USER GUIDE 2

Cypher Instrument Family User Guide

Including beta (complete, reviewed) chapters. Including draft (nearly complete, not reviewed) chapters.

Version 16, Revision: A-2110

Dated 09/20/2019

Asylum Research

an Oxford Instruments company

Contents

Introduction

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

AR Software Version It is assumed that AR Software version 13 or later is installed on your system. To download the latest software, please register at our support site: http://support.asylumresearch.com.

Getting Help There are many ways to get help with your Asylum Research instrument, and it is always free:

- Join the support site and download software, current manuals, and ask questions in our user forum. http://support.asylumresearch.com. Note that all Asylum scientists are forum members and frequent contributors.
- Contact us at https://afm.oxinst.com/Support-US.
- Call your local office or distributor.
- Call us at +1-805-696-6466. During US west coast business hours you will get a human being to speak with. After hours you still have a good chance of catching one of our scientists. Within the US you can call our toll free number if you wish (1-888-472-2795).
- If necessary we can initiate a remote session and have one of our scientists operate your AFM over the internet.

Updates to the Manual Bundled with the software updates.

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 your commenting on.

Part I

System Overview & Powering Up

Who is this part for? After the Cypher SPM has been installed in your lab and you (or someone in your facility) have completed the initial training, this part of the user guide will review the main parts of the instrument and software. Instrument power up is also covered.

Part Contents

1. Safety Precautions

CHAPTER REV. 2105, DATED 09/11/2019, 17:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

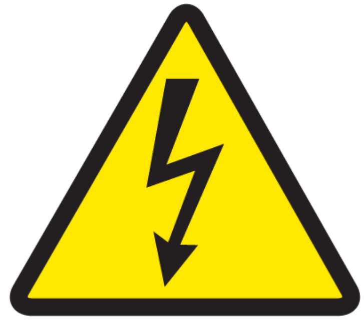
Chapter Contents

During normal use, the Cypher 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 Cypher.

1.1. Safety Label Explanations

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.	

Description	Warning Label
High Voltage: Voltages of up to 165VDC can be present on these connectors. Always turn off the ARC2 controller power (See Figure 3.2 on page 22) before connector or disconnecting cables.	
Laser Product: The Cypher AFM is a Class 1 laser product, posing no danger to the user and requiring no safety eyewear or laser training to operate.	

1.2. Motor Safety

The Cypher SPM contains six motors which direct the laser beam and move the objective lens and cantilever holder into position. All the motors are highly geared and can generate powerful torques that could seriously pinch a finger, possibly break a bone. The most important moving parts to be aware of, from a safety perspective, are the cantilever holder and the objective lens, along with its carriage. Always keep your hands clear of the Cypher when performing any software or manually controlled motor moves.

1.2.1. Avoiding unsafe situations

- Familiarize yourself with potential pinch points. Figure 1.1 on page 5 indicates the areas of concern: directly under the objective lens and cantilever holder, at the edges of the scanner module, and both above and below the two cross-roller bearing stages.
- It is advisable to always leave the optics cover in place. Removing it will expose additional areas where one could get pinched.
- Operate motors only with the enclosure door closed.

1.2.2. How to stop the motors

In case of an emergency, the motors can be stopped in one of the following ways:

- The motor control knob at the lower front of the Cypher can be used at any time to override computer commanded **objective lens** or **cantilever holder** motor moves. Turning the knob will immediately stop any current motor moves and will transfer control of both the cantilever holder and objective motion to the knob. Note that turning the knob always moves BOTH the cantilever holder and the objective lens simultaneously. *This means that if you were to have your finger pinched between the cantilever holder and the objective lens, the best way to release your finger would be to use the software to motor the objective lens upwards while leaving the cantilever holder stationary.*

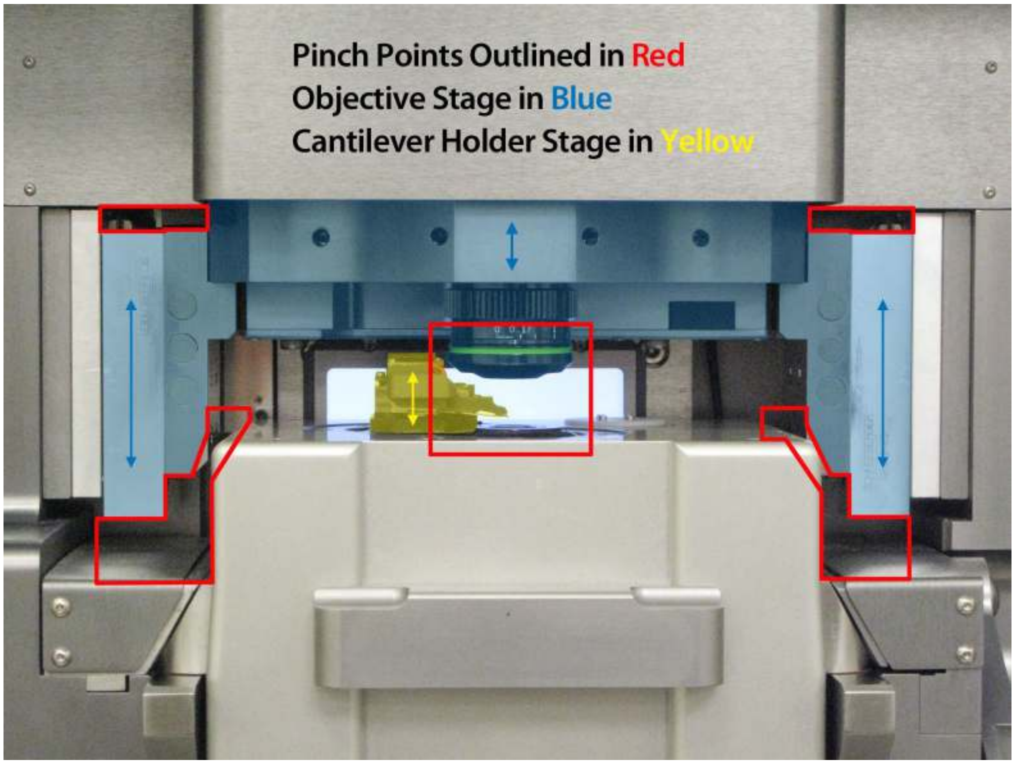


Figure 1.1.: Areas to avoid in particular when motors are driving the objective lens or cantilever holder. Tinted parts can move as shown by the arrows.

- Press and HOLD DOWN the 'Esc' on the PC keyboard. This will always stop any automated motor moves.
- Turn off the ARC2 controller. This is not advised since it will not allow you to use the knob or software to control the motors and manually move them to a safer position.
- Unplug the power brick, which is connected to the Cypher. This power brick supply feeds the motors. As was the case with turning off the controller, cutting power will stop the motors but will not give you any quick method for moving the motors to a safe position.
- If the power is cut and you must move the objective, you can reach inside the enclosure and feel for a wheel at the lower left hand side near the rear of the Cypher chassis. This wheel turns the motor manually. Ten turns are required for every millimeter of objective motion. Turn clockwise to move the objective DOWN and counter-clockwise to move the objective UP.

1.3. Light Source Safety

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

1.3.1. Non-visible Laser Diode or Super Luminescent Diode Light

The Cypher SPM contains a laser diode (LD) or super luminescent diode (SLD) light source. Superluminescent diodes are like lasers, but have a shorter coherence length. As of the writing of this manual all Cypher light sources have an output of several mW around 850 nm, which is non-visible. From a safety perspective LDs and SLDs can be regarded as identical and the terms will be used interchangeably.

The Cypher laser is sufficiently well shielded that the Cypher SPM qualifies as IEC Class 1 laser product that complies with 21 CFR 1040.10 and 1040.11, except for deviations pursuant to Laser Notice No. 50, dated June 2007. Complies with IEC/EN 60825-1, 2014-05 Ed. 3 and IEC/EN 60825-1:2007-03 Ed. 2.0.. In layman's terms this means the Cypher SPM 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 laser in the instrument and the safety features.

Figure 1.2.: A class 1 laser product (IEC 60825-1:2014-05 and EN60825-1:2007-03) is safe under all conditions of normal use.

1.3.2. The Detection Laser Optical Path

Understanding the laser optical path is the best way to reduce the possibility of harmful exposure to non-visible light, which may cause eye damage. Figure 1.3 on page 7 shows a simplified picture of the laser optical path. The light originates inside the removable laser module, then reflects via a mirror (called the "hot mirror" because it reflects infrared light while transmitting visible light) into the objective. The only place a person can be exposed to the light during normal operation is where the light exits the objective. As you will see in the next section, there are numerous interlocks to make the possibility of exposure very low. Still, here are a few things you should avoid:

- The IR light source is always on, regardless of whether the enclosure door is open or closed. In some cases the laser is turned off by software, or it can be turned off by rotating the key on the ARC2 controller.
- While unlikely, it is possible to place a small mirror below the objective and reflect the light in the direction of the user. Even then the beam spreads rapidly and is not powerful enough to classify the instrument differently. Nevertheless, you should be aware of the fact that non-visible light is coming out of the objective.
- Never remove the objective lens or you may void your warranty. It can also expose you to a collimated invisible laser beam.
- Never change or remove the laser module without first turning off the laser power key on the ARC2 controller. Never look directly into a plugged in laser module (Figure 1.4 on page 8).

1.3.3. blueDrive Laser Information

Cypher S and ES systems can be optionally equipped with blueDrive. All Cypher VRS models are equipped with blueDrive. See Chapter 34 on page 354 for more background information. BlueDrive employs a 405 nm blue Laser which follows the same path as the IR light source described in the previous section. Because of the intensity of the light, the blue laser can only be on when the enclosure door is closed.

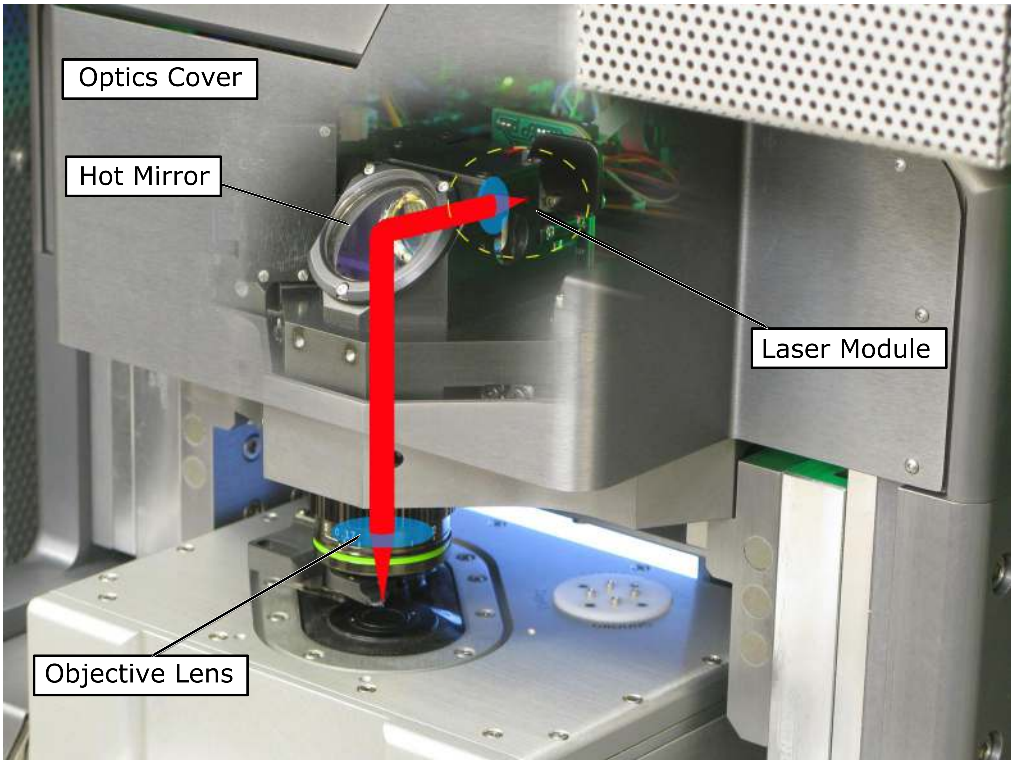


Figure 1.3.: Simplified laser path. Removing the optics cover exposes the hot mirror and laser module. The non-visible laser light originates in the laser module and comes out as a collimated beam. The collimated beam is reflected off of the hot mirror and into the objective lens, which focuses it onto the cantilever. During normal operation the only place a person can be exposed to the light is where the light exits the objective.

There is a blue LED on the front of the blueDrive filter cubes (see Figure 34.1 on page 354). This LED should only be illuminated when the enclosure door is closed. If you ever see this LED illuminated when the door is open, please contact customer service immediately and stop using the instrument.

While nearly all of the blue laser beam never leaves the vertical path in Figure 1.3 on page 7, there is small chance some fraction of light could be directed toward the AFM operator. To prevent this, the glass on the enclosure is yellow, blocking all 405nm light.

1.3.4. Laser Switches and interlocks

Cypher has various switches and interlocks which control the state of the lasers. Understanding their function is a important part of using Cypher safely. There are three interlocks which control the lasers on Cypher.

1. The door interlock, which turns off the blueDrive laser when the enclosure door is opened.
2. The blueDrive filter cube interlock, which turns off the blueDrive laser when the filter cubes are removed. Typically this has no effect since the door interlock will have already turned off the laser, but in cases where this interlock has been tampered with and overridden, the filter cube interlock offers extra protection.
3. The source module interlock. In case the user does not turn off the ARC2 power when exchanging source modules (see Chapter 33 on page 346), a magnetic interlock cuts power to the IR laser or SLD in the source module before it is fully removed from its cradle.

The text and figures below cover some scenarios where the various interlocks play a role.

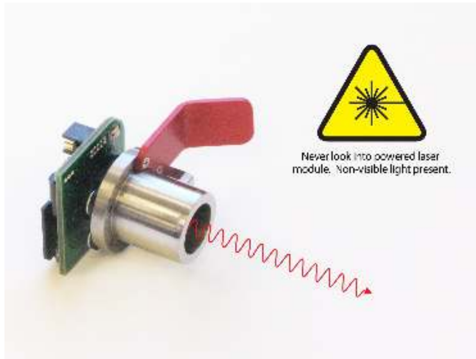


Figure 1.4.: Light source module removed from the Cypher AFM. During the removal process it is possible to tamper with safety overrides in such a way that collimated light shines out of the module. As a safety precaution, never look directly into the module while its power cable is attached (power cable not shown in this image).

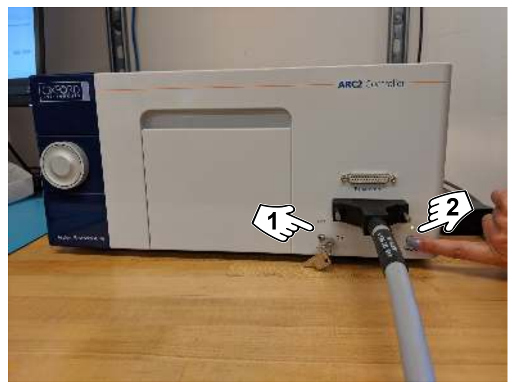
1.

Turning Lasers Off:

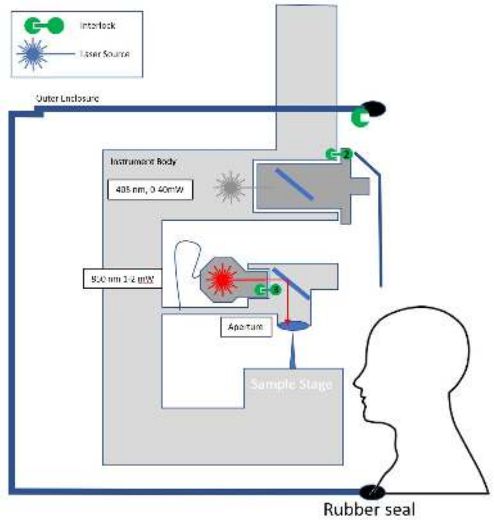
- If there is ever any reason to turn lasers off, do the following:

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..



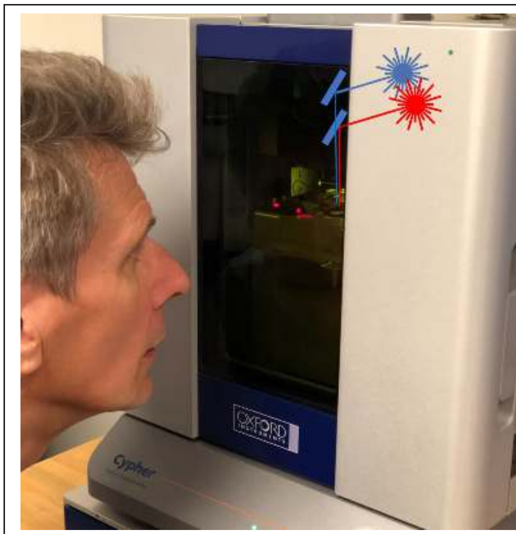
2.

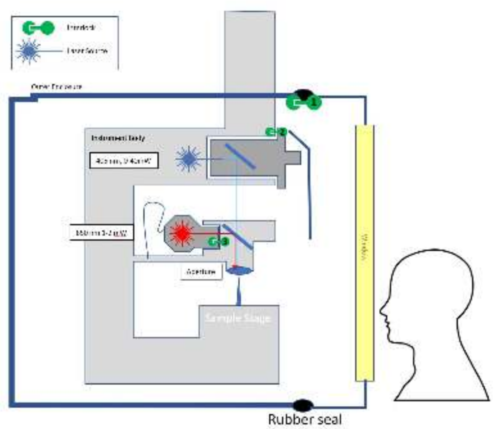


SAFE: Normal operation with the door open

- With the door open, interlock 1 turns off the blueDrive excitation laser.
- The IR detection laser is always on, but safe to view with the unprotected eye.
- Typically nearly all of the light travels down to the sample and immediately back up into the Cypher optics.

3.

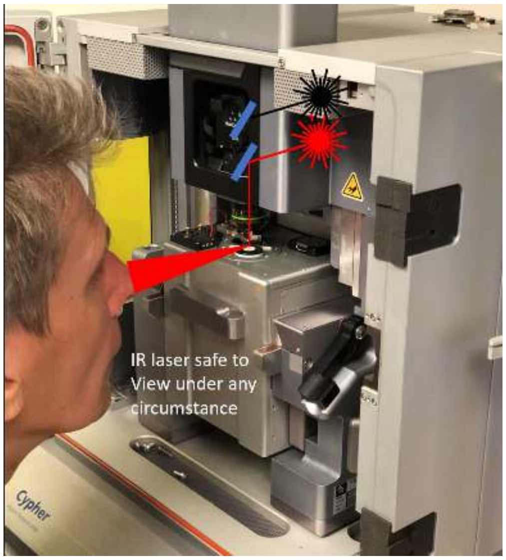


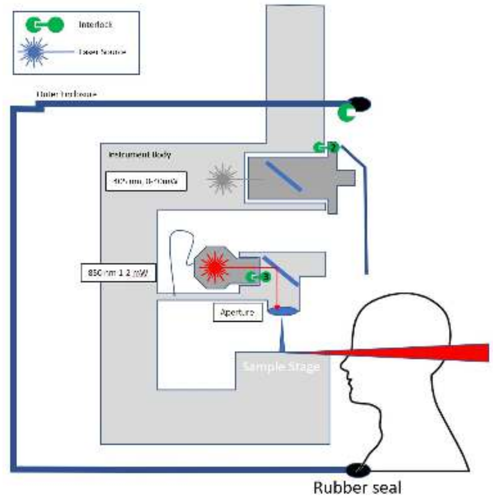


SAFE: Normal operation with the door closed

- With the door closed, interlock 1 allows the blueDrive laser to activate.
- Typically nearly all of the light travels down to the sample and immediately back up into the Cypher optics.
- Any additional blue light is absorbed by the yellow filter on the door.

4.

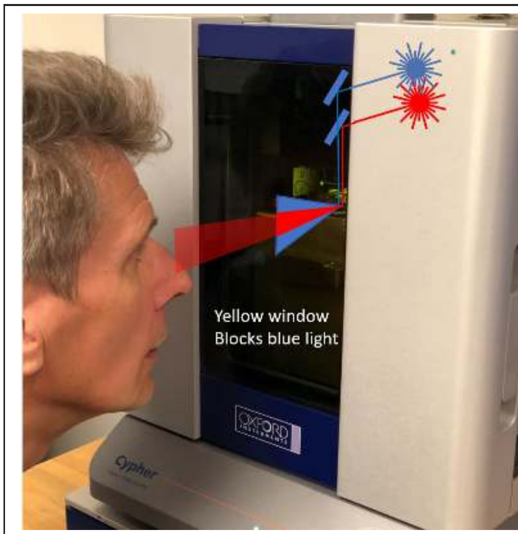


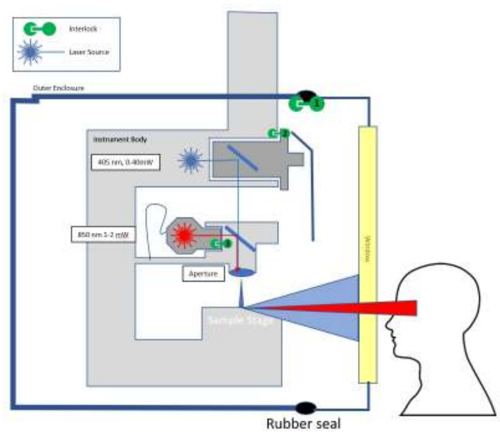


SAFE: Sample with reflective edge, door open

- With the door open, interlock 1 turns off the blueDrive excitation laser.
- In rare cases a sample might have a reflective beveled edge.
- The Cypher IR detection laser power is low enough to be safely viewed with unprotected eye, even in this worst case scenario.

5.

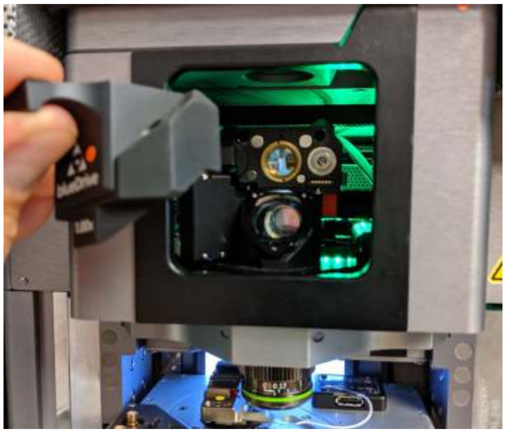


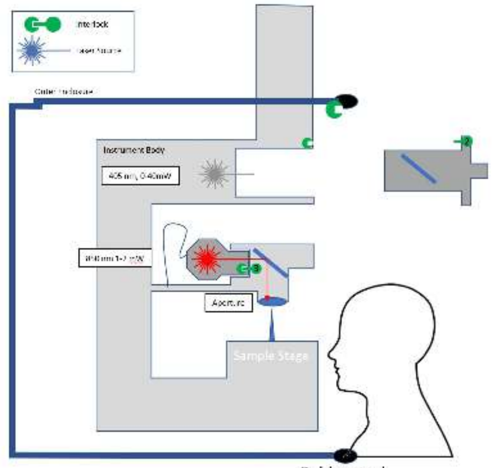


SAFE: Sample with reflective edge, door closed

- With the door closed, interlock 1 turns allows the blueDrive laser to activate.
- In rare cases a sample might have a reflective beveled edge.
- The Cypher IR detection laser is still safe to view.
- The Cypher blueDrive excitation laser light is fully blocked by the yellow filter on the window. It is safe to view the sample without protective eyewear.

6.

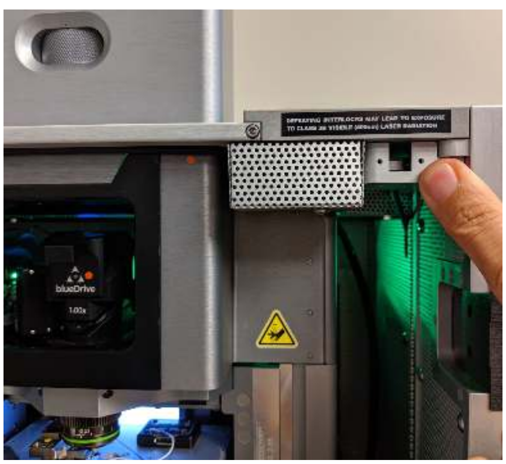


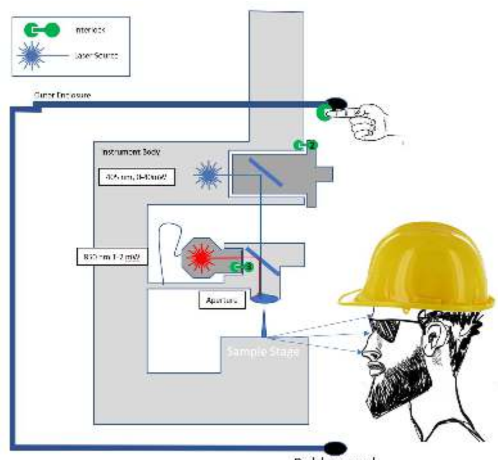


SAFE: Removing blueDrive filter cubes

- As soon as a blueDrive filter cube is removed, gold plated pins (Interlock 2) break contact with the cube. The blueDrive laser turns off.
- Since the cube is only accessibly when the door is open, Interlock 2 is only additional protection for Oxford Instruments service personnell who may override Interlock 1 during certain tests.
- In any case, it is safe to look into the lenses behind the filter cube.

7.

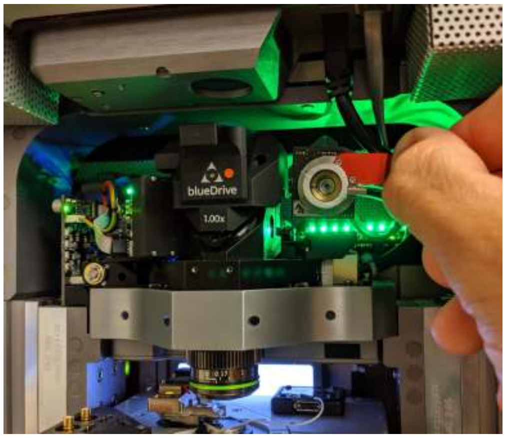


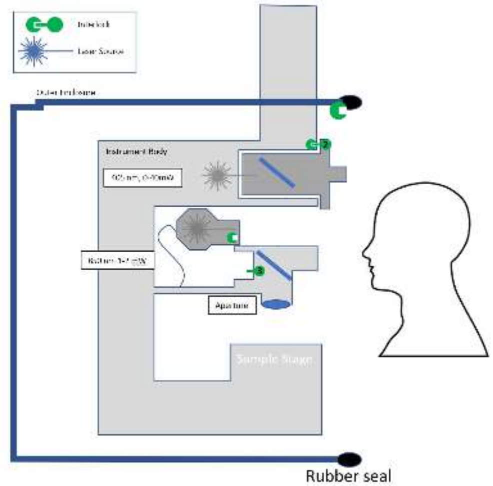


UNSAFE: Overriding the door interlock

- The door interlock switch should not be depressed.
- When depressed the blueDrive laser can be ON while the door is open.
- This may only be done by Oxford Instruments service personnel.
- You may be exposed to class 3B 405nm radiation, up to 20mW. This can lead to permanent eye damage.

8.





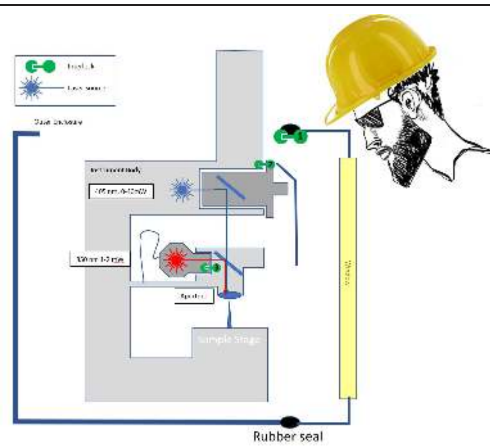
SAFE: Removing blueDrive filter cubes

- Removing the laser source module is described in Section 33.2 on page 348.
- This operation should only be performed with the system power turned off. In case this is forgotten, interlock 3 turns off the IR detection laser before it is removed from the cradle.
- It is safe to look into the lens of the source module. Note: there is also a red LED (Off in the photo above, as it should be) that indicates if the IR laser is on.
- NOTE: The photo has the system power turned on, just for demonstration purposes. The system power must be off when performing this procedure.

9.

UNSAFE: Disassembling the enclosure:

- Do not disassemble the enclosure. This is only intended for Oxford Instruments service personnel.
- The door interlock will not protect against removal of enclosure parts.
- There are no user maintainable components that can be accessed by tampering with the enclosure.



1.4. Power Supply Safety and Thermal Management

1.4.1. High Voltage

The voltages inside the Cypher SPM are as dangerous as those present in a standard wall socket; therefore, you should respect all of the components under the instrument covers as you would a wall socket. Never touch anything or insert anything conductive under the instrument covers. Also, the piezoelectric actuators in the scanner have a large capacitance and can hold charge for many minutes after the scanner is disconnected from any power supply. *For this reason never touch the scanner connector, unless it has been unplugged for at least 10 minutes.*

Warning	The Cypher SPM 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.

1.4.2. Fuses

Adhere to the fuse ratings appropriate to the main supply voltage listed on the back side of the ARC2 controller. Not following the recommended ratings may cause the instrument to overheat or sustain damage.

1.4.3. 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. 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. Don't place paper or notebooks on top of the backpack.

1.5. Instrument Specifications

1.5.1. Weight

The Cypher instrument is made of many heavy metal parts. Be prepared to have two people on hand whenever lifting of the empty enclosure is required. If you are thinking of lifting or moving the instrument (even a few inches) you MUST first contact Asylum Research or your instrument will be damaged and you will experience downtime and incur costs.

Note Even the scanner module is quite heavy. Be prepared to support its weight as you pull it from the support rails.

1.5.2. General Specifications

Cypher is a product of Asylum Research, an Oxford Instruments Company, which can be found at 6310 Hollister Ave, Goleta, CA 93111.

The Cypher SPM is designed to be run inside a laboratory setting. This means ideally the room is clean, quiet, and temperature and humidity regulated. Under no circumstances should a system be set up outdoors!

1.5.3. Voltage Ratings

The Cypher SPM will run on 100-240V but is factory configured to operate at only one voltage. Contact Asylum Research if you need to have your input voltage changed. , 50-60Hz, and a maximum of 400W. This information can be found on the back side of the ARC2 controller. See Chapter 3 on page 21.

User input and output connection ratings.

- For inputs on the ARC2 controller, see Chapter 3 on page 21.
- For inputs on the back of cypher (backpack) see Chapter 4 on page 26.

2. System Overview

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

2.1. Basic Cypher SPM Hardware

Before starting the tutorial, the user should be familiar with the names and functionality of each of the components of the Cypher. Don't worry if you don't understand everything in this section; the main goal is just to get familiar with the basic purpose of each component of Cypher. Figure 2.1 on page 14 shows a typical set-up for the Cypher SPM. The top-level components are the computer, the ARC2 controller, and the microscope itself.

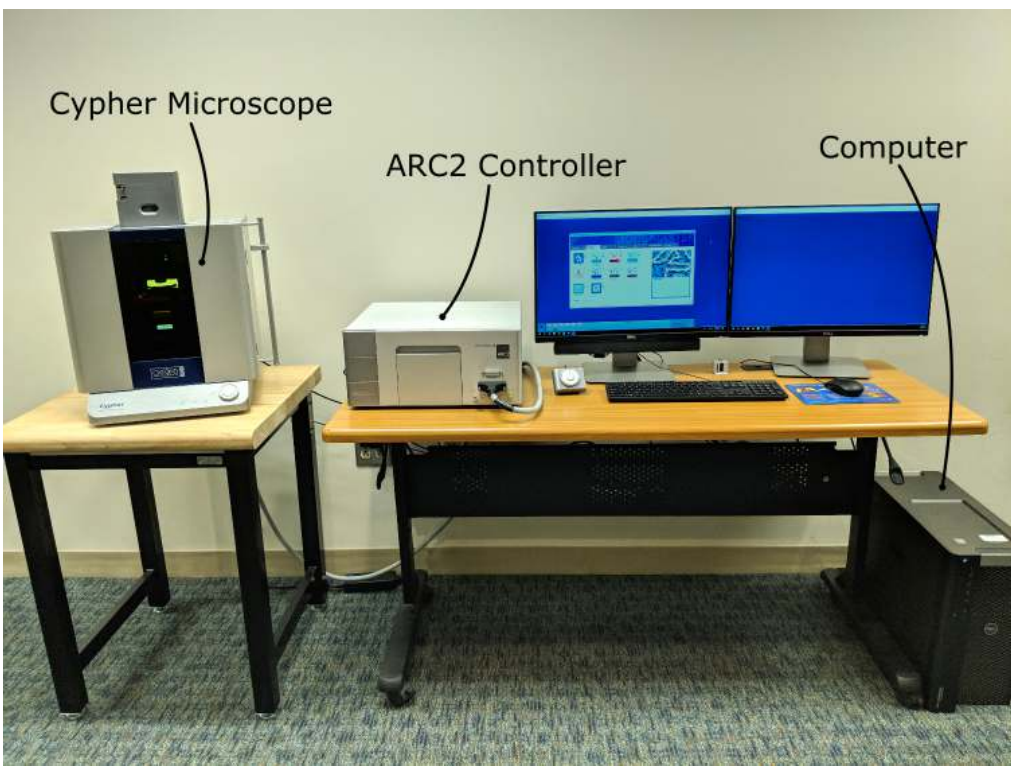


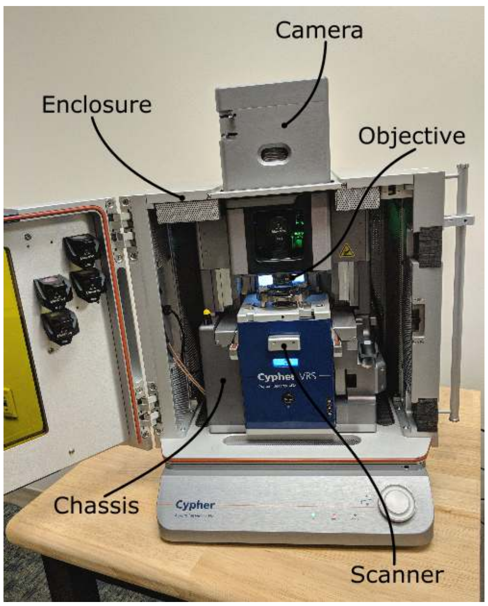
Figure 2.1.: Ideally the Cypher SPM is set up as shown, with the controller and computer on one table and the microscope on its own table. The air temperature controller (ATC) is not shown here. Please see Chapter 35 on page 366 for more information.

Computer The **Computer** is the primary interface for controlling the **Microscope**; its main communication is via a USB1.1 connection to the **ARC2** AND via USB 2.0 directly from the computer to the **Backpack**. See Section 38.2 on page 391 for recommended USB ports to use.

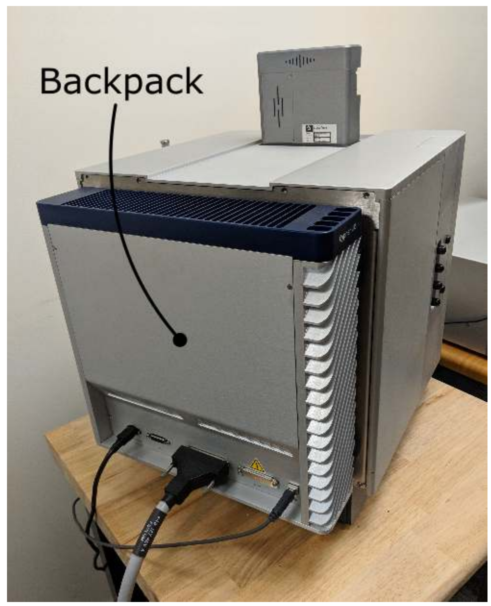
ARC2 The **ARC2 (Asylum Research Controller 2)** is what is colloquially referred to as "the controller". It houses power supplies and the necessary electronics for controlling the scan motion and acquiring image data from the microscope. To learn more about the **ARC2** and its functions, please refer to Chapter 3 on page 21.

Microscope The **Microscope** itself, where the actual imaging takes place, is the *core* of the AFM system. Although the computer, controller, and microscope all comprise the Cypher, the microscope itself will often be referred to as the Cypher.

The microscope is comprised of five basic components (see Figure 2.2 on page 15): enclosure, chassis, camera, scanner, and backpack. The enclosure and chassis are common to all versions of the Cypher. In contrast, the scanner, the backpack, and camera are designed to be modular and easily interchanged by the user.



(a) Front View. In this image the enclosure door is open and the scanner is partially pulled out.



(b) Rear View

Figure 2.2.: Cypher parts basic nomenclature

Enclosure The primary function of the **Enclosure** is to isolate the imaging portion of the microscope from acoustic noise such as talking or music. Acoustic noise can cause the mechanical components holding the sample to move, thereby showing up as noise in the microscope images. The secondary role of the **Enclosure** is to provide a local environment for the microscope itself, in which the temperature can be controlled. Keeping the microscope at a constant temperature is important for maintaining long-term control of the relative position between the cantilever and the sample. The air temperature controller (ATC) is a Cypher option that can be used to maintain the temperature inside the enclosure. To learn more about the **Enclosure** and its options, please refer to Part V on page 336.

Chassis The **Chassis** is the central structural unit supporting the scanner, camera, and head. While the scanner and camera are modular units designed to be interchanged by the user, the **Head** is just a sub-assembly of the chassis and is permanently attached to the **Chassis**. The **Head** is responsible for the detection of the cantilever deflection and has integrated motors that allow the user to automatically position the laser spot onto the cantilever. The **objective lens** attached to the head has two important functions: it focuses the laser light onto the cantilever and works with the **camera** to create an optical view of the sample. To learn more about the chassis and its options, please refer to Part V on page 336.

Camera The **camera** (also called the "**view module**") is a user changeable module that provides a top down optical view of the cantilever and sample. It is comprised of a tube lens, Koehler illumination with an LED source, and a digital camera. The camera module uses the objective lens in the head to create the optical view. The standard camera module has a bright field reflected light topology and has a 690µm by 920µm field of view with sub-micron resolution. Depending on the application, the view module can be swapped by the user in about 10 minutes, but requires Allen wrenches to complete.

Scanner The primary function of the **Scanner** is to move the sample relative to the cantilever during imaging and other measurements such as force curves. There are various scanner modules which excel at various tasks. The Cypher scanners are "sample scanners", which means that relative to the room that the microscope is sitting in, the cantilever is stationary and the sample moves. The scanner is a modular unit that can be interchanged by the user depending on the application. The scanner modules are based on a flexure design that uses piezoelectric stacks to move the sample up to 30µm in XY and 5µm in Z. The secondary function of the scanner is to provide motorized course positioning of the cantilever relative to the sample in the Z-axis. The **cantilever holder** is a component of the scanner that physically holds the cantilever during imaging. There are different cantilever holders for air and liquid operations, and there are also application specific holders for techniques like scanning tunneling microscopy (STM), see Chapter 12 on page 117. Each scanner type has its own family of cantilever holders and other accessories. The available scanner modules are:

- The Standard scanner, described in Part II on page 35.
- The Environmental scanner, described Part III on page 160.
- The Video-Rate scanner, described Part IV on page 298

Backpack The **Backpack** is located on the rearside of the **Enclosure**. It houses a very powerful set of digital and analog electronics that greatly extend the functionality of the **ARC2** controller. Just like the **ARC2**, the **Backpack** has ADCs, DACs, BNC connections, and a CrossPoint switch. To learn more about the **Backpack** and its functions, please refer to Chapter 4 on page 26. .

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

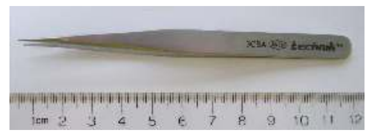
A In a typical AFM design, most of the electronics housed in the Backpack would be located in the Controller. The Backpack, however, moves these electronics closer to the microscope; Cypher is able to achieve such low noise levels in part because of the proximity between some of its electronics and the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

Q AFM or SPM? What is the difference?

A AFM stands for Atomic Force Microscope. It scans a cantilever over a sample to generate an image. SPM stands for Scanning Probe Microscope. It is the more general, all encompassing term, which also includes techniques that image using non-cantilever probes such as sharp metal needles (Scanning Tunneling Microscopy), optical fibers (NSOM) or tiny hollow glass tubes (SICM). Since Cypher is capable of both AFM and STM, it is classified as an SPM. You may see Cypher referred to in the context of an AFM when its AFM-like functions are being described.

2.2. Parts List

The contents of the accessory kit which accompanies Cypher. Asylum Inventory Number 900.110.1. These parts accompany the AFM irrespective of the type of scanners you purchased.

Itm	Part #	Item Description	Qty	Picture
1	080.122	15mm AFM Specimen Disc. Also available from Ted Pella, part number 16218.	50	
2	290.101	2A Tweezer, SA Tapered Round Blunt, Standard Grade.	1	
3	290.102	7Tweezer, SA Curves Sharp, Standard Grade.	2	
4	290.103	3A Tweezer, Extra Fine Sharp, Standard Grade.	1	
5	290.139	Hex Driver, 1/16” Small Handle.	2	
6	312.003	Renishaw Encoder Readhead Spacer (0.8mm).	1	
7	803. OLY. AC 55 TS	Olympus Cantilevers, Model AC 55 TS.	5	
8	803. OLY. BL- AC 40 TS	Olympus Biolevers (Mini): Model BL - AC40TS.	10	
9	804. NW. ARROW - UHF AUD	Nanoworld Cantilevers, Model: ARROW UHFAuD	5	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
10	900.237	AR calibration Grating - Steel Puck Mounted.	1	
11	1-72 x 3/16” SHCS SS	1-72 x 3/16” screw, spares. Fastens the cantilever holder onto the standard scanner (Step 6 on page 42) and also fits the cantilever holder changing stations.	5	
The scale in the photos is in cm and mm.				

2.3. The Igor Pro Software Environment

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 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.

Refer to the screen shot in Figure 2.3 on page 19 as we introduce the various controls and data displays. We’ll go clockwise from the upper left. (Note that if you are viewing this file on a computer, you can zoom in on the screen shot for further scrutiny.)

Master Panel Upper left hand window (Ctrl + 5). It has five tabs with controls and data displays for:

- **Image** AFM imaging, see Chapter 7 on page 40.
- **Thermal** Cantilever thermal spectroscopy.
- **Force** Cantilever force versus distance curves.
- **Tune** Cantilever vibrational tuning, see Section 7.3.2 on page 55.
- **Fmap** Maps of force versus 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.

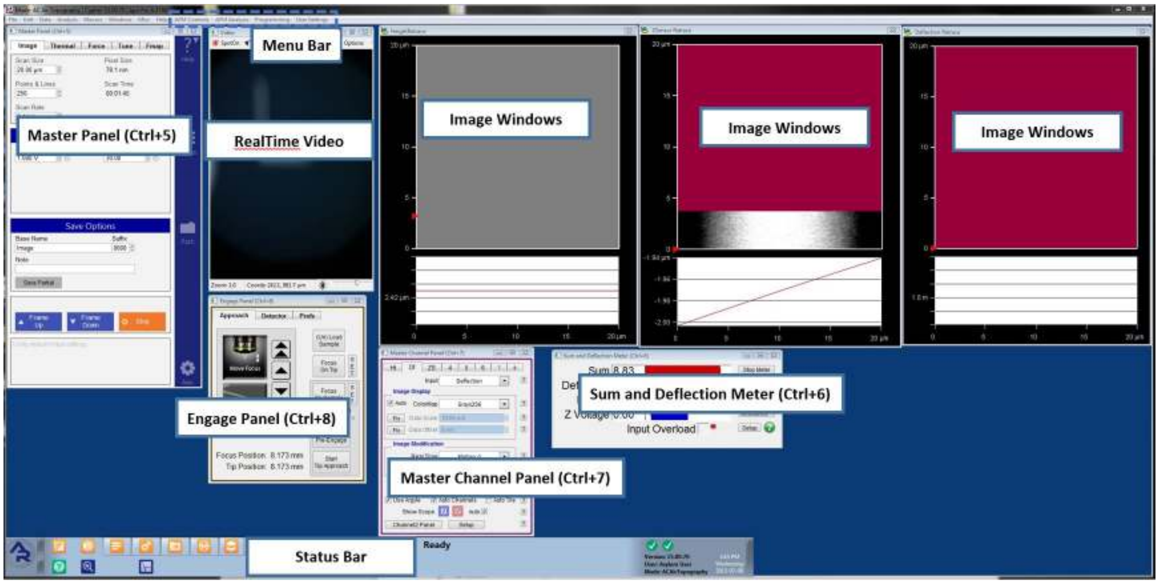


Figure 2.3.: Typical start-up screen for the Asylum Research SPM Software. A few image panels have been cut off in this figure. Usually they are found across the second monitor of your system.

Igor Command Window (Ctrl + J) Not shown. The Igor Command window has two parts: the history and the command line. On occasion items executed by clicking software buttons will generate output and print it to the history. It is not a bad idea to keep tabs on what is being printed into the history, especially if you are tracking down software bugs. Advanced users will use the command line to directly execute a variety of tasks. If you followed the Igor tutorial recommended in the Tip on page 18 you will know how to use the command line. The Igor Command Window always has the name of your current experiment, which you can also see at the top of the border of the software window.

Sum and Deflection Meter (Ctrl + 6) This is a real time display of various channels such as cantilever sum and deflection, piezo voltage, amplitude, and phase.

Engage Panel (Ctrl + 8) This panel controls the entire process of the cantilever approach to the sample. Its three tabs control:

Approach Motorized approach of cantilever and microscope objective toward the sample.

Detector Centering of reflected light beam (laser or SLD) onto the optical detector.

Prefs Preferences for the engage process such as approach speed and approach step size.

Real Time Image Display This is an example of an image window, in this case displaying the individual lines of the sample topography as the cantilever moves left to right over the sample. There is usually one such window per active tab in the 'Master Channel Panel' (Lower left hand window). The amplitude and phase data windows are to the right of this clipped screen shot. While this panel is primarily a data display, right clicking with the mouse can activate various commands such as 'Zoom' and 'Translate'. The white area at the bottom of this window shows a real time oscilloscope view of the most recent line of image data.

Scope Graph This oscilloscope view shows a graph of the most current scan line. Both trace and retrace can be selected on the 'Master Channel Panel'.

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* in the top menu bar.

A few other things of note are:

Menu Bar Along the top of the screen. There are many more controls which can be invoked by items in the menu bar. Menu items to the left are typically standard Igor Pro items, with some Asylum Research functionality. Items to the right of "help" are exclusively SPM related. In particular, the *AFM Controls* menu item is a complete list of all real time controls and the *AFM Analysis* menu item is a complete list of all offline controls.

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. E-mail

We won't dwell on the purpose of all these controls but will proceed with the general process of imaging a sample. This will necessarily cover the most pertinent software controls.

Tip	Note that nearly each individual item in the software control panels has a small question mark button next to it. Click the button to read the relevant parts of the software help file.

3. ARC2 SPM Controller

CHAPTER REV. 1970, DATED 10/06/2017, 17:13. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

Figure 3.1.: The ARC2 Controller with Hamster extended and BNC connector hatch open.

3.1. Parts List

The following lists all 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		Laser Relay Plug	1	
2		Laser Relay Key	1	
The scale in the photos is in cm and mm.				

Figure 3.2.: Front view of the ACR2

3.2. Connectors

Back (see 3.3):

- AC line input (100-240V depending on factory configuration, 50-60 HZ, 400W max)
- AC output (150W) connected to the external power supply for the backpack controller.
- USB 1.1 to be connected to the computer
- and a laser interlock jack (contact asylum support on its use)

Front:

- a large connection to the SPM
- and a smaller DB25 expansion connection for various Asylum Research accessories such as the digital interface modules discussed below.

3.3. user input / output connections

Various BNC connectors are located behind the door on the front of the ARC controller. See Figure 3.1 on page 21.

The front of the ARC2 controller is equipped with 15 BNC connections (all various analog functions, rated +/-10V), a 3.5mm audio jack,

3.4. Fuses

The controller is protected by a number of fuses on the main input power feed. If your system is not working properly after a power surge or a 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 with a like rated part. All fuses are "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 screw driver or the edge of a coin to rotate the slot on the inside of the voltage selector 1/4 turn counter clockwise. 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.

For newer models of ARC2 controller the voltage selectors are no longer present (voltage is set at the factory, but can still be changed by a field service technician) and fuse holders are clearly marked on the back of the controller.

Figure 3.3.: Back view of the ARC2

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3.5. System Diagram

3.6. Low Level Signal Access

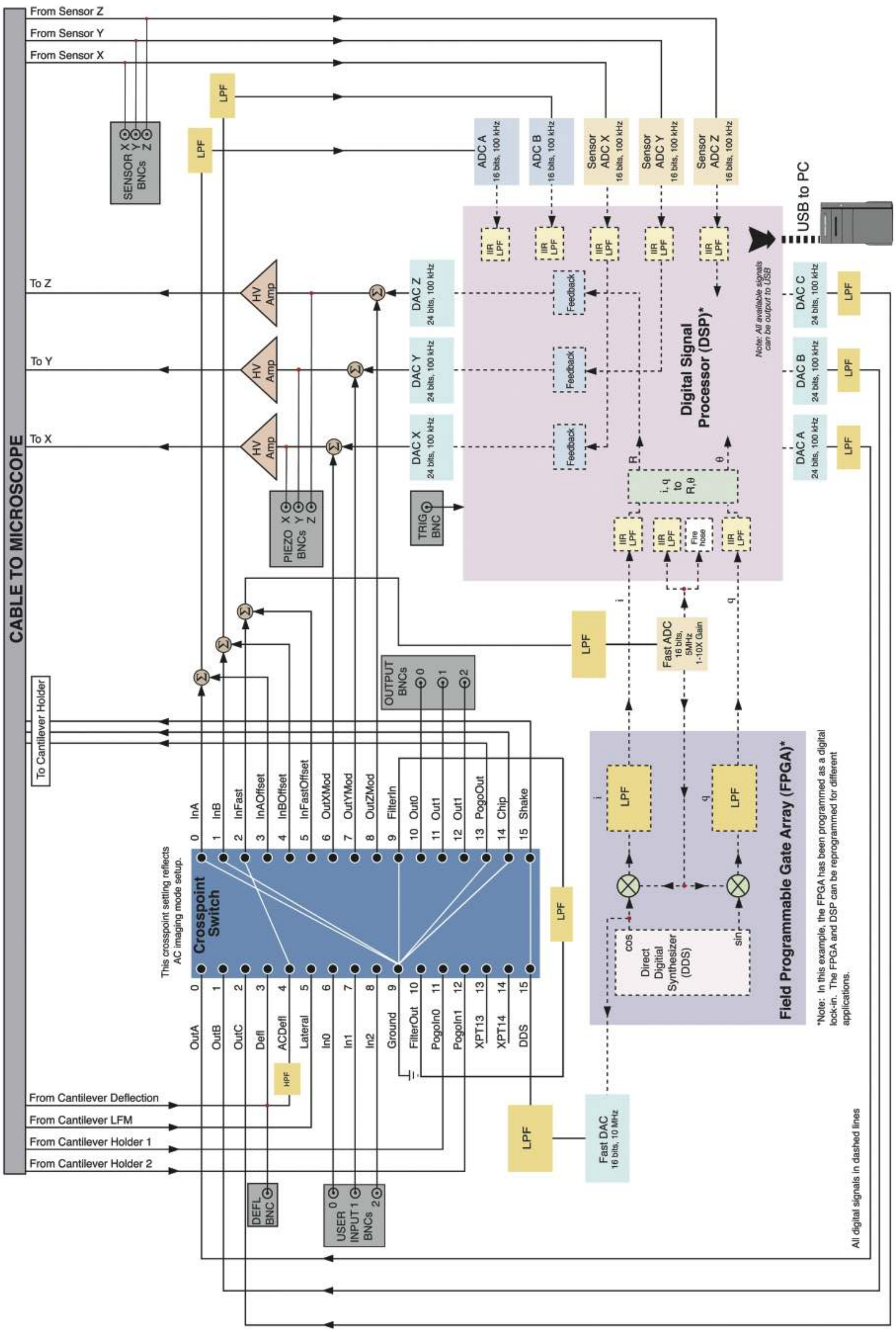


Figure 3.4.: System Diagram including the ARC2 CrossPoint Switch.

(a) Digital Access Module.

(b) Extended Digital Interface Module.

Figure 3.5.: Options which allow access to low level ARCs signals.

4. Backpack SPM Controller

CHAPTER REV. 1970, DATED 10/06/2017, 17:13.   USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

Figure 4.1.: A Front view of the Backpack Controller.

Figure 4.2.: Side view of Backpack Controller showing BNC connections.

4.1. Input and Output connections and ratings

4.1.1. User IO

There are three sets of BNC user input/output connections on the Backpack (see : Figure 4.2 on page 27)

Attention	Power down the system before connecting or disconnecting BNC cables to prevent unexpected system behavior.

