Jupiter XR AFM User Guide

Including beta (complete, reviewed) chapters.

Version 17, Revision: B-2323

Dated 03/21/2021

Asylum Research

an Oxford Instruments company

Contents

Introduction

on which member of the Jupiter family of AFMs you own, you will want to first consult one of the following sections of this user guide. Each part offers detailed step-by-step tutorials on how to operate the instrument and perform basic imaging in air.

Part 1 *Jupiter XR Operation Guide* .

Once you have mastered the basics, the following section also offers generalized tutorials applicable to the entire family of Jupiter AFMs.

Part II *General Tutorials.*

When you are skilled at basic imaging, the following sections guide you through the use of numerous accessories and techniques.

Part III *Advanced Imaging Hardware.*

Part IV *System Safety, Specifications, Set-Up, and Relocation.*

AR Software Version It is assumed that AR SPM Software version 17 or later is installed on your system. The current AR SPM Software release is version 17. To download the latest software, please register at our support site: `http://support.asylumresearch.com`.

Getting Help

For additional help with your Asylum Research instrument, including software support, refer to: `https://afm.oxinst.com/support/`

Updates to the Manual Bundled with the software, updates can be found at `http://support.asylumresearch.com`.

Send Feedback Send e-mail to sba.manuals@oxinst.com (<– clickable link) and mention which version of the user guide you are using and what chapter and section you are commenting on.

Part I

Jupiter XR AFM Overview and Basic Tutorial

Part I: Who is it for? This portion of the manual is dedicated to the general operation of the Jupiter XR AFM.

Part Contents

1. Jupiter XR AFM: Getting Started

CHAPTER REV. 2322, DATED 03/19/2021, 18:41. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

1.1. Safety Review

Before You Start It is recommended that everyone who uses the Jupiter XR AFM instrument read the Section 1.5 on page 13 section at least once. As a reminder, here are the important points:

- The Jupiter XR contains a laser-like SLD light source and a laser diode light source, both of which emit a visible, red-colored light. The lasers are classified as safe to view under any conditions without protective eyewear. Please review the details in the safety section.

- The AFM's XYZ piezos operate on voltages up to 165 V_{DC} and with sufficient current to be harmful to human life. Note that the cables connecting the controller to the base and the head and scanner to the base carry these voltages. Do not pinch or cut these cables. Turn off the controller before disconnecting any of these cables. It is safest to plug them all in before turning on the controller. Also, do not remove any covers from the controller or other instrument components. There are no serviceable components inside.
- The Jupiter XR contains many electric stepper motors. Potential pinch points are marked with yellow safety stickers.

1.2. Jupiter XR Basic Hardware Overview

This section will establish names for the various parts of your Jupiter XR AFM system. The system should have been set up, connected, and tested by an Asylum Research scientist.

1.2.1. Major Hardware Components

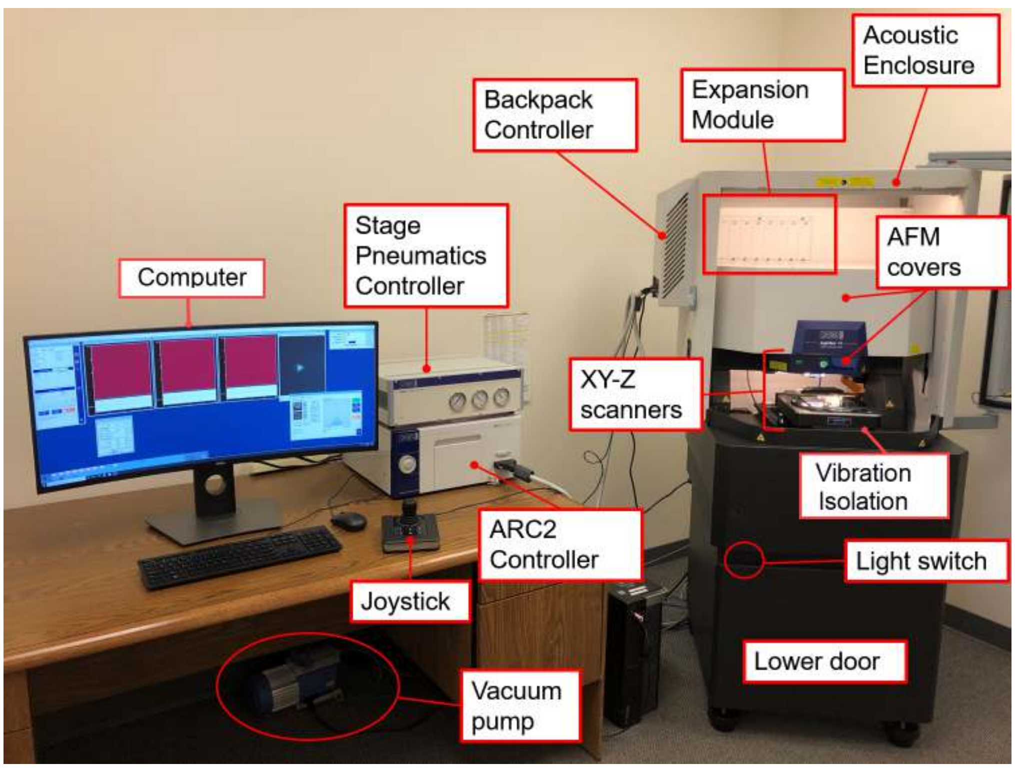


Figure 1.1.: The ideal set up for JupiterXR AFM.

The Jupiter XR AFM system and its various components are shown in the figures and briefly explained below (in alphabetical order):

Acoustic Enclosure Also called the "Hood". A heavy, steel chamber with special acoustic damping materials and vibration isolating pads under the legs. Keeps lab noise and vibrations from affecting high resolution AFM images. Also shields the instrument from air currents which degrade imaging stability.

AFM The parts sitting inside the enclosure are typically referred to as the “AFM”. The main components are, from top to bottom:

Z Scanner The AFM component which holds the cantilever chip, electronics, and the vertical (Z) motion actuator and sensor. In short, it moves the cantilever vertically as the sample moves laterally beneath it. Optics for illuminating and optically imaging the sample and cantilever are further above the Z scanner.

XY Scanner The AFM component which holds the sample and scans it laterally in X and Y beneath the tip. It contains piezoelectric actuators and high-resolution position sensors.

XY Stage The part of the instrument which floats when air pressure is turned on and allows for motorized and controlled XY movement of the XY Scanner sample assembly.

Computer The computer is the primary interface for controlling the microscope and its main communication is via a USB connection to the ARC2 controller, the Backpack, and the Pneumatics Controller.

Controller Also called the “ARC2”. The controller houses power supplies and the necessary electronics for controlling the scan motion and acquiring image data from the microscope. It connects to the computer via USB2.0 connection. (For more details about the internal architecture of the controller, including advanced topics such as interfacing with external equipment and controlling the crosspoint switch, see **Chapter 5 on page 88**.)

Backpack The Backpack controller is located on the left side of the acoustic enclosure and houses a very powerful set of digital and analog electronics that greatly extend the functionality of the ARC2 Controller. Like the ARC2, the Backpack has its own ADCs, DACs, BNC connectors, and a CrossPoint switch. It connects to the Jupiter XR ARC2 Controller via the main controller cable and to the computer via USB2.0 cable, as well as the Expansion Modules located inside of the Hood. The Backpack is typically shrouded underneath a removable, white cover. (For more details about the internal architecture of the controller, including advanced topics such as interfacing with external equipment and controlling the crosspoint switch, see **Chapter 6 on page 93**.)

Stage Controller Provides air pressure control and XY motor control to the Jupiter XR System. It is also sometimes called “Pneumatics Controller”

Q Why is there both a Backpack and a Controller? Isn’t the Backpack redundant since there is already a Controller?

A In a typical AFM design, most of the electronics housed in the Backpack would be in the Controller. The Backpack, however, instead moves these electronics physically closer to the microscope; the Jupiter XR can achieve such very low noise levels in part because of the proximity between some of its electronics and the actual microscope. Keeping these low noise electronics external to the enclosure balances noise performance with the management of the heat generated by electronics.

Expansion Module User-swappable electronic control modules.

Lower Door Allows access to the bottom of instrument.

Vibration Isolation A granite plate supported by air isolators (or Active Vibration Isolation “AVI” system). When the AVI is used, the isolation controller is stored behind the lower enclosure door.

Light Switch Controls the interior acoustic enclosure illumination.

1.2.2. User Interface AFM Cover

Figure 1.2.: LED indicators on the AFM cover

LED indicators on the AFM cover The LED indicators on the AFM cover include:

- *Detection Laser On*: When lit green, indicates that the laser is turned on.
- *blueDrive Laser On*: When lit green, indicates that the laser is turned on.
- 'Sample Vacuum' button:
  - When not lit, there is no sample vacuum.
  - When lit green, there is sample vacuum.
  - When flashing green, vacuum is not optimal (vacuum pump is off, or there might be a leak).
- *AFM In Use*: System is scanning.
- Z Scanner:
  - *Do Not Remove*: Z scanner should not be removed.
  - *OK to Remove*: Z scanner can be safely removed from the AFM.

1.2.3. User Removable Hardware Components

XY scanner, sample chuck, Z scanner, and cantilever holder are all parts that can be removed by the user.

200 mm sample chuck screws

- The sample chuck is attached to the XY scanner with four (4) torx screws.
- A torque wrench is provided to fasten the screws.

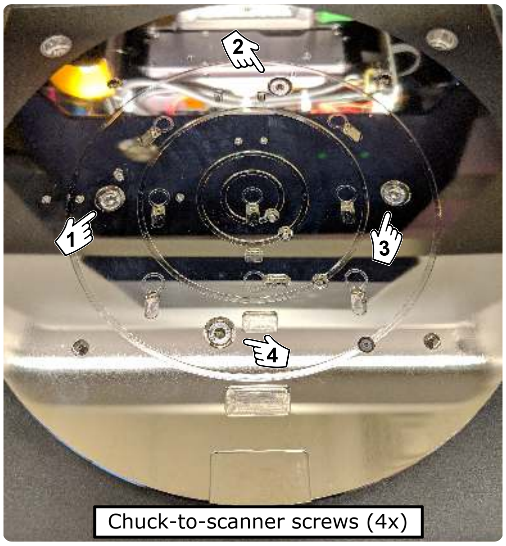


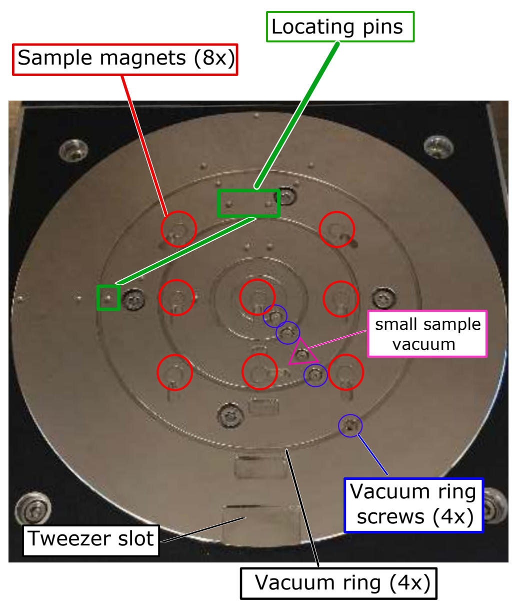
Figure 1.3.: Z scanner, XY scanner, sample chuck, and cantilever holder.

Figure 1.4.: Electrical connection to the sample chuck is controlled from the back of the XY scanner. The toggle can be switched between Bias - N/C (not connected) - GND (ground).

200 mm sample chuck magnets, wafers, and vacuum rings

- There are eight (8) sample magnets embedded in the chuck for samples on steel pucks.
- There are locating pins for wafers of varying size (2,4,5,6,8 inches; 50, 100, 125, 150, 200 mm).
- There are four (4) vacuum rings, each one has an O-ring and a screw.

Note When imaging an 8-inch wafer, all vacuum rings should be open (screws and O-rings should be removed and stored for later use).



1.2.4. Accessory Kit Parts List

The following list includes all of the parts included in the basic hardware accessory kit. The table is useful as a visual table of contents with links directing you to the specific uses of each part. When ordering parts, please refer to the part numbers in the second column.

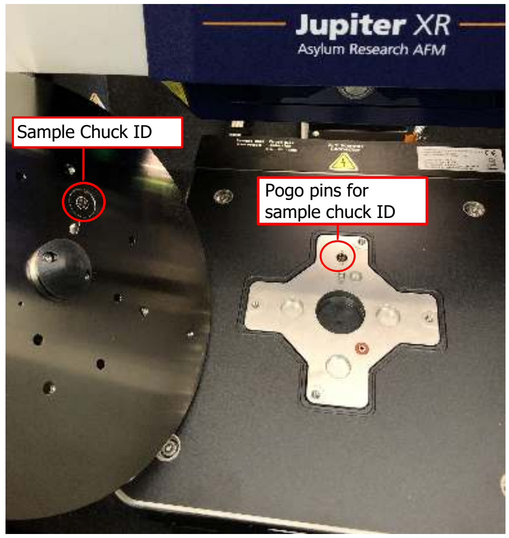


Figure 1.5.: Each sample chuck has an identification contact pad (ID). When the chuck is placed on the XY scanner and the pogo pins connect with the contact pad, the software recognizes the type of chuck that is placed on the scanner.

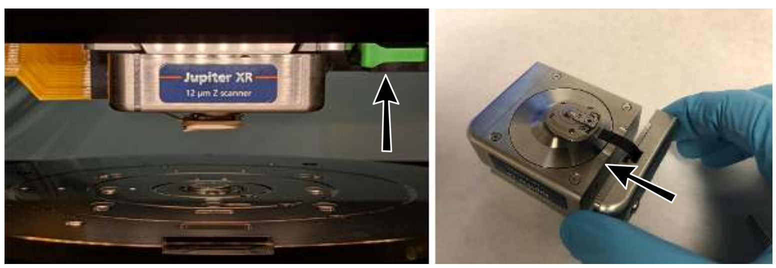
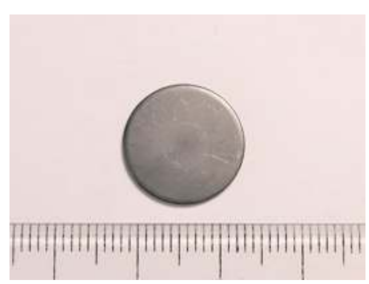
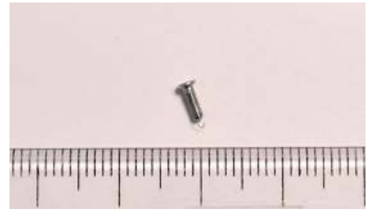
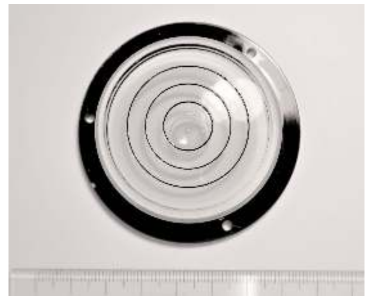


Figure 1.6.: The Z scanner is placed in the AFM using a dovetail geometry and secured in place by pushing the green lever up, as shown in the image. The cantilever holder is attached to the Z scanner. Each cantilever holder has a side module which contains the information relevant to each cantilever holder.

Itm	Part #	Item Description	Qty	Picture
1	080.122	15mm AFM Specimen Disc. This Magnetic Disc is permanently attached to the Sample, using epoxy or silver paint. Can be ordered from Asylum Research or Ted Pella (16218). See Step 15 on page 43 about placing sample into AFM.	10	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
2	116.834	M1.6 X .35 Pan Head Screw, Modified. For probe holder.	3	
3	230.067	O-ring, .070 ± .003 C/S x .162 ± .005 ID± .302 OD. Provides a seal between wafer chucks and scanner for sample vacuum hold down. See Section 8.1 on page 101.	2	
4	230.073	O-ring, .476 ID X .079 CS X .634 OD. Provides a seal between the bottom of the scanner and the XY translation stage. See Step 5 on page 106.	4	
5	231.062	¼" OD x .166 ID Clear Polyurethane Tubing. Used during installation.	120	
6	231.063	¼" OD x .166 ID Clear Blue Polyurethane Tubing. Used during installation.	120	
The scale in the photos is in cm and mm.				

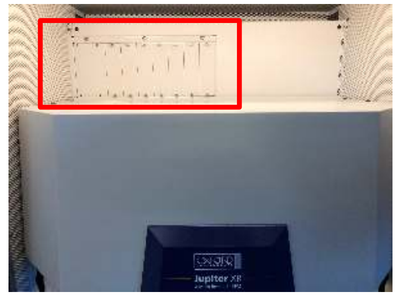
Itm	Part #	Item Description	Qty	Picture
7	232.057	Air & Water Quick-Disconnect Plug; 1/8 Coupling Size. Attached to the hood during installation.	2	
8	279.187	Bullseye Level. Used during installation to level the granite surface and the hood.	1	
9	279.188	Storage Box - 6 Compartments. To store small parts when not in use.	1	
10	290.101	2A Tweezers, SA - Tapered Round Blunt - Standard Grade. Used for picking up samples.	1	
11	290.102	7 Tweezers, SA - Curved Sharp - Standard Grade. Used to pick up cantilevers or small screws.	1	
12	290.103	3C Tweezers - Extra Fine Sharp - Standard Grade. For placing samples, tiny O-rings, and small screws.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
13	290.106	#00 Phillips Wiha Screwdriver 261 PH 00X40. For small Phillips screws.	1	
14	290.112	8mm Allen Wrench. Tool to be kept on hand in customer support calls for removing the front portion of the acoustic enclosure. Also used during system installation.	1	
15	290.135	5/32" L Key Hex Wrench. For small hex screws.	1	
16	290.138	3mm Hex Allen Wrench. Used when opening cable clamps on the sides of the enclosure.	1	
17	290.174	#0 Phillips Wiha Screwdriver 261 PH 0 x 50. For attaching side portion of probe holder.	1	
18	290.177	8mm Ratcheting Wrench. For lowering and raising granite during install. Call customer support before using.	1	
19	290.178	24mm Combination Wrench - Ratcheting. Used during installation for adjusting leveling feet under the hood.	1	
20	900.110.8	Jupiter Probe Kit	1	
21	900.237	A/R Calibration Grating - Steel Puck Mounted. Store this carefully, a replacement costs hundreds of dollars.	1	

The scale in the photos is in cm and mm.

1.3. The Expansion Box

The Jupiter XR Expansion Box can be filled by the user with additional modules which allow connection with the many, various sample stages mentioned below (e.g., environmental controller).



1.3.1. Expansion Box Modules

The following Expansion Box modules exist for Jupiter XR:

- Environmental Control

1.3.1.1. Environmental controller module

This expansion module powers a variety of environmental control sample stages. Each simply plugs into the module's connector and is subsequently recognized by the software. In most cases, a control panel for the sample stage will automatically appear in the software. [Asylum Research Part Number 900.277.]

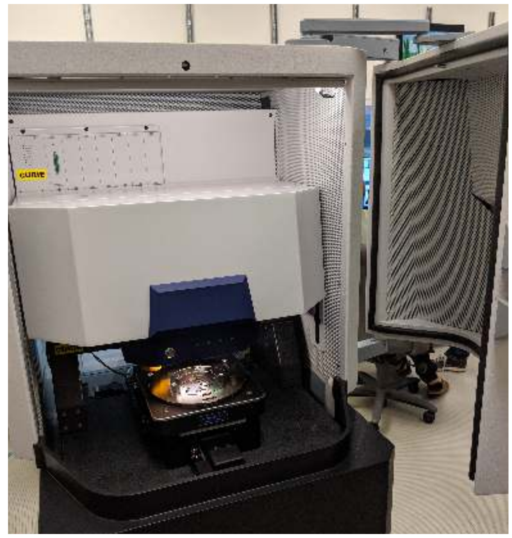
1.3.2. Swapping modules

To swap modules, complete the following steps:

1. Turn off the ARC2 Controller power.
2. Using a screwdriver, remove the leftmost cover plate and store it in a safe place.
3. Insert the new module, taking care to engage the connector.
4. Fasten the screws.
5. Power up the controller again. Once the software recognizes the controller's presence, the new hardware module will register automatically.

1.4. Enclosure Door Operation

The enclosure doors were designed to be used sitting down. Opening and closing the door requires minimal force and imparts minimal impact on the instrument when the latch is closed.



Main door opening and closing

1. Rotate the latch.
2. Pull forward.
3. Reverse to close.

Note To prevent dulling of an AFM tip, we recommend NOT operating the door while the AFM tip is engaged on the sample surface.

Note For safety reasons, a switch in the door will disconnect the blueDrive laser when the door opens.

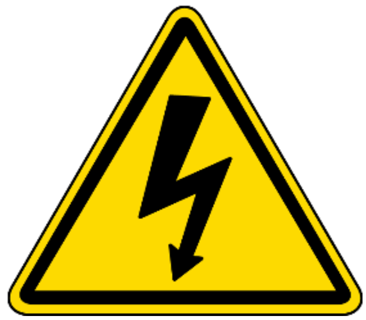
Note Be careful not to pinch your finger on the doorknob.

1.5. Safety Precautions

During normal use, the Jupiter SPM poses no harm to the operator. Nevertheless, there are potential dangers in and around the instrument. Please read this section carefully to understand where the potential dangers lie before attempting to use the system.

1.5.1. Safety Label Descriptions

Specific examples of each warning label on the instrument are covered in the next section.

Description	Warning Label
Pinch Point Avoid placing hands in these areas. In case of unexpected motor movement, injury could result.	
High Voltage Voltages of up to 165VDC can be present on the connections for the XY Scanner. Always turn off the ARC2 controller power (See Figure 5.2a on page 90) before the connector or disconnecting cables.	
Laser 1 Product The Jupiter XR AFM qualifies as IEC Class 1 laser product. When used as prescribed, there is no danger of exposure.	LASER 1 Complies with IEC 60825-1 Ed. 3 (2014) Complies with 21 CFR 1040.10 and 1040.11 except for conformance with IEC 60825-1 Ed. 3., as described in Laser Notice No. 56, dated May 8, 2019.
Laser Radiation Warning (sides and back) Harmful levels of laser power do occur behind Jupiter's enclosures. Do not disassemble or defeat interlocks!	WARNING - CLASS 3B-VISIBLE LASER RADIATION WHEN OPEN AVOID EXPOSURE TO THE BEAM AVERTISSEMENT – RAYONNEMENT LASER VISIBLE DE CLASSE 3B –EN CAS D'OUVERTURE EXPOSITION AU FAISCEAU DANGEREUSE
Laser Radiation Warning (no door) Harmful levels of laser power do occur behind Jupiter's enclosures. Do not disassemble or defeat interlocks.!	WARNING - CLASS 3B-VISIBLE LASER RADIATION WHEN OPEN AVOID EXPOSURE TO THE BEAM AVERTISSEMENT – RAYONNEMENT LASER VISIBLE DE CLASSE 3B –EN CAS D'OUVERTURE EXPOSITION AU FAISCEAU DANGEREUSE

1.5.2. Motor Safety

The Jupiter XR AFM contains motors which direct the laser beam and move the objective lens and cantilever holder into position, as well as move the sample in the horizontal plane. The motors are strong enough to cause injury and there are several potential pinch points which need to be avoided.

Best practice motor safety:

- It is recommended that motor moves are made while keeping both hands on the joystick or on the computer, keeping hands away from moving parts.
- Never operate motors when another person is touching the instrument.
- Consider operating motors only with the enclosure door closed.

Note All motors in the Jupiter XR AFM are stepper motors. In the case of the XY stage, they are directly connected to lead screws. In the case of the Z engage stages, they are connected via lead screws AND gearboxes.

Power to the XY motors is supplied from the stage controller. Power to the Z motors is supplied by the black power supply, which is plugged into and turned on and off by the ARC2 AFM controller.

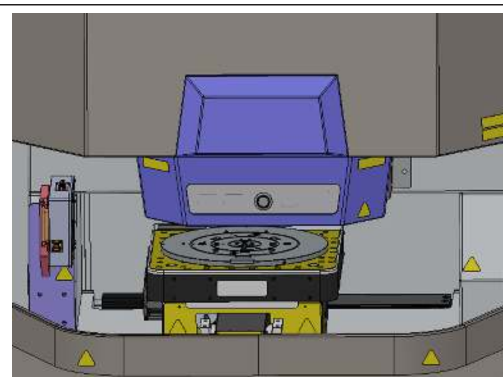
1.5.2.1. Avoiding Unsafe Situations

Areas where potential pinch hazards exist are described below in detail and are marked on the instrument with yellow warning labels.

1.

Pinch point overview:

- The yellow pinch point labels, as shown at right, highlight the various areas of concern.
- The next steps will detail each area.



2.

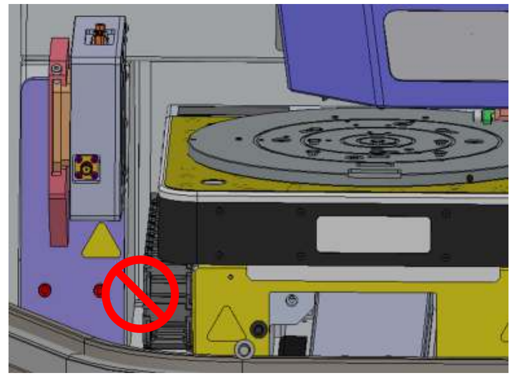
Front corner area:

- If the XY sample stage is motored completely to the front and completely to the left or right, avoid the area shown in the photo.

3.

Near the granite risers:

- If the XY stage is partially toward the rear and completely at the left or right range of travel, a pinch hazard exists, as indicated in the photo.

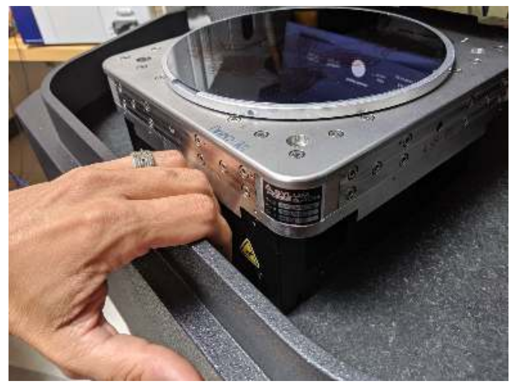


4.

Near the front of the instrument:

- When the XY stage is moved completely to the front of its range, a pinch hazard exists.
- Avoid gripping your fingers over the front edge of the instrument.

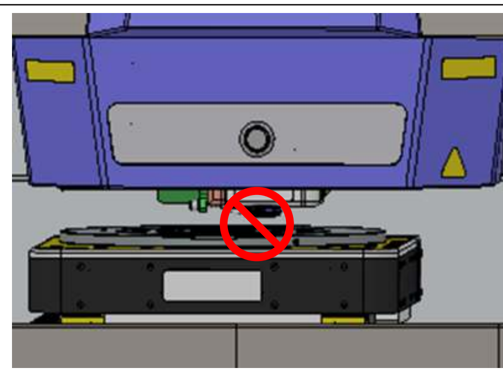
Note The risk is very low since the minimum gap is greater than 25mm.



5.

Between AFM tip and sample:

- Since the AFM tip must approach the sample and touch it, small gaps and pinch points exist near the Z actuator.
- Keep fingers clear of the area where the tip makes contact with the sample.



1.5.2.2. How to Stop the Motors

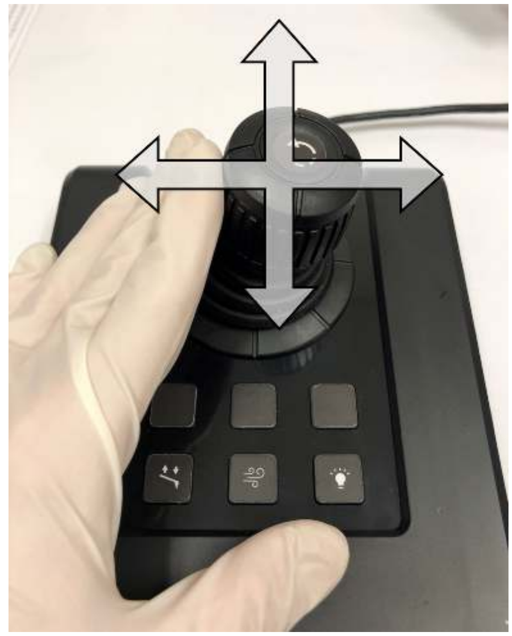
In the case of an emergency, the motors can be stopped in one of two ways, XY motion or Z motion, as follows:

XY Motion

1.

Push the joystick:

- Pushing the joystick in any direction will immediately stop any current motor moves and will transfer control of joystick.



2. Press and HOLD DOWN the 'Esc' key on the PC keyboard. This will always stop any automated motor moves.

3.

Turn off the stage controller:

- Cutting power to the stage controller will cut power to the XY motors.
- The switch is located at the rear, upper left-hand corner, as seen from the front.

Note When the motors are not powered, the XY stage can be pushed and moved by hand. One must overcome the friction in the lead screws and the unpowered stepper motors.

Z Motion

1.

Use the joystick:

- Press the (Up/Down) button, as shown in the image at right.
- Push the joystick up.
- The tip will move away from the sample.

2.

Turn off power to the ARC2 controller:

- This is NOT advised, as it will not allow you to use the joystick or software to control the motors and manually move them to a safer position.

1.5.3. Light Source Safety

Caution	Use of controls, adjustments, or performance procedures other than those specified herein may result in hazardous visible laser energy exposure.

1.5.3.1. Laser Classification

The Jupiter XR AFM contains a laser diode (LD) and super luminescent diode (SLD) light sources. Super luminescent diodes are like lasers but have a shorter coherence length.

The Jupiter lasers are sufficiently well-shielded so that the Jupiter AFM qualifies as IEC Class 1 laser product that complies with IEC 60825-1 Ed. 3.0 (2014) and with 21 CFR 1040.10 and 1040.11, except for conformance with IEC 60825-1 Ed. 3., as described in Laser Notice No. 56, dated May 8, 2019. In layman's terms, this means the Jupiter XR AFM is in the same class as a home DVD player and in a safer class than a laser pointer. When used as prescribed, there is no danger of exposure. Nonetheless, it is still good to have an understanding of the lasers in the instrument, as well as the safety features.

Complies with IEC 60825-1 Ed. 3 (2014)

Complies with 21 CFR 1040.10 and 1040.11 except for conformance with IEC 60825-1 Ed. 3., as described in Laser Notice No. 56, dated May 8, 2019.

Figure 1.7.: A Class 1 Laser Product (IEC 60825-1 Ed. 3 (2014)) is safe under all conditions of normal use.

1.5.3.2. The Laser Optical Path

Understanding the laser optical path is the best way to reduce the possibility of harmful exposure to visible light, which may cause eye damage. Figure 1.8a on page 23 shows a simplified picture of the laser optical path. Light originates behind the blue covers, and exits downward from a an objective lens, and finally into open space through a hole in the probe holder. Typically, the probe reflects the light back into the AFM for detection, but a small amount of light that spills past the lever is usually visible. If the beam is not aligned on the lever, or there is no lever or probe holder present. The team will hit the sample.

Jupiter has two light sources:

1. A relatively weak (~1mw at the cantilever tip) SLD source, visible red light, 680nm wavelength, diverging beam.
2. A relatively powerful (up to ~60mW at the cantilever tip) laser diode, part of the blueDrive system, visible red light, 640nm wavelength, diverging beam.

The blueDrive laser (2) is only on when the door of the enclosure is closed. The switch which activates the laser is shown in Figure 1.8b on page 23. Do not defeat this interlock or you can be exposed to class 3B levels of viable radiation. Do not tamper with this switch unless you are wearing the appropriate laser safety glasses. Since the beam is rapidly diverging, when it reaches the window or the enclosure side ports, the light intensity is always below class 1 levels.

The optical lever detection SLD is relatively weak (~1mW at the tip, and rapidly spreading from that point on). When it potentially reaches a human eye, it has spread far enough to fall below class 1 limits. Hence the optical lever detection laser (1) is on regardless of the door being open or closed.

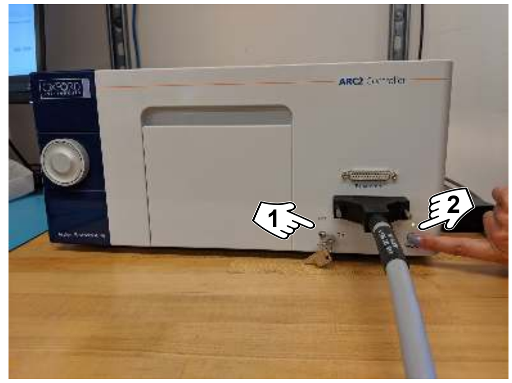
Note that under typical conditions, no significant amount of light reflects toward the user. Still, it is possible that a sample with an angled reflecting facet might direct the beam toward the user. Even under such simulated conditions the light intensities still fall below class 1 levels.

The same information is reviewed again below with illustrations and photos.

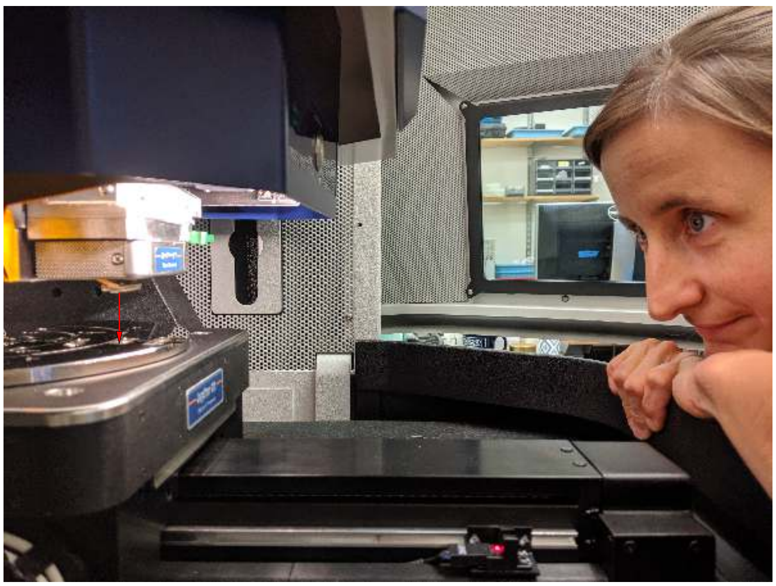
1\. **Turning lasers off:** If there is ever any reason to turn lasers off, do the following:

1 Turn the laser key on the ARC2 controller to the OFF position. This will leave all other systems operating.

2 Turn off the power to the ARC2 controller. This will cut power to all lasers, and many other systems as well.



2\.



Laser beam path:

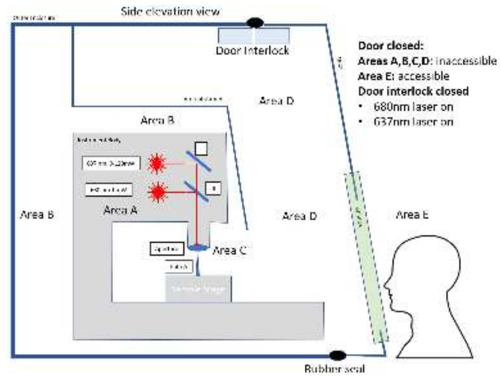
- The above photo shows the laser aperture and the small gap where the beams traverse open space.
- This open space gap is shown at its largest. When imaging samples, it will be reduced to nearly zero (0).
- The module just above the laser aperture can be removed. In this case, the beam will emerge from a microscope objective not visible in this photo.
- Various diagrams follow illustrating various conditions under which the instrument can operate and where one might expect laser radiation.

3.

SAFE: Normal operation with door closed.

- Detection laser is active.
- Excitation laser (blueDrive) can be active.
- Laser beams travel in the vertical direction, typically reflecting back into the instrument from the cantilever or a sample (Area A) with very little light scattered toward the user.
- User only has access to Area D.

Note It is safe to look at the aperture indefinitely.

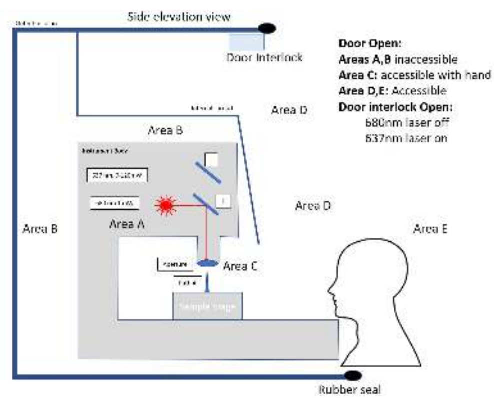


4.

SAFE: Normal operation with door open.

- Same situation as shown in the photo above.
- Detection laser is active.
- Excitation laser (blueDrive) CANNOT be active. It is shut off due to the door interlock.
- Laser beam travels in the vertical direction, typically reflecting back into the instrument from the cantilever or a sample (Area A) with very little light scattered toward ther user.
- User has access to area E and D, and can reach into Area C.

Note It is safe to look at the aperture indefinitely.

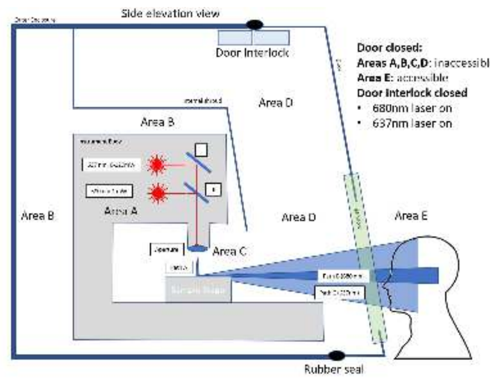


5.

SAFE: Worst case scenario operation with door closed.

- Detection laser is active.
- Excitation laser (blueDrive) can be active.
- In rare cases of a sample with a polished angled surface, laser beams could be directed toward the enclosure window.
- User only has access to Area D.

Note It is safe to look at the aperture indefinitely. The closed door puts enough distance between you and the aperture so that light levels remain below class 1.

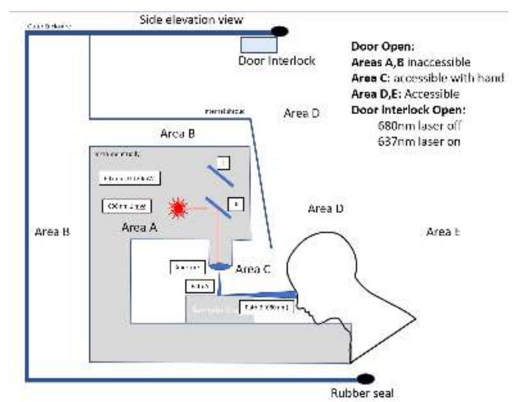


6.

SAFE: Worst case scenario with door open.

- Detection laser is active.
- Excitation laser (blueDrive) CANNOT be active. It is shut off due to the door interlock.
- In rare cases of a sample with a polished angled surface, the laser beam could be directed toward the enclosure window.
- User has access to area E and D and can reach into Area C.

Note It is safe to look at the aperture indefinitely. Even if the user gets close to the aperture, the beam is sufficiently weak and diverging so that class 1 limits of laser radiation are not exceeded.

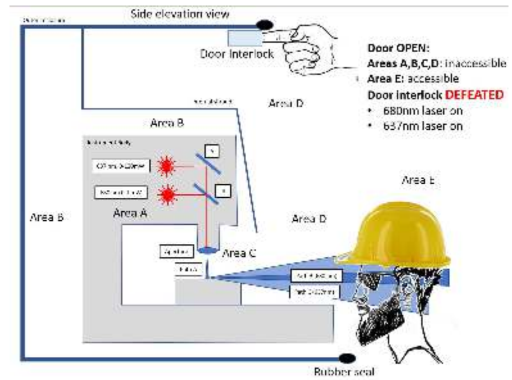


7.

UNSAFE: Door open with interlocks defeated.

- This should only be done by trained service personnel from Asylum Research.
- Getting this close to the blueDrive excitation beam will exceed class 1 radiation levels and requires training and special protective measures.

Note Do NOT override the door interlock.

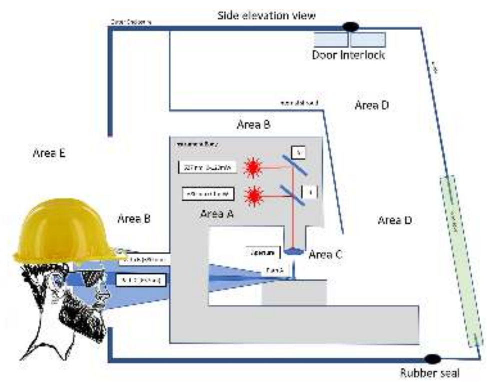


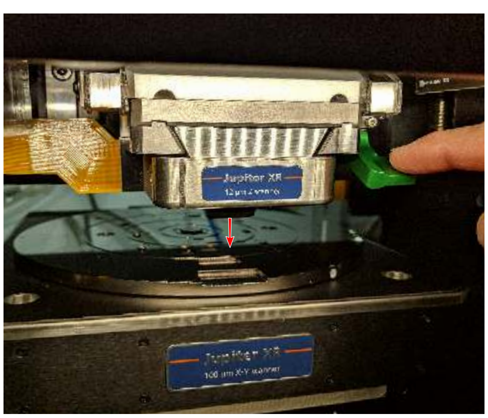
8.

UNSAFE: Rear access panel removed.

- This should only be done by trained service personnel from Asylum Research.
- The rear panel is not interlocked and not intended for user access.
- The blueDrive excitation beam may exceed class 1 radiation levels and requires training and special protective measures.

Note Do NOT remove the rear access panel or any other protective covers. The panels and covers are not interlocked and are only intended for trained service personnel.





(a) Jupiter laser light point of origin

(b) blueDrive interlock switch

Figure 1.8.: Laser Details

Means of Turning Laser On and Off The lasers on the Jupiter AFM are turned on and off by a control voltage which originates inside the ARC2 controller. On its way to the laser, the voltage passes through various safety switches as follows:

- **Light Source Remote Jack** In case your laboratory safety specifications require extra measures, such as a door or foot interlocks to operate laser equipment, you can attach such a switch to a connector on the back of the ARC2 controller. If this switch is open, the power to both SLD and blueDrive laser will be interrupted. Since such requirements are rare, the ARC2 controller ships with a shorted connector, keeping this switch permanently closed. Removing the connector will shut the laser off. Call Asylum Research for an additional connector to which you can attach your own customized interlock system.
- **Laser Power Key Switch** The laser is turned on and off by means of the key on the front of the ARC2 controller. The key is captive when the laser is on but can be removed in the 'off' position.
- **Enclosure Door Interlock** As described above, the powerful blueDrive laser turns off when the door is opened. The weaker cantilever deflection detection laser is not affected by this door switch.

1.5.4. Power Supply Safety and Thermal Management

1.5.4.1. High Voltage

The voltages inside the Jupiter XR AFM are as dangerous as those present in a standard wall socket; therefore, you should respect all components under the instrument covers as you would a wall socket. Never touch anything or insert anything conductive under the instrument covers.

Warning	The Jupiter XR AFM and ARC2 controller contain internal voltages up to 165VDC, 0.5A. Use caution when handling system pieces to avoid electrical injury. These voltages may be lethal. There are no user-serviceable components inside the AFM and covers should only be removed by trained service personnel.

Three specific places are noted with warning stickers. Please power off the ARC2 AFM controller before handling connectors in these locations.

1.

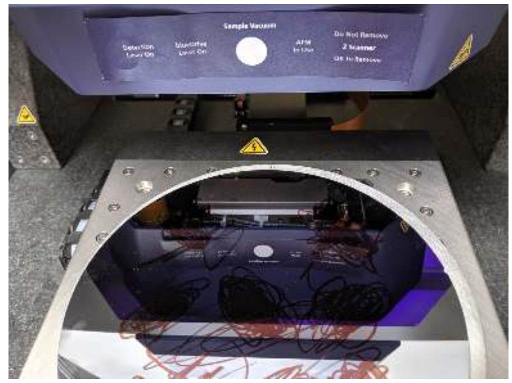
Power off the ARC2 AFM Controller:

- Press the power button so the light goes out.
- ONLY THEN, handle the cables as described in the following steps.

2.

XY scanner cable:

- Turn off power before handling the cable connecting to the back of the scanner. Note the High Voltage warning label.



3.

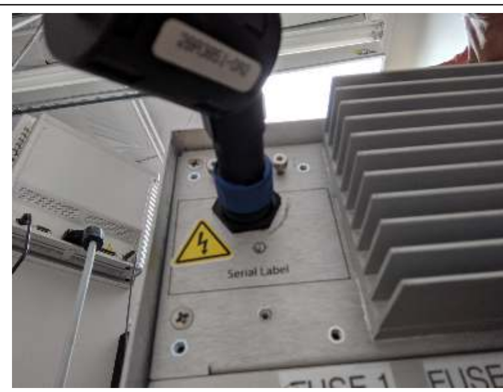
Backpack auxiliary port:

- On rare occasions, an accessory must be plugged into the auxiliary port on the backpack controller unit. Turn off power before removing the protective cover.
- The covers should always be in place if nothing is connected to the port.

4.

High voltage cable on ARC2 controller:

- This cable is typically installed by Asylum Research technicians and must be connected for the AFM to function properly.



1.5.4.2. Fuses

Adhere to the fuse ratings appropriate to the main supply voltage listed on the back side of the ARC2 controller.

Caution Not following the recommended ratings may cause the instrument to overheat or sustain damage.

1.5.4.3. Overheating

Keep the backside of the ARC2 clear. Cool air is drawn into the heat sinks on the back of the ARC2 controller and two fans exhaust warm air from the same place.

Caution Obstructing any part of the ARC2 back will cause power supplies and electronics to overheat.

Keep the top of the Cypher SPM backpack clear of items. The backpack is passively cooled and requires all the heat fins on the side and top be in open air.

Caution Do NOT place paper or notebooks on top of the backpack.

1.5.5. Instrument Weight

The Jupiter XR instrument is made of many heavy metal parts and large pieces of granite. The total instrument weight is 1200 lbs. or 550kg. The weight is typically distributed across four isolation pads with a total area of 64 square inches or 400 square centimeters.

Caution When the instrument is lifted from its wheels, the worst-case tipping angle is 17 degrees. While rolling on wheels, the worst-case tipping angle is 12 degrees, and the hood should never roll faster than 30 cm/s or 1 f/s on level ground. The hood should never be rolled down ramps of more than 6 degrees in slope, and the maximum speed down the ramp should be slower than 15cm/s. *Please contact your nearest service office to get additional instructions about moving the instrument!*

1.5.6. Power Requirements

Jupiter XR AFM power requirements are: 850 W - 100, 120, 220 or 240 V single phase; 50 or 60 Hz

1.5.7. System Setup Safety

Warning	It is highly recommended that you NOT uninstall, move, or reinstall the instrument without first contacting your local Asylum Research office to discuss the matter with our technical staff. In many cases, instrument damage may result. Also, instrument performance can suffer if it is not installed properly.

2. Hardware and Software Power Up

CHAPTER REV. 2305, DATED 03/01/2021, 17:38. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

Before You Start Before you start ANY of the following tutorials, the system must be properly started up.

We assume that you understand the aspects of running the Jupiter XR AFM system safely. For more information, see Section 1.5 on page 13.

Powerup and System Check

1. Power up the computer.

2. **Turn on power to the ARC2 controller:**
   - Press the power button as shown.
   - Turn the laser key to the ON position.

3.

Turn on the stage (pneumatics) controller:

- The switch is located at the rear, upper left-hand corner, as seen from the front.

4.

Vibration isolation using air:

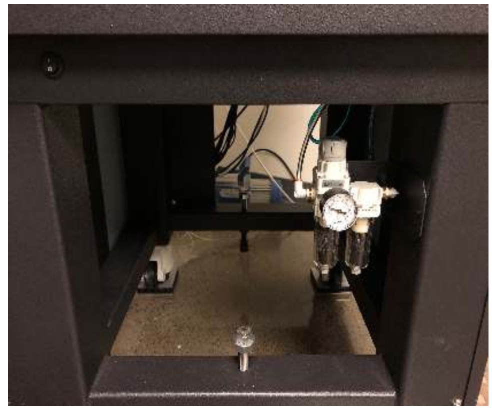
- Make sure house air is connected to the back of the AFM enclosure in the "Input" port.
- The air flows through a filter.
- The clean air is divided as follows:
  - air that goes towards the air isolators, and
  - air that goes out from the back of the enclosure "Output" port and into the stage controller, which directs it to the XY stage.

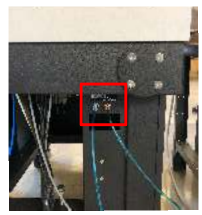
5.

OPTIONAL: Vibration isolation using active vibration isolation (AVI)

- AVI is placed under the granite and connected to the AVI controller by the installer.

  Note Even when AVI is used as vibration isolation, house air is still necessary for XY stage movements.
- Make sure house air is connected to the back of the AFM enclosure in the “Input” port.
- The air flows through a filter out from the back of the enclosure “Output” port and into the stage controller which directs it to the XY stage.
- The installer should make sure that no air is flowing into the air isolators.
- The AVI controller should be turned ON for operation.

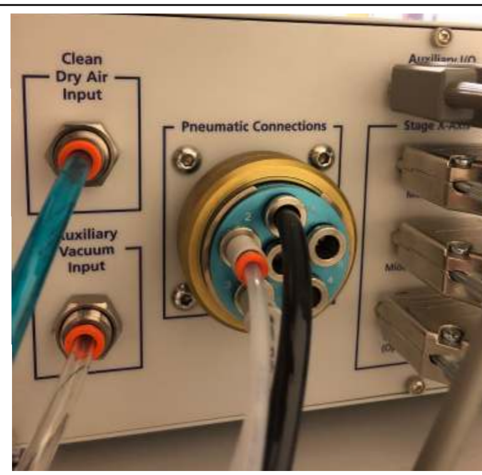




6.

Sample vacuum connection:

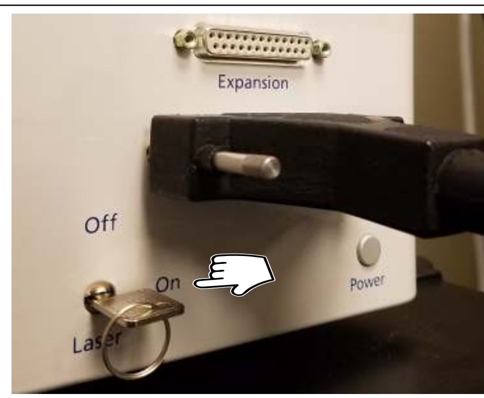
- Vacuum pump (or house vacuum) should be connected to the Stage controller and turned on.



7.

Double-check the laser key:

- Confirm that the laser key is in the ‘On’ position.



8. Locate the software shortcut to the Version 17 software on the desktop and double-click the icon to start the software.

