;
    orgimageplanx:single;
    orgimageplany:single;
    orgimageplanoff:single;
    showhistarray: array[0..800]of thistrec;
    rotoffx,rotoffy:single;
    rotation:integer;
    islandsizemode:integer;
    islandlevel:single;
    memotext,statustext1:ansistring;
    linexcal:single;
    areacalccount:integer;
    callproc: tproc;
    selected:boolean;
  end;
```

8 Additional information

This software uses XYgraph 6.0 from Graham Grieve (copyright © Kestral Computing)'

9 Contacts

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10 Appendix

Enter topic text here.

10.1 Set_Plan_Dx_Dy

Usually the sample surface is inclined against the scanning plane. While this is not a big problem for constant current mode, this has to be corrected for in the case of constant height images, where the feedback mechanism is disabled. This is corrected by tilting the scanning plane. An additional Z Offset is calculated. Z= Plandx*x + Plandy*y. To set the correct PlanDx PlanDy values first take a normal image in constant height mode. Then do a normal image plane subtraction. Use this option to set the parameters for a plane offset subtraction. The calculated values are OffsetX, OffsetY. (See the 'old' parameter form). Be sure that you done a correct background subtraction. Selecting Set_Plan_Dx_Dy will transfer these values into the PlanDx, PLanDy parameters which control the realtime background offset.

10.2 File Formats

There are 4 primary types of files:
These are *.dat, the image file, *.lat, the lateral manipulation file, *.vert, the vertical manipulation file and *.tspec, the time spectroscopy file.
All files start with a header in ASCII format (can be displayed with a text editor) containing a complete set of information about all the parameters in the program. Each line starts with the name of the parameter, which is identical to the name appearing in the parameter window in the program, followed by the value of the parameter. For example the lines Num.X=256 and Num.Y=256 mean that the image has a size of 256*256 pixels. Any name can be used for a file, but the standard filename starts with the letter describing the machine name, for example A. This letter is followed by the date and the time (separated by a dot) when the scan was started. Finally the file extension displays which kind of data (.dat, .lat, .vert, .tspec) the file contains.

10.2.1 Dat Files

The file starts with a header file in Ascii Format with a complete set of information about the status of the program with all the parameter values. The size is 128 records with 128 byte, or a total of 128 x 128 byte. The last 4 bytes are 'DATA'. The image data starts directly after 'DATA' and 4 additional still unused bytes. If the data is saved in uncompressed form then the data is written row by row in 4 byte floating point format. The length is (4Byte x nx x ny) x Channels. If the file contains several channels, then the channel images are stored one after the other.

The structure in a saved file is: after the parameter section , the string 'DATA' is followed directly the first two bytes containing the value in [0]. Then the image is coming with nx integer values for one line times ny, the number of lines in the image. If the image has several channels, they are following in the same manner.

Structure of an image data file: (*.dat)
Parameter List in ASCII Format

DATA [ ] [ ]		(after the keyword 'DATA' follow 4 empty bytes)
(Channel 1)	[1,0], [2,0].....[nx,0]	([position in the line, line number] of the 32bit data)
	[1,1], [2,1].....[nx,1]	
	....	

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[1,ny-1], [2,ny-1], ...[nx, ny-1]
(Channel 2) [1,0] .....

(Channel N) [1,0] .....[nx,ny-1]

10.2.2 Lat Files

The file starts again with all the information of the parameter set and the version name of the file. Its length is 128 x 128bytes ending with the text DATA. The file is all in ASCII format. On the next line appear 2 numbers. The first is the number of points taken during the lateral manipulation. The second is the manipulation mode number. Then the manipulation data is following in the form of (number of points) rows containing the z-height, the current, the x and the y position of the point in the image. These are all raw data in DAC values (floating point).

Version 3.0 and later

Channellist is encoded

First line after Keyword 'Data' contains 3 values:

Number of Points, Lat. man. Mode, Channellistvalue

Encoding of Channellist: Sum of

Current	1
dI/dV	2
d2I/dV2	4
ADC0	8
ADC1	16
ADC2	32
ADC3	64
	128
	256
	512
di_q	1024
di2_q	2048
Topography (DAC0)	4096

The channel data appears in this order in the file

10.2.3 Vert Files

The file starts again with all the information of the parameter set. Its length is 128 x 128bytes ending with the text DATA. The file is in all ASCII format. On the next line appear 3 numbers. The first is the number points taken during vertical manipulation. The second and third are the x and y position of the spectrum in . Then the manipulation data is following in the form of (number of points) rows.