- 5 Analog Input (rated +/-10V),
- 5 Analog Output (rated +/-10V)
- 5 Digital I/O (rated 0-5V)
- One headphone jack for use with standard audio headphones during system troubleshooting.

4.1.2. Rear backpack connections

Power down the system before connecting or disconnecting cables to prevent system damage and electrical shock hazards.

- Large cable to the ARC2 controller,
- Computer USB 2.0,
- motor power (included with system), the other end of which may plug into an AC wall outlet, or the AC output on the ARC2 controller.
- Cypher Air Temperature Controller (optional),
- Expansion port (intended for approved Asylum Research accessories only). Note this port has high voltage (165VDC) behind it and should only be removed by trained service personnel.

4.2. System Diagram

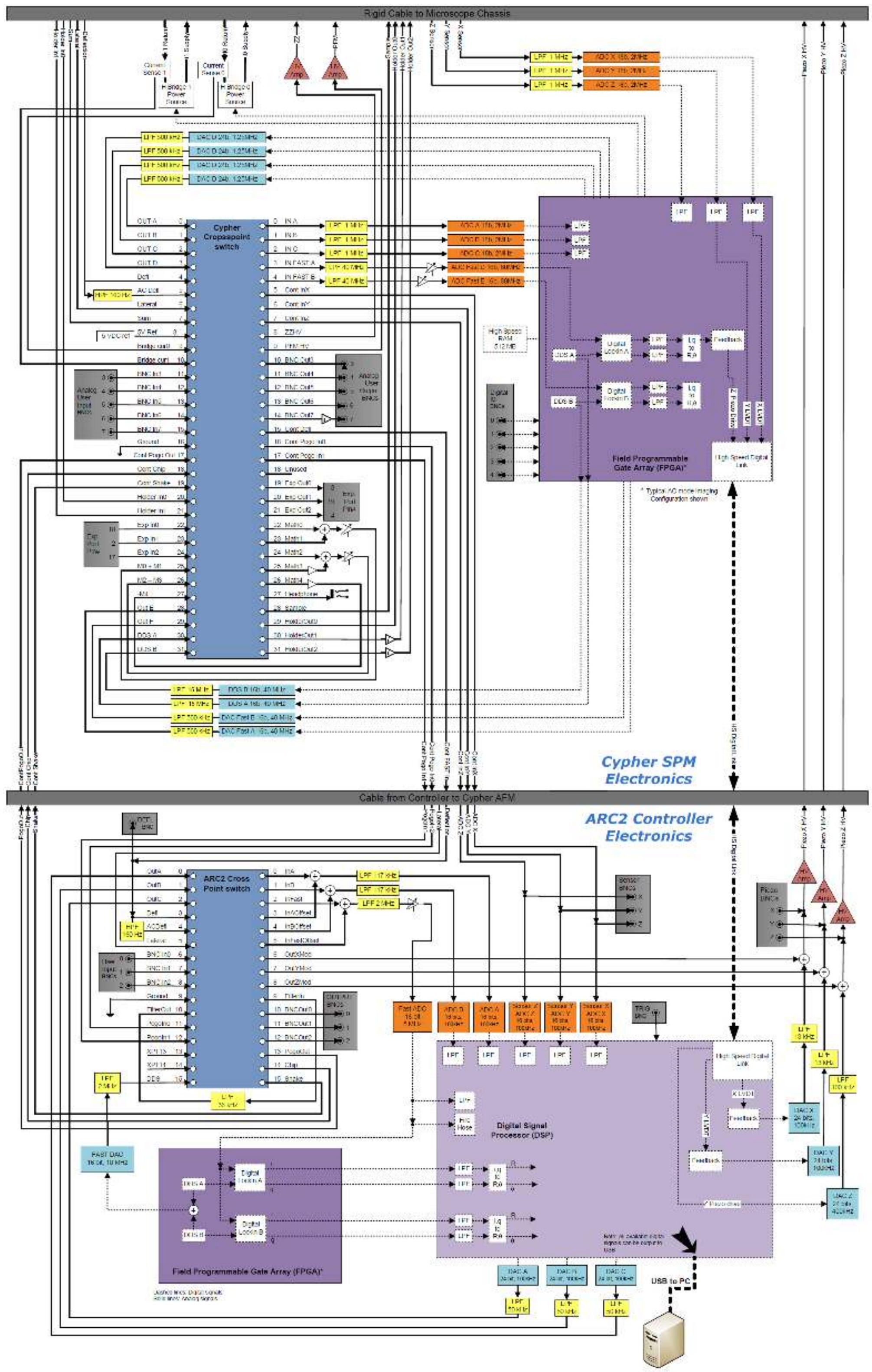


Figure 4.3.: System Diagram including the ARC2 CrossPoint Switch.

4.3. 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.

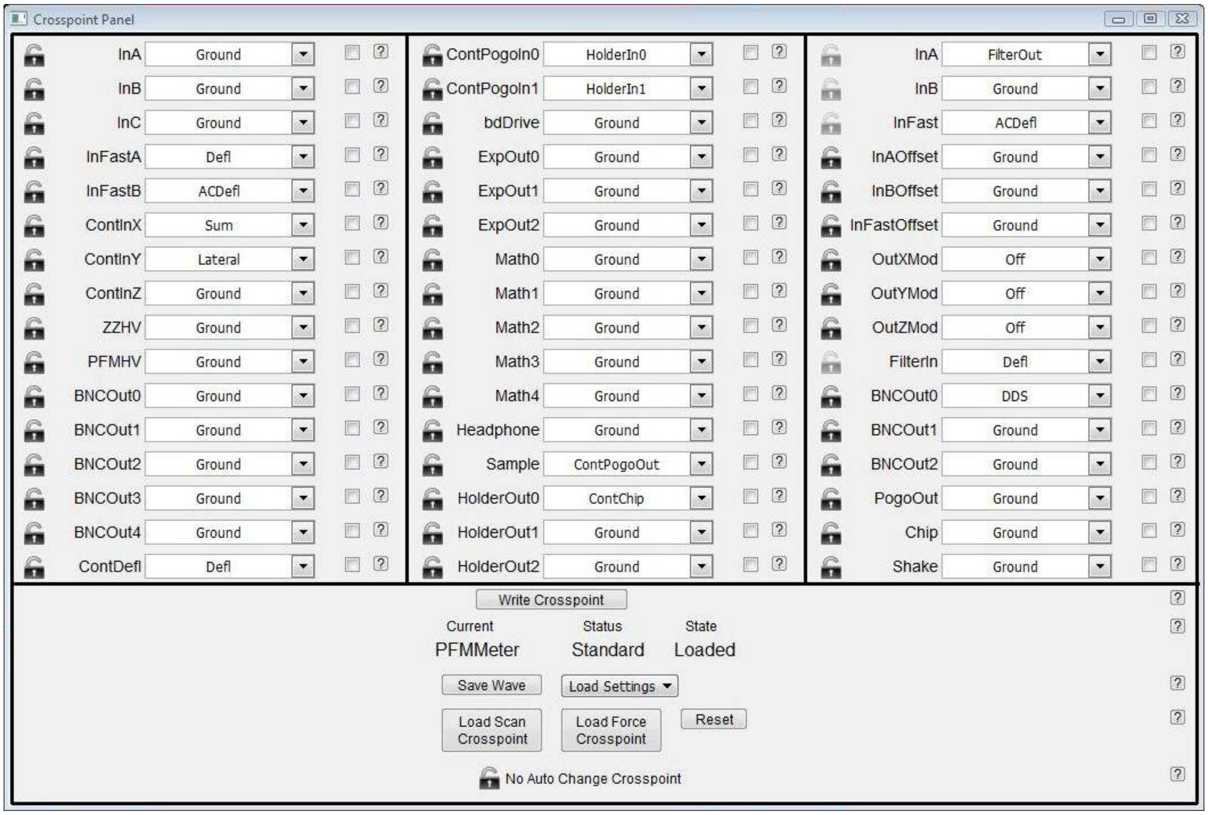


Figure 4.4.: Backpack & ARC2 CrossPoint set up for standard PFM mode.

4.3.1. Decoding the CrossPoint

The CrossPoint and signal routing in general can become a bit more complicated on 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 ampltifiers 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 top of the Cypher Scanner 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 & 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 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).

5. System Power Up

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Before you start the following tutorials, the system must be properly powered up. This section will walk you through the process.

Before you start:

- We assume you understand all aspects of running the Cypher safely: (Chapter 1 on page 3)

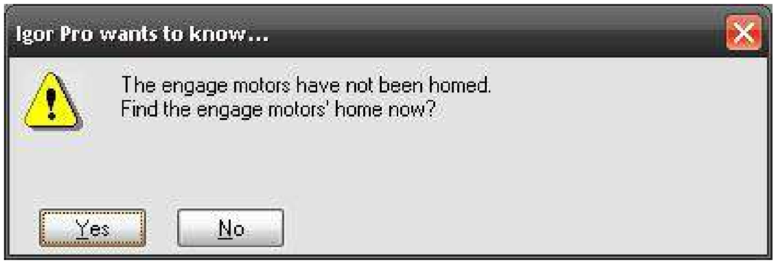
1. **Power up:.**
   In no particular order:
   - Boot up the computer.
   - Turn on the Cypher SPM by depressing the power switch on the front of the ARC2 controller.

   If everything is working correctly two different green LEDs will be illuminated. The first LED is located above the power switch on the ARC2 and the second LED (labeled "power") is located at the front of the Cypher enclosure.

2. Double check that the laser key on the ARC2 controller is in the ON position. The red LED labeled "laser" at the front of the Cypher enclosure should be illuminated.
3. Locate the shortcut to the software on the desktop, and double click the icon to start the software.
4. Now take a deep breath and count to ten while the software initializes.

Warning	Make sure your fingers are clear from any pinch points before homing the motors (See Figure 1.1 on page 5). You can abort the homing process at any time by pressing and holding down the 'Esc' key located at the top left corner of the keyboard. If you abort the homing process before it is finished, you will not be able operate the motors.

5.



- Once the software has finished initializing, you will get a prompt asking if you would like to home the engage motors.
- If necessary, slide the scanner all the way into the chassis. Close the microscope enclosure door. For safety reasons the motors cannot home unless the door remains closed during the process.
- Click 'Yes'. You will hear motors moving during the homing process, which will take about 20 seconds.

6. If you are new to the Cypher AFM system, please take the tutorial which is appropriate for your scanner:

- For the standard scanner see: Chapter 7 on page 40.
- For the Environmental Scanner see: Chapter 17 on page 178.

Part II

Standard Scanner (S)

Who is this part for? After the Cypher S SPM has been installed in your lab and you (or someone in your facility) have completed the initial training, this part of the user guide will be the principal reference for operating the instrument. Although written with the novice user in mind, experienced SPM users should complete the basic imaging tutorial at least once before attempting to use this instrument.

Part Contents

6. Standard Scanner Overview

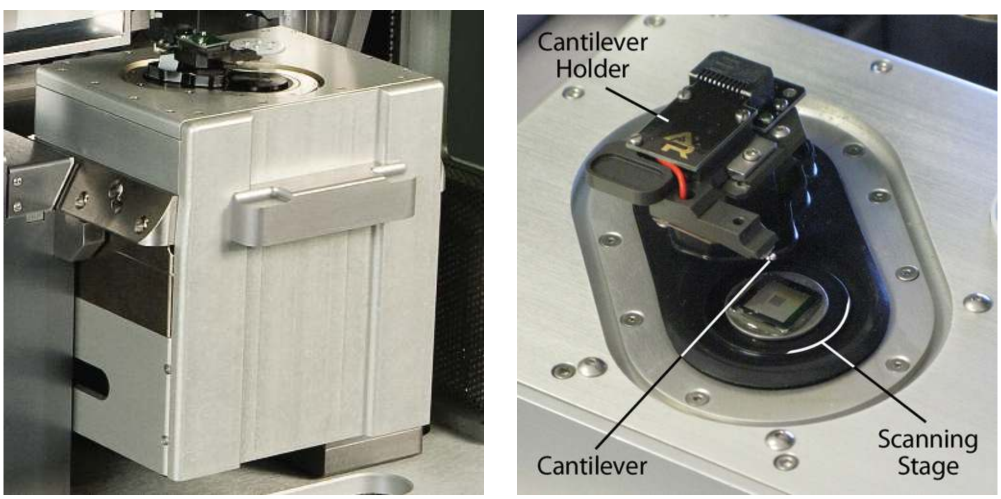
CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

The module dubbed "the scanner" contains the entire mechanics of the AFM except for the optical means for detecting cantilever deflection. This includes:

- Actuators and sensors for closed loop XY scanning of the sample.
- An actuator and sensor for the sample Z motion.
- A cantilever holder and mechanical means for engaging the cantilever with the sample surface.

Since Cypher's scanners are whole AFMs unto themselves, each comes with its own dedicated collection accessories such as cantilever holders and sample stages. In other words, a cantilever holder for one scanner usually does not fit onto a different scanner. Also, an expert user of one model of scanner will not necessarily know anything about operating another model.

This part of the user guide describes in many chapters the use of the Standard Scanner and its many accessories. Once the scanner is exchanged for another, as described in Chapter 31 on page 338, a different part of the user guide will need to be consulted. Typically the first user of a new scanner will need to be trained by Asylum Research personnel.



(a) Standard Scanner. **(b)** Names of the basic components.

Figure 6.1.: The Standard Scanner

Figure 6.1 on page 38 shows the standard scanner partially withdrawn from the rest of the AFM. The standard scanner is included with the "Cypher S" AFM, but can also be purchased separately. The Standard scanner is designed primarily for imaging in ambient conditions, either in air or in a liquid droplet. The optical access to the sample and cantilever is superior to other cypher scanner models.

Many Standard Scanner cantilever holders allow for a variety of imaging modes. See Chapter 8 on page 69 for more information.

The Scanner itself comes in regular and high voltage models. Figure 6.2 on page 39 shows the magnetic high voltage contact and specialized cantilever holder with high voltage connection to the tip. This arrangement is typically use for PFM techniques. This topic is covered in depth in *Applications Guide, Chapter: PFM Using DART* and *Applications Guide, Chapter: Single Frequency PFM*.

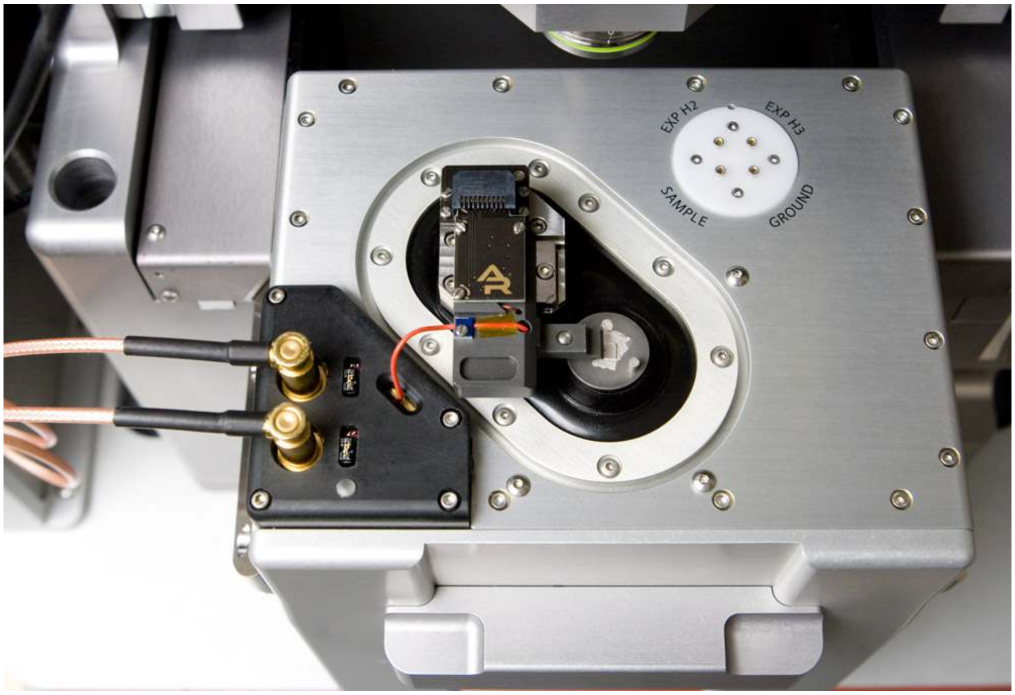


Figure 6.2.: Detailed view of the high voltage option.

7. Tutorial: AC Mode Imaging in Air with the Standard Scanner

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

This tutorial provides a quick path to learning the basic operation of the Cypher SPM equipped with the Standard Scanner. If you own the Environmental Scanner, please follow the tutorial in Chapter 17 on page 178. The tutorial contains 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.

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

The Cypher 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 3 hours.

Before you start:

- You should understand the aspects of running this system safely: (Chapter 1 on page 3.)
- You should be familiar with the basic names of the hardware components and software controls (Chapter 2 on page 14.)
- You should have powered up the Cypher and launched the software: (Chapter 5 on page 33.)

7.1. 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, providing advice.

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

1. Cantilevers: You will need an AC160TS cantilever, which is manufactured by Olympus. The AC160TS, with a spring constant of ~42N/m and a resonance frequency of ~300kHz, is a workhorse for AC mode imaging in air. Every Cypher ships with a package of AC160s, but 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 Asylum Research calibration grating that ships with every system (Asylum Part# 290.237).
3. Tweezers: It is preferable to use tweezers with curved tips (for example, Asylum Part# 290.102).
4. Wrench: A 1/16” ball head wrench (for example, Asylum Part# 290.139) is required.
5. SPM: This tutorial is designed for a Cypher equipped with the Standard Scanner and a large spot SLD or Laser Module (See Chapter 33 on page 346).

7.2. Loading the Cantilever and Sample

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

1.

Raise the cantilever holder:

- Rotate the ‘Engage Control Knob’ on the Cypher *clockwise* and hold it until the cantilever holder is far from the sample or is at its upper limit of travel.

Note Although it is not required, for safety reasons we recommend making motor moves with the door closed. Beware of pinch points (Figure 1.1 on page 5).

2.

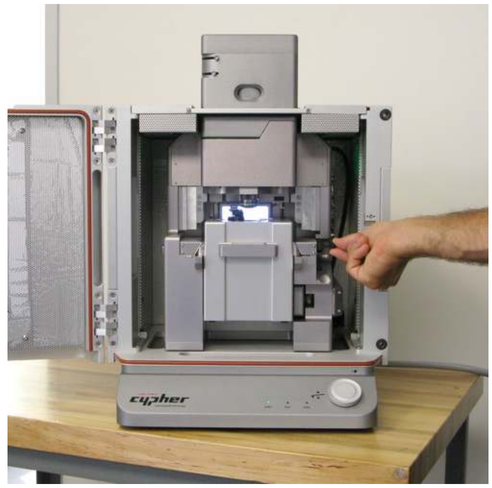
Open enclosure:

- Lift the door latch and open the enclosure door.

3.

Unlock scanner:

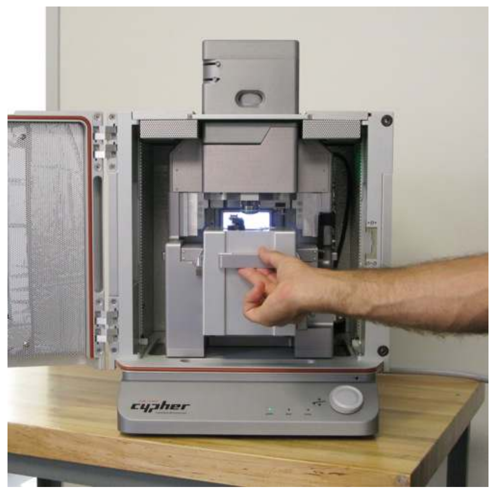
- Lift the lever to the right of the scanner.



4.

Pull the scanner out:

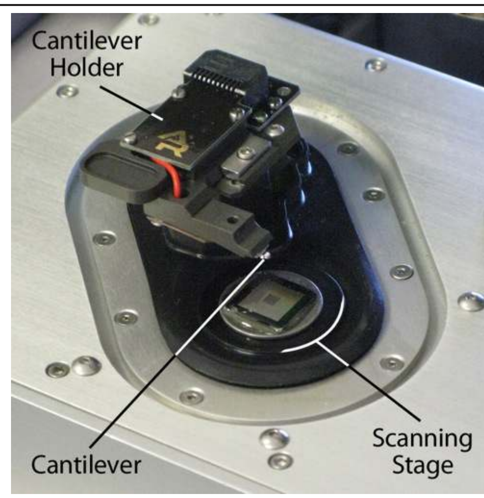
- Pull the scanner forward gently and stop when it is about halfway out. If you continue pulling the scanner, at some point you will feel resistance and should pull no further.



5.

Familiarize yourself with the sample area:

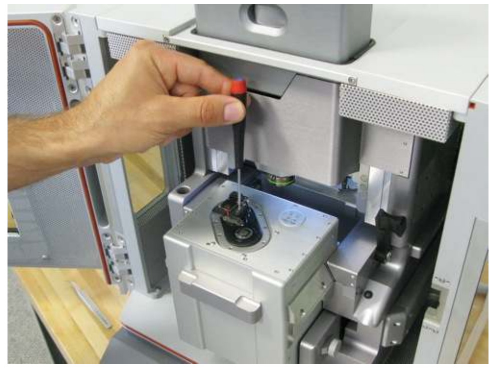
- While it may look solid, the scanner stage moves the sample in the X, Y, and Z directions imperceptibly up to 40μm.

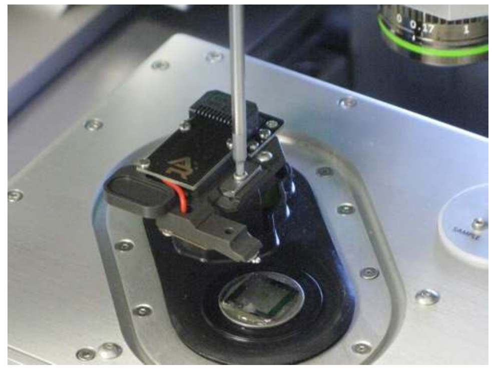


6.

Release the cantilever holder:

- Loosen the screw clamping the cantilever holder. One turn *counterclockwise* should be enough.
- Replace the tool in its storage place (hole in the chassis to the left of the scanner).





7.

Remove the cantilever holder:

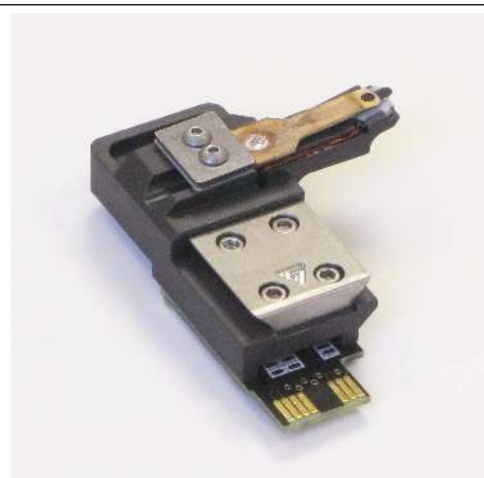
- Hold by the tab with the circular recess and pull straight out towards you.

8.

Select AC mode cantilever holder:

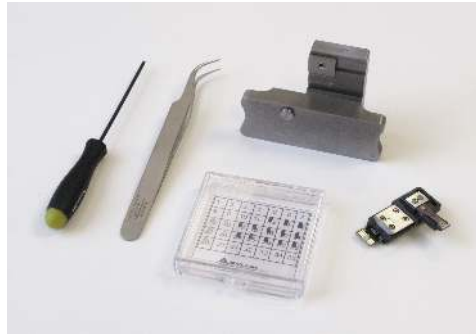
- Identify the cantilever holder. This demo requires the standard "AC Air" holder, Asylum Part# 901.705.

Note To learn more about cantilever holders for the standard scanner, please refer to Chapter 8 on page 69.



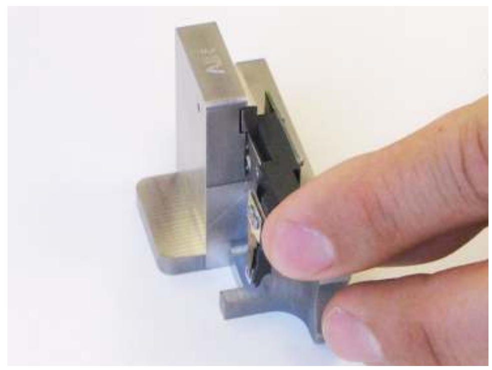
9. **Prepare cantilever mounting workspace:**

- Set out your changing station, tweezers, and cantilevers on a clean, well lighted surface. Make sure that the changing station is labeled “Air” (there is also a “Droplet” changing station for the droplet holder.)
- A low power binocular dissection stereoscope with light source can be useful for some of the following steps.
- Cleaning the tweezer tips with alcohol improves the handling of the cantilevers.



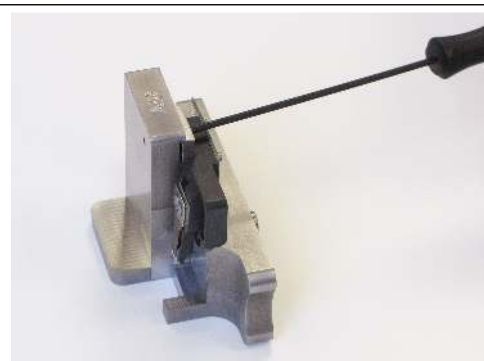
10. **Mount the cantilever holder in the changing station:**

- Carefully insert the cantilever holder as shown. The V-shaped piece of metal on the back of the holder slides into the dovetail joint on the changing station. The cantilever should be pointing down.
- If the cantilever holder does not slide in easily, loosen the screw on the clamping mechanism.



11. **Tighten the clamp:**

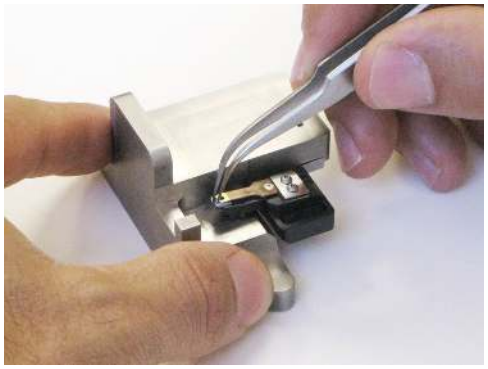
- Once the cantilever holder is fully inserted, use the ball head wrench to gently tighten the clamp.



12.

Remove the old cantilever:

- Position the changing station as shown, on a flat hard surface.
- Take the tweezers in your dominant hand.
- Press down on the station, as shown, with your other hand. This depresses a button on the bottom of the station which drives a pin up under the cantilever retaining clip.
- Remove the cantilever and release pressure on the station.
- Inspect the cantilever area for tiny silicon grit and blow clean with compressed air if necessary.



13.

Select new cantilever:

- Select a new cantilever and pick it up with tweezers.
- Close the box! Ruining $1k of levers by putting your hand on an open box is not unheard of.

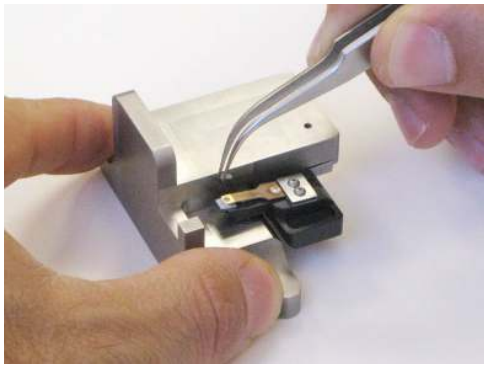
Note If your lab saves some old cantilevers, consider practicing with a “dummy” cantilever.

Tip Some find it useful to first lay the chip down on a non-sticky surface and re-grip it before continuing.

14.

Load new cantilever:

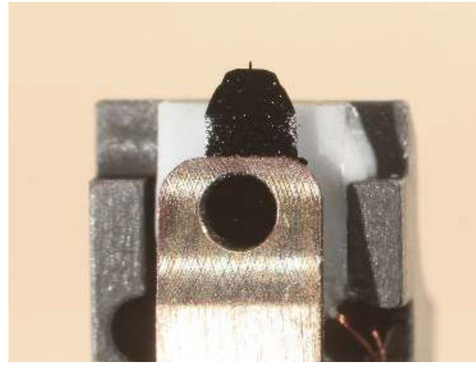
- Place and center the cantilever in the holder (also see photo in next step for alignment).
- A good technique is to release pressure on the changing station while still gripping the cantilever chip with tweezers. This prevents misalignment caused by the cantilever chip sticking to the tweezers.



15.

Check cantilever alignment:

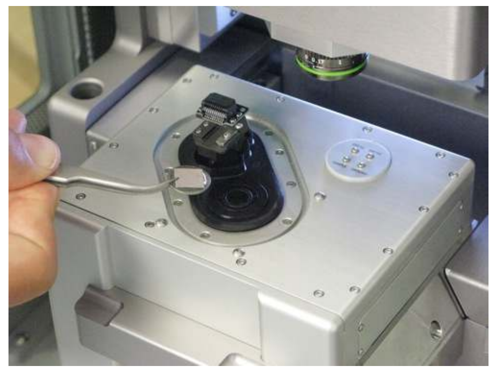
- A properly aligned cantilever seen from above.
- It helps to do this at least once under a binocular stereo microscope.



16.

Prepare scanner and load sample:

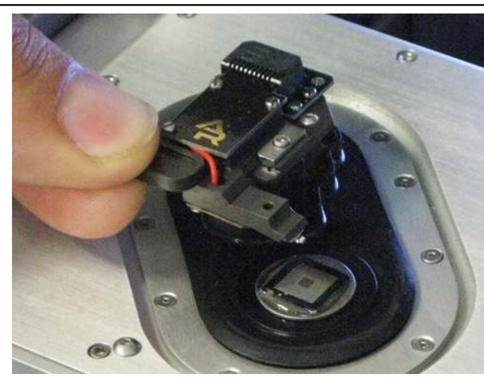
- Leave the cantilever holder in the changing station for now.
- Remove any sample that may be present on the scanner.
- Wipe the scanner stage (defined in Step 5 on page 42) clean with a soft cloth. Any dust or grit will prevent the sample disk from being properly seated.
- Place the Asylum Research calibration grating onto the scanner stage. It will attach magnetically.



17.

Insert cantilever holder into scanner:

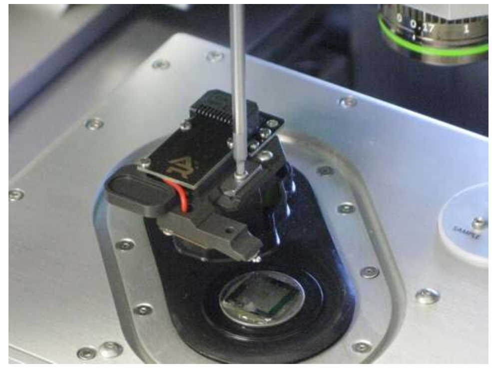
- Remove the cantilever holder from the changing station.
- Insert the cantilever holder into the scanner. Pay attention that the metal dovetail engages properly.
- If it will not go in, loosen the screw by half a turn (see Step 6 on page 42).

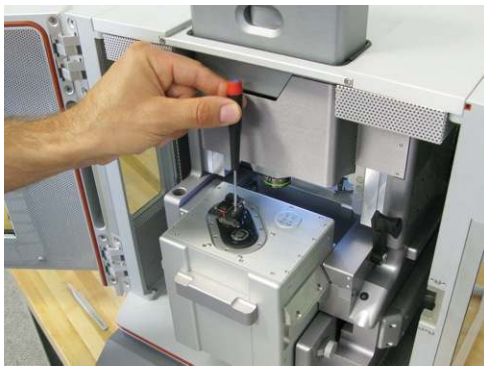


18.

Tighten cantilever holder:

- Use the ball headed wrench to *gently tighten* the screw that clamps the cantilever holder.
- Don’t use your whole hand! Be gentle!

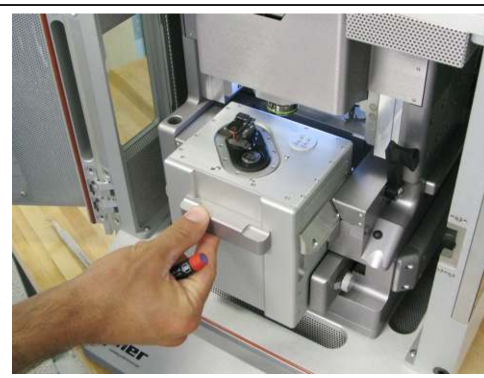




19.

Slide scanner into chassis, lock down:

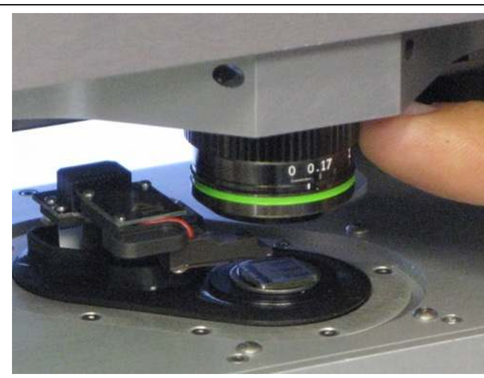
- Gently slide the scanner back into the chassis.
- Push the lever at the right of the scanner downward to secure the scanner in place.



20.

Check correction collar:

- Check that the green correction collar on the objective is set to zero (this cantilever holder has no glass window through which the light must focus).

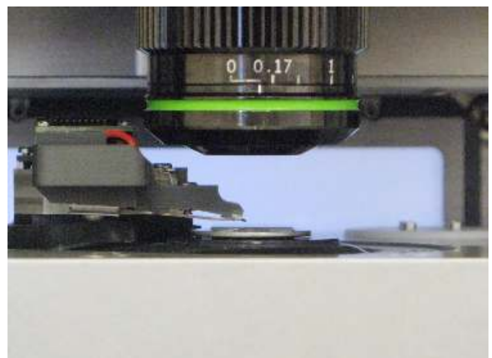


21. **Close enclosure door:**

- *Gently* close the door and latch it.

22. **Motor cantilever toward sample:**

- Place your eyes level with the cantilever and sample, so you can clearly see the gap between cantilever and sample.
- Slowly turn the 'Engage Control Knob' on the AFM enclosure *counterclockwise*. This will lower the cantilever holder and objective toward the sample. The more you turn, the faster it goes.
- Close the gap between tip and sample to about 1 millimeter. There is no harm in playing it safe and stopping a little farther away. It will 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 *SERIOUS* damage to your cantilever holder and scanner.

23. This concludes the manual interaction with Cypher. We next turn our attention to the computer.

7.3. Engaging the Cantilever on the Sample

7.3.1. Bringing the Cantilever Close to the Sample

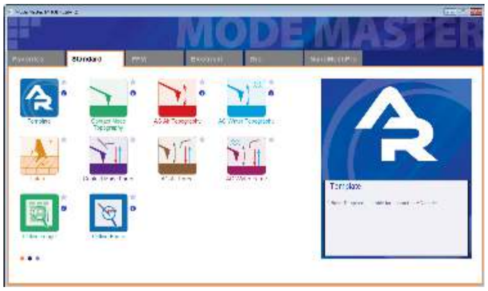
Before you start this section you should have done the following:

- Start up the software (Chapter 5 on page 33).
- Homed the motors (See Step 5 on page 33).
- Positioned the cantilever about 1mm above the sample (Section 7.2 on page 41).

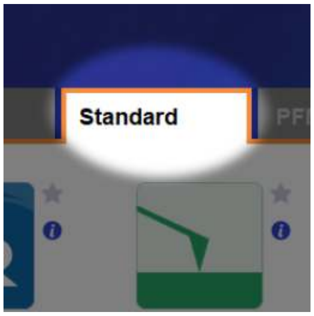
1.

The Mode Master window:

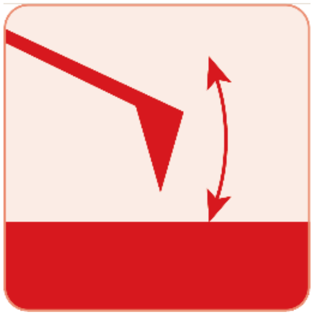
- The software should now be showing the Mode Master window.
- If not, click the Mode Master button at the bottom of the screen: .



2.



▷



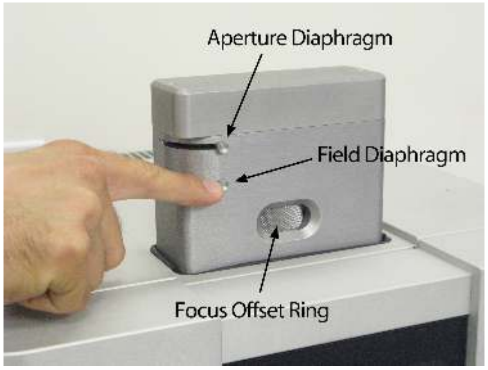
Select Mode:

- Select *Standard tab* ▷ *AC Air Topography*
- The screen will now re-arrange and present all the controls necessary for this type of AFM imaging.

3.

Prepare the view module:

- Turn the **focus offset ring** until the white dot is centered on the alignment mark. There will be a gentle click when this occurs.
- Fully open the **field and aperture diaphragms** by pushing both levers toward the front as shown.



4.

Open video window (If necessary):

- In the software, click on the camera icon on the bottom status bar.
- This will open the video window (or highlight it in case it was already open), which displays an optical view of the cantilever and sample.

Setting video zoom and illumination:

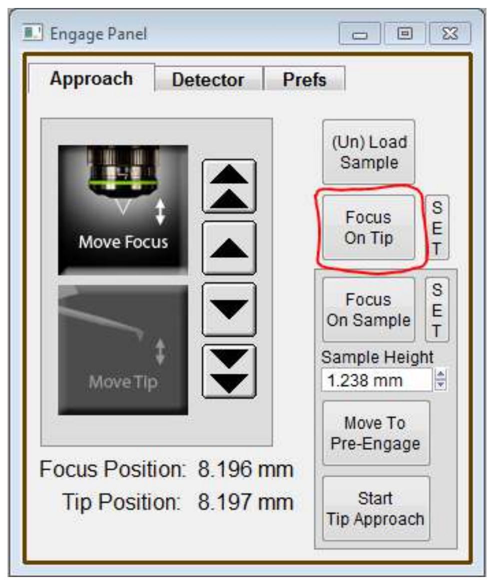
5.

- IMPORTANT: Slide the vertical slider at the lower left corner of the video window all the way to the bottom. “Zoom 1.0” will be indicated just below.
- Turn up the illumination by moving the slider (on the bottom of the video window) to the right a quarter or third of its full range.

6. Familiarize yourself with the Approach tab on the Engage Panel as described next in Step 7 on page 50. *Failure to understand the Approach controls may lead to serious damage to the Cypher*.

Go to last known Tip Focus:

- On the Engage panel, hit ‘Focus on Tip’. This will move the objective lens to the last known position where the cantilever was in focus.



Notes

7.

- 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 will most likely 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.)
- Don’t be alarmed if the cantilever is not visible at all. It most likely means that when you placed the cantilever chip in the holder, you put it in a place outside the ~1mm field of view of the objective. This will get 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.

8. **Locate cantilever in image:**

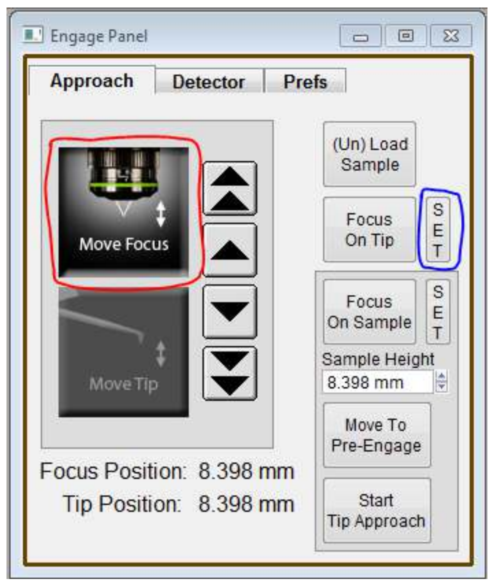
- The goal of this step is just to get the cantilever into the field of view. Use the four arrows at the top left of the video window to look for the edge of the cantilever chip and/or the cantilever. As mentioned in the previous step, most likely the cantilever will not be perfectly in focus.
- If you are oriented such that you are sitting directly in front of the Cypher microscope, hitting the left arrow will move the objective to your left, while hitting the top arrow will move the objective away from you.
- *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.* Hit the *left arrow* to move the objective towards the left and look for the cantilever chip edge.

See Figure 7.1 on page 56 for example images.

9. **Set the tip focus position:**

- Under the ‘Approach’ tab on the ‘Engage Panel’ select the ‘Move Focus’ (on the left, red) large picture button.
- Use the on screen arrow buttons until cantilever is in focus. Single arrows are slow; double arrows are fast.
- Click ‘Set’ next to ‘Focus on Tip’ button (on the right, blue).

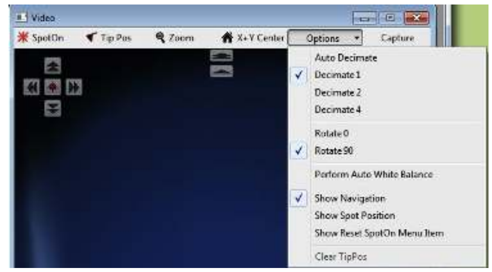
Important The cantilever is at an 11º angle and the whole lever cannot be in focus at once. Bring the end of the cantilever closest to the tip in focus.



10.

Optional image enhancement and zoom, particularly useful for small cantilevers:

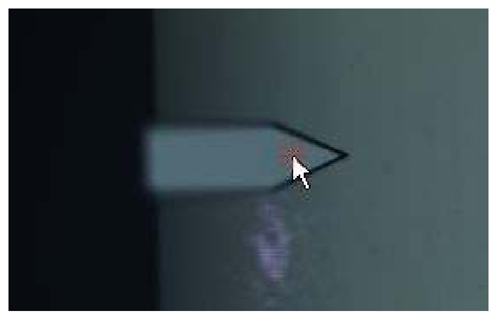
- If you want to see the image with more resolution, select *Decimate 1* from the *Options* pull-down menu. This brings all the pixels down from the video camera but will slow the screen update rate.
- To the left of the *Options* menu is a 'Zoom' button. This button, once clicked, will change the cursor into a magnifying glass. Click on the cantilever to get an enlarged view.
- Both of these 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.



11.

Center laser spot on cantilever:

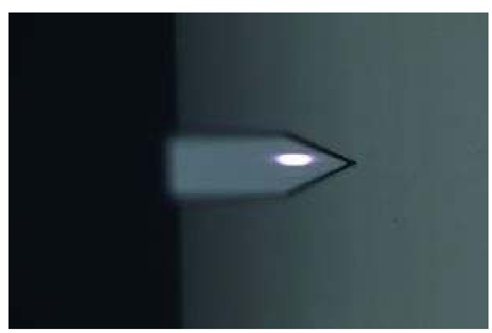
- Click on the 'Spot On' button at the top left of the video window. The mouse pointer will acquire some small red lines.
- Now click on the center of the cantilever (see figure to right).
- Alternately, right-click on the center of the cantilever and then select the 'Spot On' option.



12.

Observe spot on lever:

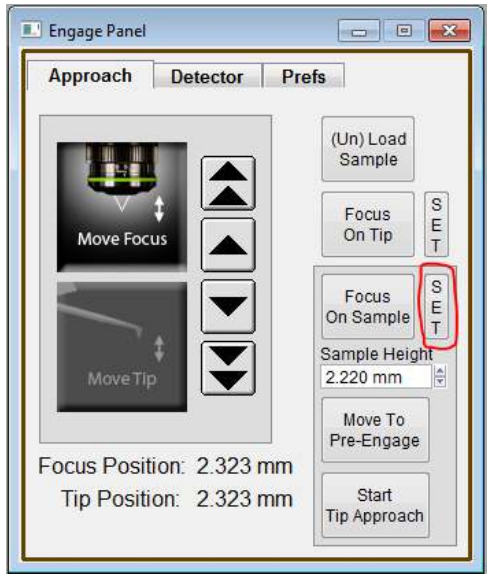
- Motors inside Cypher will now move to bring the laser spot where you clicked.
- The spot position does not need to be perfect here, only roughly centered on the cantilever to produce a decent reflected beam (measured by the Sum signal in the Sum and Deflection Panel).
- If needed, the spot position will be fine tuned in a later step.



13.

Locate sample surface optically:

- Under the 'Approach' tab on the 'Engage Panel' use the downward arrow keys to motor the microscope objective down toward the sample, until it comes in focus (See Image in the next step). Use the up arrows if you overshoot.
- Single arrows are slow, double arrows fast.
- Once in focus, hit the 'Set' button next to the 'Focus on Sample' button. Note that the sample height value updates.

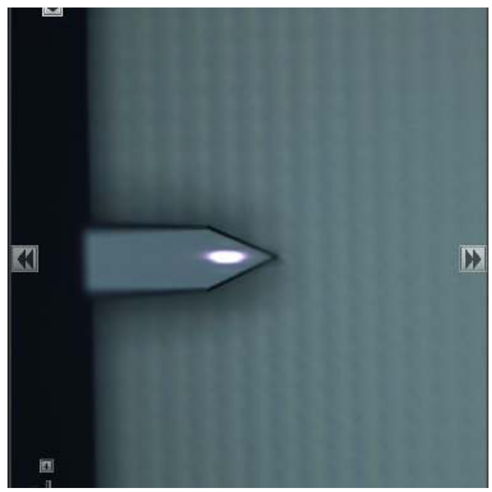


14.

Observe sample surface optically:

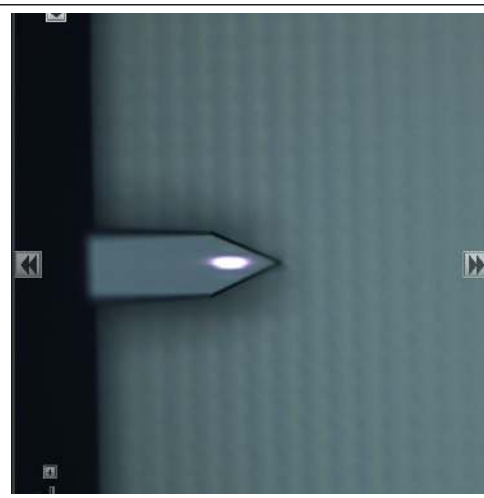
- Features may be hard to see at zoom = 1 and auto decimation turned on. For instance, in the image to the right decimation = 1 and zoom = 2. See Step 10 on page 51 for more information.

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



Question I cannot seem to focus on the surface of my rough sample.

Answer The objective can only motor down a few millimeters before it meets up with the cantilever. If you did not manually move the cantilever close enough you will never get a focused image (such as the one on the right) of the sample. In this case hit the "Focus on Tip" button in the engage panel and repeat Step 22 on page 48.



Question I cannot seem to focus on the surface of my smooth sample.

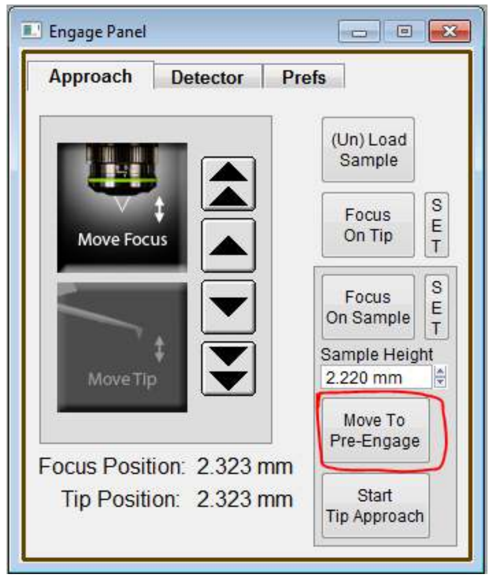
Answer Perfectly reflecting samples may not offer enough features to allow the focus to be determined. In this case move the Field Diaphragm lever (marked with an F) on the view system until you see a dark circle on the screen. As you motor down this circle will become sharper. When the ring is in focus, as in the image to the right, so is the sample.

15.

Prepare to land the tip:

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

WARNING: 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. This prevents the cantilever holder from ramming the sample.

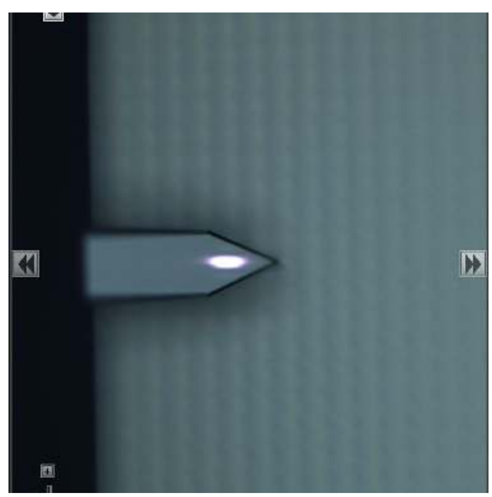


16.

Fine tune spot position:

- At this point you should adjust the spot position so that it is near the end of the cantilever using the controls in the upper left hand corner of the video panel. Note that a decrease in Sum Signal indicates that light is spilling off the cantilever. The latter is undesirable and should be avoided.

HINT For fine positioning hold down the 'SHIFT' key on your keyboard while clicking the onscreen buttons which move the cantilever under the laser spot (See Step 8 on page 50).



17.

Center the laser on the photo detector:

- Hit the red button at the center of the video window motion controls and watch the Deflection Signal go to zero. This action causes small motors to steer the laser beam to the optimum position on Cypher's photo detector.

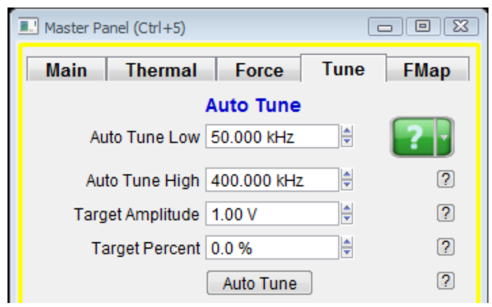
7.3.2. Tuning the Cantilever and Setting Scan Parameters

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

1.

Initiate cantilever tune:

- Select the tune tab in the master panel.
- Set the four auto tune parameters (Low, High, Amplitude, Percent) as shown to the right.
- Click the 'Auto Tune' button.

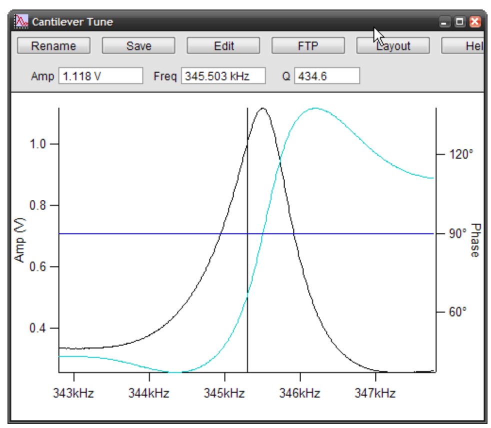


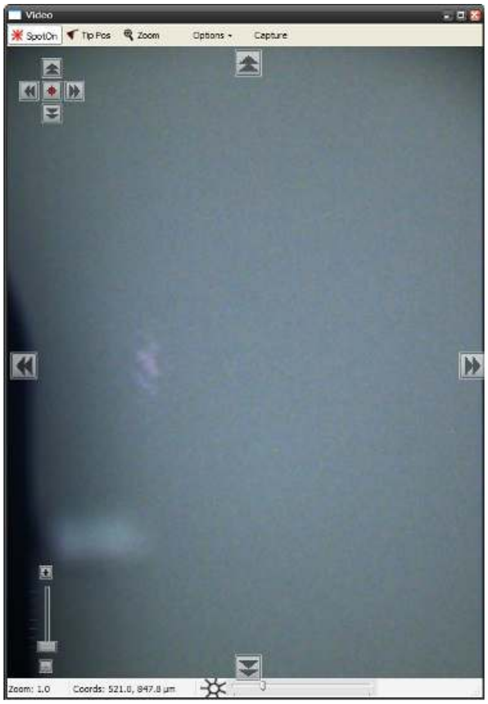
2.

Observe tune result:

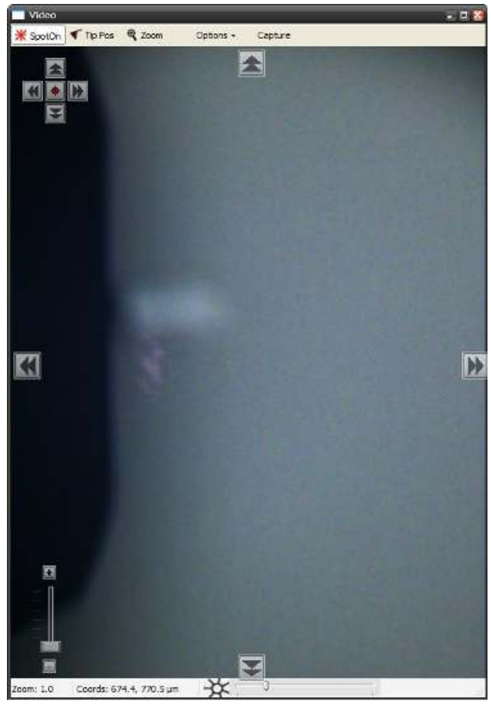
- A graph will pop up with the tune result.
- The resonance curve should peak around 300kHz.
- The relevant results are automatically stored. After inspecting that the amplitude and phase curves look "clean", you can close the graph.

