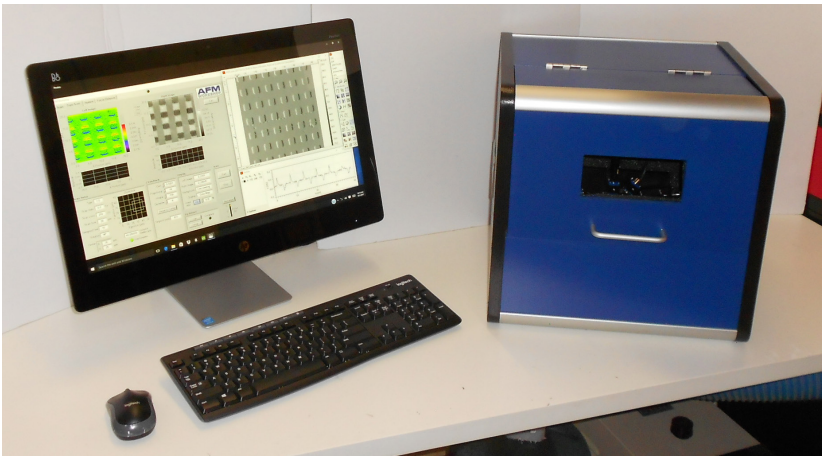
AFM WORKSHOP™

B-AFM MANUAL

Users Guide
V 1.0



Congratulations on your purchase of an AFM Workshop B-AFM.
We are excited to have the opportunity to add you to
our growing number of successful customers.

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1. Introduction to the B-AFM

This user manual is intended as a basic how-to guide for setting up your B-AFM and beginning routine scanning. For an in-depth description of AFM instrumentation, we recommend the book Atomic Force Microscopy by Peter Eaton and Paul West. This book provides a complete theoretical, as well as practical explanation for the design and application of AFMs.

The B-AFM is an all-inclusive tabletop atomic force microscope with everything needed for high-resolution imaging. It comes complete with a scanning stage, laser, probe holder, video optical microscope, electronics, computer and software. It is important to read the user manual and get acquainted with the hardware and software before attempting scans with the B-AFM.

1.1 Unboxing the B-AFM

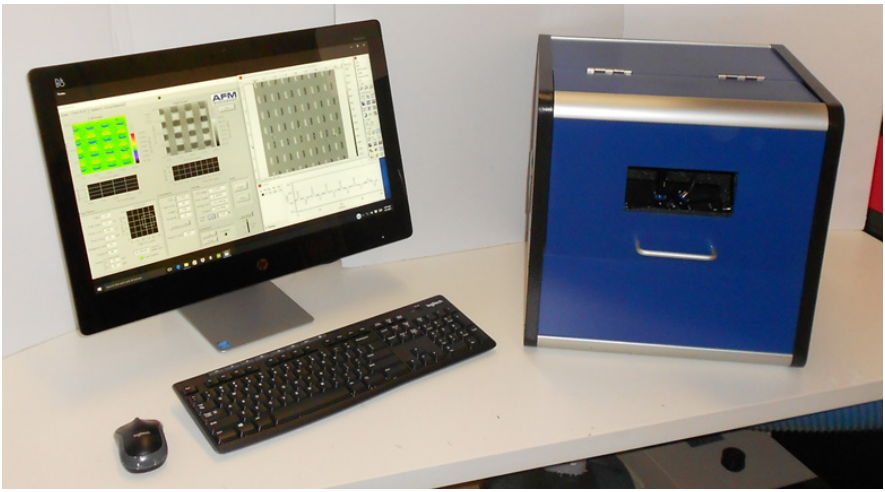

Fig. 1.1.1 - B-AFM System.

The B-AFM package from AFM Workshop includes:

1. B-AFM
    a. AFM Enclosure
    b. USB Cable
    c. Power Cable
    d. Probe Holder

2. Computer
    a. All-in-One PC
    b. Keyboard
    c. Mouse
    d. Power Cable

3. Accessories
    a. Tweezer
    b. Probes (Box of 10)
    c. Metal Sample Holders
    d. Magnetic Sample Platforms
    e. Copper Sample
    f. Standard Reference Sample
    g. Tools

1.2 Setting Up The B-AFM

1. Start by setting the B-AFM and computer on a flat surface.
2. Connect the computer to a power outlet using the computer power cable.
3. Connect the B-AFM to a power outlet using the B-AFM power cable (connected in the back of the B-AFM)
4. Connect the B-AFM to the computer using the B-AFM USB cable (connected in the back of the B-AFM)
5. Make sure all wires are connected.
6. Turn on the computer.
7. Turn on the B-AFM.
8. Open the 7-Step Software

2. B-AFM Hardware Components

It's important to get to know the components of the AFM, and make sure it is connected properly before attempting to scan any samples. The following section will describe the components in detail.

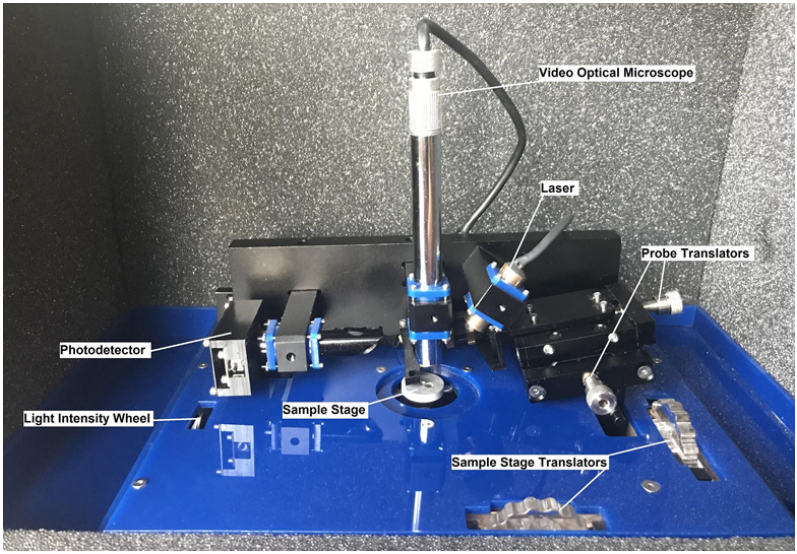

Fig. 2.0.1 - Components of the B-AFM stage.

The B-AFM enclosure is used for vibration isolation, and to house the electronics.

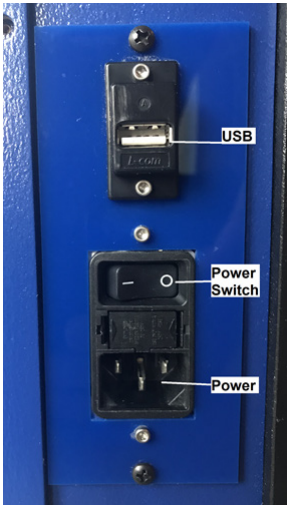

Fig. 2.1.1 - Back of the B-AFM

1. *Power Switch: To turn on the B-AFM, turn the power switch to "I".*
2. *USB Outlet: Connect USB cable here. Connect to PC.*
3. *Power Outlet: Connect power cable here. Connect to power outlet.*

2.2 Video Optical Microscope

The video optical microscope is used to locate areas of interest on a sample, as well as align the laser to the tip of the probe.