For Versions earlier than 3.0

The columns:
1: Count integer
2: I : float, in DAC units
3: dI/dV: float,in DAC units
4: Voltage: float, in mV
5: Z-Position: float in mV (includes gainz)
6: di2, float, in DAC units
7: di3 float, in DAC units

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8: di4 float, in DAC units
9: ADC0 float, in DAC units
10:ADC1 float, in DAC units
11:ADC2 float, in DAC units
12:ADC3 float, in DAC units
13: DAC0 float, in DAC untis

Version 3.0 and later

Channellist is encoded

First line after Keyword 'Data' contains 3 values:

Number of Points, Number of Channels, Channellistvalue

Encoding of Channellist: Sum of

Current	1
dI/dV	2
d2I/dV2	4
ADC0	8
ADC1	16
ADC2	32
ADC3	64
	128
	256
	512
di_q	1024
di2_q	2048
Topography (DAC0)	4096

The channel data appears in this order in the file

10.2.4 TSPEC Files

The file starts again with all the information of the parameter set. Its length is 128 x 128bytes ending with the text DATA. The file is in all ASCII format.
The recorded time signal follows directly:(timespecfftpoints)

For Versions earlier than 3.0

The columns:
1: Count integer
2: Count/timespecfrequency: float
3: DAC0: Z : float, in mV
4: ADC0: I: float in mV
5: ADC1: dI/dV: float,in mV
6: ADC2: float, in mV
7: ADC3: float in mV
8: Count2: integer
9: FFT of Z: float
10: FFT of i: float
11 FFT of di: float
12: FFT of ADC2: float
13: FFT of ADC3: float

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Version 3.0 and later

Channellist is encoded

First line after Keyword 'Data' contains 3 values:

Number of Points, Number of Channels, Channellistvalue

Encoding of Channellist: Sum of

Topography (DAC0)	1
Current (ADC0)	2
ADC1	4
ADC2	8
ADC3	16
dI/dV	32
d2I/dV2	64

The channel data appears in this order in the file

10.2.5 Internal parameter structure

The two dimensional image data is stored in a 1 dimensional field : scan2buffer[0..] of type smallint (16bit integer). This field is part of the dataimage component. The data starts at [1]. The data point[0] is empty.
The data in scan2buffer is saved starting with 0.

10.3 Old_Parameter

Enter topic text here.

10.3.1 Scan-Parameter

Delta X: Distance between two image points in DAC-Units [1 ..]
Delta Y: Distance between two image points in DAC-Units [0 ..]

NumX: Number points of the image in the x - direction [1 ..]
NumY: Number points of the image in the y - direction [1 ..]

Delay X+: Delaytime for scanning in forward direction between following DAC points
Delay X-: Delaytime for scanning in backward direction
Delay Y: Delaytime for scanning in y direction (forward or backward)
(1 unit corresponds to 20 µsec), [2 ..]

DX/D Delta X: Number of points between to DX values [>1]

PlanDx, PlanDy: Slopes for background subtraction
OffsetX, OffsetY: Offset of the image origin in DAC units [-524288 .. +524287]

GainX, GainY, GainZ: Gain of the HV-amplifier (manually switched by the operator but automatically read in by the program)

Rotation: Rotation of the image in degrees (clockwise for positive values) [-180 ... 180]

BiasVoltage: Voltage applied to the sample [mV] [-10000 .. 10000]

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GainPreamp: Base 10 logarithm of the gain of the current preamplifier - [V/A] (fully controlled by the program)
[Balzers EP112: 6, 8, 10; Femto DLPCA200 low noise: 6 ... 9; Femto DLPCA200 high speed: 6 ... 11]

Chan(1,2,4): Selection of the number of channels acquired by the program:
1: Topography: the height (z) of the tip
2: Topography in channel 1 and current in channel 2
4: Topography in channel 1, current in channel 2, ADC1 in channel 3, ADC2 in channel 4
Version 3.0 and later any value >0 allowed

Mvolt1 – Mvolt 6 : Series of voltages [mV] for voltage dependant imaging [-10000 .. 10000]

RepeatRotinc: Increment value [degrees] for rotation in repeat mode [any integer value]
RepeatBVoltinc: Increment value [mV] for the bias voltage in repeat mode [any integer value]
Repeatinterval: Timeinterval [s] at which new scans are started in repeat mode [any integer value]
Repeatcounter: Number of images taken in repeat mode [0 ..]