HINT Cleaner tunes can be obtained by blowing the cantilever holder with clean compressed air prior to loading cantilever to get rid of any left over silicon/glass debris.

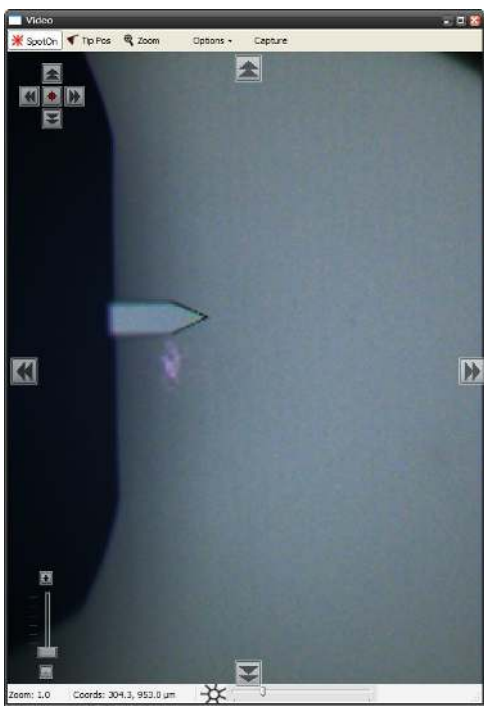




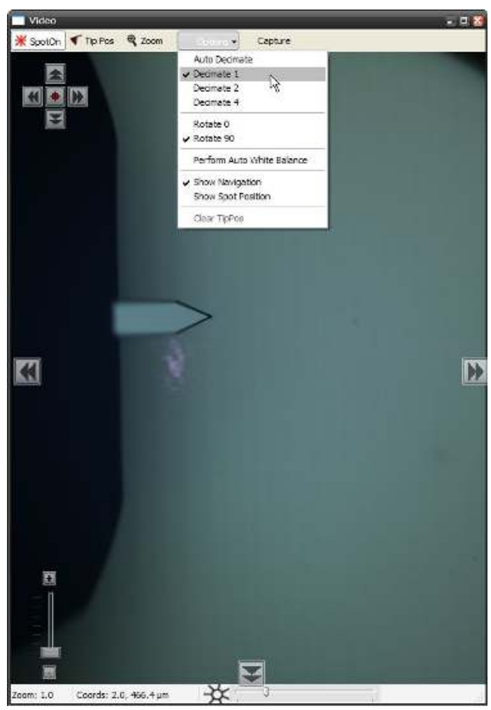
(a) First view of new cantilever.



(b) Cantilever found and roughly centered on screen. Step 8 on page 50.

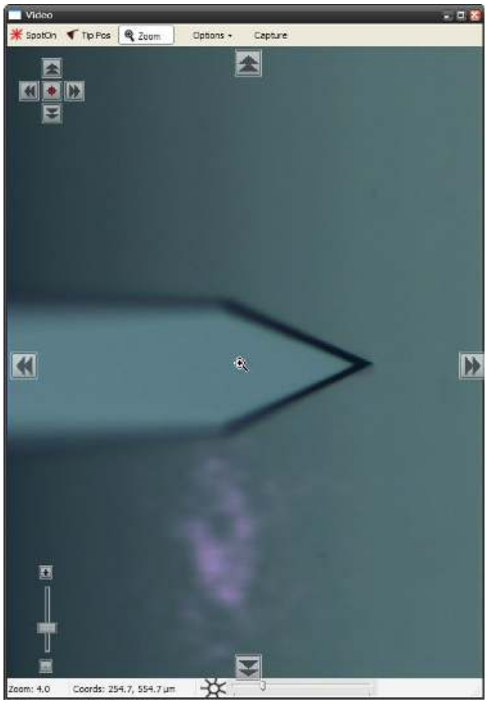


(c) Cantilever in focus. See Step 9 on page 51.

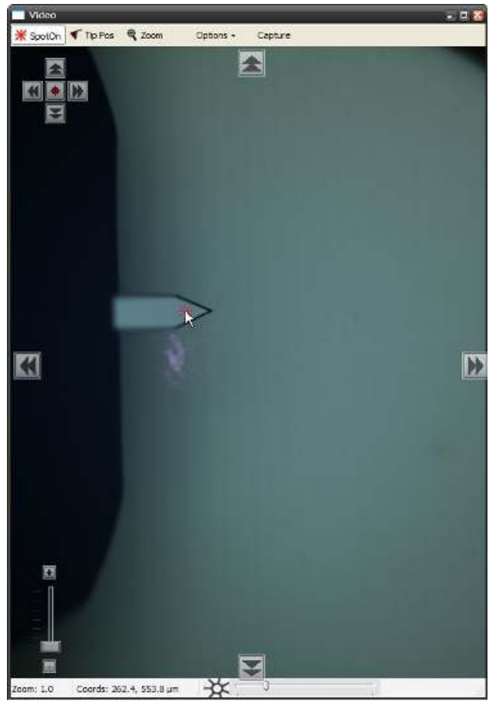


(d) Optimize Resolution. See Step 10 on page 51.

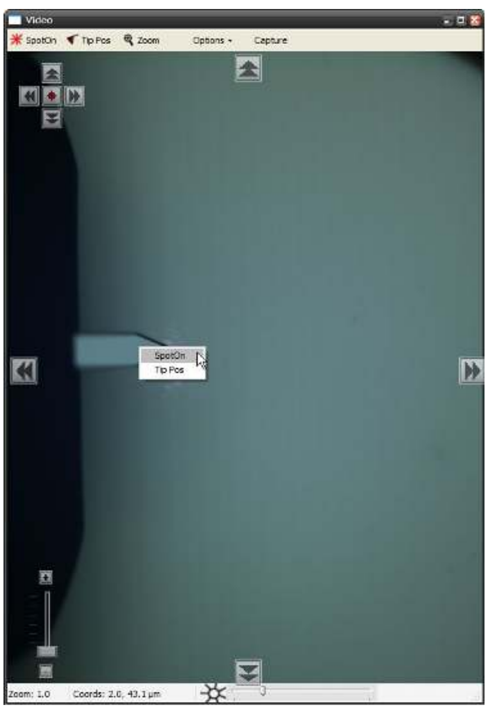
Figure 7.1.: Finding the cantilever and optimizing the video.



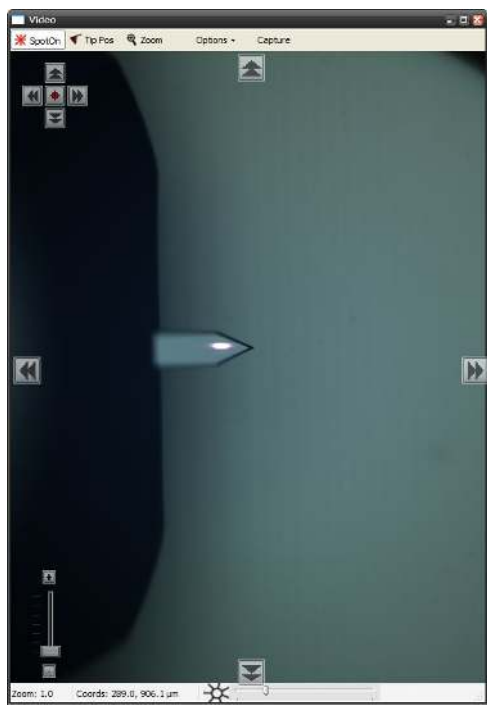
(a) Cantilever Zoom. See Step 10 on page 51.



(b) Laser Spot ON. See Step 11 on page 52.

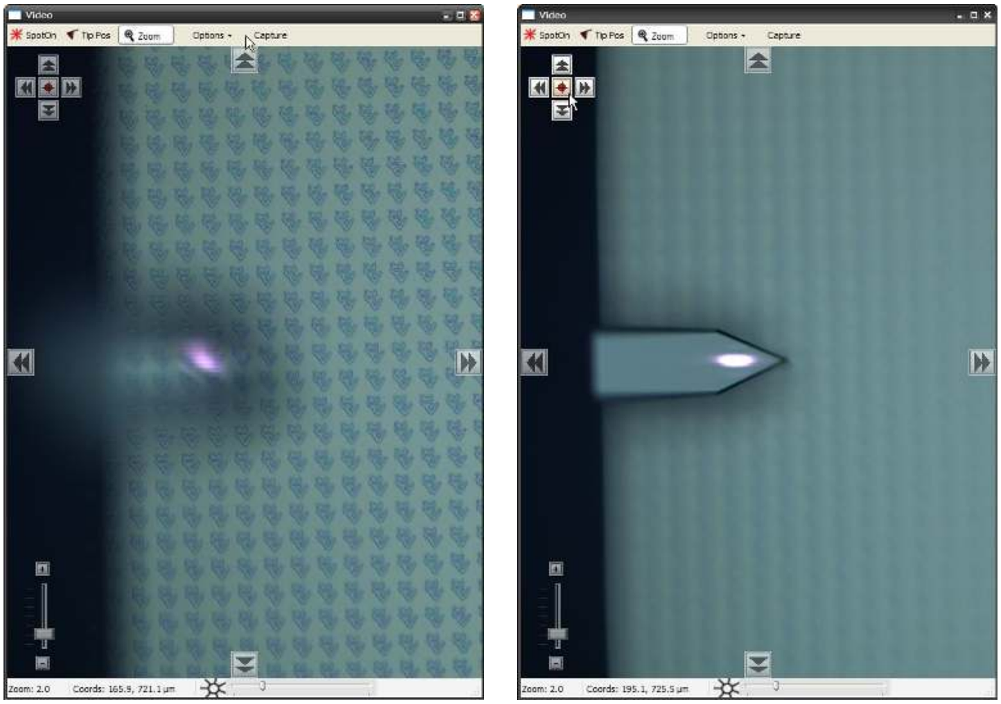


(c) Spot On by right clicking. See Step 11 on page 52.



(d) Laser spot on the lever. See Step 12 on page 52.

Figure 7.2.: Various methods for aligning the laser spot onto the cantilever.



(a) Offset.

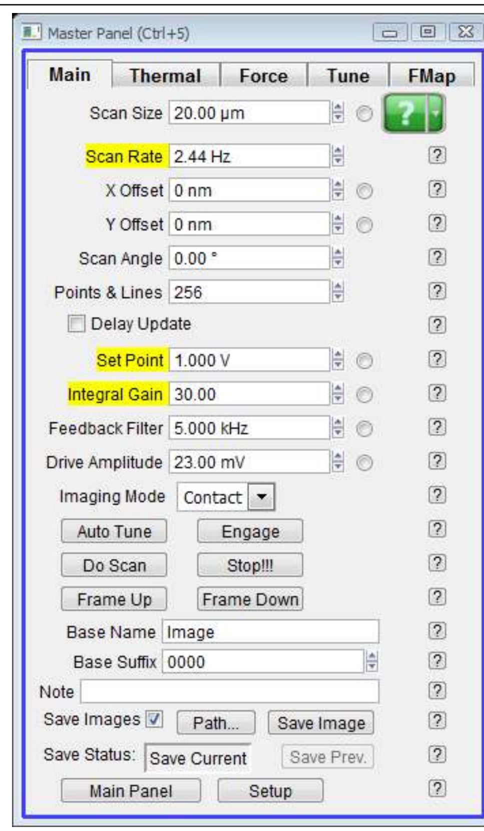
(b) The focus offset is centered and the optical image is confocal with the focused laser spot.

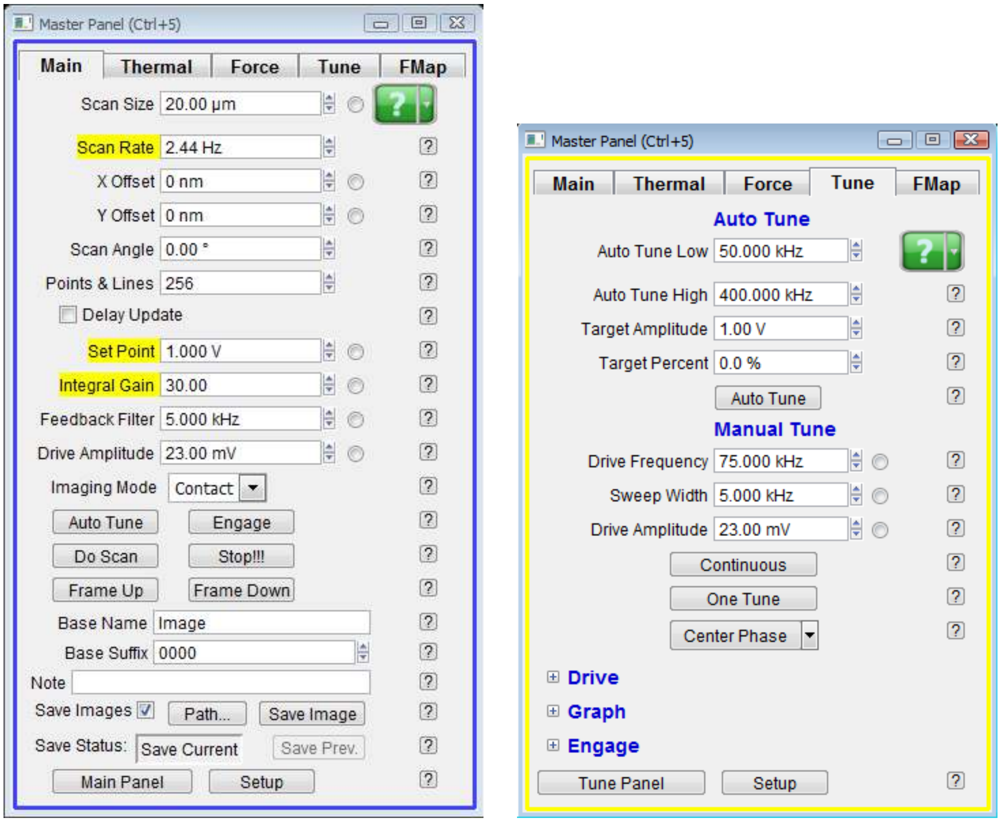
Figure 7.3.: By turning the focus offset knob, it is possible to focus on optical image on the sample while the laser stays focused on the cantilever.

3.

Set scan parameters:

- Click the ‘Main’ tab on the ‘Master Panel’ .
- Set the set point value to 700mV, the second item highlighted in yellow in Figure 7.4a on page 59.
- Check that all the other values and check boxes of your ‘Main’ tab panel are the same as 7.4a.





(a) Master Panel, Main Tab. **(b)** Master Panel, Tune Tab.

Figure 7.4.

7.3.3. Landing the Tip

The preceding sections have left the tip vibrating about 50 microns above the sample surface. It's time to land.

1. **Start final tip approach:**

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

2.

Wait for tip to reach sample:

- For the next minute or so Cypher will systematically move the tip closer to the sample until the set point is reached.
- You can cancel the approach at any time by pressing AND HOLDING the 'Esc' key on your computer keyboard.
- When the process is complete, the computer will beep and the tip will be left about half the Z range (about 3 microns) off the sample surface.

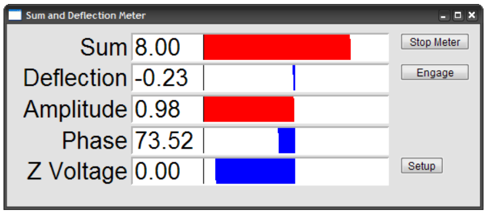
Q What's going on during the tip approach?

A Cypher executes a series of repeated steps. First the scanner fully extends the sample toward the tip while monitoring the cantilever amplitude. If the amplitude reaches the set point, the process stops. If not, the sample is fully retracted again and motors move the cantilever down by one extension length. The process is repeated until the sample is close enough to the vibrating cantilever to reduce its amplitude to the set point. One final time the sample is fully retracted and the cantilever is motored down just enough so that when the sample is brought back up it will trip the tip amplitude set point at half the scanner's vertical extension range.

3.

Meter check:

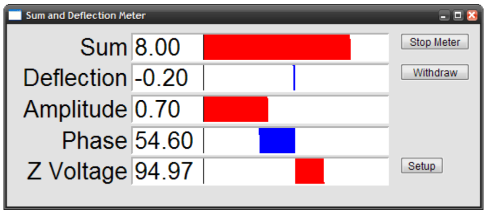
- Locate the 'Sum and Deflection Panel'(Ctrl + 6).
- The values should be similar to the figure on the right, typical for a cantilever a few microns off the sample surface.



4.

Engage:

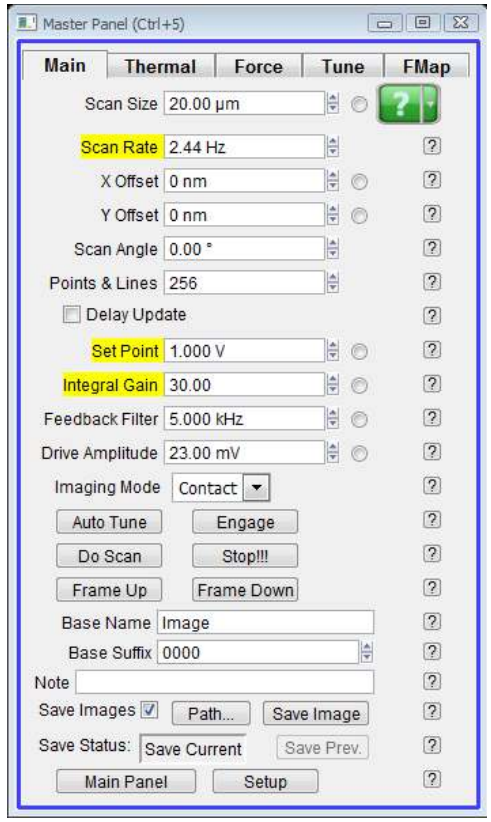
- Hit the engage button on the 'Sum and Deflection' meter panel.
- The scanner will extend the sample into contact with the tip and the 'Sum and Deflection' panel will look like the figure to the right.



Congratulations The tip is on the sample surface.

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

Answer Type in a slightly lower the set point (such as 650mV). If the Z voltage in the 'Sum and Deflection' meter panel does not change noticeably (*i.e.* more than a Volt) the tip is firmly on the surface.



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

Answer 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. Since the sample sits one tip height farther away, it will not be in focus. The fix is extra optics just before the video camera. Adjust the focus ring (at the center in the photo on the right) on the view system until the sample is in focus. Of course the cantilever and laser spot will now appear blurred in the video image.

Note When it comes to focusing on the next cantilever (Step 9 on page 51) you must be sure to set the focus adjustment back to zero, as in Step 3 on page 49. Cypher includes a sensor to see that this has occurred and the software will warn you to zero the focus offset when necessary.

7.4. Imaging

This section will get you scanning and tracking the surface.

7.4.1. Set-Up 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 difference (deflection) signal has been zeroed.

1.

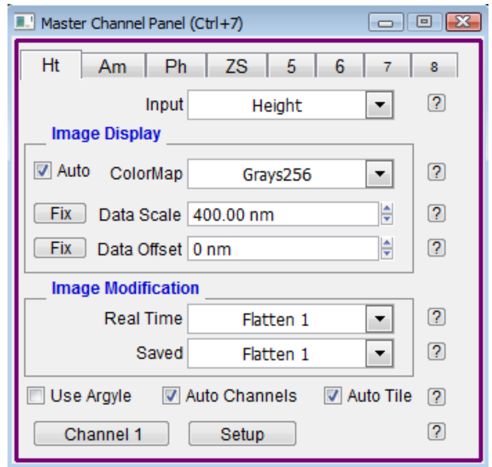
Set up Master Panel:

- In the ‘Image’ tab of the ‘Master Panel’, confirm that ‘AC Mode’ is selected from the ‘Imaging Mode’ pull down menu.
- Integral gain (I): 24 to 30.
- Scan rate: 2.44 Hz.
- Scan angle, resolution (scan points & lines) and image size is up to you. These are found in the ‘Parms.’ tab to the right.

2. **Image channel selection:**

- Go to the 'Master Channel' panel
- Select the leftmost tab and confirm the default setting of 'Height' under the *Input* pull-down menu.
- For the next two tabs do the same for 'Amplitude' and 'Phase'.
- For the fourth tab, do the same for 'Zsensor'.

Note While not necessary, it's 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's a more precise Z measurement.

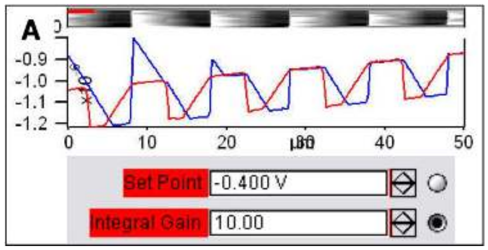


3. Images are saved to disk automatically at the end of every image if you leave the 'Save Images' check box selected, near the lower left hand corner of the Master Panel in Step 1 on page 62.

7.4.2. Start Imaging and Parameter Tuning

1.
- Click the 'Frame Up' button on the 'Image' tab of the 'Master Panel', and imaging will begin after a moment. Scan initiation first moves the tip to the starting point of the image, then lowers the tip onto the surface, and then 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.



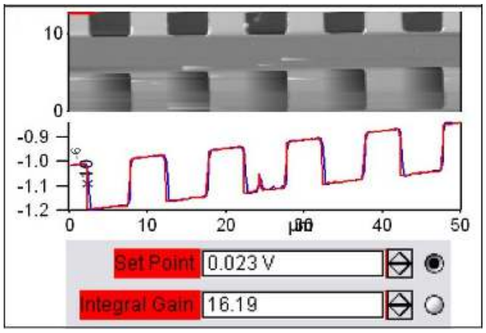
2. **Determining Image Quality:**

- Start the learning process on a sample with a known topography, like 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 previous image 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 left 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 un-deflected, 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 MFP-3D AFM controller the toggle switch to the left of the ‘Hamster’ allows you to toggle between radio buttons in the panel. On the ARC2 SPM controller the outer ‘Hamster’ ring performs this function. This tactile experience lets you concentrate on the image while tuning parameters.



3.

Adjusting Set-Point, i-gain, and scan speed:

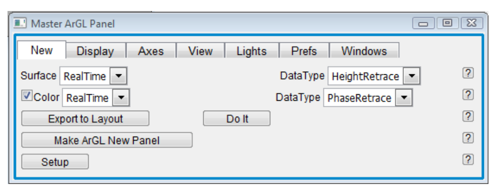
- The goal is to get trace and retrace to fall on top of each other (as shown above).
- Increase the 'Integral Gain' or *i-gain* parameter (second highlighted item in Step 1 on page 62) and see what happens. The match between trace and retrace should improve. The feedback becomes more aggressive and the slope with which the tip "parachutes" down into the pits should become steeper.
- Keep increasing the 'Integral Gain' until suddenly the trace and retrace start to oscillate wildly, a phenomenon called ringing. The feedback loop is now unstable and the i-gain needs to be lowered a bit.
- If increasing the i-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 Set Point can also improve tracking.
- Decreasing the 'Scan Rate' control will also improve tip tracking.

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

4.

View Data in Real Time 3D:

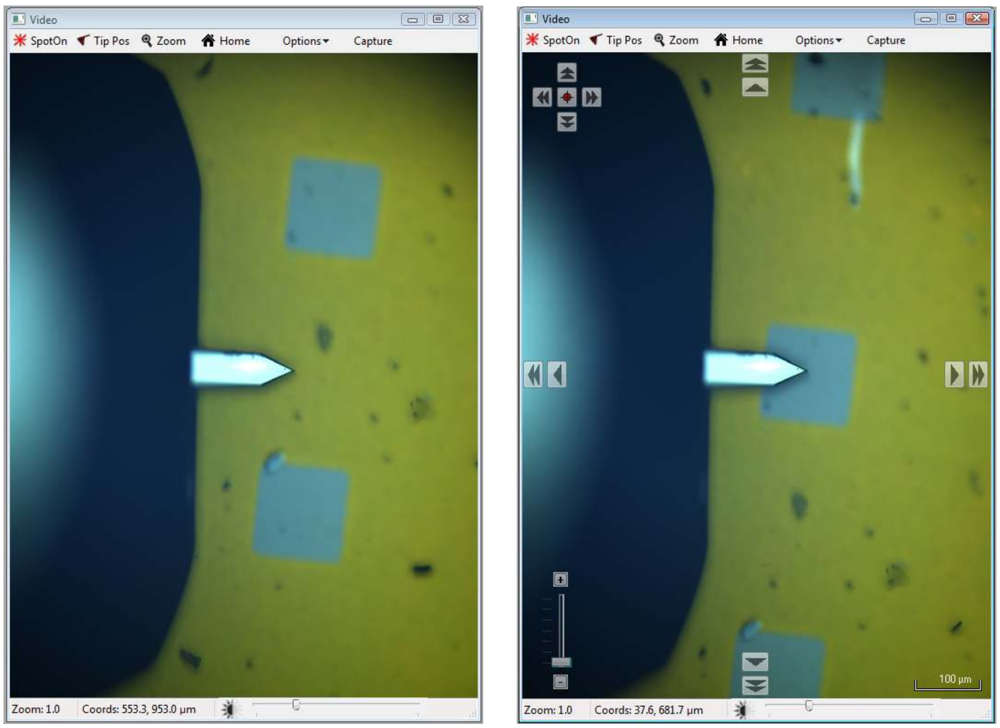
- Open the 'Master ArGL Panel' by selecting from the menu bar *AFM Analysis ▷ 3D Surface Plots*.
- From the 'Surface' pull-down select 'Real time'
- From the 'Data Type' pull-down to the right of it, select the desired channel in that image (usually *Height* or *Zsenor*).
- Click the 'Do It' button.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



Moving the Sample Between Scans:

- Sometimes, it is desirable to move to another point of interest after some scans have been taken. For features within 12.5 microns, use the *X Offset* and *Y Offset* fields. Note that a negative is to the left or below the initial area.
- For features that are further away, use the arrows toward the edges of the Video Panel. The single arrows are slow, and the double arrows are fast. It is also possible to click and hold the double arrows for faster, continuous movement. See Figure 7.5 on page 66 for an example of sample movement.

Note These buttons move the sample rather than the cantilever, and so the laser and objective stay in alignment. Be sure to avoid accidentally moving the tip, and 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.



(a) Before the Move. **(b)** After the Move

Figure 7.5.: Moving a Sample After a Scan

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

A Most parameters in the main tab of the main panel (See 1) 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 just above the 'Setpoint' parameter, then any changes you make to parameters above that box will only update next frame. Until the image is complete, the changed variables are highlighted in blue.

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.

7.4.3. Image Refinement

To learn more about using the Asylum Research SPM software to refine your imaging parameters, please refer to *Applications Guide, Chapter: AC Mode Imaging in Air* and also *MFP-3D User Guide, Chapter: Tutorial: AC Mode Imaging in Air*. Also consider watching this introductory video: AC Mode Imaging in Air (requires an internet connection).

7.5. Stopping Imaging

1.

General Procedure for Stopping Imaging

- Once a scan has begun, a 'Continuous' button on the Master Panel will appear and can be changed to 'Single Scan'.
- Clicking on 'Single Scan' will cause scanning to cease once the current scan has completed.

Note 'Last Scan' will change to 'Undo Last' if clicked. Clicking Undo Last will cause the software to keep imaging with current parameters.

2.

Emergency Stopping Procedures

- Clicking the 'Stop' button on the Master Panel will halt the scanning mid-image; this is a fairly 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 were gouging holes in the sample.
- 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.

7.6. Shutting the System Down

The following procedure should be used if the Cypher will not be used for some time, for instance, at the end of the workday.

1. Once you are done imaging, save your data to a desired directory. Close Igor and shut down the computer.
2. The tip will disengage automatically when imaging stops, but for added safety, motor the tip away from the sample. You may want to remove the sample at this point.
3. Turn off the laser key on the controller.
4. Power off the controller.

8. Cantilever Holder Guide

CHAPTER REV. 1763, DATED 02/21/2014, 11:26. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

Depending on your specific imaging application the appropriate cantilever holder must be used. This chapter serves as a guide to the available Standard Scanner options and to help you identify the types of cantilever holders you may already own.

All the available cantilever holders have many things in common:

- All have a circuit board which allows the system to identify the type of cantilever holder and to activate the appropriate software control panels.
- Nearly all have a piezoelectric actuator and allow AC mode and contact mode imaging.
- Nearly all have the ability to apply DC and AC voltage to the cantilever.

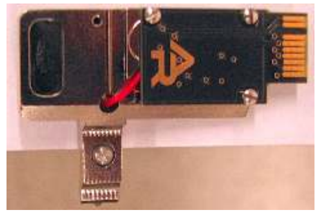
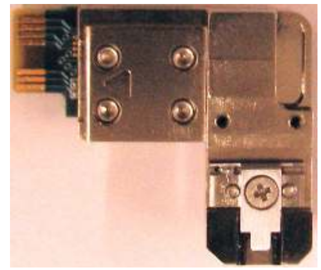
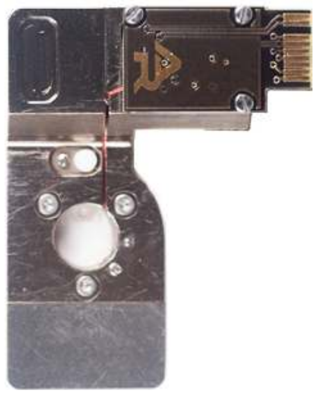
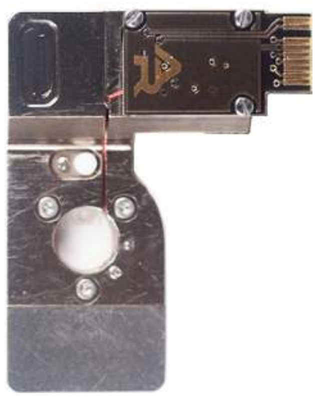
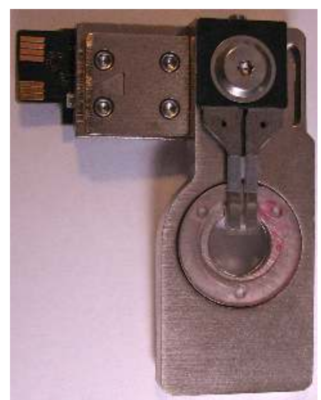
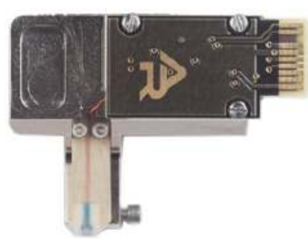
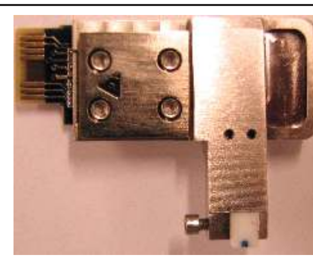
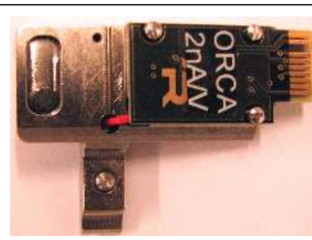
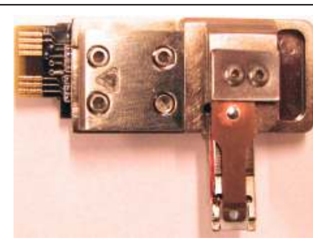
Many more contain specific electronics allowing for current measurement, application of high voltage to the tip,, and more.

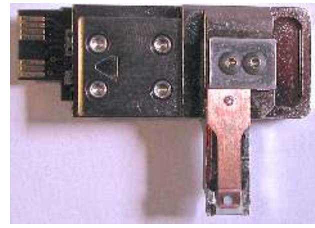
Be Careful	Cantilever holders are the most delicate components of the AFM. Treat it like you might treat your great grandfather's pocket watch. Never drop it. Remember that even the most basic cantilever holder costs thousands of dollars to replace.

8.1. Identifying Cantilever Holders

8.1.1. Visual Guide of Cantilever Holders

Please use this table to identify your cantilever holders and find the relevant sections which describe them.

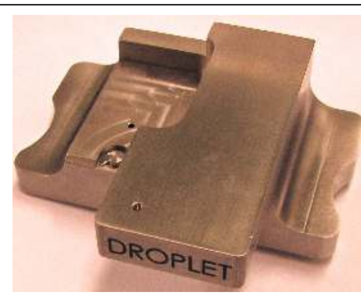
Part #	Holder Description	Front Photo	Back Photo
901.705	**Air** For most contact and AC mode Imaging. It’s use is described well in this tutorial: Section 7.2 on page 41. Fits in the Air Changing Station. For use in air only.		
901.730	**Droplet*** For fluid imaging in a droplet. See Chapter 9 on page 72. Fits in the Droplet Changing Station. For use in air or liquid.		
901.740	**iDrive*** For Electromagnetically Driven imaging, in air and droplets. See Chapter 10 on page 91. Fits in the Droplet Changing Station. For use in air or liquid.		
901.727	**STM** Scanning Tunneling Microscopy. See Chapter 12 on page 117. Fits in the Air Changing Station. For use in air or liquid.		
901.73x	**ORCA** Conductive AFM with a single current range. See Chapter 11 on page 106. Fits in the Air Changing Station. For use in air only.		

Part #	Holder Description	Front Photo	Back Photo
901.708	**Dual Gain ORCA** Conductive AFM with a two simultaneous current ranges. See Chapter 11 on page 106. Fits in the Air Changing Station. For use in air or liquid.		

8.1.2. Electronic Identification of Cantilever Holders

1. Attach the cantilever holder to the Cypher Scanner. (See Step 17 on page 46).
2. From the main menu bar in the software select *Programming* ▷ *Cantilever Holder and Sample Panel*.
3. At the bottom left of this panel click the 'Check Holder' button and the type of cantilever holder will be highlighted.

8.2. Cantilever Holder Changing Stations

Part #	Item Description	Picture
901.715	Air Cantilever Holder Changing Station. Used with Cypher cantilever holders that look like the Standard Air Cantilever Holder.	
901.716	Air Cantilever Holder Changing Station. Used with Cypher cantilever holders that look like the Standard Droplet Cantilever Holder.	

9. Fluid Imaging in a Droplet

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

This chapter explains the use of the droplet cantilever holder designed for use with the Cypher Scanner. In this design, the sample is such that the scanning area is submerged in small volume of water (typically around 100uL) which encapsulates both the scanning area and the cantilever. The water environment is maintained by the meniscus bridge formed between the sample substrate and the underside of the glass window of the droplet holder.

Liquids other than water are not recommended. Volatile solvents may fill the Cypher enclosure with damaging or harmful vapors. The membrane is made of silicone and was not designed for a high level of chemical resistance.

The cantilever holder can be used for contact mode and AC mode imaging in fluid. It has a built-in piezoelectric actuator for driving cantilevers at resonance. Please refer to Chapter 10 on page 91 for specifics on iDrive imaging only.

9.1. Nomenclature

Please refer to Figure 9.1 on page 73.

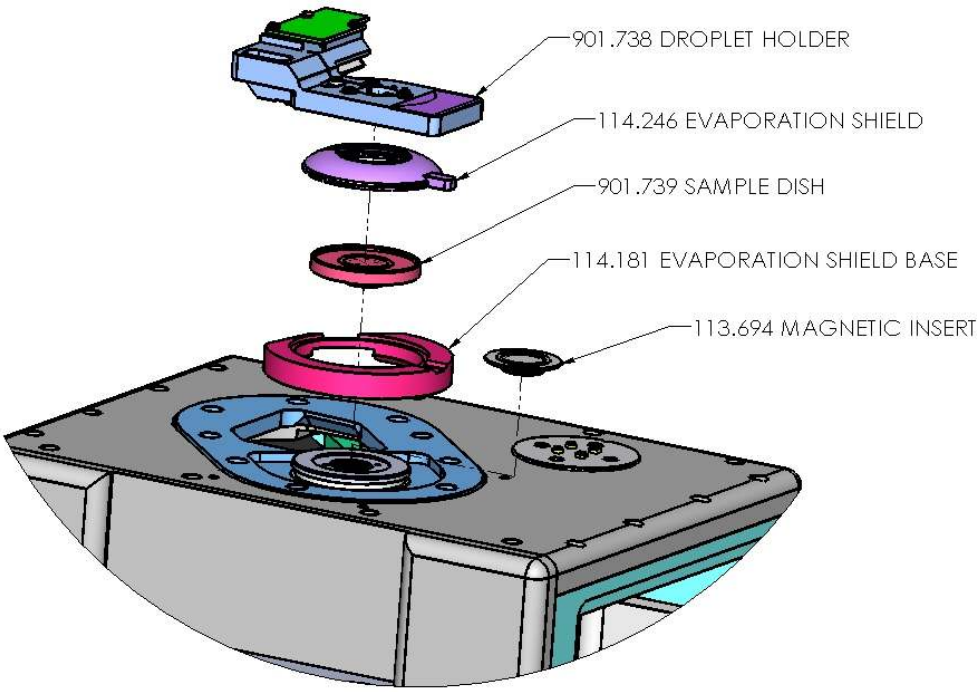
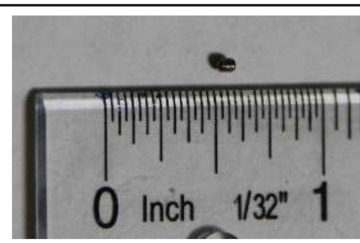
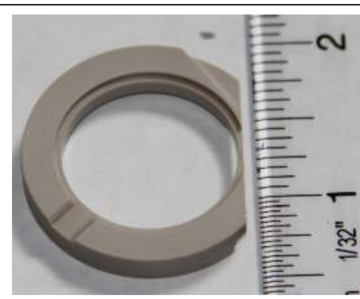
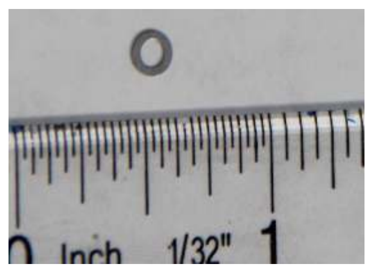
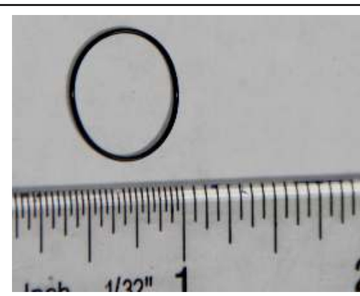


Figure 9.1.: Droplet Cantilever Holder nomenclature.

9.2. Parts List

Asylum Inventory Number 901.738.1

Itm	Part #	Item Description	Qty	Picture
1	004. SETS <#80 x 0.063> CUP	0-80 x 1/16” set screw, cup point.	6	
2	114.181	Ring, Gasket Base	1	

Itm	Part #	Item Description	Qty	Picture
3	114.246	Shield, Low Profile Evaporation.	3	
4	222.070	Socket Head Cap Screw, 0-80 X 7/64”	12	
5	222.072	Screw, M2 X 4, Stainless.	5	
6	222.094	Washer, 0.157” x 0.096” x 0.010” 17-7 stainless steel.	5	
7	230.035	O-ring, 0.551” x 0.022”, 60 Durometer FKM.	2	
8	290.111	0.050”: Wiha Allen Driver 263 1,3 ??? 0.05??? X 40.	1	
9	290.136	Short arm hex key, 0.028”.	1	

Itm	Part #	Item Description	Qty	Picture
10	290.144	T5 2.5MM Torx Driver.	1	
11	901.738	Cypher Droplet Holder Assembly, V2.	1	
12	901.739	Small Diameter Droplet Holder Cup Assembly.	1	

9.3. Preparing for Imaging

Before you start:

- We assume you understand the aspects of running this system safely: (Chapter 1 on page 3.)
- You are familiar with the basic names of the hardware components and software controls (Chapter 2 on page 14.)
- You have powered up the Cypher and launched the software: (Chapter 5 on page 33.)
- You are comfortable with AC Mode Imaging in Air, as instructed by the tutorial: (Chapter 7 on page 40).

9.3.1. Mounting the Sample Dish

The sample dish was originally integral to the evaporation control in an earlier droplet holder design where an evaporation shield attached to the droplet holder. This scheme was difficult to use so the evaporation control components were redesigned as is now described. The sample dish is now only used to catch fluid overflow.

Fluid scanning experiments can be carried out with or without the use of the sample dish since in either case the fluid should be confined between the glass of the droplet holder and the sample. The dish is not intended to be used as a reservoir for liquids. To install the sample dish remove the magnetic insert in the scanner cap and thread the dish into the scanner.

1.

Remove the magnetic insert

- Use a tool like the point of a pair of tweezers to fit into one of the holes in the insert.
- Push the insert counter clockwise to loosen the threads.
- Remove the insert and store in a safe place.

2.

Install the Sample Dish

- Thread the dish into the scanner cap and gently tighten.

9.3.2. Mounting the Cantilever

This cantilever holder requires the 901.716 droplet changing station (See Figure 9.2a on page 77).

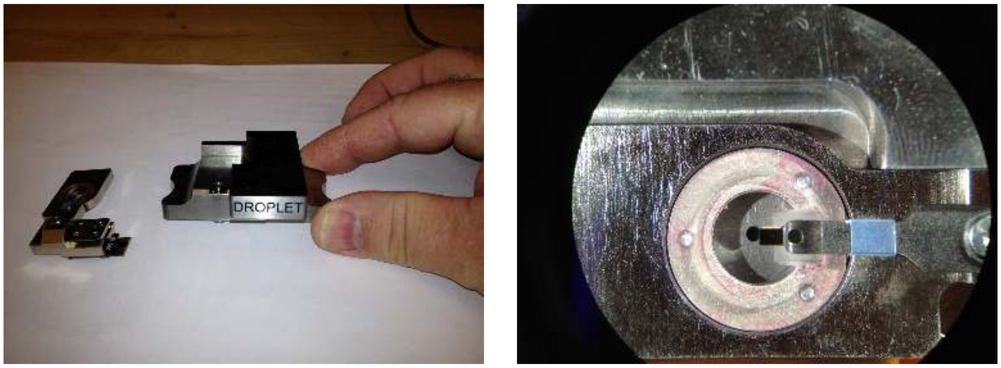
Warning	Using the wrong changing station will not work and may damage your cantilever holder.

Once you have located the changing station, the procedure is the same as you are probably familiar with from AC mode imaging in Air. If you are not familiar with this you should seriously consider following the tutorial in Chapter 7 on page 40 at least once. Herein the specifics of mounting cantilevers is described in Step 9 on page 43 through Step 14 on page 45.

When finished your aligned cantilever should look like Figure 9.2b on page 77.

9.3.3. Using the Evaporation Shield

Since the volume of liquid is small, evaporation will limit the experiment time to about 30 minutes. It is possible to extend the experiment without disengaging the tip by adding liquid into the gap between the sample and the droplet holder from the side by using a pipette.



(a) Droplet Cantilever Holder Changing Station XXX.XXX. Notice the markings.

(b) Properly centered cantilever in the Droplet Cantilever Holder.

Figure 9.2.

The droplet holder is supplied with a set of parts which will allow you to build a semi enclosed chamber to help reduce the rate of evaporation. With the evaporation control in place, the typical time of the experiment can be extended about three times compared to scanning without them. Basically, the evaporation shield surrounds the scanning area while contacting the underside of the droplet holder window.

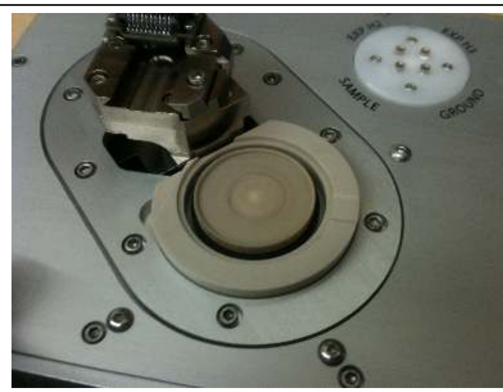
The current design of the evaporation base is sized to work with or without the sample dish using a sheet of mica or a glass cover slip mounted to a steel puck. Thicker bases can be provided if your typical specimen thickness prevents the shield from contacting the holder.

1.

Install the evaporation shield base

- Place the base into the recess around the sample stage

Note: The top of the base has a lip where the evaporation shield fits.



2.

Install the evaporation shield

- Place your sample onto the scanner.
- Place the evaporation shield on the base.
- Add a drop (approx. 100uL) of liquid to submerge the sample

Note: The tab on the shield makes a nice handle to allow you to manipulate it into position. Use tweezers to fit the bottom edge of the shield into the groove on the base.

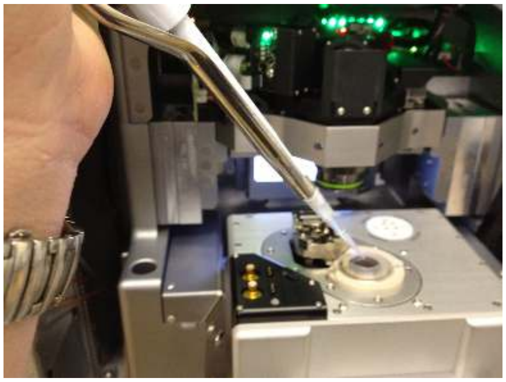
9.3.4. Sample Mounting

Typically a sample is mounted directly to a steel AFM puck as you would for air imaging. The sample should be large enough to allow a drop of liquid to be placed on it. If the specimen is a material which requires a substrate, a piece of mica or a 15mm glass cover slip should be epoxied to the steel puck.

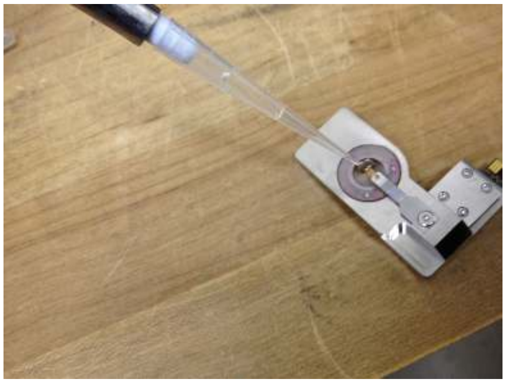
9.3.5. Installing the Cantilever Holder

1. Install the appropriate cantilever for your experiment.

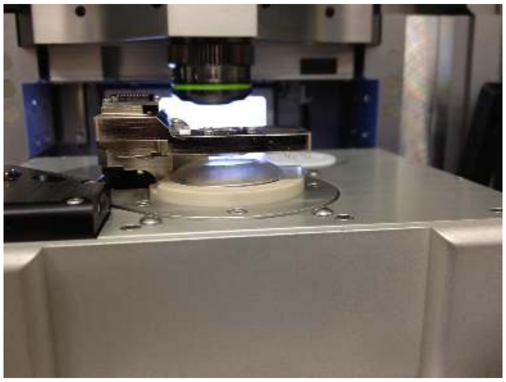
2. **Immerse the sample:**
   - Add a drop of liquid (approx. 100uL) onto the sample surface.
   - A laboratory pipette is recommended to deliver the liquid.



3. **Wet the cantilever:**
   - Add a small drop of liquid to the window of the droplet holder to submerge the cantilever.
   - This prevents bubbles and unwanted bending of very soft levers.



4. **Mount the cantilever holder:**
   - Fit the droplet holder into the dovetail socket on the scanner as you would for the air cantilever holder (see Step 17 on page 46)
   - If necessary, use the coarse approach wheel on the front of the enclosure to raise the cantilever holder pillar high enough to clear the evaporation shield if it’s installed.

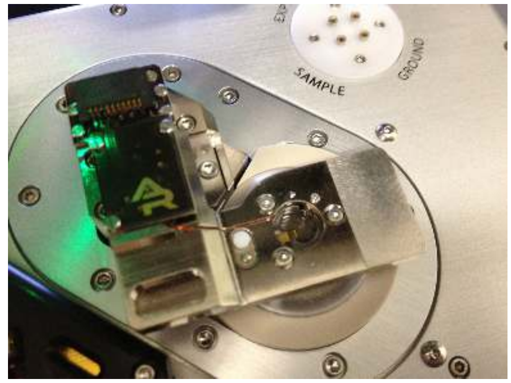


5. Secure the droplet holder to the engage pillar by tightening the dovetail clamp. Remember to only hold the driver tool with your fingertips and gently tighten the screw.

9.3.6. Engaging

9.3.6.1. Pre-engage adjustments

1. **Coarse Engage:**
   - Pull the scanner forward.
   - Using the control wheel on the instrument base, slowly lower the holder toward the sample.
   - Look down through the glass window and watch for the moment it contacts the liquid. You will notice the drop on the window will disappear and the view through the glass becomes slightly darkened.
   - Stop lowering the holder when this happens.

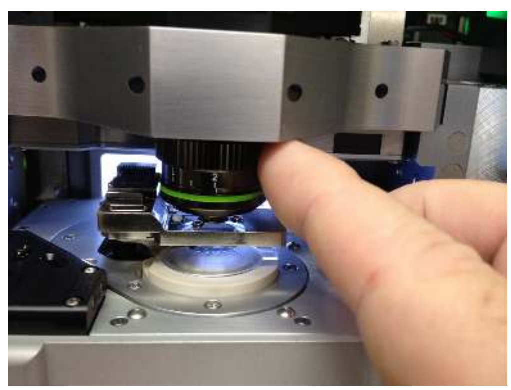
2. Push the scanner into the chassis and close the scanner clamp on the chassis.

Warning	The droplet holder is designed to work only in fluids. Do not try to engage the tip in air. The software automatically compensates for the refractive index of water. Focusing on the tip and sample in air will cause the actual distances to be incorrect and the cantilever will crash into the sample. This feature can be disabled but for general usage, please only focus the optics through water.

9.3.6.2. Focus on the cantilever

1. **Adjust objective focus ring:**
   - Move the focus offset ring on the objective to the 2mm position. This is necessary in order to compensate for the change in focal depth of the objective focusing through the glass window and liquid.

   Note: Moving the focus offset ring to 2mm is important to correctly focus the instrument's optics. The system requires correctly knowing the tip and sample focus in order to avoid the tip crashing into the sample and for proper deflection detection.

2. Focus on the cantilever as you would normally do for air imaging, outlined in more detail in 7.3. We assume you are familiar with that tutorial and will only cover the main points briefly.
3. Set the cantilever focus position.
4. Use Spot On to move the cantilever under the AFM light spot.

5. Zero the deflection voltage.

Note: On occasion, an air bubble may get trapped between the glass window and the cantilever. If this has happened, raise the droplet holder out of the liquid and lower it back into coarse position over the sample. If the bubble is still there you may need to remove the droplet holder, suck off any liquid on the window and reapply a fresh drop to the cantilever area.

9.3.6.3. Focus on the sample

1. Lower the objective until features on the sample surface come into focus.
2. Set the sample focus position.
3. Click on the ’Move to Pre-Engage’ button.
4. Make any adjustments to the AFM spot or the deflection voltage before engaging the tip.

Using the Field Diaphragm to focus on transparent samples

In cases where there is nothing to focus on because the specimen is featureless and the substrate is transparent, you can focus on the edge of field diaphragm which typically comes into focus about 30um above the actual sample surface.

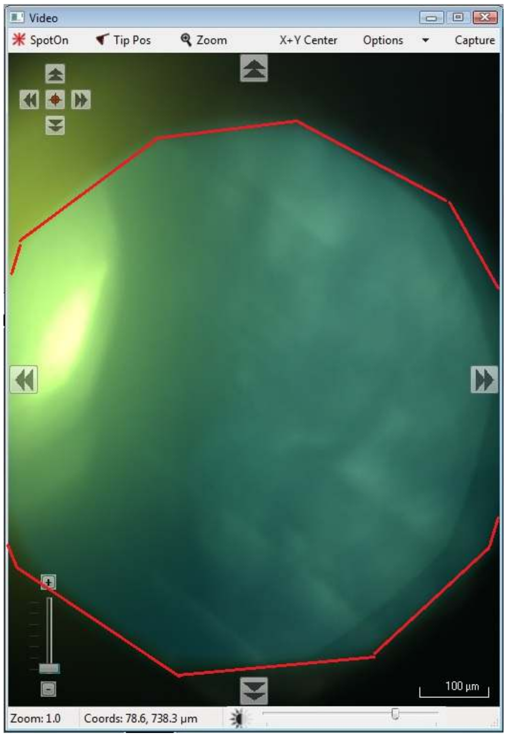
Being familiar with this method takes a little practice but once you know what visual ques to look for, it becomes relatively easy.

1. **Adjust the aperture diaphragm:**

- Adjust the Aperture Diaphragm lever (labeled A) on the View Module to reduce the illumination by about 90%.
- In the software, increase the illumination brightness to compensate for the reduction of light. This will help increase the image contrast and in many cases this is enough to see fine surface details.