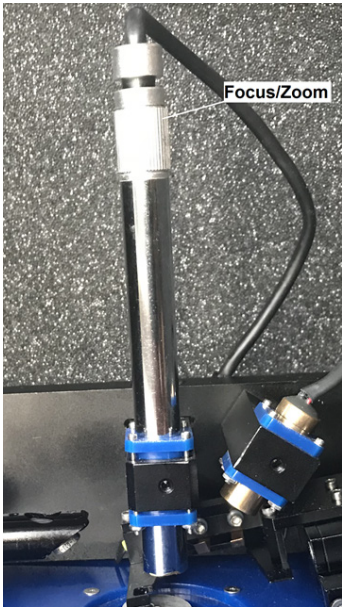

Fig. 2.2.1 - Video Optical Microscope

1. *Light Intensity: To turn on the camera light, rotate the camera light wheel on the left of the B-AFM platform (See Fig 2.0).*
2. *Focus Adjust: To focus, turn the knob at the top of the camera.*
3. *Zoom Adjust: This video optical microscope uses a coupled zoom-focus feature. To zoom in (or out), loosen the screws holding the camera, move the camera towards (or away from) the probe holder, and re-tighten the screws*
   a. *The position of the camera should already be optimized upon receiving the B-AFM.*

2.3 Sample Stage

The sample stage is mounted onto the Z-piezoelectric ceramic, and includes magnets to hold samples in place.

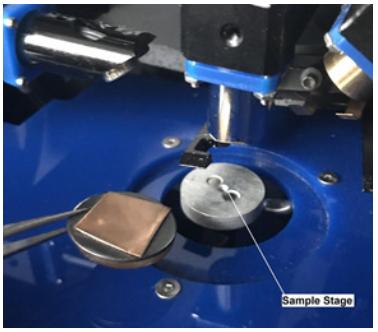

Fig. 2.3.1 - Sample Stage

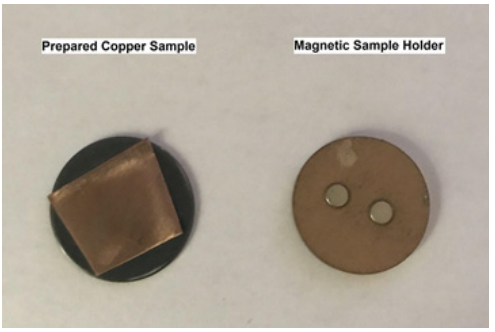

Fig. 2.3.2 - Prepared Sample

For details on how to prepare and load a sample, see section 4.2.

2.4 Sample Translators

The sample translators are used to move the sample in the XY plane to locate areas of interest for scanning.

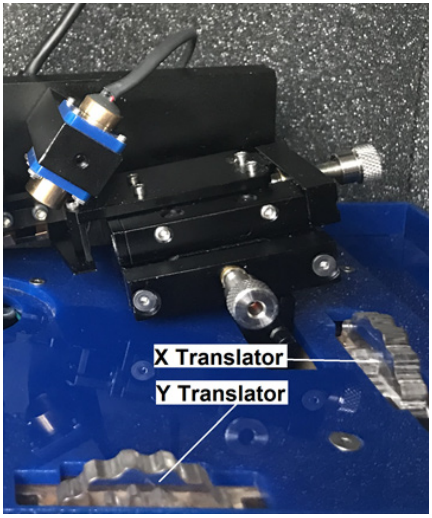

Fig. 2.4.1 - Sample Translators

1. *X Translator: To move in the X direction, use the translator on the right.*
2. *Y Translator: To move in the Y direction, use the translator in the front.*

2.5 Probe Holder

The probe holder is designed to hold a probe chip while scanning across the surface of a sample.

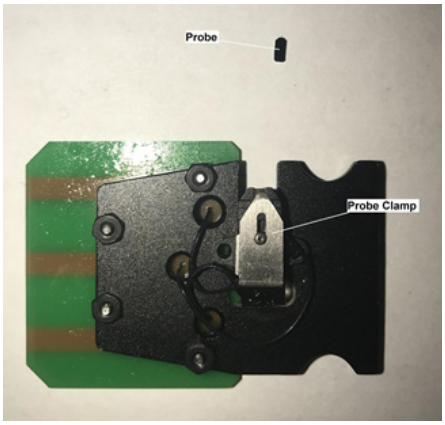

Fig. 2.5.1 - Probe Holder with Probe

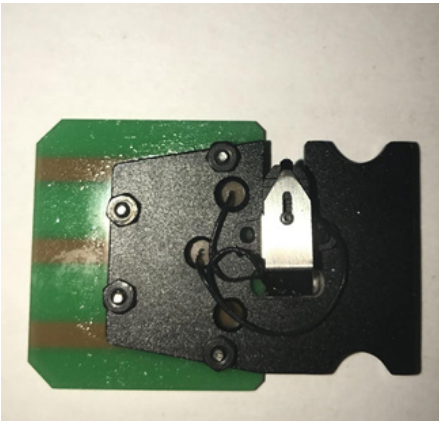

Fig. 2.5.2 - Loaded Probe

For details on how to load a probe into the probe holder, see section 4.3.

2.6 Laser

The laser is an integral part of any AFM.

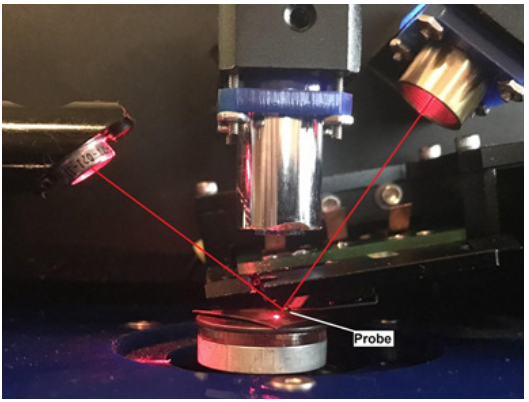

Fig. 2.6.1 - Laser

Light from the laser reflects off of the cantilever and into the photodetector, where the electrical signals are translated into surface topography measurements and images.

It is important for the laser spot to land directly on the cantilever, so that there is sufficient light collected by the photodetector.

For details on how to align the laser, see section 4.6.

2.7 Probe Translators

Since the B-AFM laser is stationary, the probe translators allow us to move the probe holder (the cantilever) into alignment with the laser.

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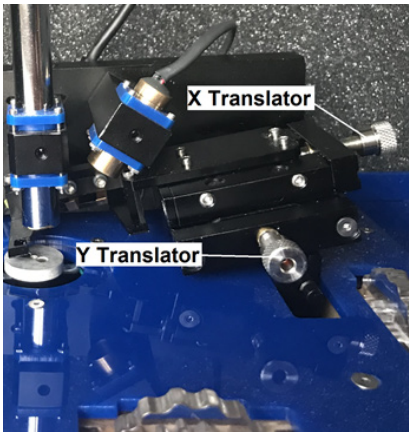


Fig. 2.7.1 - Probe Translators

1. *X Translator: To move in the X direction, use the translator on the right.*
2. *Y Translator: To move in the Y direction, use the translator in the front.*

2.8 Photodetector

The photodetector is the end of the path for the laser light, and it is important for as much laser light to reach the photodetector as possible.

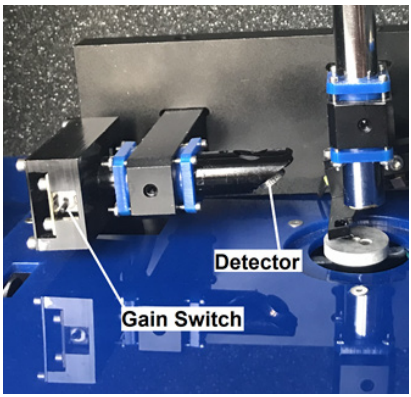


Fig 2.8.1 - Photodetector

The photodetector has 2 options:

1. *Low Gain (switch down) - this is the standard operating mode for the B-AFM. Used for non-coated cantilevers.*
2. *High Gain (switch up) - used for coated cantilevers.*

For details on how to maximize light reaching the photodetector, see section 4.7.

