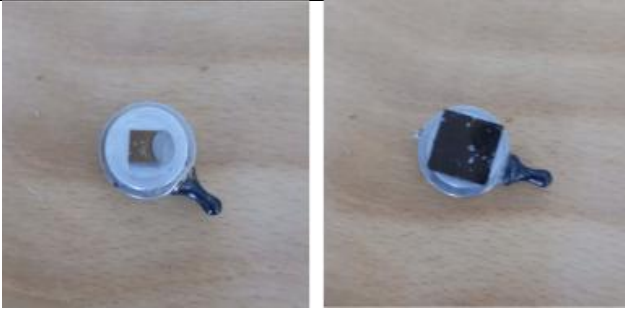
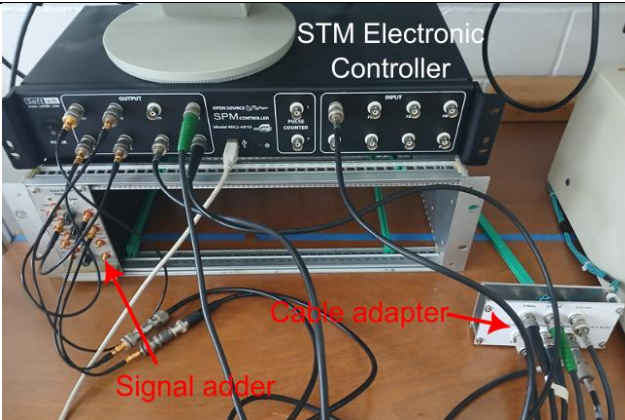


1.10 Scanning tunneling microscopy

Description of the Set-up:

Photo	Description
	STM head The STM head consists of a tip that is held magnetically at the top and a sample that rests on the bottom. Both the tip and the sample can be moved vertically. The sample motion is controlled using the rotatable knob. The tip motion is controlled either with the remote control (see below) or via the computer.
	Samples to investigate: Left: Gold grating sample Right: HOPG The orientation of the sample on the sample holder can be adjusted by loosening the small screw on the side.
	Electronic control of the STM: The STM electronic controller is responsible for applying the different voltages required for STM operation: the bias voltage between the tip and sample, the voltages applied to the piezo scanner (X–Y directions for scanning and Z direction for feedback control), and the voltage used for motor control when approaching the tip to the sample. The signal adder is used to combine the X–Y piezo voltages for scanning with the corresponding offset voltages. This allows the position of the scanning area to be adjusted within the software. A cable adapter is used to establish the connection between the electronic controller and the STM cabling.

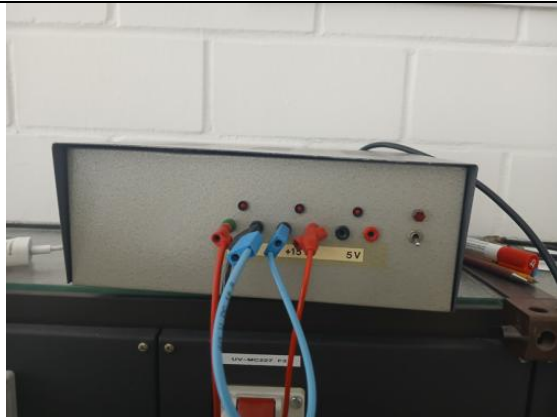


Top:

Oscilloscope used to monitor the tunneling current as well as the voltage associated with the piezo extension (i.e., the change in height).

Bottom:

Old STM electronic controller, now used only as a high-voltage controller. The piezo voltage supplied by the other controller is amplified (the amplification factor is adjusted using the middle knob) to control the measurement range and resolution of the STM.



Power supply for the signal adder:

This power supply must be switched on for the signal adder to operate.



Remote control for the tip approach:

When the LED is blue (remote deactivated), the approach is controlled by the software. This mode is used for the final automatic approach.

When the LED is off (remote activated), the approach is controlled using the remote control. This mode is used for the rough approach.

The remote control is activated (deactivated) by pressing buttons **1 and 4 simultaneously (2 and 3, respectively)**.