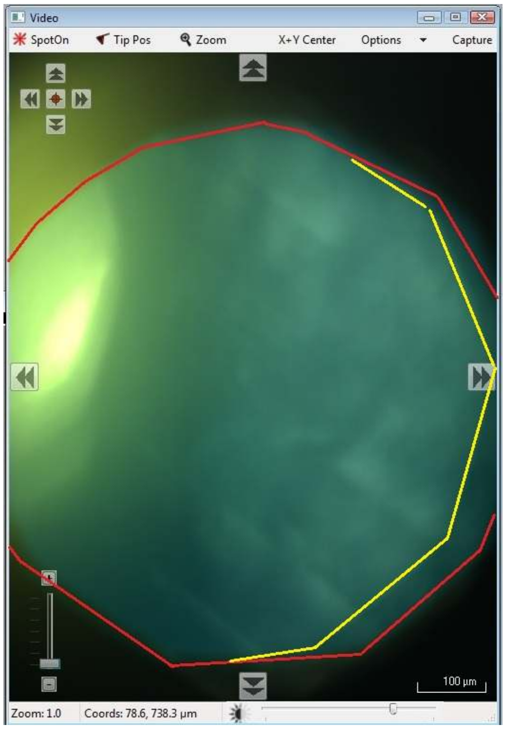
2. **Adjust the aperture diaphragm:**

- Adjust the Field Diaphragm lever (labeled F) on the view module until the edge of the aperture comes into view in the video image.



3. **Lower the objective:**

- Lower the objective while watching for the surface to come into focus.
- As you lower the objective, you will first see the edge of the field diaphragm come into focus.
- Once the field diaphragm is in focus, slowly continue to lower the objective. Look for subtle structures like the edge of a layer of mica or small bits of debris. This is most likely the sample surface.

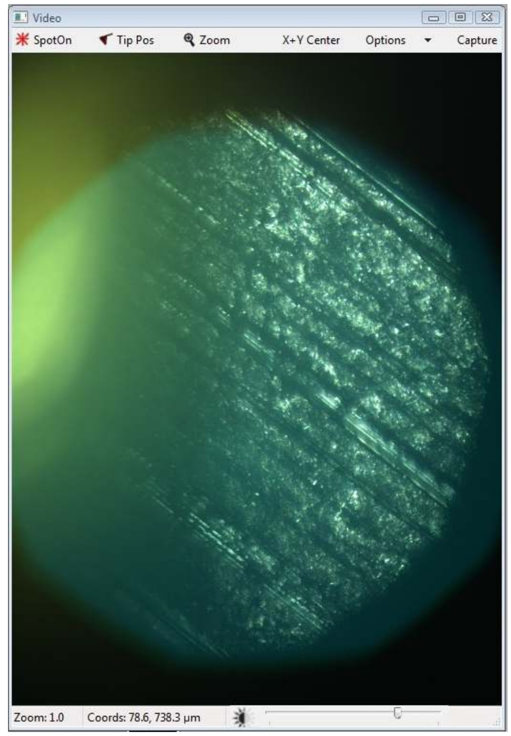


4. One way to confirm this is to note the focus position distance located just below the arrow buttons. Raise the objective back up to focus on the field diaphragm and note how much the focus distance has changed. Typically, the sample focus distance is about 30um below the focus distance of the field diaphragm.

Note You may see that the edge of the field diaphragm is shifted off center. This is due to a small amount of misalignment of the illumination path in the view module. In many cases this can help you distinguish when the edge of the field diaphragm is in focus.

5. **Going too far:**

- If you cannot confirm you are focused on the surface, slowly continue to lower the objective until you see lots of coarse looking features. These features are typically scratches on the steel puck you have mounted beneath the substrate. If you see this type of structure, you have focused below the sample surface and need to raise the objective.
- Slowly raise the objective until you either see:
  – 1st - a feature on the sample surface or
  – 2nd - the edge of the field diaphragm or
  – 3rd - the cantilever.



6. If you have raised the objective focus all the way up to the level of the cantilever then lower the objective back down to focus on the field diaphragm and set the sample focus there. You will be approximately 30um higher than the actual sample. The result of this is a slightly longer time for the system to engage the tip.

7. Once the tip and sample (Field Diaphragm) focus have been set, click on the 'Move to Pre-Engage' button and make any small adjustments to the AFM spot position or deflection voltage prior to engaging the tip.

9.4. Imaging with the Droplet Holder

9.4.1. AC Mode Tuning Specifics

The technique of AC mode imaging in fluid relies on the motion of the piezoelectric actuator in the droplet holder to be sent to the cantilever through the fluid. This indirect or ”acoustic” drive of the cantilever is greatly affected by the volume of fluid, the stiffness of the cantilever, and the frequency of the drive signal.

In most cases it is not possible to simply auto tune the cantilever at it's resonance. Manually tuning the drive signal is the preferred method. In order to know where to tune you typically find the amplitude peak by first measuring the thermal resonance of the lever. Once the thermal resonance is found, you can overlay the thermal spectrum on the tune plot. As you drive the piezo in the droplet holder will see several peaks in the amplitude plot as the drive frequency is swept. The peak you choose is typically the highest peak inside or near the thermal peak.

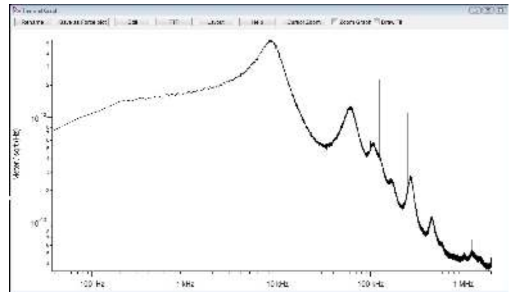
Once an amplitude peak is selected and the engage routine initiated it is not uncommon for the system to false engage as the driving forces on the cantilever change. It is therefore common to re-tune the system as the tip gets closer to the surface. A typical tuning session goes something like this:

1.

Capture a thermal plot

- Collect the thermal signature of the cantilever.
- For more information on capturing thermal spectra please read *Applications Guide, Chapter: Thermals*.

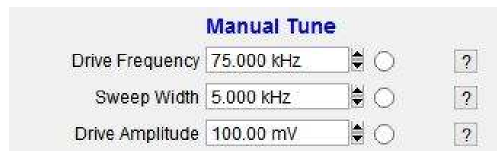
In this example the cantilever used is an Olympus TR400PSA having a nominal air resonance of about 40KHz and a spring constant of .1nN/nM. In water, the thermal resonance is about 7KHz.



2.

Manually tune the cantilever

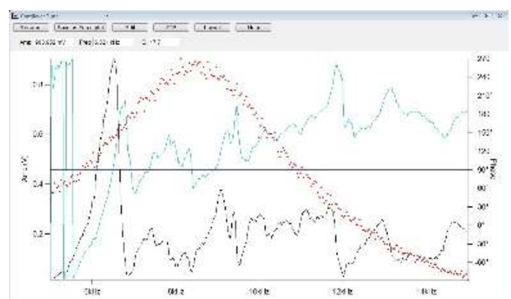
- In the manual tune parameters set the drive frequency to the approximate frequency of the cantilever's thermal resonance.
- Set the sweep width to 10KHz.
- Set the drive amplitude to 1-2v.
- Click on the continuous tune button and sweep the drive frequency.



3.

Select an amplitude peak

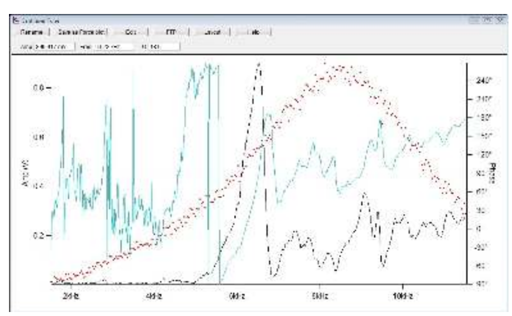
- Click on the append thermal check box to overlay the thermal data onto the amplitude plot
- Look for a peak inside the thermal signature. Generally the peak with the highest amplitude is the one to try. The peak should have a smooth rise in amplitude and have stable output as the frequency is swept.
- The peak near 6Khz is good although the lower amplitude peak at 9KHz would also work.



4.

Set the drive frequency and calibrate the phase signal

- Move the mouse cursor to the apex of the amplitude peak, right click and select 'Set Drive Frequency'
- The software will center the pot on the peak.
- Click on the 'Center Phase' button in the tune panel to adjust the phase signal to the center of it's range.



5. Click on the ’Stop’ button in the tune panel when the system is tuned.

9.4.2. Imaging Specifics

9.4.2.1. Engaging in fluid in AC mode

As the tip is being lowered to the surface during the engage routine, the Cypher is doing a series of triggered force curves looking for the free amplitude to equal the setpoint voltage. Once the free amplitude is seen as equal to the setpoint voltage, the system stops the approach and is considered to have found the surface. This works pretty well but in fluid there are several things that can trigger a false engagement.

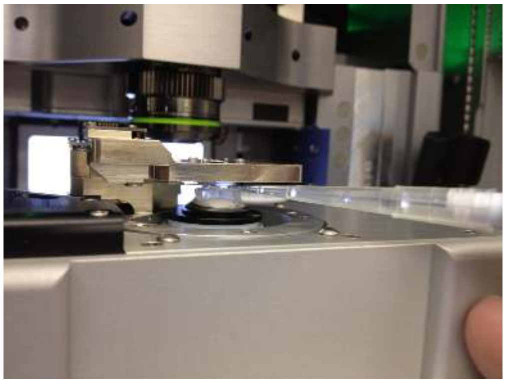
- The Feedback Filter - The default frequency response of the feedback filter is 5KHz. Since the resonance of the cantilever in this example is around 6.5KHz, the instrument is allowed to see frequencies too close to the oscillating frequency of the lever. This will cause the software to detect the alternating movement of the cantilever as the amplitude is changing and trigger a false engagement. Lowering the feedback filter value to around 2KHz will avoid this. Using stiffer cantilevers with a higher natural resonance will not need this adjustment.
- Hydrodynamic drag - The abrupt drop in the cantilever holder pillar during a motor step can cause a jump in the deflection signal. This is caused by the drag of the liquid bending a low spring constant cantilever. Lowering the Feedback Filter to around 2KHz will help reduce this effect. Stiffer cantilevers will not show this problem.
- The amplitude changes due to the peak shifting frequency - As the probe is lowered to the surface, the amount of liquid between the glass in the droplet holder and the sample surface can change the coupling of the drive signal into the cantilever. This may excite the cantilever at a different frequency so a previously tuned cantilever may not be in tune anymore. If the instrument triggers an engagement, you may want to go back to the tune panel and do a single tune to see the amplitude response and re-tune if necessary.

Check for a real tip engage by clicking on the ’Engage’ button in the Sum and Deflection meter panel. Reduce the setpoint voltage in the master controls panel and watch the behavior of the Z control voltage. If by lowering the setpoint voltage you see the Z voltage move all the way to 150volts then the system has false engaged and you should check the tuning of the lever and adjust as necessary. If you see the Z control voltage move to a value and stop then you most likely have correctly engaged. Begin scanning.

Tip	One useful thing is to monitor the deflection signal. Normally the deflection signal is not shown since the feedback signal is the Amplitude. Monitoring the deflection signal is helpful because in some cases the deflection will jump up as though the tip is has engaged in contact mode when the amplitude is falling. If this happens it indicates that the amplitude signal may be the result of deflections from the droplet holder components themselves resonating or the cantilever bending in a way that produces angular motion of the optical spot and not the result of the cantilever flexing at the tip end. If you see the deflection signal changing as though it’s engaging in contact mode then most likely you should re-tune the system and try driving the lever at a different frequency (choose a different peak). This behavior is the result of using low spring constant cantilevers. Stiffer levers typically do not do this. To display the deflection signal, click on the ’Setup’ button in the Sum and Deflection meter panel. Change the deflection from Auto to Show.

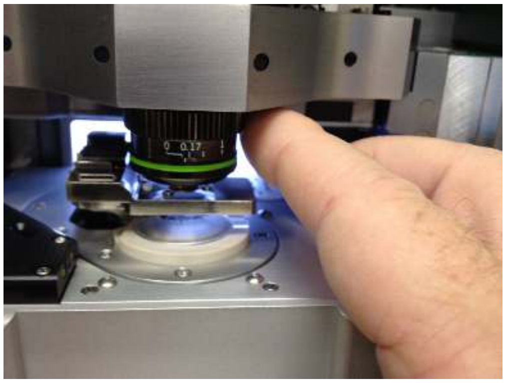
Tip	Do a force curve and monitor the amplitude signal. The amplitude signal should show an abrupt drop to 0 volts just before tip contact is made. Doing a force curve is equivalent to seeing the conditions of the last engage cycle during the tip approach.

1\. **Adding additional fluid during scanning**
During the experiment, you may find that the tip develops a tendency to float off the surface. This may be due to evaporation causing a loss of fluid volume which directly affects the AC drive oscillating the cantilever. If you suspect this has happening, use a pipette to add additional fluid to the tip/sample area and re-tune the system.



2\. **After scanning**

- After you are finished scanning move the focus offset ring on the objective back to 0mm.



9.5. Removal and Storage

9.5.1. Removing the Dish

Please seeSection 9.3.1 on page 75for details.

1. Unscrew the sample dish from the scanner.
2. Thread the standard scanner magnetic insert into the scanner sample stage.
3. Use the point of a pair of tweezers to tighten the insert.

9.5.2. Storage

Always clean the cantilever holder before storage. If it is particularly dirty, disassemble it before cleaning. Please see Section 10.2 on page 96 for the details. When clean and dry, store the cantilever holder and the other parts and tools in its designated kit box.

9.6. Cleaning and Repair

In daily use, the droplet holder can be cleaned by rinsing the exposed surfaces of the glass window and cantilever clips with clean de-ionized water. Following the rinse, the holder can be dried using low-pressure compressed air or by blotting with a soft tissue.

For thorough cleaning, the droplet holder must be disassembled. Only the parts exposed to the sample liquid should be cleaned. The cantilever holder body and associated electronics should be kept dry.

The cantilever holder clip, window assembly and evaporation control components can be cleaned by soaking in ethanol. Sonication of the parts can also be performed. Rinse the parts in clean de-ionized water. Dry the parts with either low-pressure compressed air or a soft tissue before reassembling the holder.

9.6.1. Disassembly

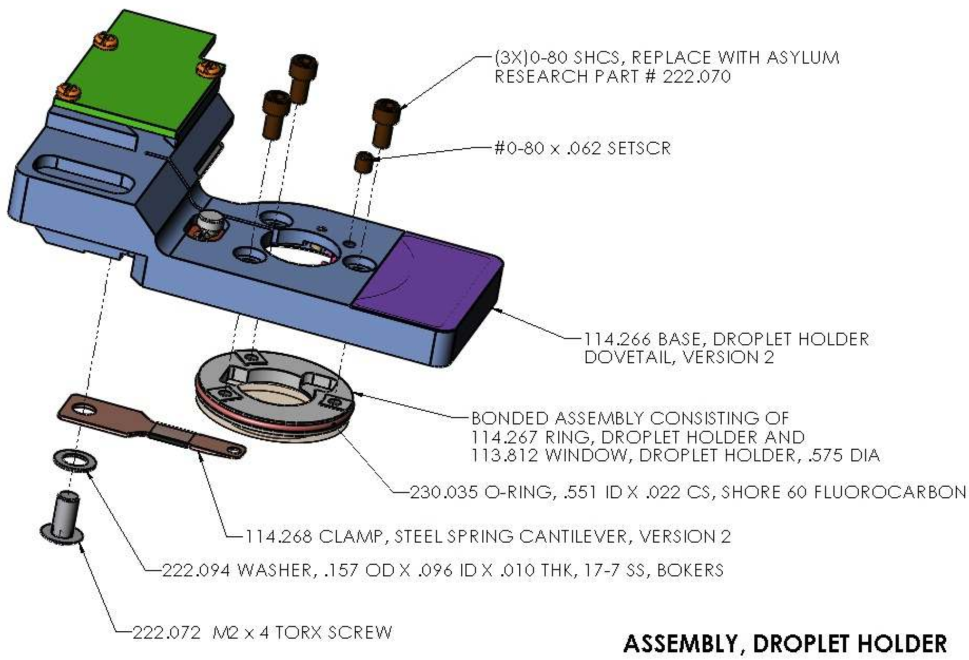


Figure 9.3.: Droplet Cantilever Holder Assembly Overview

The following steps will guide you through removing various components for cleaning as well as reassembling the holder afterward.

Before you disassemble the droplet holder, take the time to familiarize yourself with the way it is assembled.

The key components are:

- The cantilever clip and the associated mounting hardware
- The droplet holder window assembly and associated mounting hardware

As you disassemble the holder, take note that the screws for attaching the window assembly are a specific length. Reassembling the window with the longer screws can result in damage to the glass by either cracking or causing it to become detached from the metal mounting ring.

- Use only 0-80 x 7/64 Socket Head Cap Screws to attach the window assembly.
- Use only 0-80 x 1/16 Cup Point Socket Set Screws for the piezo preload screw.

Due to wear and tear of use, the droplet holder accessory kit comes with replacement screws. Please contact Asylum Research for additional hardware if proper replacements cannot be obtained locally.

1.

Required tools and fasteners:

- 0.050” hex driver or Allen wrench for the 0-80 x 7/64??? socket head screws to attach the window assembly.
- T5 x 40Torx driver for removing the cantilever clip
- 0.028” hex driver or Allen wrench for the 0-80 x 1/16 Cup Point Socket Set Screws for the piezo preload screw.

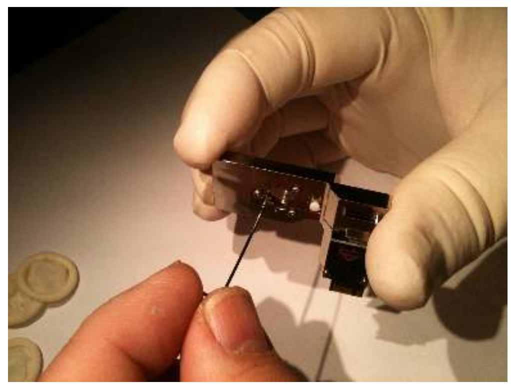
Warning Using other fasteners than those specified will damage your equipment.

2.

Loosen the piezo preload screw

Tools 0.028” hex driver or Allen wrench

- Loosen the piezo preload setscrew 1 turn.

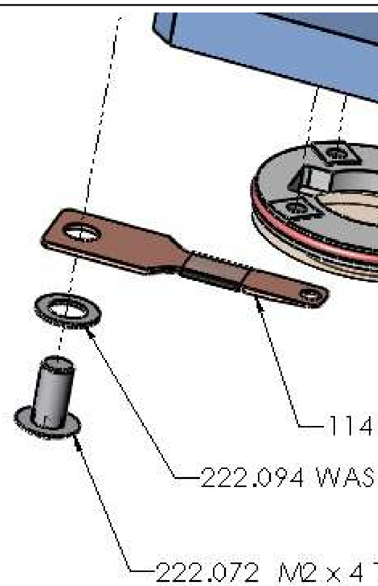


3.

Remove the spring clip

Tools T5 x 40 Torx driver

- Remove the screw securing the spring clip to the droplet holder body.
- Remove the clip from the droplet holder body.
- Set the parts aside for cleaning.

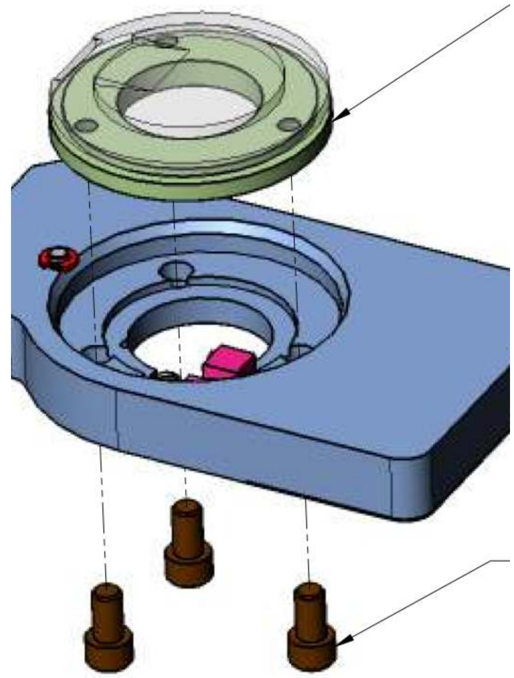


4. **Remove the window assembly**

Tools 0.050” hex driver or Allen wrench

- Remove the three screws holding the glass insert into the holder body.
- Remove the window assembly.
- Use a Q-Tip[a] to gently push the window out of the Droplet holder body

Caution: Push gently on the top side of the window. Be careful not to push on the piezo actuator (Pink block in illustration)



[a] Typically a wooden or rolled paper stick tipped with cotton. Commonly used for cleaning your ears. Also called “cotton swab”.

9.6.2. Cleaning

The cantilever holder clip, window assembly and O-ring can be cleaned by soaking in ethanol. Sonication may result in weakening the glue bond of the adhesive used to attach the window to its mounting plate so limited amounts of sonication (less than 15 minutes) of the parts is recommended. Rinse the parts in clean de-ionized water. Dry the parts with either low-pressure compressed air or a soft tissue before reassembling the holder.

The rest of the holder parts can be cleaned with a cotton swab and ethanol. Avoid areas with electrical wiring or circuit boards. If you are unsure about having gotten the wrong bits wet, dry the parts (perhaps under the warmth of a desk lamp) for a while. Dry the parts with low pressure compressed air in any case.

9.6.3. Reassembly

1. Fit the o-ring into the groove in the window mounting plate. Spare o-rings are supplied in the accessory kit for the droplet holder and more can be obtained from Asylum Research if necessary.
2. Place the window in the holder aligned so that the ramp in the glass points toward the hole for mounting the cantilever spring clip. The O-ring around the edge of the window mounting ring will prevent the window from fitting directly into the holder body.
3. Use a finger to gently push the window into the holder body. As you push on the window, be aware that the o-ring will need to compress in the recess of the holder body. In order for this to happen, it may be necessary to use a small tool like the point of a pair of tweezers to help guide the O-ring to fit.

Note: There is a small recessed area in the metal ring where the piezo actuator fits. Be careful not to hit the piezo or twist the window into position.

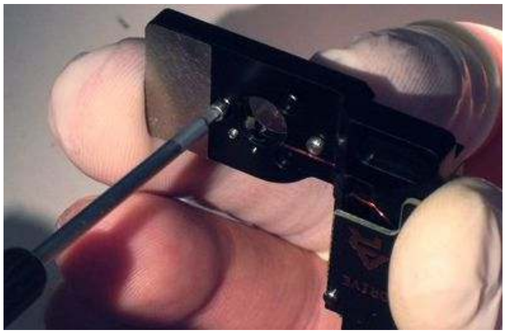
1.

Secure the window assembly

Tools 0.050” hex driver or Allen wrench.

- Using a finger to hold the window in place, thread the three 0-80x7/64 socket head screws the window to the holder using. Once all three screws are started, gently tighten them with uniform pressure.

Note Do not over tighten the screws. A small amount of torque is all that is required.



2.

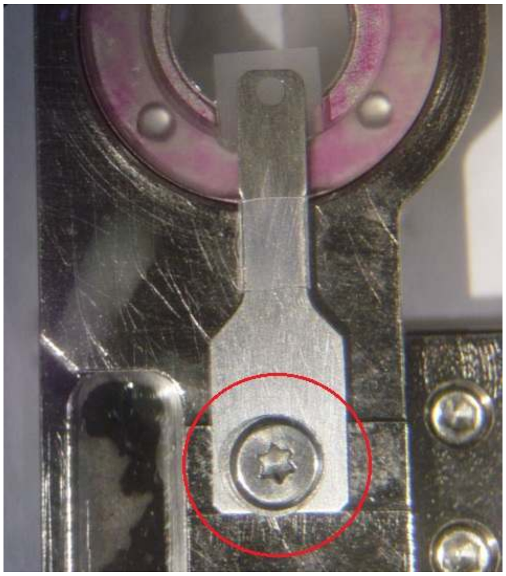
Install the cantilever clip

Tools 0.050” hex driver or Allen wrench.

- Lay the cantilever holder body circuit board side down.
- Place the clip on the holder body with the taper on the clip facing away from the window.

Note The end of the clip is tapered to provide clearance between the underside of the clip and the sample surface. Be sure the flat side is against the glass and the taper is away from the glass.

- Secure the clip to the holder with the Torx screw and washer. The clip may want to rotate as you tighten the screw. Use a pair of tweezers to hold the clip in the center of the ramp while you tighten the screw.



9.6.4. Adjusting Piezo Preload

When first disassembling the droplet holder for cleaning, the preload screw was loosened. Doing this allows you to readjust the compression on the piezo element properly after it is reassembled. This is recommended since the amount of compression is very small and the piezo position may change when you remove and reinstall the glass window.

1. Install the Droplet holder into the scanner.
2. Lock the clamp on the scanner to secure the droplet holder.

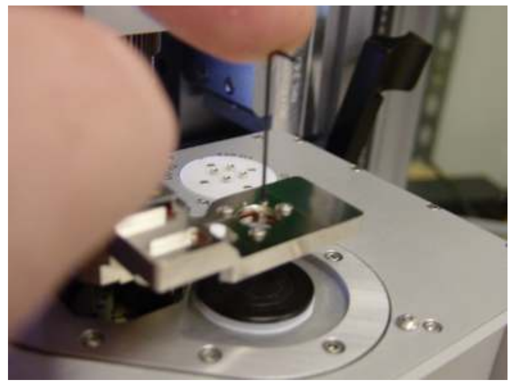
3. **Activate the tune sweep**

- In the AR SPM Software, select the *tune tab* of the *master panel*.
- Under *Manual Tune*, set the parameters as shown to the right.
- Hit the 'Continuous' (tune) button.

4. **Adjust the piezo compression**

Tools 0.028” hex driver or Allen wrench

- Listen for a small chirping sound coming from the droplet holder.
- Gently tighten the preload setscrew until the chirping sound becomes abruptly louder. This is the point where the set screw has compressed the piezo into the back of the window assembly. Once this happens the preload is set.



9.6.4.1. Finishing up

1. Back to the software, under *Manual Tune* hit the Stop Tune button.
2. Done. Remove the cantilever holder and store it or put in a cantilever and start imaging.

10. iDrive Imaging

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

This section explains the use of the iDrive version of the Cypher Droplet Cantilever Holder. In addition to the standard Droplet Cantilever Holder's functionality, the iDrive version has the ability to drive a small AC current through special iDrive compatible cantilevers. It also contains a small magnet, the field from which causes a torque on the current flowing through an iDrive cantilever causing it mechanically oscillate. This allows for an AC mode imaging experience in liquid superior to that achieved with standard acoustically driven AC Mode imaging.

Before you start:

- We assume you understand the aspects of running this system safely: (Chapter 1 on page 3.)
- You are familiar with the basic names of the hardware components and software controls (Chapter 2 on page 14.)
- You have powered up the Cypher and launched the software: (Chapter 5 on page 33.)
- You are comfortable with AC Mode Imaging in Air, as instructed by the tutorial: (Chapter 7 on page 40.)
- You have mastered fluid imaging in a droplet: (Chapter 9 on page 72.)

Review: The iDrive cantilever is based on the Droplet Holder covered in Chapter 10 on page 91. Please read this chapter for general use of the cantilever holder and the basics of using it for contact mode and AC imaging in liquid drops.

10.1. Nomenclature

See figure Figure 10.1 on page 92

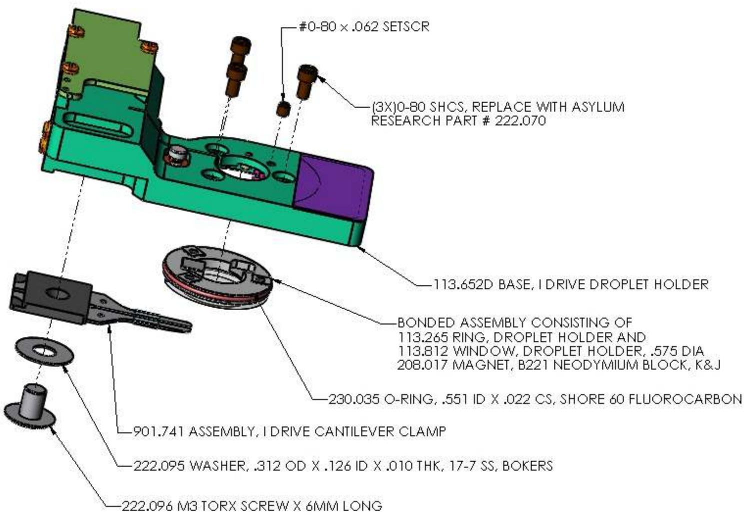


Figure 10.1.: iDrive Droplet Holder

10.1.1. Specific iDrive Droplet Holder Differences

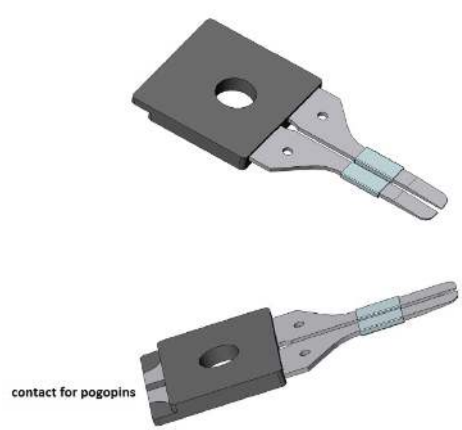
10.1.1.1. The cantilever clip assembly

The spring clip that holds the cantilever in the droplet holder is an assembly of two thin clips molded into a plastic block which together are the same basic shape as the single clip found on the standard droplet holder. In addition to clamping the cantilever, the split clip design is used as pair of electrical contacts to send the AC drive signal through an iDrive style cantilever. Inspecting the design of the iDrive holder will show that there are two gold spring clips (Pogo pins) that contact the back of the clips. These pins carry the AC drive signal from the droplet holder's circuit board.

Figure: Here are top and bottom views of the split clip assembly.

Notice:

- the exposed area of the clips which are the contacts for the pogo pins.
- the step along the molded section is used for keying the clip into the droplet holder body.
- the bands of Teflon act as a hydrophobic barrier.
- like the standard droplet holder clip, the bottom of the clips are tapered to provide sample clearance.



10.1.1.2. The window assembly

The window assembly used in the iDrive droplet holder differs only in that there is a magnet bonded to the top side of the glass window just above the cantilever.

Figure Here is a view of both window assemblies for comparison.

Note Due to limited space in the design of the droplet holders, the windows are not intended to be interchangeable. However, the standard window will fit into the body of the iDrive holder but the window from the iDrive holder will not fit in the standard droplet holder body.

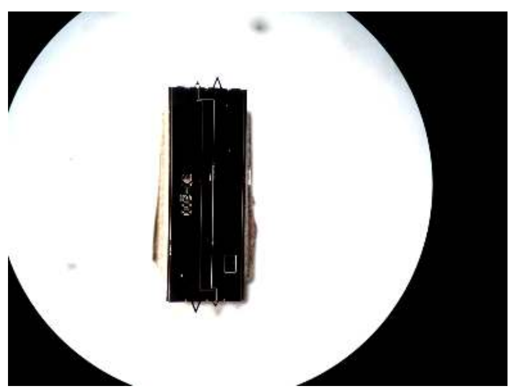
10.1.1.3. Installing an iDrive cantilever

Installing an iDrive style cantilever is basically the same process as a standard cantilever. The difference is that you need to pay close attention to the placement of the cantilever chip so that the split in the contact area on the chip is between the split in the cantilever clip. This will create a circuit so that AC current flows up through one clip, through the cantilever and returns through the other clip.

Figure Here is a view of the surface of an iDrive style cantilever.

Note

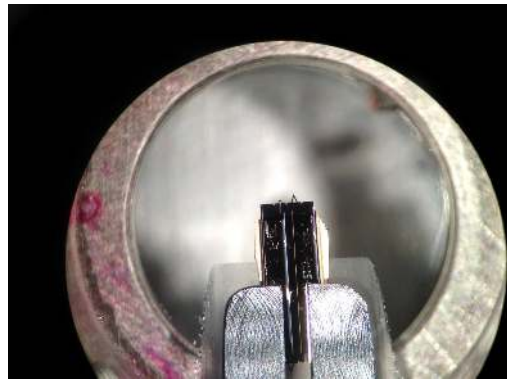
- The entire surface of the cantilever is coated with a layer of gold.
- The insulating lines are etched in surface to create to contact pads.
- Each of the outer pads are connected to one leg of the smaller cantilever.
- The center area is isolated and is not associated with the cantilever’s function.
- The typical resistance between the electrodes is 10 Ohms with both of the small cantilevers intact.
- It is okay to scan with both levers intact. Breaking off the unused small lever will simply raise the resistance of the conducting path but generally doesn’t improve performance.



1. **Install an iDrive cantilever into the droplet holder**

   - Align the chip under the electrodes so that only one cantilever clip contacts one of the contact pads.
   - Use an Ohm meter to check the resistance between the cantilever holder spring clips.

   Note The center narrower electrode is isolated so it's okay to allow one of the clips to touch it.



10.1.2. Preparing for Imaging

Since this cantilever holder is nearly identical mechanically to the Droplet Cantilever Holder, please refer to Chapter 10 on page 91 for details on

- mounting the sample and the sample dish,
- using the evaporation shield,
- installing the cantilever holder in the scanner,
- contact mode or acoustic AC mode imaging specifics,
- removal and storage.

Only keep reading on here for the specifics of iDrive imaging and cleaning and assembly instructions.

Tip	For contact mode or acoustic AC mode imaging, there is no need need to use special iDrive cantilevers. You can still use any standard cantilever for this type of imaging, just as you would with the standard Droplet Holder. Only use special iDrive cantilevers if you actually intend to use this method of exciting the cantilever.

10.1.3. iDrive AC Mode Tuning Specifics

1. With an iDrive cantilever installed, align the laser onto to the lever and take a thermal measurement.
2. Perform the same steps to manually tune the drive signal around the frequency range of the thermal peak as you would do for acoustic AC mode imaging.

Feature: Activating the tune for iDrive cantilevers

The software automatically scans the cantilever holder socket and identifies the type of holder you are using. In the Tune tab, the check box labeled iDrive will automatically be checked if an iDrive droplet holder is detected. If the iDrive check box is checked, the drive frequency is routed to the cantilever clip instead of the piezo electric actuator.

- Uncheck the iDrive check box to deselect the iDrive signal and send the drive frequency back to the piezo for acoustic AC imaging.

Figure iDrive Tune

Here is an example of a magnetically driven iDrive cantilever

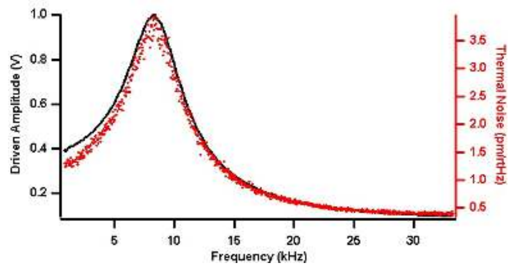
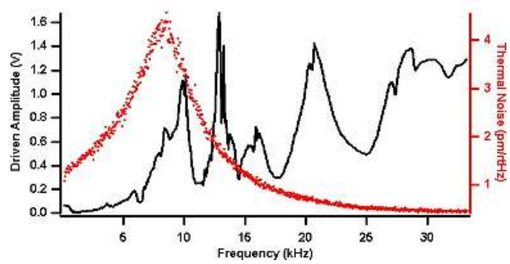


Figure Acoustic AC tune

Here is the same iDrive cantilever acoustically tuned using the piezo actuator.



10.1.4. Imaging Specifics

Once the cantilever is tunes and you initiate the engage routine, you may notice the free amplitude slowly decreases as the tip gets closer. This is due to the interacting of the steel sample puck interfering with the magnetic field lines emitted by magnet in the iDrive holder. As you see this begin to happen you may wish to increase the drive amplitude in the main controls tab. Generally a few "UP" clicks while the tip is approaching is all that's needed.

As a point of reference, a free amplitude of around 500mv may require 2-5v of drive. This is not a problem but simply a point to note as you learn to operate the system with these types of probes.

Another thing to note is that the volume of liquid has little affect over the amplitude response of the cantilever with iDrive. since the cantilever is driven magnetically and not by the acostic pressure waves transmitted through the fluid.

After an imaging session is completed, clean the cantilever holder before storage. If it is particularly dirty, disassemble it before cleaning. Please see 10.2 for the details. When clean and dry, store the cantilever holder and the other parts and tools in its designated kit box.

10.2. Cleaning and Repair

In daily use, the iDrive cantilever holder can be cleaned by rinsing the exposed surfaces of the glass window and cantilever clips with clean de-ionized water. Following the rinse, the holder can be dried using low-pressure compressed air or by blotting with a soft tissue.

For stringent cleaning, the iDrive cantilever holder must be disassembled. Only the parts exposed to the sample liquid should be cleaned. The cantilever holder body and associated electronics should be kept dry.

The cantilever holder clip, window assembly, Mounting hardware and evaporation control parts can be cleaned by soaking in ethanol. Sonication of the parts can also be performed. Rinse the parts in clean de-ionized water. Dry the parts with either low-pressure compressed air or a soft tissue before reassembling the holder.

10.2.1. Disassembly

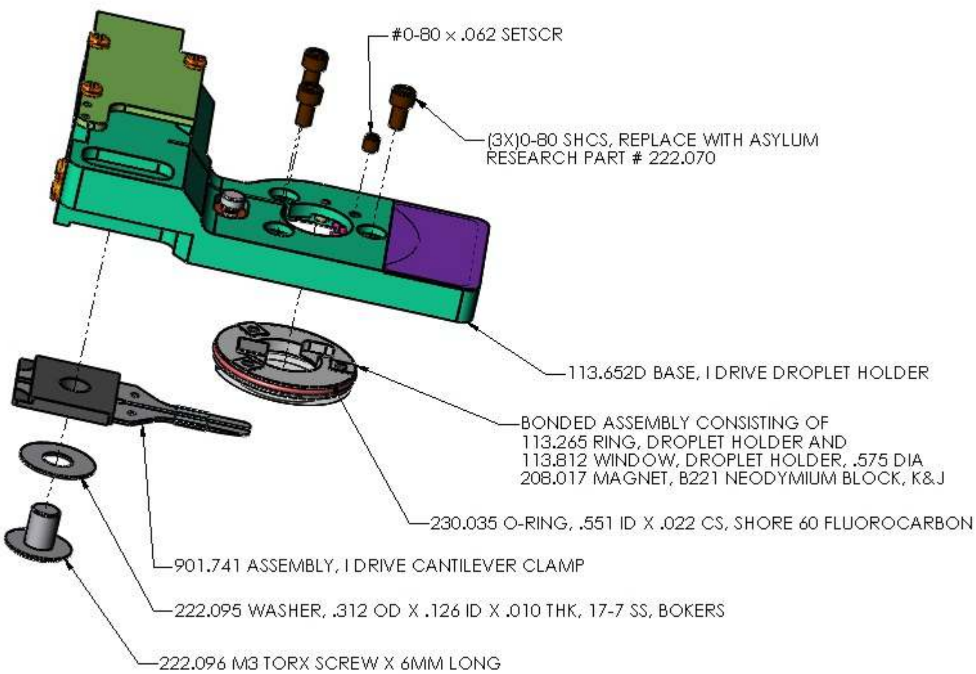


Figure 10.2.: Droplet Cantilever Holder Assembly exploded view

With the exception of the cantilever spring clip and the addition of a magnet to the window assembly, the iDrive Droplet holder is mechanically identical to the standard Droplet Holder. Please refer to the cleaning and repair section for the standard Droplet Holder.Section 9.6 on page 85

To summarize the steps to disassembling and cleaning the holder:

1. Remove the cantilever clip.
2. Loosen the preload set screw above the piezo actuator.
3. Remove the three screws retaining the window.
4. Gently push the window out of the holder body.
5. Clean the parts.

10.2.2. Reassembly

To summarize the steps in reassembling the iDrive holder

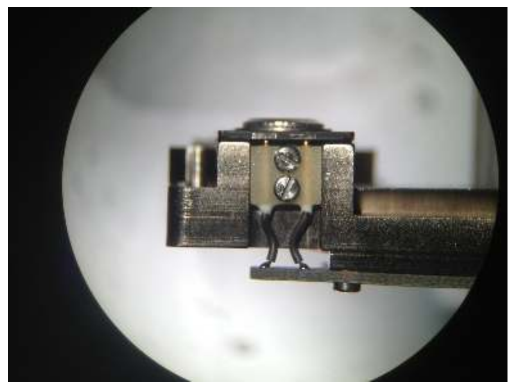
1. Install the window assembly.
2. Install the cantilever clip assembly.
3. Set the preload on the piezo for acoustic AC imaging.

Attention You may ask why the acoustic AC mode piezo is necessary when the iDrive system is available as an AC drive for the cantilever. Practically speaking, it's useful to switch back and forth between acoustically driving the cantilever and using iDrive. Even if you don't see the need, the next person using the cantilever holder might, so it's a good idea to perform the final piezo pre-load steps.

Tip Pogo pins

The pogo pins are spring loaded and carry the signal to the cantilever clip. Be careful not to bend them as you reinstall the cantilever clip assembly.

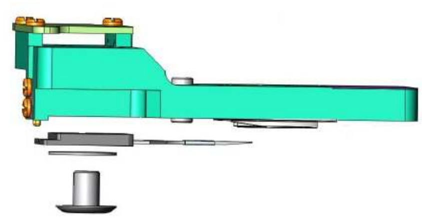
- Start by placing the cantilever clip in place
- Loosely thread the retaining screw. Don't forget the washer.
- Use tweezers to help keep the clip from rotating until the step on the back of the assembly mates with the step that is machined into the holder body.



Tip Aligning the cantilever clip on the body

The cantilever holder body and the clip assembly have a step that engage to help align the clip straight.

- The step in the plastic of the clip assembly can be crushed if you tighten the retaining screw with the clip improperly aligned.
- If the step becomes damaged residual plastic may be pushed over the pogo pin area and prevent the clip from touching the pins.
- Take time to familiarize yourself with the parts.
- Take your time when reassembling the holder



10.3. Older Models

There has been one significant redesign to both the standard and iDrive droplet holder. The design addressed:

- the complexity of disassembling and reassembling the holders after cleaning,
- Improvements in sealing the window from fluid leaks,
- ease of use of the evaporation shield.

If you have one of these versions of the droplet holders, please refer to this section for cleaning and maintenance.

Note	These revision holders are no longer made. There is an ongoing campaign to replace all of these holders free of charge. If you have already received a replacement droplet holder and you experience a failure of this design, we cannot support it. If you have not yet received a replacement droplet holder, and are experiencing a failure please contact Asylum Research.

10.3.1. Cleaning and Repair

In daily use, the iDrive cantilever holder can be cleaned by rinsing the exposed surfaces of the glass window and cantilever clips with clean de-ionized water. Following the rinse, the holder can be dried using low-pressure compressed air or by blotting with a soft tissue.

For stringent cleaning, the iDrive cantilever holder must be disassembled. Only the parts exposed to the sample liquid should be cleaned. The cantilever holder body and associated electronics should be kept dry.

The cantilever holder clips, insulator plates, window assembly and evaporation skirt can be cleaned by soaking in ethanol. Sonication of the parts can also be performed. Rinse the parts in clean de-ionized water. Dry the parts with either low-pressure compressed air or a soft tissue before reassembling the holder. please see 10.3.1.1

10.3.1.1. Disassembly

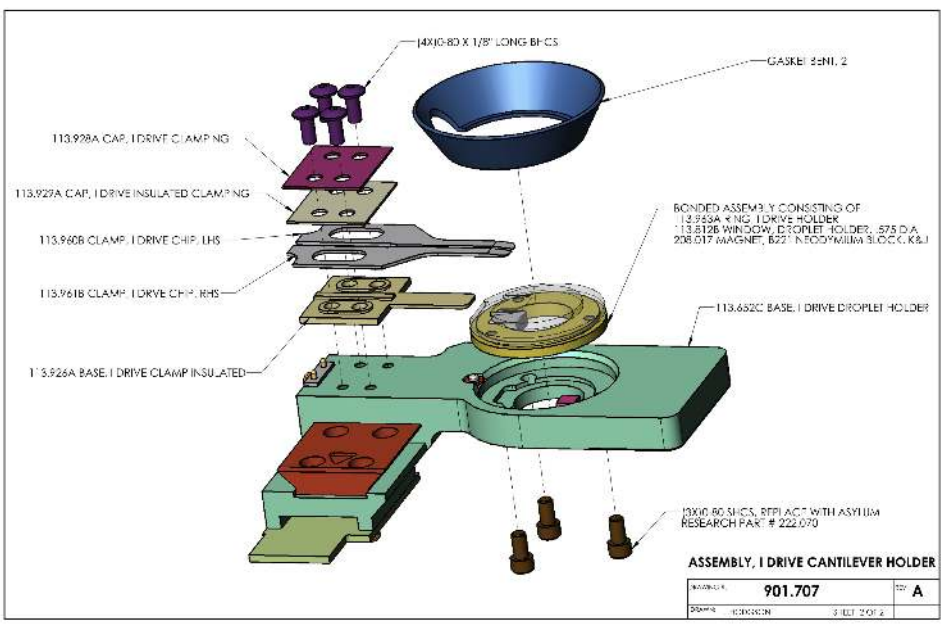


Figure 10.3.: Droplet Cantilever Holder Assembly Overview

The following steps will guide you through removing various components for cleaning as well as reassembling the holder afterward.

Before you disassemble the droplet holder, take the time to familiarize yourself with the way it is assembled.

The key components are:

- The cantilever clip and the associated mounting (insulating) plates
- The droplet holder window assembly
- The piezo actuator for performing AC mode.

As you disassemble the holder, take note that the screws for attaching the window assembly are shorter than the screws holding the cantilever clips. Reassembling the window with the longer screws can result in damage to the glass by either cracking or causing it to become detached from the metal mounting ring.

- Use only 0-80 x 7/64 Socket Head Cap Screws to attach the window assembly.
- Use only 0-80 x 1/8 Button Head Cap Screws to attach the cantilever holder clips.
- Use only 0-80 x 1/16 Cup Point Socket Set Screws for the piezo preload screw.

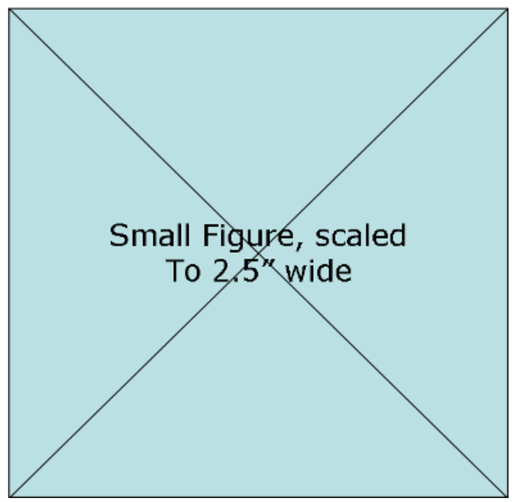
Due to wear and tear of use, the droplet holder accessory kit comes with replacement screws. Please contact Asylum Research or your local Asylum distributor for additional hardware if proper replacements cannot be obtained locally.

1.

Required tools and fasteners:

- 0.050” hex driver or Allen wrench for the 0-80 x 7/64??? socket head screws to attach the window assembly.
- 0.035” hex driver or Allen wrench for the 0-80 x 1/8??? button head screws to attach the cantilever holder clip.
- 0.028” hex driver or Allen wrench for the 0-80 x 1/16??? Cup Point Socket Set Screws for the piezo preload screw.

Warning Using other fasteners than those specified will damage your equipment.

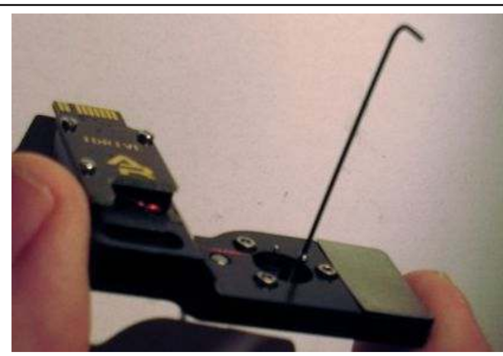


2.

Loosen the piezo pre-load screw

Tools 0.028” hex driver or Allen wrench

- Loosen the piezo preload setscrew 1 turn.

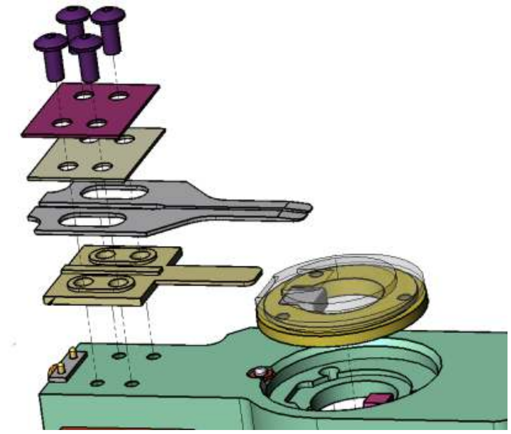


3.

Remove the spring clip

Tools 0.035” hex driver or Allen wrench

- Remove the screws securing the spring clips to the droplet holder body.
- Remove the clip and the spacer plates from the droplet holder body.
- Set the parts aside for cleaning.

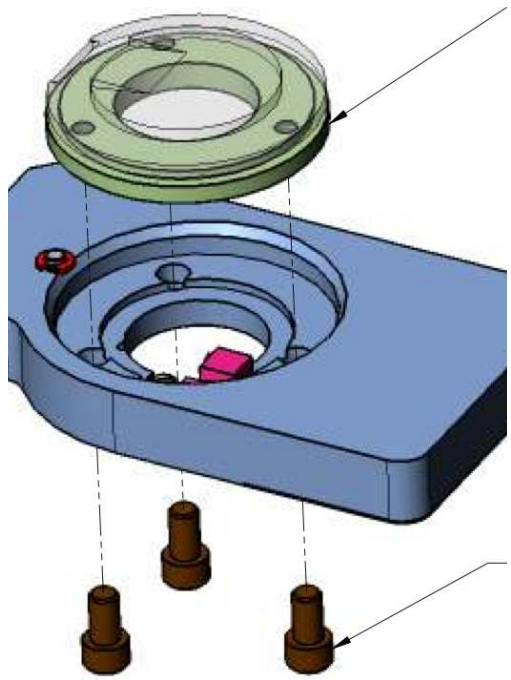


4.

Remove the window assembly

Tools 0.050” hex driver or Allen wrench

- Remove the three screws holding the glass insert into the holder body.
- Remove the window assembly.
- Separate the silicone evaporation skirt if installed.



10.3.1.2. Cleaning

The cantilever holder clips, spacer plates, window assembly and evaporation skirt can be cleaned by soaking in ethanol. Sonication of the parts can also be performed. Rinse the parts in clean de-ionized water. Dry the parts with either low-pressure compressed air or a soft tissue before reassembling the holder.

The rest of the holder parts can be cleaned with a cotton swab and ethanol. Avoid areas with electrical wiring or circuit boards. If you are unsure about having gotten the wrong bits wet, dry the parts (perhaps under the warmth of a desk lamp) for a while. Dry the parts with low pressure compressed air in any case.

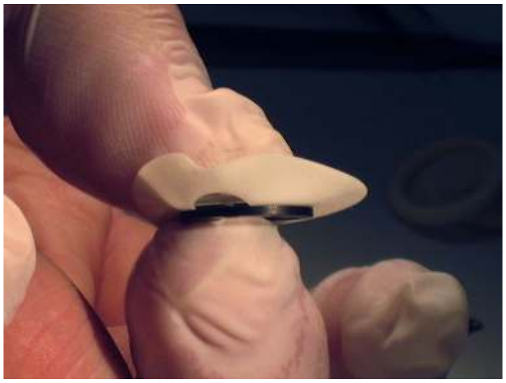
10.3.1.3. Reassembly

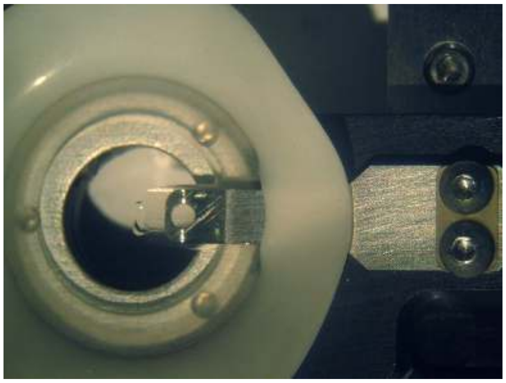
1.

Optional: Install the evaporation skirt

- Stretch the evaporation skirt around the edge of the window. The edge of the window has a small groove where the skirt fits.
- Align the cutout in the skirt with the cantilever pocket. The cutout is made to allow a hole for the cantilever clip to fit through the skirt.

Note The evaporation skirt is an optional part and is not required for normal use. If you decide not to use this part, please disregard the steps where reference to the skirt is mentioned.





2.

Position the window assembly

Tools 0.050” hex driver or Allen wrench.

- Place the window in the holder and use a finger to gently press the window into position.

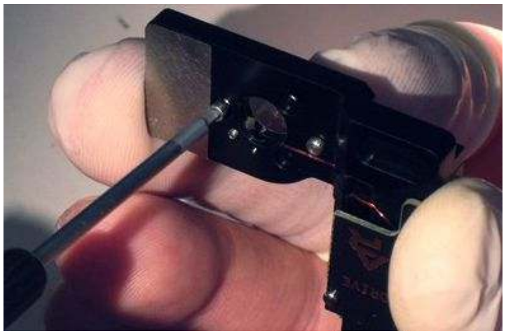
3.