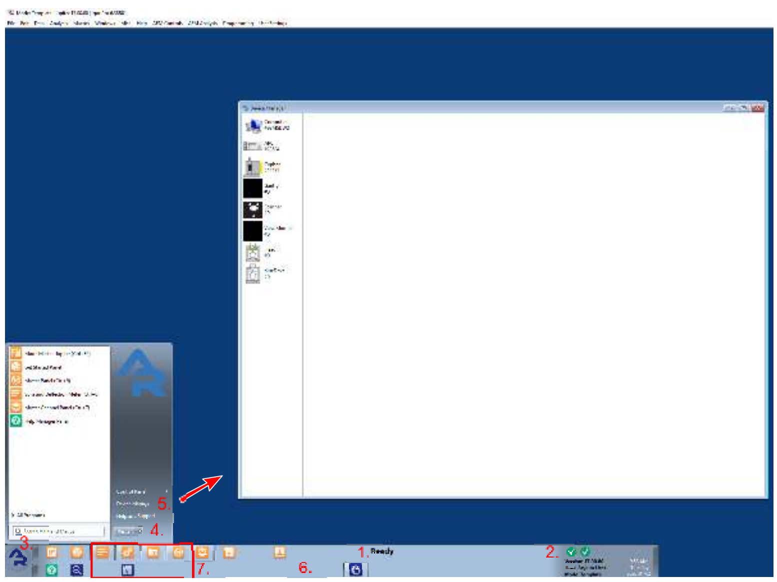
9.

System initialization check:

- During initialization, the software will not be responsive. Look at the bottom status bar for the initializing message.

- When the software is done, the status bar will say it is *Ready*.

10.



System status check:

- At the bottom of the software, you will find the Status Bar (6).
- These areas will be described in more detail later.
- Location 1 and 2 should read *Ready*, and green light checkmarks should appear.
- If some components are reported missing, check their connections. Once you have the cables secured and powered, click the ‘Rescan’ button (4). If that does not solve the problem, please contact support.

11.

The Mode Master window:

- The software should now display the Mode Master window.
- If not, click the 'Mode Master' button at the bottom of the screen: .

2.1. The Igor Pro Software Environment

2.1.1. Overall View

The Asylum Research software is primarily written within the programming environment of the commercially available software package Igor Pro, which is developed by WaveMetrics. Igor Pro itself has nothing to do with scanning probe microscopes. Rather, it is a stand-alone program that has extensive scientific graphing, data analysis, image processing, and macro programming capabilities.

Tip

The "Volume I - Getting Started" manual found on the WaveMetrics website (www.wavemetrics.com) takes two to three hours to complete and is an excellent way to learn about the basic graphing and analysis functionality of Igor Pro. Although it is not necessary to complete the Igor Pro portion of the "Getting Started" manual at this time, it is a highly recommended part of all new user training.

When you launched version 17 of the software, you opened an Igor Pro "Experiment" in which extra software specific to the operation of the AFM has been loaded. An Igor Pro experiment is the file that saves the state of Igor Pro.

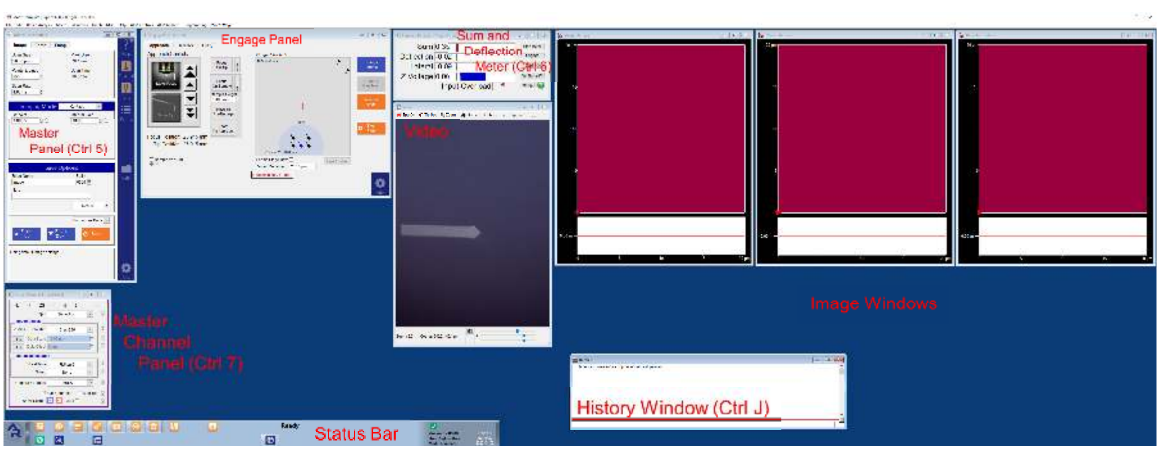


Figure 2.1.: Typical start up screen for the Asylum Research AFM Software after the Mode Master Panel has been closed. (A few image panels have been left off the right of the screen, which usually extends across the second monitor of your system.)

Refer to the screenshot in Figure 2.1 on page 31 as we introduce the various controls and data displays for frequently used AC Mode imaging technique, shown clockwise from the upper left. (Note that if you are viewing this on a computer, you can zoom into the screenshot for a closer view.)

Master Panel (Ctrl + 5) Upper, left-hand window. It has several tabs with controls and data displays, including:

- Main AFM imaging
- Thermal Cantilever thermal spectroscopy (see the ARApplicationsGuide.pdf, Section on spring constant calibration)
- Force Cantilever force vs distance curves
- Tune Cantilever resonance tuning
- Fmap Maps of force vs distance curves

Master Channel Panel (Ctrl + 7) During imaging, multiple data streams (such as height, cantilever amplitude and phase) return from the AFM to the computer. This panel contains information about those data streams and allows for some real-time scaling and processing.

Igor Command Window (Ctrl + J) The Igor Command window has two parts: the history, and the command line. On occasion, items executed by clicking software buttons will generate some output here. Power users can type commands at the command line to accomplish a variety of advanced tasks. If you followed the Igor “Getting Started” recommended in the Tip on page 31, you will know all about this window.

Sum and Deflection Meter (Ctrl + 6) Also called the “S&D Meter”. This is real-time display of various data such as cantilever deflection, amplitude, piezo voltage, and various other user definable channels. Also contains buttons for engaging and withdrawing the AFM tip.

Image Windows For each active channel on the Master Channel Panel, one image will appear on the screen. They balloon to proper size as soon as scanning starts. The windows display in real time, line by line, the sample topography (height), phase, amplitude, voltage, or any other measured quantity acquired as the sample is scanned. There is usually one such window per active tab in the Master Channel Panel (lower left-hand window). While these windows are primarily data displays, right-clicking with the mouse can activate various commands, such as *Zoom* and *Translate*. A white area at the bottom of this window shows you a real-time “oscilloscope view” of the most recent line of image data. This can be especially useful when tuning imaging feedback parameters.

Q Oops! I accidentally closed one of the control panel windows. How do I get it back?

A You can reactivate the panels via *AFM Controls* on the top menu bar.

Q How do I get the Mode Master Panel to appear again?

A Click the ‘On’ button near the bottom of the screen. When you select a new mode, the appropriate windows will appear, and the SPM controller will reconfigure itself accordingly.

2.1.2. Video Panel

Top Menus

- *Spot On*: when clicked, moves the detection laser to current position of the cursor
- *Tip Position*: when clicked, places a crosshair to indicate tip position
- *Capture*: video view is captured and saved

Arrows and Sliders

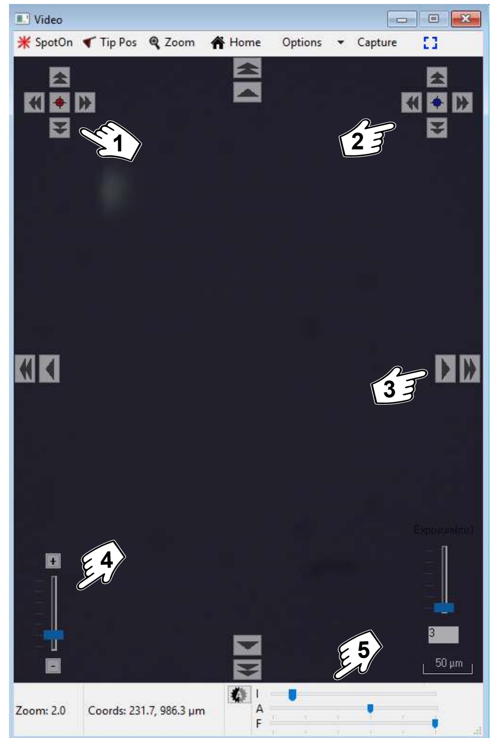
1 Detection Laser adjustment motors

2 blueDrive adjustment motors

3 Stage moves

4 Video Zoom adjustment

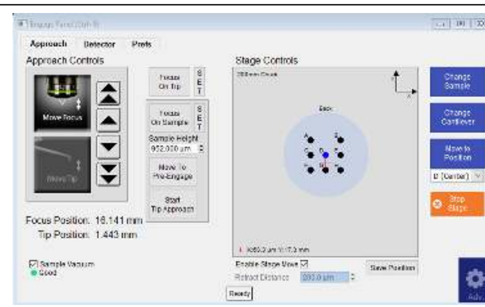
5 Slider adjustments: Illumination (**I**), Aperture (**A**) and Field of View (**F**) adjustment



2.1.3. Engage Panel

Engage Panel functions: The Engage Panel enables control of the motors for:

- objective and tip movements
- XY stage movements
- detector movements



2.1.4. Menu Bar

The menu bar is located along the top of the screen. May controls can be invoked by items on the menu bar. Menu items to the left are typically standard Igor Pro items, with some Asylum Research functionality. Items to the right of the Help menu are exclusively AFM related.

2.1.5. Status bar

Along the bottom of the screen, icon controls relate to the status of connected instrument components. The low-level software version is also displayed. Reference Figure 2.2 on page 34.

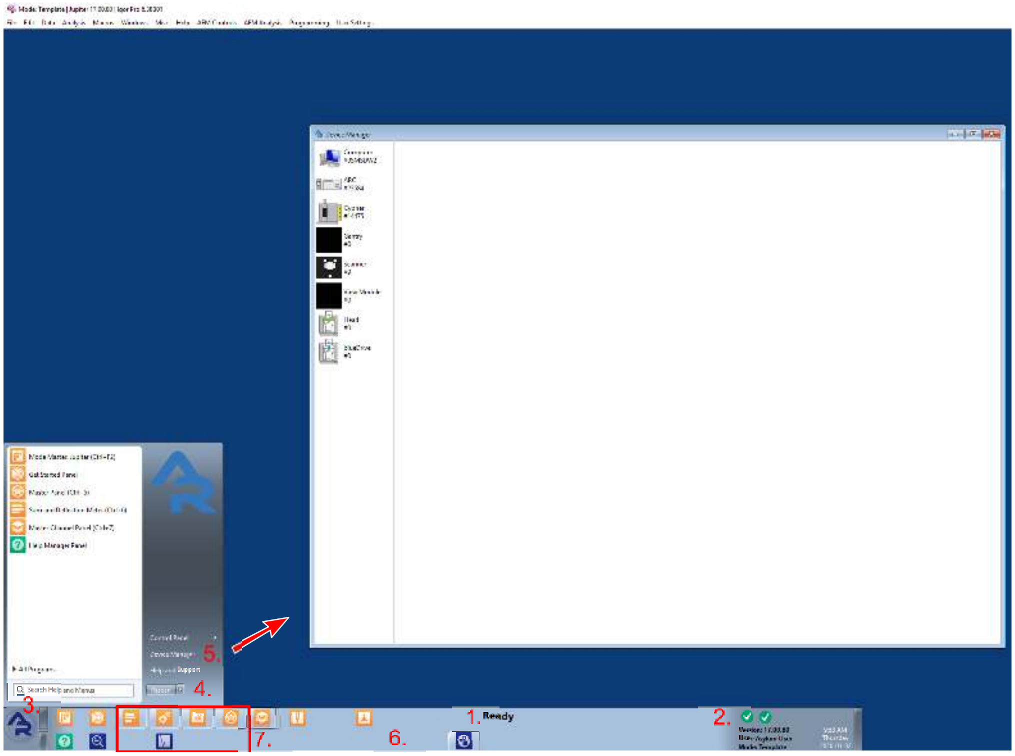


Figure 2.2.: Status Bar

While we do not want to get bogged down with the details of all of these controls, it is good to have a basic grasp of them.

1 Igor Pro Status If Igor is ready to accept a software request from you, *Ready* is shown on the status bar. If it is busy calculating, an 'Abort' button and a rotating quartered circle are shown.

2 System Status If you are missing hardware, or if there is a critical error, status notification is shown here.

3 stARrt Button Click 'AR' to display and navigate Help, Support, Device Management, and all of the various panels in the software.

4 Rescan Smartstart Bus Click 'Rescan' when adding new components to the system, such as heaters, different cantilever holders, etc.

5 Device Manager Click to see which components are communicating with the controller. Individual information, such as temperature, serial number, etc., for a component can be accessed by clicking the icon button for that component and its individual menus.

6 Current Operations Displays which operation the system is currently performing, such as thermals, scanning, etc. Some actions have progress bars that are shown here. Additional warnings may appear here as well, such as for a hard drive filling up.

7 Quick Panel Buttons include the following:

 Mode Master

 Master Panel

 Video Window

 Hides / Shows Real Time Image Windows

 Hides / Shows Offline Image Windows

 Help Browser

Real Time? Offline?

These terms have been around for a long time in image processing and acquisition systems. “Offline” has nothing to do with network connection.

Real Time Window Displayed data that are in the process of being acquired.

Offline Window Displayed data from a saved file.

3. Tutorial: AC Mode Imaging in Air

CHAPTER REV. 2322, DATED 03/19/2021, 18:41. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

This tutorial provides a quick path to learning the basic operation of the Jupiter XR. The tutorial includes a set of steps that will teach a new user with a basic understanding of AFM operation how to obtain an AC mode topography image in air.

Note All new users should complete and understand this “AC Mode Imaging in Air” tutorial before attempting any imaging.

Jupiter XR is a research grade instrument, and improper use of the instrument can cause both damage to the instrument and injury to the user. This tutorial will take approximately three (3) hours.

Before You Start

- You should understand the aspects of running this system safely. Please review the Safety section of the user manual.
- You should be familiar with the basic names of the hardware components and software controls.
- You should have powered up Jupiter XR and launched the software.

3.1. Required Materials

This tutorial is designed to be performed, not merely read. You will learn the most if you operate the instrument yourself, with an experienced user watching and providing advice.

It will be necessary to gather the following items prior to beginning the tutorial:

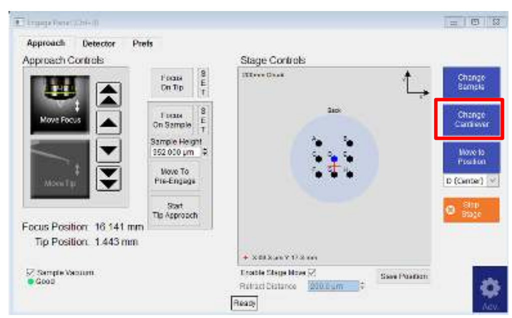
1. Cantilevers (aka Probes): You will need a FS-1500 cantilever, which is manufactured by NanoWorld. The FS-1500, with a spring constant of ~10 N/m and a resonance frequency of ~1500 kHz, is a good probe for AC mode imaging in air. Every Jupiter XR ships with a package of FS-1500s. If these cantilevers are unavailable, any cantilever with a similar spring constant and resonance frequency should work fine.
2. Sample: The tutorial will use the calibration grid included with the Jupiter XR AFM instrument.
3. Tweezers: It is preferable to use tweezers with curved tips (for example, Asylum Part# 290.102).
4. Phillips screwdriver is required.

3.2. Loading the Cantilever and Sample

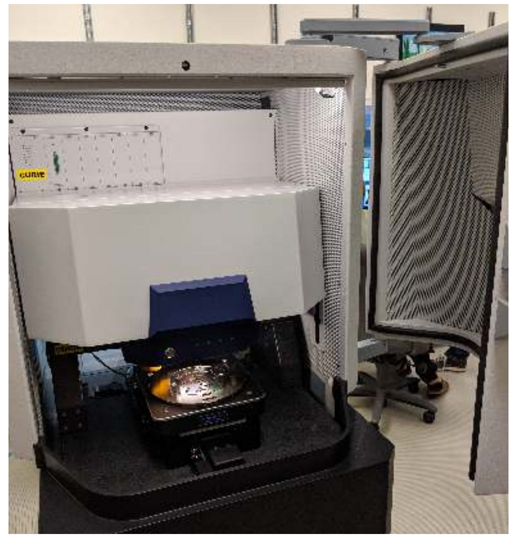
This section covers sample and cantilever loading as well as the coarse approach of the cantilever tip toward the sample.

1. **Move the XY and Z scanners into "Change Cantilever" position:**

   - Click the 'Change Cantilever' button on the 'Approach' tab of the Engage Panel. The following occurs:
     - Z stage (tip) will move up.
     - Objective (focus) will move up.
     - XY stage will move to the back and center to give access to the Z scanner.



2.



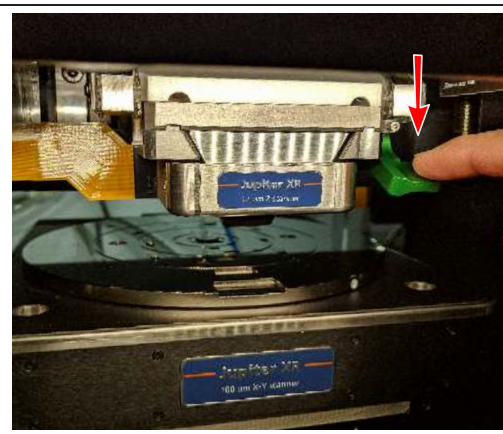
Open enclosure:

- Turn the latch counterclockwise.
- Pull on the door and guide it to the side.

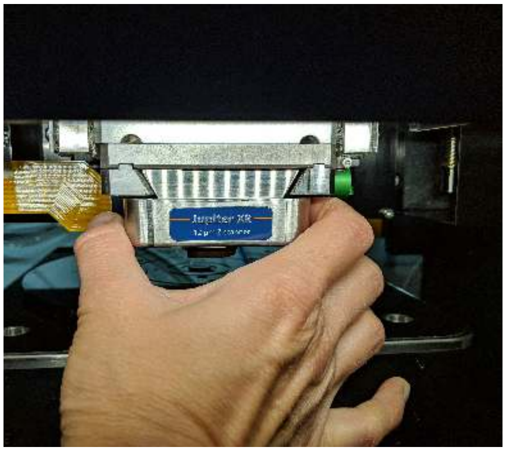
3.

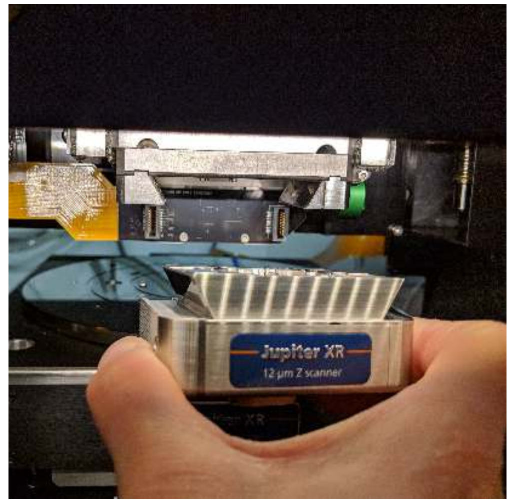
Unlock Z scanner/ cantilever holder:

- Release the Z scanner from the AFM by moving the green lever down and under.



4.





Remove the Z scanner/ cantilever holder from the AFM:

- Hold the Z scanner firmly.
- Slide the Z scanner out of the AFM.

5.

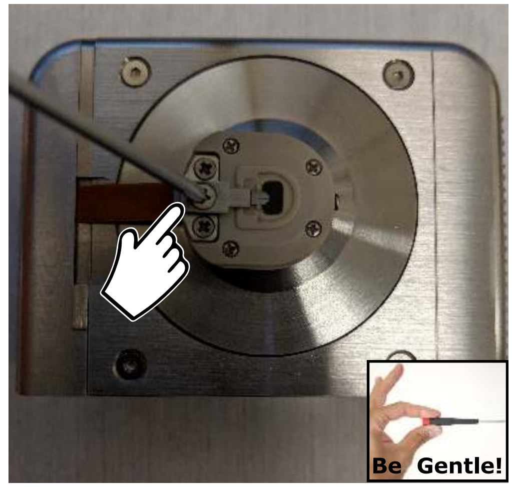
Gently place the Z scanner on the table:

- The Z scanner should be placed on the table with the cantilever holder facing up.

6. **Remove the used cantilever:**

- Loosen the clamp by turning the middle screw one turn, just to the point of freeing the cantilever.
- Remove the old cantilever with tweezers.

Good Habit Blow clean the area under the cantilever clip with *clean* compressed gas. Bits of silicon and other debris can lead to a poorly seated cantilever and suboptimal AC mode images.

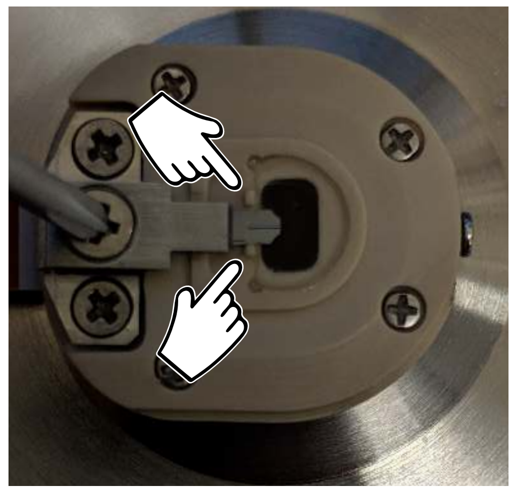


7. **Insert the new cantilever:**

- With tweezers, slide the cantilever chip under the clip.
- Center the cantilever tip (approximately) between the two bumps.

Caution Do not push the cantilever chip too far back. This can cause misalignment. We will check for this in a few steps.

Note The cantilever holder was designed to be resilient, so do not worry about scratching it with tweezers.



8. **Tighten the screw:**

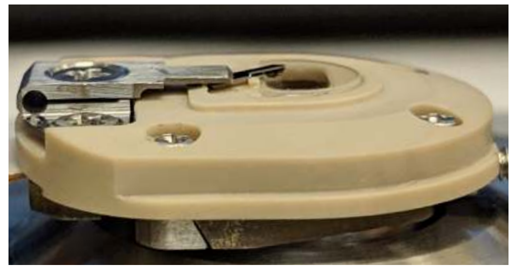
- Gently tighten the clip's screw.
- The chip should not be able to move if nudged with the tweezers. Probes that are firmly mounted perform best during AC mode imaging.

Caution Do not overtighten the clamp on the cantilever holder as this can crush the chip, strip the screw threads, and/or result in an excessively bent clamp!

9.

Inspect the cantilever seating:

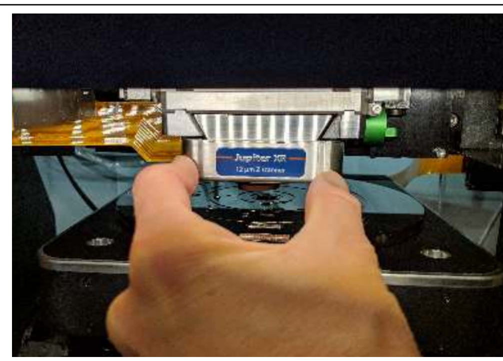
- Hold the Z scanner so you can look from the side between the cantilever clip (a low power microscope or a jeweler’s loupe, 10× is recommended).
- Check that the cantilever chip is parallel to the mounting surface and glass prism facet.
- If the probe is mounted too far back, it causes an improper angle, and you will not be able to align the laser when the cantilever has been loaded into the AFM. You can correct the position by loosening the screw and moving the cantilever forward in the pocket. Tighten the screw and inspect the “seating” again.



10.

Place the Z scanner/ cantilever holder assembly back in the AFM:

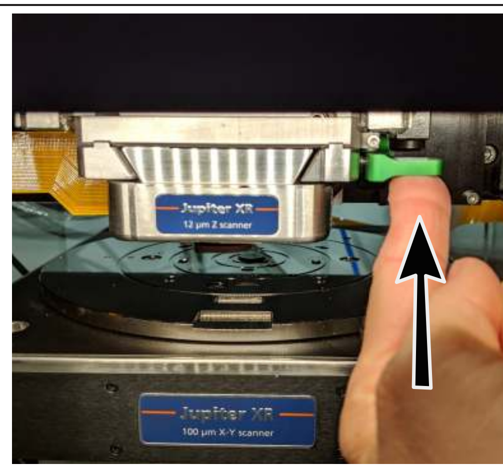
- Hold the Z scanner firmly.
- Use the dovetail to guide the Z scanner into the AFM.
- Gently push the scanner all the way in.



11.

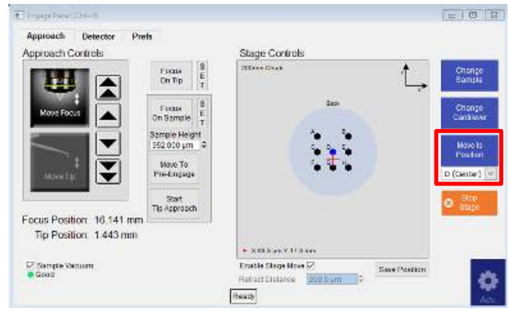
Secure the Z scanner/ cantilever holder assembly in the AFM:

- Secure the Z scanner in the AFM by moving the green lever up.



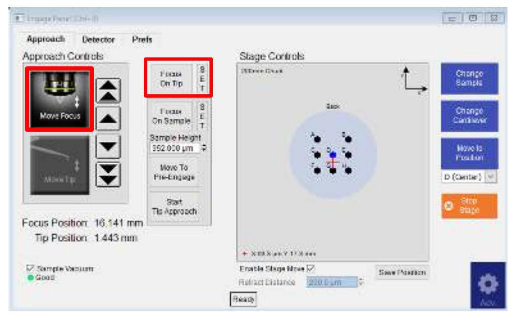
12. **Position XY stage to focus on the tip (cantilever):**

- Click 'Move to Position', on the 'Approach' tab of the Engage Panel.
- By default, the XY stage will move to the center position *D* of the chuck, and the focus will be on the tip.

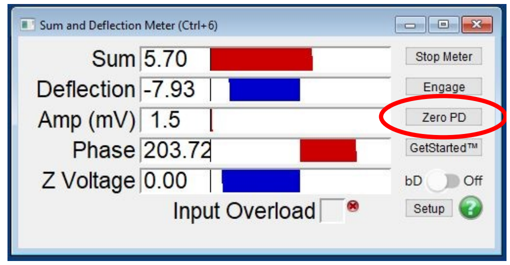


13. **Set the focus on the tip (cantilever):**

- Make sure 'Move Focus' is selected on the 'Approach' tab of the Engage Panel.
- Use the arrows beside the objective icon to move the focus, until the cantilever looks sharp in the video panel.
- Once the tip is in focus, click 'Set', located beside the 'Focus on Tip' button.



14.



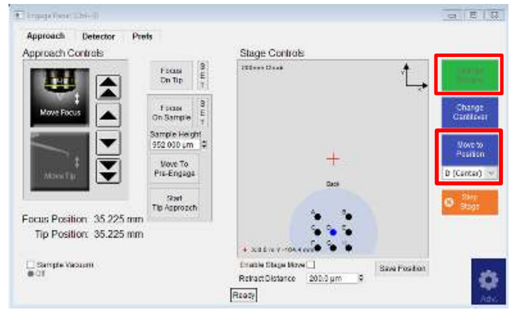
Align detection laser on the tip:

- Open the Video window.
- Place the mouse cursor over the cantilever.
- Right-click on the area of the cantilever where you want position the detection laser.
- Select 'SpotOn'.
- Laser location on the tip can be adjusted using the arrows in the top left corner of the Video panel.
- Zero the deflection signal by clicking 'Zero PD' on the Sum and Deflection Meter panel.

15.

Place sample (metal puck) on sample chuck:

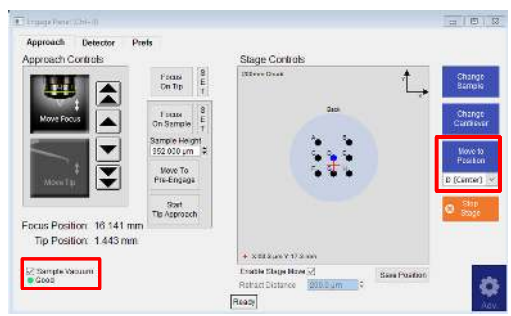
- On the Engage Panel, click 'Change Sample'.
- If the sample is glued to a metal puck, place the sample on one of the eight (8) magnet locations on the chuck.
- On the Engage Panel, click 'Move to Position'. Choose the sample location from the pull-down menu of the Engage Panel. By default, the XY stage will move to the center position *D* of the chuck, and the focus will be on the tip.



16.

Place sample (wafer) on sample chuck:

- If the sample is a wafer:
  - Make sure that the vacuum rings corresponding to the sample size are open (screw and O-ring are removed).
  - If you want to use locating pins to align the wafer on the chuck, place the pins in the chuck.
  - Place the wafer on the chuck.
  - Turn on the external vacuum pump. (Optionally, the system might be connected to house vacuum.)
  - Enable the sample vacuum by selecting the 'Sample Vacuum' check box.
- On the Engage Panel, click 'Move to Position'. Choose the sample location from the pull-down menu of the Engage Panel. By default, the XY stage will move to the center position *D* of the chuck, and the focus will be on the tip.



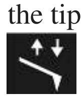
17.

Close enclosure door:

- *Gently* close the door.
- Turn the latch clockwise.

18.

Move cantilever toward sample:

- Look at the sample through the window of the enclosure.
- Place your eyes level with the cantilever and sample, so that you can clearly see the gap between cantilever and sample.
- Use the joystick to approach the tip to the sample by holding the  (up/down) button and pushing the joystick down. This will lower the Z scanner/ cantilever holder and objective toward the sample.
- Close the gap between tip and sample to about 1.5 millimeter. There is no harm in playing it safe and stopping a little farther away, as it would only cause the automated engage to take a little longer.

Warning: Nothing but your attentiveness will prevent the cantilever holder from crashing into the sample. If you crash the cantilever holder, you may cause *SEVERE* damage to your cantilever holder and scanner.

3.3. Engaging the Cantilever on the Sample

3.3.1. Bringing the Cantilever Close to the Sample

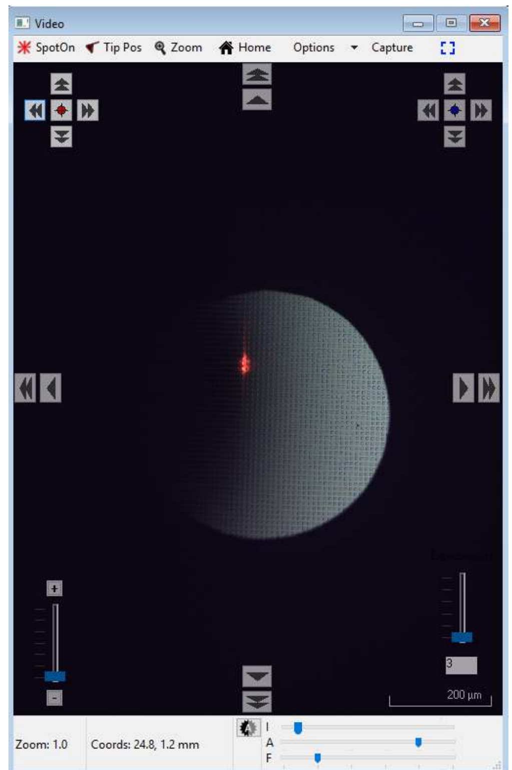
Before you start this section, you should have done the following:

- started up the software
- initialized the XY stage
- positioned the cantilever about 1.5 mm above the sample

1.

Video window controls:

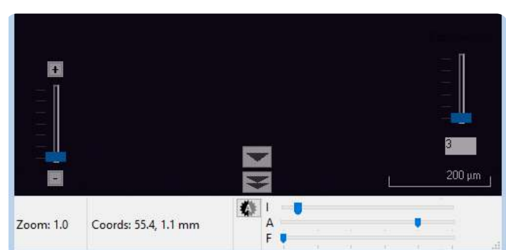
- **SpotON**: detection laser alignment tool
- **Tip Pos**: cross hair to indicate tip position
- **Zoom**: enlarged focus of the current image
- **Capture**: snapshot of the current video image
- **I**: Illumination
- **A**: Aperture diaphragm
- **F**: Field diaphragm



2.

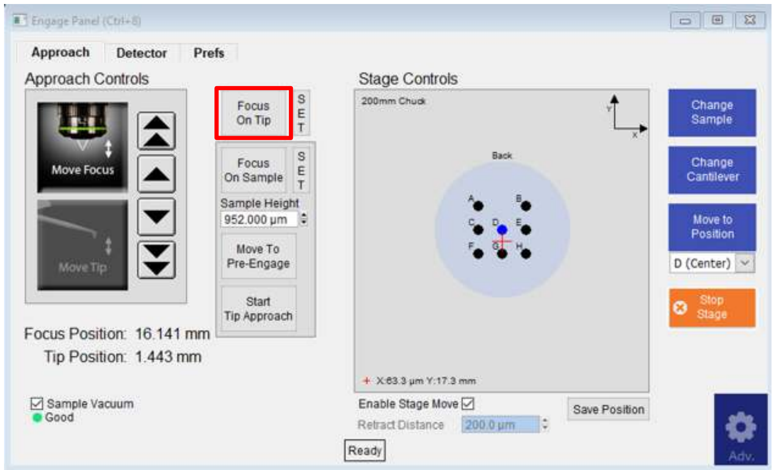
Setting video zoom:

Important Slide the vertical slider (lower left corner of the Video window) all the way to the bottom. “Zoom 1.0” will be indicated just below it.



3. Familiarize yourself with the ‘Approach’ tab on the Engage Panel.

Caution: Failure to properly use the ‘Approach’ controls may lead to severe damage to Jupiter!



Focusing the tip:

4.
- On the Engage Panel, click 'Focus on Tip'. This will move the objective lens to the position where the cantilever was last in focus.

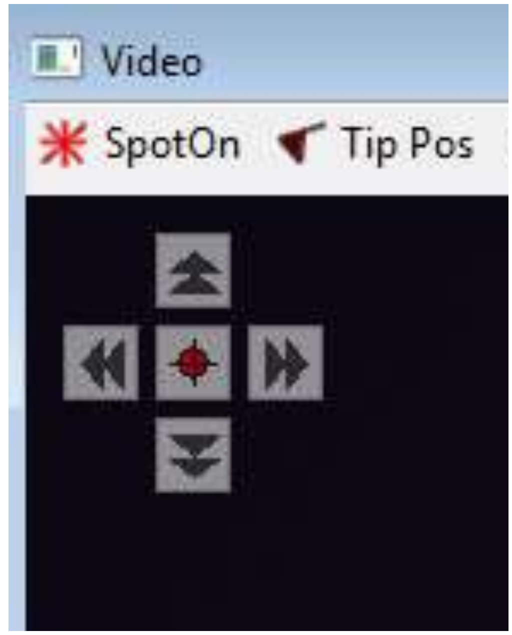
Notes

- Since the 'Focus on Tip' button only moves the objective to the *last known tip focus* and does not actually perform an auto-focus, the cantilever may not be perfectly in focus after the motors are finished moving. (Cantilever chips have varying thicknesses, and how the cantilever chip gets positioned in the holder will affect the sample position.)
- Do not be alarmed if the cantilever is not visible at all. This usually means that when you placed the cantilever chip in the holder, you put it outside the ~1 mm field of view of the objective. This will be addressed in the next step.
- If you hit the 'Focus on Tip' button and nothing happens (i.e. the motors do not move), it just means that the objective is already at the tip focus point. Note that after the motors are homed, the objective is moved automatically to the tip focus point.

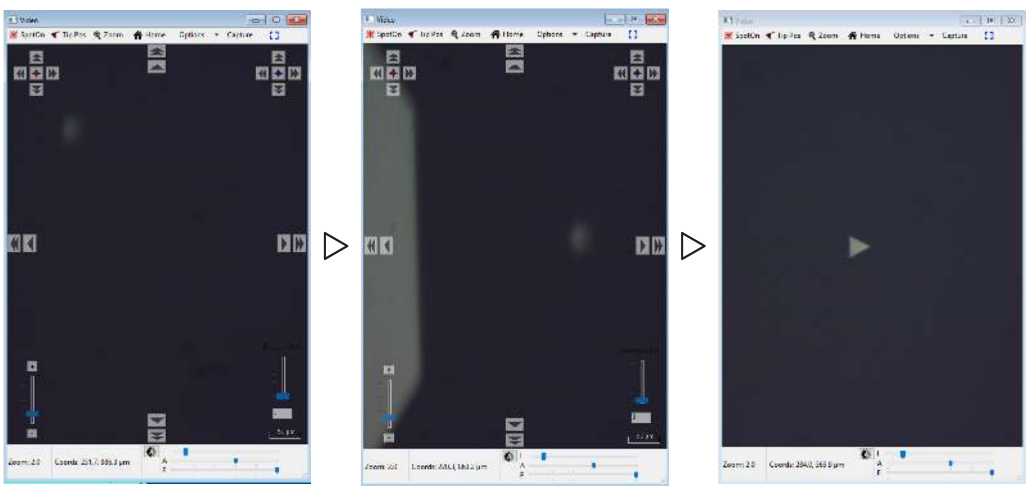
5.

Locating the cantilever in the image:

- The goal of this step is just to get the cantilever into the field of view. Use the four (4) arrows at the top left of the Video window to look for the edge of the cantilever chip and/or the cantilever. As mentioned in the previous step, the cantilever may not be perfectly in focus.
- *If you see nothing at all in the field of view, most likely the cantilever chip is located to the left of the field of view.* Use the left arrow to move the objective towards the left and look for the cantilever chip edge.



6.



Cantilever views:

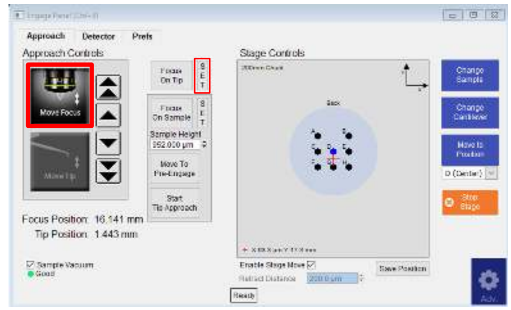
- Left image: First view of cantilever.
- Center image: Cantilever found and roughly centered on screen.
- Right image: Cantilever in focus.

7.

Setting the tip focus position:

- On the 'Approach' tab of the Engage Panel, click 'Move Focus' button.
- Use the arrow buttons for positioning until the cantilever is in focus. (Single arrows are slow; double arrows are fast.)
- Click 'Set' (next to the 'Focus on Tip' button).

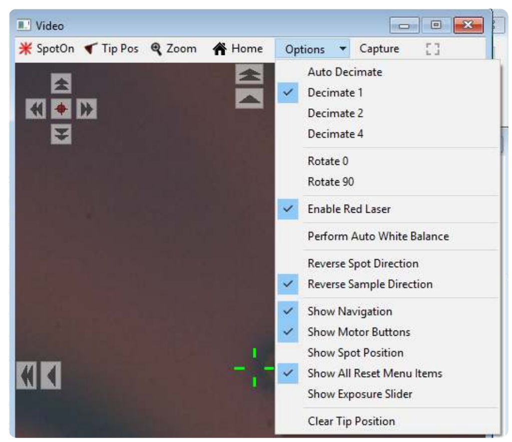
Important The cantilever is at an 11° angle, and the whole lever cannot be in focus at once. Bring the end of the cantilever closest to the tip in focus.



8.

Optional image enhancement and zoom (particularly useful for small cantilevers):

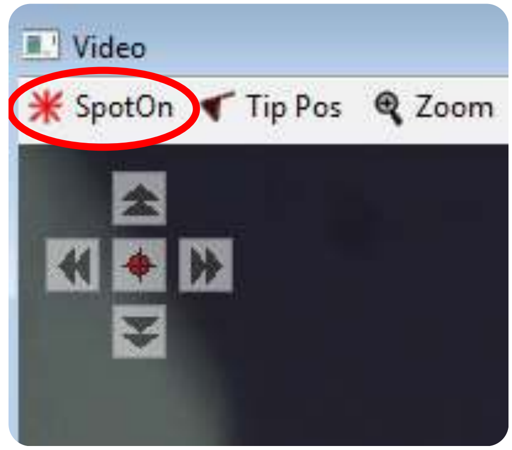
- If you want to see the image with more resolution, select *Decimate 1* from the *Options* pull-down menu. This brings all of the pixels down from the video camera but will slow the screen update rate.
- To the left of the *Options* menu is a 'Zoom' button. When clicked, this button changes the cursor into a magnifying glass. To get an enlarged view, click on the cantilever.
- Both items may improve your ability to focus from the previous step. If you do refocus, be sure to click 'Set', next to the 'Focus on Tip' button.



9.

Centering laser spot on cantilever:

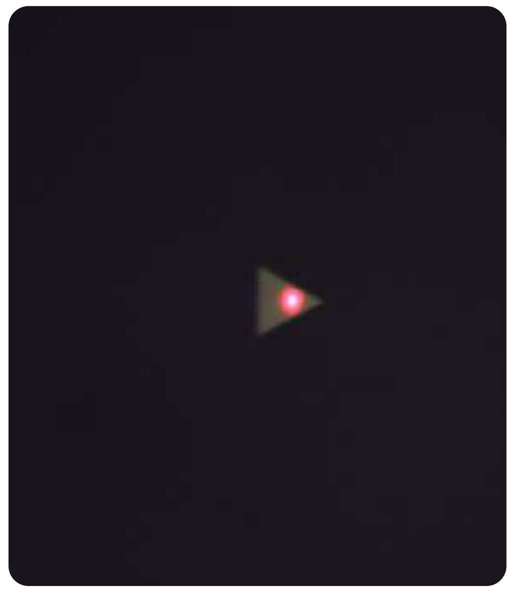
- Click the ‘Spot On’ button at the top left of the Video panel. The mouse pointer will acquire some small red lines.
- Now click on the cantilever where you want the laser to be placed.
- Alternately, right-click on the center of the cantilever, and then select the ‘Spot On’ option.



10.

Observing spot on lever:

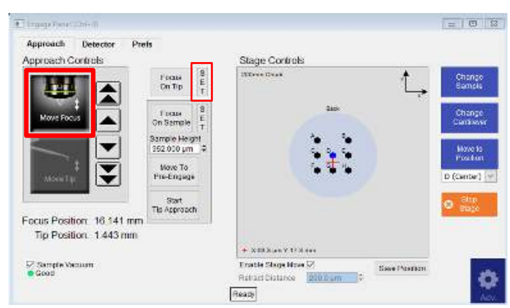
- Motors will move and align the laser spot where you clicked.
- The spot position does not need to be perfect here, only roughly centered on the cantilever to produce a reflected beam (as measured by the ‘Sum’ signal on the Sum and Deflection Meter panel).
- If needed, the spot position can be fine-tuned in a later step.



11.

Locating sample surface optically:

- On the ‘Approach’ tab of the Engage Panel, use the down-arrow keys to motor the microscope objective down toward the sample until it comes in focus. Use the up-arrows if you overshoot.
- Note that single arrows are slow, and double arrows are fast.
- Once in focus, click ‘Set’, located next to the ‘Focus on Sample’ button. Note that the sample height value updates.

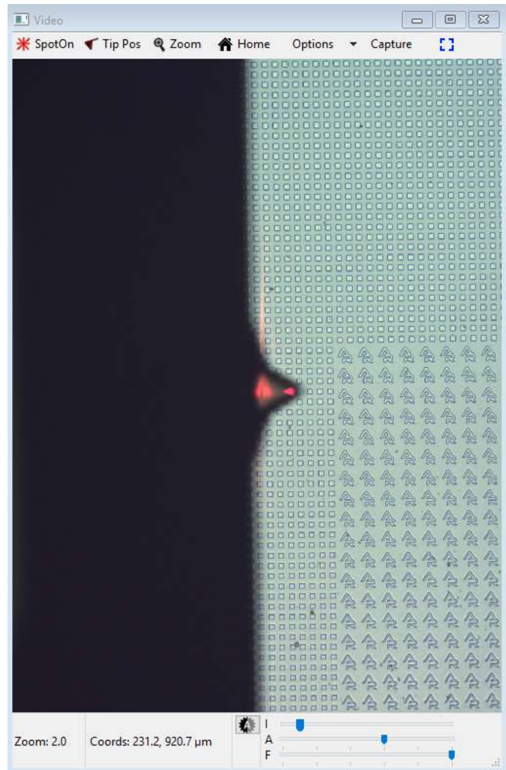


12.

Observing sample surface optically:

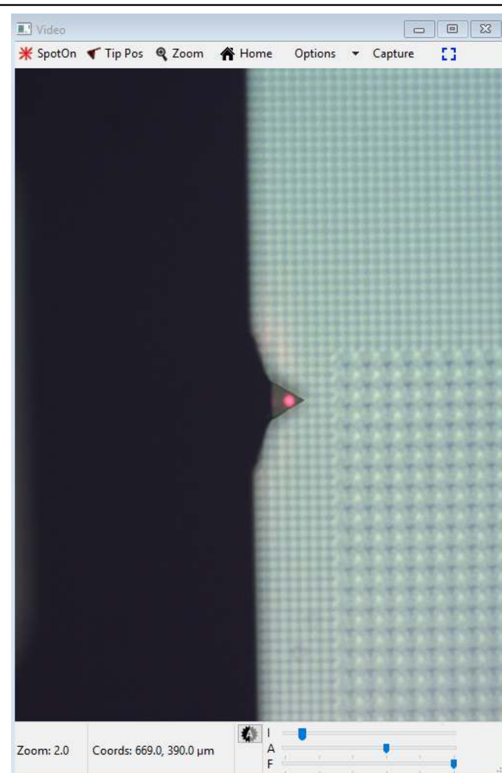
- Features may be hard to see at Zoom = 1 and auto decimation turned on. Adjust those settings until the sample is in focus.

Fun Now that you have stored the tip and sample position, you can repeatedly click the 'Focus on Sample' and 'Focus on Tip' buttons to go back and forth between tip and sample.



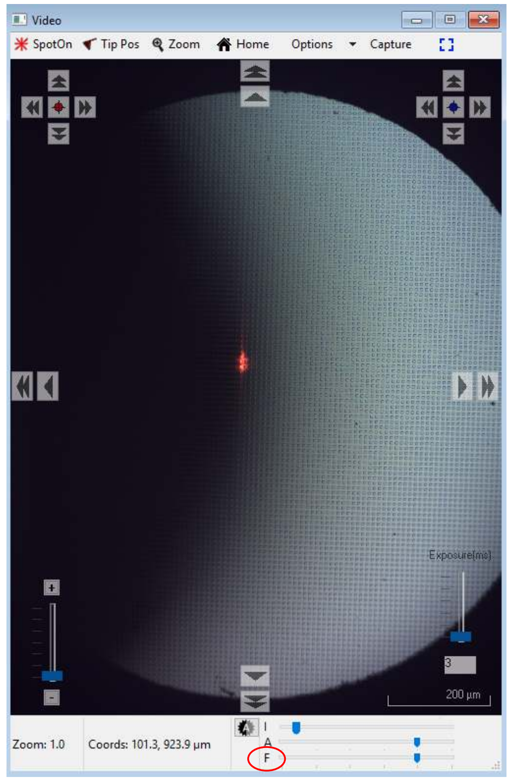
Q I can't seem to focus on the surface of my *rough sample*.

A The objective has a limited focal length and can only focus ~1.5 mm past the cantilever focus. If you did not manually move the cantilever close enough to the surface (using the joystick), you will never get a focused image of the sample. In this case, click the 'Move Tip' button in the Engage Panel, approach the sample carefully, then click the 'Move Focus' button to try to find the sample focus again.



Q I can't seem to focus on the surface of my *smooth sample*.

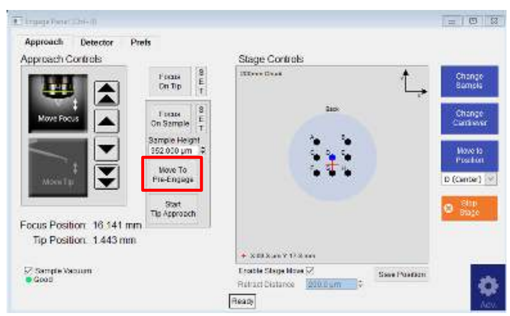
A Perfectly reflecting samples may not offer enough features to allow the focus to be determined. In this case, adjust the Field Diaphragm slider (marked with an "F") on the Video panel, until you see a dark circle on the screen. As you focus down, this circle will become sharper. When the ring is in focus, as shown in the image at right, so is the sample.



13. **Preparing to land the tip:**

- Click the 'Move to Pre-Engage' button. Motors automatically bring the tip to 50µm from the surface.

Caution If you set a bad sample height and/or tip position, you may ram your cantilever into the sample and break it. A firmware safety feature immediately cuts motor power when the optical detector fails to measure reflected light from the broken lever (= when the SUM decreases). This prevents the cantilever holder from ramming the sample.

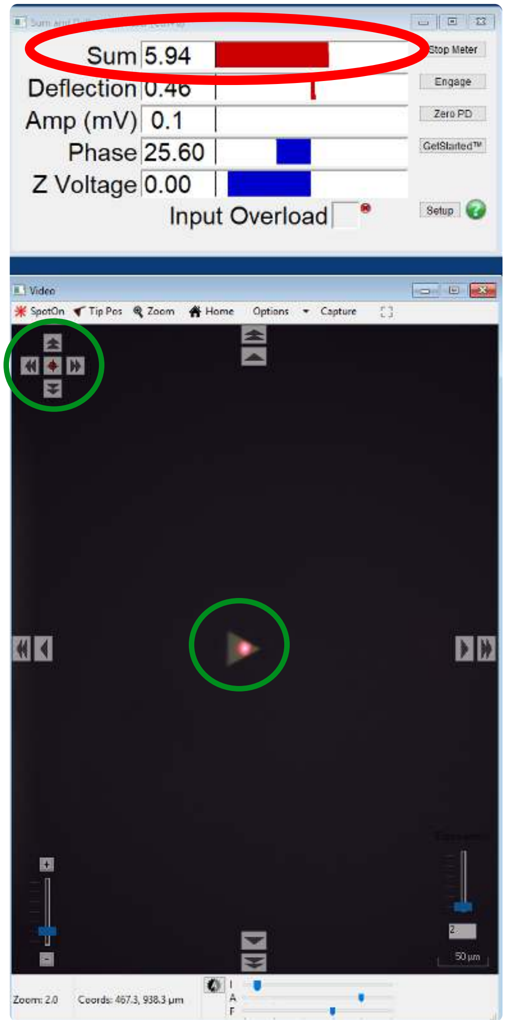


14.