3. 7-Step Software Technical Guide

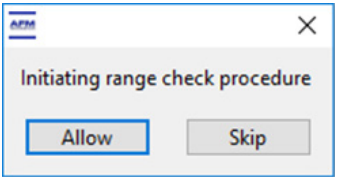
The 7-Step B-AFM software is designed for simplicity and routine scanning.

3.1 Launching the Software

Make sure the B-AFM is connected and turned on before launching the software.

1. Click the “B-AFM Application” on the Desktop of the computer to launch the software.

2. A prompt will ask you if you want to perform a Range Check.



   a. Click ALLOW.
   b. Range check function will extend and retract the piezoelectric ceramics to their full range. It is important to do this each time you turn on the B-AFM.

3. Once the software opens, you will be able to select steps to work within by using the 7-Step Menu on the left side of the program window.

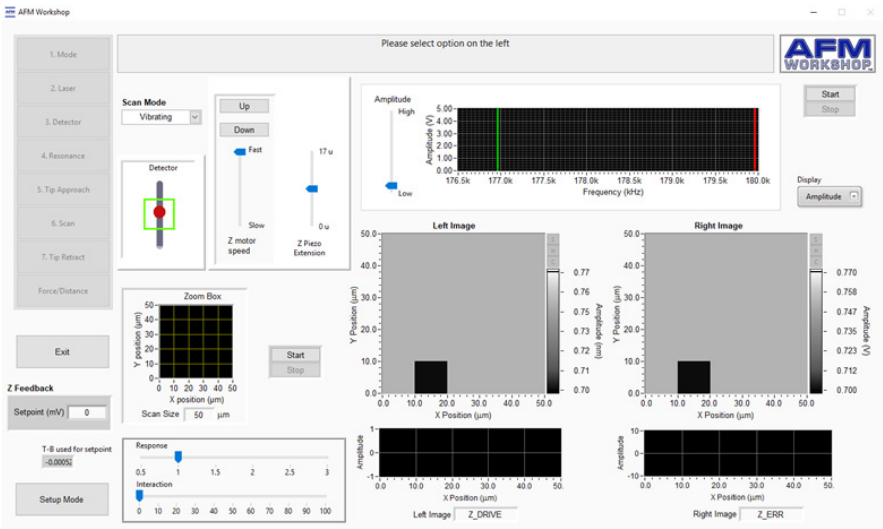


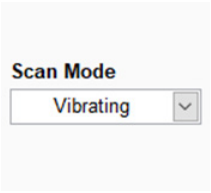
Fig 3.1.3 - Full software window.

3.2 Mode

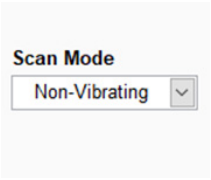
Click “Mode” to open the Mode section of the software.

Use the Scan Mode menu to select which mode to scan in. There are two scanning modes:

1. Vibrating (tapping)

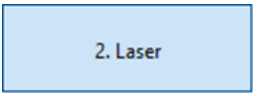


2. Non-Vibrating (contact)



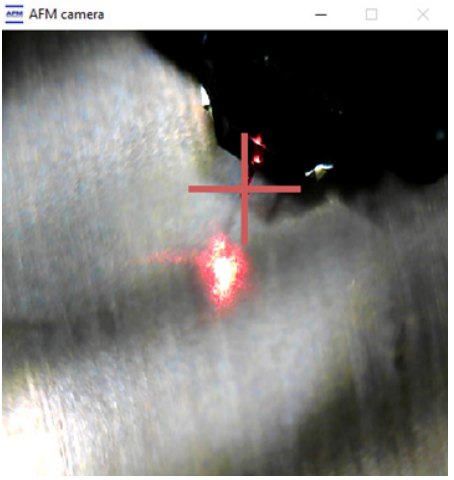
3.3 Laser

Click “Laser” to open the Laser section of the software.



To align the laser to the cantilever, use the camera application and the probe holder translators.

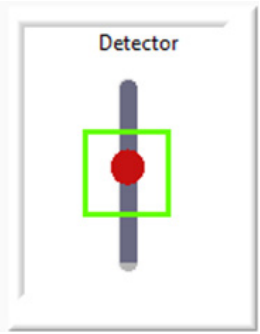
1. Use the probe holder translators to move the probe holder into place such that the laser spot hits the end of the cantilever.



2. Once the laser spot is correctly placed on the end of the cantilever, click the laser spot using the cursor on the computer.
   a. An “X” will appear to mark the spot for future scans

3.4 Detector

Click “Detector” to open the Detector section of the software.



1. *Laser Spot:* Represented by a red dot
2. *Detection Window:* Represented by a green square

To optimize the amount of light collected by the photodetector, move the photodetector back and forth (toward and away from the sample), while monitoring the Detection meter in the software.

The red spot should be inside of the green square. This translates to the laser spot being in the center of the photodetector, which will allow for better scans.

3.5 Resonance (Vibrating Mode Only)

Click “Resonance” to open the Resonance section of the software.

In vibrating mode, the probe vibrates at a specific frequency. Changes in the amplitude of this vibration are measured and converted to high-resolution topographic images.

It is important to select the correct resonant frequency of the probe to conduct successful scans. To do this we perform a frequency sweep:

1. Set the range of the frequency sweep by placing the green line at the lower limit and the red line at the higher limit.
2. Click “Start” in the Resonance section of the software.
   a. Wait until the sweep has run through all frequencies.
   b. When the sweep is complete, you should see a well-defined peak.
   c. The amplitude at the peak should be between 1-2 V. To adjust the amplitude, use the amplitude bar on the left of the Frequency Sweep window.

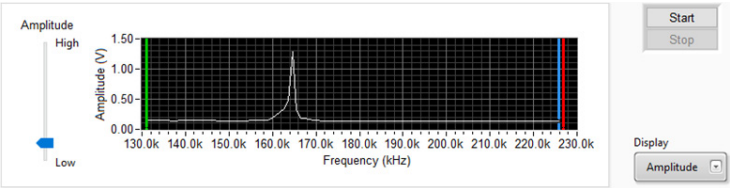


Fig 3.5.2 - Outlining steps 1 and 2.

3. Drag the low-range line (green) and the high-range line (red) towards the peak.
   a. Get as close to the base of the peak as possible to perform a more detailed sweep.
4. Drag the selected frequency line (blue) to the peak.

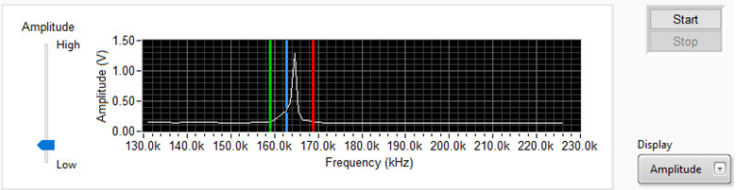


Fig 3.5.4 - Outlining steps 3 and 4

5. Click “Start” again to perform a second frequency sweep.
   a. Repeat this step until you have a detailed graph of the peak.
6. Once you have a detailed graph of the peak, use the selected frequency line (blue) to mark the peak.
   a. Move the selected frequency line to the peak.