Secure the window assembly

Tools 0.050” hex driver or Allen wrench.

- Secure the window to the holder using three 0-80 x 7/64 Socket Head Cap Screws.

Note Do not over tighten the screws. A small amount of torque is all that is required.

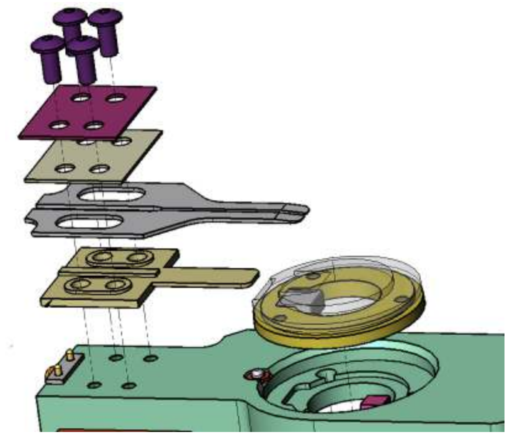


4.

Install the cantilever clip

Tools 0.035” hex driver or Allen wrench.

- Lay the cantilever holder body circuit board side down.
- Using tweezers, place the bottom spacer, clip, and top spacers. Pay attention to the raised features on the bottom spacer. They must face up to mate with the clips.
- The top-most spacer is metal (purple in the drawing) the one below that is plastic. Don’t reverse the order. The clips must be sandwiched between plastic or the iDrive current will be shorted before it reaches the cantilever.



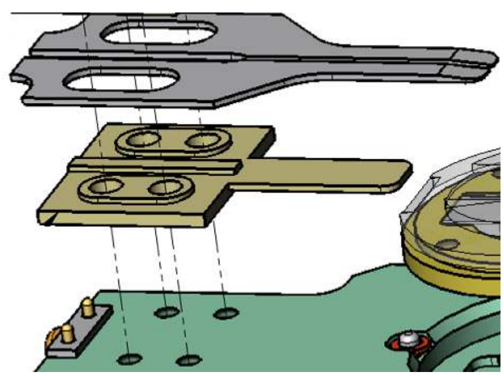
Note The tips of the clips are tapered. Be sure the flat side is against the glass.

- If using the evaporation shield, maneuver the clips through the hole in the shield.
- Thread in the 0-80x1/8 button head screws by only a few turns.

5.

Settle the parts together.

- Adjust the clips so that they seat over the raised portions of the lower insulator. As you shift the position of the clips they will locate around the raised areas on the lower insulator. When this happens the clips will feel looser in the stack up of the assembly.
- Continue to gently tighten the screws and readjusting the clip position until the gap between the parts is gone. Do not tighten the screws yet.

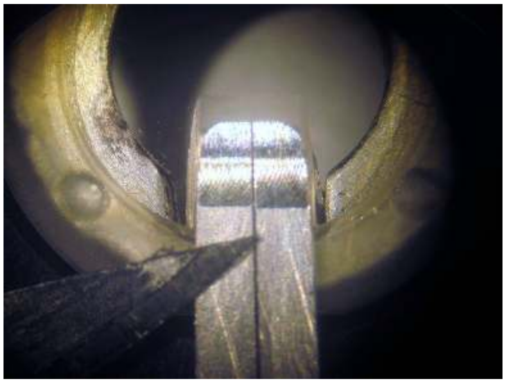


6.

Adjust clips, tighten screws

Optional Tools Stereoscope, scalpel or razor blade.

- Inspect the two clips at the end where the cantilever is held. The two clips should not touch. Adjust the clips if necessary. The point of a sharp razor or scalpel works well for this step. A stereoscope helps to see the details.
- Gently tighten the screws. Do not over tighten the screws. A small amount of torque is all that is required. Use only your fingertips on the hex driver tool.

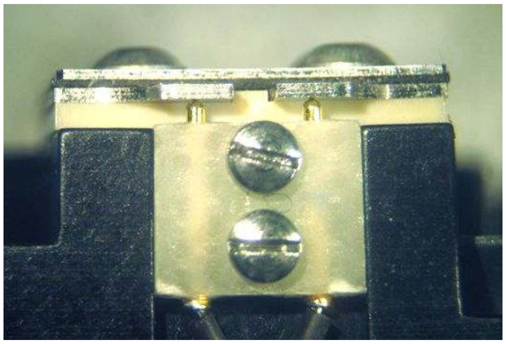


7.

Optional final inspection

Optional Tools Ohm meter.

- Where the clips are widest, measure the resistance between the two clips. It should be infinite (open circuit). If it is finite, then the clips are touching and you should loosen the four button head screws and repeat the previous step.
- The photo on the right shows a view from behind where you should see a stack-up (from top to bottom) of screw heads, metal plate, plastic plate, clips, thicker plastic plate, and then the aluminum cantilever holder. Note the two gold coated spring loaded pogo pins that must make contact with the clips for the iDrive system to function properly.



10.3.1.4. Adjusting Piezo Preload

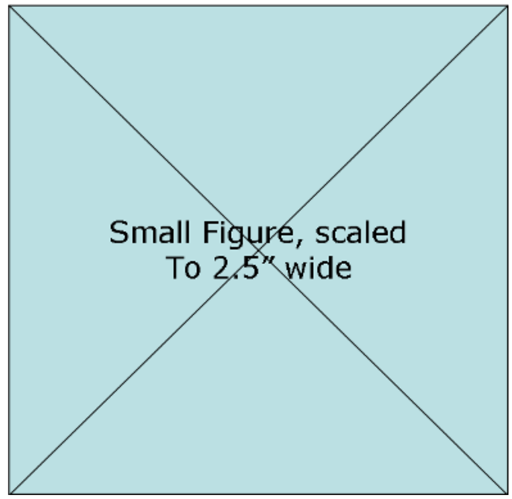
When first disassembling the droplet holder for cleaning, the preload screw was loosened. Doing this allows you to readjust the compression on the piezo element properly after it is reassembled. This is recommended since the amount of compression is very small and the piezo position may change when you remove and reinstall the glass window.

1.

Install the cantilever holder

Tools 0.050" hex driver or Allen wrench

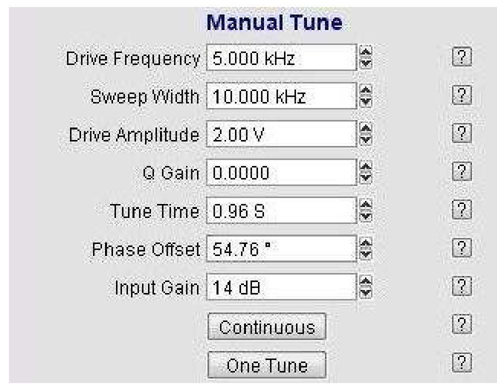
- Take the assembled cantilever holder, without cantilever installed, to the Cypher SPM.
- Insert the cantilever holder into the scanner.
- Finger tighten the screw which clamps it down.
- No need to do any motoring up or down. Move to the next step.



2.

Activate the tune sweep

- In the AR SPM Software, select the *tune tab* of the *master panel*.
- Under *Manual Tune*, set the parameters as shown to the right. Note the phase offset is not important and sweep time of 1s is fine too.
- Uncheck the *iDrive* control, or the piezo will not receive any drive signal.
- Hit the 'Continuous' (tune) button.

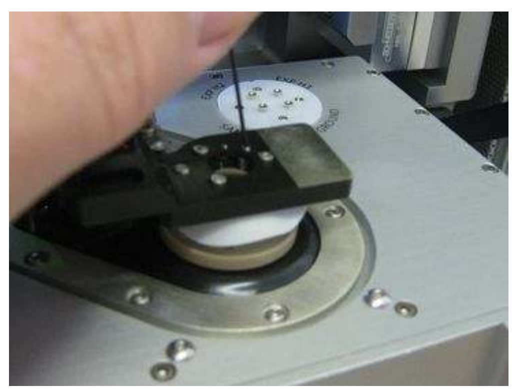


3.

Adjust the piezo compression

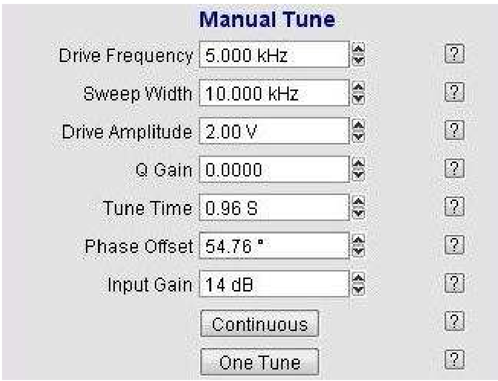
Tools 0.028" hex driver or Allen wrench

- Listen for a small chirping sound coming from the droplet holder.
- Gently tighten the preload setscrew until the chirping sound becomes abruptly louder. This is the point where the set screw has compressed the piezo into the back of the window assembly. Once this happens the preload is set.



4. **Finishing up**

- Back to the software, under *Manual Tune* hit the 'One Tune' button to stop the chirping.
- Done. Remove the cantilever holder and store it or put in a cantilever and start imaging.



You may ask why the acoustic AC mode piezo is necessary when the iDrive system is available as an AC drive for the cantilever. Practically speaking it's quite useful to switch back and forth between acoustically driving the cantilever and using iDrive. Even if you don't see the need, the next person using the cantilever holder might, so it's a good idea to perform the final piezo pre-load steps above.

11. Conductive AFM (ORCA)

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

This chapter explains the use of the ORCA cantilever holder. In practical terms, the ORCA cantilever holder is simply a standard air cantilever holder with the addition of a current to voltage converting amplifier.

Basic AC and Contact mode imaging can be performed with the ORCA holder. One major difference in its construction however is the use of the electrical connection to the cantilever spring clip. The cantilever clip is used as a connection to the input of the current amplifier rather than a connection to a bias voltage source. Because of this difference, the ORCA holder will not work for measurement techniques where the tip needs to be biased.

Note	EFM (Electric Force Microscopy), Surface Potential - SKPM (Kelvin Probe Microscopy), PFM(Piezoelectric Force Microscopy) imaging techniques require the use of the standard air cantilever holder.

11.1. Parts list

The following items are included in the ORCA cantilever holder kit. These accessories are included in both the single and dual gain versions of the holder.

Itm	Part #	Item Description	Qty	Picture

Itm	Part #	Item Description	Qty	Picture
1	901.730 901.708	ORCA Holder 2nA/V Dual Gain ORCA 1uA/1nA/V For other available versions see 11.2.	1	
2	ASTELEC-01	10 pack of conductive levers. Used for the measurements described in this section.	1	
3	823.009	HOPG sample. Used as a conductive AFM test sample. See Section 11.3.2 on page 111.	1	
4	448.079	Sample bias wire assembly. Connects sample to voltage source on top of the scanner. See Step 1 on page 112.	6	
5	208.05	Samarium Cobalt Magnet, 0.07” D X 0.104” L. Used to connect the bias wire to the sample. See Section 11.3.2 on page 111.	6	
6	290.160	Leitsilber Conductive Paint, 0.5 Oz. Used to conductively glue the sample to an AFM disc. See Section 11.3.2 on page 111.	1	

Itm	Part #	Item Description	Qty	Picture
7	448.082	Cypher ORCA 500M Resistor Assembly. A 500M Ohm Test Resistor. See Section 11.5 on page 113.	1	
8	448.081	Cypher ORCA 1M Resistor Assembly. A 1M Ohm Test Resistor (Dual Gain ORCA Only). See Section 11.5 on page 113.	1	

11.2. The ORCA Amplifier

There are a variety of ORCA cantilever holders each based on either a single or dual amplification design. The design type and amplification gain are labeled on the top of the holder. Like all the Cypher cantilever holders, a built-in circuit in the holder allows the software to automatically sense the type of holder and configure the system accordingly.

The amplification range of the ORCA amplifier is expressed by it's sensitivity. Basically the ability to produce a voltage output from a certain current flow into the tip. In terms of the full range of the ORCA amplifier, the output is +/-10v so multiplying the sensitivity by +/-10 will tell you the full range.

The ORCA amplifier incorporates the use of a trans-impedance amplifier which converts the input current from the tip to an output voltage. The input potential of the amp is referenced to ground so the tip is essentially held at 0v potential. During the measurement, the sample can be biased between +/-10v using a voltage source provided by the Cypher electronics.

Each ORCA cantilever holder has a fixed gain(s) to provide the highest current measurement range while considering the lowest noise. The following ORCA holders are currently available. Custom holders can be configured on request.

Part number	Sensitivity	Current Range	Typical noise 1-1KHz
901.730	2nA/V	+/-20nA	1.5pA
901.737	0.2nA/V	+/-2nA	750fA
901.708	1nA/V	+/-10nA	3pA
	1uA/V	+/-10uA	75pA

11.2.1. Single Gain

Here is a conceptual block diagram of the single gain ORCA amplifier. The sample is biased from a voltage source within the Cypher electronics. The feedback resistor R1 sets the amplifier's sensitivity. The output signal representing tip/sample current flow can be monitored by enabling the 'Current' channel in the master channel control panel. See Figure 11.1 on page 109.

11.2.2. Dual Gain

A conceptual diagram of the dual gain ORCA amplifier shows the initial current to voltage converter stage feeding the input of a second gain stage to create an additional output signal. In the case of this design the more sensitive

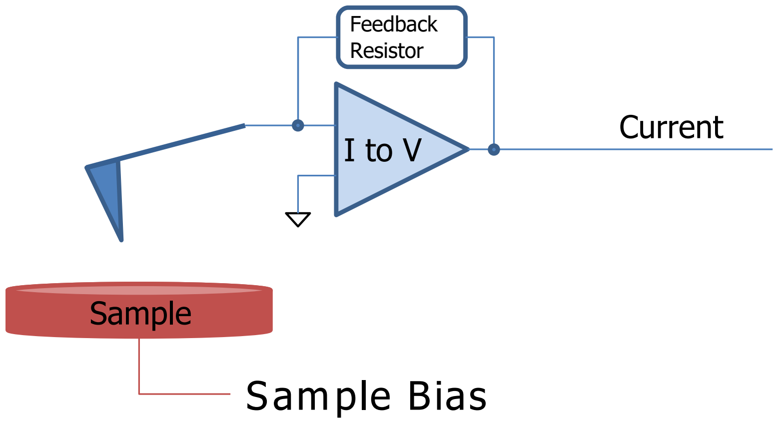


Figure 11.1.: Single Gain ORCA

signal comes from the second stage and is monitored as 'Current' from the master channel panel like the single gain ORCA holder.

The output of the current to voltage amplifier's first stage has a lower gain (more total current range) signal is monitored as 'Current 2' from the master channel panel.

Having a dual gain design is useful in that it expands the dynamic range of your measurement capability but at a sacrifice of some increased noise at small current levels. In many cases the sample you may wish to measure may have widely different regions of conductivity where the current may be too large for the range of the more sensitive stage but suitable for the lower gain stage where more current can be measured. In this case it is common to see the 'Current' signal (high gain stage) saturate while the 'Current 2' signal show a measurable current flow. See Figure 11.2 on page 109.

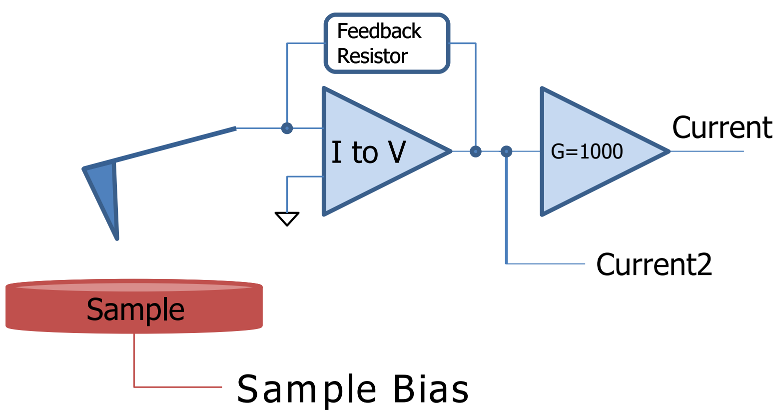


Figure 11.2.: Dual Gain ORCA

11.3. Preparing for Imaging

11.3.1. Zeroing the ORCA Current and Sample Bias signals

The signal path through the Cypher can pass through many stages of signal conditioning. Each particular circuit in the signal path can introduce a voltage offset which when added together can skew the zero point of your measurement. The following adjustments should be made to your system prior to imaging.

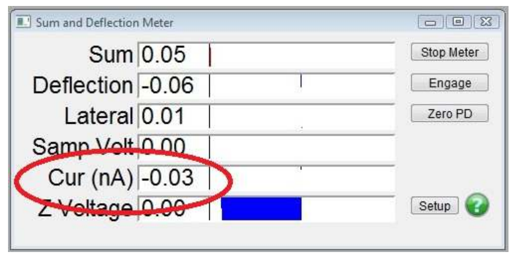
11.3.1.1. Zeroing the ORCA current signal

1. Start the Cypher software if not already running.
2. Select contact mode as an imaging mode.

3\. **Install the ORCA holder into the scanner's tip engage pillar.**

- The software will automatically add the ORCA current and Sample Voltage to the items shown in the SUM and Deflection meter window.
- Push the scanner into the chassis and close the enclosure door. The ORCA current amplifier is sensitive to RF and other emitted signals such as florescent lighting.
- Note the current being registered in the Cur display. In this example, the offset current is around -30pA.

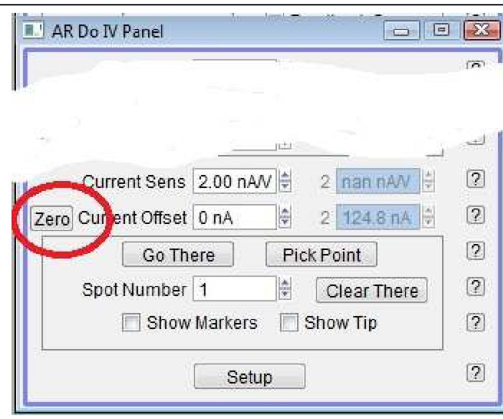
Note If the Sum and Deflection meter window does not update, Try adding Current as one of the data channels in the Master Channel panel and then reselect Contact mode as the imaging mode the system.



4\. **Open the Do IV control panel**

- Go AFM Controls to locate the DoIV panel.
- Locate the Current Offset parameter at the bottom of the window.

Note If you are using a Dual Gain ORCA holder, the Current 2 offset and Sens. will be active.

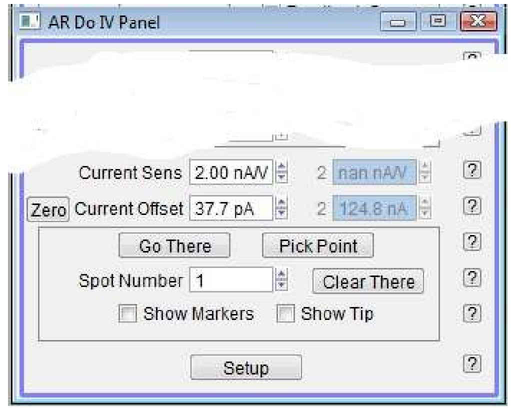


5. **Press the ’Zero’ button to zero the current**

- The Software will add the appropriate offset from the Current data to make the Current 0A.
- Verify that the current is zeroed.

Note This is only a software offset. The actual electrical offset in the instrument is still present.

Note If the zero button is not present in your version of the software, zero the offset current by typing the amount of current shown in the Cur value in the SUM and Deflection meter panel.

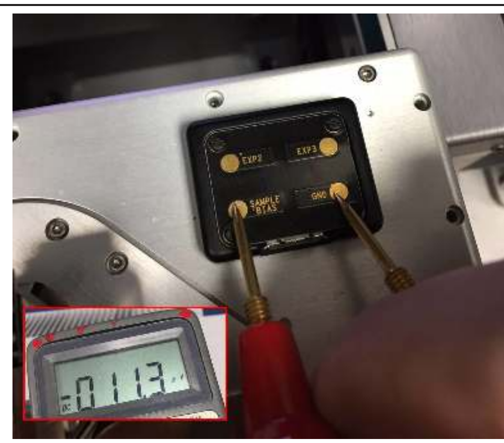


11.3.1.2. Zeroing the Sample Bias

1. **Measure the Sample Bias voltage on the scanner’s terminal block.**

- Check the ’Use’ check box next to the Sample Voltage parameter in the DoIV control panel.

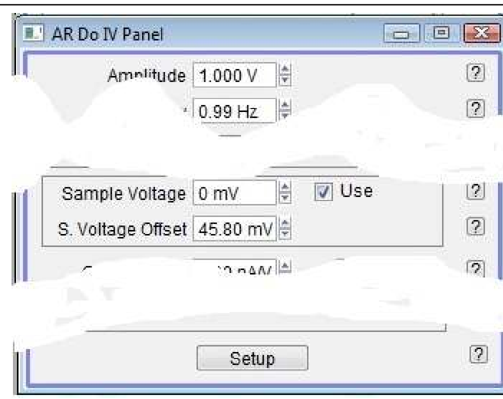
Note In this example, the measured offset Bias voltage is -46mV



2. **Enter the amount of offset voltage needed in the S. Voltage Offset control parameter.**

- Use the opposite sign of the voltage measured on the voltmeter to negate the actual voltage.

Note Make sure that the Sample voltage parameter is set to 0 volts when making this adjustment.



3. Change the Sample voltage parameter and verify that the corresponding voltage appears on the Sample pin on the scanner’s terminal block.

11.3.2. Preparing the Sample

Sample preparation varies but basically the goal is to provide an electrical path between the sample bias and the surface of your sample. In addition to the electrical connection, care should be taken to mount the sample mechanically to a sample puck as you would with any sample.

The ORCA kit comes with a practice sample of graphite (HOPG) mounted to a steel puck. A small magnet is attached to the sample puck to provide an easy way for the bias lead to attach.

The magnetic connection method is convenient but is not necessary. A bias lead of your own design can be mounted directly to the sample puck and used as long as the end of the lead is able to fit into the sample voltage socket on the scanner's terminal block. Also, be certain to use wire that is flexible enough to not impede normal scanning.

The following steps describe how this sample was prepared.

1. Use a small amount of 5 minute epoxy to attach the HOPG to the sample puck.
2. Place a magnet onto the puck.
3. Cover the sides of the sample and the entire magnet with silver paint.

Attention	The silver paint is not an adhesive. It will not provide good attachment of the sample to the sample puck. Use the paint only to make an electrical connection from the sample to the bias voltage lead.

11.3.2.1. Install the sample on the scanner and connect the bias lead

1. **Place the sample on the scanner stage and connect the bias lead**

- Position the sample so that the magnet is on the right hand side of the scanner to prevent interference with the cantilever holder.
- Attach one end of the bias wire to the magnetic contact on the scanner top.
- Place the other end of the lead on the magnet. The lead is magnetic and will stick to the magnet when it's close enough.

Note The scanner cap is hard anodized aluminum and will insulate the sample puck so bias voltages up to +/-10v can be directly connected without additional insulation.

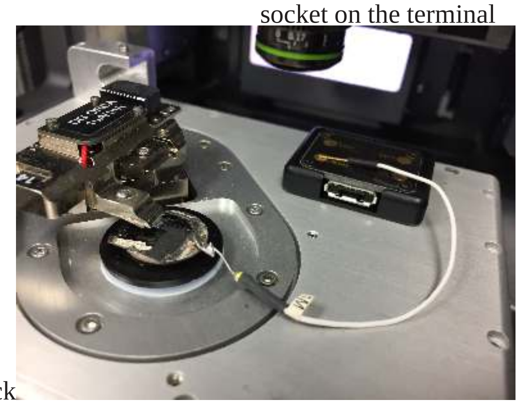
2.

Adding resistance in the bias voltage path

- In cases where your sample is highly conductive, you may want to add a known resistance to keep the ORCA amplifier from saturating. An example of this is the HOPG sample provided in the kit.
- Substitute the Bias lead with a bias lead including a resistor.

Note The ORCA holder kit includes a 500Meg. Ohm test resistor. If you are planning on scanning the HOPG sample to practice using the ORCA holder, use the test resistor instead of the bias lead.

Plug on end of a bias voltage lead into the sample socket on the terminal block



11.3.3. Mounting the Cantilever

Mounting a cantilever is the same procedure as is used in all other AFM applications with the exception of lever type. Conducting AFM (ORCA) requires a conductive path between the tip and the cantilever spring clip. The ORCA kit includes a sample pack of 10 Electrilevers. Additional levers can be purchased from Asylum Research.

If you are not familiar with basic AFM operating practices, please review The basic operating tutorials section at the beginning of this guide.

11.4. Imaging with the ORCA

Please refer to *Applications Guide, Chapter: Conductive AFM*.

11.5. Testing the ORCA Amplifier

The ORCA cantilever holder kit includes an appropriately sized resistor to test the measurement range of the ORCA amplifier. Testing the ORCA is fairly straight forward. Basically the test resistor in installed between the sample bias and the cantilever clip. An I/V ramp is plotted and the correct current flow through the resistor should be observed.

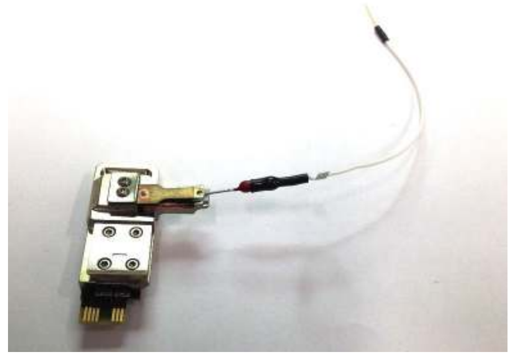
1. **Install the test resistor under the clip on the ORCA holder**

- Hold the ORCA holder upside down in your hand and use a fingernail to press on the button on the top side of the holder to open the cantilever clip.
- Slide the resistor lead under the clip.
- Release the button to clamp onto the resistor lead.

Note Using the changing stand also works but you may find that getting the resistor installed and removing the holder from the stand is a bit tricky. Using your fingers as described works well.

Note The cantilever holder body is conductive. Position the lead under the clip so that is does not touch the holder body. Basically, take care not to insert the resistor lead too far under the clip or have it off center.

Note It is not harmful if the resistor shorts to ground. The current from the sample bias through the resistor will not be measured by the holder.

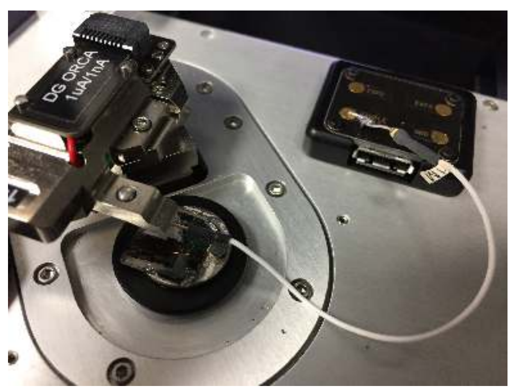


2. **Option 1: Install the cantilever holder and connect the test resistor to sample bias**

- Insert the ORCA holder into the scanner's engage pillar.
- Plug the lead from the test resistor into the sample bias socket on the scanner's terminal block.
- Slide the scanner into the chassis and close the enclosure door.

Note You may wish to double check the lead under the cantilever clip to ensure it is not shorted to the holder body.

Note The enclosure acts like a Faraday shield which will help reduce outside electrical noise.



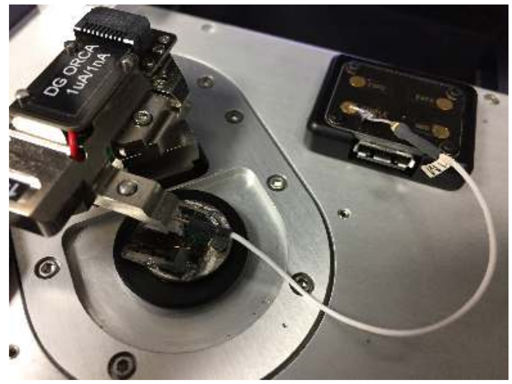
3.

Option 2: Install the cantilever holder and bias sample directly

- As is noted here and in the Applications manual, having a resistor is beneficial as in a closed circuit, the current will be much high than normal. A resistor will help dissipate issues.
- Insert the ORCA holder into the scanner's engage pillar.
- Connect the bias wire to the scanner's terminal block, either by plugging the wire in or with a magnet, then connect other end to sample.
- Slide the scanner into the chassis and close the enclosure door.

Note You may wish to double check the lead under the cantilever clip to ensure it is not shorted to the holder body.

Note The enclosure acts like a Faraday shield which will help reduce outside electrical noise.

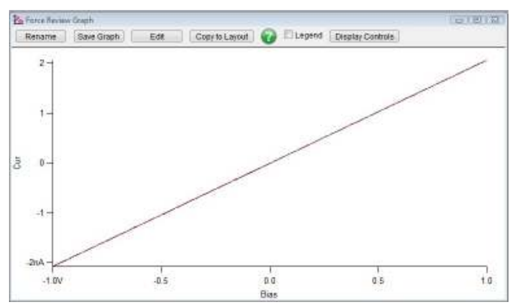


4.

Do an I/V plot and confirm the correct current flow

- Go to AFM Controls-> Do IV panel and open the I/V voltage controls.
- Press the Do I/V button to perform an I/V curve.
- Confirm the current flow is the correct amount based on the test resistor value.
- Confirm the I/V plot is linear with 0 current flow coinciding with 0 volts of bias voltage.
- If the current is not flowing through 0 then recheck the current and voltage offsets are set correctly.

Note The 500M Ohm resistor should allow 2nA of current to flow for 1V of bias voltage.



11.5.0.1. Testing the first gain stage of a Dual Gain ORCA Amplifier

Testing the final output of a Dual Gain ORCA amplifier is done in the same manner as testing the Single Gain ORCA amplifier. Since the two gain stages are in series, the first gain stage is automatically checked by default.

You can verify that both the Current and Current 2 data channels are active in the software by monitoring both signals when doing an IV plot. When using the 500M Ohm test resistor, you will notice the limits of resolution and noise in the Current 2 signal as compared to the Current signal. See Figure 11.3 on page 116.

The Dual Gain ORCA accessory kit includes a second 1M Ohm test resistor which is more suitable for the current ranges of the primary gain stage.

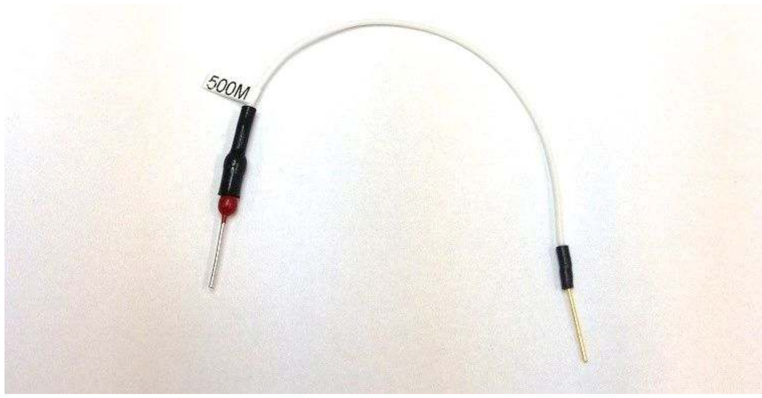


Figure 11.3.: 2nA current flow through a Dual Gain ORCA

1. **Test the first gain stage of the Dual Gain ORCA Amplifier**

- Install the 1M Ohm test resistor.
- Do an IV plot.
- Monitor both the Current and Current 2 data channels.
- Verify that the 1Meg Ohm resistor produces 1uA for 1 volt of sample bias.

Note Note the behavior of the Current signal as it saturates from too much current flow through the circuit. This test is not harmful to the ORCA amplifier. It is mainly a way of demonstrating the behavior of the circuit when the final gain stage is saturated.

12. Scanning Tunneling Microscopy (STM)

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

12.1. Introduction and Preparation

This is a fairly basic set of instructions on STM imaging with Cypher. At some point we hope to do a more proper STM tutorial chapter which focus on imaging graphite with atomic resolution.

This chapter assumes you are familiar with AFM techniques on Cypherl you should first complete the tutorial in Chapter 7 on page 40 at least once.

12.2. Required Equipment

- Cypher Standard Scanner
- Handheld Digital Voltmeter
- Cypher STM tip holder (See Figure 12.1 on page 118)
- STM tips
- Jumper wire for applying bias to conducting sample
- Some tiny magnets and some tweezers and a few tools.

12.3. Preparing an STM sample

1. Place your sample on a steel AFM disc. It’s assumed the sample is conducting and has a relatively flat bottom.

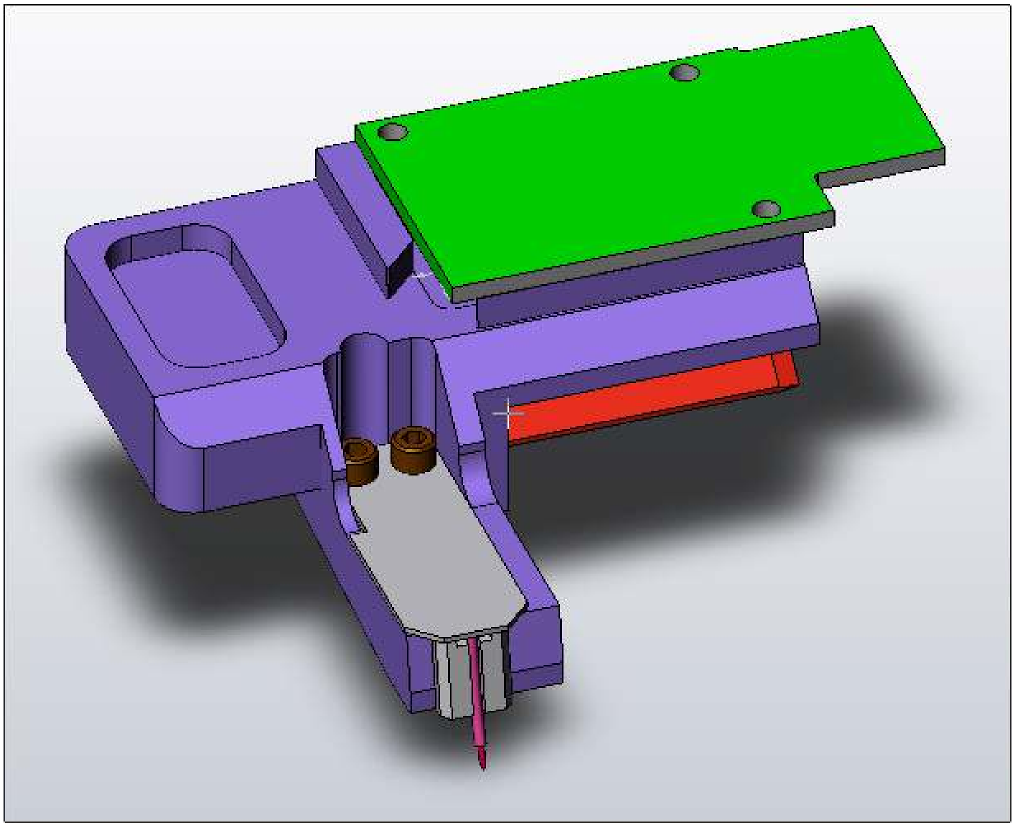


Figure 12.1.: Cypher STM tip holder. Note the probe tip sticking from the small tube.

2. Put some small dots of silver paint around the perimeter of the sample. And let the paint dry in a warm place, like under a desk lamp.
3. Place the sample on the Scanner.
4. Place a small magnet next to the sample. The STM kit includes 5.
5. Plug the bias wire into the 'sample' socket on the scanner's terminal block.
6. Stick the other end of the wire to the magnet next to the sample. You can also attach the wire directly to the sample puck.

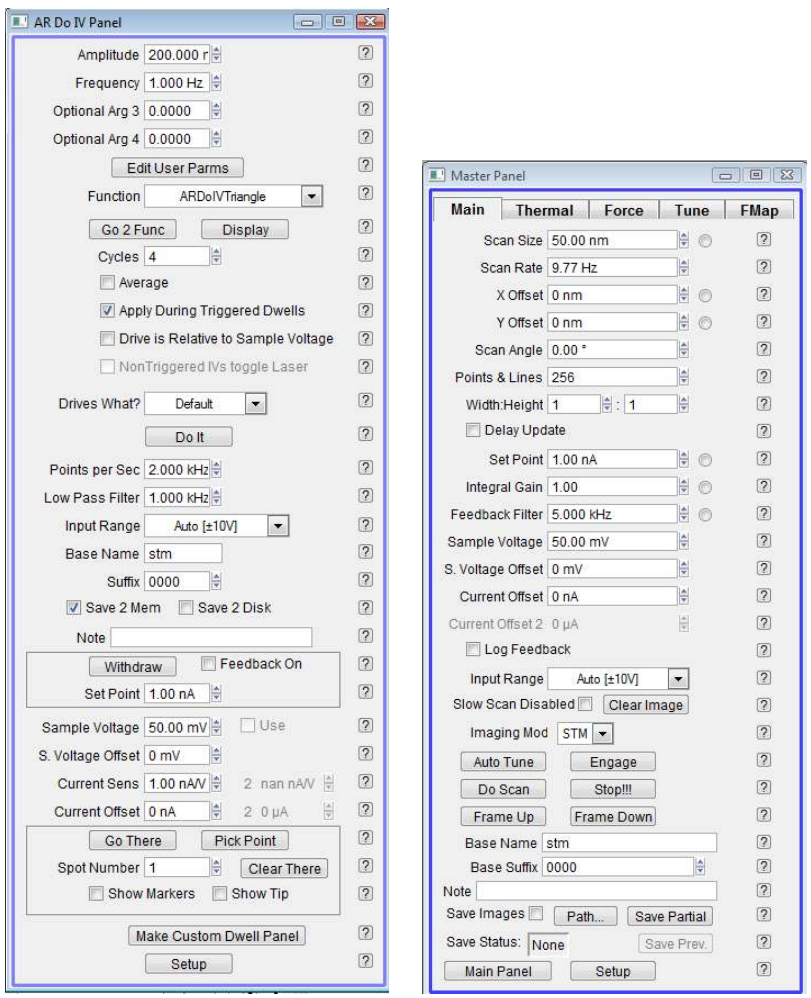
Note The surface onto which you place the magnetic AFM disc is black anodized aluminum. The anodization acts as an insulator which means the sample is only electrically connected to the attached bias wire. If you ever see any metal through the black surface (a possibility due to excessive wear, nicks, or abuse) then the sample bias may not work properly. If that is the case a thin insluating layer, such as a thin sheet of mica, can be placed under the sample disc.

Additional magnets and bias leads can be purchased separately if this mounting method is desired.

Alternately, simply bonding a small length of wire directly to the sample puck with solder or silver epoxy works well. In many cases fixing the sample and bias voltage connections are sample specific. The sample socket on the terminal block is sized to accept the diameter of a standard 1/4watt resistor lead or similar diameter wire for making your own bias leads.

12.4. Load the tip

1. Locate your box of STM probe tips or see Section 12.10 on page 125 about making your own.
2. With tweezers insert the STM probe into the holder. Note that the probes are straight and not curved. This is intentional. The tube in the STM holder is bent with a slight curve. This bend will cause the straight probe wire to fit tightly and reduce potential of drift due to the effects of stress in the wire. Push the probe wire into the tube until the end of the wire begins to extend out of the top of the tube. Don't touch the tip at any time.
3. Install the sample on the scanner.
4. Attach bias voltage lead from sample to 'Sample' socket on scanner's terminal block.
5. Insert the tip holder into the scanner and secure it with the 0.050" hex driver tool.



(a) DO IV Panel with highlights for STM

(b) Master Panel Main Tab set up for STM imaging

Figure 12.2.: Some relevant control panels you will encounter during STM operation.

12.5. Zero Various Offsets

NOTE The specific values in the screen shots in the following steps are often just examples of what you might encounter. Read the instructions carefully and record your own values where necessary. The parameters used in this procedure are for the Graphite test sample provided.

1. **The Mode Master window:**

- The software should now be showing the Mode Master window.
- If not, click the Mode Master button at the bottom of the screen: C:/svn/rasy-svn/ConfigurationFiles/ModeMasterFigures/Version 15/ModeMasterBu

C:/svn/rasy-svn/ConfigurationFiles/ModeMasterFigures

2.

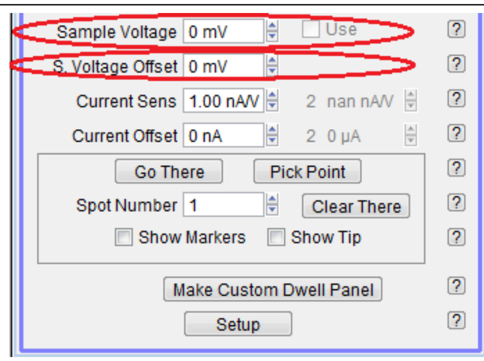
C:/svn/rasy-svn/Configu ▷ C:/svn/rasy-svn/ConfigurationFiles/ModeMasterFigures/Version 15/ModeMasterFigures

Select Mode:

- Select *Electrical tab* ▷ *STM*
- The screen will now re-arrange and present all the controls necessary for this type of AFM imaging.

3. **Set surface voltages**

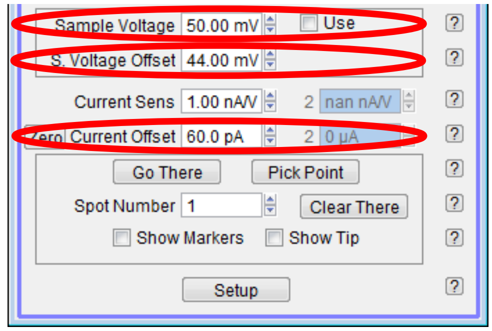
- On the *Do IV Panel* Set the Surface Voltage and the Bias offset to 0V.



4. Use a hand held digital voltmeter to measure the voltage between the Sample and Ground pins on the scanner's terminal block.

5. **Enter Bias Offset**

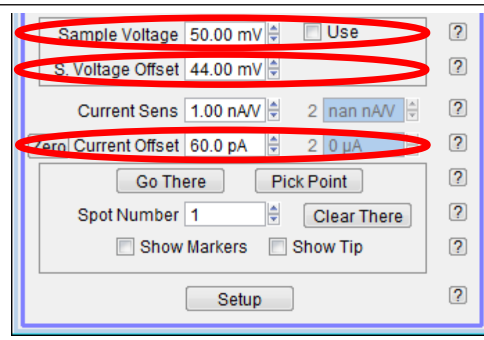
- Enter the measured voltage in the Sample Bias Offset field, but the opposite sign to zero the offset voltage.
- Enter 100mV for the ‘Surface Voltage’ and hit enter.



6. Use your digital voltmeter to measure the voltage between the Sample and Ground pins on the scanner terminal block again and verify that it also reads 100mV. Try this a few more times for some additional ‘Surface Voltage’ values to make sure the offset bias is doing its job.
7. When done, set the ‘Surface Voltage’ back to 0V.

8. **Enter Current Offset**

- Go back to the ARDoIV panel.
- Click on the zero button to the left of current offset. The current should now read zero in the sum and deflection meter.



12.6. Set up to engage

Note The optics in the view module were intended for an AFM cantilever. Due to the tip position pointing down below the probe wire and focus distance of an STM probe from the objective being relatively long, it is necessary to bypass the normal AFM alignment process and simply bring the tip down manually close to the surface and then click the *Engage* button.

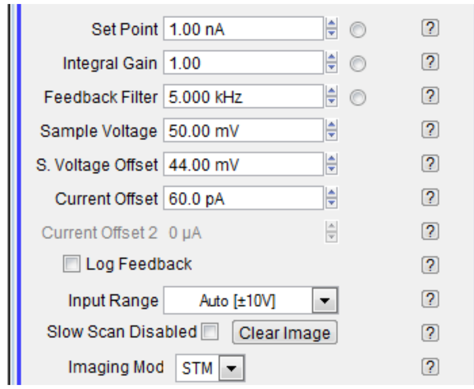
1. Use the wheel on the enclosure to move the tip to the sample. Get the tip to the desired engage distance of about 0.5 to 1 mm above the sample. Use the tip and the reflection of the tip in the sample surface as a guide to bring the probe close.

12.7. Set scan parameters

1. Go back to the *Master Panel*, Main Tab (See Figure 12.2b on page 119). You can enter your scan size and rate as in the figure and modify it once you are scanning.

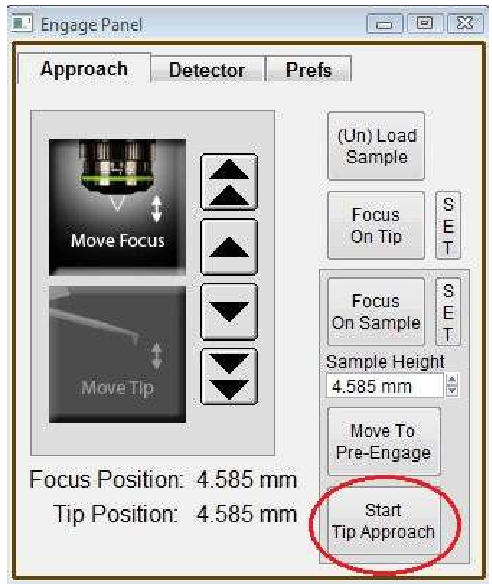
2. **Enter Feedback Parameters**

- Set the *Surface Voltage* to the desired bias voltage for the sample. For Highly Oriented Pyrolytic Graphite (HOPG) use ~50mv.
- Set the Setpoint voltage to the desired tunneling current. Use ~1nA for HOPG.
- Set the *Feedback Filter* to 10KHz.
- Set the Integral gain to ~0.5 or 1.0. The STM feedback uses much less gain than typical AFM due to the use of log feedback.



3. **Start Tip Approach**

- In the ‘Engage Panel’ click on the ‘Start Tip Approach’ button. Because the sample surface was not optically located, as we do with a typical AFM approach, this process may take a little longer than you are used to from AFM. In that case Cypher will first rapidly motor down to about 50 μm above the surface (measured from the optical image focus position) and then start its slower final engage process (for more information see the Q&A box on page 60). In the case of STM the slower engage process starts from where ever you motored the tip to manually.



4. Once on the surface you can perform scans as you are used to with AFM.

12.8. STM IV Curves

The process of doing an STM IV curve uses a triggered force curve where the system will:

1. Trigger off of the Current channel
2. Dwell at the surface using the Z position sensor to hold the tip at a constant Z height above the surface
3. Ramp the bias voltage using the ramp functions in the Do IV panel.

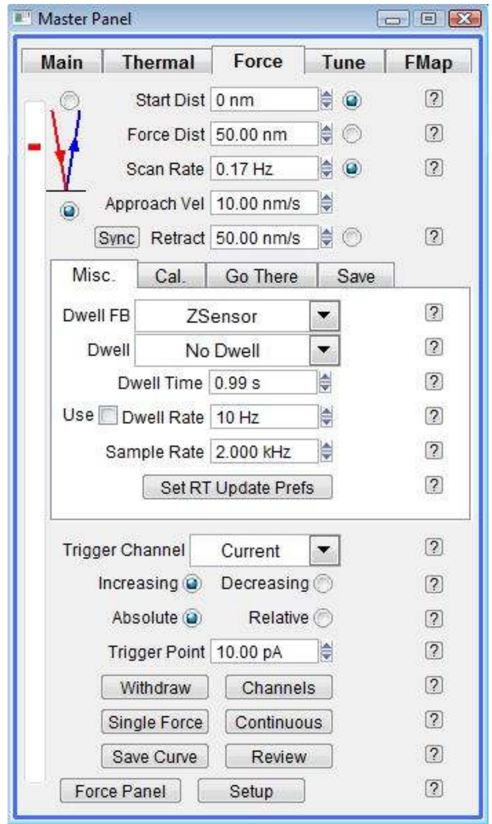
12.9. Set IV Parameters

1. The *Feedback Filter* must be reduced to 1kHz in the *Master Panel*. Typically for scanning, the feedback filter is between 5kHz and 10kHz but for IV measurements when triggering on currents as low as 10pA (in a quiet lab) high frequency signals must be filtered.

2.

Trigger Channel Current

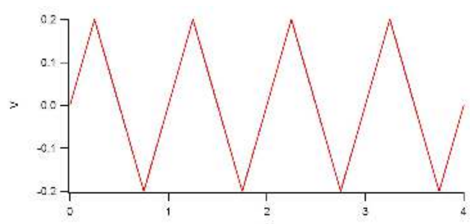
- Click on the *Force* tab and set the desired trigger point. The trigger point is the setpoint current where the system establishes the tip height during IV measurements. The lowest trigger current possible is ~10pA, any current lower than this will be close to the noise limit and cause the system to false engage.
- To reduce the approach velocity the *Force Distance* is set to 50nm and *Scan Rate* ~0.2Hz . This is necessary to avoid the tip moving beyond the height when the feedback loop clamps the Z-position. A sudden change in tip speed can cause the tip to overshoot.



3.

AR Do IV Panel

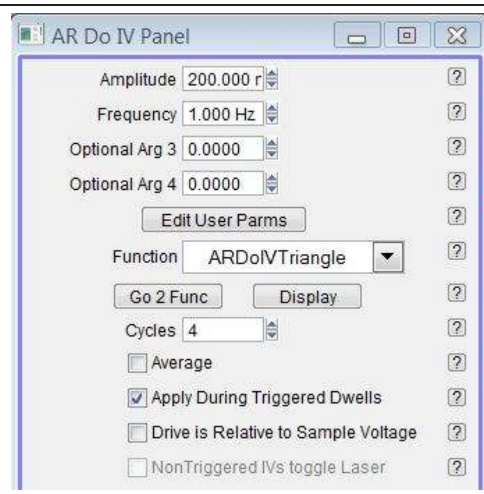
- Click on the *Display* button in the *AR Do IV* Panel to display the bias ramping waveform



4.

Drive Graph

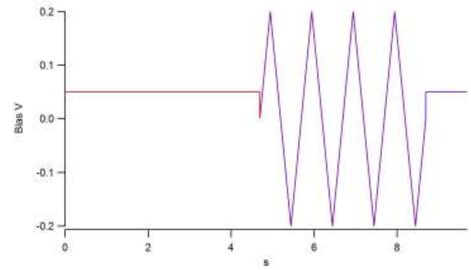
- Adjust the *Amplitude*, *Freq*, *Optional Arg 3* (Phase Offset), Optional Arg 4 (Voltage Offset) parameters to make the desired ramping waveform.



5.

Drive Graph

- This is the result of the Ramp during IV measurements. Notice that the voltage before and after the ramp is not 0v, the voltage used for the triggered current (in this case 50mV) is kept before and after the ramp.

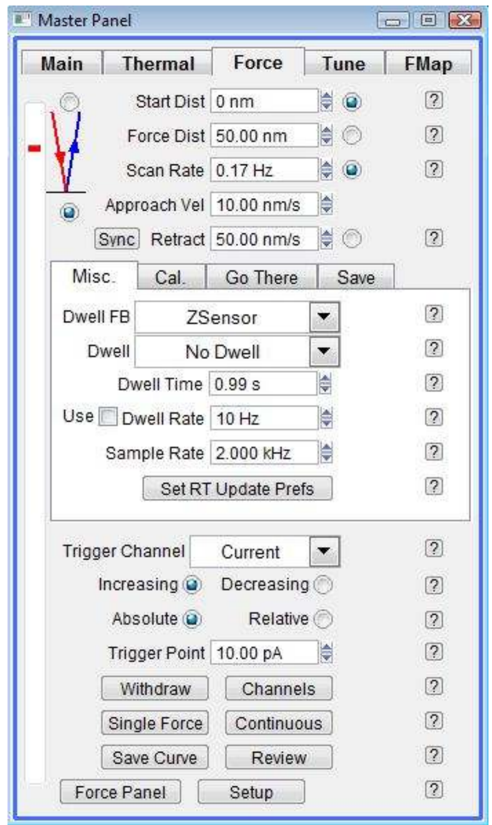


6.

Finding the Surface There are two ways to bring the tip close to the surface for IV curves

a) Click *Engage* in the master panel and when the tip is on the surface hold the shift button and left click mouse button on the vertical bar for the z-range piezo. This will set the force range to be close to the surface. Make sure the Integral gain is low enough such that the tip does not oscillate.

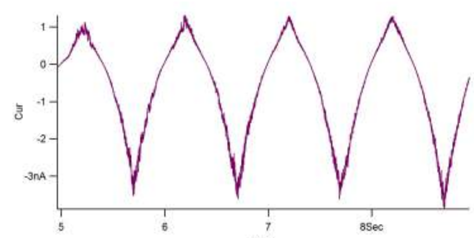
b) The other method is to change the *Force Distance* to 300nm, and click *Single Force* (50nm Force Distance will take too long). Make sure to switch the Force Distance back to 50nm when making measurements.



7.