The following parameters are controlled from the main menu in DAQ Mode. They can be changed only in the Data-Analysis Mode.

Scantype: [1:single volt, 2: multivolt]
Scanmode: [1: 1-directional, 2: 2-directional]
Scancoarse: [0: x,y - scanning is done with the center piezo, 1: x,y - scanning is done with the outer piezos]
CHMode: [0: constant current mode scanning, 1: constant height mode scanning]
Channels: Number of channels
Preamptype: Type of Preamp
RotCMode: Rotation Center Mode [0..1]
ScanYMode
ScanYDirec

CHModeZoff
CHModeGainPreamp
CHModeBias
Channelselectval: Encodes the channellist

10.3.2 Image Parameters

These parameters are used to display the image.

ImageFrame: The data file can contain several images, for example in the case of multiple channels, multiple voltages or 2 directional scanning. Imageframe displays the number of the actual image frame, which is used for processing. Imageframe=0 means all images are displayed.

Imagegrayfactor: The 16 bit original data values are divided by this factor before they are displayed in a scale of -127 to +128

Zoom: The displayed size of the image on the screen is increased by this zoom factor. [1...4]

OrgPlanX, OrgPlanY, OrgPlanOff: These parameters define the original image plane.

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DACtoxy[A]: Conversion factor from DAC values to size [Å] for x,y values (only displayed)
DACtoz[A]: Conversion factor from DAC values to size [Å] for z values (only displayed)

PlanOff, PlanX,PlanY: These values determine a plane which is subtracted from the image during the Display Plane (DP) operation, that means a plane subtraction. These parameters are usually set by the Plan2input procedure, but can be put also manually.
PlanY2: This is an optional quadratic term in the image subtraction and can be put only manually.
Planavrgnr: Determines the size of the averaging squares used in plane subtraction input. Should be an odd number. (2*Planavrgnr+1 is the size of the square)
Planoffset2, Plano2start: These 2 parameters define an additional offset, starting at Planoffset2. Used to define the plane used in plane subtraction

Imagebackoffset: This value is subtracted from the image when displayed in DispPlan mode. It is only temporarily subtracted from the image.

Frameimageoffset: When creating movies this value is added to the count variable appearing in the file name of the movie files.

DigZoomX,DigZoomY: Digital Zoom values (set after Image Data x10 or /10)

ImageAutoMode: Determines how <DA> displays the image

ImageAutoScale: Determines the Autoscale range (<LA>) Decrease the number to increase the contrast

10.3.3 Panel- Parameter (mainly for display only)

Z-Res[A]: Resolution of the image in +/- Ångström from medium gray to black/white.
LengthX[A]: Size of the image [Å] in (horizontal) x direction
LengthY[A]: Size of the image [Å] in (vertical) y direction

Biasvoltage[mV]: Sample voltage [mV]
Current[A]: Set value of the tunneling current in ampere

Sec/Line: Time for one scan line [s] (only one direction)
Sec/Image: Time for a complete image [s]

ActGainXYZ: Actual gain of the HV-Amplifier (not used in the Data-Analysis-Mode)

Channels: number of channels of the image

T-STM: Temperature [K] measured at the STM scanner base plate. Data converted from HP_Ch2.

HP_Ch1, HP_Ch2, HP_Ch3, HP_Ch4: Data of the HP DATA ACQ Channel 1 to 4 [mV]

Z-, X-, YPiezoConstant : Calibration parameter for Z, X, Y piezo sensitivity [Å/V]. Used for all evaluations in the program. **These values have to be given by the operator.** The calibration values depend on temperature.

T_ADC2[K]: Voltage on ADC2 converted in temperature [K] using the internal table for standard curve 10 Si-diodes
T_ADC3[K]: Voltage on ADC3 converted in temperature [K] using the internal table for standard curve 10 Si-diodes

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10.3.4 DSP_Parameter

These parameters control the digital feedback loop system on the digital signal processor (DSP).