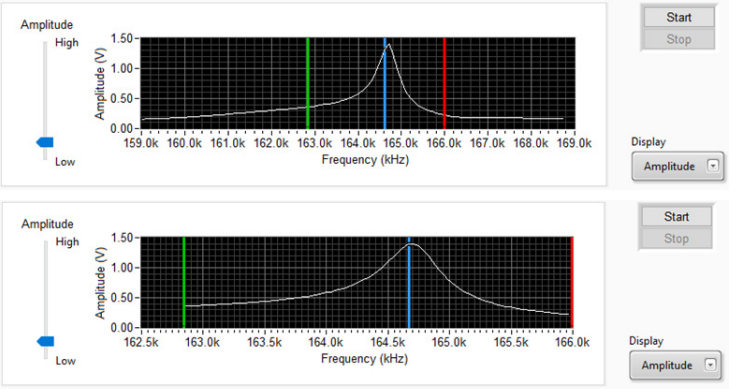


Fig 3.5.6.1 (top) and Fig 3.5.6.2 (bottom) - Outlining steps 5 and 6.

7. Under “Display” choose Phase to display the Phase graph
   a. To adjust the phase, use the phase bar on the left side of the window.

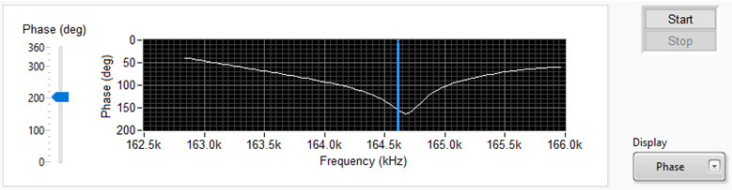
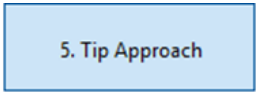
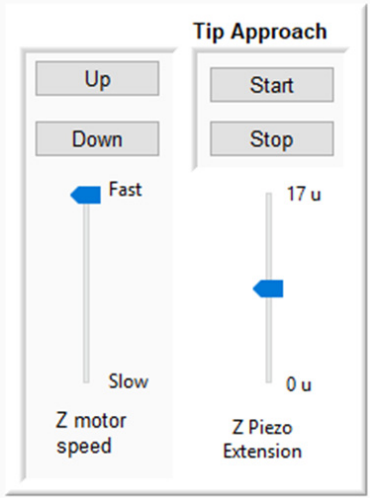


Fig 3.5.7 - Phase window.

3.6 Tip Approach

Click “Tip Approach” to open the Tip Approach section of the software.





There are two components to the Tip Approach section:

1. *Z Motor Speed:* controls the motion and speed of the Z motor.

a. *Up:* moves the sample up, towards the probe.

b. *Down:* moves the sample down, away from the probe.

2. *Z Piezo Extension:* controls the motion and position of the Z piezo ceramic.

a. *Start:* executes automated tip approach.

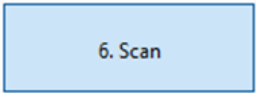
b. *Stop:* cancels automated tip approach.

To execute tip approach:

1. First use the sample translators to find an area of interest for scanning.
2. Use the manual Z motor control to bring the sample within ~ 1mm of the probe.
   a. This will reduce the time it takes for the automated tip approach.
3. Start automated tip approach
   a. The Z piezo will extend and retract while the Z motor takes small steps towards the probe, until the probe and sample are in feedback with one another.
   b. Wait until the probe and sample are in feedback with one another

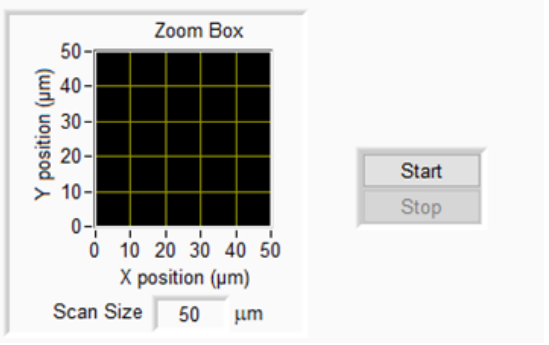
3.7 Scan

Click “Scan” to open the Scan section of the software.



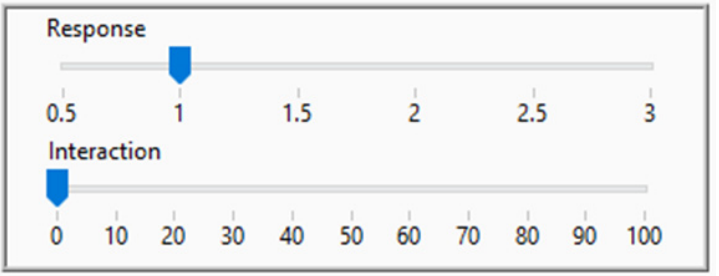
There are multiple components in the Scan window:

1. *Scan Size:* Enter a desired scan size (up to 50 µm).

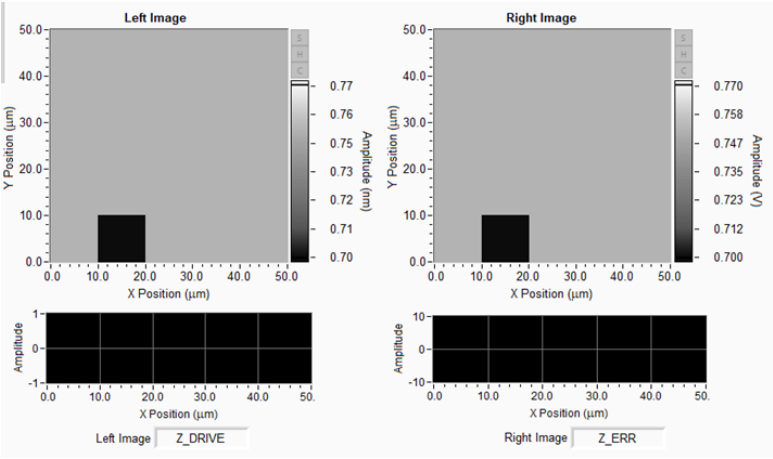


2. *Response:* Response of the control loop.
   a. Use lower response rate for large samples.
   b. Use higher response rate for tall features.

3. *Interaction:* Interaction between the sample and probe.
   a. Use higher interaction to scan through contamination.
   b. Use lower interaction forces for soft samples.

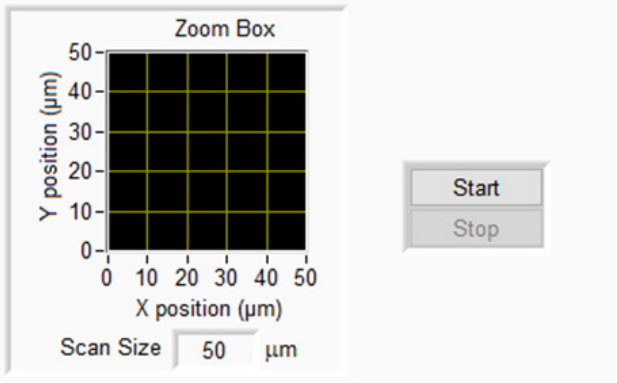


4. *Left and Right Images:* Display selected data channels.



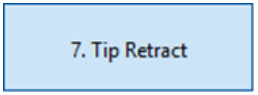
a. Z_Sense: measures displacement of the Z piezoelectric in the AFM scanner.
b. Z_Drive: voltage that goes to the Z piezoelectric.
c. Z_Err: deflection signal, proportional to the output of the light lever photodetector.
d. L-R: left - right quadrants signal from the photodetector.
e. T-B: top - bottom quadrants signal from the photodetector.
f. T+B: top + bottom quadrants signal from the photodetector.
g. Z_Phase: signal from the phase demodulator.
h. Z_Ampl: signal from the amplitude demodulator.