Single Force

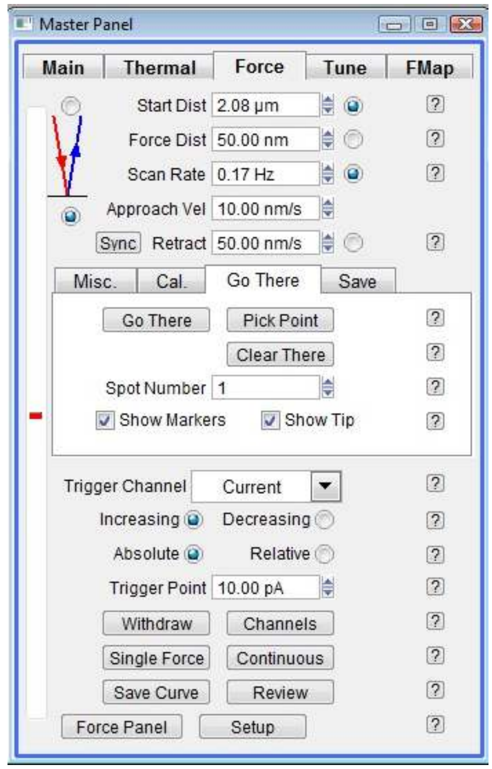
- Clicking *Single Force* button will perform individual IV measurements.
- This will perform a triggered force curve and dwell on the surface using the Z sensor while running the ramp waveform from the *Do IV Panel*.



8.

Point and Shoot Tip positioning

- Engage and image the sample surface
- Hit *Stop* or *Withdraw* to pull the tip away from the surface
- Click Show Markers and Show Tip
- Select Sights on the image to do a *Force Curve* and hit the *Pick Point* and That's It for each location
- Hit *Single Force* at each point and *Go There* to move for each numerical location



NOTE	A 10pA trigger current works only if the system is acoustically isolated well. If the trigger point is reached before the tip is on the surface, increase the trigger current greater than 10pA. Try 20pA or 50pA.

NOTE	If the magnitude of the current increases with time during the cycles this is probably due to thermal drift. If the temperature of the sample is still equilibrating, there could be expansion of the sample which will increase the tunneling current.

12.10. STM probes

The Cypher STM kit came supplied with 20 mechanically formed (i.e. carefully clipped with super sharp wire cutters) probes. Additional probes can be purchased from Asylum Research. If you wish to make your own probes the material and dimensions for making the supplied probes are:

Material: 80%/20% Platinum Iridium. Wire should be drawn straight. Wire cut from a roll has a small radius and may not hold tightly into the tube on the STM holder. The tube is bent with a large radius. This is intentional to help reduce drift due to the stress of bending the probe wire upon insertion into the holder.

Wire size: 0.01" diameter (0.25mm) , cut approximately .2" (5mm) long.

Contact Asylum Research about further tools and technique required to make the proper cuts.

Attention	Longer probes can be used but may introduce image distortion from drift due to the length.

Attention	The approximate range of the camera focus is about 3mm below the underside of the tip holder tube. Tips that extend below 3mm will not allow the sample to be viewed.

12.11. Troubleshooting

12.11.1. Testing the STM holder

A 500M Ω resistor is supplied in the STM accessories kit. The resistor is soldered to a short length of wire terminated by some Pt Ir probe wire.

To test the holder,

1. insert the platinum wire into the tip tube and
2. plug the resistor into the Sample socket in the terminal block.
3. Set the surface bias to 1V and
4. note the measured current. It should be 2nA (1/500e6 Ω).
5. Use the test panel, Email Support@AsylumResearch.com for details on loading this software.
6. Use the noise tab to measure the current noise of your holder.
7. The typical noise should be ~8mV (~8pA) Adev from 1hz-1kHz with little perceivable periodic noise in the spectrum.

12.11.2. The Current2 Signal

The initial current to voltage conversion takes place in the first stage of a two channel op amp. The first gain stage labeled Current2 in the data channels has an output sensitivity of 20nA/V. In most cases this signal is not suitable for feedback but can be monitored as well as the final 1nA/V final stage if desired. The reason for this signal is derived from the design of the STM amplifier that is the same basic circuit as the ORCA - CAFM cantilever holder.

13. Fast Force Mapping

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

Fast Force Mapping (FFM) is a deflection (sub cantilever resonance frequency) technique that allows users to acquire data (topography, adhesion, mechanical, electrical properties, etc) on a very wide range of materials. In contrast to AC Mode or Contact Mode, the principle behind FFM is based on force/deflection feedback force curves performed at rates much higher than traditional force curve maps. Force curves are acquired at frequencies ranging from 10 Hz up to 300 Hz (for MFP-3D Infinity AFMs only) and up to 1000 Hz (for all Cypher AFMs) while a feedback loop is using the maximum force detected (deflection) for each force curve. Each force curve is recorded and analyzed to extract topography information and mechanical properties of the sample. Additional signals such as electrical conductivity can be measured to obtain supplementary information about the sample (through use of the ORCA cantilever holder). The main advantage of the FFM technique is the much faster data acquisition, compared to standard force mapping, while still capturing all the information provided by force curves.

A sinusoidal driving voltage applied to the Z actuator is used to oscillate the probe at frequencies ranging from 10 Hz to 300 Hz (Infinity) and 1000 Hz (Cypher). For each force curve, the maximum deflection signal, read on the photo-detector, is used to calculate the Z height measured by the Z sensor. Maximum force (Max Force) is calculated in real-time and is used as error signal for Z feedback loop. While the probe is driven (sinusoidal wave) in Z, the sample is moving underneath it in a raster pattern in the XY plane. The resolution of the image is determined by the number of points in each scan line.

The software continuously digitizes Deflection, Z-Sensor, Z-Voltage and Current (or Current2) signals at 2MHz (Cypher) or 500kHz (Infinity).

Each force curve is analyzed to provide sample topography and its Young's modulus (based on a chosen model and parameters). If a bias is applied to the sample and a conductive tip is used, ORCA measurements (see chapter I.8 Applications manual) can be performed at the same time.

13.1. Required for Fast Force Mapping

- Fast Force Mapping is an optional imaging technique and requires software license to be activated

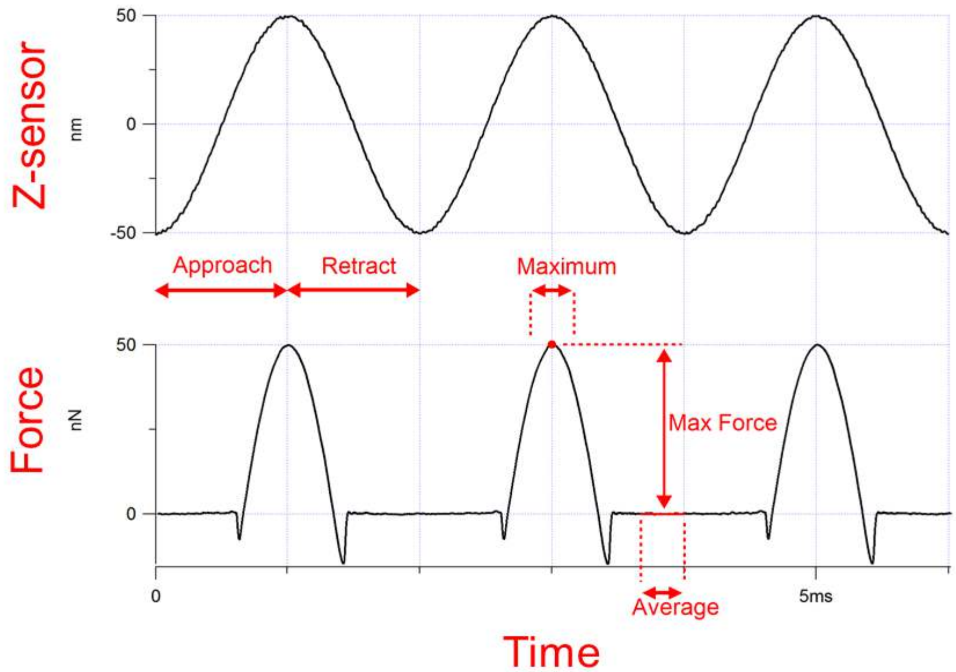


Figure 13.1.: Plot of cantilever oscillation measured by the z-senor (excited by driving voltage) (top) and the resulting force (bottom) when the tip is pushing on a hard surface. The 'Max Force' arrow indicates how the setpoint force is calculated for each force curve.

- Software version 16 or higher is required to run Fast Force Mapping mode

13.2. Fast Force Mapping in contact mode

- Fast Force Mapping (FFM) in contact mode is contact mode-based technique therfore the user needs to choose a probe with a spring constant matching the stiffness of the sample
  - Polystyrene/Polypropylene thin film sample is used for this demonstration
  - AC 200 Olympus probe with ~150 kHz resonance and 10 N/m spring constant

13.2.1. FFM automatic experimental setup: GetStarted

Automatic imaging setup: GetStarted

1.

- In the Mode Master menu select NanomechPro and then select Fast Force Map
- FFM mode automatically starts in GetStarted configuration
- Follow the instructions to set up your experiment
- You will be asked to set initial imaging parameters (look for descriptions below)
  - scan size
  - scan points & lines
  - approximate sample roughness
  - Z-rate
  - setpoint
  - force distance
  - sample stiffness
- Some of these parameters are adjusted automatically depending on user input

2.

Specific parameters for FFM - GetStarted routine

- Scan points & Lines
  - These two parameters determine the number of scan points (pixels) in each scan line and the number of lines in the scanned area. In contrast to other techniques, during FFM the number of force curves corresponds exactly to the number of pixels in the image. For comparison, during AC mode, the tip oscillates at a much higher frequency than the number of pixels. Therefore, for each pixel, it is the average value of the amplitude of oscillations that is measured by the feedback loop. To improve the resolution of images, these 2 parameters can be increased, however the acquisition time will increase at the same time.
    - Acquisition time = (lines x points per line x 2.5)/ Z rate
- Sample roughness
  - This parameter is used to determine the force distance, it should be chosen to roughly represent the height difference the lowest and highest features on the sample
- Z-rate
  - It's the ramp rate at which the force curves will be performed and it is how fast the Z actuator is moving up and down above the surface. This parameter can be increased until the user sees instability in the force curve (the instability arises when the deflection is changing rapidly and the setpoint cannot be met on all curves). On Infinity, the maximum Z rate is 300 Hz. On Cypher (S or ES), the maximum Z rate is 1000 Hz.
- Setpoint
  - It is the setpoint value used for feedback. Maximal force is calculated in real-time and used as error signal for the Z-feedback loop. When the setpoint value is reached, the lever is pulled away from the surface. The setpoint value is displayed in units of Newton and Volt (they are related by the cantilever calibration values InvOLS and k). The Newton value provides information about the amount of normal force applied on the sample. The Volt value can be compared with the deflection value displayed on the Sum and Deflection Meter panel. For example, before engaging on the surface, the deflection should read 0 Volt and the setpoint should be set to a value (Volt or Newton) greater than 0. The setpoint value is also used to obtain an image of the surface topography. For each pixel, the software measures the Z height at which the setpoint value was reached. The Z height for each pixel is then used to map the topography of the surface.
- Force distance
  - It is the distance the piezo will travel during the force curve (extend or retract portion). This distance should match (or exceed) the topography variations of the sample.
- Sample Stiffness

13.2.2. FFM experimental setup by the user

1.

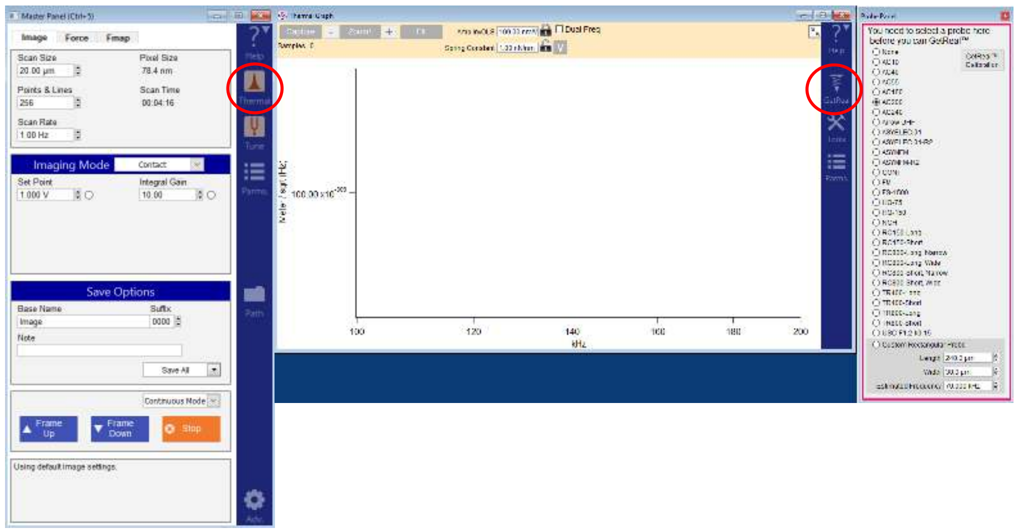
- Place the probe in the cantilever holder and mount it in the instrument
- In the Mode Master menu select Standard and then Template

2.

Align Laser

- Open the Video Panel
  - Use the arrows in the Video Panel to move the laser spot onto the cantilever and maximize the SUM signal

3.



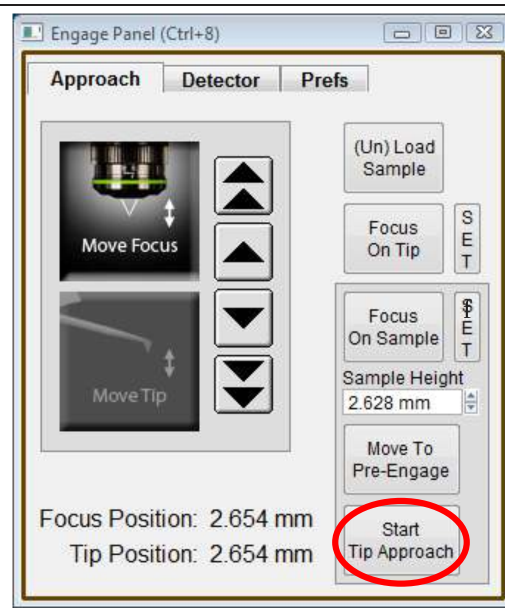
Calibrate Probe

- Choose the Thermal icon in the Master Panel
  - thermal graph will appear
- Click on the GetReal icon which will open the Probe Panel
- Choose the probe that is used for the experiment
- Click GetReal Calibration
- Once the calibration is completed, the Amp InvOLS and Spring Constant values at the top part of the thermal graph will be updated.

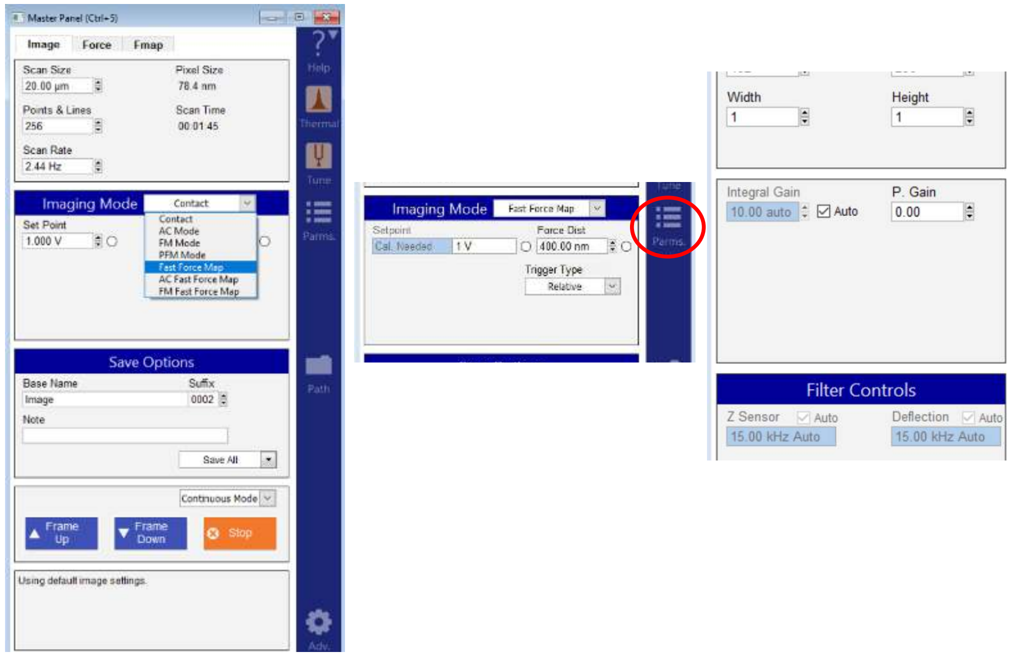
4.

Approach the sample surface

- In Master Panel
  - Imaging Mode: Contact
  - Set Point: 0.2 V (for this particular probe and sample)
- In the Engage Panel
  - Set the tip position while focused on the tip
  - Set the sample position while focused on the sample
  - Click on Start Tip Approach



5.



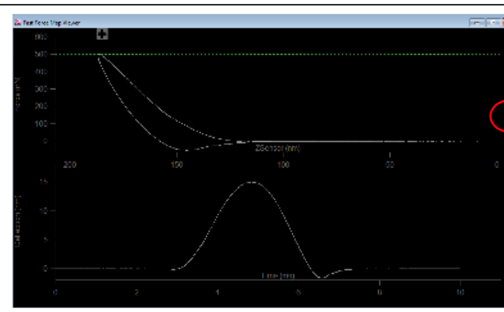
Switch to FFM mode and start imaging

- In Master Panel, switch from Contact Mode to Fast Force Map
- Master Panel will now display parameters related to FFM
  - Setpoint is now displayed in units of Newtons and in Volts: set it to 10 nN
  - Force Distance: 200 nm
  - Trigger Type: Relative
- Set the other parameters in the Master Panel
  - Scan size: 5 µm
  - scan points & lines: 256
  - Z-rate: 500 Hz
- The Gains are located in the Parms panel
- Click Engage in the Sum and Deflection Panel

6.

Engage

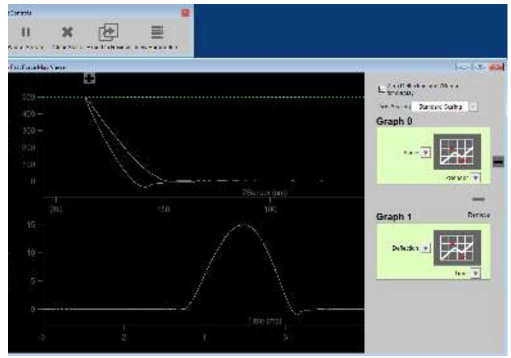
- As the tip engages on the surface, Fast Force Map Viewer will appear
- Display choices are available by clicking on the "plus" sign



7.

Real time Force curves

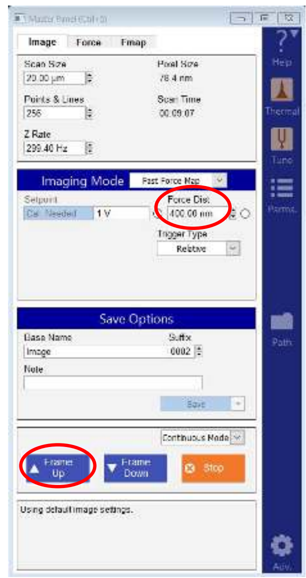
- Fast Force Map Viewer can show up to 2 channels
- Each graph has several options for each axis, in this example:
  - Graph 0 is Force versus ZSensor
  - Graph 1 is Deflection versus time
- The green line on the top graph indicated the setpoint
- Top Controls allow for superposition of several already acquired curves over the realtime curve

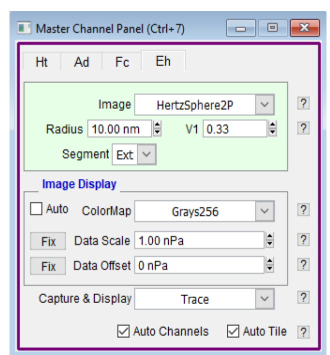


8.

Imaging parameters

- Four Channels can be collected simultaneously during FFM imaging
  - Ht - Height
  - Ad - Adhesion
  - Fc - Max Force
  - Eh - Calculated modulus channel. Model (here Hertz) and tip radius must be adjusted prior to imaging
- Adjust the force distance and setpoint
- When the imaging parameters are optimized and the force curves look good in the FFM viewer press Frame UP to start imaging





13.3. Fast Force Mapping in AC mode

The following instructions are for Fast Force Mapping in AC mode (intermittent contact mode or tapping mode) and are intended for imaging a flat sample in liquid.

1.

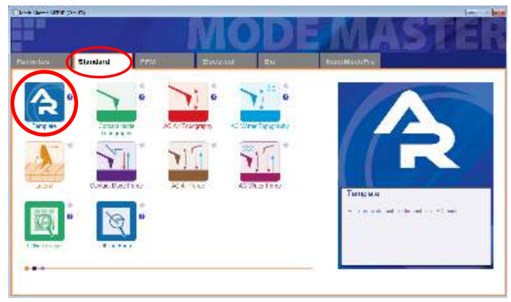
Prepare

- Fresh calcite sample
- Clean cantilever holder that will be used for imaging (either liquid holder or perfusion holder)
- ArrowUHF AuD probe
- Make sure that the software version is 16 or higher and that the FFM mode is enabled
- Use blueDrive for cantilever drive and place the 0.1x filter cube in the laser's path

2.

Start software

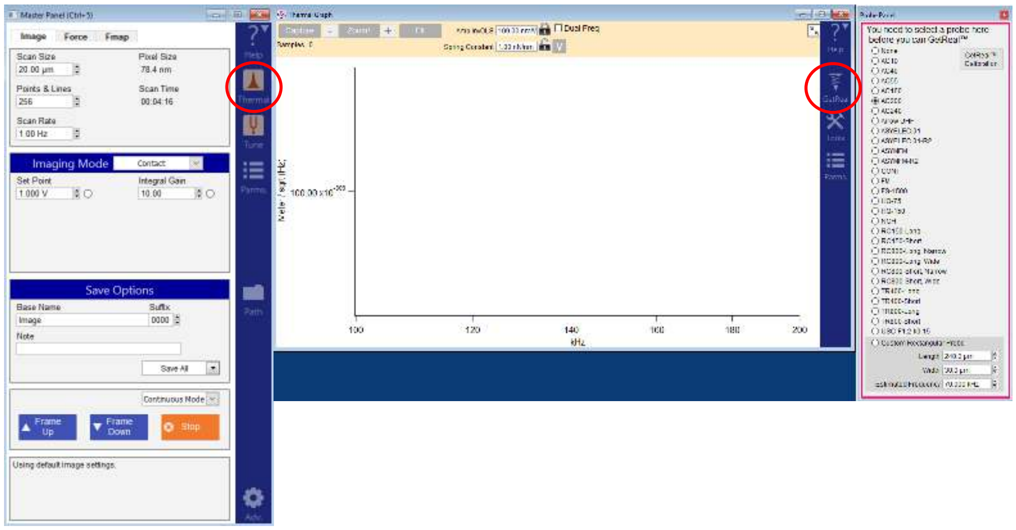
- Place the probe in the cantilever holder and mount the holder on the scanner
- In the Mode Master menu select Standard and then Template



3.

Align Laser

- Open the Video Panel
- Use the arrows in the Video Panel to move the red laser spot onto the cantilever. Try to maximize the SUM signal

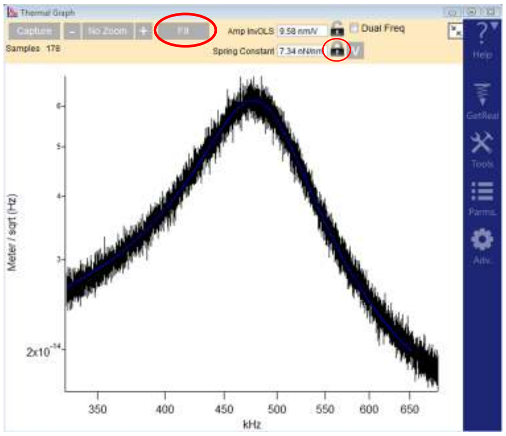
4. 

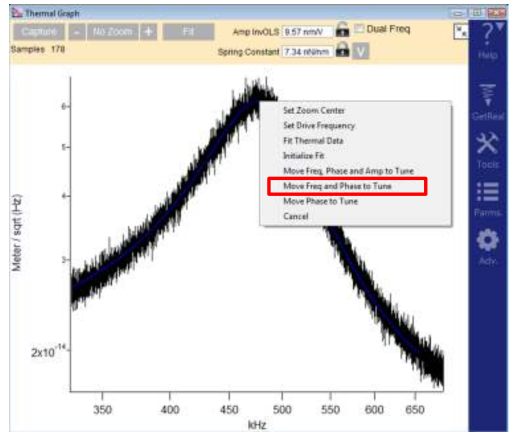
Calibrate Probe (in air)

- Choose the Thermal icon in the Master Panel
  - thermal graph will appear
- Click on the GetReal icon which will open the Probe Panel
- Choose the probe that is used for the experiment
- Click GetReal Calibration
- Once the calibration is completed, the Amp InvOLS and Spring Constant values at the top part of the thermal graph will be updated

5. Remove the cantilever holder and place the freshly cleaved calcite sample on the scanner
6. Add a drop of water to the sample
7. Put a drop of water on the probe and place the cantilever holder back on the scanner
8. While looking at the distance between the probe and the sample, approach the sample to the tip so that both water drops join and the sample and lever are both in water environment
9. Re-focus and re-align the laser on the cantilever (now in liquid) - Sum should be ~ 6V

10.

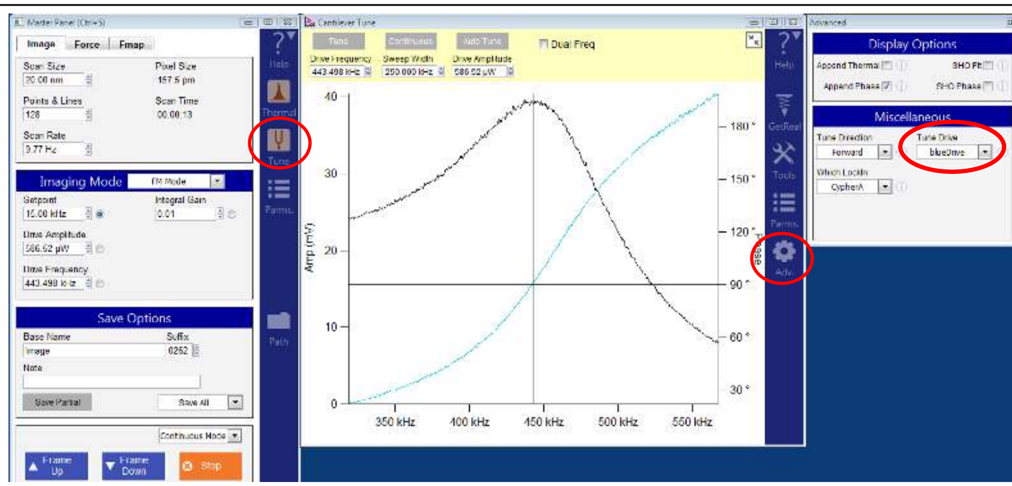




Capture a thermal of the cantilever in liquid:

- Make sure that the padlock besides Spring Constant is locked
- Re-fit the thermal data to obtain the updated (water) InvOLS value
- Transfer the frequency of thermal peak to the tune panel
  - Right click on the peak of the Thermal Graph and choose Move Freq and Phase to Tune

11.

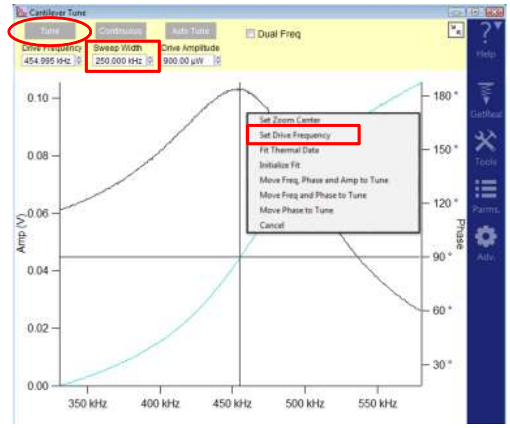


Turn on blueDrive photothermal excitation

- In the Tune graph, click on Adv.
- In the Advanced panel, choose blueDrive from the drop down menu of Tune Drive

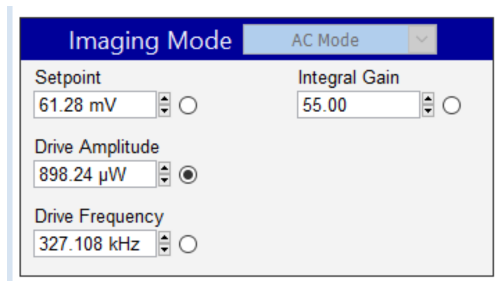
12. **Tune panel**

- Set the Sweep width to 250 kHz
- Click one Tune
- When tune is done, right click on the peak and choose set Drive Frequency
- Move the blue laser spot around the base of the cantilever to maximize the amplitude
- Adjust the drive amplitude (in the Master Panel) until the amplitude reaches ~ 80 mV (visible on the graph and in the Sum and Deflection panel)



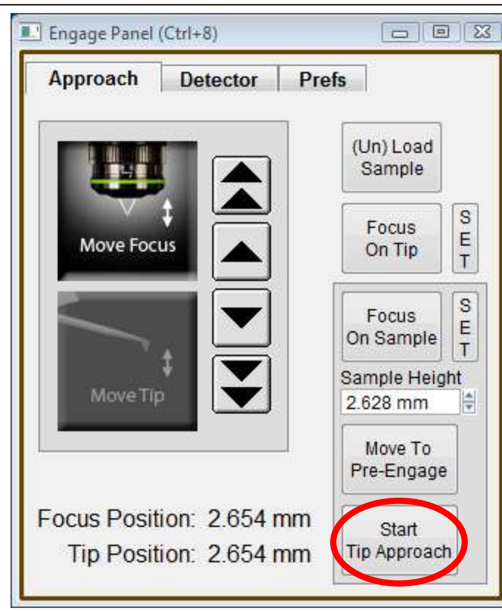
13. **Master Panel**

- Set the setpoint to ~ 60 mV
- Set the IG to 55



14. **Engage Panel**

- Set the tip position while focused on the tip
- Set the sample position while focused on the sample
- Click on Move to Pre-Engage
- Click on Start Tip Approach

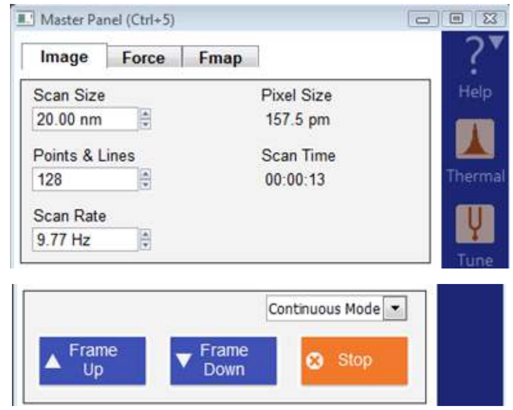


15. Once the tip is in piezo range of the sample, capture another Thermal Tune with z-piezo at 0V (sample is 2-3 um from surface)
16. Lock padlock besides spring constant on Thermal Graph to re-calculate Amplitude InvOLS
17. Right click on the peak in Thermal Graph and Move Freq and Phase to Tune
18. When the tune is complete,right click on the peak and center phase

19.

Imaging parameters - Master panel

- Set the scan size to 20 nm
- Set the scan rate to 10 Hz
- Start imaging by pressing Scan Down



20. Start imaging

a) decrease the free amplitude (by decreasing drive amplitude in the Master Panel)

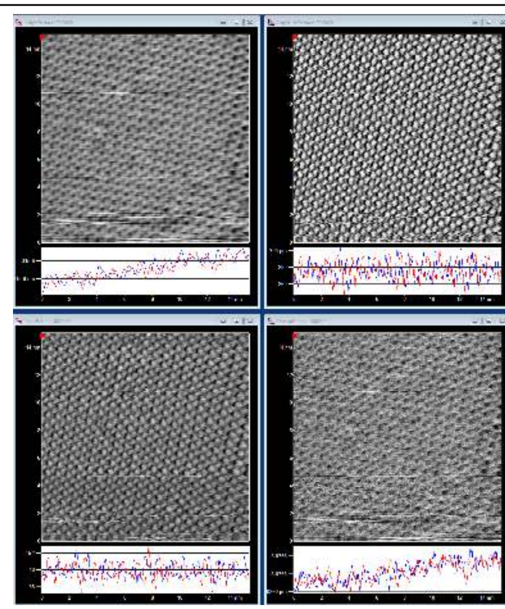
b) then, decrease the setpoint until trace and retrace overlap each other

c) repeat several times to image with the lowest amplitude possible

21.

Imaging

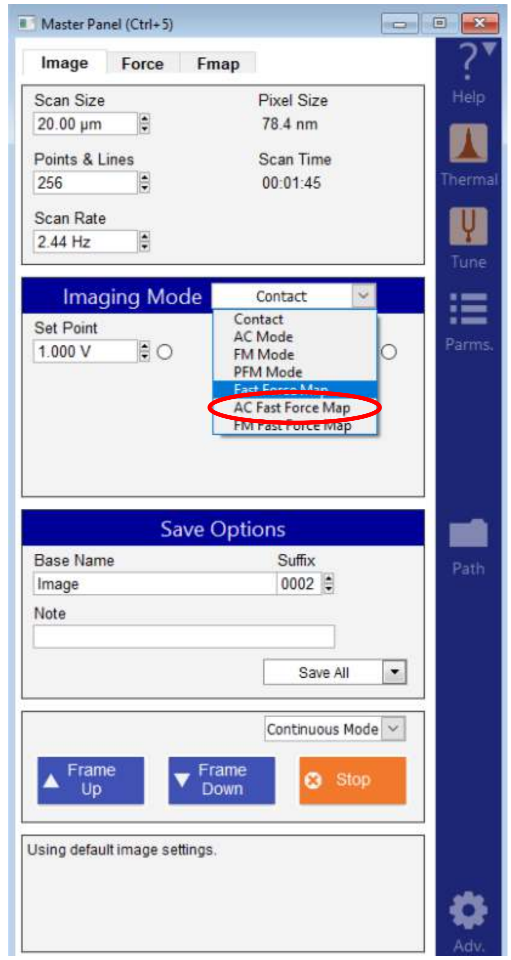
- Acquire a 20 nm image and re-size the scan to 10 nm
- Channels that are acquired include
  - Height
  - Amplitude
  - Phase
  - ZSensor
- Once the imaging looks optimized, stop the scan and switch to AC FFM mode



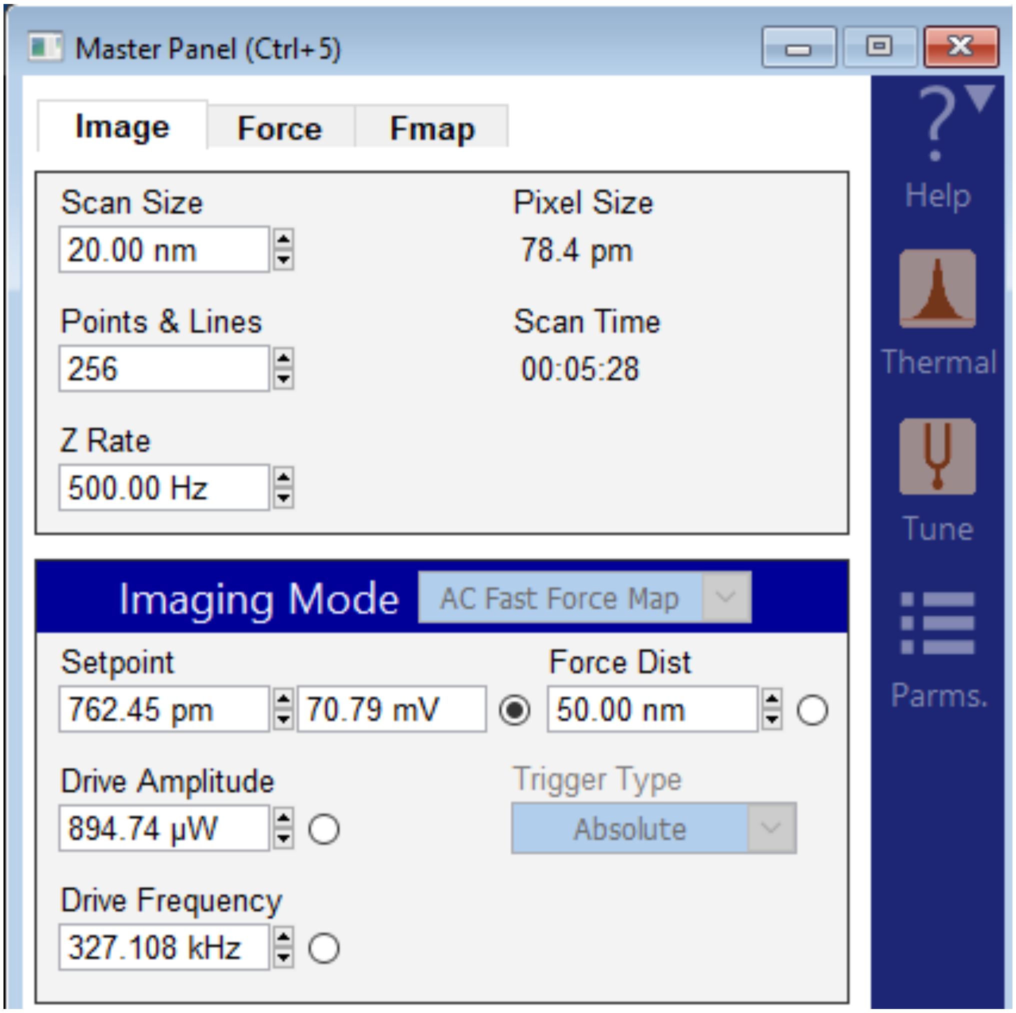
Imaging mode AC FFM

22.

- switch to AC Fast Force Maps from the drop down menu in Master Panel



23.



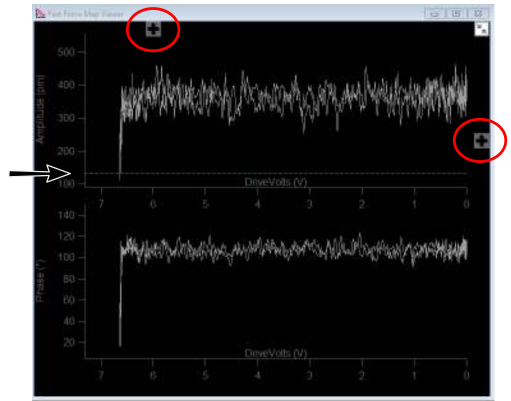
Imaging Parameters

- Master Panel will now display parameters related to AC FFM mode
  - Setpoint is now displayed in units of meters and in Volts - set it to 70 mV
  - Force Distance - set it to 50 nm
  - Trigger Type - Absolute
- Set the other parameters in the Master Panel
  - Scan size: 20 nm
  - scan points & lines: 256
  - Z-rate: 500 Hz
- The Gains are located in the Parms panel - set to 10
- Click Engage in the Sum and Deflection Panel

24.

Engage

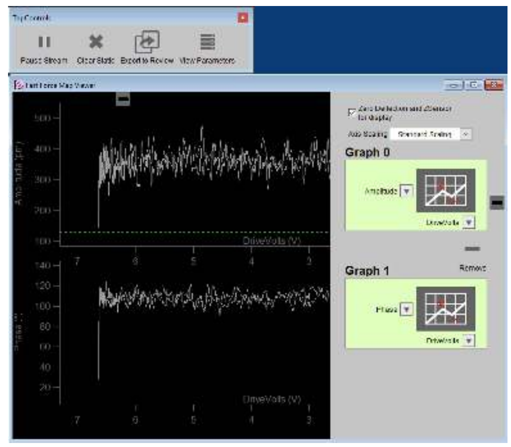
- As the tip engages on the surface, Fast Force Map Viewer will appear
- Display choices are available by clicking on the “plus” sign
- Arrow in the top graph indicates the setpoint value.

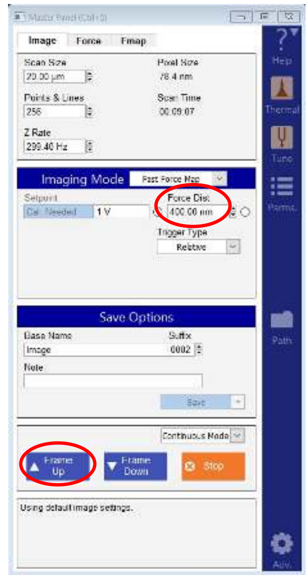


25.

Real time Force curves

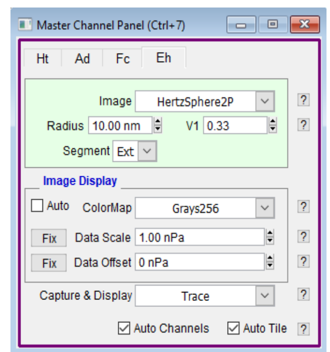
- Fast Force Map Viewer can display up to 2 channels (graphs)
- Each graph has several options for each axis, choose the appropriate axes for the imaging mode. For AC FFM, choose:
  – Graph 0 (top): Amplitude (pm) vs DriveVolts (V)
  – Graph 1 (bottom): Phase (°) vs DriveVolts (V)
- Top Controls allow for the superposition of several already acquired curves over the realtime curve



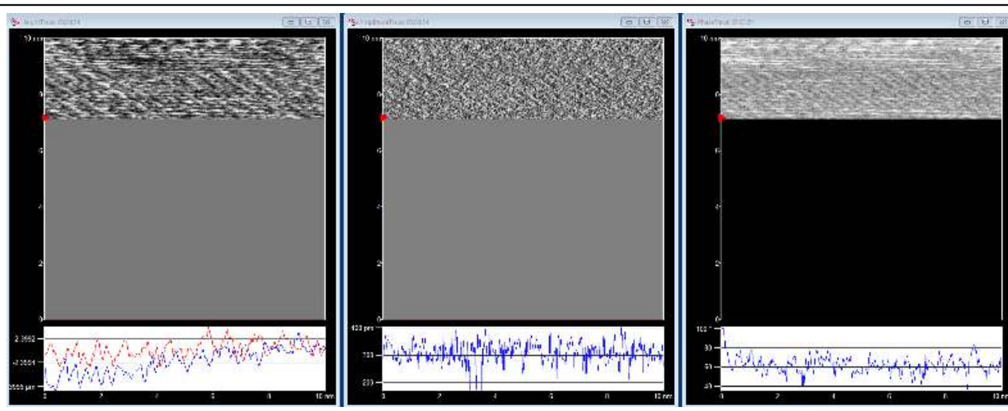


26. **Imaging parameters**

- Adjust the force distance and setpoint until the curves in the Viewer look good
- When the imaging parameters are optimized press Frame UP to start imaging



27.



Imaging

- Data is collected in 3 channels during AC FFM
  - Height
  - Amplitude
  - Phase

13.4. Fast Force Mapping in FM mode

The following instructions are for Fast Force Mapping in FM mode (frequency modulation) and are intended for imaging a flat sample in liquid. A freshly cleaved calcite sample and clean deionized water are used for this demonstration.

The user is guided through the following steps:

1) calibration of a probe

2) acquisition of an AC mode image - this step will allow the user to determine if the probe is sharp and if the area of interest is flat/clean

3) acquisition of AC force curves - this step will allow the user to approach the sample to a defined distance

4) acquisition of FM curves - this step will allow to check FM gains

5) acquisition of FM FFM images and force curves

13.4.1. Preparation and Calibration

1.

Prepare

- Fresh calcite sample
- Clean the cantilever holder that will be used for imaging (either liquid holder or perfusion holder)
- ArrowUHF AuD probe
- Make sure that the software version is 16 or higher and that the FFM mode is enabled
- Use blueDrive for cantilever drive and place the 0.1x filter cube in the laser's path

2.

Start software

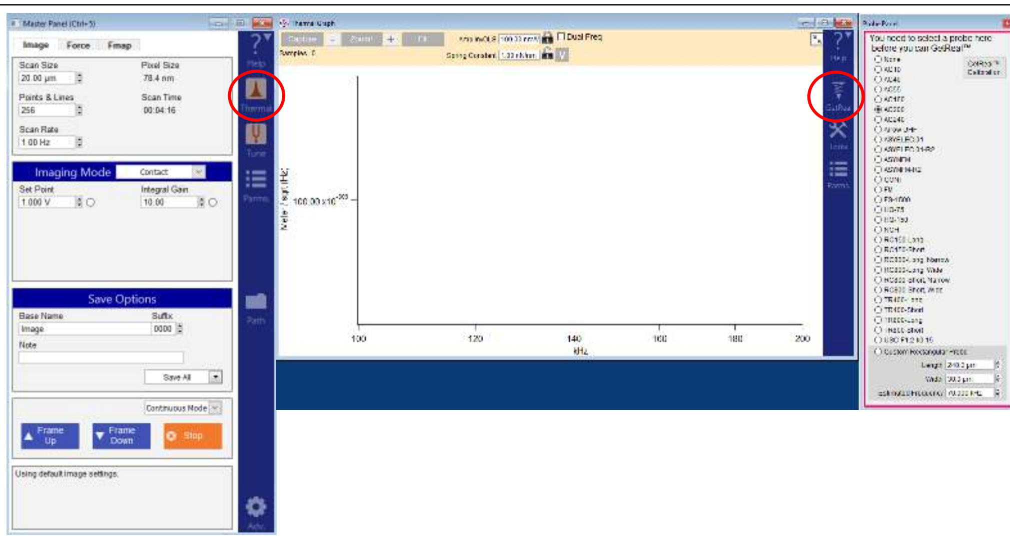
- Place the probe in the cantilever holder and mount the holder on the scanner
- In Mode Master menu select Standard and then Template

3.

Align Laser

- Open the Video Panel
- Use the arrows in the Video Panel to move the red laser spot onto the cantilever. Try to maximize the SUM signal but keep the laser spot at the end of the lever (see figure)

4.



Calibrate Probe (in air)

- Choose the Thermal icon in the Master Panel
  - thermal graph will appear
- Click on the GetReal icon which will open the Probe Panel
- Choose the probe that is used for the experiment - for this experiment choose Arrow UHF
- Click GetReal Calibration
- Once the calibration is completed, the Amp InvOLS and Spring Constant values at the top part of the thermal graph will be updated

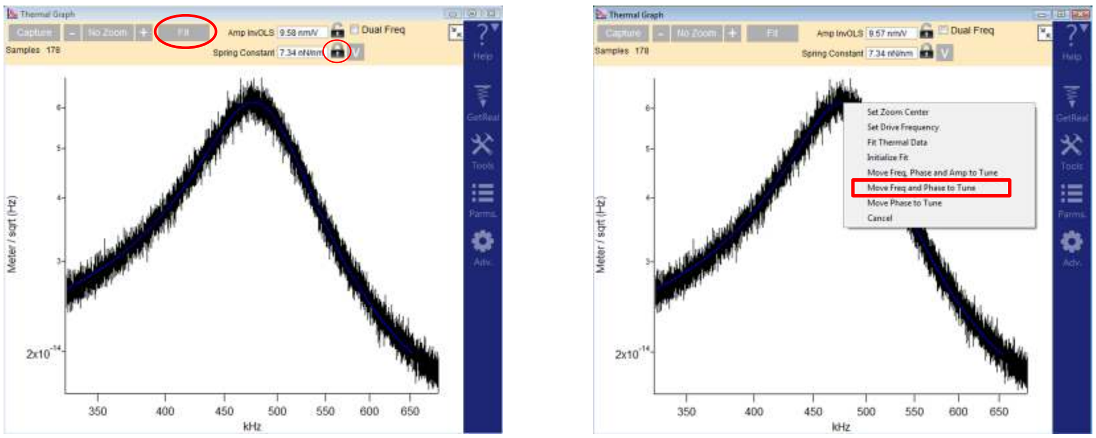
5. Remove the cantilever holder and place a freshly cleaved calcite sample on the scanner
6. Add a drop of water onto the sample

7. Add a drop of water onto the probe and place the cantilever holder back on the scanner

8. While looking at the distance between the probe and the sample, approach the sample to the tip so that both water drops join

9. Re-focus and re-align the laser on the cantilever (now in liquid) - Sum should be ~ 6V

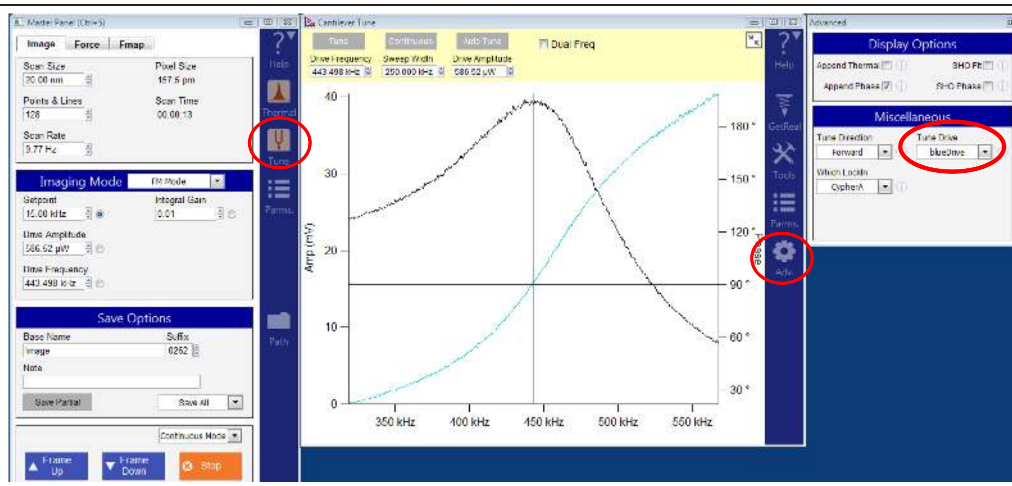
10.



Capture a thermal of the cantilever in liquid:

- Make sure that the padlock besides Spring Constant is locked
- Re-fit the thermal data to obtain the updated (water) InvOLS value
- Transfer the frequency of the thermal peak to the tune panel
  - Right click on the peak of the Thermal Graph and choose Move Freq and Phase to Tune

11.

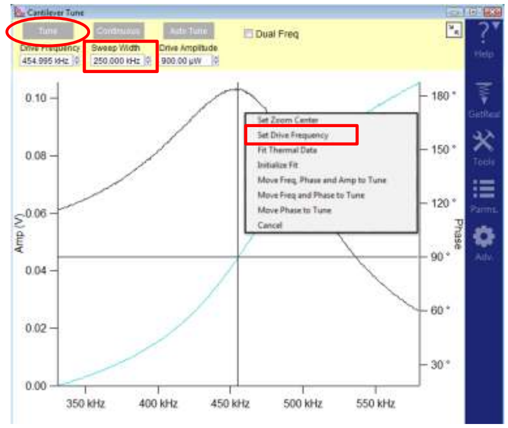


Turn on blueDrive photothermal excitation

- In the Tune graph, click on Adv.
- In the Advanced panel, choose blueDrive from the drop down menu of Tune Drive
- Use the blue arrows in the Video panel (top right side) to move the blue laser spot to the base of the cantilever

12. **Tune panel**

- Set the Sweep width to 250 kHz
- Click Tune
- When tune is done, right click on the peak and choose Set Drive Frequency
- Move the blue laser spot around the base of the cantilever to maximize the amplitude (look at the amplitude value in the Sum and Deflection panel)
- Adjust the drive amplitude until the tune amplitude reaches ~ 80 mV (visible on the graph and in the Sum and Deflection panel)

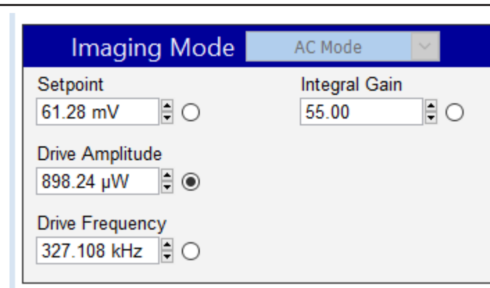


13.4.2. Imaging in AC mode

Acquire an AC image of the calcite sample to check tip sharpness and to define the area of interest.