Fine tuning spot position:

- At this point, you should adjust the spot position so that it is near the end of the cantilever. Use the controls in the upper left corner of the Video panel.
- Note that a decrease in SUM Signal indicates that light is spilling off the cantilever, which is undesirable and should be avoided.

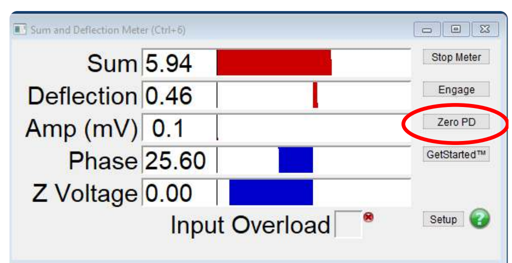
Tip For fine positioning hold down the 'Shift' key on your keyboard while clicking the onscreen buttons that move the cantilever under the laser spot.



15.

Centering the laser on the photo detector:

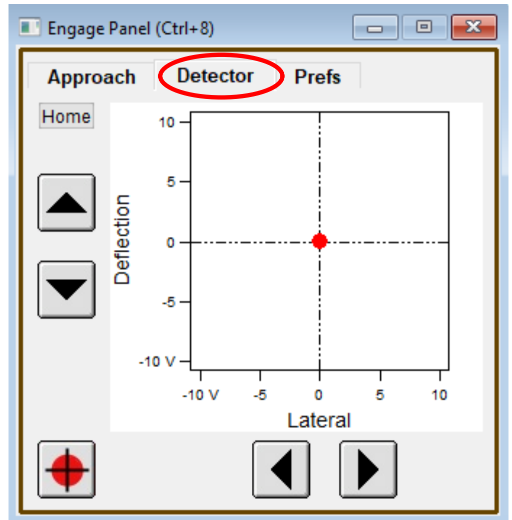
- Click the 'Zero PD' button on the Sum and Deflection Meter panel and watch the *Deflection* signal go to zero (0). This action optimizes the position of the laser on Jupiter's photo detector.



16.

Centering the laser on the photo detector:

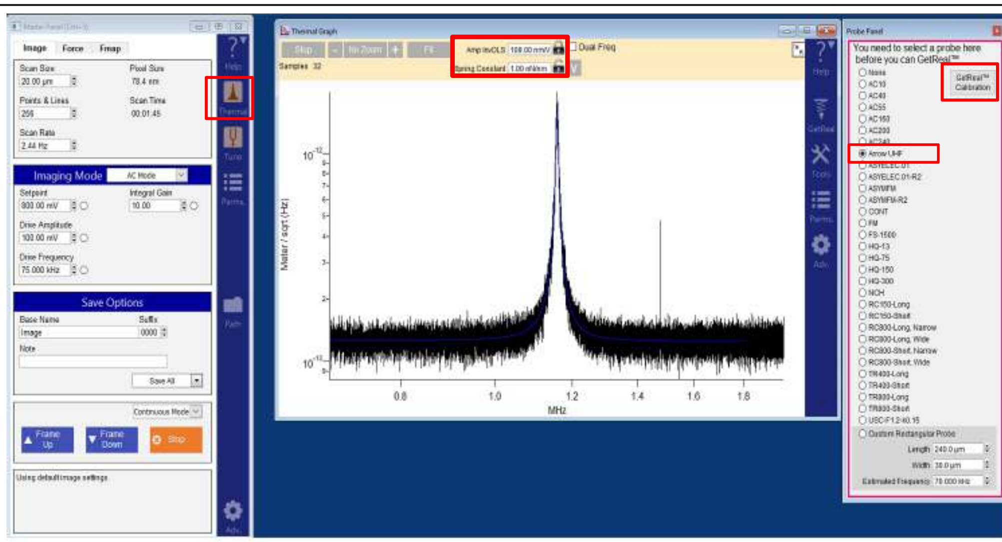
- The photo detector can be further adjusted by using the arrows on the 'Detector' tab of the Engage Panel.



3.3.2. Tuning the Cantilever and Setting Scan Parameters

Since this tutorial focuses on AC imaging, we will proceed to tune the cantilever.

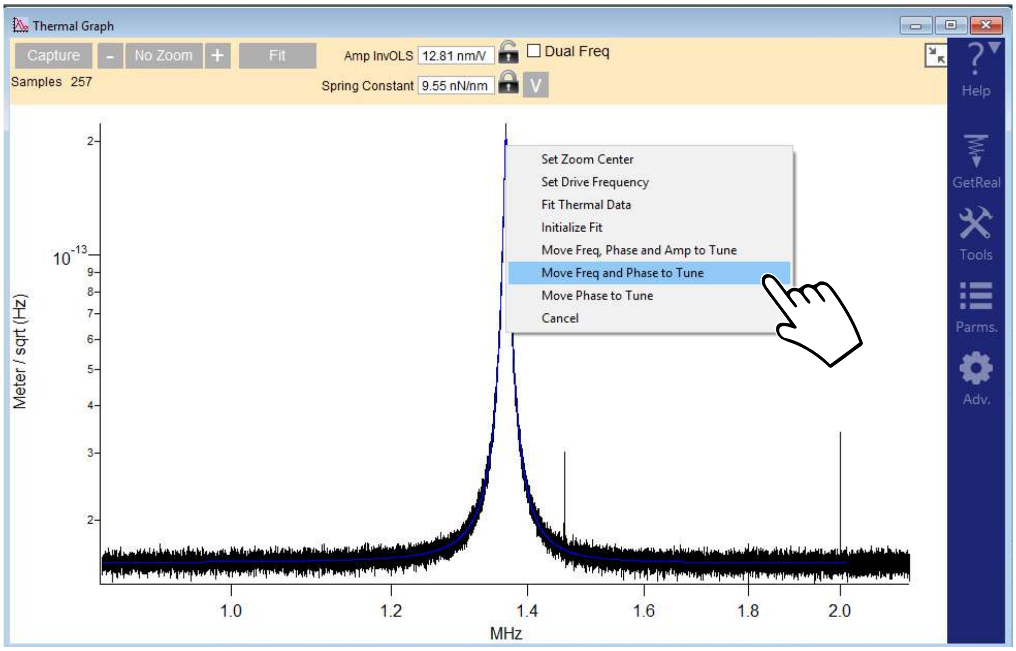
1.



Calibrating the cantilever:

- Click the 'Thermal' icon on the Master Panel.
- Select the probe type from the Probe Panel menu.
- Click the 'GetReal Calibration' button.
- As the cantilever is calibrated, the *Amp InvOLS* and *Spring Constant* values are updated.

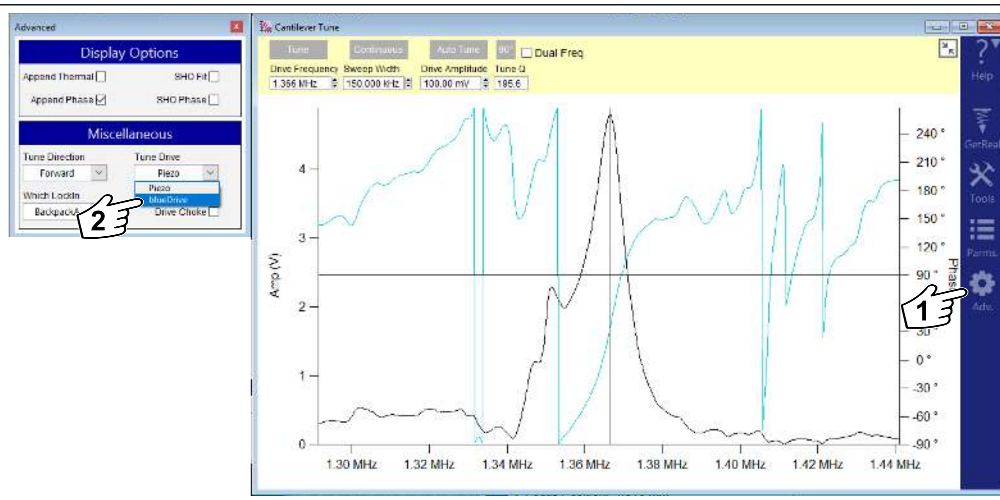
2.



Initiating cantilever tune:

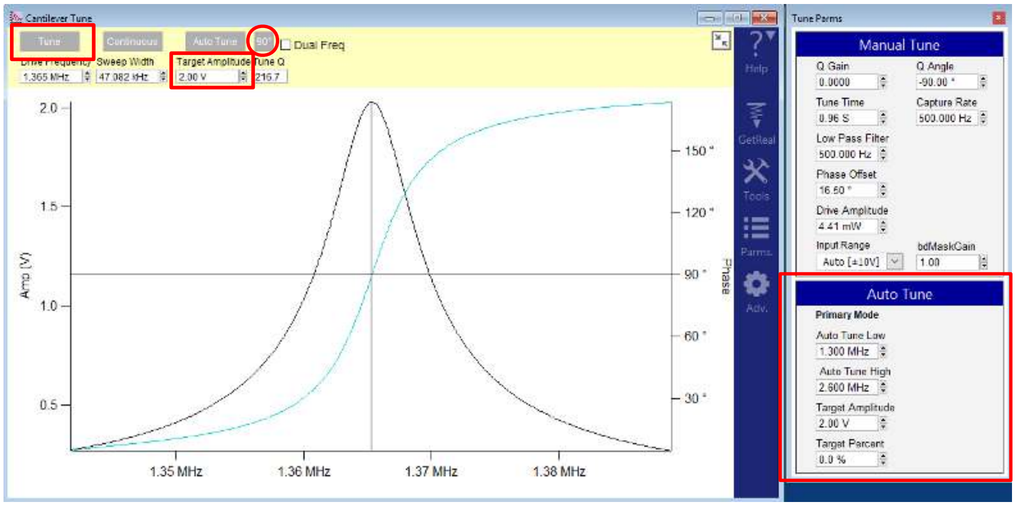
- After the 'GetReal Calibration' has completed:
  - Right-click on the resonant frequency peak.
  - Select *Move Freq and Phase to Tune* to transfer the resonant frequency value of the cantilever onto the Tune panel.

3.



Turning on blueDrive 1. Click 'Adv' (gear icon on the right side-menu) to open the Advanced panel.
2. Select *blueDrive* as the 'Tune Drive.'

4.



Observing the tune result:

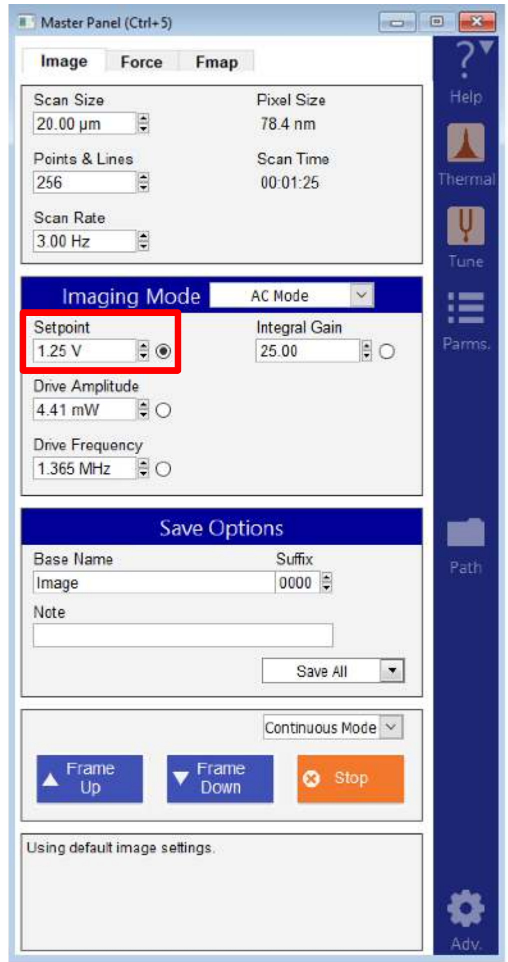
- Enter the desired amplitude in the *Target Amplitude* field and click ‘Enter’ on your keyboard.
- Click the ‘Tune’ button to update the tune graph.
- Click the ‘90’ button to set the phase to 90 degrees with regards to the tune peak.
- For the Auto Tune to function correctly, enter the low and high frequencies and then encompass the resonance peak of the cantilever.

5.

Setting scan parameters:

- On the 'Image' tab of the Master Panel, choose the scan parameters:
  - Set the *Setpoint* value to 1.25 V (since the free amplitude is 2 V) under Imaging Mode.
  - Check that the other scan parameters are correct for the sample (here, a calibration grid)
    - ∗ *Scan Size*: 20 ums
    - ∗ *Points & Lines*: 256
    - ∗ *Scan Rate*: 3 Hz
    - ∗ *Integral Gain*: 25

Note *Drive Amplitude* indicates the magnitude of the signal needed to excite the lever to the desired amplitude and is adjusted by software when the user chooses a target amplitude. *Drive Frequency* is the frequency at which the cantilever is excited at and is based on the cantilever calibration.



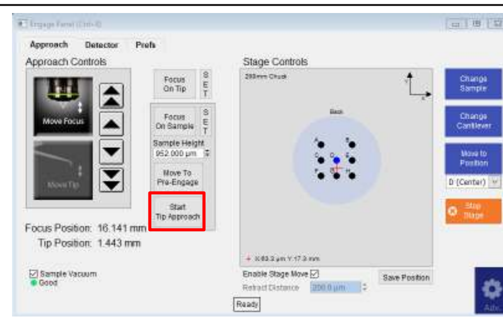
3.3.3. Landing the Tip

The preceding sections have left the tip vibrating about 50 microns above the sample surface.

1.

Start the final tip approach:

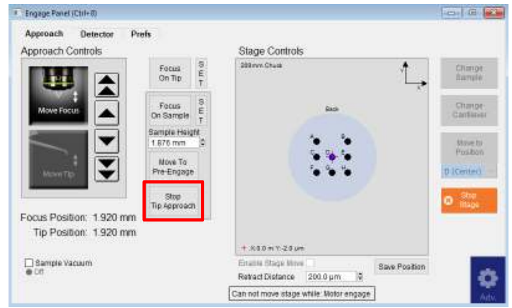
- On the Engage Panel, click the 'Start Tip Approach' button.



2.

Wait for the tip to reach the sample:

- For the next minute or so, Jupiter will systematically move the tip closer to the sample until the set point is reached.
- You can cancel the approach at any time by clicking 'Stop Tip Approach'.
- When the process is complete, the computer will beep, and the tip will be left about half of the Z piezo range off the surface (about 6 microns).



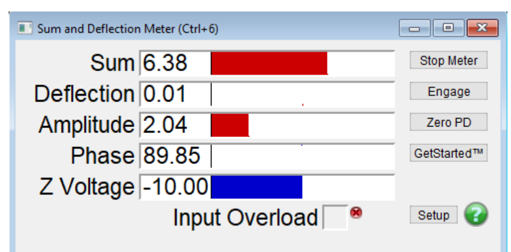
Q What's going on during the tip approach?

A Jupiter executes a series of repeated steps. First, the Z scanner piezo fully extends to move the cantilever/tip towards the sample while monitoring the cantilever amplitude. If the amplitude reaches the setpoint, the process stops. If not, the Z scanner piezo is fully retracted again and motors move the cantilever/tip down by one extension length. The process is then repeated until the sample is close enough to the vibrating cantilever to reduce its amplitude to the set point. One final time, the Z scanner piezo is fully retracted and the cantilever/tip is motored down just enough so that when the tip is brought down with the piezo, the cantilever amplitude setpoint is met at half the Z scanner's vertical extension range.

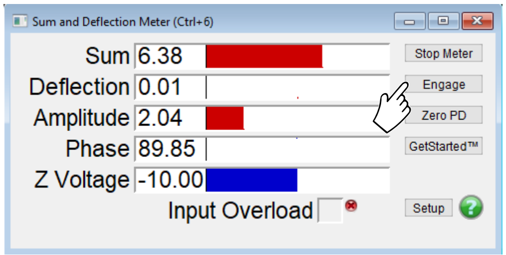
3.

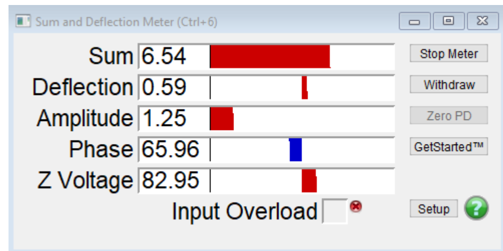
Check the meter:

- Open the Sum and Deflection Meter panel (Ctrl + 6).
- *Sum* should be around 6-8 volts
- *Deflection* should be close to zero (detector is zeroed).
- *Amplitude* should be reflecting the Target Amplitude of the Tune (2V).
- *Z Voltage* indicates the status of the Z piezo (as it is fully retracted, the value is -10 V)



4.





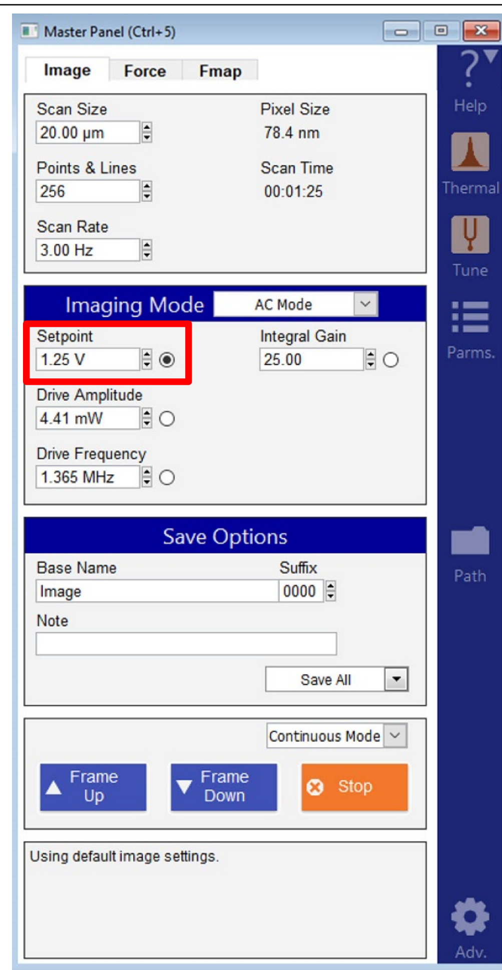
Engage:

- Click the ‘Engage’ button on the Sum and Deflection Meter panel.
- The piezo of the Z scanner will extend to bring the tip into contact with the sample (to reach the setpoint of 1.25 V).
- The Sum and Deflection Meter panel will look like the image on the right.

Congratulations! The tip is on the sample surface.

Q How do I know my tip is firmly engaged on the sample surface?

A Type in a slightly lower ‘Setpoint’ (such as 1 V). If the Z voltage in the Sum and Deflection Meter panel does not change noticeably (e.g., more than a Volt), the tip is firmly on the surface.



Q Why does the sample look out of focus when the tip is on the surface? How do I fix this?

A The laser and video image both pass through the same microscope objective. While performing AFM, the objective must remain focused on the back of the cantilever to keep the laser focused. As the sample sits one tip height farther away, it will not be in focus.

3.4. Imaging

This section shows you how to scan and track the surface.

3.4.1. Setup and Initial Parameter Selection

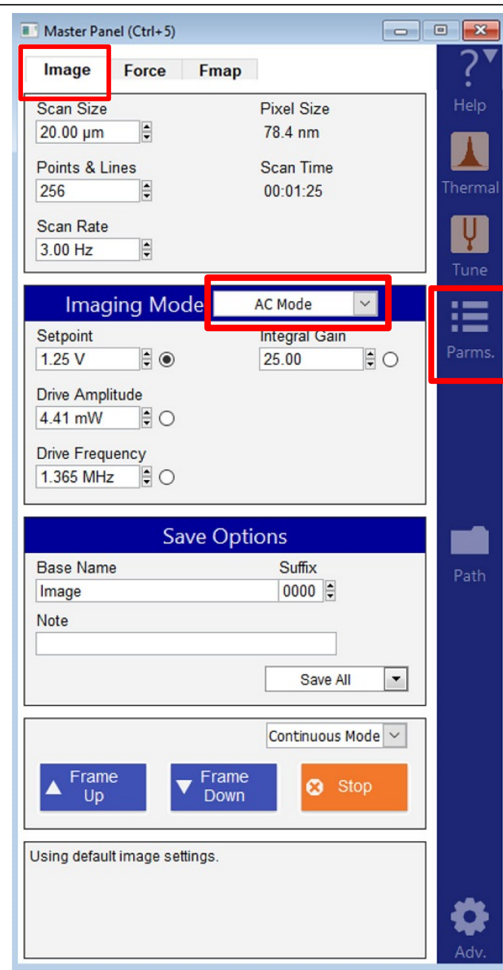
Based on the previous section, it is assumed that:

- The cantilever tip is on the surface or was just disengaged from the surface.
- The laser is aligned on the cantilever and the photo detector (deflection) signal has been zeroed.

1.

Setting up the Master Panel:

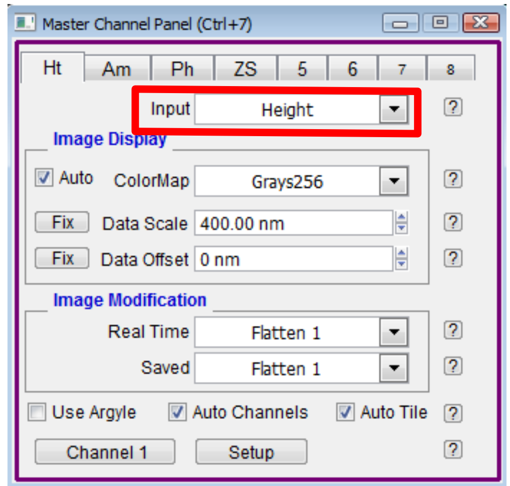
- Select the 'Image' tab on the Master Panel.
- Confirm that *AC Mode* is selected from the 'Imaging Mode' pull- down menu.
- Confirm that the following parameters are set:
  - 'Integral Gain': 24 to 30.
  - 'Scan Rate': 3.00 Hz.
- Scan angle, resolution ('Points & Lines'), and image 'Scan Size 'is up to you. (These can be found by clicking the 'Parms.' icon, to the right.)



2. **Selecting the image channel:**

- Open the Master Channel Panel.
- Select the leftmost tab, 'Ht', and confirm the default setting of *Height* in the 'Input' pull-down menu.
- Do the same on the next two tabs, 'Am' (Amplitude) and 'Ph' (Phase).
- On 'ZS', the fourth tab, do the same for the Z sensor.

Note While not necessary, it is a good habit to activate the Z sensor channel when imaging, especially when sample features are larger than a few hundred nanometers. The LVDT sensors are more linear than the piezo actuators, and thus it is a more precise Z measurement.



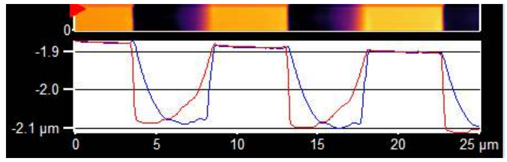
3. Images are saved to disk automatically at the end of every image, if you leave the 'Save Images' check box selected, located near the lower left hand corner of the Master Panel in Step 1 on page 60. You can save the image manually by browsing a directory to select a file in which to save your data.

3.4.2. Imaging and Parameter Tuning

1. **Start imaging and scanning:**

- Click the 'Frame Up' button at the bottom of the 'Image' tab on the Master Panel.
- Imaging will begin after a moment.
- Scan initiation first moves the tip to the starting point of the image, lowers the tip onto the surface, and begins an endless series of image scans.
- The red cursor to the left of each image window indicates the scan line/ location of the tip.

Tip	To enhance contrast on the image display, click and drag a box around the area of interest. Then right click and select fix scale.



2.

Determining image quality:

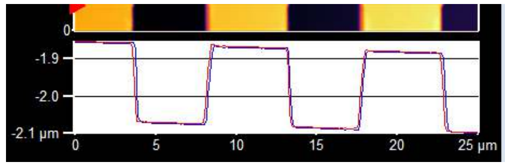
- Start the learning process on a sample with a known topography, such as the Asylum Research Calibration Grating being used in this tutorial.
- Look at the ’Scope Trace’ below the image. This graph represents the most recent line of the image. Blue indicates the tip moving left to right (a.k.a. **trace**), and Red indicates tip returning from right to left (a.k.a. **retrace**).

On most samples with relatively slowly changing features, trace and retrace should look the same. In other words, the landscape should look the same if you are flying the exact same route one way or the reverse. The image above shows the two as being quite different; this is an indication that imaging parameters need to be adjusted.

Nomenclature	In the graph shown above, the tip is not following the surface. As the blue trace shows (left to right), the tip seems to climb up out of the pits of the calibration grating quite nicely (the right edge of each pit is quite sharp), but then it descends back into the next pit along a relatively gentle slope. During this descent, the tip actually “flies through the air” while it is completely undeflected, a bit like a hang glider running off a cliff. The lateral motion of the tip simply marches on, as dictated by the XY scan pattern. The feedback control algorithm is simply not aggressive enough to bring the tip back down to the bottom of the pit. Such behavior is commonly called **parachuting** or **poor tracking**.

Hamster	The next steps will go into the details of strategies for tuning parameters in the main panel. Use the arrow clickers (to right of variable fields) to adjust parameters, rather than typing the values in. Alternatively, you can fine-tune the parameters using the ‘Hamster’ wheel on the front of the controller. Any parameter with a radio button next to it can be changed during a scan when it is activated (looks like black/ green dot in circle) with the ‘Hamster’. The Hamster gives "digital control with analog feel". On the ARC2 controller, the outer ‘Hamster’ ring allows the user to toggle between radio buttons in the panel. This tactile experience lets you concentrate on the image while tuning parameters.

3.



Adjusting Setpoint, I-Gain, and Scan Speed:

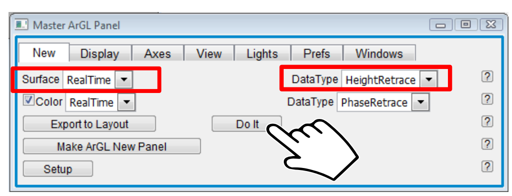
- The goal is to get trace and retrace to fall on top of each other (as shown above).
- Increase the 'Integral Gain' and see what happens. The match between trace and retrace should improve. The feedback becomes more aggressive and the slope with which the tip "parachutes" down into the pits should become steeper.
- Keep increasing the 'Integral Gain' until the trace and retrace suddenly start to oscillate wildly, a phenomenon called "ringing". The feedback loop is now unstable, and the 'Integral Gain' needs to be lowered a bit.
- If increasing the 'Integral Gain' does not seem to help, try to increase the 'Drive Amplitude' a bit. This will cause the cantilever to oscillate with greater amplitude.
- Lowering the 'Setpoint' can also improve tracking.
- Decreasing the 'Scan Rate' control will also improve tracking.

Note The overall goal is usually to make a good compromise between imaging speed and tip-sample tracking.

4.

Viewing data in real time 3D:

- Open the Master ArGL Panel by selecting *AFM Analysis ▷ 3D Surface Plots* from the menu bar.
- From the 'Surface' pull-down, select *RealTime*.
- From the 'Data Type' pull-down, select the desired channel in that image (usually *Height* or *Zsensor*).
- Click the 'Do It' button.
- To change the view, click on and drag the 3D data.



5. **Moving the sample between scans:** There are several ways to move the sample.

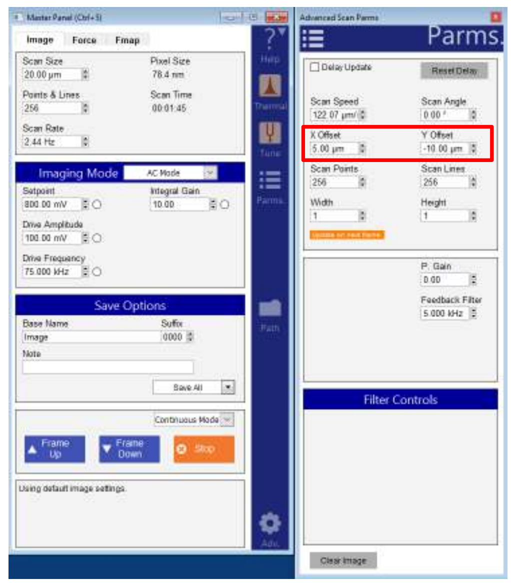
- Offsets within the XY scanner range
- Video panel: arrows, or click and go
- Engage Panel: “Move to Position” or defined distance steps in advanced controls
- Joystick motion: explained in the next section

Note These controls move the sample, rather than the cantilever, so that the laser and objective stay in alignment. Be sure to avoid accidentally moving the tip. Remember that the smaller arrow buttons in the upper left-hand corner of the Video panel are set to the cantilever rather than to the sample.

6. **Offsets:** To offset the location of the scan, input values into the Advanced Scan Parms panel as follows:

- Input the offset into the X and/or the Y direction.
- If a scan is already in progress, the offsets will be applied to the next image.

Note The total scan size (located on the Master Panel) and offsets cannot be greater than the XY scanner range (100 microns).

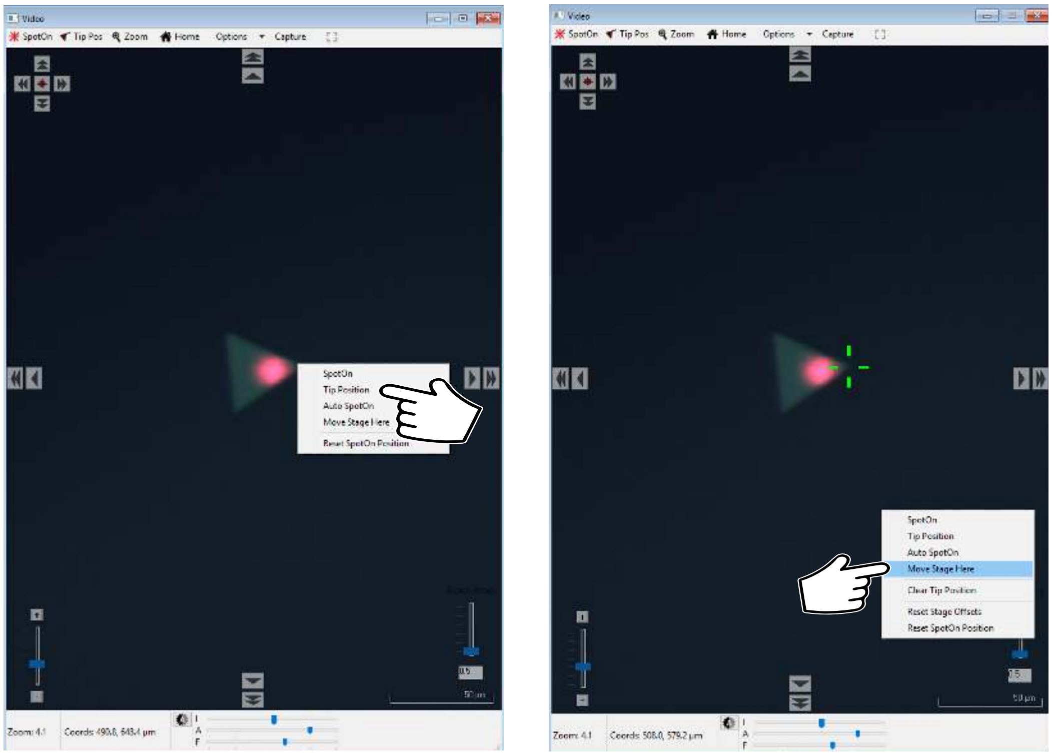


7. **Location:** The location of the scan can be chosen from the Video panel by clicking the Video panel arrows.

- Click the arrow showing the direction in which the stage should move.
- To prevent accidental retraction of the tip from the surface if the stage is not enabled, a warning message will appear. You will be asked for permission to enable stage.
- Software will move the tip up by the *Retract Distance*. (For software image, see Step 9 on page 66 .)
- XY stage will move to the new location.
- XY stage will be disabled.

Note The software will move the tip up by the *Retract Distance* (a minimum distance of 200 um). If there are features larger than several microns between the current location of the tip and the new position, you must increase the *Retract Distance* accordingly to prevent tip damage during the stage move!

8.



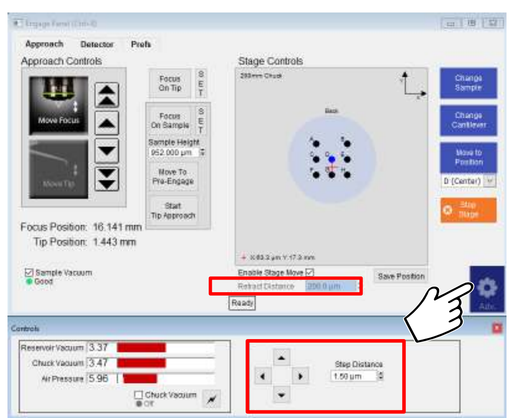
Choosing a new scanning location from the Video panel:

- Mark the tip position.
  - Focus on the tip. When the cursor is hovering above the tip, right-click, and choose *Tip Position*.
- Choose a new scanning location.
  - Focus on sample. When cursor is hovering above a feature of interest right click and choose *Move Stage Here*.

9.

Engage: The sample can be moved for a defined distance by using the arrows located in the Advanced controls.

- Click the ‘Adv’ button.
- Input the ‘Step Distance’.
- Click the appropriate arrow to indicate the direction that the XY stage should move.
- Software will move the tip up by the ‘Retract Distance’.
- XY stage will move to the new location and be disabled.



Q When I make changes to scanning parameters, when do those changes take effect in the scanned image?

A Most parameters on the 'Image' tab of the Master Panel will update as soon as you make a change. Note that changing points, lines, or scan rate will take effect next frame.

If you check the 'Delay Update' box, located on the Advanced Scan Parms panel, any changes you make to parameters will only update next frame. Until the image is complete, the changed variables are highlighted.

You can always force a new image by clicking 'Frame Up' or 'Frame Down'. A nice way to see the effect of changing imaging parameters can be as follows:

- Check the 'Delay Update' box as described above.
- Click 'Frame Up' and collect a dozen scan lines. Observe the image quality.
- Make some changes to the scan parameters (number of points, rate, gains, setpoint).
- Click 'Frame Up' again.
- Observe as the exact same scan region is "painted over" with new data taken with your new parameter choices.

3.4.3. XY Stage and the Joystick

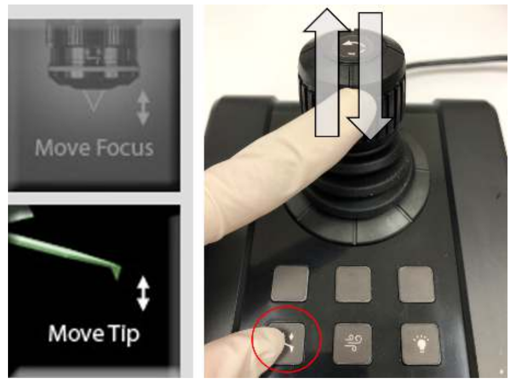
During an AFM experiment on the Jupiter XR AFM, the sample is mounted on the *Sample Chuck* which is attached to the *XY scanner* which in turn is attached to the *XY stage*. The XY stage stands on air bearings. To move the XY stage over the granite surface, it must first be enabled by air flow out of the bearings: the stage must be floating. When the stage is enabled, it moves up by several tens of microns, and care must be taken to prevent tip damage. The software automatically moves the tip up at least 200 um (retract distance) when the XY stage is enabled. It is the responsibility of the user to increase the retract distance when there are several samples of different heights on the sample chuck, or if the single sample has large features or is tilted.

The stage can be moved using the controls in the Video panel and the Engage Panel as explained earlier. Additionally, the XY stage can be moved using the joystick. The joystick has several functions which will be explained below.

 **Move Tip Up and Down**

- Press the  (Up/Down) button and push the joystick to move the tip up and down.
- Always look inside the instrument to monitor the tip-sample distance when using this command.

Caution The user is fully responsible for the movement of the tip. If you do not release the up/down button and the joystick, the tip will crash into the surface!



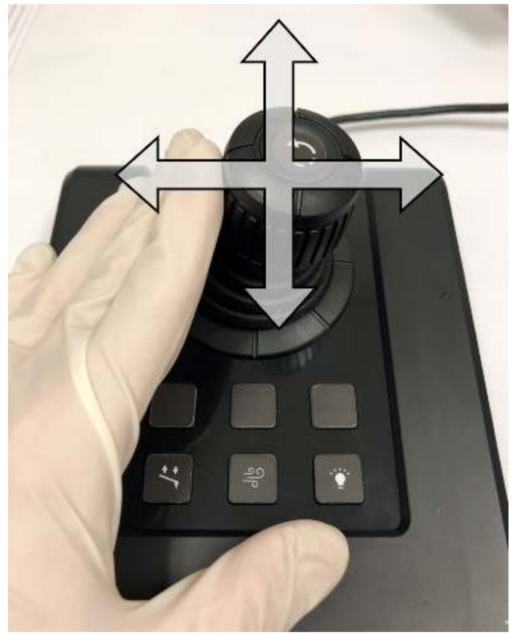
 **Enable XY stage**

- By pressing the  (Enable Stage) button, the air bearings are activated.
- Simultaneously, the tip is moved up by the Retract Distance, and the XY stage is ready to move.
- The ‘Enable Stage Move’ box gets checked on the Engage Panel.
- By pressing the ‘Enable Stage’ button again, the XY stage gets disabled.

Move XY stage

- When the stage is enabled, the XY stage can be moved in any direction when using the joystick.

Note Software limits will prevent the user from driving the XY stage into the sides of the instrument. However, care should be taken to keep the granite surface clean and free of any obstacles, such as tools and samples.



Joystick Summary of Joystick button functions:

-  : Moves tip.

  Caution Be careful not to crash the tip into the sample!
-  : Enables/Disables the XY stage (enable/disable air flow through the bearings).
-  : Turns the light above the sample On/Off (for a better profile view of the probe holder and sample).

3.4.4. Image Refinement

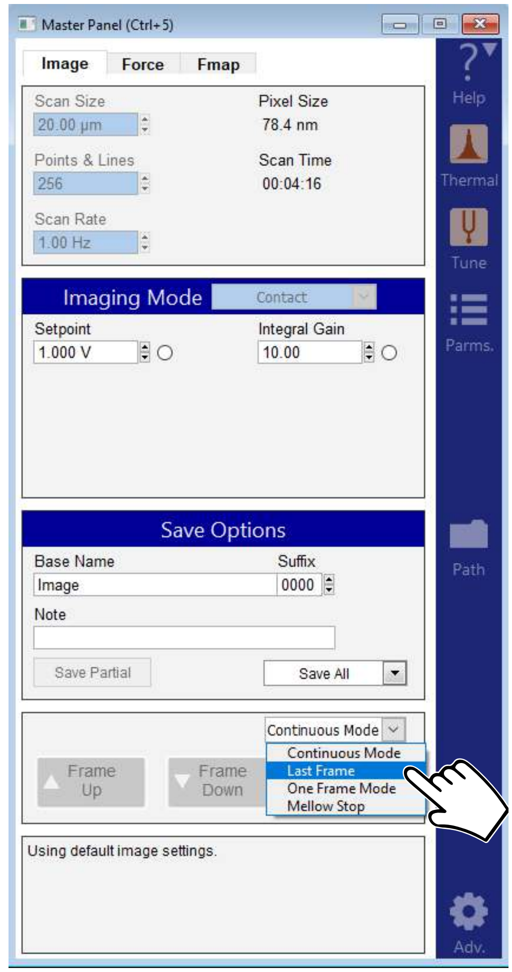
To learn more about using the Asylum Research SPM software to refine your imaging parameters, please refer to the manual. Also consider watching an introductory video that can be found on our user forum.

3.5. Stopping Imaging

1.

Basic procedure to stop imaging:

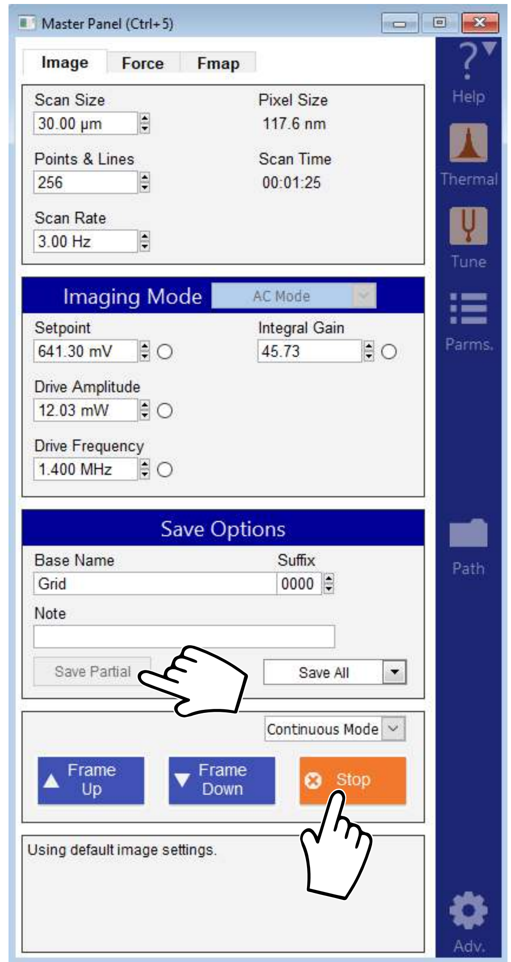
- Once a scan has begun, 'Continuous Mode' will appear on the Master Panel.
- Selecting 'Last Frame' from this drop-down menu will cause scanning to cease once the current scan has completed.



2.

Emergency stopping procedures:

- Clicking the 'Stop' button on the Master Panel will halt the scanning mid-image. This is a very abrupt way of halting scanning and should only be used if there is a problem. For instance, it would be appropriate to use this button if the cantilever was gouging holes in the sample.
- To save an unfinished image frame, click the 'Save Partial' button that will appear in the 'Save Options' section of the Master Panel.
- Measures such as closing the software, turning off the controller, or unplugging the microscope will stop scanning, but are not recommended except in extreme circumstances because of the complications and the risk of tip, sample, or hardware damage.



3.6. Shutting the System Down

3.6.1. Daily Use Shutdown

If the AFM system is used on the daily basis, there is no need to fully shut down the instrument. The following procedure is recommended for shutting down the system:

1. Finish the last scan.
2. Click 'Change Sample' on the Engage Panel. The Z scanner/ cantilever holder will move up and the XY stage will move to the front and center of the granite.
3. Remove the sample from the sample chuck.
4. To remove the probe from the cantilever holder, click 'Change Cantilever' on the Engage Panel. The XY stage will move to the back, and the Z scanner will be moved up. The objective will be moved up as well, allowing for removal of the Z scanner from the AFM.
5. Once the cantilever is removed from the cantilever holder, put the Z scanner back in the instrument until the next use.
6. Turn off the light (switch on the front of the enclosure).

7. Turn off the software.

3.6.2. Prolonged Shut Down

The following procedure should be performed if the Jupiter system will not be used for an extended period (one week or longer):

1. Finish the last scan.
2. Click 'Change Sample' on the Engage Panel. The Z scanner/ cantilever holder will move up and the XY stage will move to the front and center of the granite.
3. Remove the sample from the sample chuck.
4. To remove the probe from the cantilever holder, click 'Change Cantilever' on the Engage Panel. The XY stage will move to the back, and the Z scanner will be moved up. The objective will be moved up as well allowing for removal of the Z scanner from the AFM.
5. Once the cantilever is removed from the cantilever holder, put the Z scanner back in the instrument until the next use.
6. Turn off the light (switch on the front of the enclosure).
7. Once you are done imaging, save your data to a desired directory. Close Igor and shut down the computer.
8. Turn off the software.
9. Turn off the laser key on the controller.
10. Turn off the controller
11. Turn off the pneumatics controller.

Part II

General Tutorials

Part II: Who is it for? This portion of the manual contains general tutorials applicable to all models in the Jupiter XR family of AFMs.

Part Contents

4. Tutorial: Replacing the Cantilever

CHAPTER REV. 2313, DATED 03/06/2021, 17:11. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

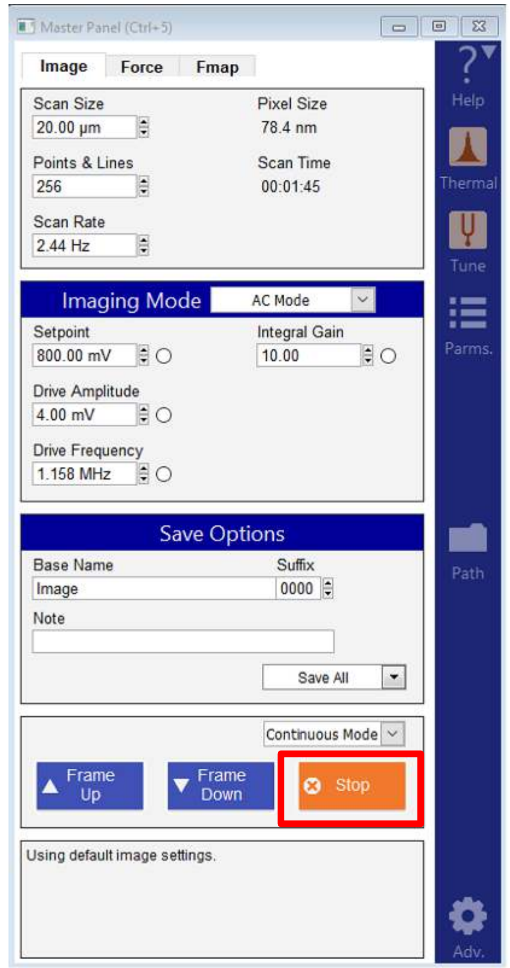
Before You Start The AC Mode Imaging in Air tutorial assumed that you found the instrument in a completely unknown state and included many alignment steps which do not apply to a typical situation, such as changing a cantilever and resuming scanning on the same sample. Scanner alignment, optical alignment, and even most scanning parameters should already be set for imaging in most cases.

4.1. Replacing the Cantilever

This tutorial assumes the starting point where the last tutorial ended up: imaging the calibration grating sample in AC mode. When finished, it should leave you at the same point again, scanning the same sample, but with a fresh cantilever.

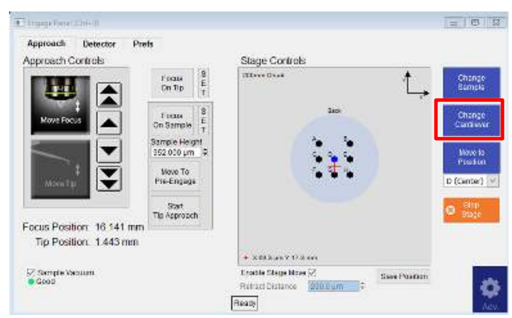
1. **Stop the scan:**

   - Halt the scan by clicking the ‘Stop’ button on the ‘Image’ tab of the Master Panel. This will stop the scan and retract the tip from the surface.



2. Open **Move the XY stage and Z scanner into position:**

   - Click the ‘Change Cantilever’ button on the ‘Approach’ tab of the Engage Panel.
     - Z stage (tip) will move up
     - Objective (focus) will move up
     - XY stage will move to the back and center to give access to the Z scanner

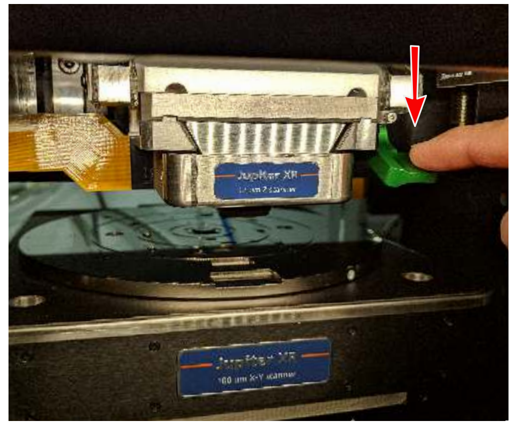


3. **Open the acoustic enclosure.**Remove the used cantilever:

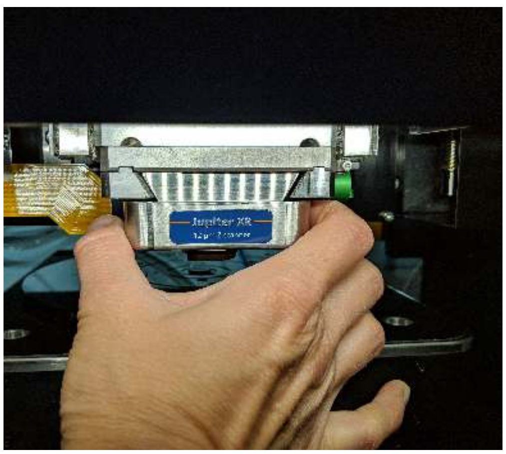
4.

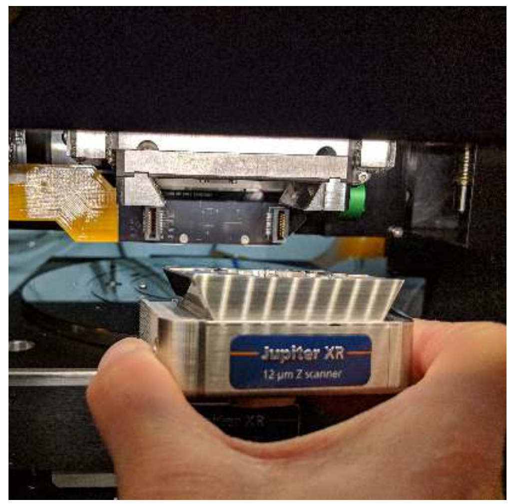
Unlock Z scanner/ cantilever holder:

- Release the Z scanner from the AFM by moving the green lever down and under.



5.





Remove the Z scanner/ cantilever holder from the AFM:

- Hold the Z scanner firmly.
- Slide Z scanner out of the AFM.

6.

Gently place the Z scanner on the table:

- Z scanner should be placed on the table with the cantilever holder facing up.

7.

Remove the used cantilever:

- Loosen the middle screw about one turn, just to the point of freeing the cantilever.
- Remove the old cantilever with tweezers.

Good Habit Blow clean the area under the cantilever clip with *clean* compressed gas. Bits of silicon and other debris can lead to a poorly seated cantilever and suboptimal AC mode images.