FBLogIset: Current Set value [displayed in mV, current = Gainpreamp * FBISET/1000]
FBIntegral: Integral gain (1/FBIntegral) of the feedback loop: a small value corresponds to a large time constant [any positive value, typical: 0.1 ... 10]
FBProp: Proportional gain of the feedback loop [any positive value, typical: 0]
FBVoltRC: Time constant prop. to (1/FBVoltRC) of the feedback loop: a small value corresponds to a large time constant
FBVoltGain: Linear gain used in the voltage feedback loop in voltage feedback mode
FBBackLogIset: Current Set during for backward scanning. 0: same as in forward scanning
CurrentRC: Timeconstant for low pass filter of current signal in channel 2

FBLog: Determines whether linear (=0) or logarithmic (=1) mode of feedback is used
0/1: Lin/Log for current feedback
0/2: Lin/Log for voltage feedback
0/4: OFF/ON constant height mode (permanent !)
0/8: OFF/ON voltage feedback mode (permanent !)

FBChannel: Feedbackchannel

Imaxcurrent: When the actual current is higher than imaxcurrent, then the scanning is stopped [mV]
Imaxdelay: The delay is used as a time buffer to keep the 'time per line' constant if imaxcurrent is used. The unused part of imaxdelay is added at the end of the scanline. [clockcycles] (1 clockcycle=20µs)
ImaxZret: When current>imaxcurrent the tip is retracted additionally by ImaxZret [mV]

SpecAvrgnr: In time spectroscopy (TS) defines the number of scans
SpecFreq: Defines the rate at which data is taken in TS [points/s]
FFTPoints: Number of FFTPoints in TS, corresponds to the number of points in one spectrum

These parameters control the operation of the internal Lock-in:
LockinFreq: Lock-in frequency [Hz]
LockinAmpl: Modulation amplitude [mV]
LockinPhase: Detector phase [degrees]
LockinPhase2: Detector phase [degrees] 2nd Harmonic
LockinRC: xxx
LockinMode: xxx

SBC_Clk[MHz]: Clock Frequency of SBC6711 DSP Board (either 150MHz or 250MHz)
DSP_Clock: Clock Frequency of Feedback Loop (typical 50000 Hz)

These parameters are read from an external SRS Lockin (has to be enabled in DSPMenu):
SRS_Frequency:
SRS_ModVoltage:
SRS_InpGain:
SRS_InpTime:

LockinRefAmpl: Amplitude of Reference Signal on DAC4 (not available in AFM Mode)
LockinRefPhase Phase of Reference Signal on DAC4 (not available in AFM Mode)
DAC5[V}: Output Voltage on DAC5 (not available in AFM Mode)

Userpreampgain: Here a user specific preamplifier gain table can be defined. 4 bits can be used in the format: **<Gain>:<bit0><bit1><bit2><bit5>/**

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HPIB_Address: Address String of Agilent DAU

10.3.5 Ramp - Parameter

Parameters used for the coarse motion - Ramping

XYinc, XYcount: Define the shape of the voltage pulse of the ramp for the xy motion
Rotinc, Rotincquad,Rotcount: Define the shape in rotation direction

XYBurst, RotBurst: Define the number of pulses of a burst

AproBurst: Number of steps between two checks for tunneling current
AproPeriod: Time for the check for tunneling current [ms]

AproRetryNr: Number of retries before approach really stops

X,Y,Z Puls Count: Counts the number of ramp pulses

10.3.6 Info Panel

The status of the program is fully controlled by the parameters displayed in the parameter panel. A complete set of parameters is loaded automatically with a new image, or can be loaded separately by loading a specific parameter set shown in the info panel. A particular set of parameters can also be stored by selecting first a special entry and then using the save button. The name displayed in the info box is the title of parameter set.

Attention: Any file loaded into the program in DAQ will load its full parameter set into the program. E.g. bias, current and feedback parameters. Therefore it's recommended not to analyse files in DAQ.