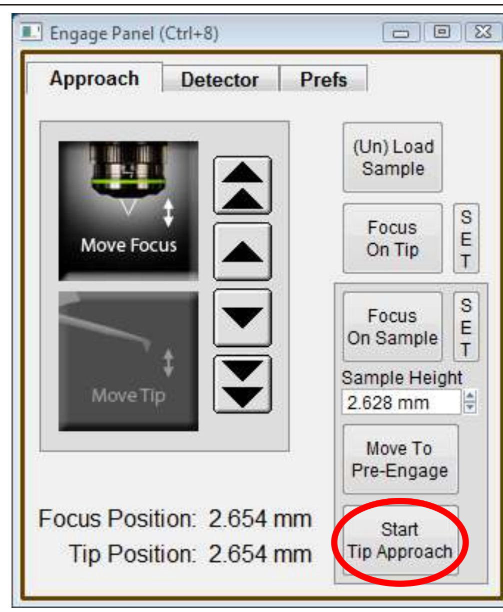
1. **Master Panel**

- Set the setpoint to ~ 60 mV
- Set the IG to 55



2. **Video and Engage Panels**

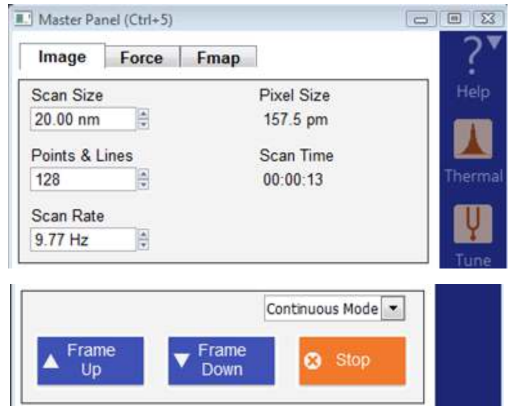
- Click on SET button besides Focus on tip while focused on the tip
- Click on SET button besides Focus on sample while focused on the sample
- Click on Move to Pre-Engage (tip is now 50 μm from surface)
- Click on Start Tip Approach



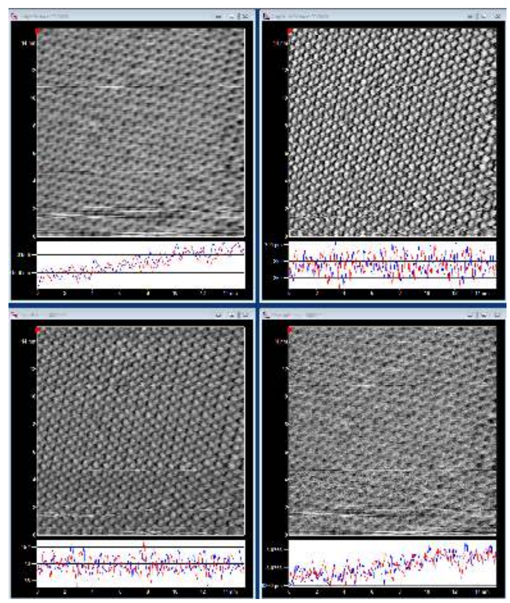
3. Once the tip is in piezo range of the sample, capture another Thermal Tune with z-piezo at 0V (tip is 2-3 μm from surface)

4. In thermal graph panel, keep the padlock besides spring constant locked and re-calculate Amplitude InvOLS

5. Right click on the peak in Thermal Graph and Move Freq and Phase to Tune
6. When the tune is complete, right click on the peak and center phase
7. **Imaging parameters - Master panel**
   - Set the scan size to 20 nm
   - Set the scan rate to 10 Hz
   - Start imaging by pressing Frame Down



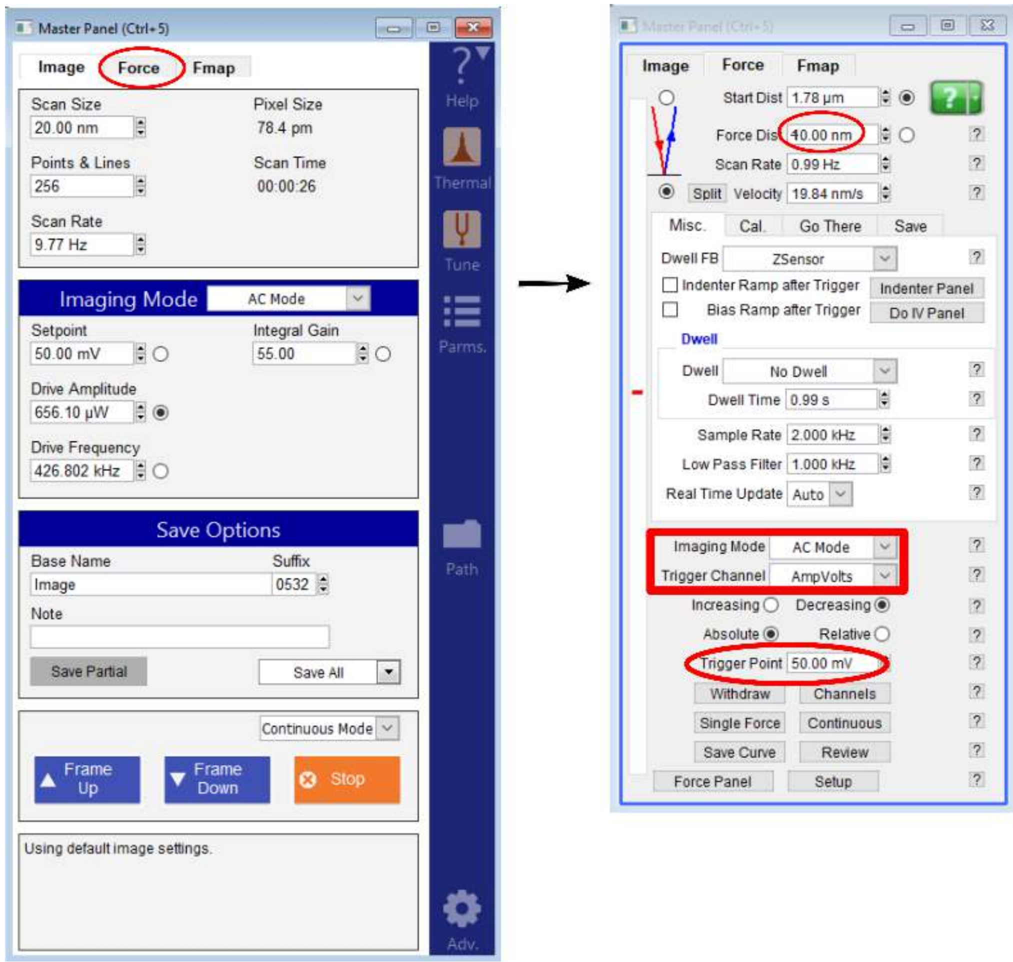
8. Start imaging and optimize imaging parameters
   a) decrease the free amplitude (by decreasing drive amplitude in the Master Panel)
   b) then, decrease the setpoint until trace and retrace overlap each other
   c) repeat several times to image with the lowest amplitude possible
9. **Imaging in AC mode**
   - Acquire a 20 nm image and re-size the scan to 10 nm
   - Channels that are acquired include
     – Height
     – Amplitude
     – Phase
     – ZSensor
   - Once the imaging looks optimized, stop the scan and switch to the Force tab



13.4.3. AC force distance curves

The user will acquire several AC force curves to bring the tip within 50 nm of the surface and re-Tune the cantilever.

1.



Force Tab

- In Master Panel, switch from AC mode imaging to AC mode force curves
- Master Panel Force tab will now display parameters related to AC mode force curves
  - Set the setpoint to about 60% of the amplitude (if amplitude is 80 mV set the setpoint to 50 mV)
  - Begin with force distance set to ~ 500 nm. Force distance will be the distance between the tip and sample after the curve has been acquired
  - Set the Trigger Channel to AmpVolts, Decreasing and Absolute

2.

AC Force Curves

- Acquire a single force curve
- Click on Continuous and, as the curves are being acquired, gradually decrease the force distance down to 50 nm
- Acquire ~20 curves with 50 nm force distance and click on Stop curves
- The z voltage should remain between 70 and 150 Volts

Re-tune 50 nm away from the surface

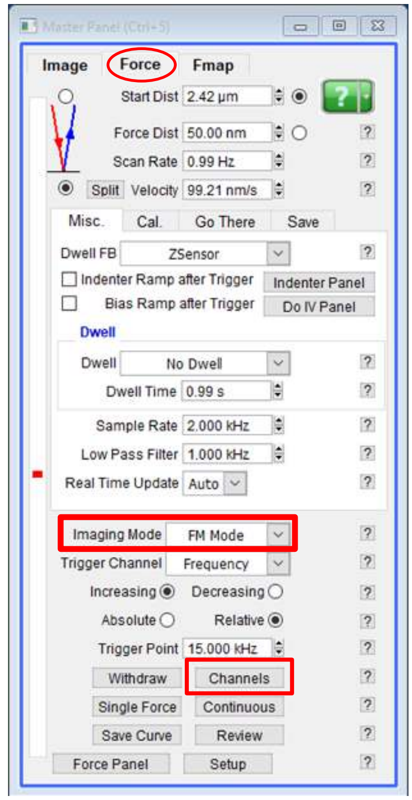
- Click tune on the Tune Graph
- Right click on the peak of the graph and choose Set Drive Frequency
- Right click on the graph again and choose Center Phase
  - Z voltage should still be at the same value as when the force curve was acquired (meaning that the tip is ~ 50 nm away from the sample)

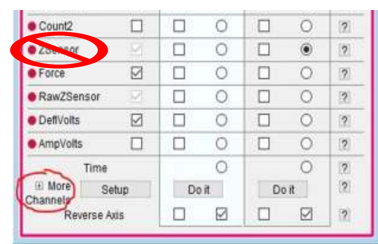
13.4.4. FM force distance curves

This step will allow the user to calculate FM gains and check if the setpoint is appropriate.

1.

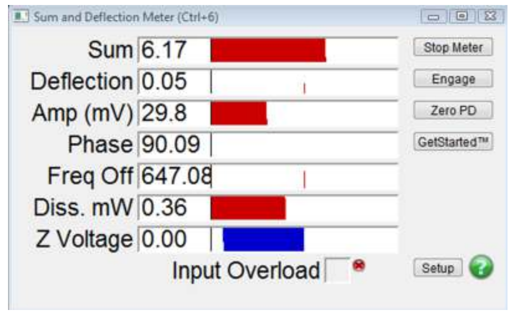
- Choose FM Mode for Imaging mode
- Click on Channels button in the Force tab and select
  - Frequency
  - Dissipation
  - Amplitude
  - Phase
  - Make sure to plot versus DRIVE (not ZSensor) for short curve (tens of nm) as Drive is a quieter signal than ZSensor (which has 50 pm of noise in a1 kHz bandwidth)
- Choose trigger: Frequency
  - Increasing
  - Relative
- Trigger Point: 5 kHz is a good start

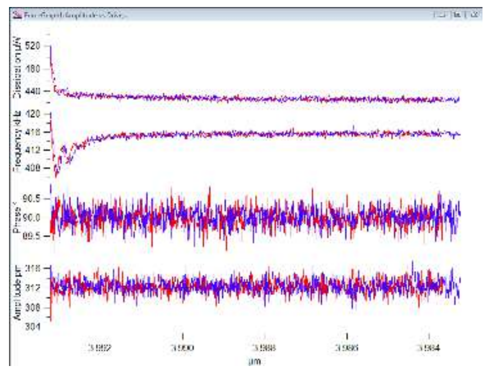




2.

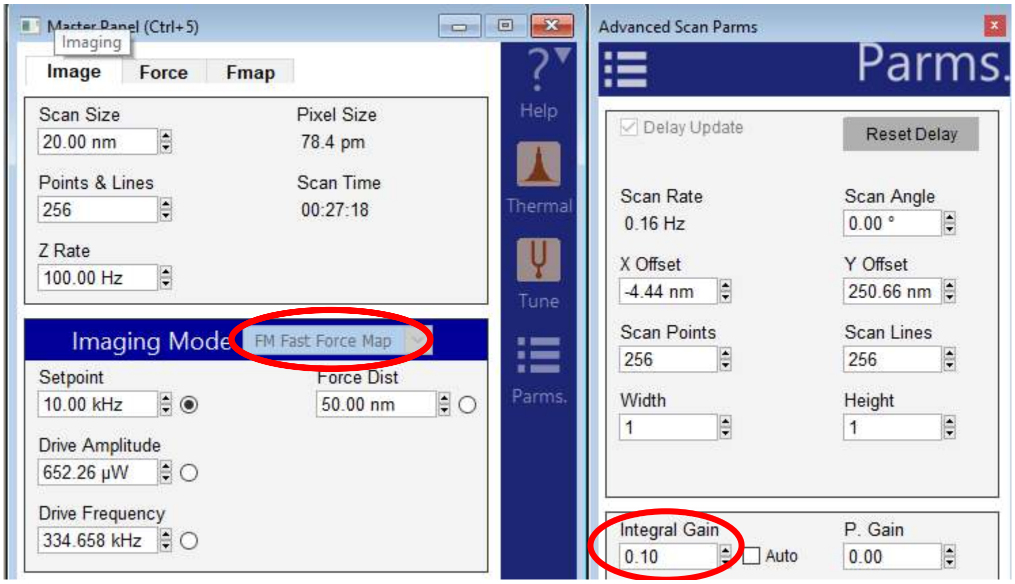
- Locate the FM Panel (AFM Controls –> Other –> FM Panel)
- Un-check and check the Auto Calculate Gains checkbox, the values should update
- Set the Drive Set Point to the required amplitude
  - start with 3 Angstroms: 3A = 0.3nm;
  - Ex: 0.3nm / 10.25nm/V InvOLS = 0.0292V = 29.3mV
- Activate Feedback Loops by checking the boxes besides
  - FM feedback ON
  - Drive Feedback ON
- When the frequency and drive feedbacks are ON, the following values will appear in the SUM and Deflection meter
  - Amp (mV) = Drive SetPoint Value
  - Phase = 90
  - Freq Off = frequency offset compared to the value of drive frequency from tune, here 647 Hz
  - Diss mW = power (in mW) needed to keep the Drive Set Point Value at 30 mV
- Click Single curve to acquire a FM force curve
  - If the FM gains are correct, force curve should appear on the graph





13.4.5. Fast Force Mapping in FM

1.



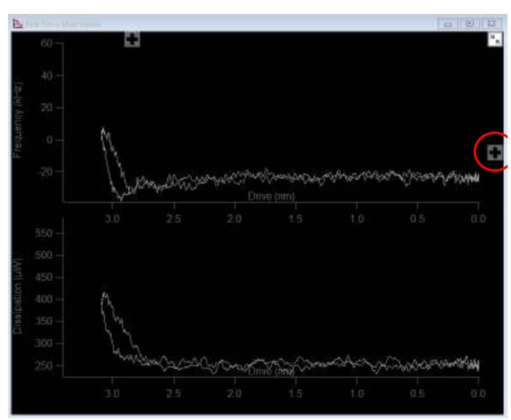
Imaging Parameters

- In Master Panel, switch from FM Mode to FM Fast Force Map
- Master Panel will now display parameters related to FM FFM mode
  - Setpoint is now displayed in units of Hertz (if frequency feedback is chosen, and watts if dissipation feedback is chosen in the FM Panel)
  - Set the force distance to 50 nm
- Set the other parameters in the Master Panel
  - Scan size: 20 nm
  - scan points & lines: 256
  - Z-rate: 100 Hz
  - Z-voltage should still be between 70 and 150 V
- Click Engage in the Sum and Deflection Panel
  - FM FFM settings should now be reflected in the Sum and Deflection panel
- Set the IGain located in the Parms panel to 0.1

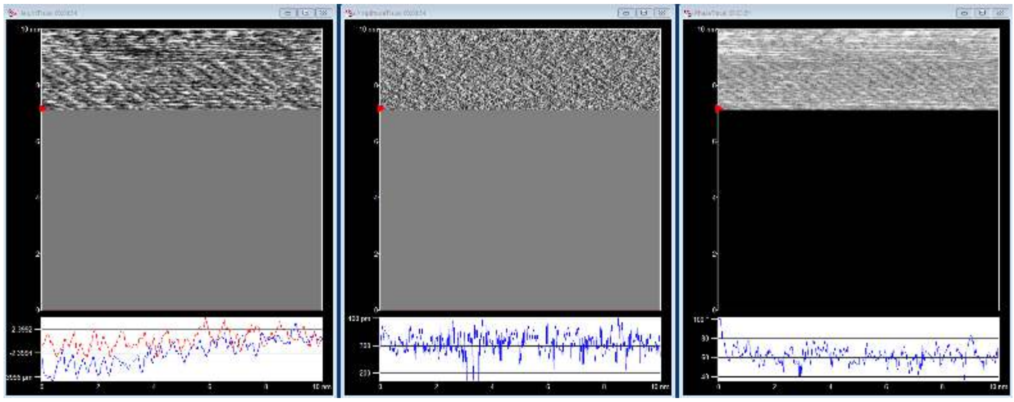
2.

Real time Force curves

- Fast Force Map Viewer can display up to 2 channels (to add a graph, click on the plus sign on the right side of the viewer)
- Each graph has several options for each axis, user must define the appropriate axes for the imaging mode. For FM FFM, choose:
  - Graph 0 (top): Frequency (Hz) vs DriveVolts (V)
  - Graph 1 (bottom): Dissipation (µW) vs DriveVolts (V)



3.



Imaging

- Data is collected in 3 channels during FM FFM imaging
  - Height
  - Frequency
  - Dissipation

14. Surface Potential AFM

CHAPTER REV. 1912, DATED 03/03/2017, 08:49. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

Only the start of a few files Jeff wrote. Waiting for him to edit them further in Word before we port them and get LyX software installed on his rig. This note refers to software version 0909009+27. The functions described in this note are based on the hardware signals used to perform Surface Potential as you would on an MFP3D. As system development progresses this procedure will change as the software incorporates circuitry in the Cypher Backpack.

The following procedures are for Cypher users and Asylum employees only. The goal of this note is to help the user set up the system to perform Surface Potential imaging as the software exists as of this writing.

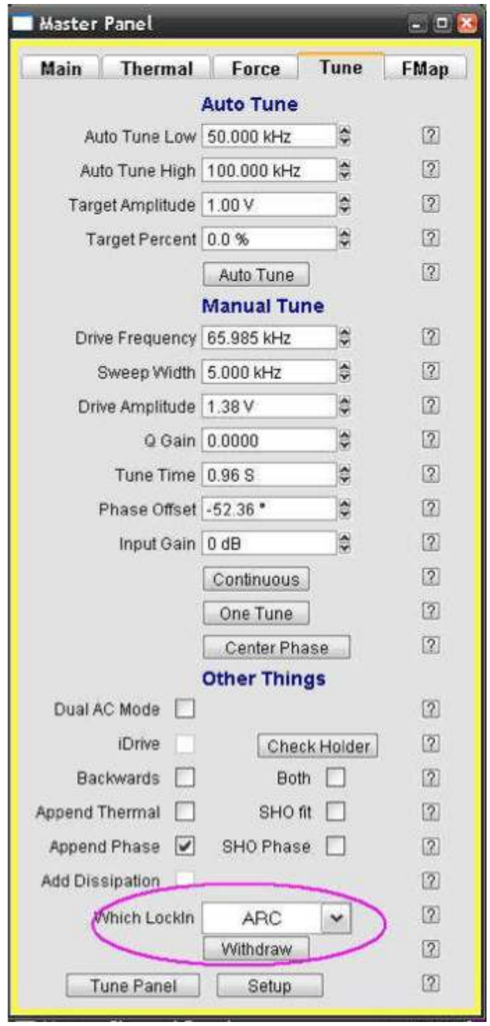
It is assumed that the user is familiar with the theory of operation of the technique and is familiar with the basic operation of an AFM.

14.1. Software Setup

Setting up the software for surface potential is slightly different from the 3D. The main difference is the introduction of the additional lockin circuits that exist on the Cypher backpack. Currently, the software is in transition and will eventually use them but for now the software needs to be directed to use the lockin in the ARC controller.

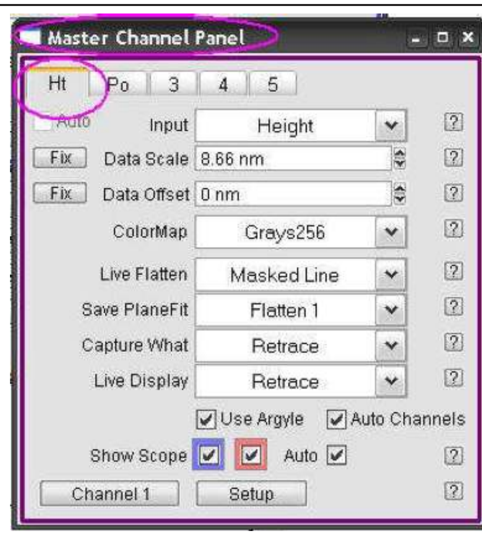
1.

- Go to the tune tab in the master panel and set the ‘which lockin’ to ARC.



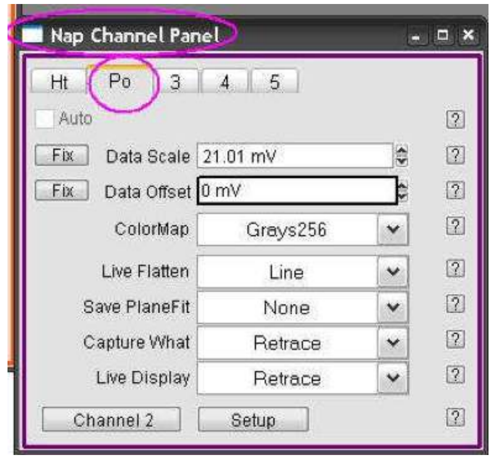
2.

- Open both the main chanel panel Set the main channel to display Height and Potential. This will allow the NAP channel panel to display Potential data.



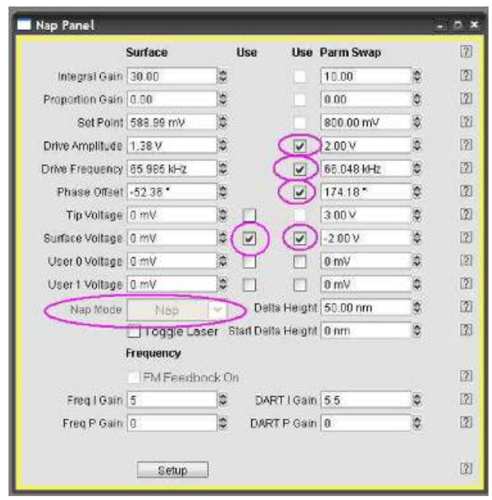
3.

- Open both the main and NAP channel panel. Set it to display potential data.



4.

- Open the NAP control panel and check the Drive Amplitude, Drive Freq and Surface Voltage check boxes. Set the Nap mode to NAP.



14.2. Hardware Setup

1. Install a sample that is prepared with a conducting path from the surface to a bias lead. Connect the lead to the 'Sample' socket on the terminal block on the scanner. (See the Further notes and recommendations section at the end of this document)
2. Install an electrilever or other conducting AFM lever suitable for this type experiment.
3. Engage on the sample surface.

14.3. Calibrate the operating conditions

1. Open the Electric tune panel and use the top section of the controls to perform a triggered force curve. This will establish a close working distance necessary to do an electric tune. Performing an electric tune is a method of calibrating the surface potential software controls and must be performed each time the tip is replaced.

Note that the trigger point is typically the setpoint voltage you used to engage. 700mv is nothing special. Use whatever you needed to get the tip to engage on the sample.

14.4. Electric tune versus a Normal tune

The process of performing surface potential requires that the AC drive signal be used in two different ways. During the normal scanning pass the tip is in AC mode and is driven mechanically with the piezo actuator on the cantilever holder mechanically vibrating the cantilever. During the NAP scan pass above the surface, the AC drive signal is disconnected from the piezo actuator on the holder and is routed to the clip holding the cantilever. The AC signal is then used to electrostatically drive the cantilever.

1. Once the single force curve is done, click on the ‘Normal Tune’ button to do a normal mechanical tune.
2. You may want to shift the drive oscillation freq. slightly lower than resonance as you normally might do to scan in the repulsive region of the cantilever’s resonance.
3. Once you are set up, click on the arrow button to shift the drive freq. over to the electric tune parameter column.
4. Perform an electric tune by clicking on the ‘Electric Tune’ button. This will cause the instrument to switch the DDS signal from the AC drive piezo to the cantilever clip. Note that the Drive Amplitude is 2V and the Tip Voltage is +3V in this panel. This is because you are now applying a 2V AC signal with a +3v DC offset to the tip. Also note that the Surface voltage is set to 0V. These settings establish the correct condition to drive the cantilever electrostatically.

Note	The drive amplitude parameter is typically 1-2v. Remember that the DDS is driving the metal film on the cantilever which varies the electric field between the tip and the sample during the NAP scan pass. The drive amplitude in the Normal tune is the amplitude sent to the piezo actuator to perform AC mode imaging on the main scan pass. The two conditions are decoupled from each other by setting the check boxes in the NAP window as described in the Software Setup section of this note.

Note	The tip voltage is set to 3v only for the purposes of creating a steady state condition where the tip has a large positive potential on it relative to the sample. This is necessary in order to cause the cantilever to oscillate for the purposes of set up during the electric tune routine.

5. Tune the drive frequency to shift to the cantilevers resonance freq. This is typically slightly higher than the mechanical resonance of the lever.
6. Once the drive freq. is adjusted in the electric tune controls, click on the ‘Center Phase’ button to calibrate the phase offset. This set is important to perform because it establishes the correct conditions for the software to control the potential voltage applied to the tip during scanning.

14.5. Testing your setup

The surface potential feedback loop can be tested by clicking on the checkbox labeled ‘Surface Potential Feedback On’ in the electric tune window. Once the feedback is turned on you can vary the slider bar below the Potential bar graph or type in specific DC offsets in the Surface Voltage menu item to apply a voltage to the sample surface.

The feedback loop is working correctly if the value in the Potential bar graph follows the slider bar position or matches the voltage you enter in the Surface Voltage parameter.

What you are doing by sliding the bar or adding a voltage to the surface is to apply a potential to the sample which causes the potential feedback circuit to compensate by adjusting the offset voltage applied to the tip. The

Potential Bar graph is a graphic display of the output signal (Tip Voltage + AC drive from the DDS) from the Potential feedback loop.

Note	Uncheck the 'Surface Potential Feedback On' check box to turn off the potential feedback loop. The feedback will automatically be activated when you begin scanning.

14.6. Scanning while performing Surface Potential measurements

1. Check the Amplitude in the Sum and Deflection meter window. If it's 0v then click on 'Normal tune' to establish the correct signal routing of the DDS to the piezo in the cantilever holder.
2. Set the initial scan parameters you wish to use and begin scanning. The potential feedback loop will automatically activate if you have selected Potential (Po) as a data channel.
3. Monitor the Height or Z sensor channel to collect the topographic image data. Monitor the NAP Po channel for collecting the Surface Potential voltage data.

14.7. Troubleshooting

Open the crosspoint window and verify that the settings are correct. On the Cypher the left two columns are the settings for the crosspoint switch on the backpack board. The right column is the settings for the ARC2's crosspoint switch. The circled items are the settings for correct signal routing if you are doing surface potential.

Starting with the right column: PogoOut = Out C which connects to Cont(troller) Pogo Out which is routed to the Sample.

This means that the User Out C DAC in the controller is being sent out the pogo out wire from the controller and routed to the 'Sample' socket on the Cypher.

Chip and Shake – alternately set to either DDS or to Ground. The software will route the DDS to the Shake line during the scanning pass (left sub-column) and to the Chip line on the NAP scan pass (Right sub-column)

Holder Out 0 = Cont(roller) Chip. Holder out 0 is the signal line wired to the cantilever clip on the Cypher.

Holder Out 1 = Cont(roller) Shake. Holder Out 1 is wired to the + lead of the piezo on the cantilever holder used for AC mode imaging.

Notice in the settings above that the Out C line is also routed to the BNC Out 1 connection. This allows you to monitor the sample bias from the output 1 BNC on the ARC2 controller. It is sometimes helpful to see the actual feedback signal going to the tip during scanning. Routing the DDS to the BNC Out 0 will allow you to do this.

Further notes and recommendations

You should be familiar with imaging your sample before you try taking potential data. Image the surface in standard AC mode and get a feel for the conditions you need on order to reliably scan. The NAP scan pass over the surface relies on knowing where the surface is so be certain you can image the sample.

Get familiar with the technique. Try a sample that is highly conductive and straight forward to image to prove the system is working. Try scanning a gold or graphite surface and confirm that you can, 1) image the surface, 2) apply a surface voltage and see that the DC offset of the Potential data matches.

A complete circuit must be made between the tip and the sample so make sure that your sample is electrically connected to either Ground or the Sample. In special applications you may want to drive the sample externally. The Exp2Holder2 and Exp2Holder3 sockets on the terminal block are directly wired to Pins 35 and 36 of the expansion connector on the Cypher Backpack. In this case, the circuit will be complete though the ground common to the Cypher and your external voltage source.

15. High Voltage Techniques

CHAPTER REV. 1659, DATED 10/07/2013, 22:54. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

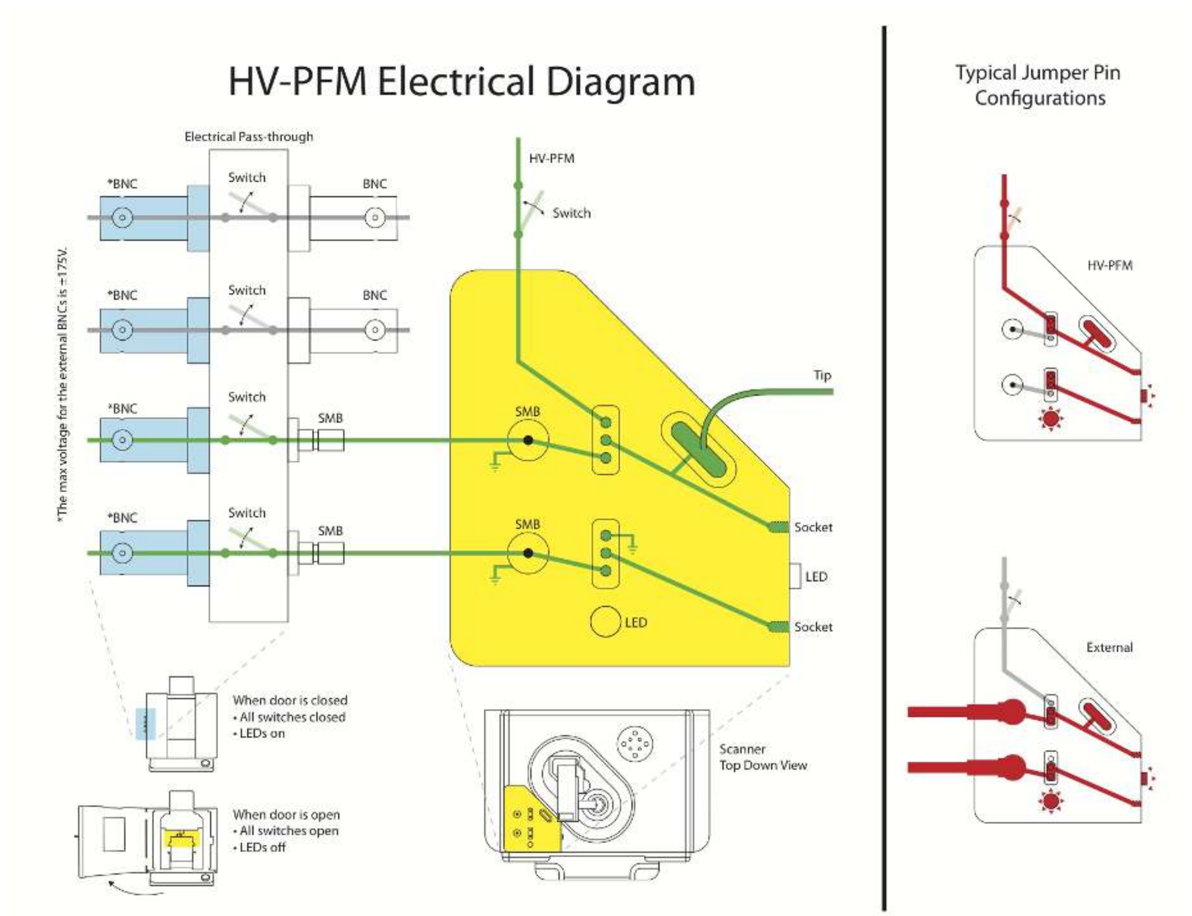


Figure 15.1.: The Cypher High Voltage Option

Part III

Environmental Scanner (ES)

Who is this part for? After the Cypher ES Environmental AFM has been installed in your lab and you (or someone in your facility) have completed the initial training, this part of the user guide will be the principal reference for operating the instrument. Although written with the novice user in mind, experienced SPM users should complete the basic imaging tutorial at least once before attempting to use this instrument.

Part Contents

16. Environmental Scanner Overview

CHAPTER REV. 1912, DATED 03/03/2017, 08:49. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

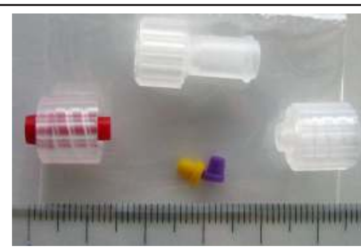
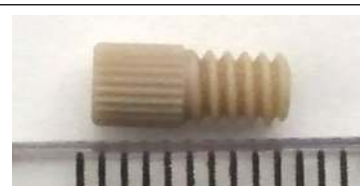
Chapter Contents

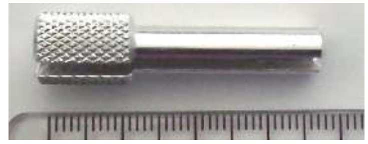
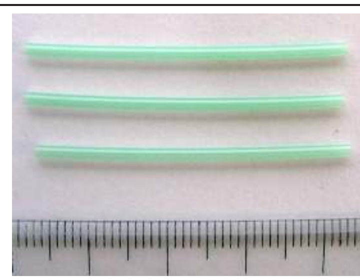
The Environmental Scanner is included with the Cypher model ES AFM. Please review the parts lists below and the basic imaging tutorial in Chapter 17 on page 178.

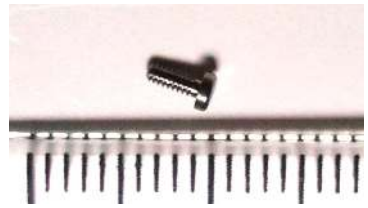
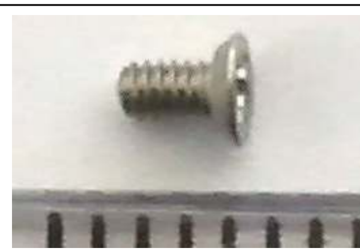
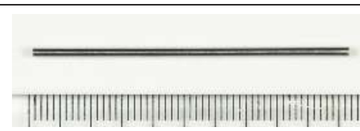
16.1. Parts list

The following table describes all the tools and other items included with your Environmental Scanner. Please refer to the part number when seeking support or ordering replacements.

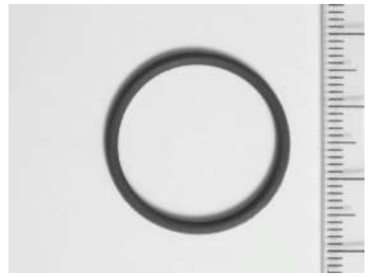
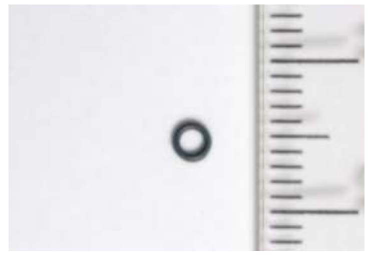
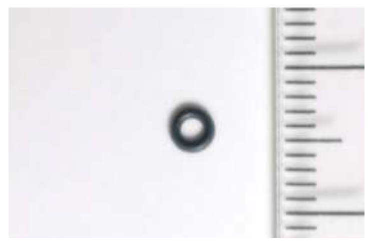
Itm	Part #	Item Description	Qty	Picture
1*	290.147	Scalpel Handle. Used to attach liquid perfusion tubing to the cantilever holder. Also useful when trimming thicker tubing for gas exchange.	1	
2*	290.148	No. 15 scalpel blade. Used to attach liquid perfusion tubing to the cantilever holder.	10	
3	290.130	1/16” Hex Driver. Used to remove the cantilever holder (see Step 6 on page 180) and chamber bodies (see Step 2 on page 217).	1	
4	290.106	#00 Phillips Screwdriver. Used to replace the cantilever. See Step 12 on page 182.	1	
5	290.163	5/64” (2mm) Hex Driver. Used to remove the cell body from the scanner. See Step 1 on page 217.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
6*	080.165	1cc HSW Norm-Ject Syringe. Typically used to perfuse fluid.	4	
7*	080.010	5cc syringe, HSW. Typically used for fluid or gas perfusion.	4	
8	231.006	PFA Tubing, 1/16" OD, 0.040" ID. 5 ft package. Special large bore tubing for gas perfusion. . IDEX part number 1503.	2	
9*	231.028	FEP Tubing, 1/32" OD, .016" ID. 5 ft package. Used for fluid perfusion. . IDEX part number 1692. Note, all 4 sections are in one container.	4	
10	231.008	Luer Right fitting 1/16". Used for connecting tubing to syringes. . IDEX number P-837.	4	
11	232.015	Fittings, 1/16". Used to connect 1/16" tubing to the cell chamber wall. See Step 4 on page 218. IDEX part number M660. Use with tool 290.164.	4	
The scale in the photos is in cm and mm.				

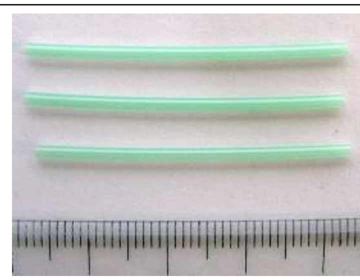
Itm	Part #	Item Description	Qty	Picture
12	114.800	Extender Tool Fitting Wrench. Use to tighten Fittings 230.015. See Step 1 on page 225. IDEX part number N-290. DO NOT use on the cell body fittings: Step 4 on page 218.	1	
13	232.016	1/16” Ferrules. Each ferrule requires a metal and a plastic part. Used with 1/16” fittings. IDEX part number M660.	6	
14	114.721	Fitting Compression Fixture. Required to attach fitting ferrules to 1/16” tubing.	1	
15	290.165	Platypus Tweezers. EMS part 78317 style 2AZ. Useful for removing standard sample pucks from the sample chamber. See Step 19 on page 184.	1	
16*	231.019	1/16” to 1/32” tubing reducer sleeve. Used to connect 1/32” OD fluid perfusion tubing to standard syringes. IDEX part F-247X	4	
17	1-72 x 0.25 SHCS SS	1-72 x 1/4” long screw. Spare screws used to lock down the cantilever holder. See Step 2 on page 211.	10	
18	114.576	Stage locking screw with integrated ball end . Spare screws used to lock down the sample stage. Step 8 on page 220. Be careful, these are very expensive screws.	2	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
19	2-56 x 0.125 SHCS SS	2-56 x 1/8” long screws. Spare screws used to lock down the cell chamber body. See Step 2 on page 217.	12	
20	00-90 x 1/8” Pan Head SS	00-90 x 1/8” screw. Spare screws used to fasten the sample stage membrane to the cell body. See Step 4 on page 211.	12	
21	230.040	FKM O-ring, 1.5mm x 0.5mm, 75A Durometer. Now obsolete, use 230.039 instead.	0	
22	230.039	FKM O-ring, 1.5mm x 0.7mm, 75A Durometer. Used to seal the cantilever clip. Custom size, only available from Asylum Research. Equivalent FFKM part is 230.050.	18	
23	114.738	Modified (shortened) Flat Head Phillips M2 screw, Stainless steel. Spare screws to hold down the cantilever clip.	3	 photo needs update!
24	222.077	1/16” dowel pin. Used to restore slightly compressed fitting parts.	2	
25	290.168	1.8mm slotted screwdriver. Used to fasten the sample stage membrane to the cell body.	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
26	232.017	1/8” NPT X 6mm tubing connector. Used to connect 6mm tubing to gas flow rotameter.	1	
27	232.018	1/8” X 1/4” union. Used to connect 1/4” tubing to gas flow rotameter.	1	
28	xxx.xxx	1/8” OD X 1/16” ID vinyl tubing. Used to connect to the gas flow rotameter.	6 ft	
29	114.801	Thermal pad, spare. Adheres to the back of the environmental scanner. Use as a replacement in case the original is damaged.	1	
30	114.820	Cantilever holder cleaning cup. Used to rinse and clean the cantilever holders while not causing damage to the circuit board.	1	
31	230.044	O-ring, 0.75"ID X 1"OD Viton, Durometer 75A. Equivalent FFKM part is 230.038. Standard AS568-020 size, can also be purchased from other vendors. Sits around cantilever holder perimeter.	2?	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
32	230.038	O-ring, 0.75"ID X 1"OD Kalrez 6375, Durometer 75A. Equivalent FKM part is 230.044. Standard AS568-020 size, can also be purchased from other vendors. Sits around cantilever holder perimeter. Stored in separate box, see Figure 16.2 on page 177.	1	
33	230.050	O-ring, 0.022" C/S X 0.063” ID x 0.107” OD, FFKM, 75A Durometer. Obsolete, now use 230.051.	0	
34	230.051	O-ring, 0.032" C/S X 0.062” ID x 0.126” OD, FFKM, 75A Durometer. Custom size, only available from Asylum Research. Equivalent FKM part is 230.039. Used to seal the cantilever holder clip. Stored in separate box, see Figure 16.2 on page 177. For use,	3	
35	448.140	Electrical Sample Puck Assembly. Used to electrically bias or ground a sample. Includes Puck Bias Lead wire (448.139) and Modified 000-120 screw (114.853).	3	
36	901.778	ES tubing kit. Pre-made tubing with fittings and ferrules for making connections between the cell side ports and manifold. See 20.	2	
The scale in the photos is in cm and mm.				

* These items are only likely to be used for fluid perfusion experiments which require a perfusion capable cantilever holder and a fluid compatible sample stage .

Itm	Part #	Item Description	Qty	Picture
6*	080.165	1cc HSW Norm-Ject Syringe. Typically used to perfuse fluid.	4	
7*	080.010	5cc syringe, HSW. Typically used for fluid or gas perfusion.	4	
9*	231.028	FEP Tubing, 1/32” OD, .016” ID. 5 ft package. Used for fluid perfusion. . IDEX part number 1692. Note, all 4 sections are in one container.	4	
16*	231.019	1/16” to 1/32” tubing reducer sleeve. Used to connect 1/32” OD fluid perfusion tubing to standard syringes. IDEX part F-247X	4	
		Labsmith		
The scale in the photos is in cm and mm.				

16.2. Terminology

Referring to figure Figure 16.1 on page 170:

Cantilever Holders: Chapter 18 on page 188

Cell Bodies: Section 19.1 on page 195

Sample Stages: Section 19.2 on page 207

Scanner Swapping: Chapter 31 on page 338

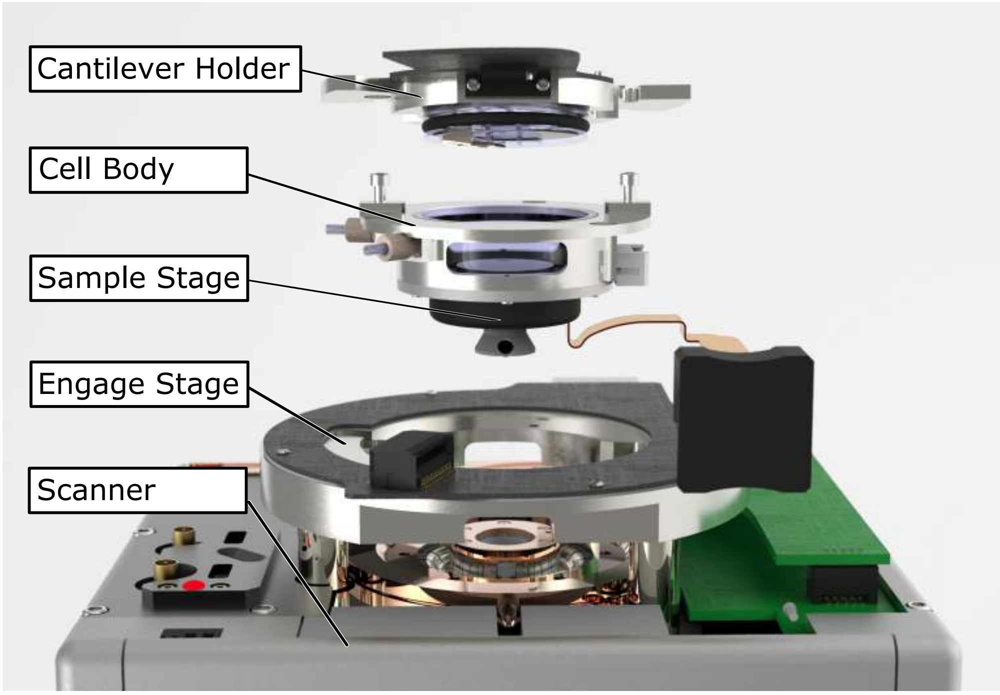


Figure 16.1.: Cypher Environmental Scanner Basic Parts

16.3. Cypher ES Quick Reminder List

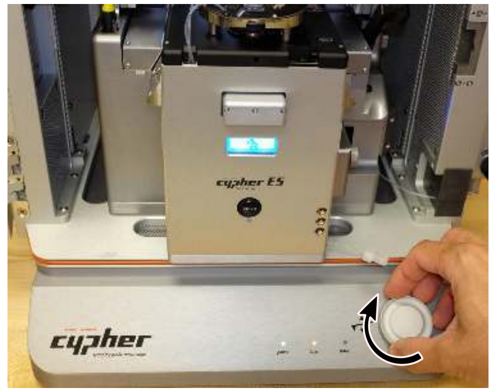
In this section, we provide a list of pitfalls to avoid during use of the Cypher ES. The target audience of this section is fairly specific: it is written for those users who are experienced Cypher S users but have had only a basic training on the Cypher ES. This list then allows the regular Cypher S user a quick way to remind themselves of important warnings before using the Cypher ES. Note that this reminder list assumes the user has already received basic training on the ES. New users can safely skim this section and then return to it after they have had a better understanding of ES operation.

16.3.1. Reminders for imaging

1.

Remember to fully raise the engage stage before loading the cantilever holder.

- Compared to the S, on the ES scanner it is more difficult to see if there is enough clearance for safely loading the cantilever holder.
- The stage needs to be high enough so that when you mount the cantilever holder it does not come in contact with the sample.
- Rotate the 'Engage Control Knob' on the Cypher *clockwise* and hold until the engage stage is at its upper limit of travel. Or, Hit the '(Un)/Load Sample Button' prior to mounting the cantilever holder. The upper position is safe for all samples other than those that are too thick to be run in the ES.

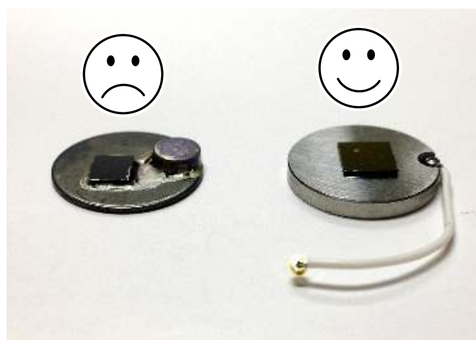


Warning: Pay attention! Failure to check for clearance may cause serious damage to your cantilever holder and/or sample stage.

2.

Never load "non-flat" samples into the ES scanner.

- Unlike the S scanner, the ES scanner cannot accept "non-flat" samples.
- *A "non-flat" sample is any sample in which the region to be scanned is not the tallest feature on the sample puck.* For example, the sample shown shown on the left has a magnet glued to the puck that is taller than the sample.
- Given the low profile of the ES cantilever holders, it would not be possible to engage on the sample shown shown on the left since the magnet would hit the cantilever holder before the cantilever engaged on the sample.
- For electrical measurements, use the low-profile electrical sample puck (as shown on the right) provided in the accessory kit.

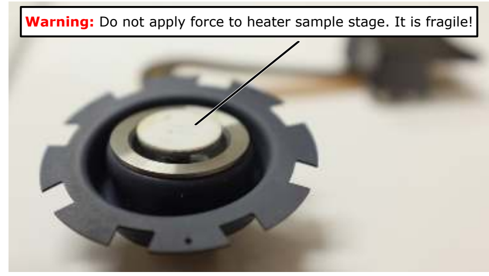


Warning: Pay attention! Attempting to starting a tip approach on a "non-flat" sample may cause serious damage to your cantilever holder and/or sample stage.

3.

Never touch the Heater sample stage with your tweezers.

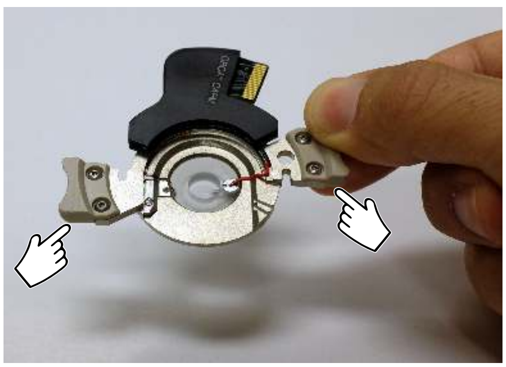
- The Heater sample stage is extremely fragile. In order to achieve high temperatures while still maintaining low drift performance, the Heater Sample Stage is constructed with fragile ceramics.
- When loading/unloading the samples, take care to never push directly on the sample stage with your tweezers.
- When adjusting the lateral position of the sample, use minimal force. Pushing on the sample with too much force may crack the heater.

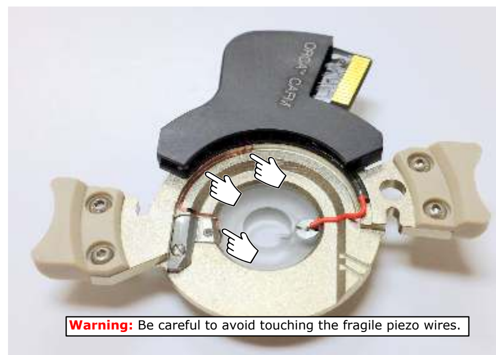


Note Although it is not required, lowering the cantilever holder stage fully (with the cantilever holder removed!), will make it easier to exchange samples without touching the heater stage.

Warning: Pay attention! If you are careless when loading/unloading the Heater sample stage you will break it.

4.





Hold the cantilever holder only by its handles.

- Hold the cantilever holder only by its two plastic handles (upper image).
- In particular, avoid contacting the wires running to the tapping piezo (lower image).
- Be careful not to scrape the piezo wires when tightening the right side cantilever holder locking screw.

Warning: Pay attention! The piezo wiring is very fragile. Be careful not to touch it.

5.

Always power off the microscope *before* exchanging scanners.

- Before exchanging scanners, remember to first motor the objective to its upper limit of travel.
- Then *power off the controller* before disconnecting the scanner.
- Exchange scanners and then power the controller back on after the new scanner has been reconnected.

Warning: Pay attention! On older Cyphers, exchanging the scanner while the system is powered up can damage the backpack electronics.

6.

Make sure the scanner is fully seated against the chassis before locking in place.

- Unlike the S scanner, which has a hard stop on the back of the scanner, the ES scanner has a spring loaded stop that needs to be fully engaged.
- When inserting the ES scanner into the chassis, push the scanner until you feel the spring on the back of the scanner engage. Fully depress the spring until you feel the hard stop.
- After fully engaging the spring loaded stop at the back of the scanner, lock the scanner in place.

Note Proper seating of the scanner is most important when using the cooling capabilities of the Cooler-Heater sample stage. During normal operation it is not particularly important.

7.

Take care to properly set the correction collar on the objective.

- The ES scanner uses different correction collar settings than the S scanner.
- The ES scanner uses 1.5 for gas operation and 2.0 for liquid operation.

Note Incorrectly setting the correction collar will degrade the optical image quality. In addition it will cause slight errors in the XY calibration of the scanner.

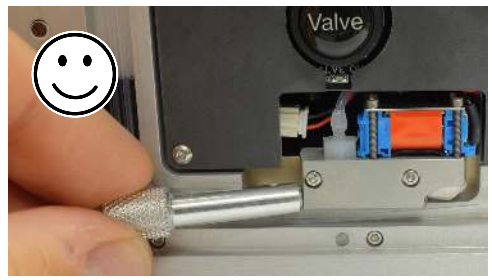
16.3.2. Reminders for cell exchange and handling

1.

The fitting wrench should never be used to attach gas lines to the cell body.

- The fitting wrench (114.800) supplied in the accessory kit should **NEVER** be used with the cell bodies (see top right image).
- The fitting wrench should only be used with the fitting fixture (114.721), which is also supplied in the accessory kit, or the manifold on the front of the scanner. See the bottom right image.

Warning: Pay attention! Using the fitting wrench on the cell body will crack the cell body glass.



2.

Be careful not to poke the sample stage diaphragms.

- Be careful never to poke the sample stage diaphragms with tweezers or screwdrivers as this may cause a hole in the diaphragm.
- Some versions of the sample stages have permanently attached diaphragms. These stages cannot be repaired if their diaphragms are damaged.

Warning: Pay attention! Don't poke a hole in your sample diaphragm by being careless.

3.

Be careful when reattaching the cantilever clip to not crack the glass.

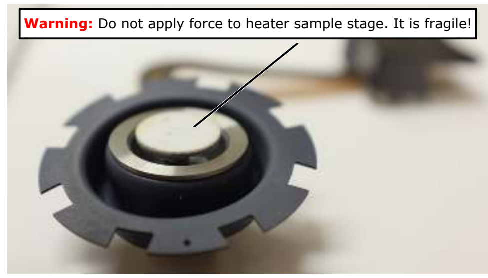
- Anytime the cantilever clip has been completely removed - for cleaning - care must be taken when reattaching the clip.
- Do not tighten the screw until you are sure that the clip is aligned correctly and has dropped into the pocket in the glass body.