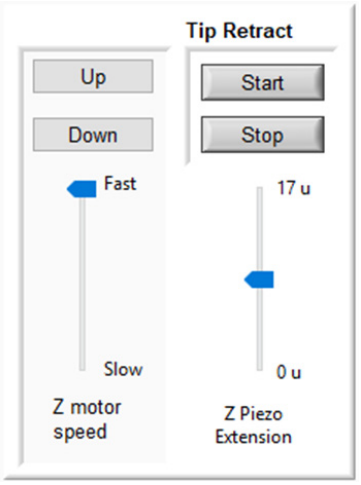
5. *Start and Stop:* Starts and stops the imaging scan.



3.8 Tip Retract

Click “Tip Retract” to open the Tip Retract section of the software.





There are two components to the Tip Retract section:

1. *Z Motor Speed:* controls the motion and speed of the Z motor.
2. *Z Piezo Extension:* controls the motion and position of the Z piezo ceramic.

To execute Tip Retract:

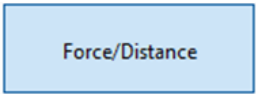
1. Start Tip Retract by pressing “Start”.

a. It is important to retract the tip before using the Z motor control to avoid damage to the probe and/or sample.

2. Move the sample further away from the probe by pressing “Up”.

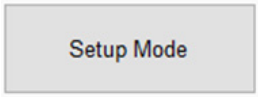
3.9 Force/Distance

Click “Force/Distance” to open the Force/Distance section of the software.



3.10 Setup Mode

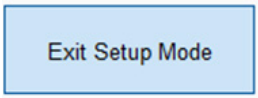
Click “Setup Mode” to open the Setup Mode section of the software.



Setup Mode should only be used by advanced AFM operators. The B-AFM is designed so that a novice user will be able to get routine AFM imaging scans without changing any parameters in Setup Mode.

For more advanced operators and for higher-resolution scanning, Setup Mode allows the user to enable all 7 steps at once, perform range check, as well as change scanning parameters, tip approach parameters, calibration settings, and other settings including feedback limit.

Click “Exit Setup Mode” to close Setup Mode.

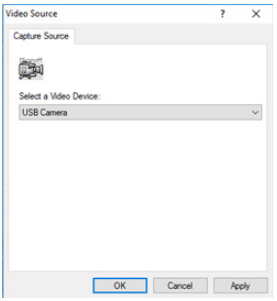


4. Step-by-Step Operators Guide

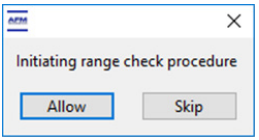
4.1 Initial Setup

Before loading samples or probes, the system should be turned on, and the software and camera application should be opened. To load samples, it is a good habit to raise the manual Z motor control to allow enough space between the probe and sample before loading.

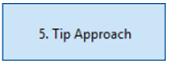
1. Turn on the B-AFM and the computer.
2. Launch the B-AFM 7-Step Software.



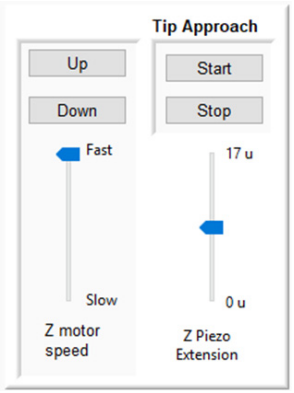
3. Select camera input.



4. Execute Range Check.



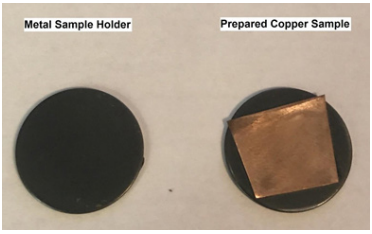
5. Click the “Tip Approach” section of the software.



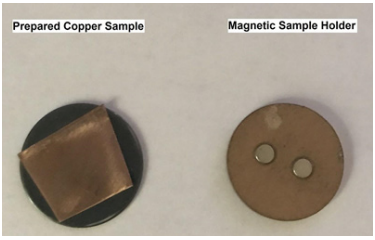
6. Move the probe holder away from the sample stage by pressing “Up” on the Manual Z Motor Control.
   a. This will ensure the sample is far enough away from the probe upon loading the probe holder and sample.

4.2 Sample Preparation

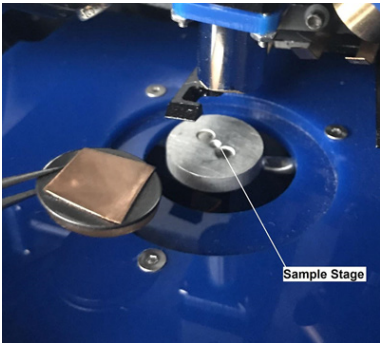
The B-AFM uses a magnetic sample stage to secure samples. In this guide, we will use a piece of copper that has been scraped with fine sandpaper.



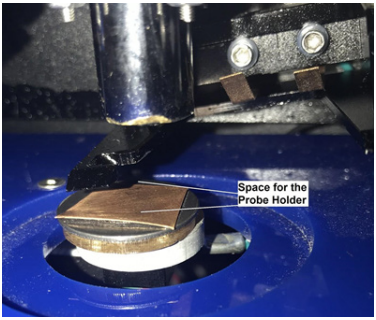
1. Secure the sample to a metal sample holder (included).
   a. This can be done using double-sided tape.



2. Secure the metal sample holder to a magnetic sample platform (included).



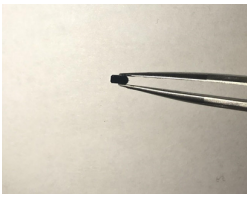
3. Carefully place the sample onto the magnetic sample stage.



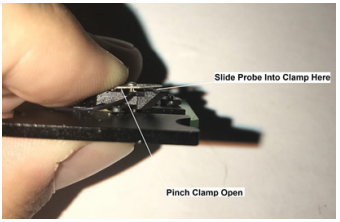
4. Make sure there is enough space above the sample for the probe holder.
   a. Move the Manual Z Motor up if you need more space.

4.3 Loading a Probe

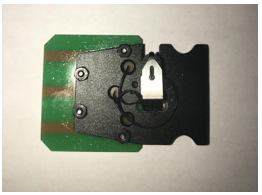
Loading a probe into the probe holder is a delicate process, and will take some practice.



1. Using tweezers, pick up the probe from the sides.



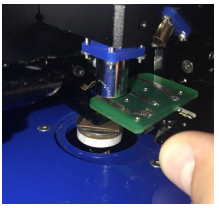
2. Pinch the probe holder clamp so it opens.



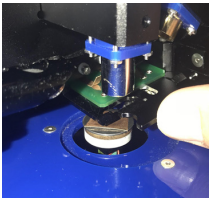
3. Carefully slide the probe under the clamp.
   a. Slide the probe so that the top of the “T” on the probe is in line with the edge of the clamp.
4. Release the clamp, securing the probe in place.

4.4 Loading the Probe Holder

Be sure there is enough space between the sample and the probe holder before loading the probe holder. If there is not enough space, see 4.1 Step 5.