10.3.7 Manipulation (and Spectroscopy) Parameters

Latmanmode: Number of the used manipulation procedure
LatmResist: Tunneling resistance [Ohm] during the actual manipulation
LatmanVolt: Bias voltage [mV] used during the actual manipulation procedure
Latmanlgi: Set point current [mV] during the manipulation (value read at ADC0)
Latmangain: Base 10 logarithm of the gain of the current preamplifier [V/A] during the actual manipulation
Latmanddx: DDX value used during the manipulation [DAC units]
Latmandelay: Delay value [20µs units] for moving during the manipulation
Latm0Delay: Delay value [20µs units] in manipulation mode 0
Latmanccdz: Offset value [mV] in constant height mode manipulation
Latmanextension: Extension value (a factor) for manipulation modes 4-6

TipForm_Volt: Bias voltage [mV] during tip forming
TipForm_Z: Max value of the z movement [mV] during the tip forming process
Tip_Delay: Delay value [20µs units] that determines the speed of the tip forming process
Tip_Latddx: DDX value for the lateral movement to the tip forming position [DAC units]
Tip_LatDelay: Delay value [20µs units] for the lateral movement to the tip forming position
Tip_Gain: Preampgain during Tip forming

Vertmangain: Base 10 logarithm of the gain of the current preamplifier [V/A] during the vertical manipulation

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Vertmandelay: Delay value [20µs units] that determines the speed of the vertical manipulation
Vpoint0.t, ... Vpoint7.t: Time points for the voltage values [20µs units]
Vpoint0.V .... Vpoint7.V: Voltages at specific time points [mV]
Zpoint0.t... Zpoint7.t: Time points for the z values [20µs units]
Zpoint0.z... Zpoint7.z: Z values at the specific time points [mV] (includes the gain of the High Voltage amplifier)
Zoffset: Constant z offset during the vertical manipulation procedure [mV]
Zdrift: z drift correction during vertical manipulation
VertSpecBack: Defines whether the spectrum is taken forth or forth and back (0: forward only, 1:forward and backwards, n: n-times forward and backwards)
VertSpecAvrg: Number of spectra taken for averaging
VertRepeatCount: Defines the number of spectra taken in the defined manner (all are stored in separate files)
VertLineCount: Defines the number of spectra taken along a line (all are stored in separate files)

SpecXGrid,SpecYGrid: Grid spacing in X,Y for GridSpectra
SpecXYGridDelay: Delay before and after each SpecGridSpectrum

VerttreshImax,Verttreshimin
VertFBMode
VertFBLogiset
Vertchannelselect
VertLatddx
VertLatdelay

10.4 Tips

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10.4.1 Approach

Here you find a few tips in case you have with problems the tip approach.

10.4.1.1 How to approach the tip to the sample

1. Use a telescope or a CCD-camera to have a good look at the tip sample distance. We recommend (and re-sell) the LINOS Photonics telescope with 16x magnification eye-piece and a working distance of 300mm. A CCD-camera can also be used, but it usually needs more light to give a good contrast. This heats up the STM when working at low temperatures.
2. Click on Ramp to use the coarse approach. Set Rotation = 0 (in the Scan parameter table), ResetXYOffset in the software (in the menu DSP) and on the front panel of the HV-amplifier for the X and Y channel. The Z-channel should have around +100V offset to give more room for the retraction of the tip - in case you crash it. Select Gain 1 or 3 for X and Y when working at 300K or Gain 3 or 10, when working at lower temperatures. The Z-channel should have Gain 3 or 10 respectively. **Gain 30 should not be used** for the approach as we noticed some degradation (depolarisation) of the piezos over time. In some cases the power stage of the HV-amplifier blew due to the high load over a long time when approaching with Gain 30.
3. Set the gain of the preamplifier to 109V/A (LowNoise) and the current to 1 ... 3nA. The bias voltage should be 0.1 ... 1.0V. The feedback values should be: Integrator = 5 [1 ... 10], P-Gain = 0 FBRC = 0.000100 for the old feedback loop.
4. Select XYBurst and RotBurst = 100 … 1000 [steps] - This is the number of steps to be done when you press a button. Check the boxes for BurstXY and BurstROT.
5. Use the arrow keys (left, right, up, down) of the keyboard to position the tip in X and Y direction above the sample. Use PageUp / PageDown to retract / approach the tip from / to the sample. You may also use the mouse. When you use the keyboard, you'll hear a beep after each

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step (or multi-step when Burst* is checked). When you hold down a key, than the tip will continue its motion until the key is released (and the multi-steps of a burst are finished). When you press a key repeatedly, all steps will be stored and done successively. In this case it's recommended to check the CrashProtection too. Otherwise the tip might crash into the sample, when you've pressed PageDown too often.