Tip holder and wire for tips:

How to use the Set-up:

Prepare the tips:

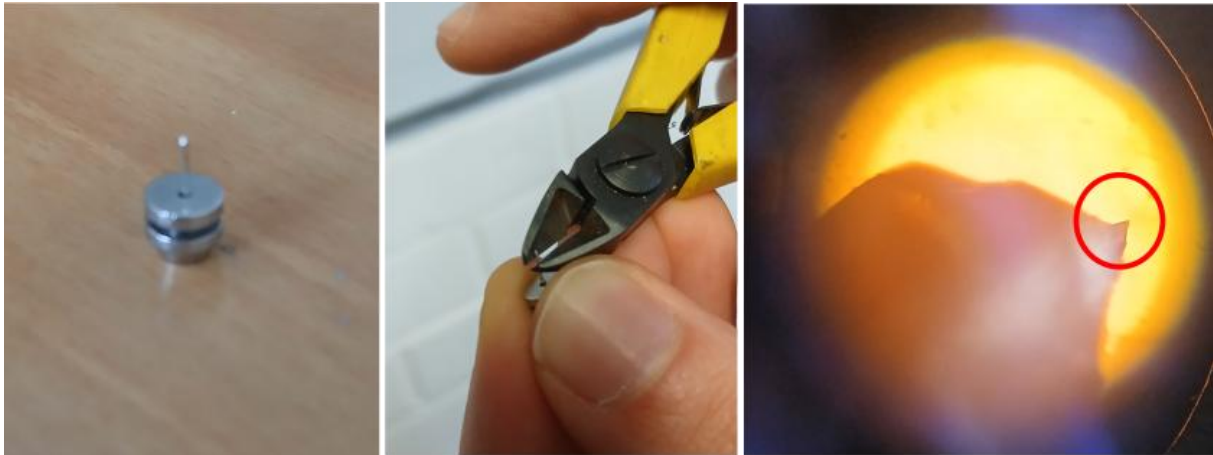


Figure 1. How to prepare the tips

The wire used to prepare the tip is made of platinum/iridium (Pt/Ir) and has a diameter of 0.4 mm. Note that this is an expensive material; approximately **1 cm of wire should be sufficient for each group**.

Start by cutting approximately 1 cm of wire. The wire is held in the tip holder by friction. You may need to slightly bend the wire using pliers to ensure that it is securely fixed inside the tip holder. The wire should protrude from the larger end of the tip holder (see left of Figure 1).

Next, prepare the apex of the tip. Hold a pair of cutting pliers against the wire **at an angle of approximately 45°** (see middle of Figure 1). Gently squeeze the pliers until you feel resistance from the wire, but do not cut completely through it. Then, pull the wire while maintaining a constant force on the pliers until the wire tears at the partially cut section. To prevent the wire from being pulled completely out of the tip holder, it may be necessary to hold the wire with a pair of flat pliers during this process rather than holding the tip holder itself.

This procedure should produce a sharp apex at the breaking point of the wire. However, the sharp section may be very small compared with the diameter of the wire and may not be visible to the naked eye (see the microscope view on the right of Figure 1). The final tip should have a **length of approximately 2–4 mm**. If the remaining wire is sufficiently long, several attempts at tip preparation can be made using the same piece of wire.

Computer start:

The Computer is used with the Ubuntu system

Password for starting session: pentia

Camera:

The Camera is controlled with the VLC Software:

- ⇒ Click on Media → Open Capture Device
- ⇒ Select for the Video Device Name: /dev/Video0
- ⇒ Click on play

A light can be switched on and off using the button on the side of the camera.

The camera is used to assist with the rough tip approach using the remote control. You should be able to see both the tip and its reflection on the sample, allowing you to estimate the distance between the tip and the sample.

There is no need to take unnecessary risks by approaching the tip too close to the surface. In the example shown in **Figure 2**, a small gap is still visible between the tip and its reflection. With such a starting position, the automatic approach should take less than one minute.