1. Slide the probe holder into the B-AFM as shown.

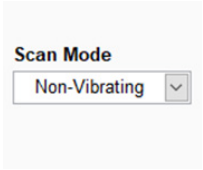


2. Make sure the probe holder is in place by wiggling it all the way into the B-AFM.

4.5 Choose a Scan Mode

The B-AFM has two primary scanning modes: Vibrating and Non-Vibrating.

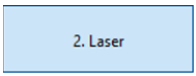
1. Click “Mode” to open the Mode section of the software.



2. Use the drop down menu to select which mode to scan in.

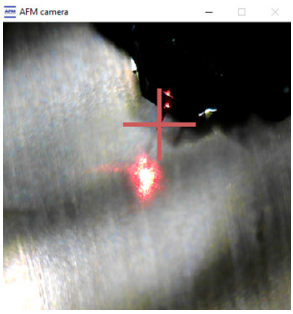
4.6 Align the Laser

Aligning the laser to the cantilever is a crucial step to ensuring the AFM operates correctly.



1. Click “Laser” to open the Laser section of the software.

2. Find the laser spot in the camera application.
   a. Use the Focus Assist if the camera is out of focus.
3. Use the Probe Holder Translators to move the probe holder into place.
   a. The laser spot should land directly on the tip of the cantilever as shown.

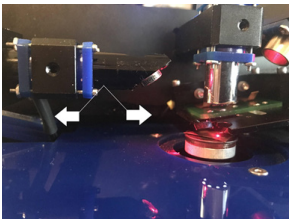


4. Left-click the cursor in the spot where the laser hits the cantilever. The software will remember this spot with an “X” and make laser alignment quicker in the future.

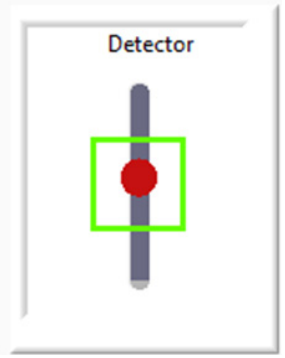
4.7 Align the Photodetector

Aligning the photodetector optimizes the amount of reflected laser light entering the system.

1. Click “Detector” to open the Detector section of the software.



2. Using your hands, move the detector back and forth (towards and away from) the probe while monitoring the detection meter in the software.



3. Monitor the Detector window: the laser spot (red dot) should fall within the green square (center of the photodetector)

4.8 Execute Resonance Sweep (Vibrating Mode Only)

A resonance sweep is only necessary when scanning in vibrating mode to find the resonance frequency of the cantilever. The range of resonant frequency should be listed on the packaging for the probes.

1. Click “Resonance” to open the Resonance section of the software.

2. Use the low limit line (green) to set the low limit of the frequency sweep.
3. Use the high limit line (red) to set the high limit of the frequency sweep.
4. Press “Start” to execute the frequency sweep.

a. When the sweep is complete, you should see an obviously defined peak, which is the resonant frequency.

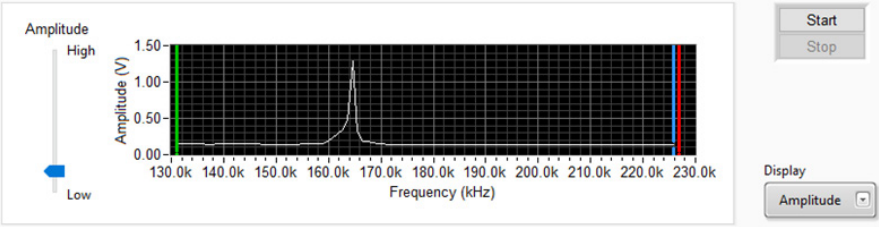


Fig. 4.1 - Outlining steps 2-4.

5. To get a more detailed frequency sweep, move the low and high limit lines towards the base of the peak.
6. Press “Start” again to repeat a more detailed frequency sweep.

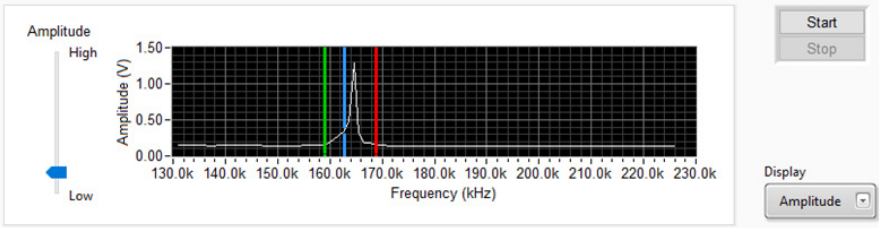


Fig 4.2 - Outlining steps 5-6.

7. Repeat Step 5 and 6 until details of the peak are visible.
8. Use the selected frequency line (blue) to set the selected frequency to the peak.

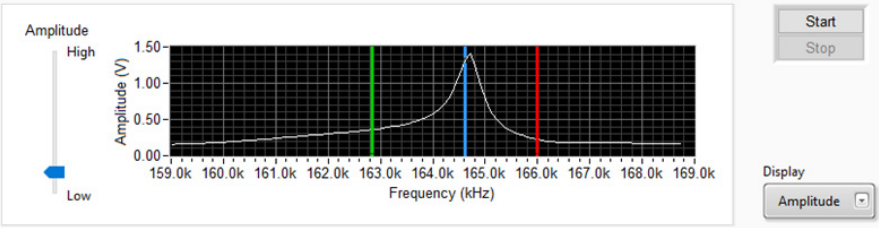
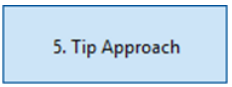


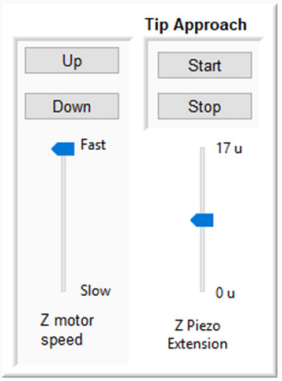
Fig 4.3 - Outlining steps 7-8.

4.9 Tip Approach

Tip approach will bring the probe into contact with the surface of the sample.



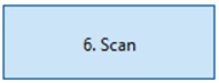
1. Click “Tip Approach” to open the Tip Approach section of the software.



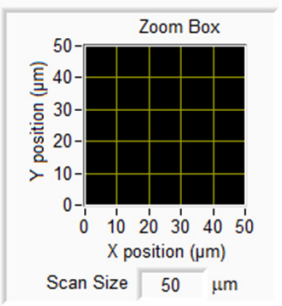
2. Press “Down” on the Z motor speed until the probe is close to the sample
   a. Watch the probe directly, as well as through the camera application until the probe is close *but not touching* the surface of the sample. This will save time during automated tip approach.
3. Click “Start” to execute automated tip approach.
   a. The probe and sample will be brought towards one other until they are in feedback.

4.10 Scanning

Scanning consists of the sample surface being scanned across the probe, creating a topographic image with useful data.



1. Click “Scan” to open the Scan section of the software.



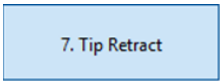
2. Zoom Box: Enter the scan size (up to 50 µm) click Enter.

3. Left Image: Select which data channel to display in the left image.
4. Right Image: Select which data channel to display in the right image.