6. When the tip is close enough to the sample, you can start the automatic approach program. Select AproBurst = 5 [steps] and AproPeriod = 300 [ms] (These are the default values, you might find different ones are more suitable for your STM). The Period is the time for the feedback controller to check for the tunneling current. During this time the feedback goes from +10V (fully retracted tip) to -10V (fully expanded tip) and back to +10V (the backwards speed is 2x the forward speed). Than the DSP waits 50ms for the current to settle, makes the number of steps forwards that you've defined in AproBurst and does the next check. The feedback controller is switched on all the time and tries to get the defined tunneling current. When the current is reached, the approach is stopped and you'll hear a beep. If your tunneling current is noisy (spikes), you might want to use Retry Count [number] and the DSP tests more often for the appropriate tunneling current. After the approach the DSP automatically retracts the tip by switching the set point current to zero.
The according values for the old approach control are: AprologIset = 2 (defines the noise level of the current [mV]); AproLimit = 10000 (defines the stop of the approach [arbitrary value], the actual value is displayed during the approach) ; AproDelay = 150 (time for the feedback controller to check for a current [ms], analogue to the new AproPeriod), AproRC = 0.00020 (defines the RC - constant for the feedback loop during the approach).
7. Switch back the set point current to the desired value and check for the tunneling current with the oscilloscope. If it is unstable, you might want to make some steps in X or Y to change to a different area of the sample. Retract the tip by using a lower Z-offset until you are at least 50V lower than the tunneling contact. Now you're safe to make some single steps in X or Y.
8. Set the gains for X, Y, Z to the desired values for the tunneling. Switch off the Ramp controller and go back to the tunneling position by using the Z-offset. Try to adjust the feedback loop (Z = DAC0) to a value near zero. So you have the full range (+/- 10V) for the scanning. You might have to adjust the Z-offset from time to time due to drift or piezo creep. Both are temperature dependent.
9. Start the scan.

10.4.1.2 How do I get good (fast and safe) values for *inc and *count in the Ramp menu?

The easiest way is to use a frequency generator. Set the output to +/- 5 ... 10V with a saw-tooth voltage and connect it to Xin of the HV-amplifier. Select Gain 3 for 300K or Gain 10 for lower temperatures. Now you can sweep the frequency (usually between 100Hz and 2kHz) to find the best possible value. Changing the polarity should move the tip (ramp ring) in the opposite direction. You can still use the STM-program to switch between XY and ROT movement. The tip should run smoothly in all directions. Usually it's also possible to move the ramp with a lower gain too (gain 1 for 300K and gain 3 for LT). But the steps will be very small. In all cases it might be good to use a CCD-camera to see the movement of the ramp ring.
Once you've figured out the best frequency and amplitude to move the ramp ring, you fit the values of *inc and *count accordingly. The new software menu also allows putting in the values for amplitude and duration directly.

10.4.1.3 The approach is very slow. How can I make it faster?

Determine the size of the steps that are done with your parameters:
Retract the tip and switch on the Ramp controller. Set it to Coarse and Rot.
Go into tunneling position and read the Z-value at the HV-amplifier using a digital voltmeter.
Retract the tip to the maximum (Z = -200V) and make 5 steps towards the sample using the ramp controller.
Go into tunneling position and read the Z-value at the HV-amplifier again.

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Now you can calculate the step size: dZ[V] x ZPiezoconst[Å/V] / 5.
You should repeat this procedure at different spots of the sample to get a better mean value. (If the steps are small enough you can also make 100 instead of 5 steps to get better mean values)
Now you can increase the number of steps that are done during one approach cycle (AproBurst):
StepsizeZ[Å] x AproBurst [integer number] x 3 (Security factor to prevent crashes) < ZPiezoconst[Å/V] x 20V x GainZ
Usually AproBurst can be safely set to 5.
Assuming that the tunneling current increases 1 order of magnitude per Å, it takes 3Å to go from 1pA (noise limit) to 1nA (set point current). So you may additionally decrease AproPeriod to the limit of the preamplifier (1.2kHz for 109V/A at LowNoise):
ZPiezoconst[Å/V] x 20V / (3Å x AproPeriod[ms]) < 1.2kHz
With these values the approach should take not more than 20min.

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