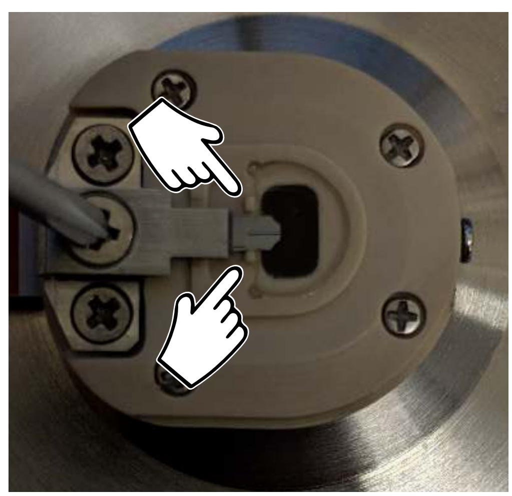
8.

Insert the new cantilever:

- With tweezers, slide the cantilever chip under the clip.
- Center the cantilever tip (approximately) between the two bumps.

Caution Do not push the cantilever chip too far back. This can cause misalignment. We will check for this in a few steps.

Note The cantilever holder was designed to be resilient, so do not worry about scratching it with tweezers.

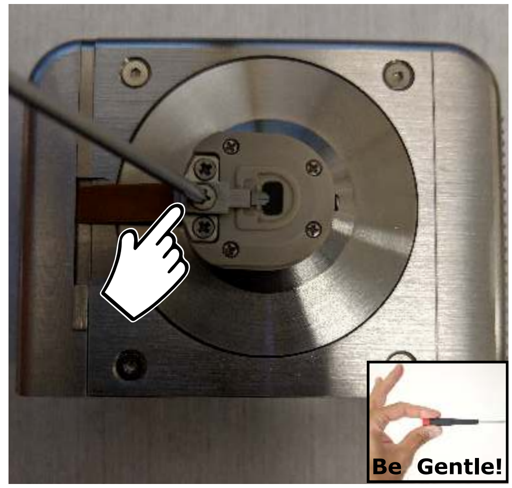


9.

Tighten the screw:

- Gently tighten the clip's screw.
- The chip should not be able to move if nudged with the tweezers. Chips that are firmly mounted will perform best during AC mode imaging.

Caution Do not overtighten the clamp on the cantilever holder; this can crush the chip, strip the screw threads, and/or result in an excessively bent clamp!



10.

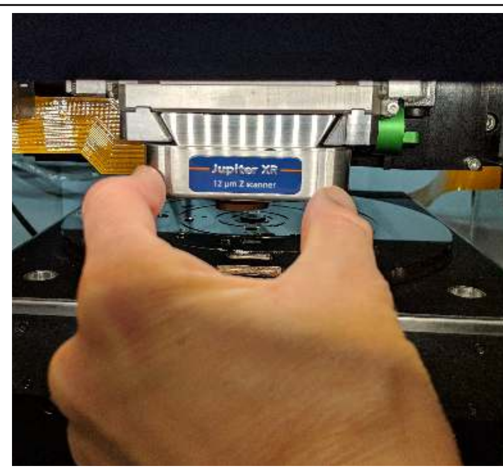
Inspect the cantilever seating:

- Hold the Z scanner so you can look from the side between the cantilever clip (a low power microscope or a jeweler's loupe, 10× is recommended).
- Check that the cantilever chip is parallel to the mounting surface and glass prism facet.
- If the probe is mounted too far back, it will cause an improper angle, and you will not be able to align the laser when the cantilever has been loaded into the AFM. Correct the position by loosening the screw and moving the cantilever forward in the pocket. Tighten the screw and inspect the "seating" again.

11.

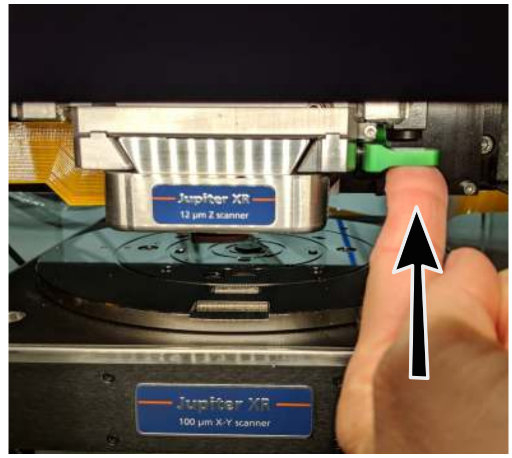
Place the Z scanner/ cantilever holder assembly back in the AFM:

- Hold the Z scanner firmly.
- Use the dovetail to guide the Z scanner into the AFM.
- Gently push the scanner all the way in.



12. **Secure the Z scanner/ cantilever holder assembly in the AFM:**

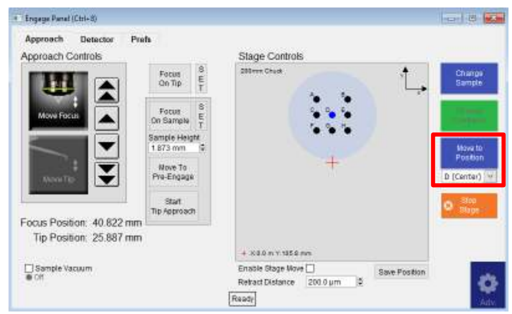
- Secure the Z scanner in the AFM by moving the green lever up.



13. Close the instrument enclosure.

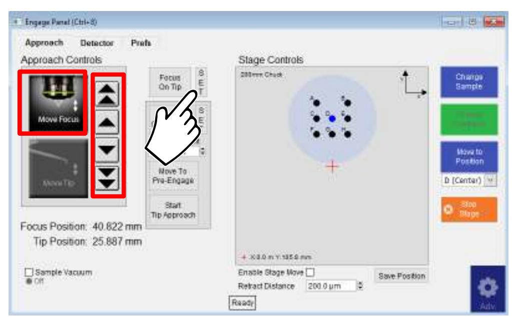
14. **Move the XY scanner, Z scanner and objective into position:**

- Click the ‘Move to Position’ button on the ‘Approach’ tab of the Engage Panel.
- Objective will move down to focus on the cantilever.
- XY stage will move to the position indicated in the lower part of the panel (ex: position D (Center)).



15. **Focus on the tip (cantilever):**

- Make sure ‘Move Focus’ is selected on the ‘Approach’ controls of the Engage Panel.
- Use the up/down arrows to move the focus until the cantilever looks sharp in the Video window.
- Once the tip is in focus, click ‘Set’ beside the ‘Focus on Tip’ button.



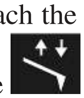
16.

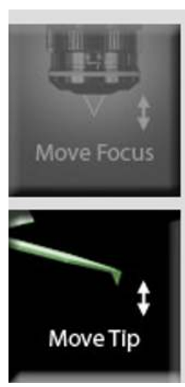
Align detection laser on the tip:

- On the Video panel:
  - Place the mouse cursor over the cantilever.
  - Right-click where you want to position the detection laser.
  - Select *SpotOn*.

17.

Approach the tip to the sample:

- Look at the tip-sample distance through the window of the enclosure.
- Use the joystick to approach the tip to the sample by holding the  (Up/Down Joystick) button and pushing the joystick down.
- Move the cantilever down until about 1.5 mm above the surface.

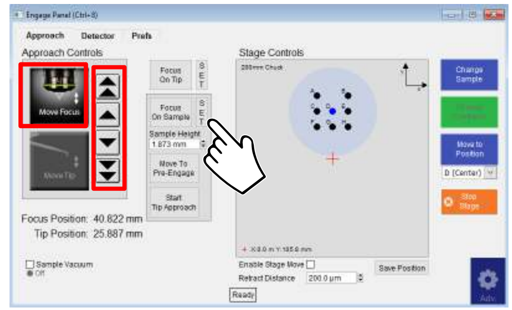


18.

Focus on sample:

- Make sure 'Move Focus' is selected on the 'Approach' tab of the Engage Panel.
- Use arrows located beside the objective icon to move the focus until the cantilever looks sharp in the video panel.
- Once the sample is in focus, click 'Set', beside the 'Focus on Sample' button.

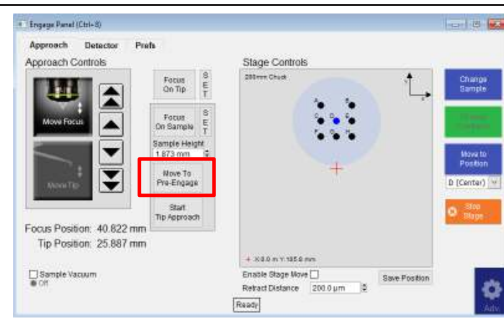
Note Objects up to 1.5 mm below the tip can be focused on. If the tip-sample distance is greater than 1.5 mm, the tip must be moved closer to the sample.



19.

Move to pre-engage height:

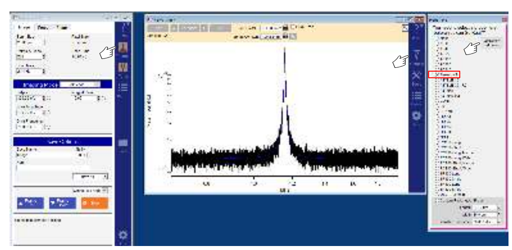
- Once the 'Focus on Tip' and 'Focus on Sample' are set, click 'Move To Pre-Engage'.
- The tip will be moved to 50 um above the sample surface.



20.

Calibrate cantilever:

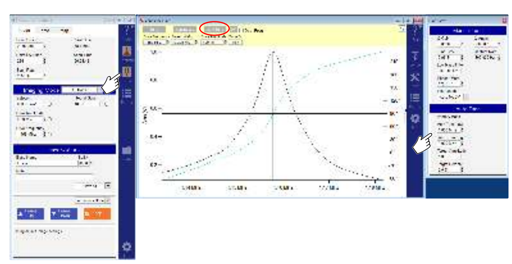
- You can calibrate the cantilever using GetReal, as follows:
  - Click 'Thermal' on the Master Panel.
  - Click 'GetReal'.
  - Select the probe type.
  - Click 'GetReal Calibration'.



21.

Initiate cantilever tune:

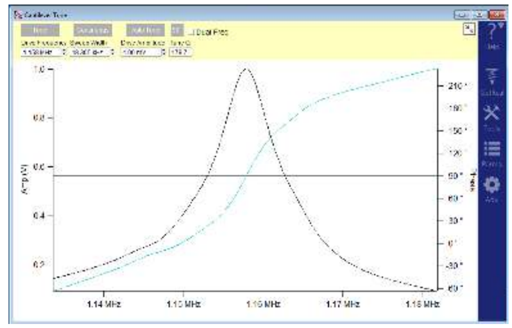
- Click 'Tune' on the Master Panel.
- Set the four Auto Tune parameters: (*Auto Tune Low*, *Auto Tune High*, *Target Amplitude*, *Target Percent*), as shown to the right.
- Click the 'Auto Tune' button, above the graph.



22.

Observe tune result:

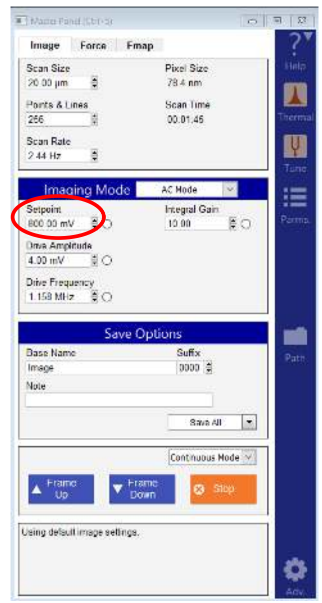
- A graph will pop up with the tune result.
- The resonance curve should peak around 1000 kHz for an FS-1500 FS.
- The relevant results are automatically stored.
- After inspecting the amplitude and phase curves to confirm that they look "clean", you can close the graph.



23.

Set the feedback set point:

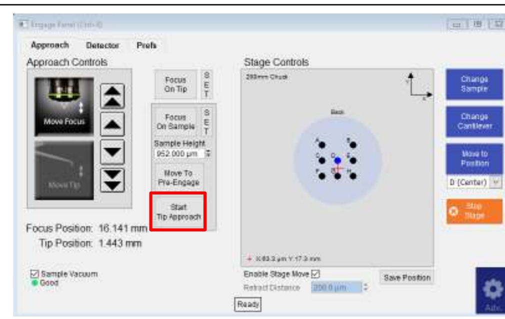
- Set the *Setpoint* value to 80% of the target amplitude.
- All other parameters should still be fine from the scanning before replacing the cantilever.



24.

Start the tip approach:

- Click the 'Start Tip Approach' button on the 'Approach' tab of the Engage Panel.



25.

Scan with the tip:

- Click the 'Frame Up' button (or 'Frame Down') on the 'Image' tab of the Master Panel.
- The tip will begin scanning from the top or bottom of scan area.

Part III

Advanced Imaging Hardware

Part III: Who is it for? This portion of the manual is dedicated to the advanced accessories of the Jupiter XR AFM. Once you have become familiar with basic imaging, as described in the previous tutorials of this manual, the following material will guide you through the many advanced accessories which the Jupiter family of AFMs offers. For example, to collect images on samples heated above 200° C, a Polymer Heater is required.

Part Contents

5. ARC2 SPM Controller

CHAPTER REV. 2273, DATED 09/22/2020, 11:20. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

Figure 5.1.: The ARC2 Controller with Hamster extended and BNC connector hatch open.

5.1. Parts List

The following list includes all of the parts in your accessory kit. The table is useful as a visual table of contents with links directing you to the specific uses of each part if applicable. When ordering parts, please refer to the part numbers in the second column.

Itm	Part #	Item Description	Qty	Picture
1	249.012	Laser Remote Safety Plug - 2.1 MM. Must be plugged into the back of the controller or the AFM's laser(s) will not work. Contact customer support to wire this plug to a laboratory laser safety interlock.	1	
2	657.001	Key Switch w/Keys. Used to turn on the AFM's laser(s) before it can work..	2	

The scale in the photos is in cm and mm.

(a) Front view of the ACR2

(b) Back view of the ARC2

Figure 5.2.: Front and Back view of the ARC2

5.2. Fuses

The controller is protected by several fuses on the main input power feed. If your system is not working properly after a power surge or similar electrical event in your lab, you may wish to check the fuses. If you see that one or more of the fuses is damaged, replace it with a similar rated part. All fuses are either "slow blow" or "time lag" type. Please note the current rating on the fuse itself or on the label on the back of the controller.

To remove the fuse for inspection, use a screwdriver or the edge of a coin to rotate the slot on the inside of the voltage selector 1/4 turn counterclockwise.

Please consult the back of your controller to find the specific fuse information. It can vary from instrument to instrument, depending on when it was manufactured.

5.3. System Diagram

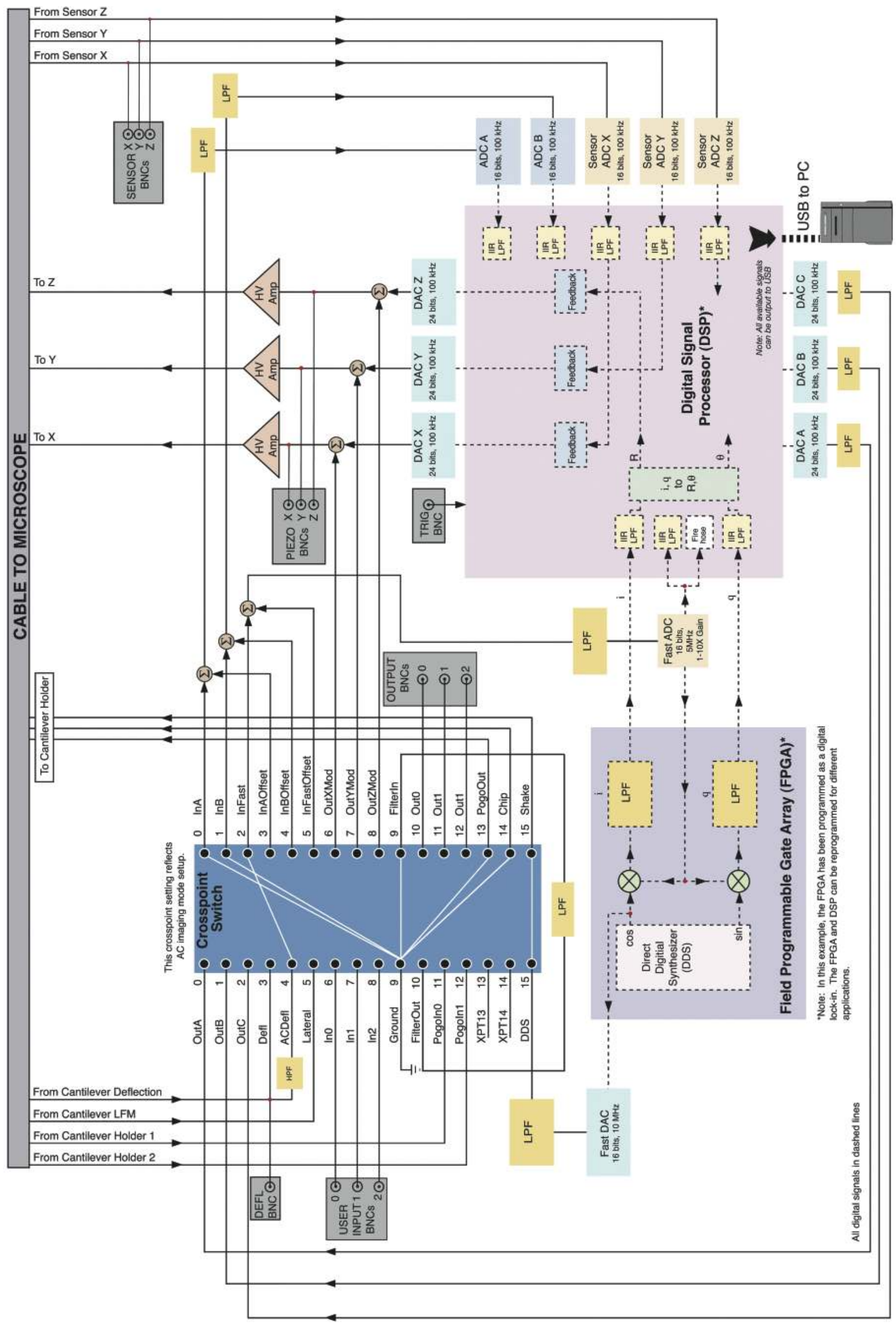


Figure 5.3.: System Diagram Including the ARC2 CrossPoint Switch.

5.4. Low Level Signal Access

(a) Digital Access Module.

(b) Extended Digital Interface Module.

Figure 5.4.: Options Which Allow Access to Low Level ARC signals.

6. Backpack SPM Controller

CHAPTER REV. 2306, DATED 03/01/2021, 18:01. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

Figure 6.1.: Front view of the Backpack Controller

Figure 6.2.: Side view of Backpack Controller showing BNC connections

6.1. System Diagram

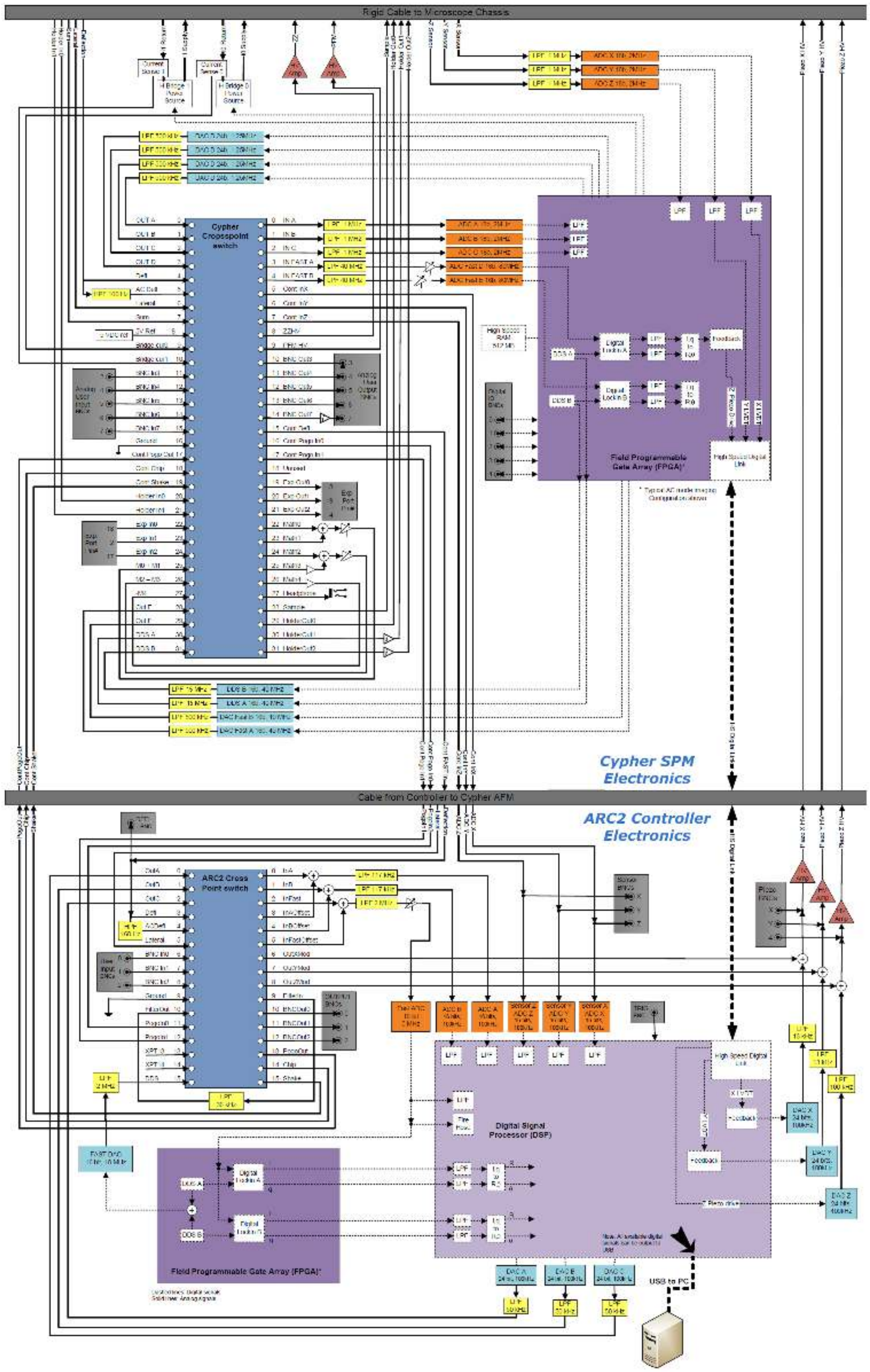


Figure 6.3.: System Diagram including the Backpack and ARC2 CrossPoint Switch

6.2. CrossPoint

The left two columns in the **Crosspoint Panel** are for all signals passing through the CrossPoint in the Backpack. The right single column is for all the signals passing through the CrossPoint in the ARC2. Refer to Figure 6.4 on page 96.

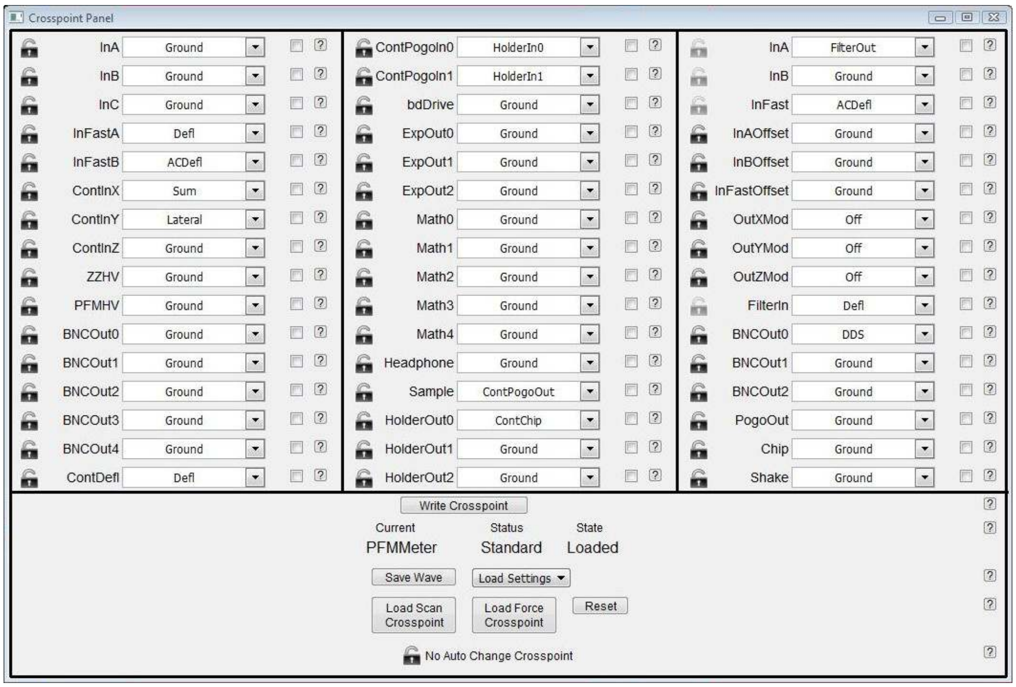


Figure 6.4.: Backpack and ARC2 CrossPoint set up for standard PFM mode

6.2.1. Decoding the CrossPoint

The CrossPoint, and signal routing in general, can become a bit more complicated for the system when the Backpack is present. In this section, we will "decode" some of the names and aliases you will encounter in the various columns and rows.

Left Column Outputs [Backpack]

InA, InB, InC 18-bit 2 MHz ADCs. Signals on these paths will be accessible by reading "cypher.input.a", "cypher.input.b", and "cypher.input.c", respectively.

InFastA, InFastB, InFastC 16-bit 80 MHz ADCs. Signals are accessible by reading "cypher.infasta" and "cypher.infastb".

ContInX, ContInY, ContInZ Connections to the ARC2 that were originally used for reading the LVDT (sensor) signals. Now the LVDTs are read by the Backpack and these channels can be reused.

ZZHV, PFMHV Connected to the inputs of the optional (non-standard) high voltage amplifiers in the in Backpack. ZZHV is unipolar (-10V to +150V) [and so far, unused.] PFMHV is bipolar (±150V) and used for applications like PFM.

BNCOut0, BNCOut1, BNCOut2, BNCOut3, BNCOut4 Output BNCs on the Backpack.

ContDefl Connection to the Deflection input of the ARC2. Signals routed here can be accessed by selecting “Deflection” in the right column, which is the ARC2 CrossPoint. This connection path is served by a coaxial cable in the Main Microscope Cable.

Center Column Outputs [Backpack]

ContPogoIn0, ContPogoIn1Signal Signal paths from the Backpack to the ARC2. Signals routed through here can be accessed by selecting “PogoIn0” or “PogoIn1” in the right column, which is the ARC2 CrossPoint.

bdDrive Drive voltage for controlling blueDrive output. In older versions of the SPM software this is called “Unused”.

ExpOut0, ExpOut1, ExpOut2 Outputs to the labeled Expansion port on the rear of the Backpack.

Math0, Math1, Math2, Math3, Math4 Connections to the “math” circuits.

Headphone Connection to the headphone jack on the Backpack.

Sample Signal path to the Expansion Box for sample bias.

HolderOut0 Connection to cantilever holder. Normally used for tip bias. No buffer, lower noise.

HolderOut1 Connection to cantilever holder. Normally used for the shake piezo. Has a 100 mA current buffer.

HolderOut2 Connection to cantilever holder. Has a 100 mA current buffer.

Right Column Outputs [ARC2]

InA, InB 16-bit 100 kHz ADCs. Signals on these paths will be accessible by reading “arc.input.a” and “arc.input.b”, respectively.

InFast 16-bit 5 MHz ADC. This channel has an additional LPF and is piped back into the DSP for the digital lock-in. The digital lock-in is used to calculate the Phase and Amplitude signals. This output is also piped into the “Fire Hose” (Thermal), as well as the USB banks. It is accessible by reading “arc.input.fast”.

InAOffset, InBOffset, InFastOffset These channel signals are added to the InA, InB, or InFast data lines as, hence, offsets.

OutXMod, OutYMod, OutZMod These channel signals are added to the voltage applied to the X, Y, or Z piezos. Gain was originally set to 15x. After May 2012 gain is 1x for lower noise performance.

FilterIn Input to a 36 kHz LFP.

BNCOut0, BNCOut1, BNCOut2 Output BNCs on the front of the ARC2.

PogoOut Connection from the ARC2 to the Backpack CrossPoint input “ContPogoOut”.

Chip Connection from the ARC2 to the Backpack CrossPoint input "ContChip".

Shake Connection from the ARC2 to the Backpack CrossPoint input "ContShake".

Right and Center Column Inputs [Backpack]

Off Completely disconnected; high impedence.

Ground Analog ground (0 Volts); quieter than the "Off" input signal.

OutA, OutB, OutC, OutD 24-bit 1.25 MHz DACs. Write to "cypher.output.a", "cypher.output.b", "cypher.output.c", and "cypher.output.d", respectively.

Defl The PD signal of the cantilever vertical deflection.

ACDefl The PD signal of the cantilever vertical deflection passed through a 160 Hz high-pass filter.

Sum The signal from the PD indicating the total amount of the light hitting it.

5VRef A 5 Volt reference signal.

BridgeCur0, BridgeCur1 A voltage signal proportional to the current passing through the two (2) H-bridges in the Backpack.

BNCIn0, BNCIn1, BNCIn2, BNCIn3, BNCIn4 Input BNCs on the Backpack.

ContPogoOut Signal connection from ARC2 "PogoOut" signal to the Backpack CrossPoint. "PogoOut" output is in right column.

ContChip Signal connection from ARC2 "Chip" signal to the Backpack CrossPoint. "Chip" output is in right column.

ContShake Signal connection from ARC2 "Shake" signal to the Backpack CrossPoint. "Shake" output is in right column.

HolderIn0, HolderIn1 Signal connections from the Cantilever Holder to the Backpack CrossPoint.

ExpIn0, ExpIn1, ExpIn2 Signal connections from the labeled Expansion port on the rear of the Backpack to the Backpack CrossPoint.

M0+M1 A signal that is the sum of the Math0 (M0) and Math1 (M1) outputs.

M2-M3 A signal that is the difference between the Math 2 (M2) and Math3 (M3) outputs.

-M4 A signal that is inverted of the Math4 (M4) output.

OutE, OutF 16-bit 40 MHz DACs. Write to "cypher.output.e" and "cypher.output.f".

DDSA, DDSB The direct digital synthesizer (DDS) signals on the Backpack. They make sine waves.

Right Column Inputs [ARC2]

Off Completely disconnected; high impedence.

Ground Analog ground (0 Volts); quieter than the "Off" input signal.

InA, InB, InC 24-bit 100 kHz DACs. Write to "arc.output.a", "arc.output.b", "arc.output.c", respectively.

Defl Signal connection from Backpack CrossPoint output "ContDefl" to ARC2 CrossPoint.

ACDefl Signal connection from Backpack CrossPoint output "ContDefl" to ARC2 CrossPoint through a 160 Hz high-pass filter.

Lateral The PD signal of the cantilever horizontal deflection. Not connected in the Backpack.

BNCIn0, BNCIn1, BNCIn2 Input BNCs on the front of ARC2. Originally these were 10 kΩ input impedance. After Jan 2010, the input impedance is >20 MΩ.

FilterOut Output of the36 kHz LFP. See "FilterIn" signal.

PogoIn0, PogoIn1 Signal connections from the Backpack CrossPoint outputs "ContPogoIn0" and "ContPogoIn1", respectively.

XPT13, XPT14 Currently unused.

DDS The direct digital synthesizer (DDS) signal on the ARC2. It makes sine waves (for AC Mode, Dual-AC, etc).

7. Jupiter Stage Controller

CHAPTER REV. 2057, DATED 03/20/2019, 20:37. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Figure 7.1.: Front view of the Stage Controller.

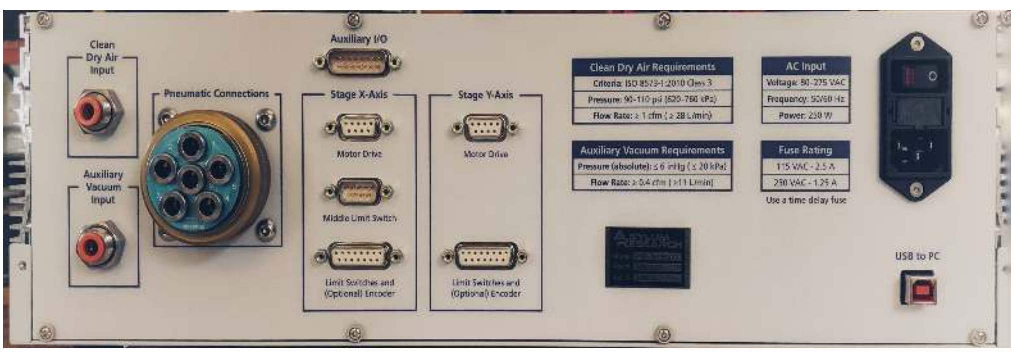


Figure 7.2.: Back view of the Stage Controller.

The Stage Controller provides power to the XY sample positioning motors and directs pressurized air and vacuum from external sources to the necessary parts of the Jupiter XR AFM. The connectons are all set up during system installation, and the controls inside the box are all set automatically by the AR AFM software. The dials on the front need to be consulted only during troubleshooting sessions with our technical support staff.

The are no safety features that the Jupiter XR AFM user needs to be familiar with. The maximum pressure entering the stage controller is marked on the rear panel. The stage controller is protected from large variations in “house air pressure” by means of the air pressure regulator installed under the Jupiter XR AFM Hood.

There are no user serviceable components inside the stage controller. Your only interaction with the device is to power it up or down with the power switch, located on the left rear of the unit (as seen from the front of the unit).

8. Sample Chucks

CHAPTER REV. 2303, DATED 03/01/2021, 17:04. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

8.1. 200mm Wafer and General Purpose Chuck

The standard 8” chuck can accommodate flat samples, like silicon wafers held down with vacuum or multiple small samples held down magnetically.

8.1.1. Removal, Installation, and Storage

Please see Section 8.2.2 on page 106 on how to remove the chuck and switch to another one, and how to properly store the chuck.

8.1.2. Various Features on the Chuck Surface.

The 200 mm chuck has various features for handling and accessing sample. Please refer to Figure 8.1 on page 102.

1. One of four relief cutouts for using wafer tweezers to place silicon wafers on the chuck.
2. One of eight magnetized sample mounting locations for placing standard magnetic AFM pucks. A relief cutout allows access for tweezers.
3. One of four screws (222.220) for plugging the vacuum feed to the associated vacuum groove (note one screw is not on a groove, see the next item in the list for its function). Use together with (230.071) O-rings, which can be found in the accessory kit. When using vacuum to hold down samples (requires house vacuum, or an optional vacuum pump to be connected to the stage controller), remove all the screws for all the vacuum rings smaller than your particular wafer. Store the plugs and O-rings in the storage box supplied with the chuck.

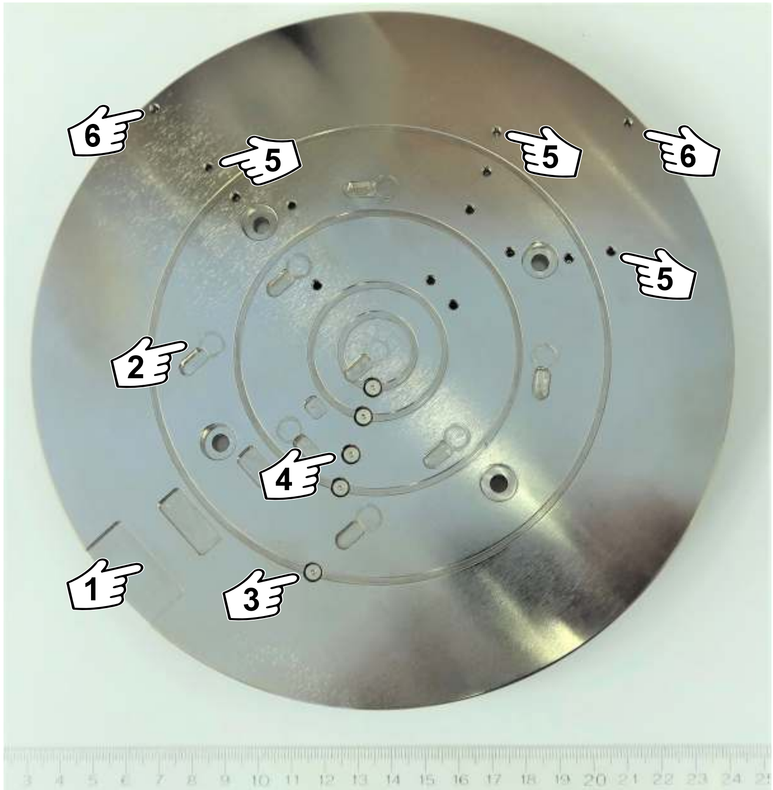


Figure 8.1.: The standard 200mm chuck which ships with every Jupiter AFM.

4. Note this screw does not sit on a vacuum groove. By removing this, and only this screw, a single point of vacuum is created. This can be handy to hold down a small chip of silicon without the need for mounting it on a magnetic puck. To pick the sample up again after releasing vacuum, nudge it over to the nearest depression in the chuck to allow for pickup by tweezers.
5. Threaded holes which accept small posts (116.935) against which a wafer is pushed for repeatable centering. Each wafer size (except for the largest) has three posts. Two for locating against the wafer edge and one for locating against the wafer flat.
6. The largest wafer size (200mm) only has two locating posts, one for the wafer notch, and one for the wafer edge.

8.1.3. Cleaning and Caring for the Chuck

The chuck is made of aluminum and coated with a conductive nickel plating to improve hardness. Please be careful when using tweezers near the chuck to avoid scratches. Clean the chuck with alcohol and a soft cloth.

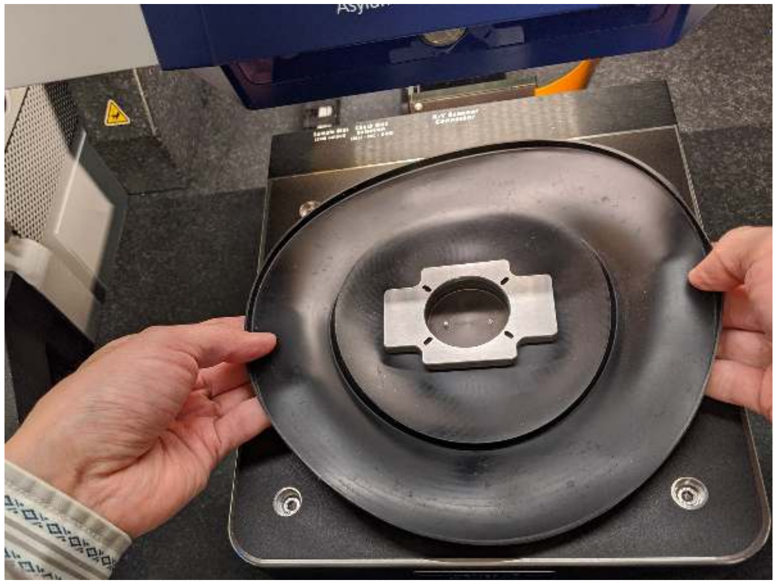


Figure 8.2.: View of Accessory Chuck

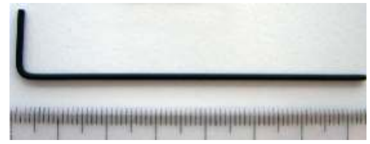
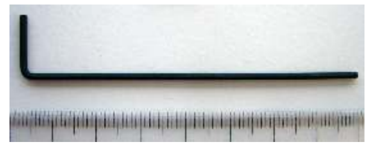
8.2. Accessory Chuck

8.2.1. Parts List

The following list includes all of the parts in your accessory kit. The table is useful as a visual table of contents with links directing you to the specific uses of each part. When ordering parts, please refer to the part numbers in the second column.

Itm	Part #	Item Description	Qty	Picture
1	116.935	Mod, M3 Cross Recessed Screw. Locating pins to be used when placing wafers on the sample chuck. See Section 8.1.2 on page 101.	6	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
2	222.211	Hexalobular M5 X 8mm Low Profile Screws. Used to fasten the sample chuck to the XY scanner.	4	
3	222.220	M2.5 X 3MM, Low Profile Socket Head Cap Screw. Used for plugging vacuum channels on the sample chuck that are not in use. See Section 8.1.2 on page 101.	5	
4	230.071	O-ring, .044 ± .003 C/S x .097 ± .005 ID x .185 OD. Used together with low profile screws to plug unused vacuum channels. See Section 8.1.2 on page 101.	5	
5	279.099	Meiho 6 Compartment Box, Blue. Used for storing small parts and tools when not in use.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
6	290.116	.050" Ball End Allen Wrench	1	
7	290.117	1.5MM Hex Allen Wrench	1	
8	290.180	Jupiter Torque Wrench, 10lbs Max, 2.25" Long. Used to fasten the screw of the sample chuck to the XY scanner.	1	
9	290.181	T25 Torx Bit, 1/4" Hex Shank. Used together with the Jupiter torque wrench to fasten the sample chuck to the XY scanner.	1	
10	290.182	2MM Hex Allen Wrench	1	
11	900.008.2 (Comes with all Jupiter XR)	Jupiter 200mm Sample Chuck. See Section 8.1 on page 101.	1	
12	900.008.3 (Sold as a separate Accessory)	Jupiter Accessory Chuck. For use with Jupiter accessories. See Section 8.2 on page 103.	1	

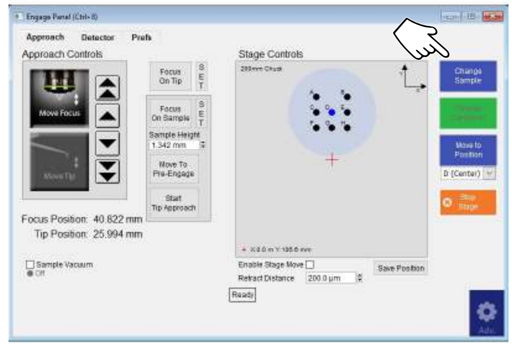
The scale in the photos is in cm and mm.

8.2.2. Tutorial: Accessory Chuck Setup

1.

Move sample chuck to front:

- Click the ‘Change Sample’ button to move the sample chuck to the front.



2.

Loosen the screws:

- Loosen the screws holding down the sample chuck using the provided torque wrench.
- The torx bit can be found in the storage box included with your kit and must be inserted into the wrench.

3.

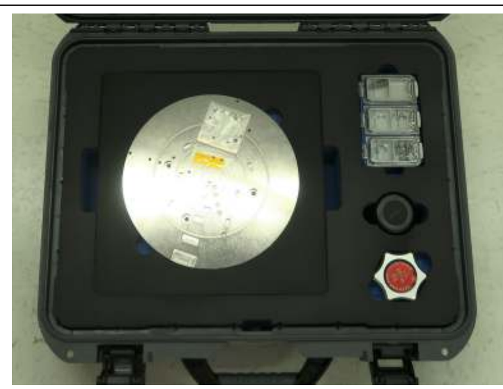
Remove the chuck:

- Remove the chuck from the XY scanner.

4.

Store the chuck:

- Store the chuck as shown.



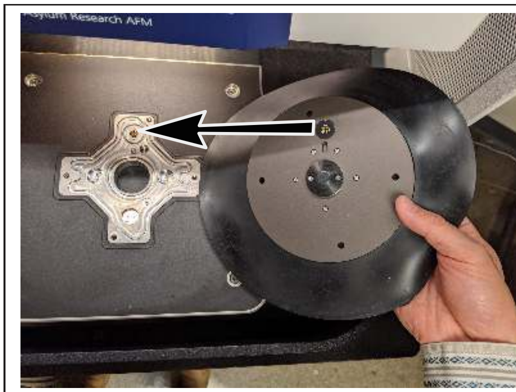
5.

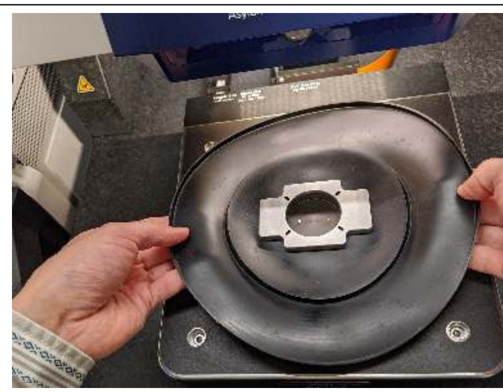
Note the O-ring:

- There is a single O-ring between the XY scanner and sample chuck. Make sure that it does not get stuck to the chuck or lost.
- Keep the O-ring with the scanner, while it serves no purpose for the accessory chuck we are about to install, it does no harm to keep it in place until the next time the standard chuck is used.

Note The O-ring is orange and visible to the right. If it is lost, vacuum sample hold down on the standard chuck will no longer work. Spare O-rings (230.071) are included in the storage case for the XY scanner. See Section 1.2.4 on page 7.

6.





Orient the accessories chuck:

- Orient the accessories chuck so that the electrical contacts and locating pin are aligned. (The picture on the left shows the underside of the chuck.)
- There is only one correct orientation for the locating pin.
- The bottom of the chuck should be level with scanner surface.

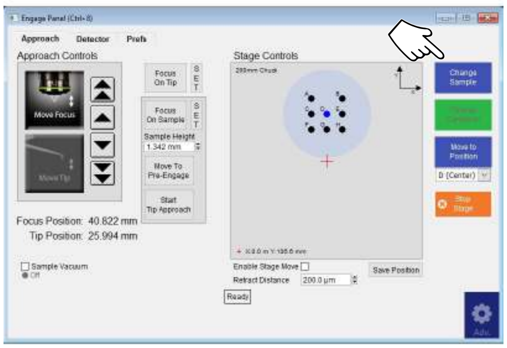
Note The O-ring between the XY scanner and the sample chuck is necessary only when the vacuum is used, not for the accessory chuck.

7.

Tighten the Screws:

- *Gently* fold back the flexible silicone portion of the accessories chuck to expose the mounting screws.
- Tighten each of the four (4) screws using the provided torque wrench.

8.



Switching back to the standard chuck:

- To switch back to the standard chuck, click ‘Change Sample’ on the Engage Panel to bring the stage to the front.
- Always use the provided torque wrench when loosening and tightening the screws.
- Make sure that the O-ring is on the scanner before placing the sample chuck.

8.2.3. Cleaning and Care

Refer to the parts list for the materials of which the chuck is made. All the parts used can be cleaned with a tissue and isopropanol. If you need replacement parts, contact your local Asylum Research office or distributor, and use the parts list as a guide.

9. Fluid Cell Lite

CHAPTER REV. 2279, DATED 10/28/2020, 08:42. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

Figure 9.1.: Fluid Cell Lite body, top view.

9.1. Compatibility and Prerequisites

Warning	Even small fluid spills around an AFM can lead to costly repairs. Educate yourself on how to work safely with fluids.

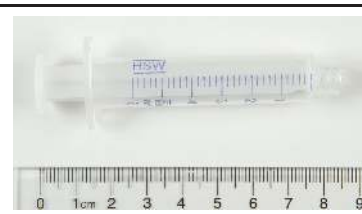
9.2. Overview and Specifications

The **Fluid Cell Lite** is the simplest of the environmental accessories. It is used for basic liquid imaging where optical access from the bottom side of the sample is possible. The cell itself consists of a peek dish with a removable glass bottom.

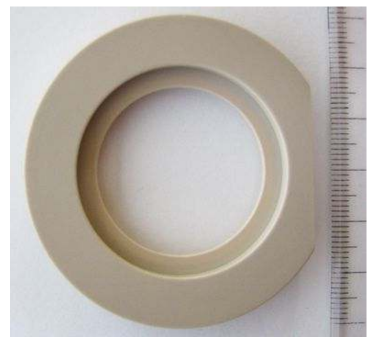
Warning	While imaging in fluid is considered routine with the Jupiter XR AFM, one should always be *extremely* cautious about spilling fluid on or around the Jupiter XR AFM.

9.3. Parts List

The following list includes all of the parts in your accessory kit. The table is useful as a visual table of contents with links directing you to the specific uses of each part. When ordering parts, please refer to the part numbers in the second column.

Itm	Part #	Item Description	Qty	Picture
1	080.010	5 ml Syringe. Can be used to fill the cell with fluid once it is in place on the AFM stage.	2	
2	111.420	Closed Cell Bottom Clamp. The stainless steel retaining ring which holds the glass bottom or the cover slip holders against the closed fluid cell. See Section 9.4.1 on page 112.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
3	111.425	35mm X 1mm glass disc, custom made of Glaverbel float glass by Asylum Research. See Section 9.4.1 on page 112 for insertion instructions.	5	
4	112.256.01	Closed Cell Bellows, Viton. 50 durometer black FKM fluoroelastomer. See Step 8 on page 121.	2	
5	230.015	O-ring, 1.228"ID X 0.032"CS, Brown Viton, 75 Durometer. This FKM O-ring creates a seal between the sample disc 111.425 and the fluid cell body.	5	
6	290.103	3C Tweezers – Extra Fine Sharp – Standard Grade. For placing samples, O-rings, and small screws.	1	
7	290.111	0.050": WIHA Allen Driver 263 1,3 – 0.05" X 40. For all socket head screws; for instance, when sealing fluid ports.	10	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
8	939.008	Spanner Wrench Assembly. Used to secure bottom pieces into closed cells (See Section 9.4.1 on page 112).	1	
9	939.010	Portless Fluid Dish. Serves as the sample holder during liquid environment experiments. Shown at right: back side view (top), front side view (bottom). Made of PEEK plastic. For use where fluid ports and pressurized operation are not important. The best choice for any initial investigation. Simple to clean, easy to assemble.	1	
The scale in the photos is in cm and mm.				

9.4. Assembly

9.4.1. Inserting the Fluid Cell Glass Bottom

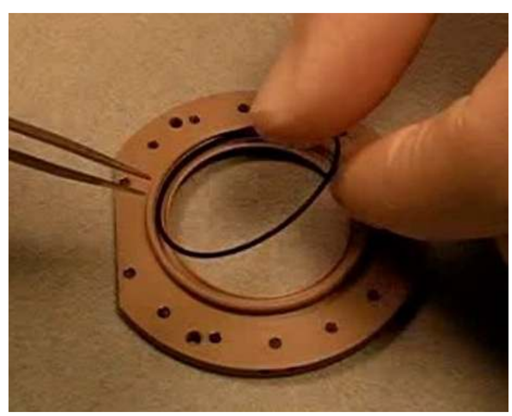
Part numbers are noted in parentheses.

1.

Place the bottom O-ring:

- Take the bottom O-ring (230.015) and place it in the groove on the bottom of the Fluid Dish.

  Note The O-ring (230.015) will shrink a little over time, so you will likely need to stretch it out with your fingers.
- If the ring fits, skip to step Step 3 on page 113.
- If the ring is too small, move to the next step to enlarge the ring.