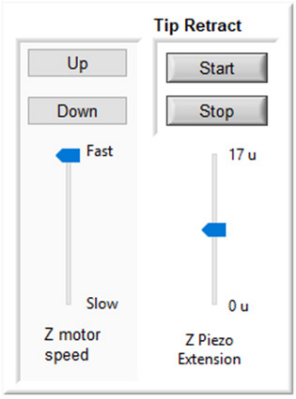
5. Start the scan by pressing “Start” next to the zoom box.
   a. *Interaction Bar:* Controls the tip-sample interaction forces.
   b. *Response Bar:* Controls the feedback loop response rate.
   c. S: Size
   d. H: Histogram
   e. C: Color Scale
6. When the scan is complete, a pop-up will appear giving you the option to save the data.
7. Completed scan

4.11 Tip Retract

After each scan, perform a tip retract to ensure the sample and probe are not damaged.



1. Click “Tip Retract” to open the Tip Retract section of the software.

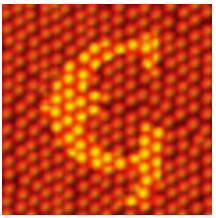


2. Click “Start” to execute automated tip retract.
   a. It’s important to do this before Manual Z Motor Control to ensure the tip and sample are not damaged.
3. Move the probe away from the sample by pressing and holding “Up” on the Manual Z Motor Control until the probe is a safe distance from the sample.

5. Image Processing

5.1 Introduction

Gwyddion image processing software allows users to visualize AFM images and data in various ways. AFM images are a three-dimensional array of numbers that represent a sample surface. Gwyddion has three primary functions for the data:



1. Click the Gwyddion icon to open the image processing software.
2. Click “Open” and find recent scan data in “Test Data” file in the B AFM folder.

1. **Process**: Changes the numbers in an array.
   a. Plane Subtract Leveling
   b. Line by Line Leveling
   c. 3-Point Leveling

2. **Display**: Changes how the numbers in an array are viewed.
   a. 2D and 3D Visualization
   b. Pallet Adjustments
   c. Light Shaded Image
   d. Histogram Adjust

3. **Analysis**: Extracts numbers from the data array.
   a. Line Profile Analysis
   b. Surface Roughness Analysis

5.2 Process

1. **Surface Subtract**: Level data by mean plane subtraction.

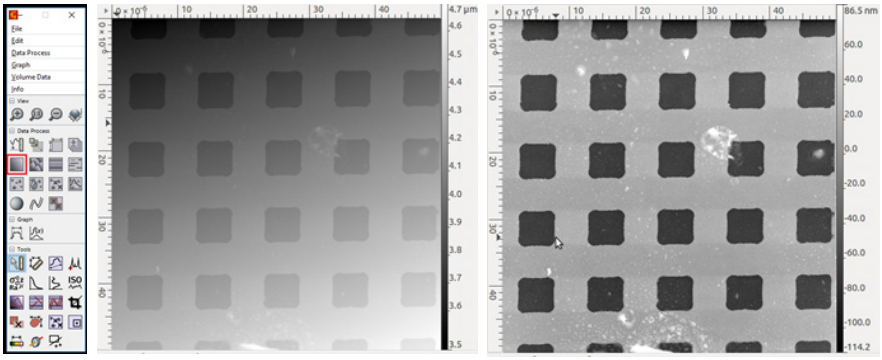


Fig 5.2.1 - Results of performing a mean plane subtraction.

2. **Line by Line**: Correct lines by matching height median.

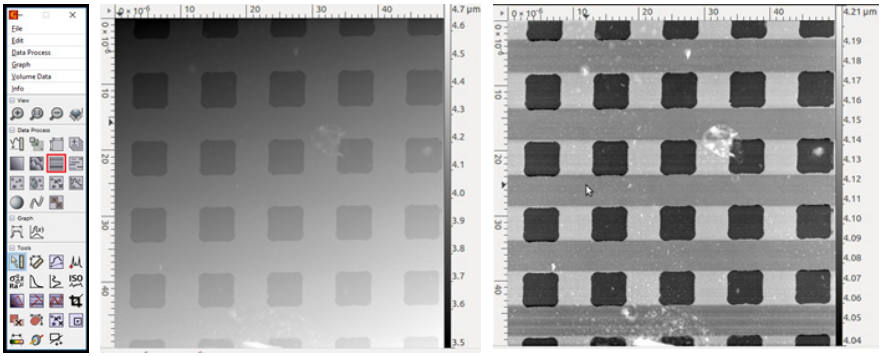


Fig 5.2.2 - Results of performing a line by line correction.

3. **Three Point Plane**: Level data by fitting a plane through three points.

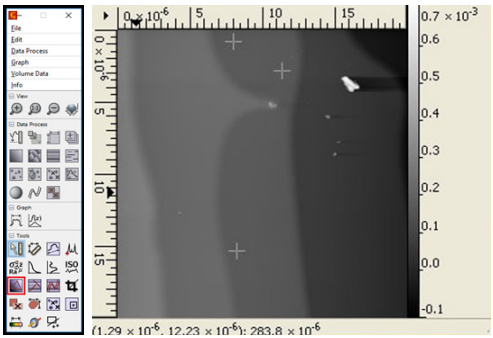
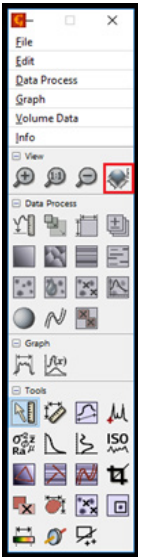


Fig 5.2.3 - Three point plane correction.

5.3 Display

1. **3D Display**: Displays data in 3D.



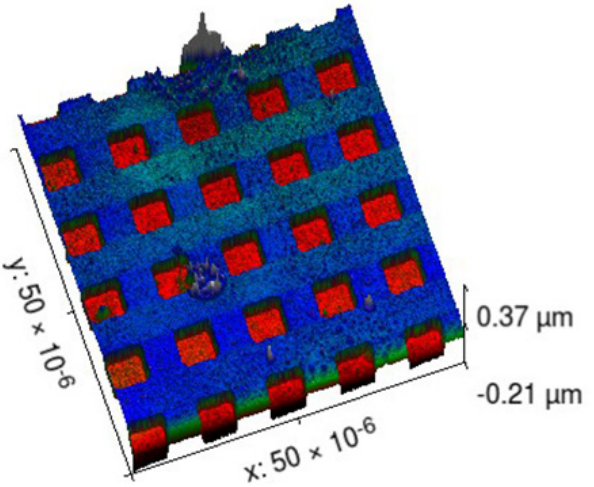
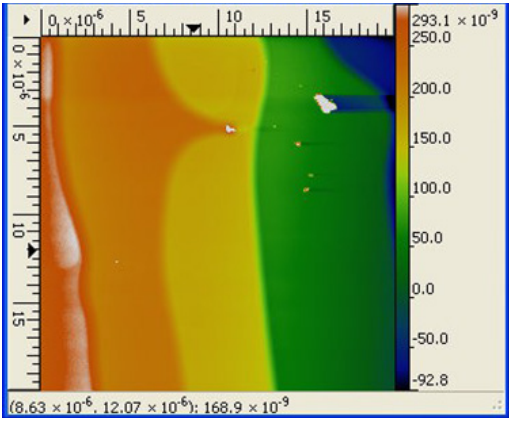


Fig 5.3.1 - 3D Display of data in Gwyddion.

2. **Pallet**: Allows adjustments to the color pallet of the data.



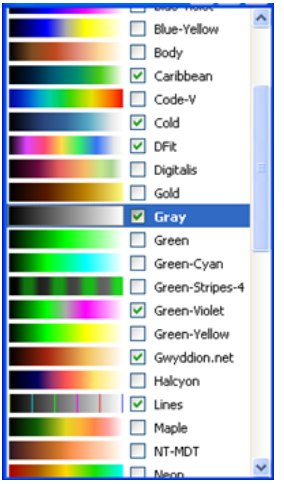


Fig 5.3.2 - Color pallet options.