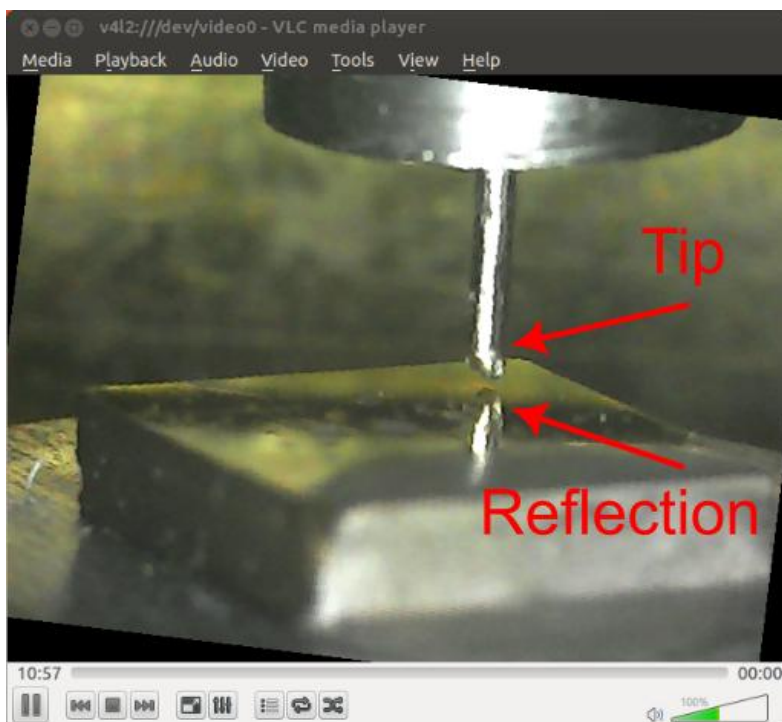


Figure 2. View from the camera of the STM tip and its reflection in the sample

Note: The camera light introduces significant electrical noise (50 Hz) into the current signal. To avoid this interference, switch off the camera light once the approach is finished. Even better, place the metal shielding enclosure (cubic-shaped, with a grounding cable) over the STM.

GXSM :

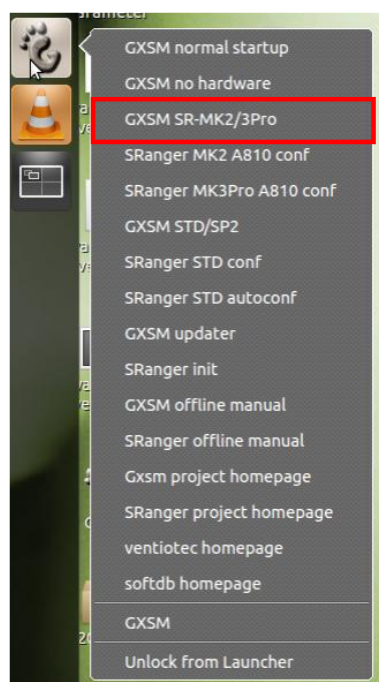
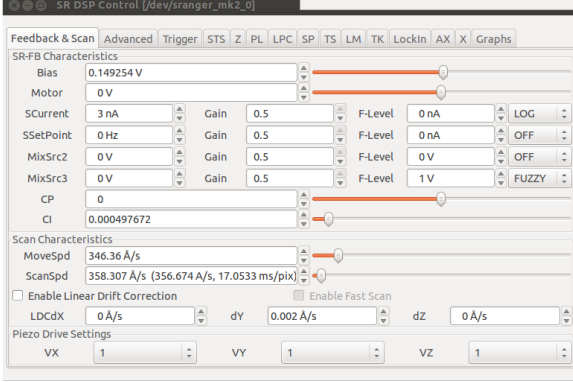
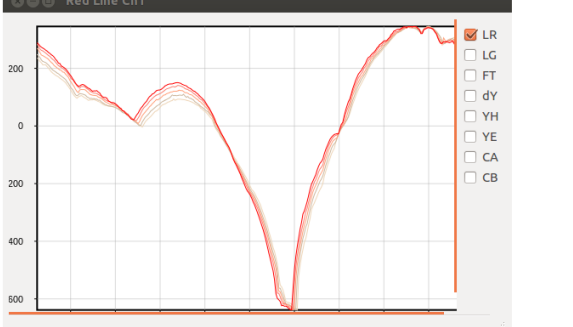
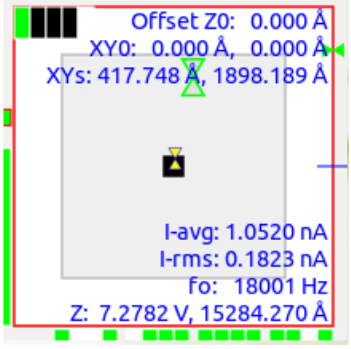


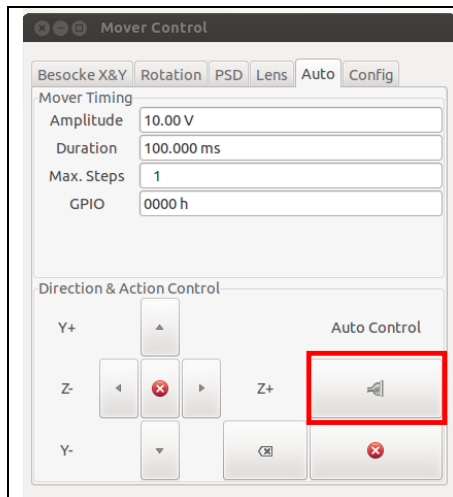
Figure 3. How to start GXSM

GXSM is the software used to perform the STM experiments. Several versions are installed on the computer. To open the correct version, right-click on the GXSM icon on the left side of the screen, then left-click on **GXSM-SR-MK2/3Pro** (see Figure 3).

Remark: When starting the GXSM program, the STM electronic controller must be switched on.