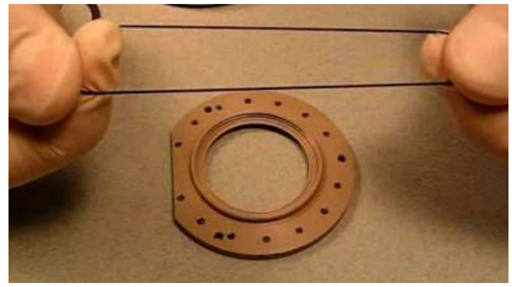


2.

Stretch the bottom O-ring:

- Stretch the O-ring a bit and try fitting it again (see previous step), and repeat the process by stretching out, doubling the ring size.

Note If you overstretch the ring, it will shrink back in a few minutes, or you can try again with a spare.



3.

Join retaining ring and spanner wrench:

- Set the spanner wrench upright with the narrow end on the table.
- Match the indentations in the retaining ring (111.420) to the pins on the spanner wrench.
- Place the ring on the wrench. They will hold together magnetically.

4.

Place glass bottom against cell body:

- Inspect the O-ring to be sure that it fits perfectly in the groove.
- Place the glass bottom onto the cell body.

5.

Secure glass with retaining ring:

- Place the wrench/spanner ring on top of the glass and hold it all as shown in the photo.
- Rotate the wrench a few turns counterclockwise (loosening). You should feel a click when the threads properly align. Stop at the click.
- Tighten clockwise. It should turn easily at first, then finish with moderate force. The O-ring should be fully compressed, and the glass bottom needs to be firmly against the plastic. If the glass bottom is only “floating” on the O-ring, you will likely experience thermal drift in your images.

Note The initial threading process should be smooth. If not, you may have crossed threads - this can cause damage to the peek cell body.

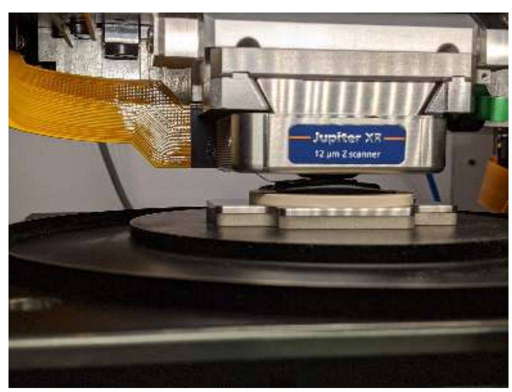
6. The Fluid Cell is now ready for sample mounting.

9.4.2. Blind Engage

1.

Before lowering the AFM tip:

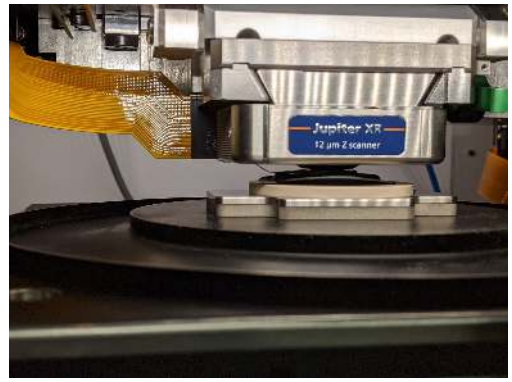
- Manually moving the AFM tip toward the sample when you cannot see the cantilever holder and sample in profile is not recommended. This would be the case when using one of the Jupiter environmental cell accessories such as those covered in Chapter 9 on page 109, the Chapter 10 on page 125, or the Chapter 11 on page 139.



2.

Lower the tip with joystick or software buttons:

- Lower the tip as much as possible with the joystick or the software buttons while monitoring the tip position and looking through the window.
- The cantilever holder profile should still be visible and not blocked behind anything.



3.

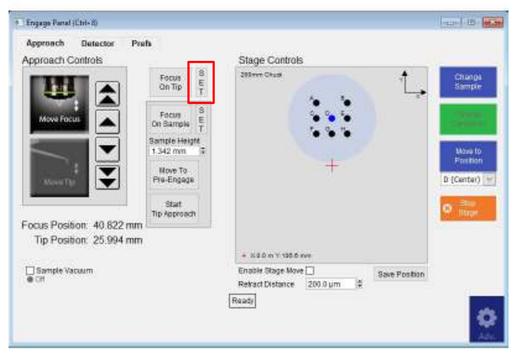
Focus on the cantilever and position the spot:

- Focus on the cantilever. Assuming that the tip is still far from the sample, the video window may appear somewhat dark.
- Position the spot onto the cantilever.

4.

Focus and set tip:

- With the tip in focus, click the ‘Set’ button (beside the ‘Focus On Tip’ button on the Engage Panel) to set the position of the tip.

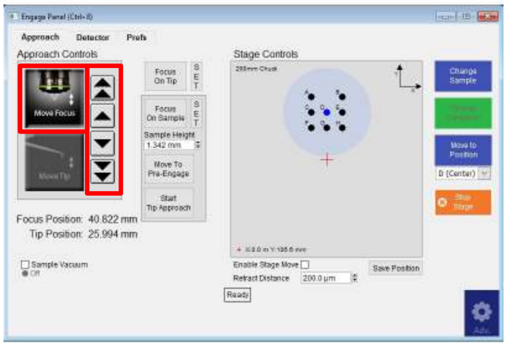


5.

Adjust the Field diaphragm setting:

- Step down the field diaphragm to the second lowest setting, as shown. This can be done by using the ‘F’ slider bar at the bottom of the Video panel.
- Ensure that the video view is not zoomed in. This will allow you to see the edge of the field diaphragm.

6.



Search for the sample:

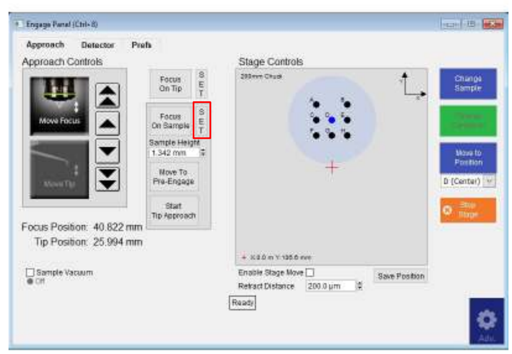
- In the ‘Move Focus’ mode, use the ‘up arrow’ and ‘down arrow’ buttons to search for the sample.
- In some cases, particularly for transparent samples or small samples on transparent substrates, it may be easier to use the edge of the field diaphragm as an indication of sample focus. In the picture above, part of the edge of the field diaphragm is in focus.
- The sample can be shifted slightly with the arrow buttons on the Video panel to verify whether sample focus has been achieved.

  Caution Do NOT use the joystick for this if using an environmental cell.
- If the sample or the edge of the field diaphragm cannot be focused, proceed to the next step.

7.

Use the arrow buttons to extend the focus:

- If the sample or edge of the field diaphragm cannot be focused, the assumption is that the tip is still far above the sample surface.
- In this case, use the arrow buttons to extend the focus down as far as possible, and then “Set” this as the sample height.



Caution If your sample is within range of being focused, but you cannot find the focus, there is the potential of a tip crash in the next steps, so please be careful.

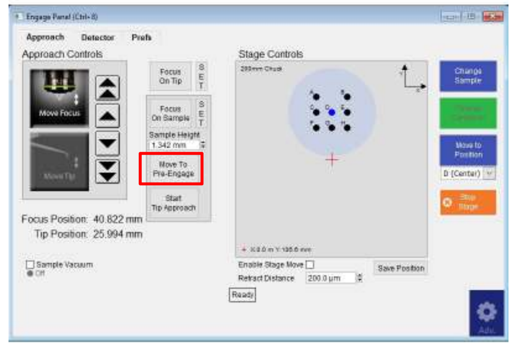
8.

Move the cantilever closer to the sample surface:

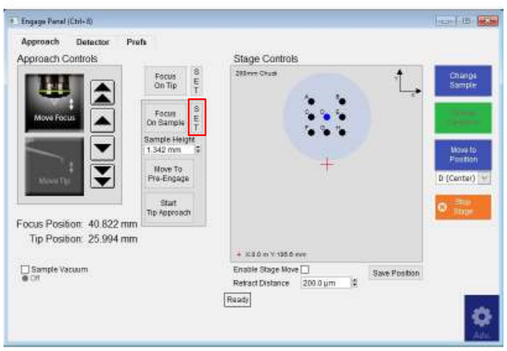
- Click the 'Move to Pre-Engage' button. This step should move the cantilever closer to the sample surface.
- Iterate again from Step 6 until the sample can be focused.

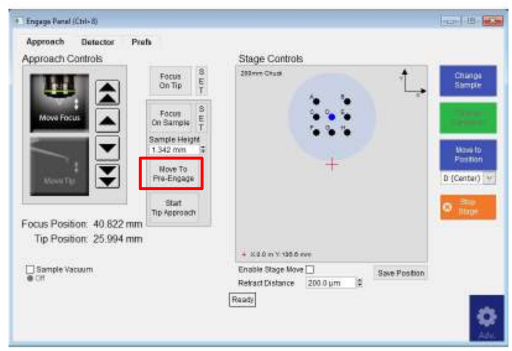
Tip Typically, the closer the tip is to the sample, the brighter the video image will be.

- When proper sample focus has been achieved, proceed to the next step.



9.





Set the focused sample to mark the position:

- Once the sample is in focus, click 'Set', beside the 'Focus On Sample' button, to mark the position of the sample.
- The click the 'Move to Pre-Engage' button and proceed as with normal operation.

Tip Make a note of the sample height. In case you must change your tip, you can use this value to have an approximate idea of how much you can lower the tip to be within range.

9.4.3. Liquid Operation: Fluid Cell and Fluid Cantilever Holder

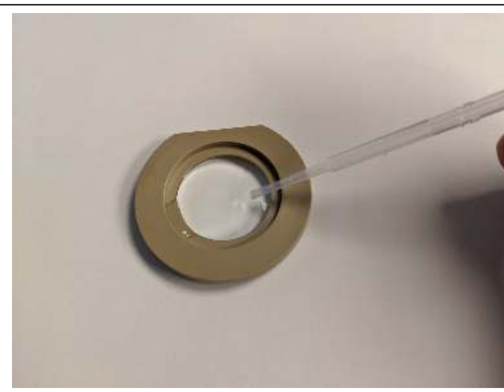
1. **Attach accessory chuck to Jupiter stage:**

   - Attach accessory chuck to the XY scanner stage. Refer to the Section 8.2.2 on page 106 for more details.

   Caution Moving the sample laterally with either the joystick or the software buttons when the tip is within one of the environmental cells is NOT recommended and can cause damage to the probe and the Z scanner!

2. **Leak test on lab bench:**

   - If using the portless CellLite fluid dish, leak test it on the lab bench to ensure there are no leaks.

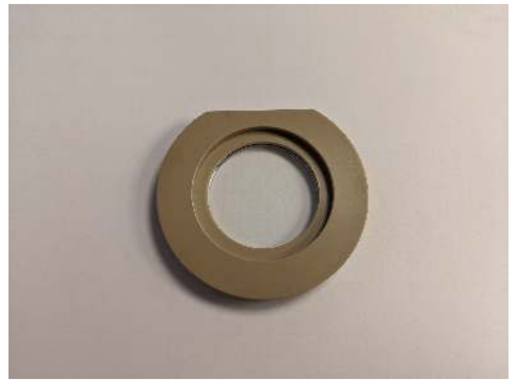


3.

Load sample onto slide or dish:

- Load your sample onto a glass slide or the portless CellLite fluid dish.

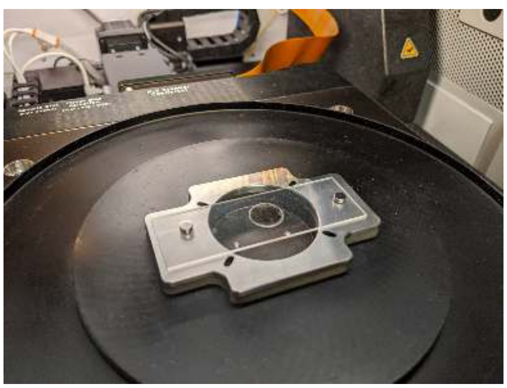
  Caution If using the portless CellLite fluid dish, note that this kit shares common parts with the similar kit associated with the environmental cells associated with the Jupiter platform. Any part not included in the Jupiter parts list for this fluid accessory is not compatible with operation of this accessory on Jupiter.
- Specifically, if you are using an environmental kit originally purchased with a Jupiter AFM, these parts should not be used with Jupiter operation: Clear silicone membrane (112.256.02), the membrane clamp (939.007 or 939.015, or 939.044), and the magnetic steel shim (207.004).

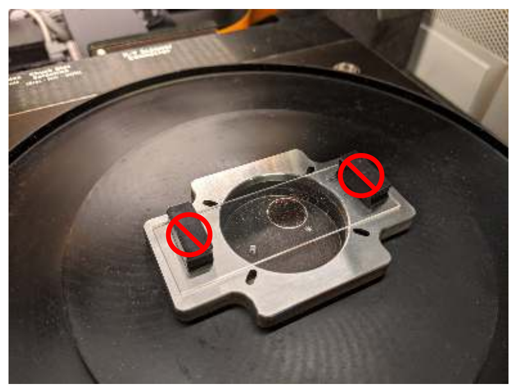


4.

Load cell, slide, or other sample mount onto chuck:

- Bring the stage to the front and center by clicking the 'Change Sample' button on the Engage Panel.
- If using the portless CellLite fluid dish, place it onto the accessory chuck. It will attach magnetically. The cell should be oriented with the flat edge facing the back.
- If using a glass slide or another sample mount, you can now load it onto the chuck. If you want to use magnets to secure your sample mount or slide, use magnets shorter than 5mm in height. The standard magnets used with the Jupiter platform are NOT compatible with Jupiter.



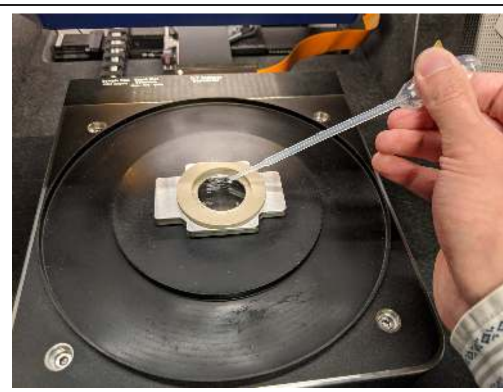


5.

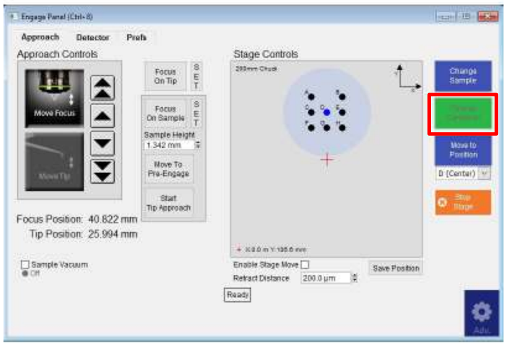
Fill the cell slowly:

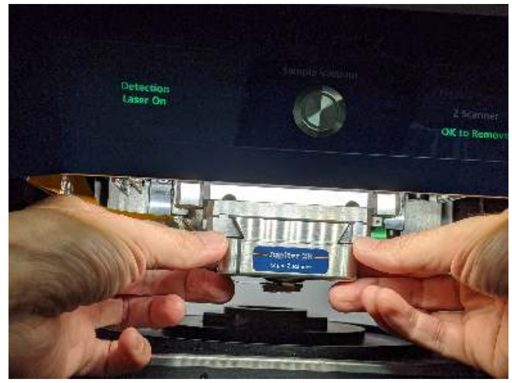
- Fill the cell slowly with fluid.

Caution Do NOT overfill the cell as this may cause the liquid to spill over the sides of the cell walls when the cantilever holder displaces it!



6.

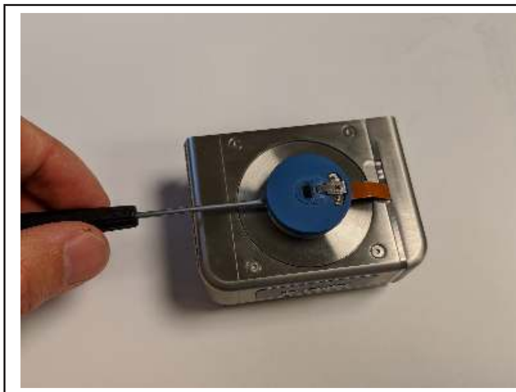




Change the cantilever holder:

- Click the ‘Change Cantilever Holder’ button.
- Unload the Z scanner if it has not already been unloaded.

7.



Load the fluid cantilever holder and tighten the screws to hold in place:

- Load the fluid cantilever holder onto the Z scanner, if not already in place.
- Tighten the screw that secures the fluid cantilever holder in place. Note that this screw does not protrude out from under the blue plastic body of the fluid holder.
- Look from the side to ensure that the fluid cantilever holder is seated properly.

8.

Attach membrane to fluid cantilever holder:

- Attach the black Viton membrane to the fluid cantilever holder prior to loading a cantilever.
- Ensure that the molded O-ring of the membrane is seated properly in the cantilever holder groove. The membrane can be loaded in any orientation.

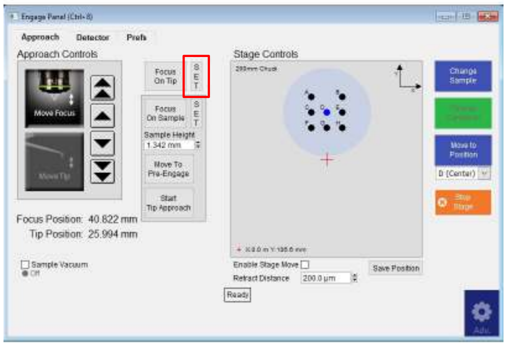
Caution Only the Viton (black) variety of the membrane provided in the Jupiter Fluid Holder kit is compatible with Jupiter operation.

9.

Lower the Tip:

- If using the portless fluid dish, lower the tip until the membrane just starts to make contact with the top of the cell. Do not immerse the tip in fluid yet.
- If using a glass slide, bring the cantilever close to the liquid surface but do not yet immerse the cantilever.

10.



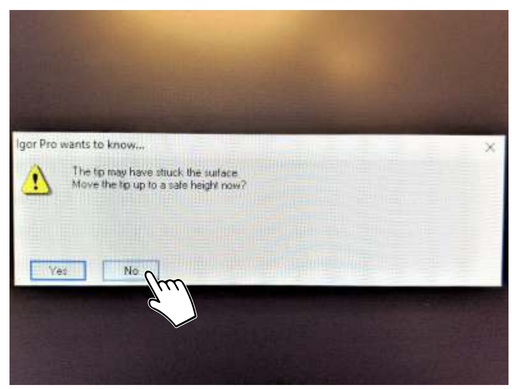
Set the Focus position and align the laser spot:

- Set the Focus position on the cantilever as you would in normal air operation.
- Align the laser spot on the cantilever. This will ensure that the Z motor will stop if the Sum signal is lost during an automated move to pre-engage or tip approach. Note that this safety behavior will not pertain to when you manually move the tip in Z.

11.

Engage the tip on the sample:

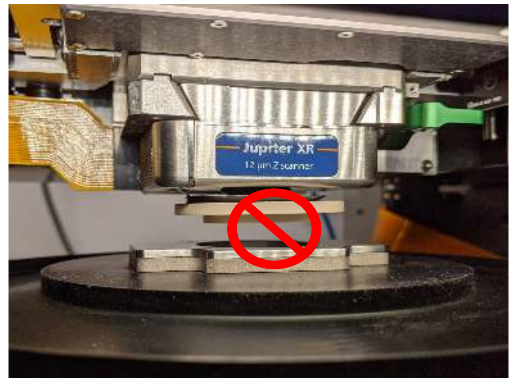
- To engage the tip on the sample without being able to see the tip and sample in profile, refer to the Section 9.4.2 on page 114 section in this tutorial.
- Note that when working with fluid, the tip will at some point become immersed in fluid and the focus and spot position will change. The system will register this as a tip crash and ask if "you want to move the tip up to a safe height". Click ‘No’ for this specific case.



12.

Raise the tip up *slowly* after imaging

- After imaging, do NOT raise the tip up at full speed with the joystick or the software buttons. Instead, raise the tip up at the slowest possible speed while monitoring the membrane and cell. Capillary forces resulting from liquid between the membrane and the cell can cause the entire cell to lift off the accessories chuck.



9.5. Cleaning and Care

Refer to the parts list (Section 9.3 on page 110) for the materials of which the fluid cell is made. All the parts used during imaging can be cleaned with solvents such as alcohol. Parts can also be autoclaved.

- Avoid the use of acetone. The rubber parts will not do well when exposed to acetone.
- Please store your fluid cell in its designated case. If you own multiple accessories that are similar to this one, it is best to keep all the parts where they belong and not get things mixed up.
- If you need replacement parts, contact your local Asylum Research office or distributor and use the parts list (Section 9.3 on page 110) as a guide.

10. Polymer Heater

CHAPTER REV. 2303, DATED 03/01/2021, 17:04. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

10.1. Overview

Figure 10.1.: Top view of the Polymer Heater.

The polymer heater was designed to heat small samples in air (or inert gas) to elevated temperatures up to 300C while keeping thermal drift and unwanted heating of the AFM to a minimum.

This accessory requires the accessory chuck and the environmental control expansion module. (Section 1.3.1.1 on page 12).

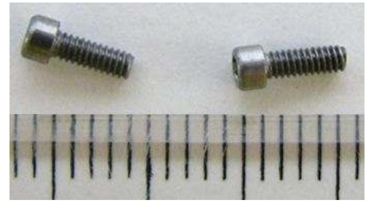
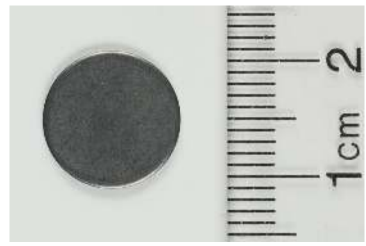
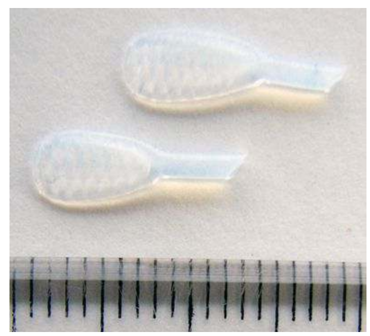
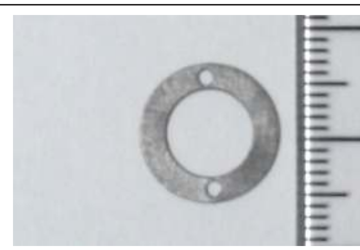
10.2. Compatibility and Prerequisites

Also familiarize yourself with the use of the standard closed fluid cell in terms of how to use fluid ports, seals, plugs, etc.: Chapter 9 on page 109.

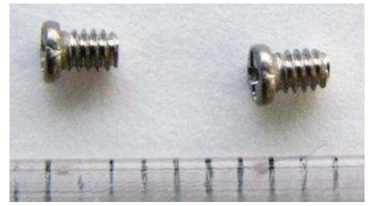
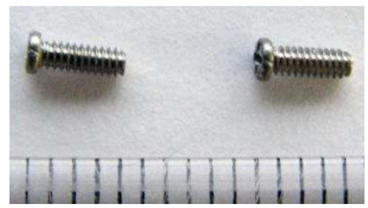
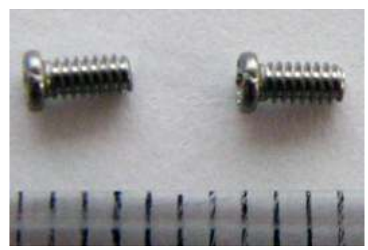
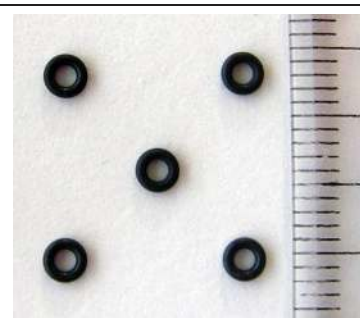
Warning	DO NOT use this accessory with liquids. It was designed for use with gases only.

10.3. Parts List

The following list includes all of the parts in your accessory kit. The table is useful as a visual table of contents with links directing you to the specific uses of each part. When ordering parts, please refer to the part numbers in the second column.

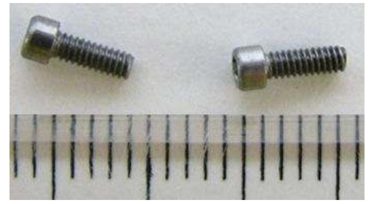
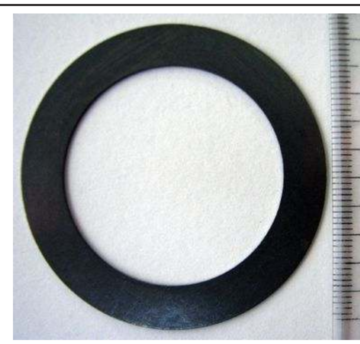
Itm	Part #	Item Description	Qty	Picture
1	001.SHCS <#0-80X.188> SST	0-80 X 3/16” Stainless Steel Socket Head Cap Screw. Connects 111.886 and 102.204 O-ring clamps to the fluid cell body. See section 11.6 Sample Mun Section 10.7 on page 136.	8	
2	080.105	12 mm AFM Specimen Disc. Magnetic disc which is permanently attached to the Ssample. Can be ordered from Asylum Research or Ted Pella (16208). See Section Section 10.7 on page 136 about sample mounting.	10	
3	111.924	1/16” OD Port Plug. PTFE plugs for blocking unused in/outlets on the closed fluid cell. Also consider using PTFE cord 0.062" Diameter (McMaster Carr Part Number 84935K48).	10	
4	111.240	Mini Sample Holder Clip. Used for holding down samples in the polymer heater. Stainless steel. Use screws 222.021 to affix to polymer heater. See Section 10.7 on page 136.	5	
5	113.544	Poly Sample Clamp, used to hold down small thin samples. See Section 10.7 on page 136.	2	

The scale in the photos is in cm and mm.

Itm	Part #	Item Description	Qty	Picture
6	222.021	Screw, Pan Head Phillips, M1.4 X 2. 2mm long Stainless-steel metric miniature screw. For mounting thin samples directly to the heater stage. Also used for mounting spring clips 111.240 to the polymer heater body. See Section 10.7 on page 136.	12	
7	222.022	Screw, Pan Head Phillips, M1.4 X 3. 3mm long Stainless-steel metric miniature screw. For mounting medium thickness samples directly to the heater stage. NOT used for mounting spring clips 111.240 to the polymer heater body. See Section 10.7 on page 136.	6	
8	222.023	Screw, Pan Head Phillips, M1.4 X 4. 4mm long Stainless-steel metric miniature screw. For mounting thicker samples directly to the heater stage. NOT USED for mounting spring clips 111.240 to the polymer heater body. See Section 10.7 on page 136.	6	
9	230.018	O-ring, 0.062” ID X 0.032” CS, Viton, 70 Durometer. FKM O-rings that seal around the four 1/16" fluid ports.	15	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
10	231.006	Tubing, PFA, 1/16" OD X .040" ID X 5 FT. This PFA tubing makes it possible to introduce gas into the polymer heater. Order from Asylum or purchase directly from Upchurch Scientific (p/n 1503). See **??** on page **??**	1	
11	290.103	3C Tweezers – Extra Fine Sharp – Standard Grade. For placing samples, tiny O-rings (e.g. 230.018) and small screws.	1	
12	290.106	#00 Phillips Wiha Screwdriver 261 PH 00X40. For small Phillips screws (222.021, 022, and 023) in the polymer heater.	1	
13	290.109	Leitsilber Conductive Paint. Used for mounting samples (See Section 10.7 on page 136). Can be purchased from Asylum Research or directly from Ted Pella (16035).	1	
14	290.111	0.050": Wiha Allen Driver 263 1,3 – 0.05" X 40. For all socket head screws; for instance, when sealing fluid ports.	1	
15	902.616	Polymer Heater Sample Stage for Jupiter.	2	

The scale in the photos is in cm and mm.

Itm	Part #	Item Description	Qty	Picture
16	001.SHCS <#0-80X.188> SST	0-80 X 3/16" Stainless Steel Socket Head Cap Screw. Connects 111.886 and 102.204 O-ring clamps to the cell body. See **??** on page **??**.	8	
17	112.204	Fluid Port Clamp Bar. Stainless Steel. Compresses and seals two mini O-rings (230.018). Fastens with 0-80 X 3/16" screws. Part of 1/16" fluid ports.See **??** on page **??**.	2	
18	112.430	Cell Triple Clamp. Fluid Port Clamp Bar. Stainless Steel. Compresses and seals three mini O-rings (230.016). Fastens with 0-80 X 3/16" screws. Part of 1/16" fluid ports. See **??** on page **??**.	2	
19	207.004	Steel Shim, 0.020" Thick x 1-½" ID x 2-1/8" OD. Used to moderately seal the humidity cell. See **??** on page **??**.	2	
The scale in the photos is in cm and mm.				

10.4. Assembly Instructions

There is little to disassemble from the polymer heater. Only the port clamps around the perimeter of the cell should be removed.

Do NOT remove any other screws or items from the polymer heater. There are no serviceable parts inside.

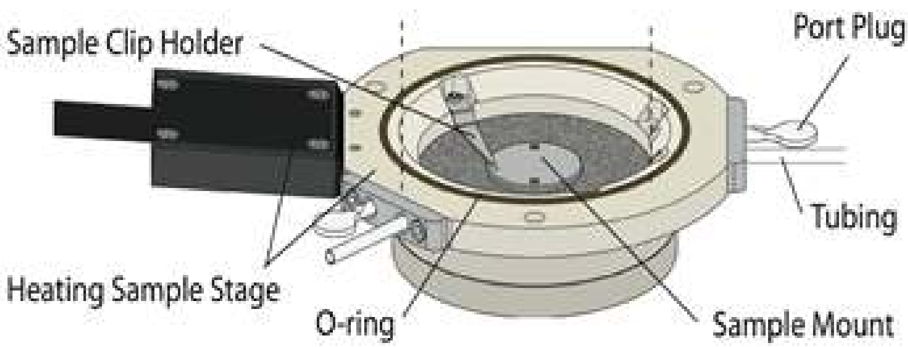


Figure 10.2.: A nice overview of the Polymer Heater and its parts.

10.5. High Temperature Imaging

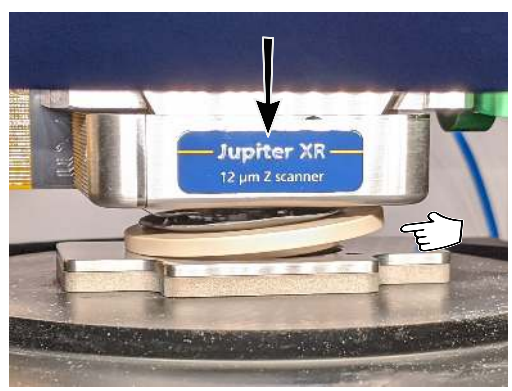
10.5.1. Tutorial: High Temperature Imaging

Imaging at high temperatures does not differ much from imaging at room temperature. For large temperatures you will experience more thermal drift than usual. You may "run out of" Z range as the sample might approach or retreat by more than the full range of the Z actuator. You will have to experiment.

1.

CAUTION! SEVERE DAMAGE POSSIBLE!

- As you follow this procedure, you will engage the probe INSIDE of a cup with high sidewalls.
- If you use the joystick, or GO TO POSITION command or the controls on the Video panel to move the stage when engaged inside the cup, you risk serious damage to the probe and the Z scanner!!



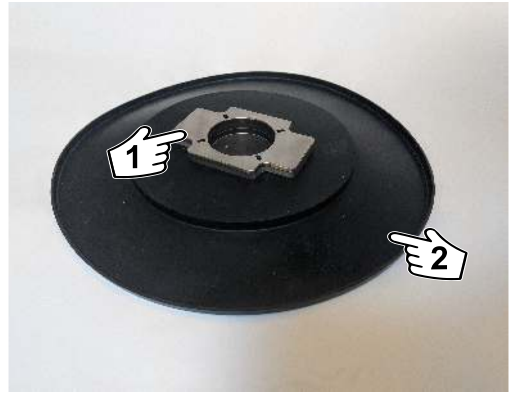
2.

Collect required equipment and materials

- Accessory Chuck, consists of:

  1) magnetic plate (compatible with Jupiter accessories)

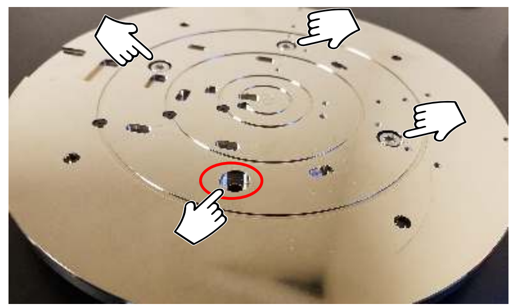
  2) flexible silicone cover (to contain any spills or splashing, avoiding damage to the scanner)
- Polyheater sample stage
- Environmental control expansion module



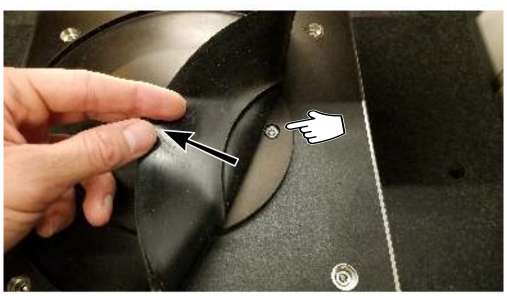
3.

Remove the standard chuck

- Four (4) screws need to be removed. (Retain these screws as they will be used for the Accessory Chuck as well as for putting the Standard Chuck back.)
- Notice that one screw has already been removed.



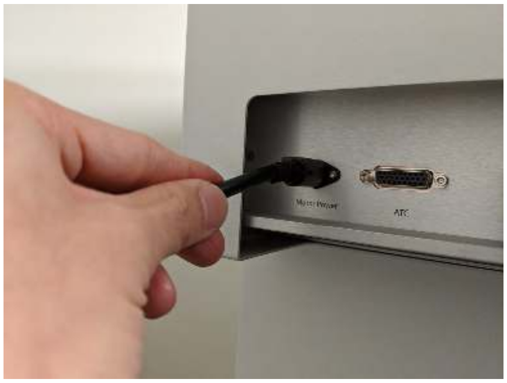
4.



Install the accessory chuck on the XY scanner

- Install the accessory chuck on the XY scanner. Refer to Section 8.2.2 on page 106 for details.
- There are four (4) screws under the flexible silicon cover that need to be tightened; fold it back, as shown above.
- Tighten with the torque wrench. (10 in.-lbs.)

5.



Install the environmental control expansion module

- If the environmental control expansion module is not already installed, follow the steps listed here first:
  a) Turn off the ARC2 controller power.
  b) Detach the Motor Power cable connected to the backpack controller. This is sometimes referred to as the "dirty power".
  c) Remove the left-most available slot cover in the expansion box and install the environmental control expansion module.
  d) Reattach the Motor Power cable to the backpack controller and turn on the ARC2 controller.

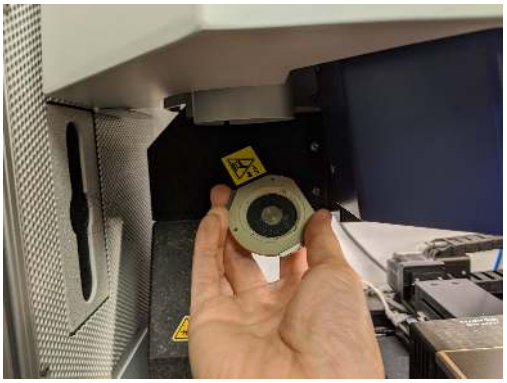
Note Accessories that are attached to the expansion box must be installed in order, from left to right, without any unoccupied slot.

6.

Attach the PolyHeater cable to the environmental control card

- Attach the PolyHeater cable to the expansion box.
- If this is your first time using the polymer heater, consider testing the heater stage without a sample mounted so you are familiar with its operation. See Section 10.6 on page 135.

7.



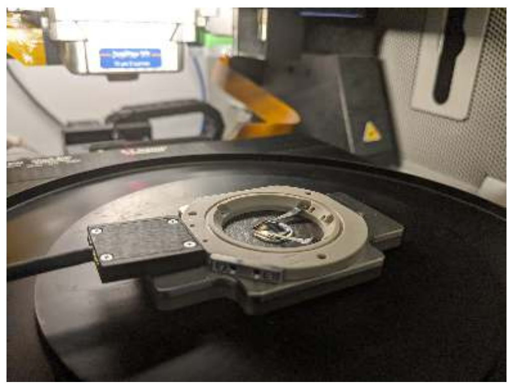
Route the PolyHeater to the Accessory Chuck

- Gently pull the PolyHeater through the tube.
- There should be enough cable length to accommodate full sample stage travel.
- Leave any excess cable length on the shelf in front of the expansion box.

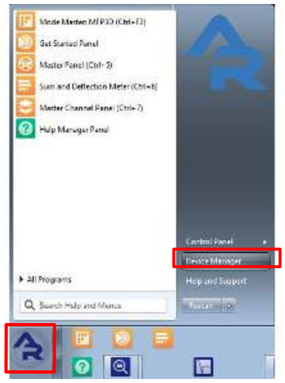
8.

Position the PolyHeater on the Accessory Chuck

- Mount your sample. See Section 10.7 on page 136.
- Place the PolyHeater onto the Accessory Chuck. The flat side should face the back of the Jupiter enclosure.
- The cable should extend out to the left when facing the instrument.
- If using the PolyHeater in a semi-sealed state, ensure that any gas tubing does not get damaged during the XY stage.



9.



Power up, start software, and check device connections

- The ARC2 controller should be turned on (button on front bottom right of controller), and the power connected to the backpage controller.
- Start the AFM software and select the desired imaging mode in ModeMaster (e.g. AC Mode, AM-FM, Contact Mode, etc).
- Verify that all components are identified in the software by clicking the ‘AR’ button and selecting the ‘Device Manager’.
- The software should automatically recognize the PolyHeater accessory and open the appropriate heater panel with the controls.
- The stage type should be recognized as *Polyheater*.

10.

Engage the cantilever to the sample

- Move the XY stage so that the Z scanner is centered above the sample holder.
- Descend the tip to the sample using the technique shown in Section 9.4.2 on page 114.
- It is a procedure to engage when you cannot see the lateral profile of the cantilever and cannot judge how close to the sample the tip is.

Caution Do NOT move the stage around with the joystick in this position or you risk damaging the Z scanner, PolyHeater stage, or accessory chuck!

10.6. Testing the Polymer Heater

1. Enter a ‘Target Temp’ setpoint of 150 ºC.

2. Enter a 'Ramp Rate' of 50 ºC/min.
3. Set the 'Mode' to On.
4. Set the 'Feedback' to On.

Warning	The polymer heater can get hot enough to cause serious burns. Even the black ceramic material around the perimeter of the device will get hot enough to cause injury. The plastic parts can get hot to the touch but are always safe to handle and will not cause burns.

5. Watch the temperature rise on the history graph. An example of what you might see is in Figure 10.3 on page 136.
6. You can play around changing the setpoint and eventually turn off the heater.
7. Turn the 'Mode' to Off and observe the temperature graph until the heater is below 50 ºC. This will take at least five minutes.
8. Now it is safe to handle without getting burnt and safe to store.

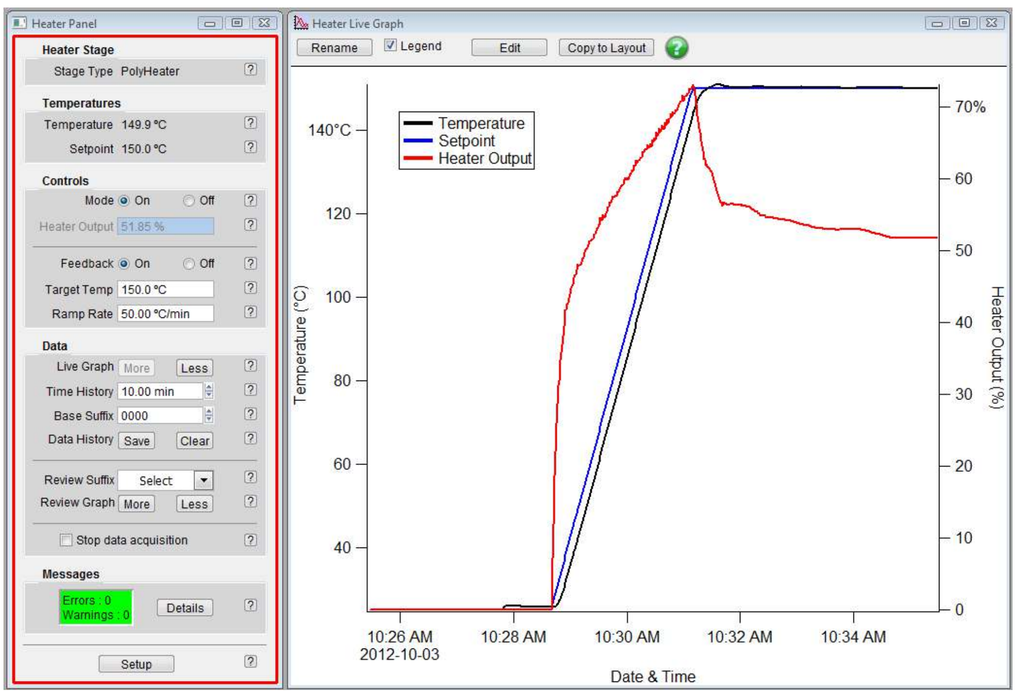


Figure 10.3.: Test of the Polymer Heater. What you might expect to see.

10.7. Sample Mounting Techniques

10.7.1. Silver Paint

It is common to use a bit of silver paint to attach a small sample to an AFM disc, which in turn magnetically attaches to the polymer heater.

(a) Magnetic Disc

(b) Clips. NOTE: Three clips may be excessive. See Step 8 on page 134 where two clips were used successfully on Jupiter. Be careful when arranging the clips so they do not interfere with the probe holder.

(c) Screws

Figure 10.4.: Some ways to mount a sample.

For very small samples we often use a tiny bit of silver paint to attach the sample directly to the metal stage at the center of the heater. Be careful not to spill the paint onto the black ceramic perimeter. It may not be possible to completely clean the paint from there.

After imaging, one can easily pop the sample off with some tweezers and clean the sample stage with a cotton swab and some solvent, such as isopropyl.

10.7.2. Clips

Some hold down clips are supplied (111.240) that attach to the four cutouts in the plastic perimeter of the polymer heater. You can see one clip in place here: Figure 10.2 on page 131.

IMPORTANT: Only use the shortest screws in your kit (222.021) to attach the clips. Do not over tighten since you may strip out the delicate threads in the plastic body.

Note that the clips are magnetic: Beware that when you loosen the screws, they can be pulled toward the center of the sample and possibly damage the surface of the sample. See Figure 10.4 on page 137.

10.7.3. Screws

Three (3) lengths of tiny screws are supplied to help you attach small samples directly to the heated center of the polymer heater. We have used tiny washers under each screw to clamp a sample or we have also taken a large washer and drilled to small holes in it (the holes are exactly 10mm apart) to old down a sample. Contact us if you need more help with sample mounting. See Figure 10.4 on page 137.

10.7.4. Epoxy

A few good choices are Cotronics Duralco™ 4703 (good to 370 ºC) or Cotronics Duralco™ 124 or Resbond 989FS. Use these adhesives only to attach a sample to a magnetic AFM disc since it may be difficult to remove these adhesives from your polymer heater. See Figure 10.4 on page 137.

10.7.5. Inert Gas Flow

For samples that might otherwise combust (react with ambient oxygen), it is common to flow inert gas (Nitrogen or Argon) through a polymer heater.

10.7.6. Condensation and AC Mode Tuning Issues

10.8. Thermal Drift

When the temperature setpoint is changed, the materials inside the polymer heater will thermally expand and contract. Asylum Research has tried to minimize these effects though careful choices of materials and design geometry. Nevertheless, images taken while the temperature is changing will experience thermal drift. Looking at Figure 10.3 on page 136 you can get an idea of the period during which thermal drift will be worst. Certainly, while the temperature is changing, you can expect some thermal drift effects.

Note that once the temperature setpoint is reached, the heater power does not immediately reach a steady state. It slowly tapers off during the next 5-10 minutes. During this period, the low thermal conductivity materials surrounding the sample are slowly heating up. You can also expect thermal drift effects during this period.

10.9. Cleaning and Care

The polymer heater was not designed to be disassembled for thorough cleaning. Typically, one should rub the metal and black ceramic surfaces with a cotton swab moist (not soaking!) with alcohol.

Note that the heated metal surface is made of a hard tungsten alloy and can be gently scraped with steel objects like the tips of tweezers or curved blades without worrying about scratching the surface. The black ceramic material around the heater, on the other hand, is not very hard and should NOT be scraped with metal objects.

Please store your polymer heater in its designated case. If you own multiple accessories similar to this one, it is best to keep all the parts where they belong and not get things mixed up.

If you need replacement parts, contact your local office or distributor and use the parts list in this chapter as a guide.

10.10. Electrical Connections to the Sample

11. Cooler Heater

CHAPTER REV. 2303, DATED 03/01/2021, 17:04. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

11.1. Overview

The Cooler Heater accessory was designed to cool and heat small samples in air (or inert gas) or liquid drops from below freezing to above boiling. To go to temperatures significantly below freezing, the included coolant pump must be attached.

11.2. Compatibility and Prerequisites

This accessory is a variant of the closed fluid cell discussed in Chapter 9 on page 109. You should be familiar with the closed fluid cell before you embark on this chapter. Here we will only discuss specific issues relating to measuring and controlling humidity around your sample.

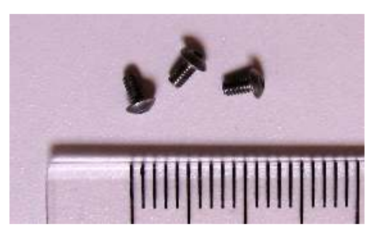
Figure 11.1.: Top view of the Cooler Heater.

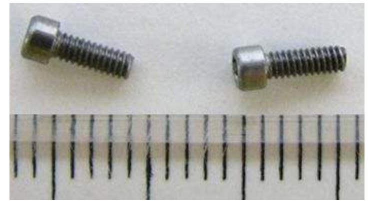
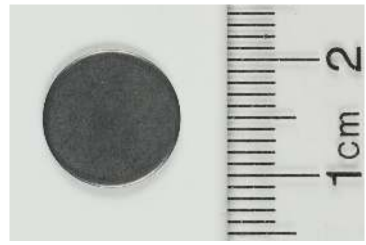
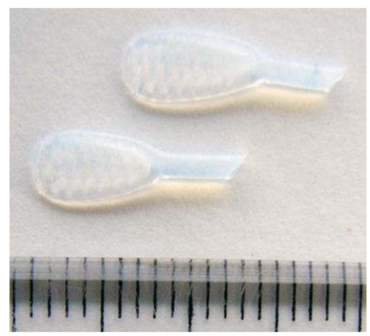
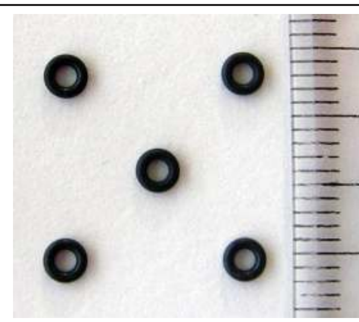
Warning	DO NOT use this accessory with large amounts of fluid. It was designed for use with gases or small amounts of fluid.

11.3. Parts List

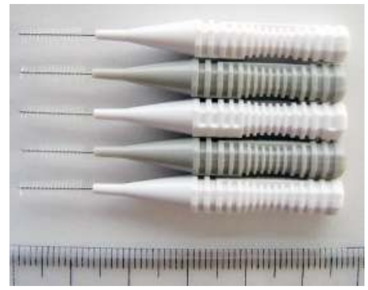
The following list includes all of the parts in your accessory kit. The table is useful as a visual table of contents with links directing you to the specific uses of each part. When ordering parts, please refer to the part numbers in the second column.

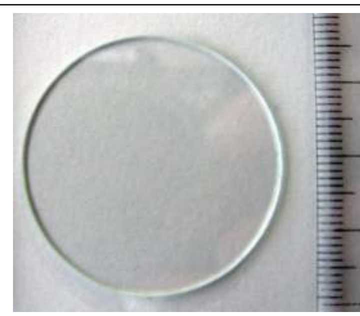
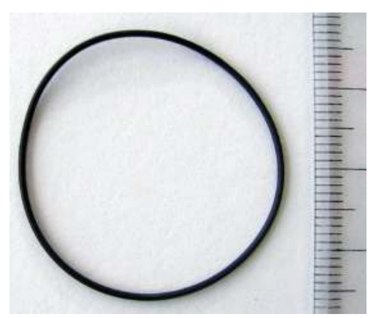
Note The following table may refer to other chapters with regard to components like tubing clamps and O-ring seals that are common across a variety of sample stages.