3. **Shaded Data**: Views data in greyscale and light shading.

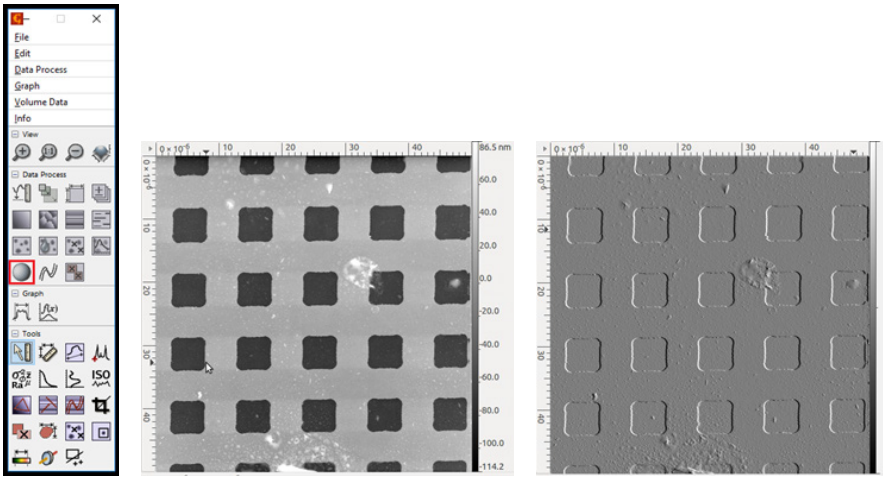


Fig 5.3.3 - Shaded image: Middle - Light Shaded; Right - Greyscale.

4. **Histogram**: Selects which data to show in color/greyscale.

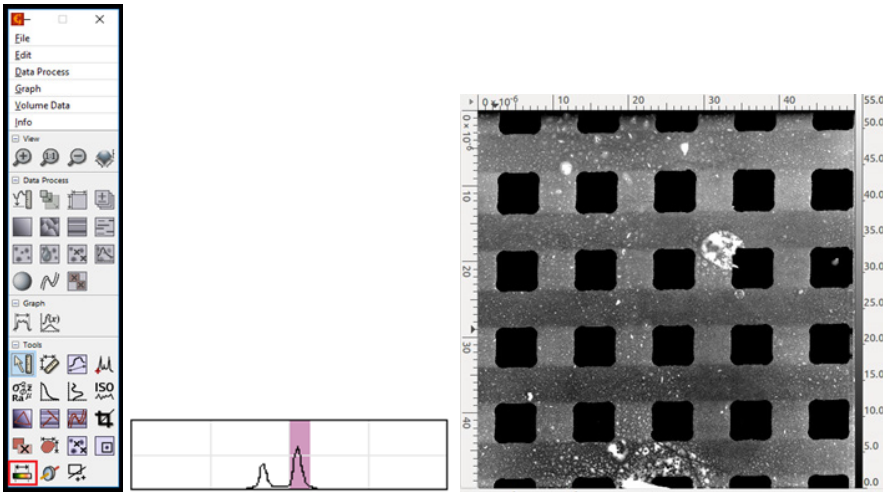


Fig 5.3.4 - Histogram adjust.

5.4 Analysis

1. **Line Profile**: Extracts height data over a chosen line.

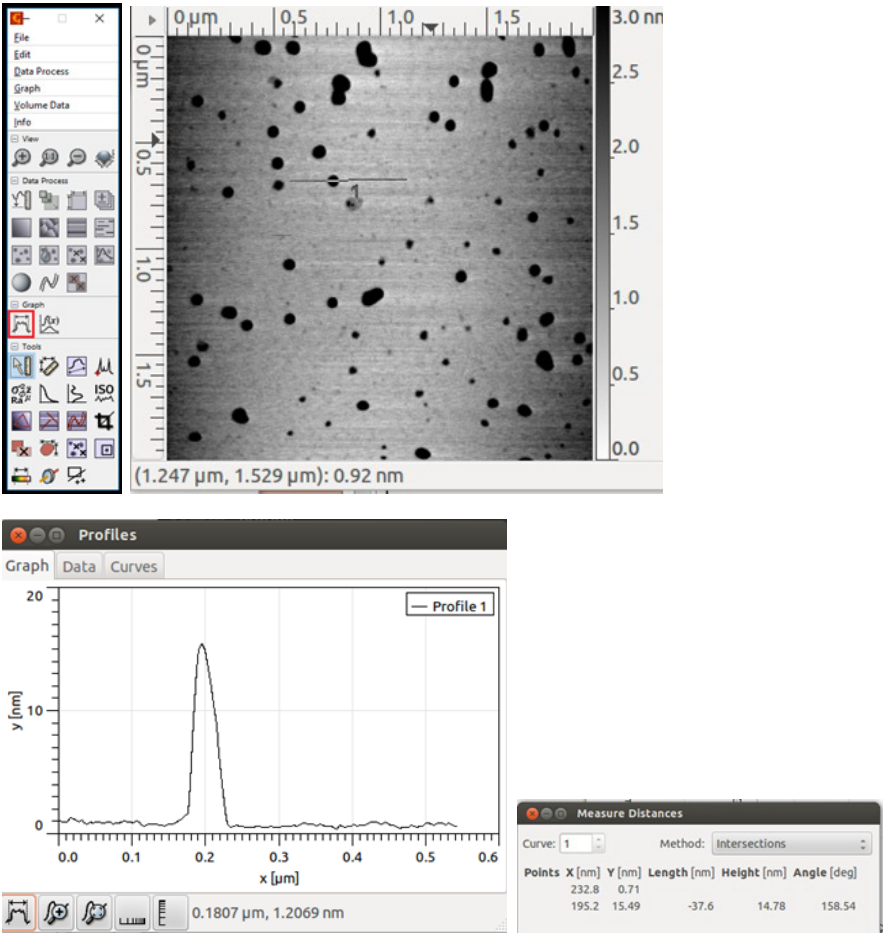


Fig 5.4.1 - Top Right - Line profile over surface; Bottom Left - Height profile over the line; Bottom Right - Extracted data from line profile measurement.

2. Surface Texture: Extracts surface texture data over a certain region.

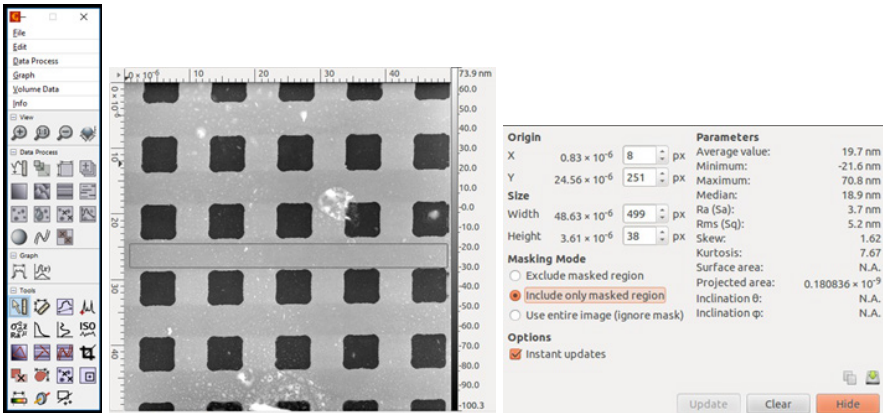


Fig 5.4.2 - Surface texture measurements and data in a certain region.