GXSM Window	Description/Comments
	Main GXSM Window: Used for: - Starting and stopping STM scans - Definition of the scanning area with: Size, number of pixels, Rotation angle, position versus the piezo scanner range (Offset XY) - Saving options. - Control of the contrast for the scanning window (VRangeZ and Voffset Z) Comments: For changing the saving folder click on the button close to the Autosave checkbox. Think to select the Autosaving option

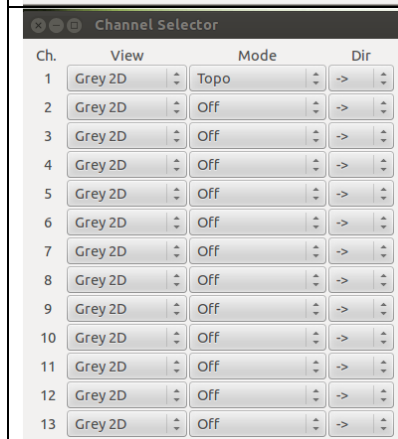
	Feedback Control window: Used for: - Control of the setpoint tunneling parameter (Tunneling current and voltage) - Control of the feedback parameter CP and CI (for proportional and integral) - Scanning and tip moving speed - Control of the consider gain for the Piezoscanner (VX, VY and VZ) Comments: Typical Integral (CI) value for approaching (0.003) and for scanning (0.0005) VX and VY value should be link with the magnification choosen on the Burleigh electronic (1 for magnification X2, and 0.04 for magnification X50)
	Scanning Window: Window in which the topographic image is shown.
	Profile Line window: Line profile of the last scanned lines are shown. Can be open by right clicking on the scanning window and selecting red profile.
	Piezo Range Window: Live tracker of the Piezoscanner: Indicates the scanning area (Selected with scan range and X-Y Offset) relative to the piezo range area. Indicate also actual position of the piezo in the z direction (small green arrow in the right). If the arrow is completely up (down), piezoscanner is completely retracted (extended). Give also the actual value of the tunneling current.



Motor control window:

Click on the button marked by the red rectangle to start the auto approach

Note: The remote control needs to show the blue LED to enable the auto approach!



Channel Selector:

You can add additional channel (As current channel, or topography backward) which can be shown like with the Scanning Window and which will be saved.

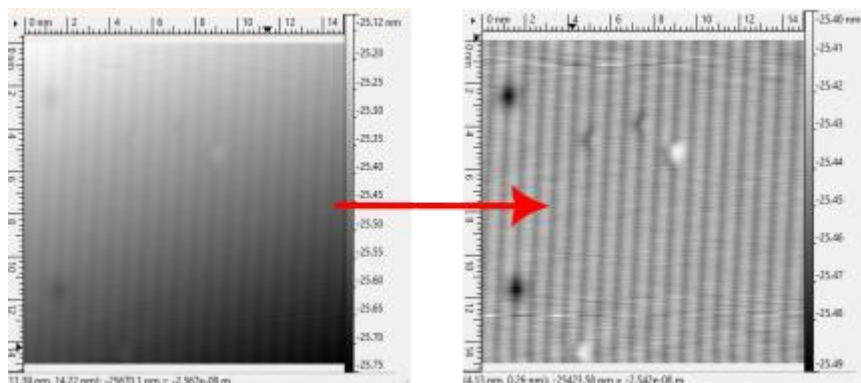
Basic analysis with Gwyddion:

The measurement data are provided in a binary type format specific to the measuring software. For data analysis, the free software **Gwyddion** is recommended and can be downloaded from <http://gwyddion.net/download.php#stablewindows>.

Below is information for realizing some basic data treatment with the software. For more advanced analysis multiple tutorials can be found online:

Note: the STM images showed below are here for the explanation but are related to the sample studied during the experiment.

Plane correction:



If the topography in the image presents a tilt, you can do a plane correction treatment (See figure above). Two possibilities for this are:

- Level data by mean plane subtraction (icon 

Filtering and correction of the image:

- Convolution Filter (Data Process => Integral Transform): Smooths the image by averaging over several pixels. This can help reduce random noise.
- Correct horizontal scar (icon

- 2D FFT Filtering (Data Process => Correct Data): Allows specific spatial frequencies in the signal to be filtered or extracted. This can be useful for revealing a weak periodic signal, such as atomic corrugation, in the image.

Extracting the topographic signal along a line (Line Profile)



Use the icon . Draw a line on the STM image of interest. A graph showing the variation in topography along the selected line will appear in a new window.

Click **Apply** to validate the selected line profile. An additional window will then appear, providing access to the line-profile data and the corresponding distances.

Zooming and cropping the image



Select the icon . Then select the area of interest in the image and click **Apply** in the window associated with the process.