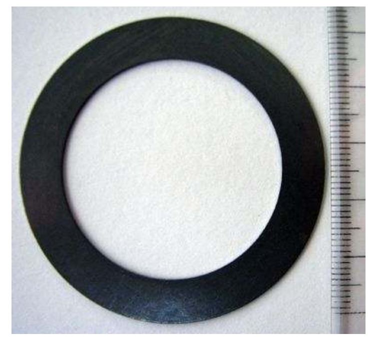
Itm	Part #	Item Description	Qty	Picture
1	0-80 X 1/8 BHCS SS	0-80 X 1/8" Button Head Cap Screws, SS. Used to attach items to the three threaded holes in the cooler heater body.	12	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
2	001.SHCS <#0-80X.188> SST	0-80 X 3/16” Stainless Steel Socket Head Cap Screw. Connects 111.886 and 102.204 O-ring clamps to the cell body. See **??** on page **??**.	8	
3	080.105	12mm AFM Specimen Disc	10	
4	111.924	1/16” OD Port Plug. PTFE plugs for blocking unused in/outlets on the closed fluid cell. Also consider using PTFE cord 0.062" diameter (McMaster Carr Part Number 84935K48.) See **??** on page **??**.	10	
5	230.018	O-ring, 0.062” ID X 0.032” CS, Viton, 70 Durometer. FKM O-rings that seal around the four 1/16" fluid ports. See **??** on page **??**.	15	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
6	231.006	Tubing, PFA, 1/16” OD X .040” ID X 5 FT. This PFA tubing makes it possible to introduce and remove fluid or gas from the closed fluid cell. Order from Asylum or purchase directly from Upchurch Scientific (p/n 1503). See **??** on why it is important to use this type of tubing.	1	
7	279.110	Alphacool Reservoir Holder for 50MM TubeE, ABS Black. Attaches to coolant pump assembly 900.171. Comes pre-assembled on the pump body.	2	
8	290.106	#00 Wiha Phillips Screwdriver, 261 PH 00 X 40. For small Phillips screws.	1	
9	290.109	Leitsilber Conductive Paint. Used for mounting samples (See Section 10.7 on page 136). Can be purchased from Asylum Research or directly from Ted Pella (16035).	1	
10	290.111	0.050”: Wiha Allen Driver 263 1,3 – 0.05” X 40. For all socket head screws.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
11	290.113	Brush 1/16 Cleaning. Used for cleaning out the access ports on the side of the cooler heater body.	5	
12	290.129	Coolant. Protects the cooler heater from internal corrosion. Can be used undiluted. See Step 6 on page 147. Purchase from https://www.aquatuning.us/	1	
13	290.103	3C Tweezers – Extra Fine Sharp, Standard Grade. For placing small O-rings and screws.	1	
14	449.011	Cable CB25M-DB25F, 2 meters, shield intact. (comes with cooler pump assembly)	1	
15	900.170	Cooler Heater Stage Assembly. See Section 11.4 on page 145	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
16	900.171	Coolant Pump Assembly. See Step 6 on page 146 about adding coolant. Also see Figure 11.5 on page 157.	1	
17	112.204	Fluid Port Clamp Bar. Stainless Steel. Compresses and seals two mini O-rings (230.018). Fastens with 0-80 X 3/16" screws. Part of 1/16" gas ports. See **??** on page **??**.	2	
18	112.430	Cell Triple Clamp. Fluid Port Clamp Bar. Stainless Steel. Compresses and seals three mini O-rings (230.016). Fastens with 0-80 X 3/16" screws. Part of 1/16" fluid ports. See **??** on page **??**.	2	
19	111.425	35mm X 1mm glass disc. Custom made by Asylum out of Glaverbel float glass. See Section 9.4.1 on page 112.	5	
20	230.015	O-ring, 1.228"ID X 0.032"CS, Viton, 75 Durometer. This FKM O-ring makes the seal between the sample disc 111.425 and the fluid cell body. See Section 9.4.1 on page 112.	5	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
21	111.420	Closed Cell Bottom Clamp. The stainless steel retaining ring which holds the glass bottom against the closed cell. See Section 9.4.1 on page 112.	1	
22	207.004	Steel Shim, 0.020” Thick x 1-½” ID x 2-1/8” OD. Used to moderately seal the humidity cell. See **??** on page **??**.	2	
The scale in the photos is in cm and mm.				

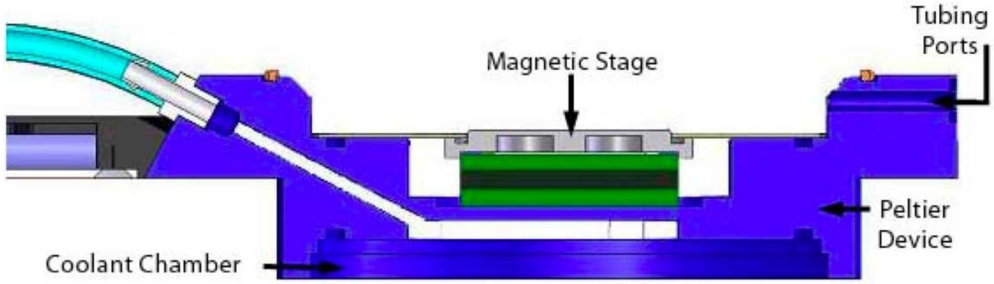
11.4. The Cooler Heater Stage

The Cooler Heater stage is another variation of our family of closed environmental chambers. The Cooler Heater stage utilizes a Peltier thermoelectric device to achieve an operating temperature range of –20º to +120ºC. A flow-through liquid cooling system is supplied to allow the stage to reach temperatures below ambient conditions. Although the system is primarily designed to operate in liquid and air environments above 0ºC and non-liquid below 0ºC, it is also possible to configure the stage to operate in a semi-sealed cell configuration where specific gas environments are required regardless of operating temperature.

Like the other environmental systems, there is an integrated software control panel that allows for control of temperature as well as coolant flow rate.

Some key points of interest in the Cooler Heater stage are:

- Samples are typically mounted to a magnetic steel puck. A supply of pucks comes in the accessory kit. Additional pucks may be purchased from Asylum Research.

- 

  Side view cross section
  – The side view cross section shows that only the center part of the cooler heater is temperature controlled. The entire perimeter of the sample chamber is thermally connected to the hot side of the Peltier element.
  – Fluid operation is therefore only recommended for a small liquid drop that does not spill over to the “blue” areas, which are not temperature controlled.

11.5. Cooler Heater Setup

11.5.1. Setup for -20 to +120C operation:

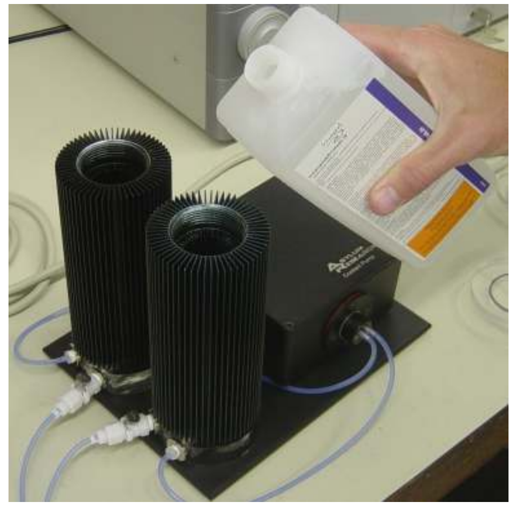
This configuration allows for –20º to +120ºC temperature range.

1. Use the 25-25 pin signal cable (449.011) provided with the Cooler Heater system to connect between the Jupiter controller’s expansion port and the Coolant Pump housing.
2. Connect the Cooler Heater stage to the expansion box through the environmental control expansion module.
3. Connect the two coolant hoses from the Cooler Heater stage assembly to the Coolant Pump assembly. There is no specific flow direction through the coolant housing; therefore, the connections of the two hoses to the pump are not important.
4. See **??** on page **??** for a photo of the fully connected setup.
5. **Open the pump reservoirs:**
   - Remove the tops from the cooling towers.

6. **Add coolant:**

- Fill each tower between 1/2 and 3/4 full of coolant.
- Tightly screw the caps back onto the reservoirs.



11.5.2. Setup for 0º to +120ºC

It is also possible to run the Cooler Heater without the coolant pump in circuit. There is no benefit to this configuration other than simplification of the amount of hardware in your system. Configuring the system in this way is the same as the full system connections, except for the elimination of the coolant hoses and the coolant pump.

11.5.3. Further Setup

Once the basic connections are made, place the Cooler Heater stage on the accessory chuck. The stage has magnets embedded into the bottom of the stage body that will hold it to the accessory chuck. Place the stage on the chuck so the cable and coolant hoses are routed to exit toward the left. Like with all closed fluid cells, the flat area on the cell body aligns with the rear of the system.

It is acceptable to build the stage into the cable clamp.

11.6. Testing the Cooler Heater

1. Follow the general setup steps in Section 11.5 on page 146.
2. Enter a ‘Setpoint’ of 5°C.
3. Enter a ‘Ramp Rate’ of 50°C/min.
4. Set the ‘Mode’ control to *On*.
5. Set the ‘Feedback’ control to *On*.
6. Watch the temperature fall on the history graph. When it is cold, you should see condensation on the stage.
7. Turn the pump on by setting ‘Pump Speed’ to 50%.
8. Lower the temperature setpoint to -10°C.

9. Frost should form on the stage. See Figure 11.2 on page 148 for an example of what your temperature history might look like.

10. Turn the pump off and set the 'Mode' to *Off* to conclude the test.

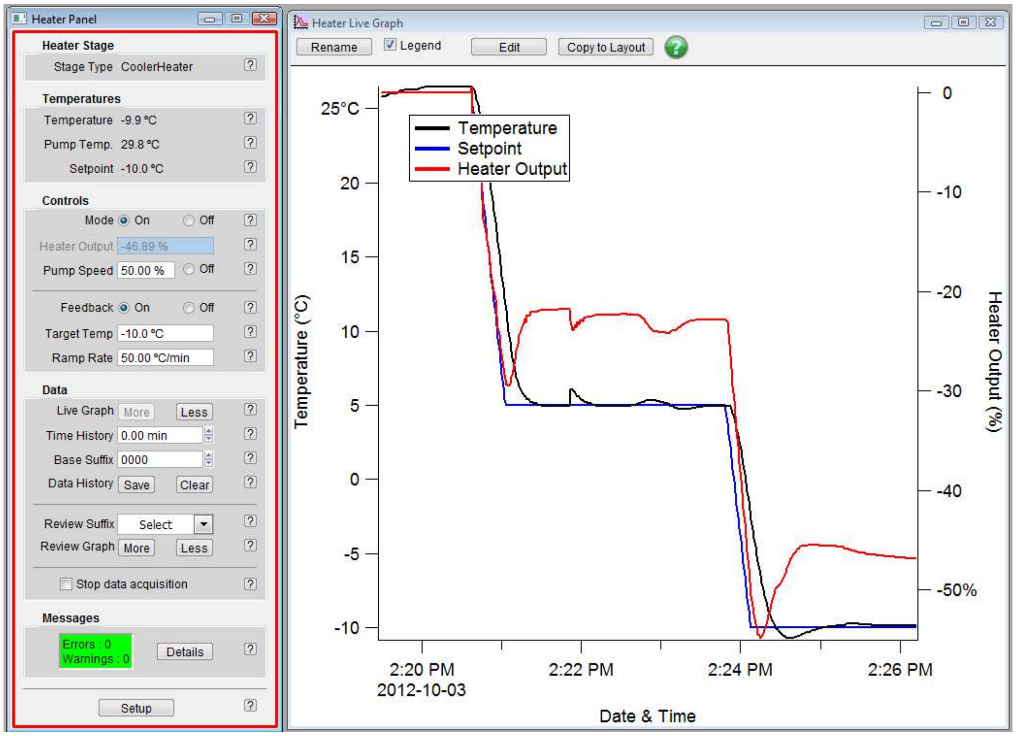


Figure 11.2.: Test of the cooler heater. What you might expect to see. Note that the temperature control will be less noisy if the cell is covered. You will discover this when using it inside the AFM.

11.7. Sample Mounting

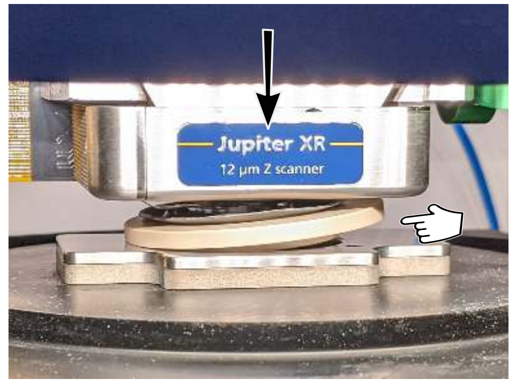
The standard method is to glue the sample to a magnetic AFM disc, some of which are supplied with your system. A small dab of a basic epoxy (like 5-minute epoxy) should be sufficient. Be sure to NOT use double-sided tape or glue tabs. For a few more ideas on sample mounting, please see Section 10.7 on page 136.

The sample stage is made of a very, hard, tungsten-based alloy and should withstand scratching from tweezers or other steel tools.

11.8. Tutorial: Cooler Heater

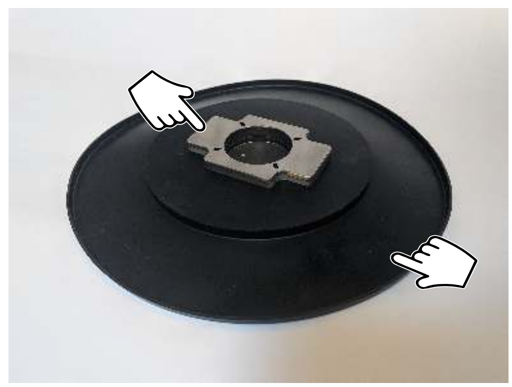
1. **CAUTION! SEVERE DAMAGE POSSIBLE!**

   - As you follow this procedure, you will engage the probe inside of a cup with high sidewalls.
   - If you use the joystick, the GO TO POSITION command, or the controls in the Video panel to move the stage when inside the cup, you risk serious damage to the probe and to the Z scanner!!



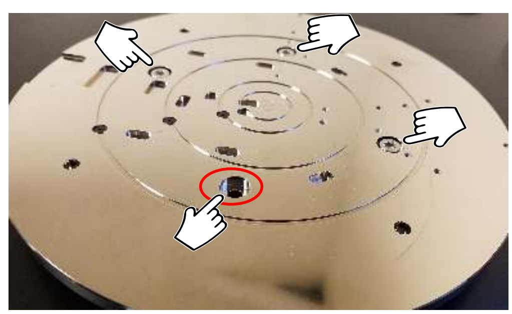
2. **Collect required equipment and materials**

   - Accessory chuck, consisting of:
     - magnetic plate, and compatible with Jupiter accessories.
     - flexible silicone cover (to contain any possible spills or splashing and avoid damaging the scanner)
   - Cooler Heater stage, P/N 900.170 or 900.310 (Infinity)
   - Coolant Pump, P/N 900.171
   - Environmental control expansion module
   - Deionized water or pump coolant
   - High vacuum grease



3. **Remove the standard chuck**

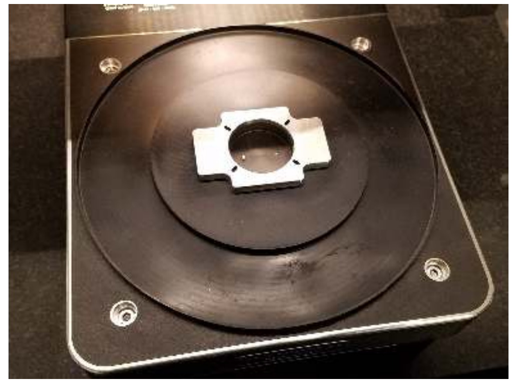
   - Four (4) screws need to be removed:
     - Retain these screws as they will be used for the accessory chuck, as well as for putting the standard chuck back.
   - Notice that one screw has already been removed.

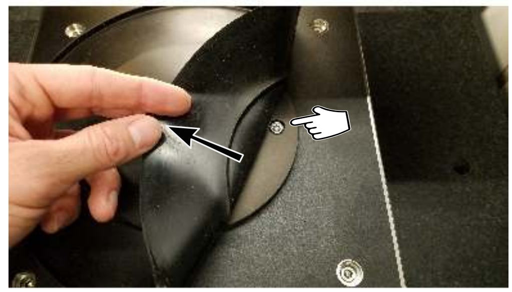


4.

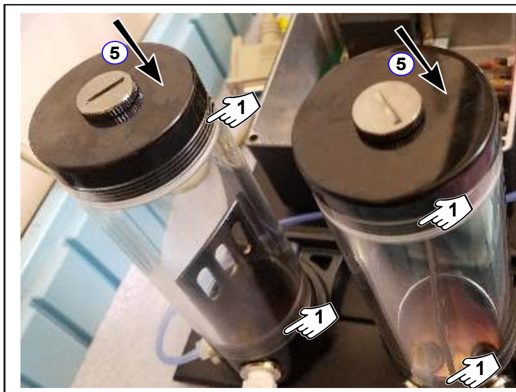
Install the accessory chuck

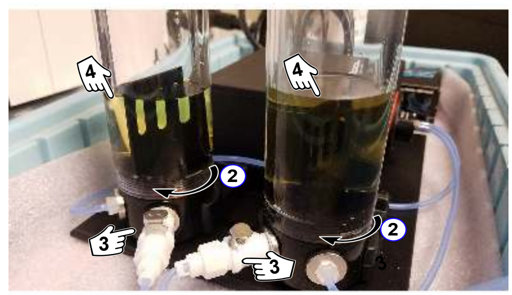
- Install the accessory chuck on the XY scanner. Refer to Jupiter Section 8.2 on page 103 for details.
- There are four (4) screws under the flexible silicone cover that need to be tightened.
- Tighten with the torque wrench (10 in.-lbs.).





5.





Assemble coolant reservoir towers:

1. Apply vacuum grease to the threads of both end pieces (base and lid) of each of the coolant reservoir towers.

2. Screw reservoir towers into the base.

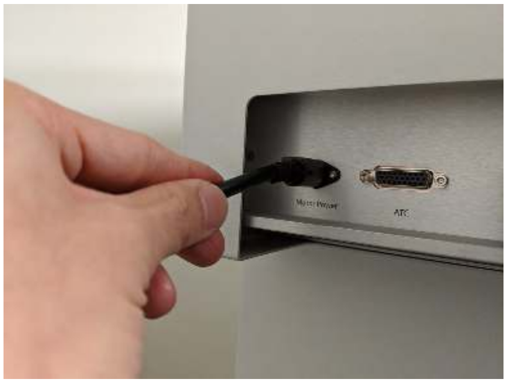
3. Attach tubing.

4. Fill towers with coolant liquid (deionized water is fine, but coolant is better).

5. Seal lids down (do not overtighten).

6. Check for Teflon tape or any particles potentially blocking flow of coolant and clear as needed.

6.



Install the environmental control expansion module

- If the environmental control expansion module is not already installed, follow the steps listed here first:
    a) Turn off the ARC2 controller power.
    b) Detach the Motor Power cable connected to the backpack controller. This is sometimes referred to as the "dirty power".
    c) Remove the left-most available slot cover in the expansion box and install the environmental control expansion module.
    d) Reattach the Motor Power cable to the backpack controller and turn on the ARC2 controller.

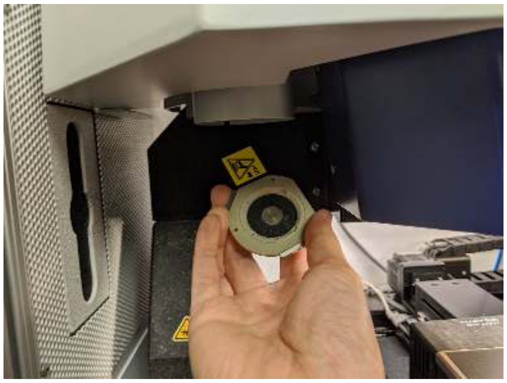
Note Accessories that are attached to the expansion box must be installed in order, from left to right, without any unoccupied slot.

7.

Attach the cooler heater cable to the environmental control card

- Attach the cooler heater cable to the expansion box.

8.



Route the cooler heater to the accessory chuck

- Gently pull the cooler heater through the tube.
- There should be enough cable length to accommodate full sample stage travel.
- Leave any excess cable length on the shelf in front of the expansion box.

NOTE: Pictures shows the similarly shaped polymer heater.

9.

Connect the expansion cable between the pump assembly and the ARC expansion port

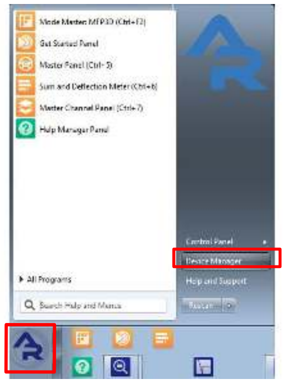
- The expansion plug port is immediately above the master cable on the ARC2.

10.

Mount the cooler heater stage

- Place the cooler heater stage on the accessory chuck.
- Tubing should extend out to the left when viewing from the front of the instrument.

11.



Power up, start software, and check device connections:

- The ARC2 controller should be turned on (button on front-right of controller) and the power connected to the backpack controller.
- Start the AFM software and select the desired imaging mode in ModeMaster (e.g. AC Mode, Contact Mode, etc.).
- Verify that all components are identified in the software by clicking the ‘AR’ button and selecting the ‘Device Manager’.
- The software should automatically recognize the cooler heater accessory and open the appropriate heater control panel.
- Stage type should be recognized as "CoolerHeater"

12.

Engage the cantilever to the sample:

- Move the XY stage so that the Z scanner is centered above the sample holder.
- Descend the tip to the sample using the Section 9.4.2 on page 114 technique.
  - It is a procedure to engage when you cannot see the lateral profile of the cantilever and cannot judge how close to the sample the tip is.

Caution Do NOT move the stage around with the joystick in this position, or you risk damaging the Z scanner, cooler heater stage, or accessory chuck!

13. Refer to the Applications User Manual for additional information.

11.9. Operation

Simply operate the temperature controls as you did on the tabletop test in Section 11.6 on page 147. To minimize thermal drift effects, consider using the image stabilization software feature described in *Hoods and Isolation User Guide, Chapter: Software Options for Image Stabilization*.

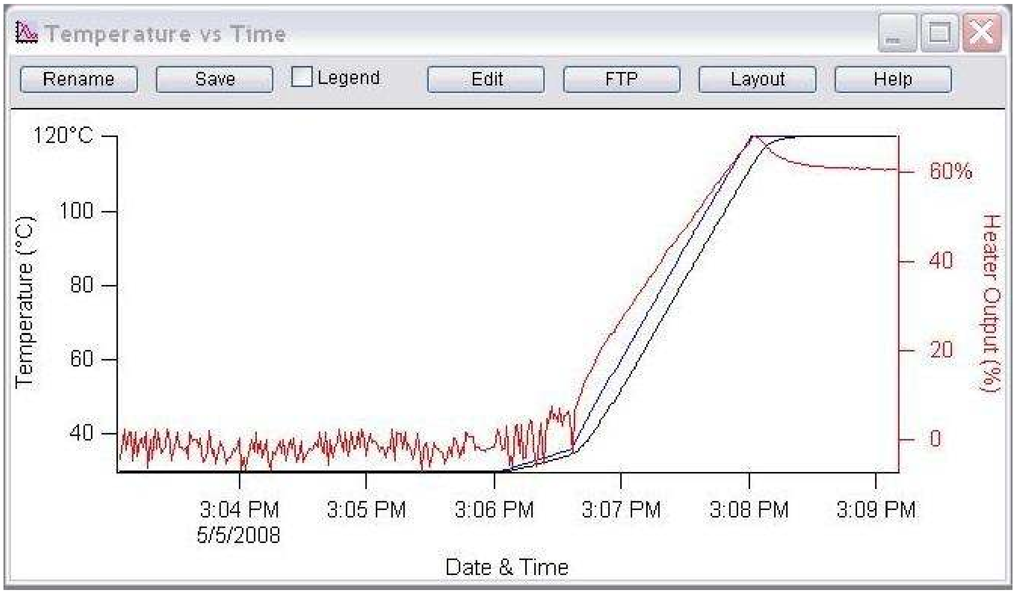


Figure 11.3.: The latter part of this graph shows the heater power as the temperature ramps up to 120C.

11.9.1. Heating

When heating, it is a good habit to note the heater power percentage as the system is heating. Typically heating the stage to 120ºC will result in the heating power running at around 60% (see Figure 11.3 on page 154).

11.9.2. Cooling

The Heater Output percentage is an important indicator that should be noted during cooling experiments. The typical range of the heater output should be kept within +/-85%. In cooling experiments, the Peltier device draws current, thus generating heat. When temperatures become lower than 0ºC, the system's coolant pump is needed to circulate fluid in order to draw off excess heat from the sample stage. As the set temperature becomes closer to the limit of -20ºC, the Peltier device requires increasing current flow to reduce temperature. This in turn creates more heat which then requires greater heat transfer into the coolant. This effect is most noticeable between -15ºC and -20ºC. It is important to monitor the Heater Output percentage when temperature feedback is used during experiments below 0ºC to ensure that the heat removal from the sample stage is adequate to prevent the power output from going beyond -85%. If the stabilized cooling temperature is reached, but the heater power climbs during the experiment or requires more than -85% to maintain temperature, the surrounding ambient temperature must be lowered or the coolant temperature

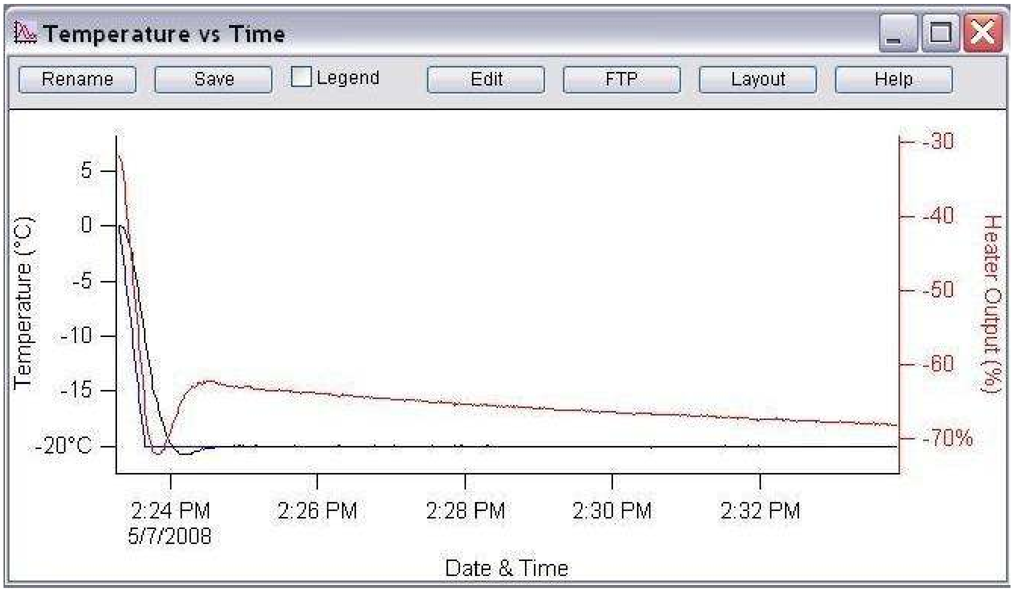


Figure 11.4.: The latter part of this graphs shows the heater power as the temperature ramps down to -20C. Note the steady increase in cooler power due to the body of the cooler heater warming up, and the Peltier has to work harder to maintain the temperature setpoint.

must be lowered. The plot shows the heater power slowly increasing in order to maintain -20ºC. The plot was taken with the coolant pump flowing at a rate of 600. We have found that -20ºC can be maintained with a heater output of ~-85% given a lab temperature of 21ºC.

11.9.3. Inert Gas Purge

For a typical laboratory, the relative humidity will be between 40 and 70 percent, or a dew point range between 10 and 20°C. In other words, below 10 or 20°C water will start to condense onto the sample in a typical lab. Below 10°C, the condensation will become significant, and below 0°C it will turn into frost. Dry gas flow will alleviate most of these problems. See **??** for more information on inert gas purge and on how to connect tubing to the cooler heater.

11.9.4. Operating the Coolant Pump

The speed of the cooling pump is controlled through the “pump speed” control in the heater panel. Typically run it at as low a speed as you can while cooling. It is not required when heating. If you find that you cannot reach your cold temperature setpoint, try turning up the pump speed. If that is still not enough, resort to Section 11.12 on page 156.

11.10. About Peltier Devices

Peltier devices work by creating a thermal difference between two heating plates. As one or the other plates are heated, the thermal difference between them causes the heating or cooling of the sample stage. An indication of activity of the Peltier device can be seen by monitoring the direction of the heating current seen in the heating power output in the Heater control panel. Positive current flow results in heating (red box next to the Heater On/Off status). Negative current flow cools the stage indicated by the heater status box changing to Blue. Monitoring the heater output percentage is especially important during cooling experiments where the sample is held below 0ºC. This is explained further in the cooling operation section. The first step in learning the limits of the system, as well as becoming familiar with the controls, is to operate the instrument without a sample or scanning experiment being performed. Due to thermal loss from the surrounding air, you should cover the top of the cell while you are operating the cell controls. You can use a business card or an adhesive note to cover the top of the cell.

11.11. Finding the Lower Limit of the Cooler in Your Lab

An effective way to test the cooling limit of the cooler heater system in your lab is to set the Feedback to "Off" and set the Heater Output to "–85%". This will set the heater power to its lower operating limit without allowing the system to go into feedback runaway.

1. Place the cooler heater stage on the accessory chuck.
2. Place a cover over the stage to keep the surrounding air from affecting the operating temperature.
3. Set the 'Feedback' control to *Off*.
4. Set the 'Heater Power' to *–85%*.
5. Monitor the 'Current Temperature' parameter with the coolant pump off. Allow adequate time for the temperature to stabilize. You should see the temperature stabilize within 10-20 minutes.
6. Turn the coolant pump on and monitor the 'Current Temperature'. The coolant pump operates at a good flow rate when set to around 500-600. Setting the pump to its maximum range of 700 will not remove heat much faster so it is typically not necessary or desired, due the possibility of the motor stalling. You should see the current temperature drop to between –15º and –20ºC. Allow adequate time to stabilize. Usually within 20 minutes you will see the lower limit of the system's cooling range.

11.12. Cooling Below -20C

The coolant reservoirs can be detached from the pump by removing a screw from the bottom. With extra tubing (please contact Asylum Research and we will send you some, or purchase some generic silicone tubing with ID 1/16" and OD 1/8", or metric ID ~1.5mm, OD ~ 3.0mm), the container between the pump outlet and the cooling cell (there is a arrow on the pump head which indicates the direction) can be placed in an ice bath or in a bath circulator filled with cold temperature controlled antifreeze fluid. At Asylum, we have reached below -35C using this method.

11.13. Operating the Cooler Heater Near Room Temperature

The cooler heater stage has a window of operation near room temperature where very little heater power may be needed to maintain the setpoint temperature. By maintaining the temperature close to ambient with temperature feedback enabled, the heater power may end up switching on and off or alternate between positive and negative power conditions. We have seen this condition cause scan line noise in the AFM image. Typically, the noise appears as line-by-line variations or abrupt height changes in a single scan line.

You may try to either turn the coolant pump on or off, or even place one of the coolant reservoirs in ice water to shift the base temperature of the cooler heater and force it either into a cooling only or heating only state to dodge this issue, or try the low noise checkbox in the software.

11.14. Cleaning and Care

The cooler heater can be cleaned using ethanol or isopropanol. Some small brushed are provided to clean out the side ports. DO NOT fully immerse the heater into liquids, as they may creep inside and cause electrical shorts or corrosion.

11.15. A Little History

At some point in 2011, the supplier discontinued the coolant pump reservoirs. We have replaced them. See Figure 11.5 on page 157 for examples of the two styles. Both perform the same.

(a) Old Style

(b) New Style

Figure 11.5.: Coolant Pumps.

12. Scanning Capacitance Microscopy (SCM)

CHAPTER REV. 2311, DATED 03/03/2021, 18:22. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

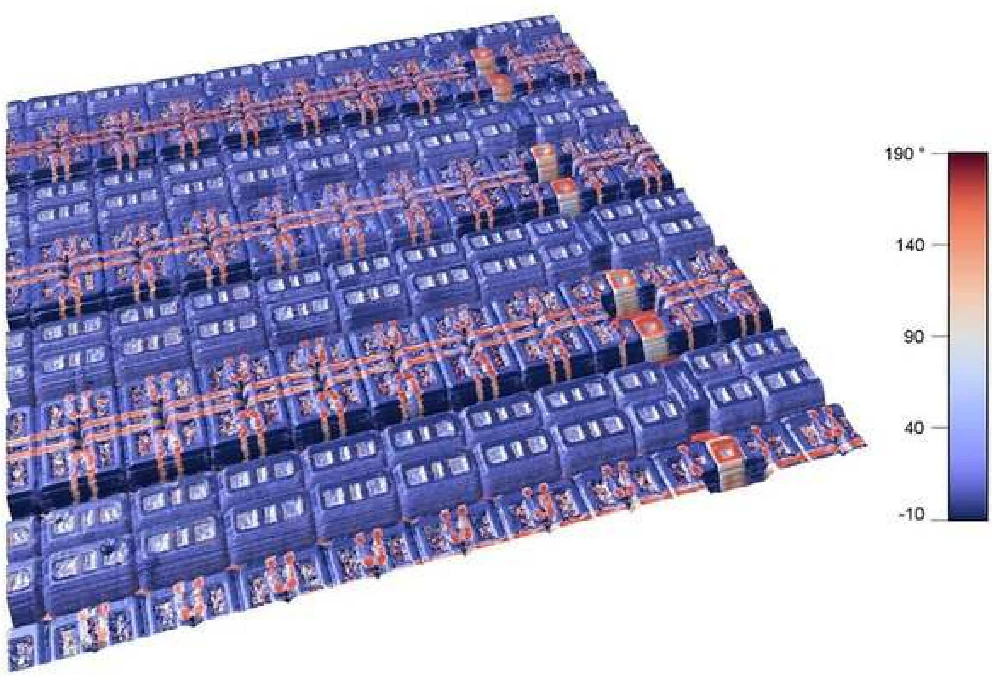


Figure 12.1.: 3D Rendition of SRAM Sample Imaged in SCM Mode.

12.1. Overview and Specifications

The Scanning Capacitance Microscopy (SCM) was designed to enable Failure Analysis engineers to probe the devices at the sub-micron scale and identify issues both during device fabrication and failure analysis. The unique capabilities of this SCM accessory include higher sensitivity, faster imaging, higher resolution, and direct measurement of capacitance instead of only differential capacitance (dC/dV). The sensitivity of the circuit also allows the probing of metals and insulators, along with non-linear materials outside the class of traditional semiconductor devices—including those that do not form a native oxide.

This accessory requires a SCM probe holder, SCM expansion module (for Jupiter XR only), SCM RF module, and probe impedance matching cables.

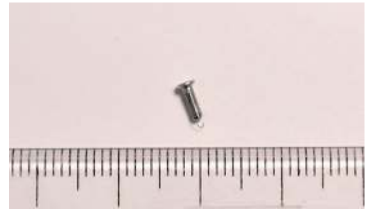
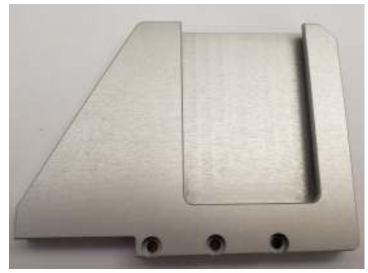
12.2. Compatibility and Prerequisites

The SCM accessory is compatible with the Jupiter XR and Cypher S AFMs.

12.3. Parts List

The following list includes all parts in your accessory kit. The table is useful as a visual table of contents and contains links directing you to the specific uses of each part. When ordering parts, please refer to the part numbers in the second column.

Itm	Part #	Item Description	Qty	Picture
1	002.SHCS <M3X10> SST	M3 X 10MM SHCS SS. Used for attaching 116.986 and 116.987 and used to lock RF box into place. Only used during installation.	6	
2	002.SHCS <M4X12> SST	M4 X 12MM SHCS SS. Used to attach 116.986 to the left granite riser. Only used during installation.	4	
The scale in the photos is in cm and mm.				

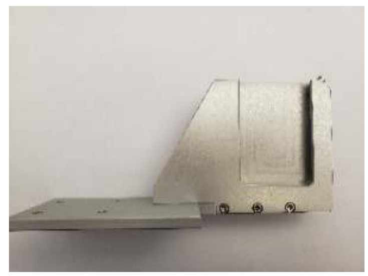
Itm	Part #	Item Description	Qty	Picture
3	116.834	M1.6 X .35 Pan Head Screw, Modified. Used to clamp probe holder dovetail. Has a rounded end. Spare.	2	
4	116.986	Plate, SCM RF Box Vertical Mounting. Attaches to 116.987 with M3 screws. Only used during installation. RF box 902.803 attaches in T-slot and fastens with M3 screw.	1	
5	116.987	Plate, SCM RF Box T Slot Mounting. Attaches to the left granite riser with M4X12mm screws. Only used during installation.	1	
6	222.226	Cross Recessed FHMS, M1.6 X 3MM. Attaches RF connector to cantilever holder.	2	
7	222.227	Cross Recessed FHMS, M1.4 X 2MM	4	
8	290.106	#00 Wiha Phillips Screwdriver, 261 PH 00 X 40. For small Phillips screws.	1	
9	290.138	3MM Hex Allen Wrench. For 4mm Allen screws. Only used during installation.	1	
10	290.174	#0 Phillips Wiha Screwdriver 261 PH 0 x 50. For Phillips screws.	1	

The scale in the photos is in cm and mm.

Itm	Part #	Item Description	Qty	Picture
11	290.183	2.5MM Allen Wrench. For 3mm Allen screws. Used to remove the RF electronics box from its mounting bracket.	1	
12	448.220	Jupiter SCM D-Sub Cable Assembly. Connects the RF electronics box (902.806) to the Jupiter SCM Xbox Card (902.802)	1	
13	448.224	SCM Coax Cable. Used with silicon probes coated in a conducting material, like the MFM-R2 probes included in this kit.	1	
14	448.225	SCM Coax Cable. Used with solid metal probes like the 25Pt300B included in this kit.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
15	805. ASYMFM. HM-R2	Asylum Research High Moment MFM-R2 Cantilevers	5	
16	808.RMN. 25PT300B	Rocky Mountain Nanotechnology Cantilevers, Model 25Pt300B	5	
17	902.615	Jupiter SCM Cantilever Holder. See “Installing the Probe Holder” (1) on how to install.	1	

The scale in the photos is in cm and mm.

Itm	Part #	Item Description	Qty	Picture
18	902.802	Jupiter SCM XBOX Card	1	
19	902.803	RF Electronics Box. Installs on the 902.806.	1	
20	902.806	Jupiter SCM RF Box Mount Assy. (Assembly is made from line items 1,2,4, & 5.)	1	
21	902.807	Jupiter XBOX Card, 1-Wire Pullup Assembly. Only required for early models of Jupiter. Later models do not need this card.	1	
The scale in the photos is in cm and mm.				

12.4. SCM Setup

12.4.1. Sample Preparation

The sample for SCM measurement needs to flat and free of contamination. If starting with a semiconductor device, several rounds of polishing and cleaning are necessary. Additionally, a thin layer of oxide (a few tens of nanometers) is needed on top of the surface by either depositing or chemical reaction. A recommended way to prepare most semiconductor samples is to heat them on a hot plate up to 200° C for 30 min and then irradiate them under UV light for 10 min. [V. V. Zavyalov, J. S. McMurray, S. D. Stirling, C. C. Williams, and H. Smith, J. Vac. Sci. Technol. B 18, 549 (2000).]. Samples can also be hydrogen terminated with dilute HF acid; however, extreme care and special training and equipment are needed to use HF acid safely and effectively.

12.4.2. Hardware Setup

The SCM measurement is based on contact-mode imaging with modulation voltage applied to the sample. A specific SCM probe holder is necessary, and the probe choices include solid platinum probes (Rocky Mountain Nanotech), other coated silicon probes (SCM-PIC, AsyMFMMHM), or conductive diamond probes.

The SCM module is shipped with two SMA coaxial cables, one with red shrink wrap and one with black. The red cable is to be used with silicon probes coated in a conducting material, and the black cable is to be used with solid metal probes. Using the incorrect cable will result in a large shift in the tune frequency and dramatically reduced sensitivity.

12.4.3. Cantilever RF Tune

After setting up the hardware, the operator runs a quick cantilever RF tune to check that the probe is loaded properly the hardware is working. In the tutorial, the cantilever RF tune is shown in on the SCM control panel with a broad resonance near 1.8 GHz. The minimum value is within the green region, indicating that the impedance matching is working. The software also automatically calculates the optimal RF detection frequency. In this case at 1.7687 GHz. There is yet no signal in the dC/dV channel because the tip is still far away from the surface.

The setup is then ready to engage the tip on the surface and start scanning. Imaging parameters including sample bias are set to default values; however, the user can change them anytime during imaging.

12.5. Tutorial: Jupiter SCM (Scanning Capacitance Microscopy)

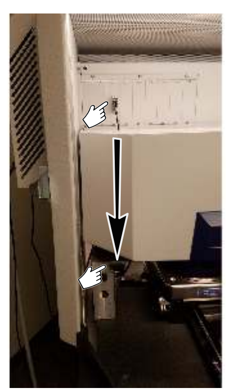
12.5.1. Installation

1. Install the latest software.

2. **Plug in the cable to the XBox:**

   - Install the SCM RF module box.
   - Feed the cable through the tube:
     - Connect to SCM RF module box.
     - Connect to the Expansion module port.

   Note Expansion module (XBOX) ports must be populated from left to right. If there is a gap, the rightmost ports will not function.

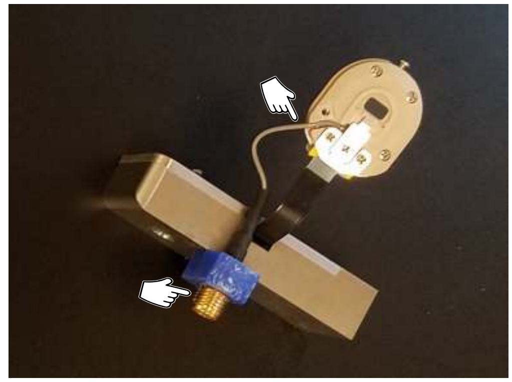
   

3.

Locate the cantilever holder:

- A special SMA connector is mounted to the frame.

Caution Be careful with the coaxial cable attached to the cantilever clip.

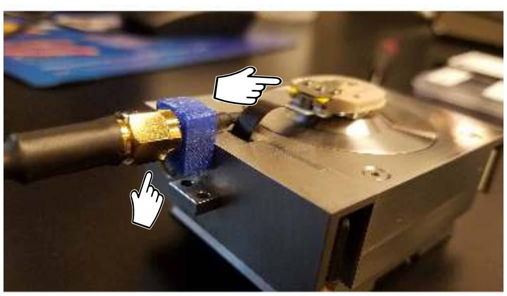


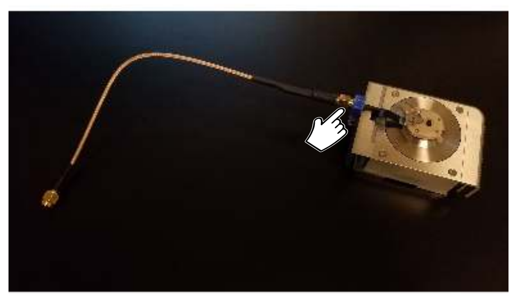
4.

Locate the SMA cable:

- There are two different ends on the cable:
  - The end that has impedance matching hardware is covered in more shrink tubing (shown on the left in this image). This end plugs into the Z scanner/ cantilever holder.
  - The "simple" end (shown on the right) plugs into the SCM box.

5.





Install the cantilever holder and SMA cable on the Z scanner

- Mount the cantilever holder.
- Attach the SMA cable, tighten it only “finger tight”. If a torque wrench is used, the setting should be 0.57N-m/5lb-in.

6.

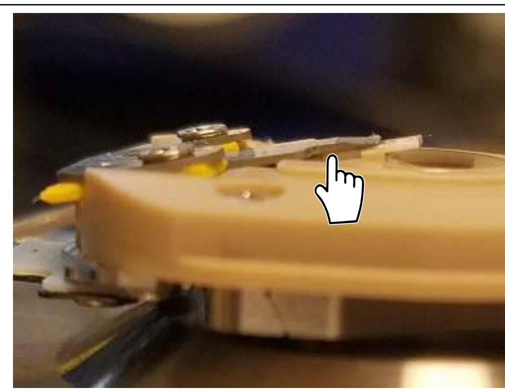
Choose the appropriate probe:

- Any of the following probes shown here are functional:
  - Rocky Mountain Nanoprobes: pure Pt
  - ASYMFMHM-R2: Lever = Si, tip = CoCr, R = 64 +/- 10 nm, f = 75 kHz, k = 2.8 N/m

7.

Mount the probe:

- Make sure the probe chip rests against the backstop of the cantilever holder. (An RMN probe is shown in this image).



8.

Place the Z scanner, SCM cable, and sample

1. Place Z scanner in the AFM.

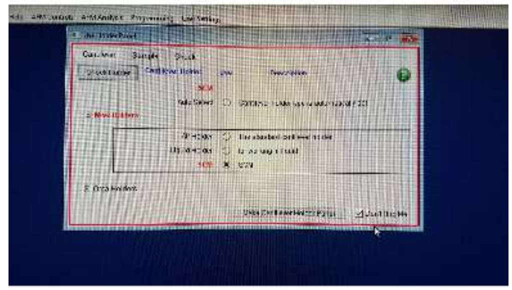
2. Connect the SMA cable coming from Z scanner to the SCM RF module box.

3. Place the sample on chuck. To bias the chuck, flip the switch on the back of the XY scanner to bias.

9.

Confirm the cantilever holder is recognized:

- The software will automatically detect the cantilever holder in use. Otherwise, you can select the cantilever holder. To do so, navigate to *Programming* > ‘Holder Panel’ > ‘Cantilever Tab’ > and select the SCM holder, under Misc Holders, as shown in the mage at right.



12.5.2. Scanning

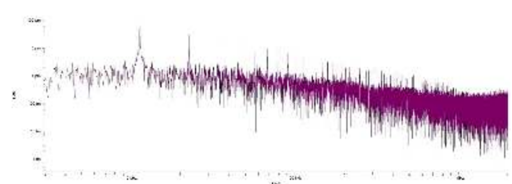
When devices are installed and set up, you can start scanning.

1.

Choose the SCM:

- On the Mode Master panel, click *SCM Contact*.

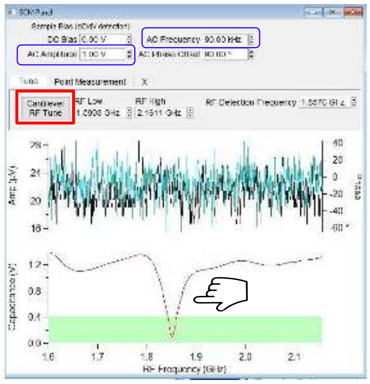
2.

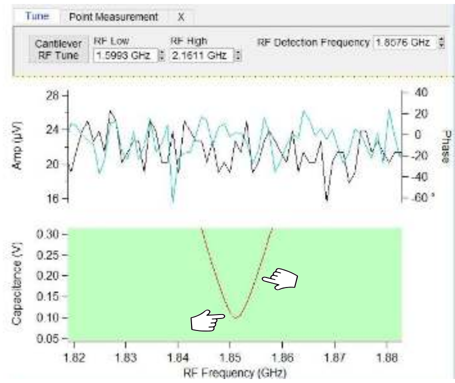


Align laser on cantilever:

- Using the Video panel, align the laser on the cantilever. (The Rocky Mountain nanoprobe is used in this example.)
- Thermal peaks are displayed.

3.

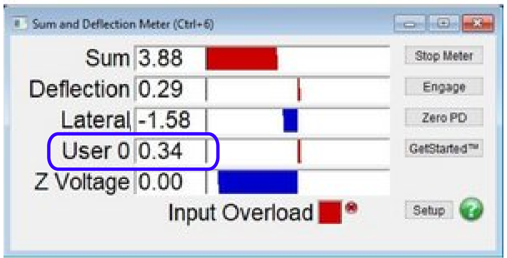


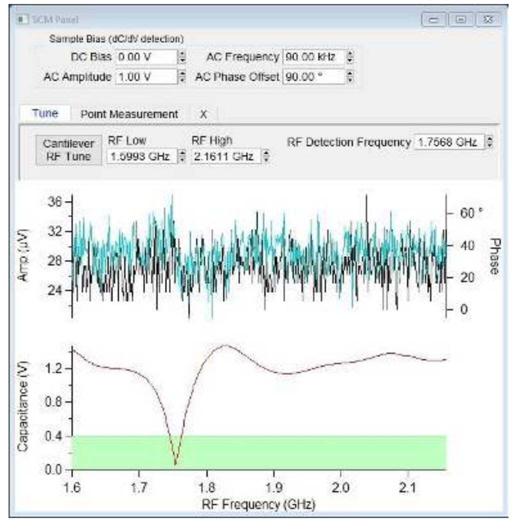


RF Tune the cantilever (off-surface):

- With the probe away from the surface, click the 'Cantilever RF Tune' button.
- You should see a resonance peak associated with decreased capacitance (e.g. the impedance is matched between holder and RF circuitry.
- The AC Frequency defaults to 90 kHz, and the AC Amplitude defaults to 1 V, both values are fine.
- AC Frequency from 40-100 kHz is excellent, and the AC amplitude can be arbitrarily high. The AC voltage makes charge carriers move, changing the sample's capacitance. The probe detects the sample's capacitance as an RF antenna when using the lock-in at that AC frequency.
- During the tune, the RF Frequency is 1.8756 GHz.
- If you have an excellent impedance match, the capacitance will fall below 0.1 V, shown on the Y axis as the green zone. This will change a little bit when the tip is engaged on the surface.

4.





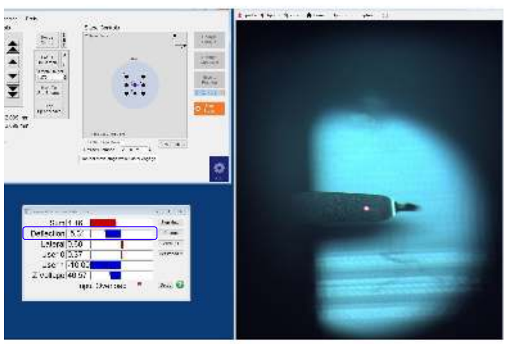
Look at the SCM signal:

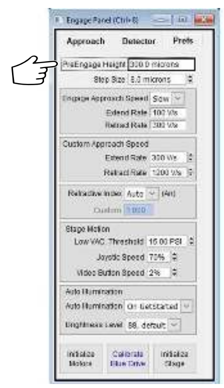
- You can view the SCM signal (User 0) on the Sum and Deflection Meter panel.
- It should be < 0.5 V (see green zone in the RF Tune graph).
- Smaller values of capacitance (User 0) are better, but recall that the value is determined from the point of highest slope in the tune.

5.

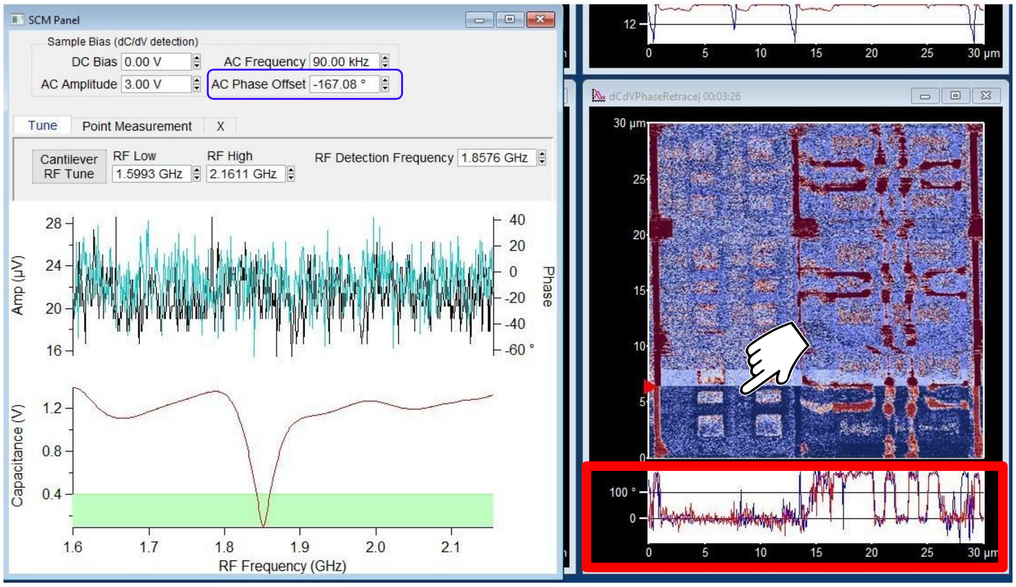
Engage the probe and start imaging:

- Your setpoint should be between 0.2V and 2V, depending on the probe. Cleaner samples will require less aggressive setopoints. (Recall that this is a contact-mode technique.)
- On the Engage Panel, notice that the *PreEngage Height* is 300 um. This is intentional as the RMN probe is exceptionally long. You can change it to a small value if you use other levers, but it is not necessary.
- After the tip is engaged on the surface, on the Master Panel, click 'Frame Up' or 'Frame Down'.





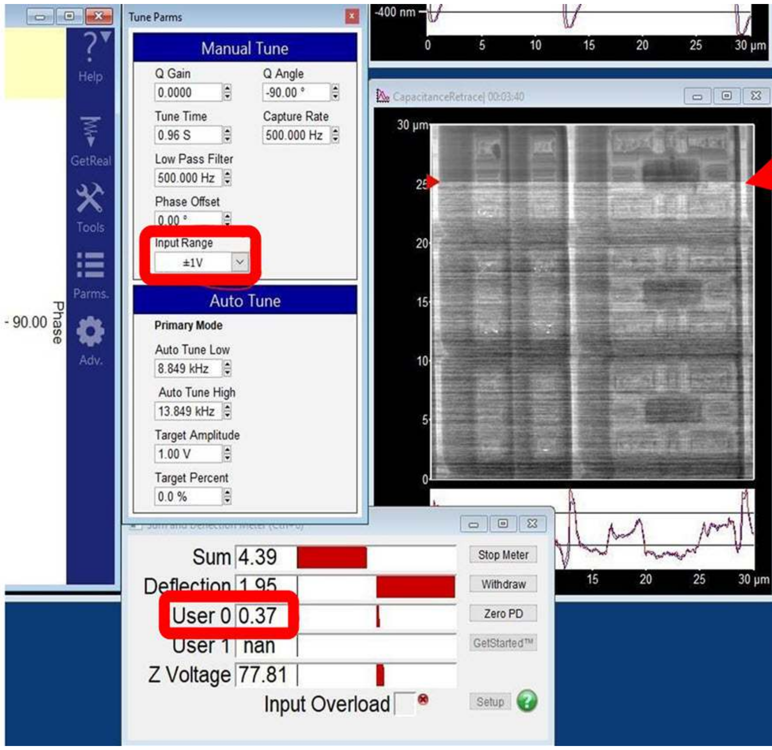
6.



Adjust AC Phase Offset:

- Find the *AC Phase Offset* control in the SCM panel.
- The goal is to correct any phase wrapping; the lowest phase should be zero (0) while the highest should be 180. If phasing wrapping happens, adding phase offset 90° usually helps.
- WHY? Because n-type and p-type charge carriers have phases that are 180 degrees off from each other.

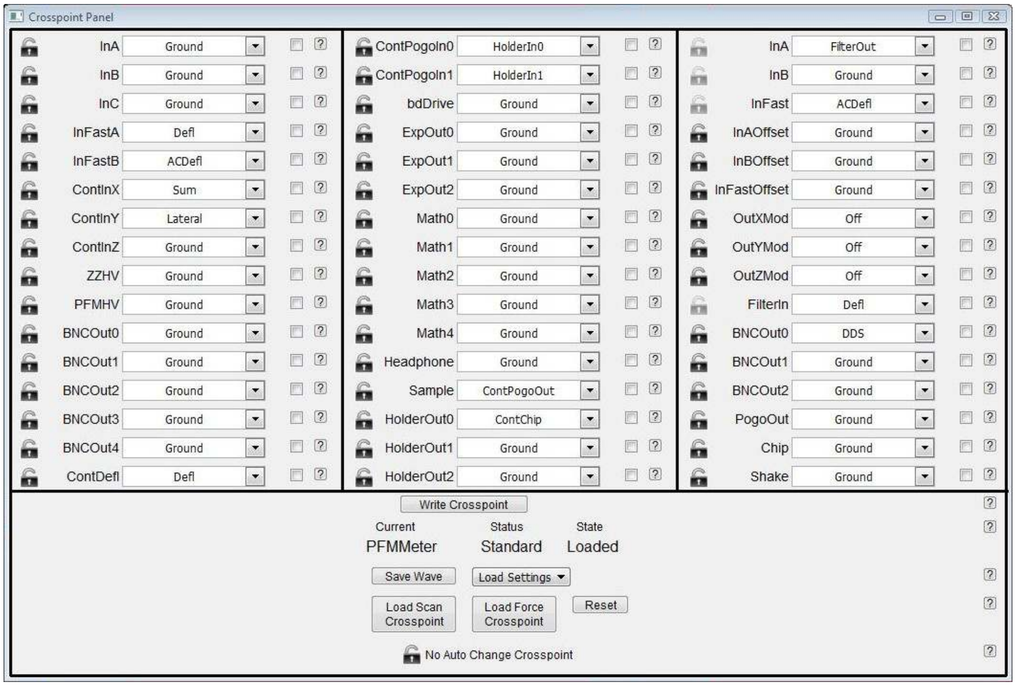
7.



If needed, adjust the lock-in input range:

- Take note of the *User 0* voltage.
- On the Master Panel, select the 'Tune Parms' panel.
- Set the *Input Range* to +/- 1 V (or to +/- 0.5 V, if your User 0 voltage is less than 0.5 V).
- Notice the "bad" portion of the image is where there was more noise in the capacitance signal because it was set to +/- 10 V.
- Notice the improvement from setting it to +/- 1 V on the subsequent down scan.

8.



Troubleshooting – Crosspoint:

- This is what the Crosspoint Panel should look like.

12.6. Cleaning and Care

Refer to the parts list for the materials of which the SCM is made. All parts used can be gently wiped with isopropanol and tissue paper. Do not immerse the probe holder or the cables in liquids. SCM is meant to be performed in air (gas) environment.

If you need replacement parts, contact your local Asylum Research office or distributor, and use the parts list as a guide.

13. Conductive AFM (ORCA) Hardware

CHAPTER REV. 2277, DATED 10/14/2020, 18:33. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

This chapter describes the hardware required to perform conductive AFM with the Jupiter AFM. Conductive AFM Theory and SPM software instructions are described in another manual: *Applications Guide, Chapter: Conductive AFM*.

13.1. Prerequisites

Conductive AFM Imaging is an advanced technique. It is assumed that you are proficient at:

- AC Mode Imaging in Air (Chapter 3 on page 36).

13.1.1. Single and Dual Gain ORCA Hardware Operation

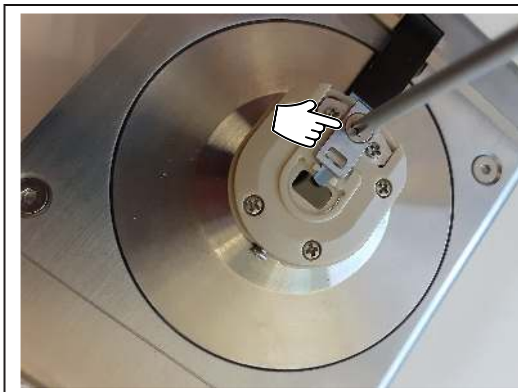
This section describes how to set up and perform a basic ORCA experiment on the Jupiter XR AFM.

1.

Install the ORCA cantilever holder:

- First, you need to replace a standard air cantilever holder with an ORCA cantilever holder. The ORCA holder has a label identifying whether it is a single or dual-gain version. Either is fine to use in this experiment.
- To swap out a cantilever holder, you need to undo the two (2) screws as shown in the pictures.

2.

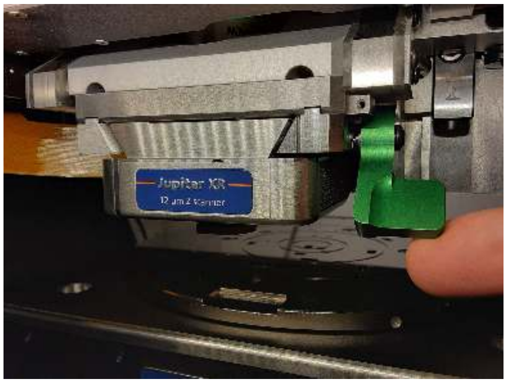


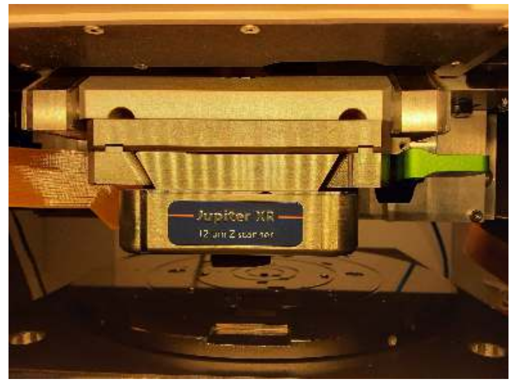
Load a conductive probe:

- Load a conductive (metal or diamond coated) probe into the cantilever holder.
- To insert the probe, you need to loosen the center screw that holds the metal clip, as shown in the picture.
- Slide the probe under the clip and then tighten the screw back into place.

Note The screw only needs to be “finger tight”.

3.

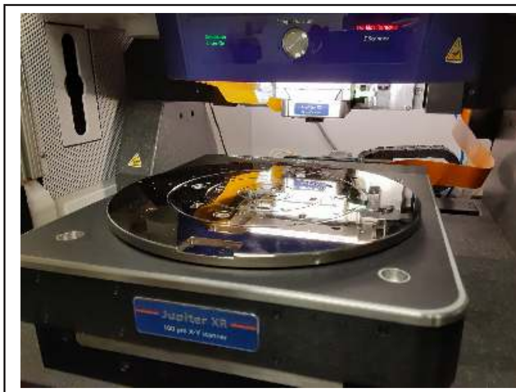


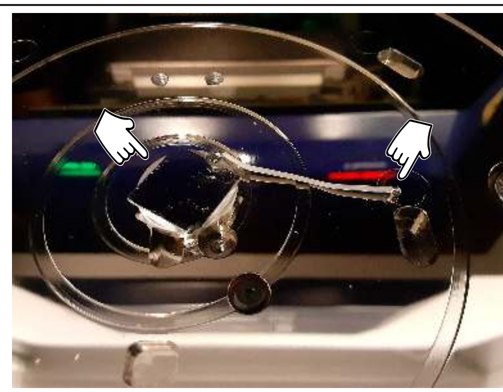


Insert the Z scanner:

- Slide the Z scanner back into its slot and then tighten the green lever all the way up to lock it in place, as shown in the pictures.

4.



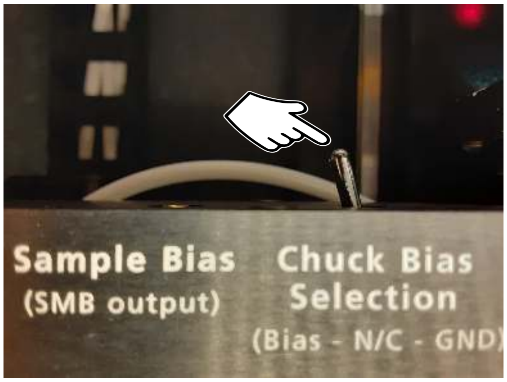


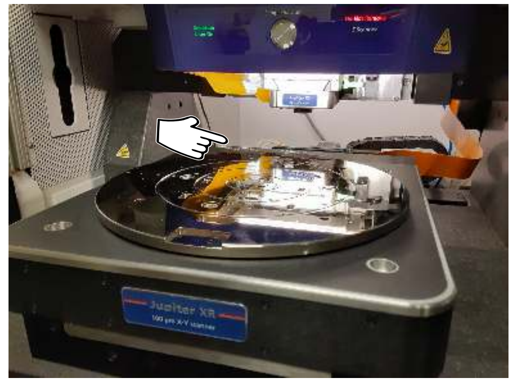
Attach the Sample:

- First, click the ‘Change Sample’ button on Motor Controls panel. This moves the sample stage out, as shown in the picture.
- Place the sample anywhere on the sample chuck stage.

  Note If you are using a metal puck-mounted sample, you can use one of eight magnetic spots on the sample stage to attach the sample.
- Ensure that the sample is electrically connected to the stage by either a wire or a test resistor. It is recommended to check continuity with a multimeter.

5.





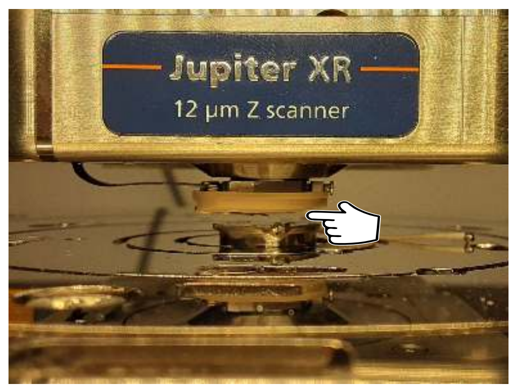
Set the 'Chuck Bias Selection' switch:

- Set the 'Chuck Bias Selection' switch, located at the rear of the XY Scanner, to the 'Bias' position, as indicated in the pictures.

6.

Approach the sample:

- Click on the 'Move to Position' button to move the stage to the magnetic location where you placed the sample.
- Using either the joystick (hold the button 4" down while tilting the joystick downwards) or the arrow-buttons on the Control Panel to move the AFM head down to the sample. The picture illustrates this by pointing at the gap.



Note Ideally, you should have about a 1mm wide gap between the probe and sample surface.

Caution Keep a close eye on the probe–sample the approach distance. The only thing stopping the probe from crashing at this point is your own attentiveness.

7. **Load the Software:**

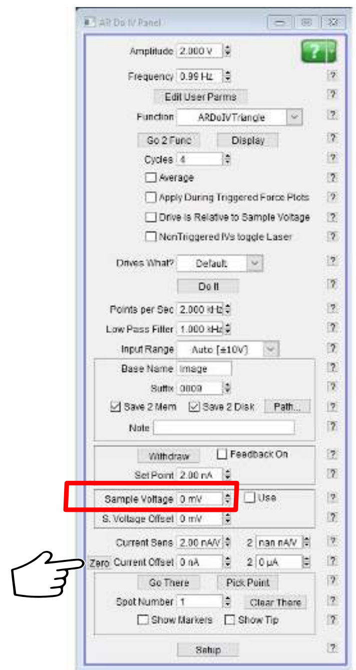
- Launch the Mode Master panel and select the *Orca* mode from the 'Electrical' tab.

Note You need to have an ORCA holder installed to load the *ORCA* mode, otherwise it will not load.

8. **Set the parameters:**

- Once the the ORCA mode workspace has loaded, select the AR Do IV Panel.
- You can set the desired 'Sample Voltage' as indicated in the image.

  Note It is recommended that you double-check the voltage between the sample and the microscope group (e.g., Z scanner body) with an external multimeter.
- There may be some residual current in the Current/Current2 channel on the Sum and Deflection Meter panel. Simply click the 'Zero' button as shown in the image.



9. **Start your image:**

- Begin the engage on the sample the same as you would when performing a standard Contact Mode imaging.
- Once engaged, your current signal will be displayed on the Sum and Deflection meter panel. The corresponding current map will appear on the Current/Current2 window.

Note We recommend using both trace and retrace for displaying current images.

13.1.2. Thorough Cleaning of the ORCA Cantilever Holder

In some cases, the cantilever holder must be thoroughly cleaned or sterilized in an autoclave. The back side circuit board prevents the whole device from being immersed, so some disassembly is required.

13.2. Conductive AFM Imaging

The specifics of conductive AFM imaging are described in another manual: *Applications Guide, Chapter: Conductive AFM*.

14. NanoRack

CHAPTER REV. 2273, DATED 09/22/2020, 11:20. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

Figure 14.1.: NanoRack accessory

14.1. Parts List

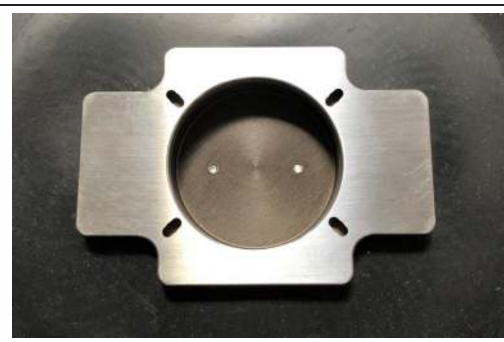
The following list includes all of the parts in your accessory kit. The table is useful as a visual table of contents with links directing you to the specific uses of each part. When ordering parts, please refer to the part numbers in the second column.

Itm	Part #	Item Description	Qty	Picture
1	900.185	NanoRack Stage. Attaches to the accessory chuck and is what stretches the sample to be imaged. It measures the Force and Strain put on the sample. Comes with a 20lb Force Sensor installed.	1	
2	900.199	NanoRack Accessory Kit. Contains the following: 900.204 5lb Force Sensor; 908.026 Leg Extender Assembly; 112.041 VFM Stage Cover Plate; 113.778 Stretch Upper Clamp; 050" and 1.5mm Allen Wrenches; Flat and Phillips Screwdrivers; and 0-80 x 1/4", 3/8", and 1/2" Socket Head Cap Screws	1	
3	448.121	15 pin NanoRack Cable	1	
The scale in the photos is in cm and mm.				

14.2. Hardware Installation

1. **Install the accessory chuck:**

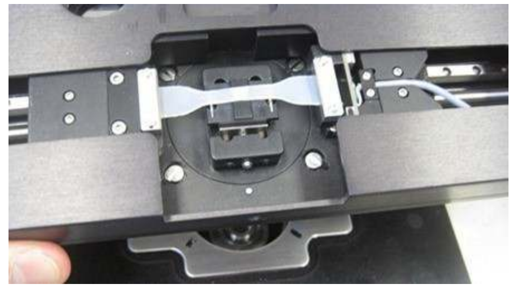
   - This will be used to mount the NanoRack on the stainless steel "+"-shaped piece of the accessory chuck.



2.

Align the NanoRack on the accessory chuck:

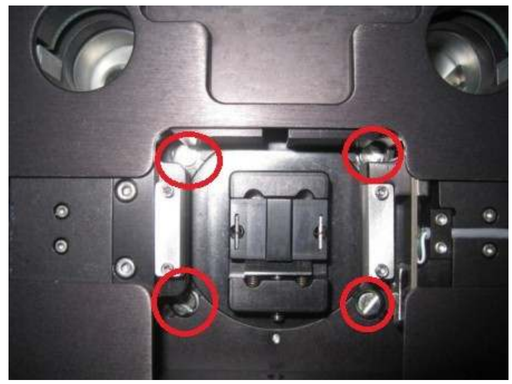
- Remove the NanoRack stage.
- Locate the four quarter-turn fasteners on the NanoRack stage.
- Align the fasteners with the notches on the chuck at a 45 degree angle.



3.

Secure the NanoRack to the accessory chuck:

- Once the fasteners are aligned, set the NanoRack onto the accessory chuck, dropping the quarter-turn fasteners into the notches.
- At right is a view of the fastener in the unlocked position.



4.

Install the NanoRack expansion module: If the NanoRack expansion module is not already installed, follow the steps listed here first:

- Turn off the ARC2 controller power.
- Detach the Motor Power cable connected to the backpack controller. This is sometimes referred to as “dirty power”.
- Remove the left-most available slot cover in the expansion box and install the NanoRack expansion module.
- Reattach the Motor Power cable to the backpack controller and turn on the ARC2 controller.

Note Accessories that are attached to the expansion box must be installed in order from left to right, without any unoccupied slot.

5. **Connect the NanoRack cable to the control module:**

- Run the NanoRack cable from the expansion card down gently through the tube. There should be enough cable length to accommodate full sample stage travel. Leave any excess cable length on the shelf in front of the expansion box.
- Connect the 15-pin NanoRack cable to the NanoRack stage.
- Tighten the thumbscrews.
- Connect the other end of the cable to the NanoRack control module installed in the expansion module

14.3. Software Setup

Open your software and let it detect both the NanoRack Controller and the Force Sensor. If the NanoRack Controller needs reprogramming, you will be led through it's programming. (All controllers ship with the most current version so this should not be necessary.)

Verify that all the components are identified in the software by clicking "AR" button and selecting the "Device Manager".

Click on the gear icon and you will see icons for "NanoRack" and "Force Sensor" along with their Serial Numbers. You can access the low level information about these devices by clicking on the icon and choosing "parameters" and "infoblock." You will then be able to view serial numbers, revision information as well as calibration information. Do not adjust any of these values.

The NanoRack interface is available via the 'AFM Controls' drop-down menu by choosing *NanoRack Panel*.

In the NanoRack Panel, as shown in Figure 14.2, you can do the following:

- See if the installed Force Sensor is 20 lb (default as shipped) or 5 lb
- View the current Force while actively updating
- View Absolute and Relative positions of both the right and left Stages, and well as the total Deformation
- Reset the Absolute ('Abs') and Relative positions of each stage ('A' and 'B')
- Turn Data Logging 'On' or 'Off'
- Display History opens a graph. (Use the 'More' and 'Less' buttons to show Force, Deformation, and the Absolute and Relative positions of the right and left stages.)
- Set the Time Window
- Set the Base Suffix
- Save or clear Data History

Figure 14.2.: NanoRack Panel

Figure 14.3 shows a sample of the graph looks like with all of the data logging turned on. To change the position, move both stages on both the NanoRack Panel and the graph.

14.4. Loading a Sample

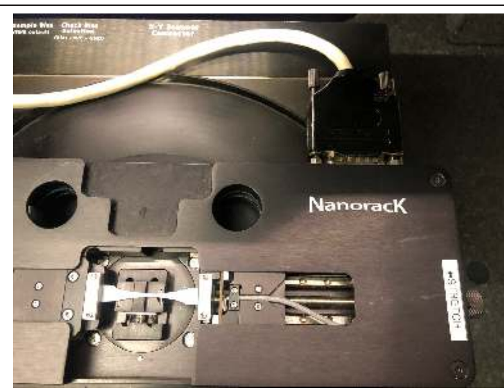
With the NanoRack installed correctly and the software setup, you are free to load samples, stretch them out, and make measurements.

Note: The tip needs to first be raised manually before changing the sample or cantilever.

1.

Adjust the stages

- To load a sample, adjust both stages to their inside location, or whatever distance you need for the length of your sample.
- The sample must be at least 40mm to fit on the NanoRack.



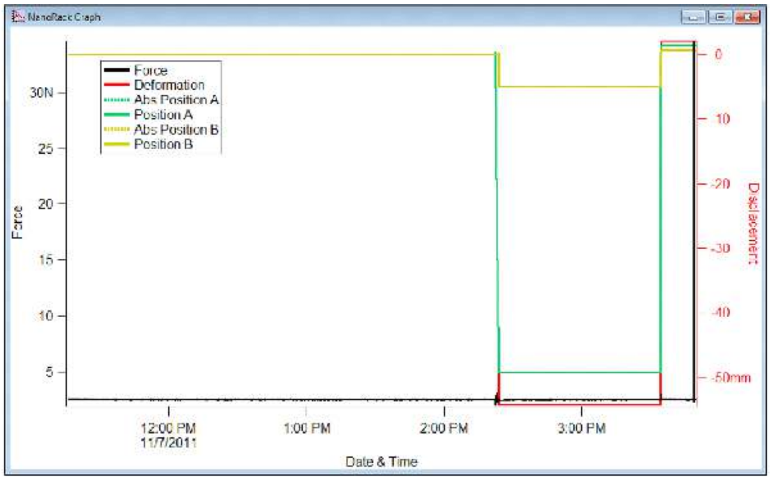


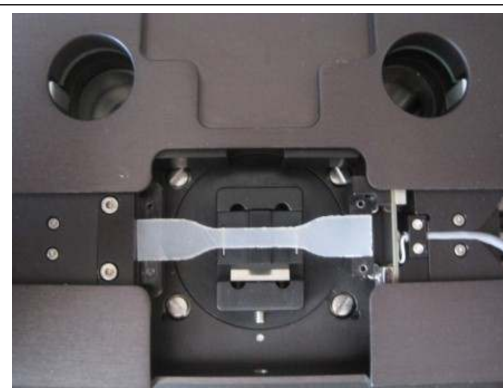
Figure 14.3.: Display History Graph

2. **Remove screws and clamps:**

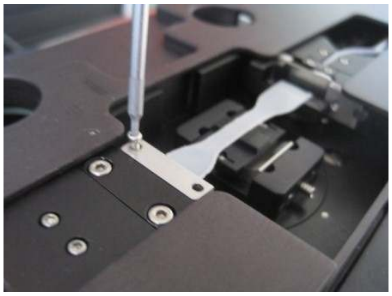
- Use the supplied .050" Allen Wrench (the tool may be in the bag with the Leg Extenders in the Accessory Kit) to remove the four 0-80 Socket Head Cap Screws (SHCS)
- Remove both of the upper clamps (113.378).

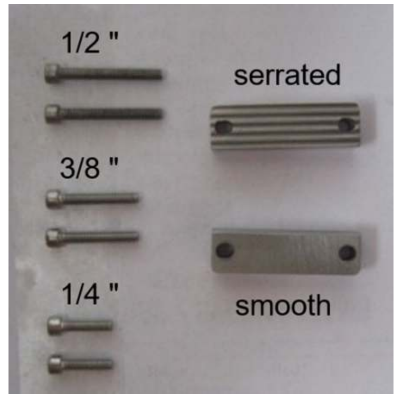
3. **Place the sample:**

- Place your sample so that rests on both of the lower sample clamps and is centered.
- The maximum width of a sample is 12mm, and the maximum height is 6mm.



4.





Clamp the sample down:

- Put the upper clamps back on and use the 0-80 socket head screws and .050" Allen wrench to clamp the sample down. (You will need to use the correct length screw depending on the thickness of your sample. Your accessory kit contains all the lengths of screws you need.)
- Screw the clamps down until the sample is adequately clamped.
- Note that the upper clamp has a smooth side and a serrated side, you can use whichever side best clamps onto your sample. The serrated side will sheer some soft and thin samples, in which case turn it over and use the smooth side.

5.

Adjust the Sample Support:

- You can then adjust the Sample Support, which moves up and down in Z motion, using the same .050" Allen Wrench via the hole in the front cover.
  - For stiff thick samples it is best to lower the Sample Support completely out of the way.
  - For thin and/or soft samples, move the Sample Support up enough so that it lightly deflects your sample.

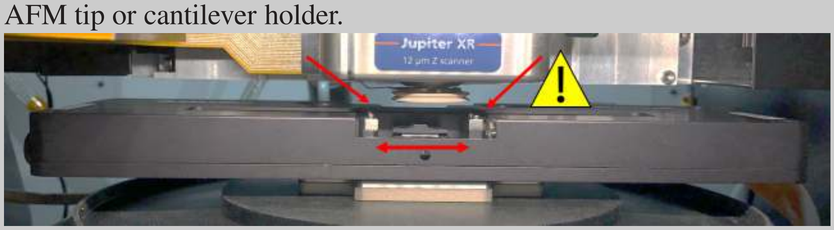
6.

Reset the stage positions:

- Once your sample is mounted, you can use the 'NanoRack Panel' to Reset the position of the Left and Right Stages and clear the graph.
- You can now image your sample, or move the stages to your desired Deformation or Force and then image.

Important!

Pay attention to the distance between the AFM tip and the NanoRack sample stage when moving the XY stage. There are no limits to the movement of the XY stage, so it is possible to hit the higher parts of the NanoRack with the AFM tip or cantilever holder.



Tips

- Soft samples relax after being stretched; the time period could be minutes to hours, depending on the material and the strain. You can monitor the relaxation with the Force Sensor. When you see the number stabilizing, imaging will become stable, too. If you try to image during heavy relaxation, there will be drift from frame to frame.
- When stretching soft samples with high strain, the sample will thin out; and, in extreme situations, will require you to lower the head or move the Sample Support up.
- You will find that your Force Sensor does not always return to zero when no load is on the stage.

Note In the future, a software function will be available to "zero out" the force sensor.

15. Variable Field Module 4 (VFM)

CHAPTER REV. 2323, DATED 03/21/2021, 15:16. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

15.1. Overview

Note	This chapter was written for the third generation VFM3 model, but much of it should be relevant for the VFM4, as well as for prior generations. For a discussion about differences of the previous VFM models, please see 15.12. This will help you identify your model of VFM.

15.1.1. Prerequisites

Imaging with applied magnetic fields is a fairly advanced technique. It is assumed that you are already proficient in:

- Basic AFM Safety (Section 1.5 on page 13).
- AC Mode Imaging in Air (Chapter 3 on page 36).

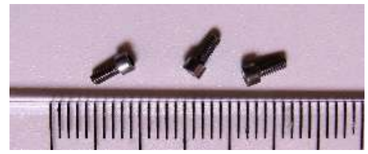
15.2. Parts List

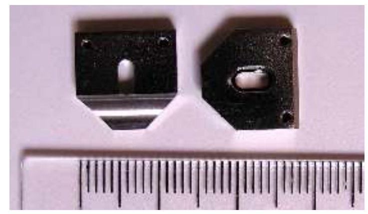
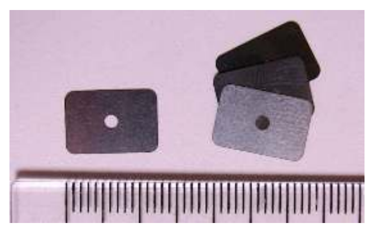
This table lists all relevant parts, with photos and links to the relevant parts of the documentation which describe how to use them. All parts and assemblies have six-digit Asylum Research part numbers. If you ever see such a number in the text and do not know what it refers to, go to the top of this document and run a search for that number, and you will find it in the list.

Before you begin, please check that you have the following components and tools. If you are missing anything or have questions about obtaining consumables, please contact Asylum Research for assistance.

Note Many of the items below are part of the VFM2 accessory kit (Asylum Research Part #900.244).

Itm	Part #	Item Description	Qty	Picture
1	BHCS 0-80 X 1/8" SS	0-80 X 1/8” button head cap screws, stainless steel. Use 0.035”: Allen Driver (290.104). Used to fasten the clips (112.959) or the ground wire (448.114).	8	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
2	SHCS 0-80 X 1/4" SS	0-80 X 5/32” socket head cap screws, stainless steel. For holding down the pole pieces with few or no shims. See Section 15.9.2 on page 209.	8	
3	SHCS 0-80 X 3/16" SS	0-80 X 3/16” socket head cap screws, stainless steel. For holding down the pole pieces when using many shims. See Section 15.9.2 on page 209.	8	
4	SHCS 0-80 X 5/16" SS	0-80 X 5/16” socket head cap screws, stainless steel. Spares for attaching the scanner top plate 112.041. Use with a #0 washer (next item in the list).	8	
5	#0 FLAT WASHER MS801	Number 0 stainless steel washer, Spares for attaching the scanner top plate 112.041. Use with the previous item.	8	
6	111.737	Modified 0-80 Screw. Used to attach the cantilever clip to the body. Note that these screws have been machined to a nonstandard length. You must only use this Asylum part number.	2	
7	111.738	Modified 1-72 Screw. Used to tighten the cantilever under the clip. Note that these screws have been machined to a nonstandard length. You must only use this Asylum part number.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
8	112.959	Beryllium Copper Clip. Used with BHCS 0-80X1/8" SS screws. See Section 15.9.6 on page 214.	5	
9	113.672	Low profile pole pieces. Attach with SHCS 0-80X5/32" SS. See Section 15.9.2 on page 209. Note, Only compatible with VFM2 stages. See Section 15.12 on page 218.	2	
10	114.250	High profile pole pieces. Obsolete, but they were included in a few VFM2 models.	2	FIGURE NEEDED
11	114.645	0.003” (75 µm) thick shim stock. Used for spacing the pole pieces when using large flat samples. See Section 15.9.2 on page 209.	30	
12	115.507	Pole Pieces, VFM3. For in plane field. Note, Only compatible with VFM3 stages. See Section 15.12 on page 218.	2	FIGURE NEEDED
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
13	249.033	Adhesive tab sheet. You may order more from Ted Pella, part 16079. Can be used to stick flat samples on top of the VFM pole pieces. See Section 15.9.6 on page 214.	2	
14	290.102	Tweezer, Curved Sharp, Standard Grade. Typically used for handling samples and the small screws supplied with the VFM.	1	
15	290.104	0.035”: Wiha Allen Driver. For the screws (BHCS 0-80X1/8" SS) that fasten the clips. See Section 15.9.6 on page 214. (112.959) or the ground wire (448.114).	1	
16	290.111	0.050”: Wiha Allen Driver 263 1,3 – 0.05” X 40. For most socket head screws on the VFM2. Typically used to remove the pole pieces. See Section 15.9.2 on page 209.	1	
17	290.114	Screwdriver, Slotted, 3.0 mm Width. Wiha 260 3,0 X 50. Used to mount the VFM to the scanner.	1	
18	449.011	Cable CB25M-DB25F, 2 meters, unmodified. See Section 15.5.2 on page 196.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
19	805. ASYMFM. HC	Asylum Research high coercivity MFM cantilever. A useful cantilever for MFM imaging. See Section 15.3 on page 194.	10	
20	805. ASYMFM. SMPL	Asylum Research MFM sample pack. 5 EA of STD, HC, HM, LC, LM cantilevers, 25 in all. A useful collection of cantilevers for MFM imaging. See Section 15.3 on page 194.	1	
21	900.282	VFM Expansion Module for Jupiter XR. See Section 1.3 on page 12.	1	
22	900.287	VFM2 Sample Stage - the subject of this chapter.	1	
The scale in the photos is in cm and mm.				

15.2.1. Temperature Sticker

The VFM contains magnetic materials which can lose their “potency” if exposed to temperatures above 80°C. Please inspect the sticker attached to the VFM cable. If the sticker has turned black, indicating temperatures in excess of 80°C, please test the ability of your VFM to reach its specified maximum field (see Section 15.9.4 on page 211).

15.3. AFM and MFM in an Applied Magnetic Field

A powerful tool for understanding the behavior of a magnetic sample is an applied field. Applying a field may prove useful in applications such as imaging the domain reversal behavior of a ferromagnetic thin film, studying magnetic field dependent resistance in sensor devices, or imaging magnetic particles that have been used as biological tags. The bibliography at the end of this chapter gives a partial list of references where researchers have used an applied field in magnetic force microscopy (MFM) studies.

MFM imaging in an applied magnetic field can actually complicate the interpretation of your images significantly. In addition to the sample behavior being field dependent, the magnetic state of the MFM tip can also change in an applied field. One way to simplify interpretation in an applied field is to use a tip with a coercivity (or switching field) that is very different from that of the sample, either much lower or much higher. Then, when the contrast is changing, one can be relatively confident of the origin of the change. For this reason, super paramagnetic tips or very high coercivity tips can be useful for applied field imaging. For applied field MFM work, we generally recommend starting with high coercivity MFM cantilevers such as the type ASYMFMHC. These cantilevers have coercivities greater than 5,000 G and therefore will not be re-magnetized by use with the VFM. For your specific application, do not hesitate to contact Asylum Research if you would like further information.

15.3.1. How it works

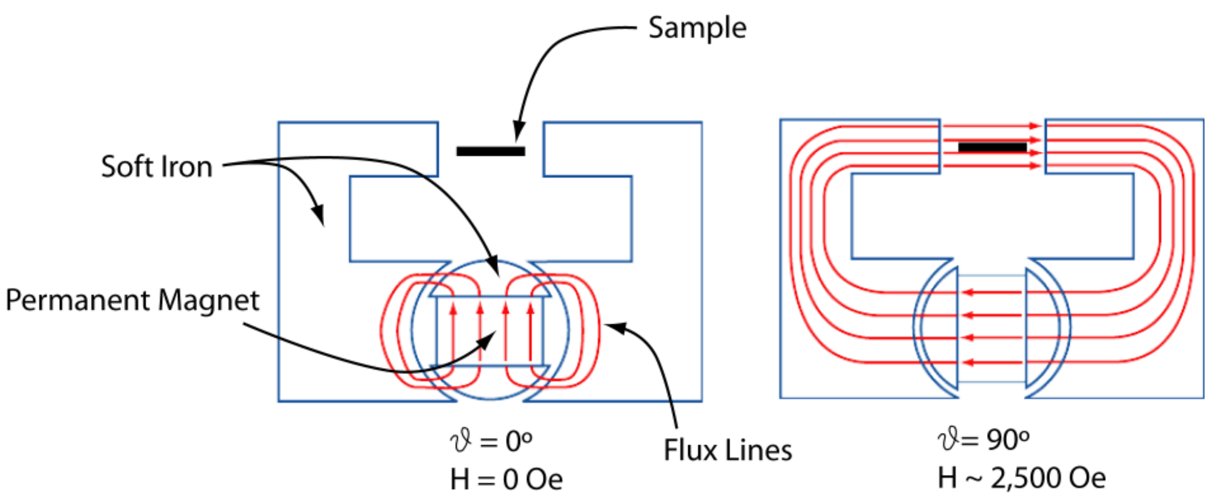


Figure 15.1.: How it works: A rare earth permanent magnet is at the heart of the VFM. The strength and sign of the magnetic field applied to the sample depends on the rotation angle of the magnet. When the magnet is at 0° or 180°, the magnetic flux is shunted away from the sample by the soft iron armature and pole pieces. As the magnet rotates, more and more flux is channeled instead through the sample. At 90° and 270°, the field magnitude is maximized.

The Asylum Research Variable Field Magnet (VFM) module relies on a rare-earth permanent magnet to apply a field to the sample. By rotating the magnet, different amounts of magnetic flux can be channeled through the sample. Referring to Figure 15.1 on page 194, the flux through the sample is maximized when the magnet is oriented at 90° and 270° and minimized when the magnet is oriented at 0° and 180°. By using permanent magnets, we avoid using electromagnetic coils that can require significant current to maintain a large magnetic field. This current inevitably leads to unwanted joule or resistive heating. Heating can degrade the performance of the AFM as well as change the physics of the sample being studied. A motor controls the magnet rotation. Motion of the motor is controlled through menu settings in a control panel within the Igor Pro software interface, detailed below. The software uses the signal from a magnetically sensitive sensor embedded close to the sample mounting area to control the desired field strength of the VFM stage to within ± 1 G. The software feedback control can also be disabled to allow the user to manually control the VFM field strength.

15.4. Accessory Chuck for Mounting VFM Module

An accessory chuck must be used to mount the VFM module on the XY scanner. Exchanging the 200 mm sample chuck for the accessory is described in the 8.2.2. Once the accessory chuck is mounted, it will look like the image Figure 15.2 on page 195.

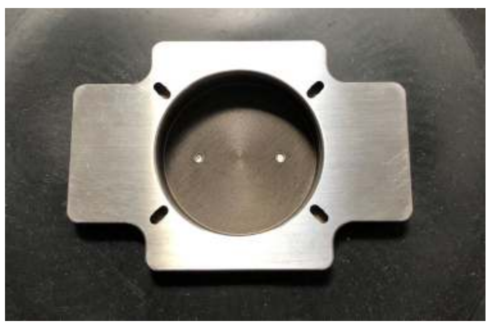
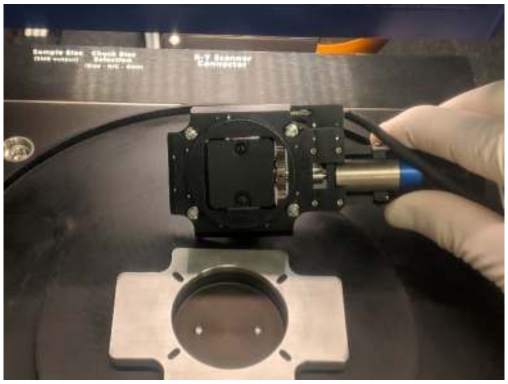


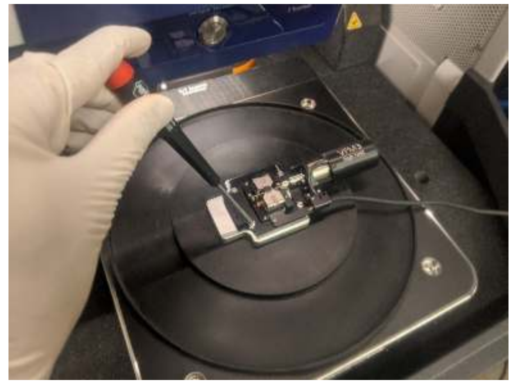
Figure 15.2.: Center part of the Accessory Chuck

15.5. Installing the VFM Sample Stage

15.5.1. Mounting the VFM onto the accessory chuck

1.





Mount the VFM on the accessory chuck

- Using the slotted screwdriver (290.114), carefully align the slots of the four screws with the white lines on the VFM.
- Place the VFM onto the accessory chuck in the orientation shown above.
- If necessary, adjust the screws slightly to properly engage the slots in the plate.
- Rotate all screws by 90 degrees to lockdown the VFM.

15.5.2. Installation – Electrical connections

While not strictly necessary, it is good practice to turn off your AFM controller before making the electrical connections.

1. **Install the VFM expansion module:** If the VFM expansion module is not already installed, follow the steps listed here first:

   a) Turn off the ARC2 controller power.

   b) Detach the Motor Power cable connected to the backpack controller. This is sometimes referred to as “dirty power”.

   c) Remove the left-most available slot cover in the expansion box and install the VFM expansion module.

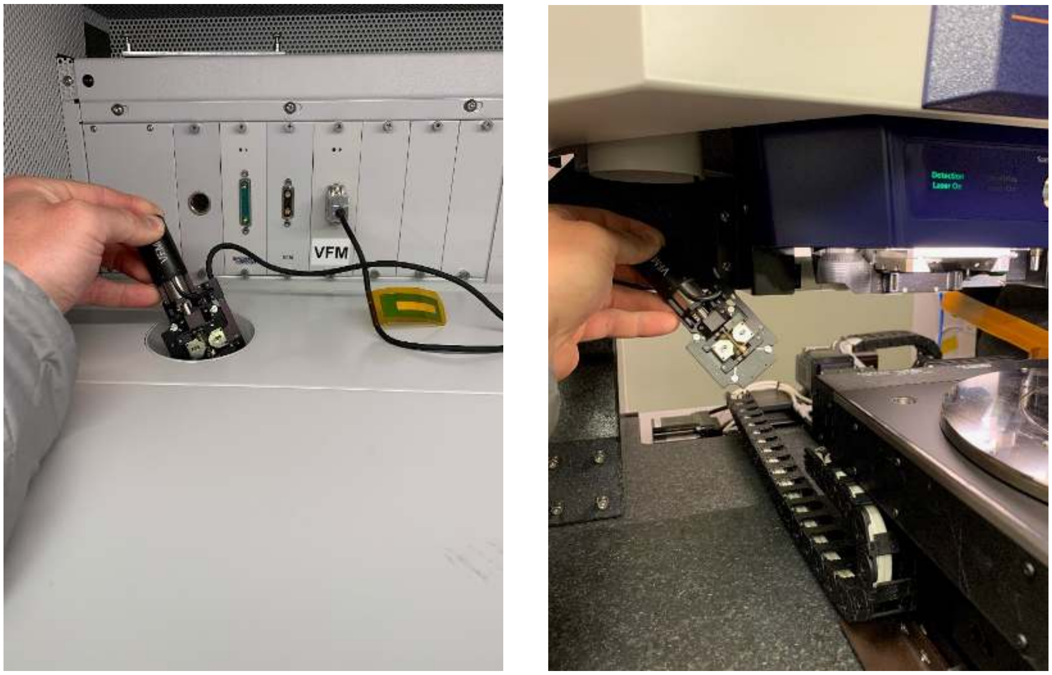
   d) Reattach the Motor Power cable to the backpack controller and turn on the ARC2 controller.

   Note Accessories that are attached to the expansion box must be installed in order from left to right, without any unoccupied slot.

2. **Attach the VFM cable to the VFM control module:**

   • Connect the VFM to the VFM expansion box using the supplied DB25 cable (449.011).

3.



Route the cable and connect to VFM

- Route the cable through the hood and connect with the VFM.
- When the VFM is connected, a bright blue light should illuminate from the small circuit board between the pole pieces.

Note: When the VFM is connected, a bright blue light should illuminate from the small circuit board between the pole pieces.

15.6. Software Tutorial

Power up, start software, and check device connections as follows:

- The ARC2 controller should be turned on (button on front right of controller) and the power connected to the backpack controller.
- Start the AFM software and select the desired imaging mode (e.g., AC Mode, Contact Mode, etc.) in ModeMaster.
- Verify that all the components are identified in the software by clicking 'AR' button and selecting the 'Device Manager'. (See Figure 15.3 on page 199.)
- The software should automatically recognize the VFM accessory.

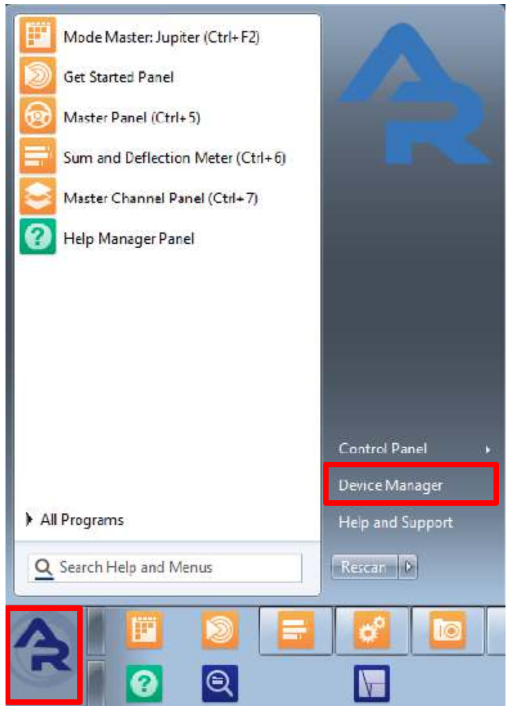


Figure 15.3.: Opening the software Device Manager.

The control panel for the VFM (Figure 15.4 on page 200) will automatically appear once the software is started, as long as it is connected to the MFP3D controller. The panel can also be displayed by selecting AFM controls > VFM panel from the main menu bar.

A complete description of each control parameter in the panel can be found by clicking on the box with the question mark next to the parameter of interest.

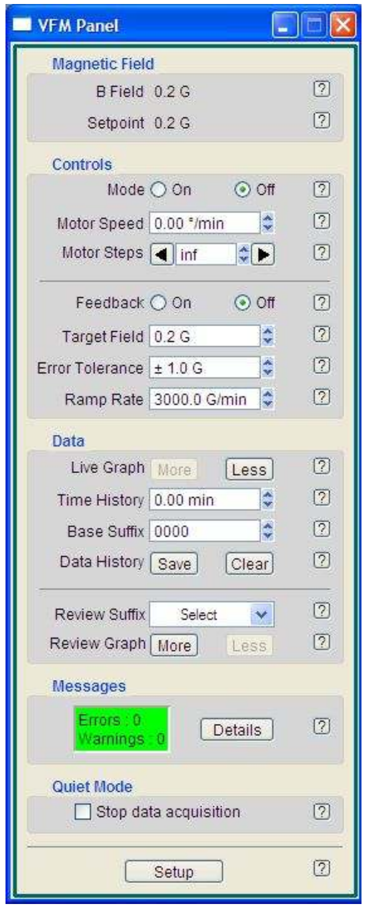


Figure 15.4.: The VFM panel. A complete description of each control parameter in the panel can be found by clicking on the box with the question mark next to the parameter of interest.

This tutorial gives instruction for a few rudimentary tasks to demonstrate the controls.

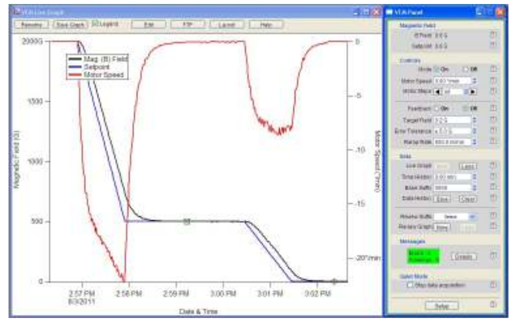
1. The VFM panel should start out as it appears in Figure 15.4 on page 200, with 'Mode' and 'Feedback' turned off. Your field may be reading a different value than that in the figure, depending on the rotor position of the VFM when it was last used.
2. Make sure the pole pieces are 3mm apart for the following examples to function. Use the supplied 0.050" allen driver (290.111) to move the pole pieces. Also see Section 15.9.4 on page 211.
3. Click the 'More' button next to Live Graph three times. This will bring up a realtime record of field, motor speed, and field setpoint.
4. Set the Ramp Rate to "3000 G/m", Target Field to "500 G", and Error Tolerance to "5.0".
5. Set Feedback to "On" and Mode to "On". The motor should start turning and the values on the graph will change. Wait until the field settles down to 2000G.
6. Set Feedback to "Off" and Mode to "Off".
7. Click the 'Clear' button next to Data History to clear the graph.

8.

Controlled Field Ramp

- Set the Ramp Rate to “2000 G/m”.
- Set the Target Field to “500 G”.
- Set Feedback to “On” and Mode to “On”.
- The motor will execute a controlled field reduction and gently stop at 500G. Once it reaches the target value within the set error tolerance, it will turn the feedback off and the motor speed to zero.

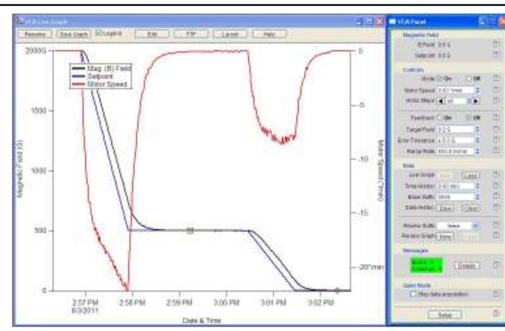
Caution If the error tolerance is too narrow, the motor will never stop adjusting and may cause imaging noise. Always turn the mode to off before imaging if you are uncertain.



9.

Controlled Field Ramp, continued

- Set the Ramp Rate to “500 G/m”.
- Set the Target Field to “0 G”.
- Set Feedback to “Off” and Mode to “Off”.
- The motor will execute a slower ramp down to zero.

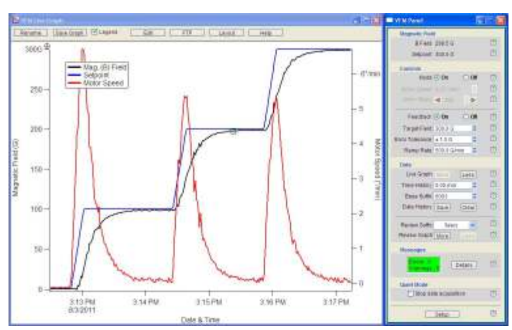


10.

Changing the field by 100 G steps

- Set the Target Field to “100 G”.
- Set Feedback to “On” and Mode to “On”.
- Observe and repeat at 100G increments to produce the graph to the right.

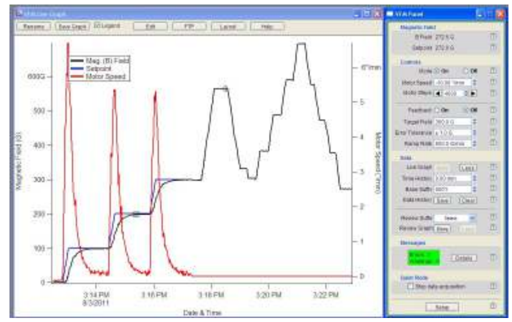
Note A real ramp never quite executes. The feedback control parameters are set conservatively. If faster settling times are needed, please contact Asylum Research, or read on for more suggestions.



11. **Changing the field by motor steps**

- Set Feedback to “Off”.
- Set Motor Speed to “10 °/minute”.
- Enter “10,000” Motor Steps.
- Click on the RIGHT arrow next to Motor Steps.

  The motor turns on immediately, executes its steps, and stops. The graph shows the field history.
- Click on the LEFT arrow next to Motor Steps.

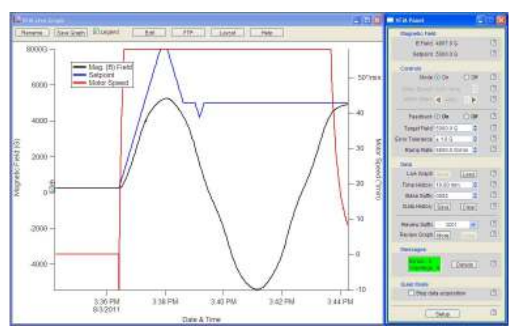


Note The field stops short of where it was before. This is due to backlash in the motor’s gearbox. We had continued with a number of 4000 step positive increments followed by negative 4000 step increments. The settling time is faster but the benefits of feedback control, like backlash elimination, are compromised.

12. **Setpoint out of range**

- Set Ramp Rate to “5500 G”.
- Set Target Field to “8000 G”.
- Turn Mode and Feedback to “On”.

For a while the motor tries to keep up with the rising setpoint, but eventually the VFM2 reaches the maximum field for the given 3mm pole face separation. In any case, we chose a setpoint too high and the motor will keep spinning forever trying to reach it.



Note The setpoint was reduced to a reachable 5000G after the field had reached its maximum. The VFM can only operate in the positively sloped region of field vs motor direction. Even though it might reach its setpoint, it will complete one more full rotation until it is back in the positively sloped area before slowing the motor to land at 5000G.

13. Turn the motor and feedback off before imaging.

Note	**When the VFM4 is used in conjunction with the Jupiter AFM, the applied magnetic field may induce an offset in the Z-Sensor signal on the order of 100's of nanometers – this does not affect normal operation in which the magnetic field is not changing during the AFM scan.**

15.7. Field Gradients

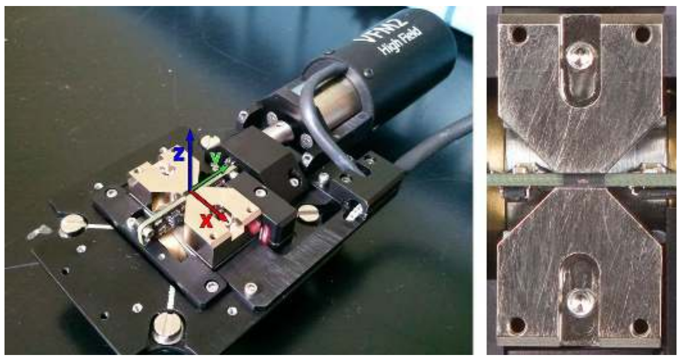


Figure 15.5.: Coordinate Axes defined and the field orientation. Positive sensor values are defined as B field components along the positive X-axis. To the right, a close up view of the preferred origin for imaging, which lies directly over the field sensor, highlighted as a tiny white line between the pole faces.

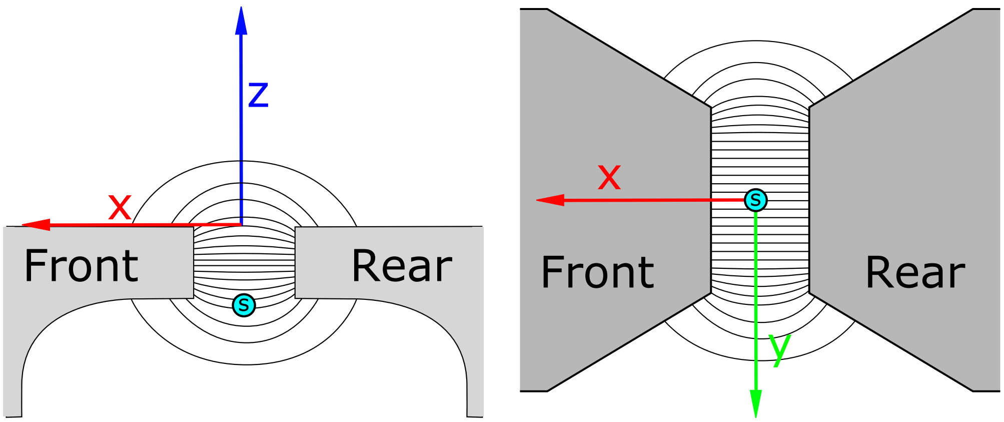
VFM2 vs VFM	This discussion largely focuses on the magnetic sensor of the VFM2. The original VFM had a larger sensor which was located much farther away from the sample. Please see Section 15.12 on page 218 for further discussion about their differences.

Proper sample mounting is only possible with some understanding of the magnetic field gradients produced by the VFM. In an ideal world, the field would be very uniform and the magnetic field sensor would be only few microns long, separated from the imaging region by only a few microns. In reality, the sensor is hundreds of microns on a side (with an active measuring area of 70 by 70 microns) and is embedded in a package which adds at least several hundred more microns to its size, and the sample thickness will likely add hundreds more microns. As shown later in more detail, the field can change by 1000's of Gauss over this distance.

To overcome this problem of not being able to put the sensor directly in the same place as the imaged surface of the sample, we take advantage of the symmetry of the field. With proper sample and pole face placement, the relative locations of sensor, sample, and pole faces can maximize the likelihood that the sensor is registering a meaningful field.

Figure 15.5 on page 203 defines the coordinate system of the VFM. It also shows the exact position of the magnetic sensing element, aligned with the bottom edge of the pole pieces. The origin of the coordinate axes has been placed in the plane of the tops of the pole pieces and directly above the center of the sensing element. This is the optimal position for the sample's top surface.

Figure 15.1 on page 194 shows how the VFM routes flux from a permanent magnet to the sample. This cartoon shows the field lines as perfectly parallel and uniform and the sample not accessible for imaging. A more realistic depiction can be seen in Figure 15.6 on page 204. The scale of the pole faces is 1.5mm tall and 3mm wide.



(a) View from +y to the origin. **(b)** View down from +z to the origin.

Figure 15.6.: Cartoons of the approximate fields between the pole faces. On the left, a side-view section, on the right a top down view. “s” denotes the position of the field sensor’s active element. The origin was chosen at the optimal point for imaging. The central position of this point will maximize the field along x and minimize the other components. The origin also best mirrors the sensor position so that the field measurement is as accurate as possible.

Some observations:

- The field decreases in strength away from the area between the pole faces (we’ll quantify this shortly).
- At x=y=0 the field is horizontal (parallel to x), which is also the only component the sensor can measure. Moving away from the origin along the x axis (and to a lesser extent along y) the field vector will gain other components and rotate away from its direction at the origin.
- The sensor is placed so that it measures a field which is a mirror image of the field at the origin. Asylum Research individually aligns the sensor position on each VFM so that it is aligned with the bottom edge of the pole faces.

Some conclusions:

- Place the area of the sample to be imaged as close to the origin as possible and it will enjoy:
  - “Horizontal” applied field.
  - Fields which are very close to what the sensor measures.

These observations do not change with larger pole face separations; only the field values and the field gradients will reduce in size.

15.7.1. Vertical Field Variation

To take a more quantitative look at the field profiles and gradients, we mounted a magnetic field sensor on an XYZ translation stage and made various measurements of the field along the X, Y, and Z axes. Note that the sensor was oriented to measure only the field component parallel to the X axis, or B_x.

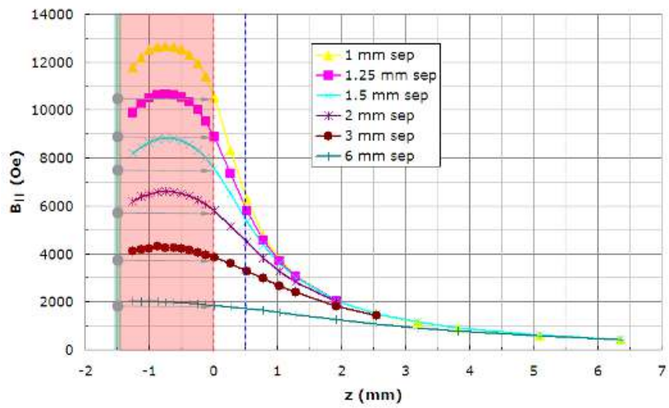


Figure 15.7.: Magnetic field component parallel to the x-axis as a function z position above the pole faces in a VFM2 set to maximum field strength. Different curves represent different pole face separations (see legend). The shaded area is the volume between the pole faces. The red dashed line (z=0) indicates the preferred plane for a sample surface to be imaged. The blue line (z=0.5) indicates a sample which is 0.5mm thick. The broad green line indicates the position of the Hall sensor attached to each VFM2. The gray arrows connect the field measured by the sensor to the field experienced by a sample mounted flush with the pole pieces.

Figure 15.7 on page 205 shows B_x for various separations of the pole faces on a VFM2 set to maximum field strength. Let's dissect a few of the curves. The yellow (top) curve with triangle markers shows data gathered with the pole faces as close as possible, touching the sensor circuit board between them. At Z=0, B_x is slightly more than 1 Tesla. Note that when this VFM is placed on the scanner, the field drops a bit. This experiment was performed on the bench top. Going down into the shaded area (indicates the sensor is going between the pole faces) the field rises, and then falls again as the sensor emerges from between the pole faces. The symmetry of the field caused us to choose the sensor position at Z=-1.5mm, which does a respectable job of matching B_x at Z=0.

Going up from Z=0, the field falls quickly. Only 500 microns above the pole faces, it has dropped to a little over 6000 G. The implication is that if you are studying a sample which is 500 microns thick and set it flat on top of the pole faces, your maximum field can only be 6000 Gauss. You will have to cut the sample smaller so it can fit between the 1mm separated pole pieces to get to closer to the VFM's maximum field.

Look at the brown curve with circular markers (one up from the bottom). The magnet orientation was left in the same position, but the pole faces were separated from 1mm to 3mm. The maximum B_x at Z=0 has dropped to ~4000 G, but the field gradients are also significantly less. B_x at Z=0.5 is now ~3000 G. Smaller gradients tend to make for better measurements. To conclude, it is always best to separate the pole faces as far as possible depending on your maximum field requirements.

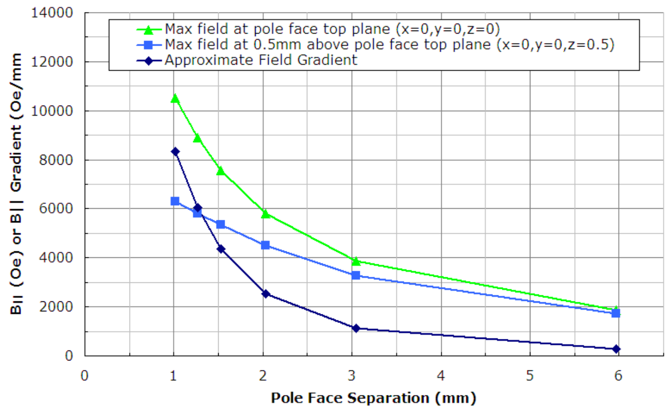


Figure 15.8.: Maximum field along the x-axis measured at the origin (sample in plane with pole face tops) and 0.5mm above (0.5mm thick sample resting on pole face tops). Also, the approximate field gradients at each point for Z=0.

15.7.2. Fields vs pole piece separation and vertical gradients

Figure 15.8 on page 206 summarizes some key information from the family of curves in Figure 15.7 on page 205. For various pole face, it shows:

- The maximum B_x at Z=0, i.e a sample clamped between the pole faces so its top surface is flush with the tops of the pole pieces. Use this curve to determine the pole face separation needed, based on your maximum field requirements. Always choose the largest separation possible.
- The maximum B_x at Z=0.5mm, i.e a larger sample, 0.5mm thick, sitting on top of the pole faces.
- The approximate field gradients at Z=0.

15.7.3. Lateral Field Gradients

B_x variations along X and Y in the plane of the pole faces (Z=0) were also measured for a pole face separation of 3mm. The results are shown in Figure 15.9 on page 207.

The main observation is the nearly zero gradients in B_x as long as the imaging region is within 0.25mm from X=Y=Z=0.

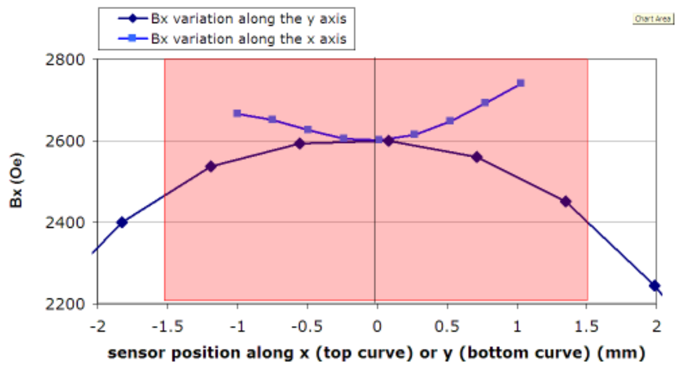


Figure 15.9.: Variation of the x component of the magnetic field along the x and y axes (with z=0). Pole faces were separated by ~3mm. x-axis data cannot extend the full 3mm range due to the sensor plastic enclosure hitting the pole faces. The pole faces are also 3mm wide andF so the red area indicates measurements taken with the sensor in the gap between the faces.

15.8. Things to keep in mind

15.8.1. Sample's effect on the field

A magnetic sample can be a bridge for magnetic field lines from one pole piece to the other. The sensor placement at the "mirror image" of the sample assumes the field is symmetric at the upper and lower edges of the pole faces. Placing a piece of magnetic material (i.e., the sample) will break that symmetry and will direct flux through the sample and away from the sensor. Fortunately, the effect is negligible for most samples.

A suitable test is to set the field at a relatively high value (we chose 5000 G with an approximately 2mm pole face spacing) and to monitor the sensor reading for a minute or so. Then place the sample on top of or in between the pole pieces. If the field changes measurably, then the field experienced by the sample will no longer equal the field measured by the sensor. Here are the results for four materials:

Sample	Effect
8mm wide piece of video tape	no measurable effect
8 x 8mm piece of hard drive platter	no measurable effect
4mm wide strip of 1-micron thick amorphous cobalt alloy	5 G (0.1%) drop in measured field
5mm wide strip of 0.25mm thick magnetic steel	100 G (2%) drop in measured field

In the last case, it is not clear that the 2% drop at the sensor implies a 2% increase at the sample, but at least it gives some cause for further investigation. The best course of action is probably to substantially reduce the size of the sample and repeat the test until the presence of the sample has little or no effect on the sensor reading.

A good indication that there is going to be an effect is when the sample is noticeably attracted to the gap between the pole pieces. This can best be felt with the VFM set to a high field value.

15.8.2. Scanner's effect on the field

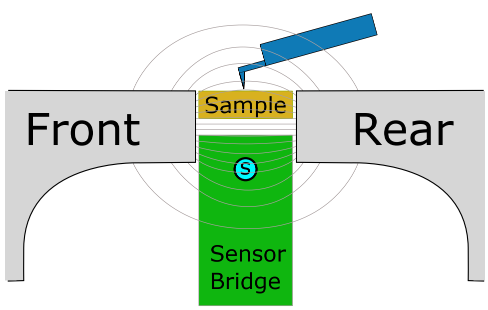
If you set the VFM to its maximum field and then place it on the scanner, you may notice a drop in the maximum field value of about 10%. This is due to magnetic field lines under the VFM channeling into the magnetic steel inside the scanner. If you must have more field than the reduced maximum, contact Asylum Research to fashion a spacer to mount the VFM a little higher on top of the scanner.

Also beware that if a sample is very near some maximum field it should not exceed, be sure to reduce the field before removing the VFM from the scanner, or there may be a sudden 10% increase in field strength.

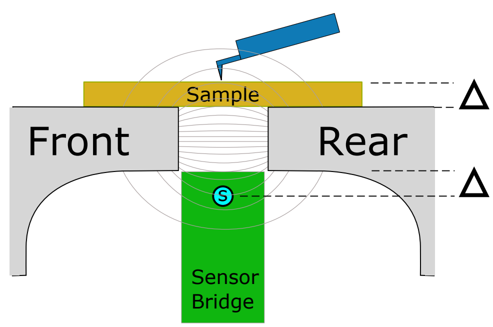
15.8.3. Temperature Effects

The strength of the permanent magnets used in the VFM vary with temperature. While the effect will be relatively small, you may notice that the sensor reads a lower field value once the AFM warms up the inside of its acoustic enclosure. Also, for long term measurement, it is possible that there will be a small field variation due to daily temperature changes of the lab. Most labs with proper air conditioning should not notice this effect.

15.9. Sample mounting



(a) Side view of a small sample between the pole faces.



(b) Side view of a large flat sample on top of the pole faces. The sensor reads true when the spaces marked with Delta are equal.

Figure 15.10.: Side views showing a small sample mounted between the pole faces with its top surface flush with the top of the pole faces. This allows for the maximum field. In sub figure B, a larger flat sample sitting on top of the pole faces is shown. The max field is less and the distance from the top edge of the pole faces to the top of the sample needs to equal the distance from the bottom edge of the pole faces to the sensor (The two Delta spaces).

As described in Section 15.7 on page 203 (if you did not read this, you should, in order to correctly interpret the sensor readings) the magnetic field sensors sit below the sample at a position where the field strength mirrors that experienced by the sample.

15.9.1. Small Samples (best)

As shipped from the factory, the pole pieces are configured for a sample which can be mounted as shown in Figure 15.10a on page 208. The sample should be thin enough to fit on top of the sensor bridge without rising above the top surface of the pole pieces.

To achieve the highest possible field, the sample should be narrow enough to allow the pole pieces to slide all the way together and touch the sensor bridge. The sample may have to be clamped between the pole faces to keep its top surface flush with the tops of the pole pieces. A few small dots of five-minute epoxy or some wax may come in handy when mounting the sample.

Note that keeping the sample small has other advantages, as described in Section 15.8 on page 207

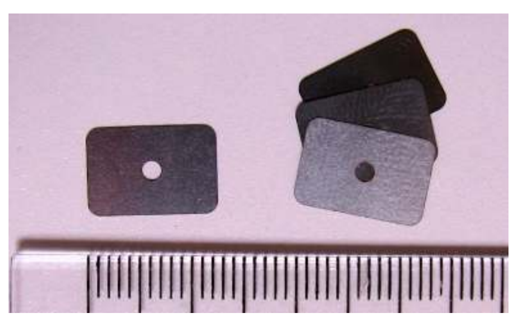
WARNING	The sensor bridge is somewhat fragile. It is made of epoxy and fiberglass. Do not cover it with paint, glue, or other contaminants. While you can clean it with a mild solvent such as isopropyl alcohol, but you should NOT scrape it with sharp objects such as tweezers, scribes, or scalpels.

15.9.2. Larger Thin Samples (good)

Often a sample will be in the form of a thin film on a wafer substrate. If very high fields are not necessary, or it is not possible to dice the sample into the preferred 1mm wide strip, then one can proceed by mounting the sample on top of the pole faces as shown in Figure 15.10b on page 208. See the steps below to mount the sample and properly adjust the field sensor:

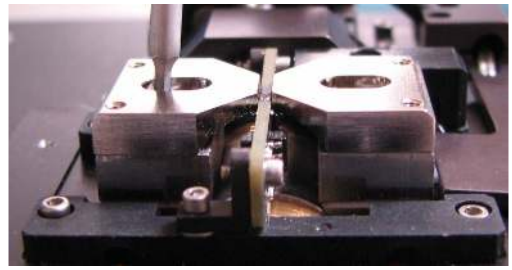
1. Measure the sample thickness with an accuracy of 25 µm (0.001 inches).
2. Divide the thickness in microns by 75 and round to the nearest integer. For instance, a 300 µm silicon wafer results in 4, a 500 µm wafer gives 7. This is the number of shims (per side) you will need in step 4.
3. If the VFM was not already at a very low field, please see Section 15.6 on page 198 and set the VFM to zero field. This will make it easier to remove the pole faces without suddenly snapping together and possibly damaging the sensor bridge.
4. Unplug the VFM stage from its controller box. Working with the shims could create an electrical short circuit during installation and could damage the VFM sensor circuit board electronics.
5. **Gather shims:**
   - Choose twice that number of shims calculated in step 2. (114.645).
   - Divide the shims into two equal stacks.

   Note These shims were cut from 75 µm thick magnetic stainless steel.



6. **Remove the pole pieces:**

- Using the 0.050” allen driver, remove both pole pieces and set aside.



7. **Place the shims under the pole piece:**

- Align the shims under the pole piece.
- Use the screw to keep the shims centered as shown.

8. **Replace the pole pieces:**

- Place the pole piece back on the VFM, while keeping the shims against the pole piece.
- Tighten the screw with a few turns.
- Nudge the shims to rotate them flush. The photo on the right shows shims in need of adjustment.
- Position the pole face at the desired distance from the sensor bridge.
- Tighten the screw until it is snug, taking care not to misalign anything.

9. Repeat this process for the other pole face, making sure the two pieces are equidistant from the sensor bridge.

NOTE	For thick samples, you may need so many shims (we allow for up to 1.5mm total) that the screws which hold the pole pieces down will no longer reach. In that case, your kit contains some longer screws (see the parts list). Store the other screws in the parts kit. They are easily obtained in the US but cannot be found internationally.

15.9.3. Larger Thick Samples (discouraged)

Samples thicker than a few mm should be cut down to a smaller size in order for the VFM to work properly. Contact Asylum Research and we can help you solve your sample mounting problems.

Note that bulk magnetic samples thicker than even a fraction of a millimeter will distort the field, so the sensor reading is no longer reliable. Please see Section 15.8 on page 207 to determine if your sample is affecting the sensor reading.

15.9.4. Checking the Maximum Field

Note The pole pieces on the original VFM should not be separated. For more discussion, see Section 15.12 on page 218.

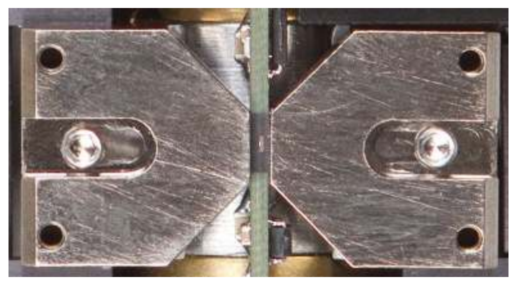
As discussed at length in Section 15.7 on page 203, unwanted field gradients are reduced by separating the pole pieces. Please follow these steps to accomplish this.

1. Determine the maximum field your experiments will require. This should be done with the VFM mounted in the AFM since the AFM reduces the field a little. See Section 15.8 on page 207.

2. **Start the pole pieces in a close position:**

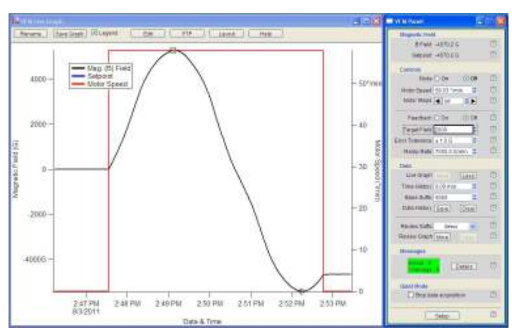
   - Loosen the two screws shown to the right using the 0.050” Allen tool.
   - Move the pole pieces so they are touching the sensor bridge.

   Note If there are enough shims raising up the pieces, then manually adjust them so that seen from above, it looks like the photo.

3. **Explore the VFM field extremes**

   - Set the feedback and mode to off.
   - Set the motor speed to 100. This is beyond the max and it will automatically change to the maximum allowed value instead.
   - Set the motor steps to “inf” it is not already so.
   - Set the mode to on.
   - Next to Live Graph click “more” a few times.
   - Next to data history click “clear”.
   - Observe the field sensor values until the maximum and minimum field have been reached.
   - Set the mode to off, preferably when the field is still at maximum or minimum.

4. If the maximum field reached is more than what you need, we advise that you separate the pole pieces a little to reduce field gradients and the error in the sensor reading. Remember, if the vertical sample position is off by even 50 µm when operating in the strongest field (smallest pole face separation), you may have absolute error in field reading by hundreds of Gauss.

   Note Moving pole pieces at high field levels can be somewhat challenging since the pole pieces strongly attract each other. One may have to rotate to a lower value first, move the pole pieces, and then go back to see what the maximum has changed to. Remember that a pole piece snapping against the sensor bridge can cause serious damage.

The goal is to get the maximum separation while still achieving the required fields. As mentioned before, this minimizes gradients and maximizes the likelihood that the field sensor will give an accurate reading of the field your sample will experience.

15.9.5. Centering the Sample

As explained in Section 15.7 on page 203, the sensor reading is best represented at a point directly above the sensor, in the plane formed by the tops of the pole pieces. Please follow these steps to center the VFM with respect to the cantilever tip.

1. Follow the hardware installation instructions in **??** on page **??**. Have the legs extended to the point where the cantilever clip is a few millimeters above the top of the VFM pole pieces.
2. With the 0.050" allen tool, remove both pole pieces and set them aside. Note that it helps to have the field set to a low value or the pieces will snap together when the screws are loosened.
3. Put a cantilever (this can be an old one) in the cantilever holder and place the head on the AFM base.
4. Align the head optics until you have a clear and centered image of the cantilever. See **??** on page **??** for more information. Try to have the head relatively level.
5. Press down on the head and exert force with a clockwise twisting motion. This seats the head firmly in the grooves. If you repeat this same twisting pressure each time, you will greatly improve your odds at placing the head so the cantilever ends up in the same area.
6. **Coarse center the VFM sample stage:**

   - Using the sample align-x and y micrometers (see **??** on page **??**) center the cantilever as best as you can above the center of the sensor circuit board.

   Note The small white dash was added to the image to indicate the top-down view of the sensor's active area.

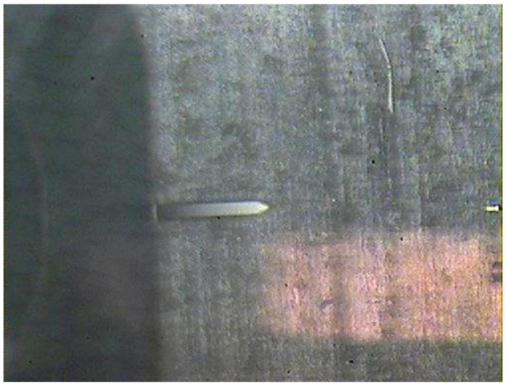
   

7.

Approach the sample:

- While looking at space between sample and tip, approach the tip to the sample using the joystick until ~ 1 mm away from the sample.

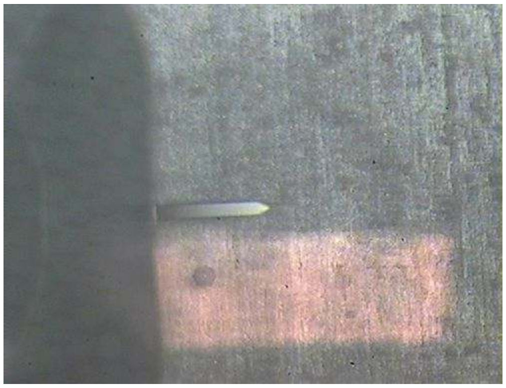
Note Do not go down too far or the lever will crash. Using an old lever is recommended for beginners.



8.

Explore the width of the sensor:

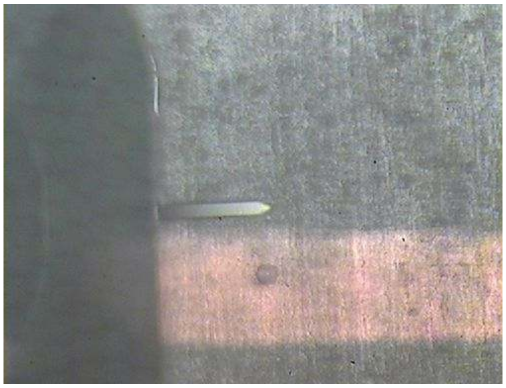
- Using the joystick of arrows in the software, explore the left and right edges of the light-colored area. This area is a metal tab which holds the magnetic field sensor. The sensor is about as wide as the length of the cantilever and mounted on the back side of the tab, as seen from the front of the AFM.



9.

Center the tip over the sensor:

- Finally, move align-x and y until the tip is at the upper edge of the metal tab and centered between the left and right edges. At this point you have found X=Y=0 and the tip is directly over the active area of the magnetic field sensor.



10.

Raise the tip:

- Using the software, save the current XY stage position.
- Raise the tip all the way up in Z.

Note It is crucial to move the tip *all the way up* in the Z before moving the XY stage.

11.	**Mount the sample:** • Once you have full clearance, move the XY stage to the front of the AFM, replace the pole pieces, and mount your sample. • Lower the tip ~ 1 mm away from the sample. Proceed with regular engage procedure and imaging. • This was our best attempt at keeping X=Y=0 directly above the magnetic field sensor, for the most accurate field readings of the area that will be imaged.

15.9.6. Flat Sample Mounting

Preferably use the clips (112.959) and short button head screws and the 0.035” allen driver (290.104) supplied with the kit.

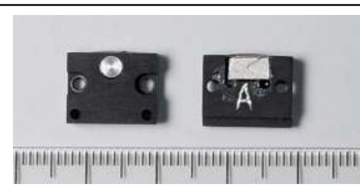
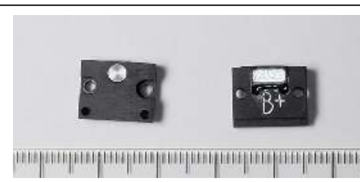
If the sample is too small for the clips to reach it, use the sticky tabs (113.672). Note that the sticky tabs may cause some thermal drift and you must take the thickness of the glue into account when determining the number of shims to use when raising up the pole pieces (see 15.9.2).

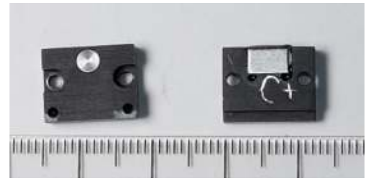
15.10. Imaging

There are no particular requirements with regard to imaging. Most often one will perform Magnetic Force Microscopy (see *Applications Guide, Chapter: Magnetic Force Microscopy (MFM)*), but sometimes one might also perform Piezo Force Microscopy (See *Applications Guide, Chapter: PFM Using DART* or *Applications Guide, Chapter: Single Frequency PFM*).

15.11. VFM Out of Plane Option

15.11.1. Parts list

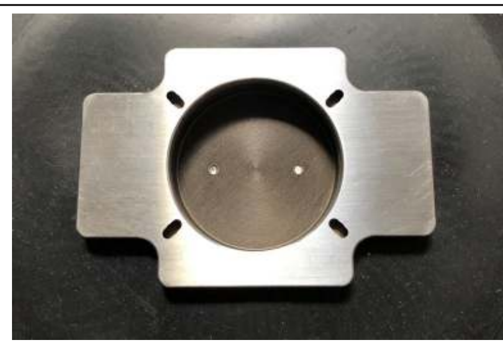
Itm	Part #	Item Description	Qty	Picture
1	930.001	VFM3 OP Pole Piece, Neutral, marked A.	2	
2	930.002	VFM3 OP Pole Piece, Positive High Field, Marked B+.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
3	930.003	VFM3 OP Pole Piece, Negative High Field, Marked B-.	1	
4	930.004	VFM3 OP Pole Piece, Positive Medium Field, Marked C+.	1	
5	930.005	VFM3 OP Pole Piece, Negative Medium Field, Marked C-.	1	
The scale in the photos is in cm and mm.				

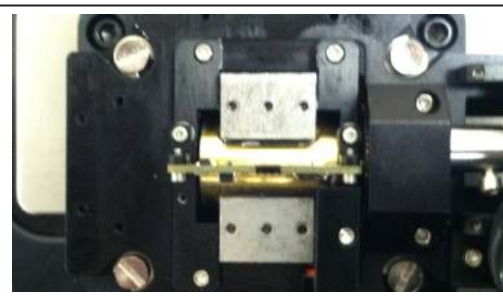
Note that the VFM out-of-plane kits sold after 2018 or included standard with the VFM4 do not have the B+/B- and C+/C- pole pieces.

15.11.2. Installation

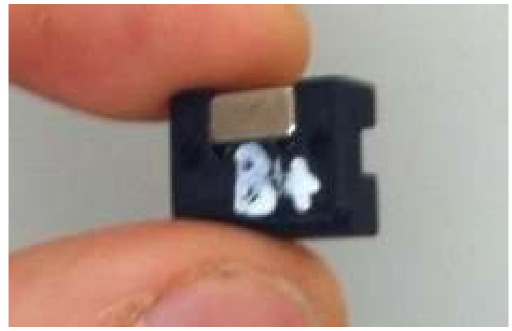
1. **Mount the top plate on the accessory chuck:**
   - The top plate of the accessory chuck should have slots as shown on the right.



2. Plug in the VFM3 stage and set the field to zero. This will make removing the pole pieces in the next steps far easier.
3. Unplug the VFM3 from its controller box.
4. **Remove Pole Pieces:**
   - Remove the existing pole pieces and any spacers. Store them in a safe place.
   - At right, the VFM3 is shown with pole pieces removed.



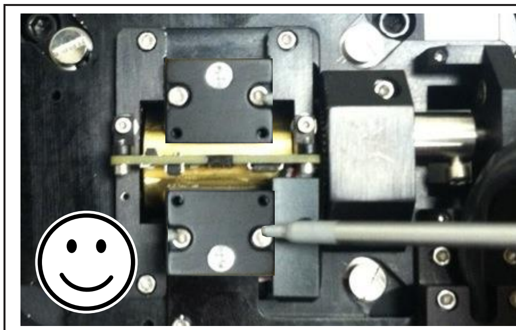
5.

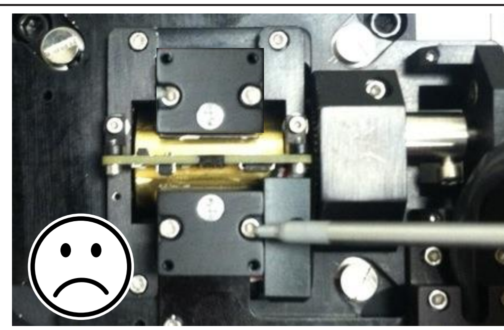


Select a set of OP Pole Pieces:

- Use them in matched sets, (A, A), (B+, B-) or (C+, C-). The A pole pieces have passive iron cores, and the B and C pieces have built in permanent magnets to shift the field to higher maximum values.

6.





Install the pole pieces:

- Install the pole pieces as shown on the left. NOT as shown on the right.

7.

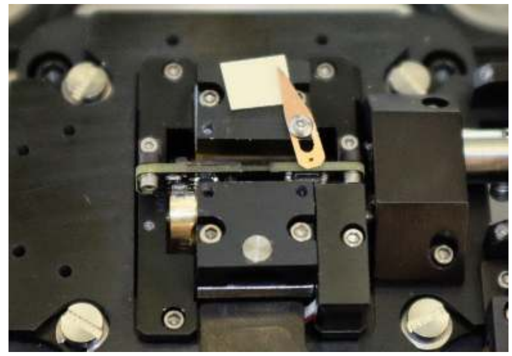
Mount the VFM3:

- Mount in the orientation as shown.

8.

Place the Sample:

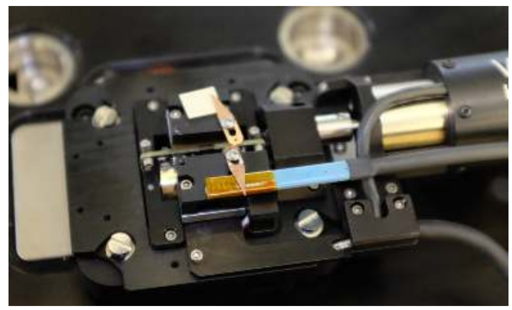
- Install the sample, preferably using the clips (112.959) supplied with the VFM (not included in the OP kit).
- Thinner samples are better since the field strength drops strongly with vertical distance from the pole face.



9.

Place the Gauss meter:

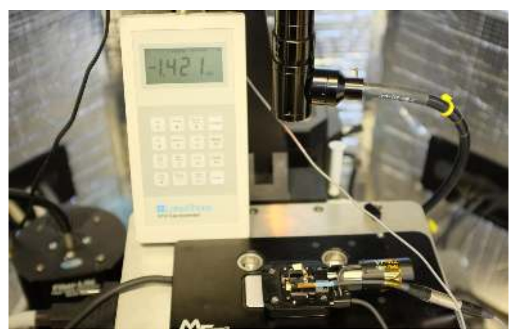
- The gauss meter can be used to measure the field at the opposite pole piece. This is a good indicator of field at the sample.
- You can experiment and compare those values.



10.

Field Measurement:

- Before imaging, collect a series of test fields comparing the reading of the built-in sensor on the computer to the values on the hand-held gaussmeter and note the values down in a lookup table.
- To go to a particular field, use your lookup table and enter the appropriate value into the computer as a target field, but continue to monitor using the hand-held guass meter.



15.11.3. Operation

The operational principles for the out of plane fields are identical to the in-plane operation with the exception that the field displayed on the computer is only proportional to the field experienced by the sample. See Step 10 on page 217 creating a lookup table between Out of plane field as seen by the sample and in plane field measured by the VFM3's internal sensor.

Note that the field drops off quickly with vertical distance away from the pole face. We recommend using a plastic spacer of the same thickness as your sample when making field measurements with the hand-held gaussmeter. the gauss meter sensing element is visible on one side of the probe. We recommend placing that probe face down against the pole piece (or spacer) to get the closest possible measurement of the field. Experiment with some spacers of 0.1mm increments to get an idea of the field changes. You may have an idea of the positional uncertainly by which you can estimate the sample thickness or your ability to place the gaussmeter probe. That positional uncertainty can then be converted to a field measurement uncertainty which can be used for error bars on your presented data.

15.11.3.1. Choice of pole pieces

For fields which are symmetric about zero, use the pole pieces marked with “A”. In other words, as the magnet inside the VFM rotates, the vertical field will explore values from +1500 to -1500 (this is just an example, not a verified range of values, but based on some preliminary observations). For the pole pieces marked “C”, it will explore a range of (0 to +2000), and for the pieces marked “B” a range from +1000 to +3000. Note that these values will vary from unit to unit, and the best way to find your values is to put a spacer of similar thickness to your sample under the Gauss meter probe and cycle the field through one full revolution and collect data.

15.11.3.2. Sample Issues

Samples should be kept as small as possible, preferably smaller than the diameter of the pole pieces. Larger samples with high magnetic permittivity can cause the field to be distorted to the point where the Gauss meter at the opposite pole is not making a proper measurement. Samples on ferromagnetic substrates should especially never be larger than the pole face since field lines may be guided through the edges of the sample back to the opposite pole face, causing a distorted field measurement. Experiment with your hand-held Gauss meter by measuring field values above the actual sample, before you blindly trust the measured field from the opposite pole face.

15.12. VFM vs VFM2 vs VFM3 vs VFM 4

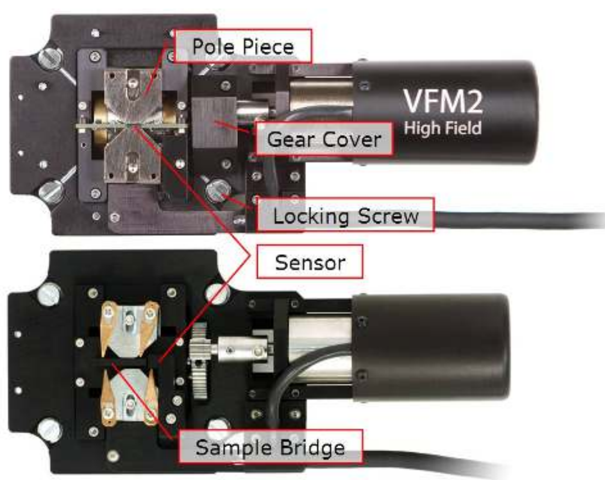


Figure 15.11.: Some of the basic components of the VFM defined. Also, a side-by-side comparison of the sample stages of the VFM and the VFM2-Tesla. The original VFM can be distinguished by the lacking text on the motor cover, no gear cover, and no small sensor circuit board between the pole pieces.

15.12.1. Basic Differences

	VFM	VFM 2	VFM 3	VFM 4	Notes
Max Field	<=2500G	>7000G	>7000G	>7000G	
Sensor Position	Off to the side	Under Sample	Under Sample	Under Sample	VFM2 sensor makes a much better estimate of the field.
Sensor Range	<=2500G	>10% over max field	>10% over max field	>10% over max field	VFM2 sensor has more headroom and better linearity.
Sensor Resolution	~1G	~0.5G	~0.5G	~0.5G	VFM2 has an improved 16-bit sensor ADC.
Movable Poles	Yes*	Yes	Yes	Yes	* Moving the poles from the closest speacing renders the sensor calibration incorrect.
High Voltage	No	Yes	Yes	Yes	VFM2 high-voltage accessory attaches to the Samuel stage. Not available for the first generation VFM for safety reasons. Not available as an option with the Jupiter VFM4.
Out of Plane Option	No	No	Yes	Yes	VFM3 is basically the VFM2 with a slight modification to how the pole pieces mount.
In plane pole piece part number	114.250	113.672	115.507	115.507	Note that the pole pieces for all models are different. They may look very similar but are indeed different enough to not be fully cross-compatible.
Field Gradients	Strong	Weaker-Stronger	Weaker-Stronger	Weaker-Stronger	Typically, field gradients go up as pole pieces are brought closer. See 15.7.

The original VFM had its sensor located away from the sample (See Figure 15.12 on page 220). At the time this was due to a lack of sensors small enough to fit under the sample. The VFM was calibrated once with a larger calibrated sensor between the pole pieces and this value was tabulated against the VFM's built in sensor. As long as the orientation of the pole pieces stayed fixed as they were during calibration, the remote sensor gave a reasonably accurate value of the field. This had a number of requirements:

- The pole pieces could never be moved.
- The sample had to fit between the pole pieces so that the sample top surface was flush with the top of the pole pieces.
- If the sample had any substantial volume and was ferromagnetic, the subsequent field distortion was enough to render the sensor calibration ineffective.

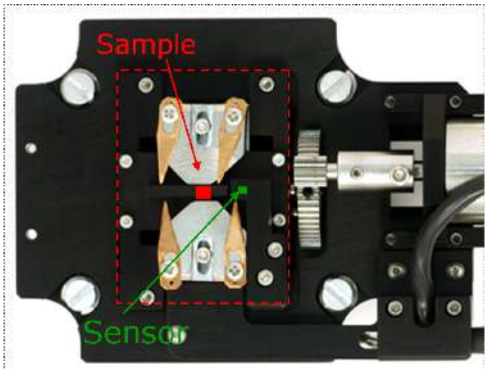
The only advantage to the old setup was the absence of a sensor bridge directly below the sample. One could remove the otherwise inert bridge between the pole pieces and put a rather thick sample in between, as long as it was no more than 1.5mm wide.

The VFM2 improves this situation by placing the sensor much closer to the sample, in a place where the field has a higher degree of symmetry, allowing the use of shims (see Section 15.9.2 on

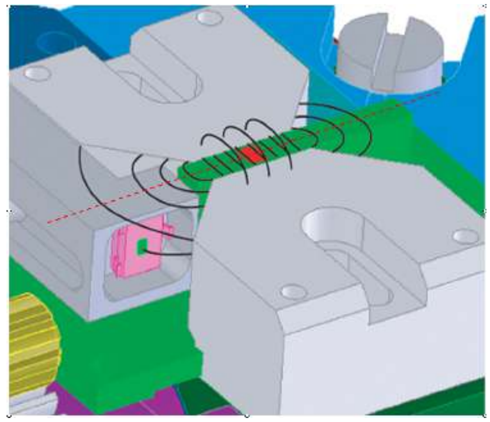
page 209) to keep the sensor reading very close the field values near the area being imaged.

The VFM2 also allows the pole pieces to be moved. As long as they are placed symmetrically on either side of the sensor, measurements will remain valid.

Please contact Asylum Research if you would like a quote to upgrade your original VFM to an VFM2.



(a) Sample and sensor positions for the original VFM.



(b) Artistic rendition of the field lines in the original VFM. Sample position is red, sensor position is green.

Figure 15.12.: The original VFM had the sensor positioned far away from the sample.

15.13. Scientific References

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Part IV

Specifications, Maintenance, Installation, and Shipping

Part IV: Who is it for? If you need to move your AFM or ship it to Asylum Research for any reason, please consult this manual. Beyond that, this part of the manual will probably not see much day to day use.

Part Contents

16. Maintenance

CHAPTER REV. 2319, DATED 03/16/2021, 18:55. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Chapter Contents

Warning	There are no user maintainability components inside the Jupiter AFM. Do NOT remove any cover plates or access panels. Doing so may expose motor, voltage, and laser hazards. Please read and understand the Safety chapter (see Section 1.5 on page 13) before proceeding. If in doubt, please call your nearest Asylum Research office or distributor.

16.1. Cleaning

Clean the outer surface of the instrument and enclosure with a damp soft cloth. Isopropanol is acceptable to dampen the cloth, but do not use stronger solvents such as acetone or soaps.

Do NOT reach behind any protective covers.

Turn off the AFM controller power (see Chapter 5 on page 88) and the stage controller power (see Chapter 7 on page 100) before cleaning any parts inside of the enclosure, such as the horizontal granite surface.

16.2. Compressed Air

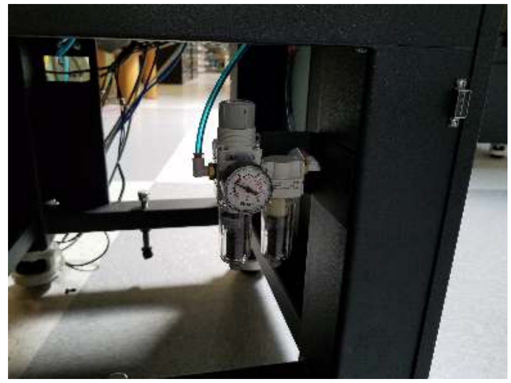
Jupiter XR AFM calls for a clean dry air supply. Nevertheless, moisture can still accumulate in Jupiter's moisture trap.

Check the condition of the air filter/moisture traps regularly.

16.2.1. Filter Maintenance

Inspect the filters

- Open the door under the hood.
- See if the liquid traps are more than half full.
- If yes, hold a cup under the liquid trap while partially unscrewing the gray bleed valve at the bottom of each trap.
- Tighten the screw when done.



16.2.2. Compressor Maintenance

In cases where facility compressed air is not available, a Jupiter XR AFM system may be outfitted with a small, oil-less air compressor. Such compressors may require frequent draining of accumulated water. At the time of this writing, Asylum Research was supplying the Jun-Air oil-less air compressor. Please refer to the Jun-Air manual for a full description.

Below, we have listed an overview of recommended maintenance.

Weekly: Drain water

- Water will automatically drain from the air compressor.
- Drain the condensate that has collected in the draining cup from the valve.

Quarterly: Check air intake filter

- Every three (3) months, check the air intake filter. Replace, if necessary.

Refer to the compressor manual for more detailed information about these operations.

Note: The Jun-Air 6-25 air compressor is the recommended compressor when house air is not available. The compressor should be maintained as indicated by the manufacturer.

16.3. Vacuum Pump

If your system has a vacuum pump, please refer to the Vacuum Pump (Vaccubrand MD1, model# 20696087) maintenance manual.

16.4. Fuses

Both the ARC2 AFM Controller and Jupiter Stage Controller contains fuses. If they need to be replaced, please refer to the following chapters:

- ARC2 AFM Controller: see Chapter 5 on page 88.
- Jupiter Stage Controller: see Chapter 7 on page 100.

17. Installation

CHAPTER REV. 2242, DATED 07/14/2020, 13:36. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

Currently the Jupiter XR AFM should be installed only by personnel certified by Asylum Research and its affiliates. Even if it is relocated by you within your laboratory, we cannot guarantee it will meet published specifications unless we are involved. By all means, call Asylum Research if you have any questions.

18. Shipping

CHAPTER REV. 2241, DATED 07/13/2020, 18:26. USER GUIDE REV. 2323, DATED 03/21/2021, 15:16.

SAVE YOUR CARTONS!	You must use the official cartons and foam inserts to ship your equipment back to Asylum Research for repairs. We can provide replacements, but you will be charged for materials, shipping, and handling.

Shipping should be done in the original cartons. If you cannot find them or did not save them, please contact Asylum Research, as we can supply you with new cartons (for a fee). Also note that there are some parts of the instrument (such as movable optics in the AFM head and floating components in vibration isolation stages) which must be locked down in preparation for shipping or else instrument damage may result. Please contact Asylum Research, and we will help you.

Part V

Bibliography, Glossary, and Index

Bibliography

Cited Asylum Research Documents

Applications Guide, Chapter: Conductive AFM.

Applications Guide, Chapter: Magnetic Force Microscopy (MFM)., Placeholder

Applications Guide, Chapter: PFM Using DART.

Applications Guide, Chapter: Single Frequency PFM.

Hoods and Isolation User Guide, Chapter: Software Options for Image Stabilization.