Warning: Pay attention! Failure to align the cantilever clip with the pocket before tightening the clip will break the cantilever holder glass.

4.

Use extra care when loading the Heater sample stage.

- The heater sample stage is extremely fragile. Only use minimal force when seating the sample stage dovetail against the scanner.
- If you use your finger to push the stage down into the scanner, you should only need enough pressure to extend the diaphragm. Any more pressure will break the heater. If it is taking more pressure to push the dovetail into the scanner, simply push the dovetail over (with a wrench from the bottom of the sample stage) until it drops into the scanner.
- It is a good idea to wear gloves when doing this so that you minimize finger grease getting cooked onto the heater stage.



Warning: Pay attention! If you apply too much force to the heater stage you will break it.

5.

Remember to cut off extra tubing before connecting gas lines to the cell body.

- If you are using a Cypher ES that shipped before 2014 it is likely that you need to cut off the extra length of tubing that extends past the end of the ferrule on the gas lines.
- Cut the tubing so that is flush with the ferrule. You only need to do this for the end of the line that connects to the cell body.
- Failure to cut off the tubing will not break anything, but it will make it much more difficult to get a good seal between the gas line and the cell body.

6.

When unlocking the sample stage from the scanner you only need 3 turns.

- To unlock the sample stage from the scanner, turn the locking screw counter-clockwise three turns.
- Turning the locking screw more than three turns may cause the screw to come all the way out.
- If the screw comes all the way out, you may need to lean the scanner forward until the screw slides out to a place where you can put it back on the wrench.

7.

Don't apply more than 200mbar pressure to the cell.

- When checking for leaks in the cell, it is useful to apply pressure to the chamber by using a syringe.
- Don't pressurize the chamber over 200mbar as higher pressures may damage the diaphragm.

Image Needed

16.4. Chemical Compatibility

The ES scanner is equipped with FKM (Viton equivalent) O-rings in the factory. For cases where viton is chemically attacked, please switch to the included FFKM (Kalrez equivalent) O-ring. These rings can be found in a small box, shown in 16.2. When you no longer require these O-rings, please store them back in the case. FFKM Costs between 10 and 100 times more than FKM, so do not misplace them.

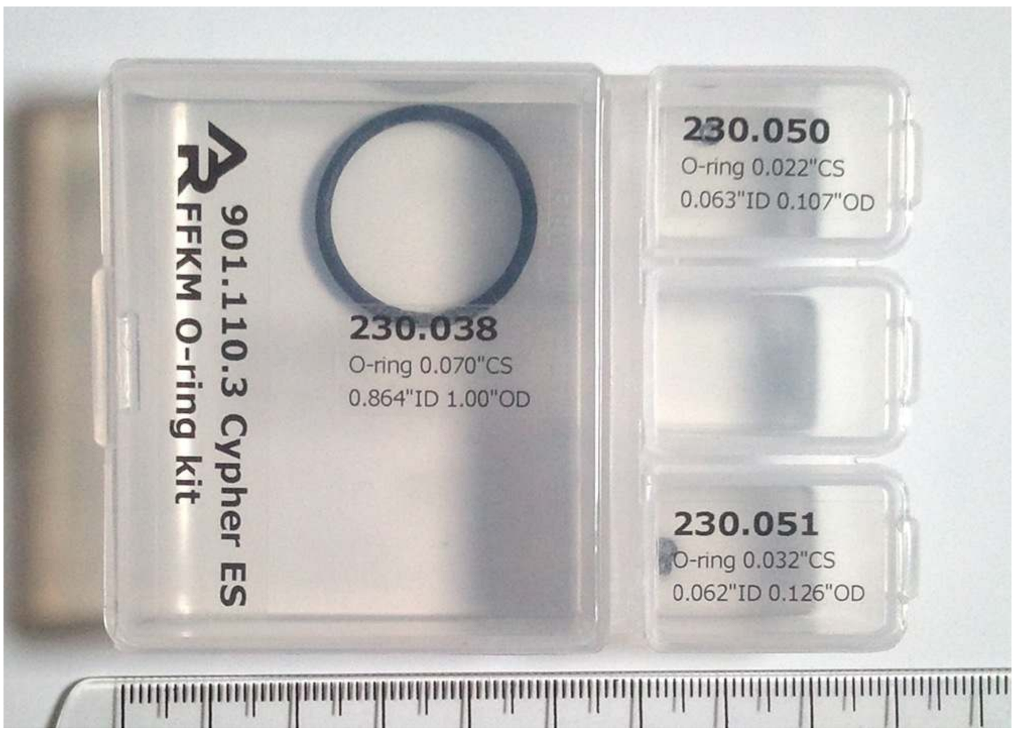


Figure 16.2.: The FFKM O-ring Kit, 901.110.3.

17. Tutorial: AC Mode Imaging in Air with the Environmental Scanner

CHAPTER REV. 2035, DATED 08/15/2018, 11:50. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

This tutorial provides a quick path to learning the basic operation of the Cypher ES Environmental AFM. If you own the standard scanner, please follow the tutorial in Chapter 7 on page 40. The tutorial contains 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.

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

The Cypher is a research grade instrument and improper use of the instrument can cause damage to the instrument and/or injury to the user. This tutorial will take approximately 3 hours.

Before you start:

- We assume you understand the aspects of running this system safely: (Chapter 1 on page 3.)
- You are familiar with the basic names of the hardware components and software controls (Chapter 2 on page 14.)
- You have powered up the Cypher and launched the software: (Chapter 5 on page 33.)

17.1. Required Materials

This tutorial is designed to be performed, not merely read. If possible, take the tutorial under the supervision of an experienced user (tell them to mostly sit back though, or you will not learn as much as you would by yourself).

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

1. Cantilevers: You will need an AC160TS cantilever, which is manufactured by Olympus. The AC160TS has a spring constant of ~42N/m and a resonance frequency of ~300kHz and is a workhorse for AC mode imaging in air. Every Cypher ships with a package of AC160s, but 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 Asylum Research calibration grating that ships with every system (Asylum Part# 290.237).
3. Tweezers, preferably with curved tip (for example, Asylum Part# 290.102).
4. Tweezers, “platypus style” (Asylum Part# 290.165).

5. A 1/16” ball head wrench (for example, Asylum Part# 290.139).
6. A Cypher equipped with the Environmental Scanner and a large spot SLD or Laser Module (See Chapter 33 on page 346).

17.2. 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.

Raise the cantilever holder:

- Rotate the ‘Engage Control Knob’ on the Cypher *clockwise* and hold until the cantilever holder is far from the sample or is at its upper limit of travel.

Note Although it is not required, for safety reasons we recommend making motor moves with the door closed. Beware of pinch points (Figure 1.1 on page 5).

Warning: Pay attention! If you turn the knob the wrong way (counterclockwise), you will *lower* the cantilever holder instead of raising it. When you lower the cantilever holder, you can crash the cantilever holder into the sample and cause serious damage to the scanner.

2.

Open enclosure:

- Lift the door latch and open the enclosure door.

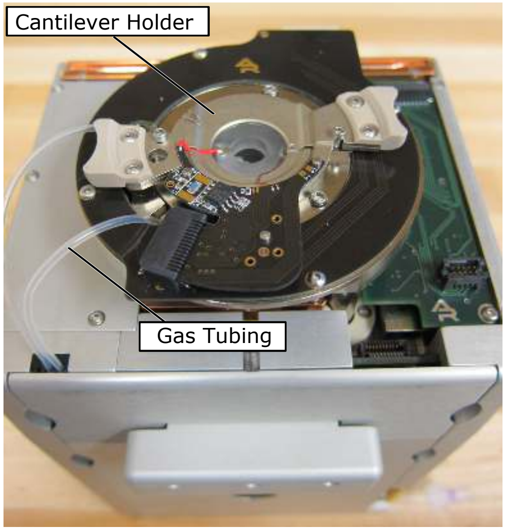
3. **Unlock scanner:**

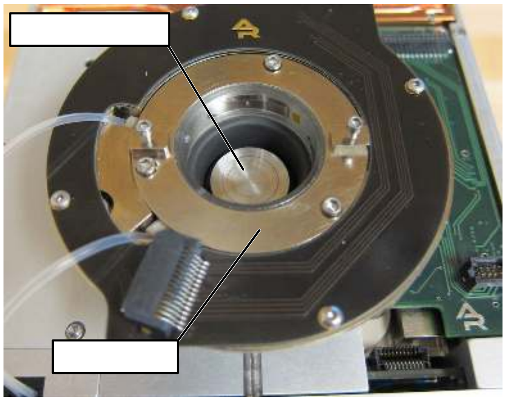
- Lift the lever to the right of the scanner.

4. **Pull the scanner forward:**

- Pull the scanner forward gently and stop when it is about halfway out. As you pull the scanner out, at some point you will feel resistance and should pull no farther.

5.



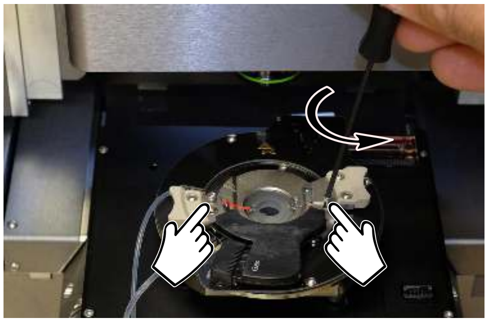


Familiarize yourself with the sample area:

- While it may look solid, the scanner sample stage moves the sample in X, Y, and Z imperceptibly up to 40μm.

6. **Release the cantilever holder:**

- Locate the tool with yellow tip in the chassis to the left of the scanner.
- Use tool to loosen the two screws clamping the cantilever holder. One turn *counterclockwise* should be enough (do not completely unthread screws.
- Replace the tool.

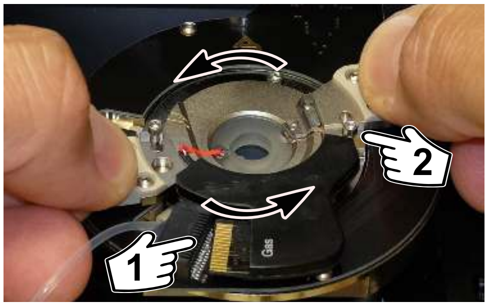


7. **Rotate the cantilever holder:**

- Place your fingers on the two side cantilever holder handles.
- Rotate *counterclockwise* a few degrees.

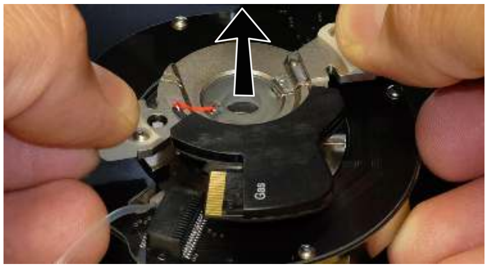
1 the cantilever holder circuit board come out of its mating connector. Stop when the board has cleared the connector.

2 Notice the screws come away from the cutouts in the cantilever holder.



8. **Remove the cantilever holder:**

- Once the board has cleared the connector, *carefully* wiggle the cantilever holder up and out.
- The resistance you feel as you remove the cantilever holder comes is the cantilever holder O-ring sliding out from the cell body. Once the O-ring clears the cell body, be ready for the resistance to drop suddenly. *Keep a firm grip on both handles* to keep from flinging the cantilever holder across the room!



9. **Set aside the cantilever holder:**

- Set the cantilever holder on its handles with the cantilever facing up so that you do not crush the cantilever.

10.

Locate your cantilever holder:

- Identify the appropriate cantilever holder. This tutorial requires the standard Gas cantilever holder, Asylum Part# 901.758.
-

Note To learn more about cantilever holders for the Environmental Scanner, please refer to Chapter 18 on page 188.

11.

Prepare cantilever mounting workspace:

- You will need the following items:

a) Tweezer, curved (Asylum Part #290.102)

b) 300 Philips Screwdriver (Asylum Part #290.106)

c) Box of AC160TS cantilevers

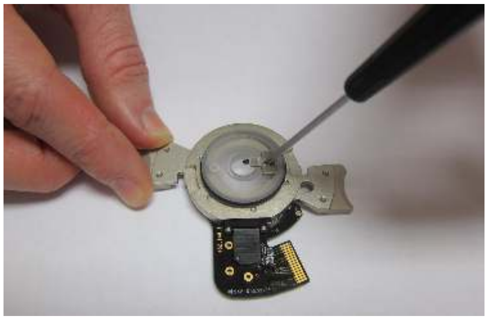
d) Gas cantilever holder

- A low power binocular dissection stereoscope with light source can be useful for some of the following steps.
- Cleaning the tweezer tips with alcohol improves the handling of the cantilevers.

12.

Loosen the cantilever clip:

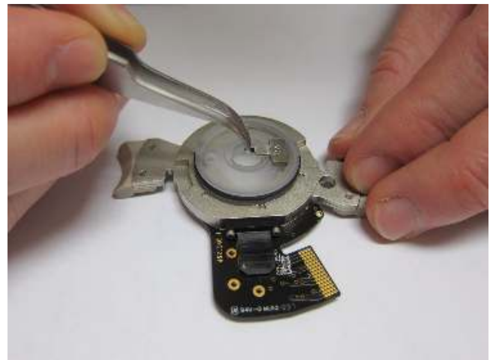
- Unscrew the clamping screws by one half turn.
- Do not unthread the screw completely. If you accidentally do, please refer to the cantilever holder chapter.



13.

Remove the old cantilever:

- If a cantilever has already been loaded, use tweezers to remove it from the cantilever holder.



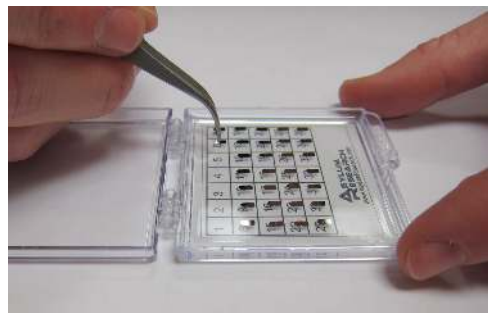
14.

Select new cantilever:

- Use tweezers to pick up new cantilever.
- Close the box! Ruining $1k of levers by putting your hand on an open box is not unheard of.

Note If your lab saves some old cantilevers, consider practicing with a “dummy” cantilever.

Tip Some find it useful to first lay the chip down on a non-sticky surface and re-grip it before continuing.

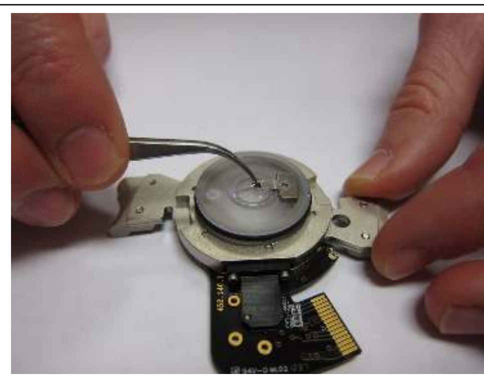


15.

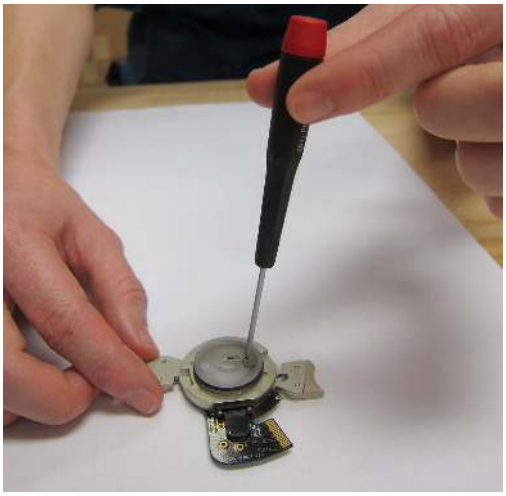
Load new cantilever:

- Use tweezers to slide the new cantilever under the clip. You can “push” or “pull” the cantilever into place as you find comfortable.
- Position the cantilever so that the tip is approximately centered in the cantilever holder window.

Note You may nudge the cantilever chip from the side to align it, but do NOT nudge the end of the chip, as you risk damaging the cantilever. It helps to do this at least once under a binocular stereo microscope.



16.



Secure the new cantilever:

- Using *fingertip pressure only*, lightly tighten the screw securing the cantilever to the cantilever holder.
- The clip should be just tight enough to secure the cantilever chip when it is pushed from the side.

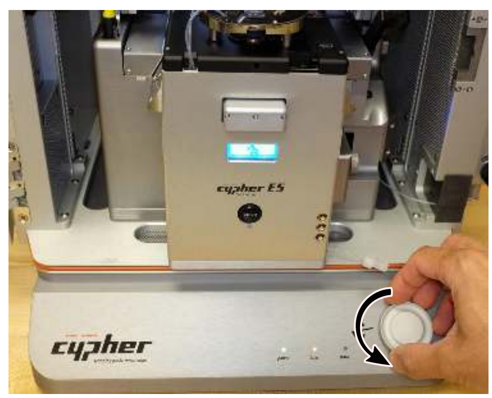
17.

Prepare scanner to remove old sample:

- Leave the cantilever holder on your workspace for now.

Note To load or unload a sample, you will need to lower the coarse engage stage so that you can access the sample stage.

- Rotate the Engage Control Knob *counterclockwise* until it reaches its lower limit of travel.



18.

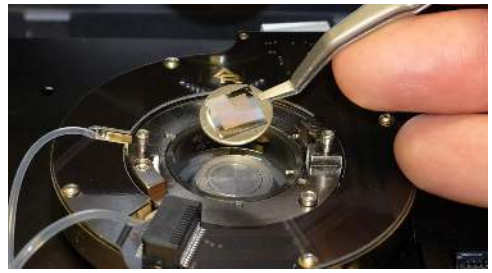
Remove old sample:

- Use “Platypus” tweezers (Asylum Part # 114.721) to remove the old sample from the sample stage.
- Wipe the sample stage clean with a cloth or use compressed air. Any dust or grit will prevent the sample disc from seating properly.

19.

Replace with new sample:

- Use “Platypus” tweezers (Asylum Part # 290.165) to place new sample on sample stage. For this tutorial, use the Asylum Research calibration grating sample, part # 900.237. It will attach magnetically.

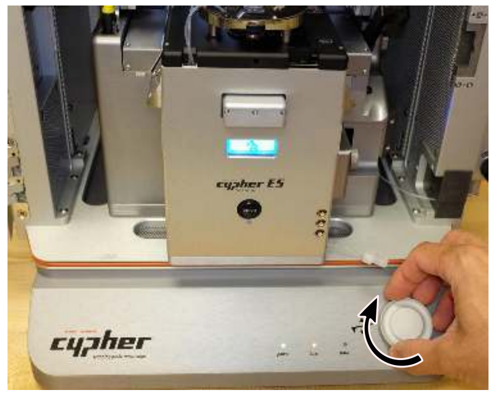


20.

Prepare scanner to load cantilever holder:

- RAISE THE COARSE ENGAGE STAGE by turning the Engage Control Knob *clockwise.*Raise the stage until it reaches its upper limit of travel.

Warning: Before loading the cantilever holder, raise the coarse engage stage. If you do not raise the coarse engage stage, you will crash the cantilever into the sample and ruin your cantilever, sample, and possibly even the cantilever holder!



21.

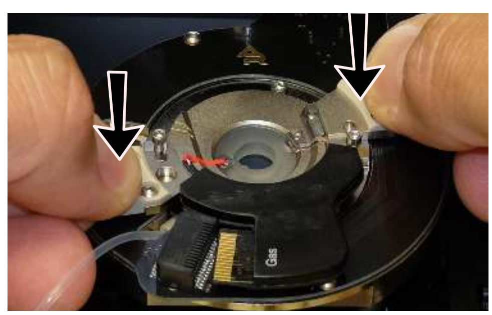
Place cantilever holder:

- Check to make sure that the coarse engage stage is raised to its highest position.
- Position the cantilever holder in the cell body as shown in the image to the right. The cantilever holder should sit level and be rotationally aligned so that the cantilever holder board is almost touching its mating connector.

22.

Press the cantilever holder down:

- Before starting this process it is important that the cantilever holder is sitting level with respect to the top of the cell body.
- With fingers on both handles of the cantilever holder, use firm pressure to wiggle the cantilever down into the cell body. The O-ring will offer some resistance. When the cantilever holder is firmly seated, you will feel a hard stop as metal parts make contact.



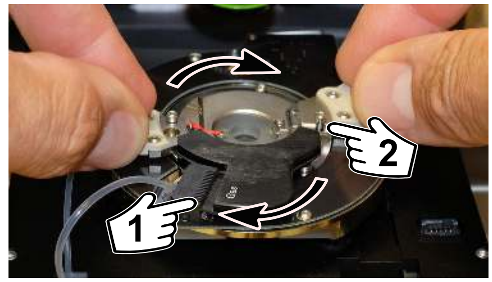
23.

Rotate:

- Rotate the cantilever holder *clockwise* until you feel a hard stop.

1 The cantilever holder contacts slip into the mating connector.

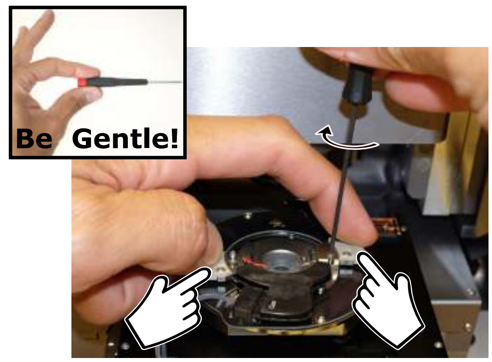
2 Notice the screws cause the hard stop as they slip into the matching metal cutouts.



24.

Tighten the screws:

- Place pressure on the cantilever holder handles as shown. Make sure it's firmly seated.
- Finger tighten one of the screws **and stop as soon as you feel any resistance**.
- Do the same to the other screw.
- Release the pressure on the handles and tighten both screws a tiny bit more.
- At all times, only hold the screwdriver with your fingertips.



25.

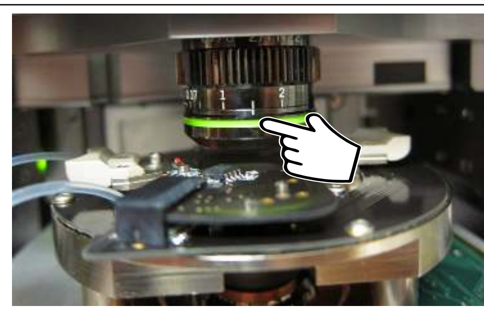
Slide scanner into chassis:

- Slide the scanner back into the chassis. Use firm pressure until you feel a hard stop. Before you feel a hard stop you will feel a spring-like resistance. You are making thermal contact between the scanner and the chassis. This is necessary for best performance.
- Maintain pressure on scanner and press the lever at the right downward to lock the scanner into place.

26.

Check correction collar:

- Check that the green correction collar on the objective is set properly. For the Gas cantilever holder, set the correction collar to 1.5.

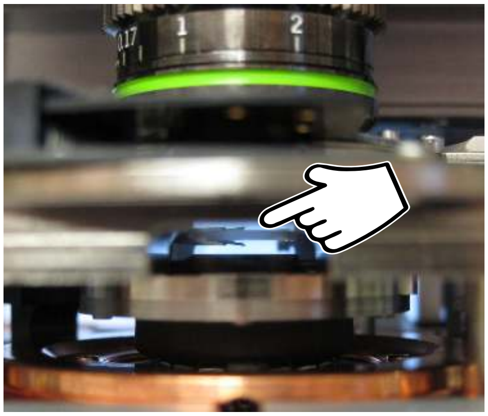


27. **Close enclosure door:**

- *Gently* close the door and latch it.

28. **Motor cantilever toward sample:**

- Place your eyes level with the cantilever and sample, so you can clearly see the gap between cantilever and sample.
- Slowly turn the 'Engage Control Knob' on the AFM enclosure *counterclockwise*. This will lower the cantilever holder and objective toward the sample. The more you turn, the faster the stage moves.
- Close the gap between tip and sample to about 1 millimeter.



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

29. This concludes the manual interaction with Cypher. We next turn our attention to the computer. Please jump to Section 7.3 on page 48.

18. Cantilever Holder Guide

CHAPTER REV. 2030, DATED 07/26/2018, 13:29. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

Depending on your specific imaging application the appropriate cantilever holder must be used. This chapter serves as a guide to the available options and to help you identify the types of cantilever holders you may already own.

All the available cantilever holders have many things in common:

- All have a circuit board which allows the system to identify the type of cantilever holder and to activate the appropriate software control panels.
- All have a piezoelectric actuator and allow AC mode and contact mode imaging.
- Nearly all have the ability to apply a voltage to the cantilever.

Many more contain specific electronics allowing for current measurement, application of high voltage to the tip, and more.

Be Careful	Cantilever holders are the most delicate components of the AFM. Treat it like you might treat your great grandfather's pocket watch. Never drop it. Remember that even the most basic cantilever holder costs thousands of dollars to replace.

18.1. Identifying Cantilever Holders

18.1.1. Visual Guide of Cantilever Holders

Please use this table to identify your cantilever holders and find the relevant sections which describe them.

Part #	Holder Description	Top Photo	Bottom Photo

Part #	Holder Description	Top Photo	Bottom Photo
901.758	**Gas** For most contact and AC mode Imaging.		
901.770	**Liquid** For fluid imaging in a droplet.		
901.745	**Perfusion** For fluid imaging in a droplet with flow.		
901.767	**ORCA** Conductive AFM with a single current range, 2nA/V.		
901.771	**High Voltage** Typically used for High Voltage PFM Imaging.		
901.777	**STM** Scanning Tunneling Microscopy.		

18.1.2. Electronic Identification of Cantilever Holders

1. Attach the cantilever holder to the Cypher Scanner.
2. From the main menu bar in the software select *Programming ▷ Cantilever Holder and Sample Panel*.
3. At the bottom left of this panel click the 'Check Holder' button and the type of cantilever holder will be highlighted.

18.2. Disassembly

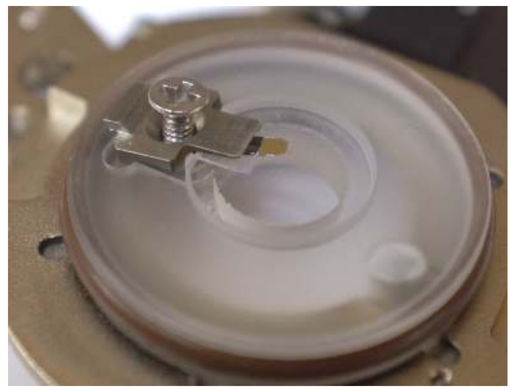
Only the cantilever clip can be removed from the cantilever holder. All other parts should not be removed or serviced by the user.

18.2.1. Removing the Clip

1\.

Remove the screw:

- Using a small phillips screwdriver, simply unscrew the screw completely.



2\.

The clip:

- The clip should come off as shown.
- Spare screws and O-rings can be found in the parts kit (see Section 16.1 on page 163).

18.2.2. Attaching the clip

1\.

Cantilever holder:

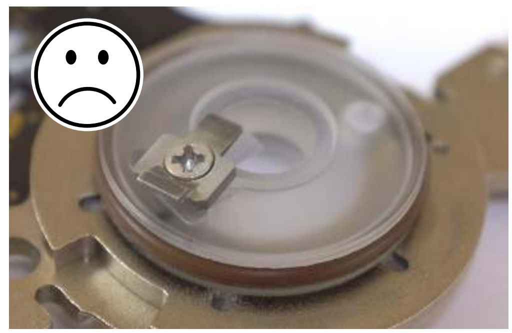
- The Cantilever holder should be sitting ready without a clip, as shown.

2.

Prepare the clip:

- Put the screw, clip, and O-ring together as shown.
- Screw only a few turns into the threaded hole in the glass of the cantilever holder.
- DO NOT TIGHTEN YET!

3.



Check clip rotation:

- Rotate the clil so it does not overhang any of the glass cutout's edges.
- Press down on the clip so it settles down into the cutout area of the glass.

4.

Tighten the screw:

- Using a small phillips screwdriver, tighten the screw until you feel some resistance. This will be the O-ring compressing.
- If the clip still has a tendency to turn around during tightening of the screw, consider holding the clip pressed down (right photo) so it seats properly in the cutout feature.

18.3. Cleaning

Only the glass parts of the cantilever holder should come into contact with fluid during cleaning. To prevent fluid from touching the circuit components, please use the cleaning cup as shown below.

1. **Locate parts:**

   - Locate the Cleaning Cup (114.820).
   - Select the cantilever holder you want to clean.
   - Optionally, remove the screw and clip (see Section 18.2.1 on page 190).

2. **Attach holder to cup:**

   - Make sure the screws are loose enough.
   - Fit and rotate the holder onto the the cup, same procedure as fitting the holder to the AFM (see Step 22 on page 185).
   - Tighten the screws lightly.

   Note: A perfusion cantilever holder should have plugged fluid ports before proceeding to the next step.

3. **Add cleaning fluid:**

   - Pour a small amount of solvent or water into the cup. We recommend ethyl or isopropyl alcohol or deionized water.

   Note Acetone and Methylene Chloride and other aggressive solvents should not be used since they can attack epoxy which is exposed when the cantilever holder clip is removed.

4. **Clean:**

   - Use a soft swab to clean the surface of the cantilever holder.
   - Rinse and repeat as desired.

5. Blow dry with compressed filtered air.
6. Remove the holder from the cup.
7. Blow dry around the large O-ring, some solvent may have become trapped in the outer perimeter O-ring groove.

18.4. Storage

After cleaning, store the cantilever holder in the membrane box in which it originally shipped.

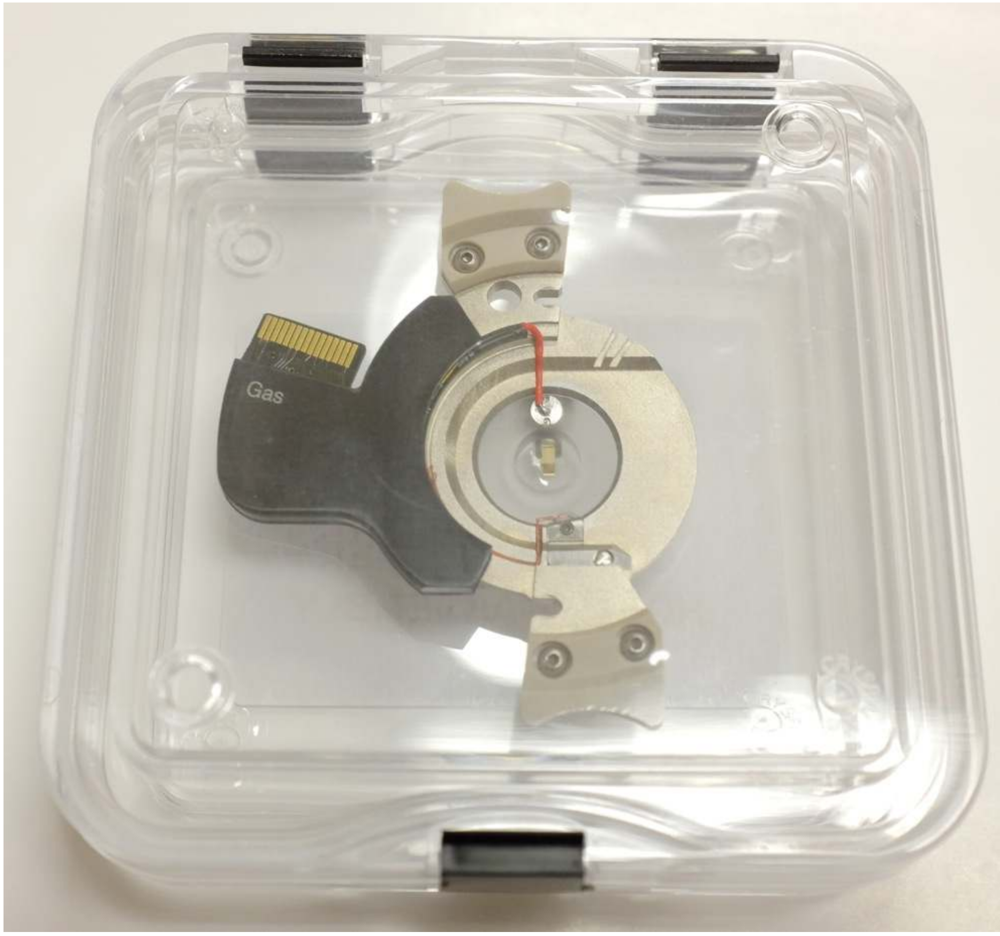


Figure 18.1.: A cantilever holder properly stored in its box.

19. Cell Body and Sample Stage Guide

CHAPTER REV. 2030, DATED 07/26/2018, 13:29. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

The sealed environment around the sample and cantilever is formed by three components:

- The cantilever holder forms the lid.
- The cell body forms the sides.
- The sample stage forms the bottom.

(a) A Perfusion Cantilever Holder, Fluid Cell Body, and Ambient Sample Stage, disassembled.

(b) A fully sealed assembly.

Figure 19.1.: Ambient Stage

The various cell bodies are described in Section 19.1 on page 195, the cantilever holders in Chapter 18 on page 188, and the samples stages in Section 19.2 on page 207.

The connection between cell body and sample stage is always the same mechanism and is described in Section 19.3 on page 210.

The process of attaching the gas lines to the side of the cell body is described in Section 19.4.4 on page 218.

19.1. Cell Body Guide

19.1.1. Identifying Cell Bodies

Please use this table to identify your cantilever holders and find the relevant sections which describe them.

Part #	Holder Description	Front Photo	Back Photo
901.746	**Gas** This cell is meant to be used primarily for gas environments as it has electrical feedthroughs. However, it can also be used in a droplet environment.		
901.760	**Fluid** This cell is the same ast the Gas cell, but it does not have electrical feedthroughs.		

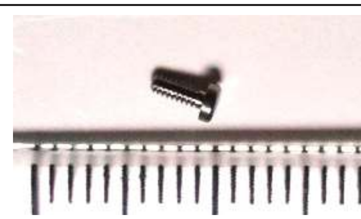
19.1.2. Gas Cell

The Gas cell has three magnetic contacts which can be used to route electrical signals to the sample.

(a) Electrical Connector **(b)** Magnetic Contacts

Figure 19.2.: Gas Cell Body

19.1.2.1. Parts list

Itm	Part #	Item Description	Qty	Picture
1		Gas Cell Body.	1	
2	114.916	Boot Clamp Ring, 8 Bolt Pattern. Connects to the bottom of the cell to form the seal between the cell body and the sample stage membrane. See Step 3 on page 213.	1	
3	00-90 x 1/8” Pan Head SS	00-90 x 1/8” screw. Spare screws used to fasten the sample stage membrane to the cell body. See Step 4 on page 211.	8	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
4	1-72 x 0.25 SHCS SS	1-72 x 1/4” long screw. Used to lock down the cantilever holder.	2	
5	448.137	Gas Cell Cable. Cable to connect to magnet contacts. See Section 19.1.2.3 on page 197.	1	
The scale in the photos is in cm and mm.				

19.1.2.2. Specifications

Exposed Materials:

Cell wall: Borosilicate Glass.

Contacts: Nicked or Gold Plated.

Other: Epoxy.

Cleaning: The whole cell body can be immersed or sonicated in ethyl or isopropyl alcohol or water. Do not use acetone or methylene chloride or other aggressive solvents as it will attack the epoxy between the glass and metal parts.

Liquid use: Safe for use with most liquids being used in a droplet, but we recommend the fluid cell body for use with liquids.

19.1.2.3. Gas Cell Cable Installation

1. Raise the engage stage fully (see Step 1 on page 179).
2. Unlock the scanner and pull it all the way forward. This will give enough access to plug in the cable. You may find it more comfortably to take the scanner out of the AFM completely. To do so, turn off the system power and follow instructions here: Section 31.1 on page 338.
3. **Locate Cable:**
   - Locate the Gas Cell Cable (448.137).

4.

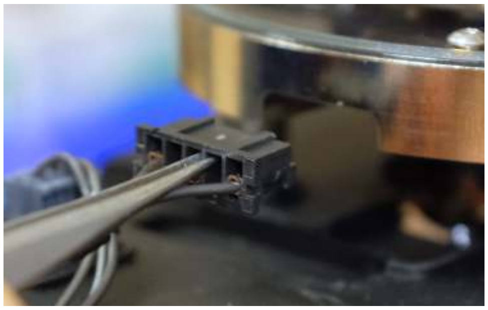
Orient the cable:

- The cable will plug in with the holes facing toward the top of the scanner.

5.

Grip the cable with tweezers:

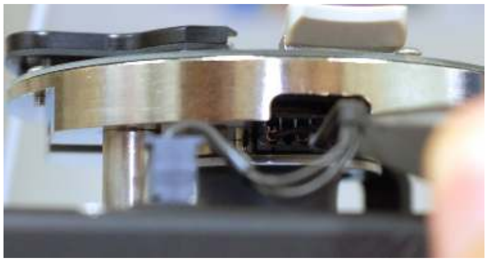
- Using sharp straight tipped tweezers, grip the connector as shown.



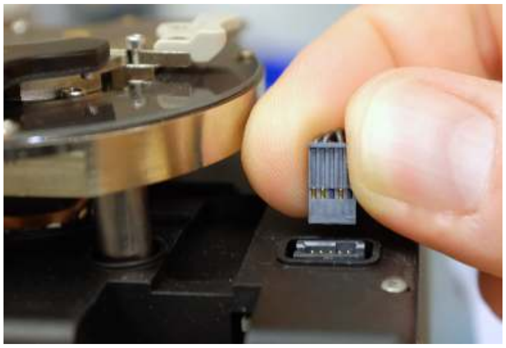
6.

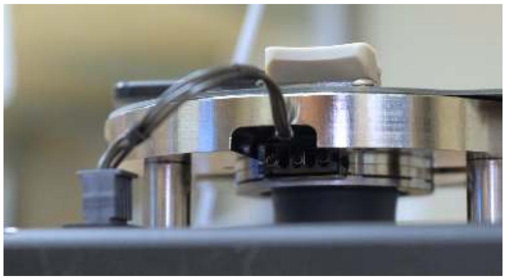
insert the connector:

- Carefully insert the connector as shown.



7.





Insert the smaller connector:

- Insert the smaller connector as shown on the left.
- The final cable position is shown on the right.

19.1.2.4. Applying Sample Bias or Ground

1.

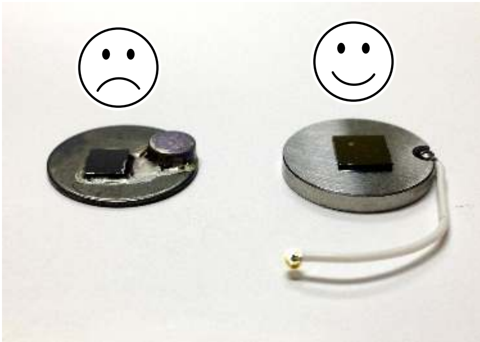
Sample mounting:

- Mount your sample onto the Electrical Sample Puck Assembly (448.140) using silver paint or some other conductive adhesive.

2.

WARNING: Never load "non-flat" samples into the ES scanner.

- Unlike the S scanner, the ES scanner cannot accept "non-flat" samples.
- *A "non-flat" sample is any sample in which the region to be scanned is not the tallest feature on the sample puck.* For example, the sample shown shown on the left has a magnet glued to the puck that is taller than the sample.
- Given the low profile of the ES cantilever holders, it would not be possible to engage on the sample shown shown on the left since the magnet would hit the cantilever holder before the cantilever engaged on the sample.
- For electrical measurements, use the low-profile electrical sample puck (as shown on the right) provided in the accessory kit.



Warning: Pay attention! Attempting to starting a tip approach on a "non-flat" sample may cause serious damage to your cantilever holder and/or sample stage.

3.

Sample BIAS Connection:

- Insert the sample puck as shown.
- Use blunt tipped tweezers to connect the wire as shown: to the FRONT connection. This applies a sample bias.

Note Lower the cell body to get more sample access: see Step 17 on page 184.

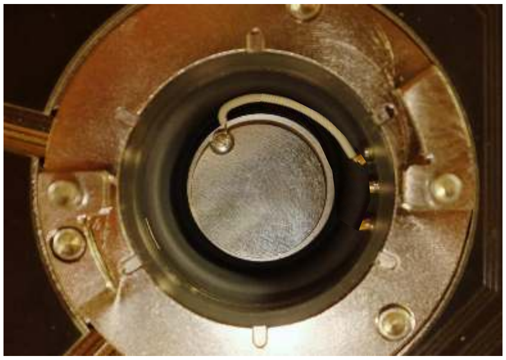
4.

Sample GROUND Connection:

- Insert the sample puck as shown.
- Use blunt tipped tweezers to connect the wire as shown., to the MIDDLE connection. This grounds the sample.

Note Lower the cell body to get more sample access: see Step 17 on page 184.

5.



Sample User Connection:

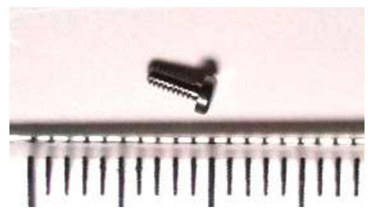
- The middle SMB connector on the front of the scanner connects directly to the third magnet, as shown in the photo on the left.

NOTE: This is when using the standard gas cell cable (448.137). There are other cables which assigning the magnet connections differently.

NOTE: If you don’t have a connector then use the crosspoint switch panel to route one of the BNC inputs from the side of the backpack to the “ sample” line. You won’t get an ohmic connection because the input passes through a buffer then through the crosspoint switch and then through another buffer. In that case he input range is like all the others. +/-10 V.

19.1.3. Fluid Cell Body

19.1.3.1. Parts list

Itm	Part #	Item Description	Qty	Picture
1		Fluid Cell Body.	1	
2	114.916	Boot Clamp Ring, 8 Bolt Pattern. Connects to the bottom of the cell to form the seal between the cell body and the sample stage membrane. See Step 3 on page 213.	1	
3	00-90 x 1/8” Pan Head SS	00-90 x 1/8” screw. Spare screws used to fasten the sample stage membrane to the cell body. See Step 4 on page 211.	8	
4	1-72 x 0.25 SHCS SS	1-72 x 1/4” long screw. Used to lock down the cantilever holder.	2	
The scale in the photos is in cm and mm.				

19.1.3.2. Specifications

Exposed Materials:

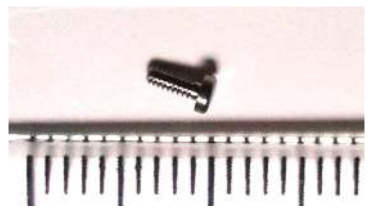
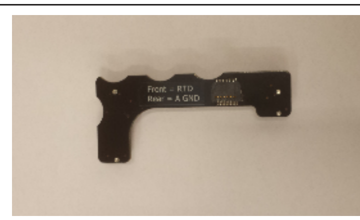
Cell wall: Borosilicate Glass.

Cleaning: The whole cell body can be immersed or sonicated in ethyl or isopropyl alcohol or water. Do not use acetone or methylene chloride or other aggressive solvents as it will attack the epoxy between the glass and metal parts.

Liquid use: Safe for use with any liquid compatible with borosilicate glass.

19.1.4. Humidity Cell

19.1.4.1. Parts List

Itm	Part #	Item Description	Qty	Picture
1		Humidity Cell Body.	1	
2	114.916	Boot Clamp Ring, 8 Bolt Pattern. Connects to the bottom of the cell to form the seal between the cell body and the sample stage membrane. See Step 3 on page 213.	1	
3	00-90 x 1/8” Pan Head SS	00-90 x 1/8” screw. Spare screws used to fasten the sample stage membrane to the cell body. See Step 4 on page 211.	8	
4	1-72 x 0.25 SHCS SS	1-72 x 1/4” long screw. Used to lock down the cantilever holder.	2	
5	458.257.1	Applications Board. Used to connect the Humidity sensor to the scanner electronics.	1	
The scale in the photos is in cm and mm.				

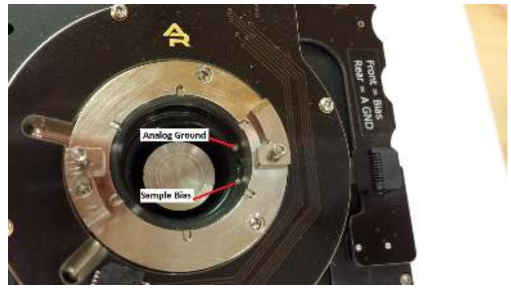
19.1.4.2. Overview

1.

Humidity Cell assembly:

- The Humidity Cell assembly consists of the cell body and an inrterconnect board called an Applications Board.

2.



Sensor and electrical connections:

- The humidity sensor is located behind the center hole in the side of the cell's interior. The two electrodes located on either side of the sensor opening provide electrical connections to analog ground and sample bias. Note that the stock applications board is configured this way. Other connections can be provided if your experiment requires something different. Please contact Asylum Research for details.

19.1.4.3. Installation

1. Use the coarse adjust wheel on the enclosure to raise the scanner's tip stage to the top of its range.
2. Remove the cell/stage assembly that is currently installed in the scanner. Please refer to the Cypher's user manual if you are not familiar with doing this.

3.

Install the applications board:

- Place the applications board over the connections on the top right side of teh Environmental scanner.

4.

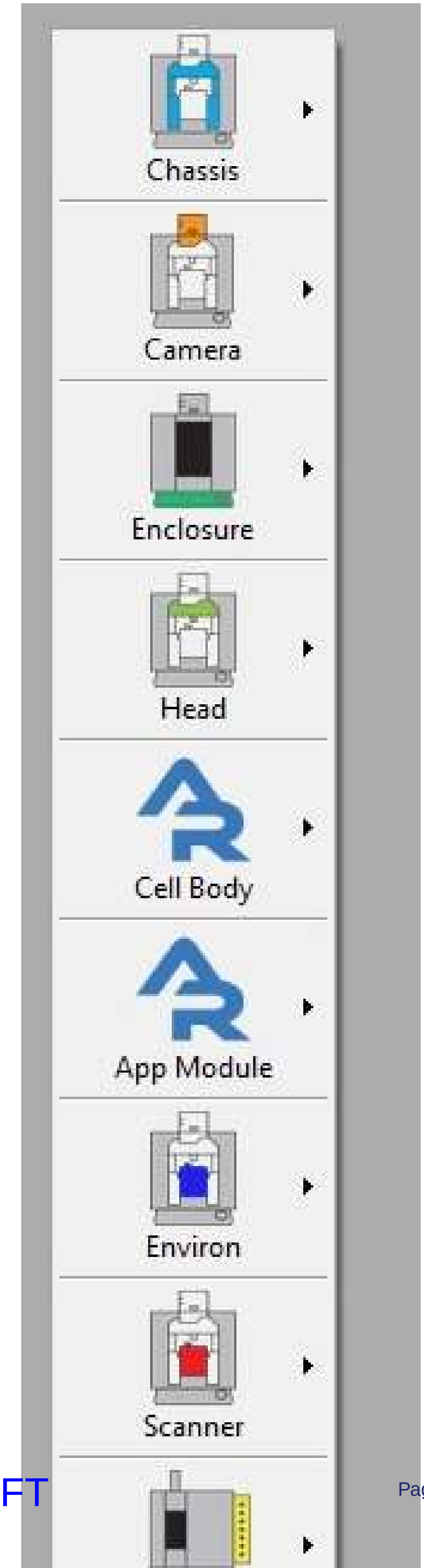
Seat the board:

- Gently push the board onto the connectors.

5. Fit the cell body into the scanner and secure it to the engage stage ring with 3, 2-56 x 1/8" screws.
6. Secure the stage base into the scanner. Note that the humidity cell is delivered with an Ambient Stage already installed. The humidity cell body is compatible with all the Environmental Scanner Stages. If your experiment requires temperature control then the ambient stage can be substituted for one of the active stages..

7. **Connect the “pigtail “ cable from the humidity cell body to the applications board:**

- Gently push the plug on the cable into the connector on the board.

8.	**Rescan the smart start bus:** • Rescan the smart start bus to allow the software to detect the addition of the applications board and the cell body. • Verify that the devices are now present in the device list. • Note: You may need to update the version of the software to version 14.16.136 or higher.	

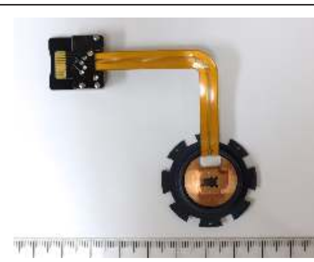
9. **Record the humidity:**

- The humidity and temperature data from the humidity sensor will now appear in the Environmental controls panel.

19.2. Sample Stage Guide

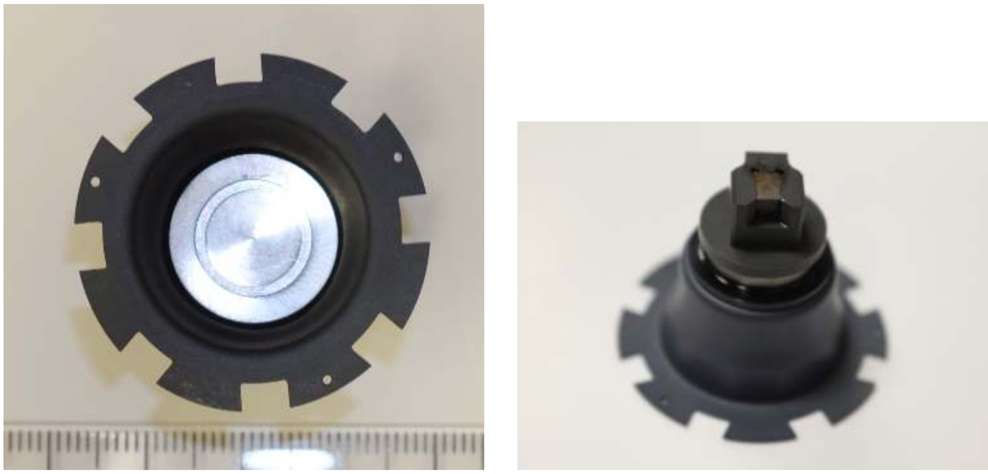
19.2.1. Identifying Sample Stages

Please use this table to identify your cantilever holders and find the relevant sections which describe them.

Part #	Holder Description	Front Photo	Back Photo
901.761	**Ambient** For imaging at ambient temperatures. Safe for gas and fluid operation.		
901.747	**Heater** For imaging at ambient temperatures up to 250C. Safe for gas operation only.		
901.748	**Cooler Heater** For imaging at 0C to 120C. Safe for gas and fluid operation.		

19.2.2. Ambient Sample Stage

The ambient sample stage is the first choice for imaging at room temperature



(a) Top Surface

(b) Bottom View

Figure 19.3.: Ambient Stage

19.2.2.1. Parts list

There are no associated parts. The stage comes by itself and has part number 901.761.

19.2.2.2. Specifications

Exposed Materials:

Membrane: FFKM.

Stage surface: 316 Stainless Steel.

Sample Hold down: Embedded magnets.

Electrical: Stage surface is not grounded (floating) and sufficiently isolated to be safe for use with high voltage applications. .

Cleaning: The whole stage can be immersed or sonicated in ethyl or isopropyl alcohol or water.

Liquid use: Safe for use with samples in liquid droplets.

19.2.3. Heater Sample Stage

The ambient sample stage is the first choice for imaging at room temperature

19.2.3.1. Parts list

There are no associated parts. The stage comes by itself and has part number 901.747.

Figure 19.4.: Heater Stage

19.2.3.2. Specifications

Exposed Materials:

Membrane: FFKM.

Stage surface: Alumina Ceramic.

Other surfaces: Stainless steel, Epoxy.

Sample Hold down: Embedded magnets.

Electrical: Stage surface is not grounded (floating) and sufficiently isolated to be safe for use with high voltage applications. .

Cleaning: Only wipe the sample stage with a swab dampened with alcohol.

Temperature range: Ambient to 250CºC as measured by a sensor embedded several 0.5mm below the surface on which the sample sits.

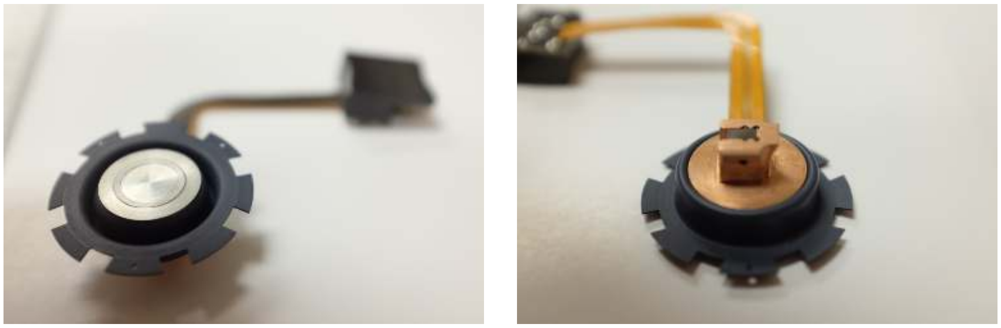
Liquid use: Not for use with any kind of liquid. Only use in air or with inert gas purge.

19.2.4. Cooler Heater Sample Stage

The ambient sample stage is the first choice for imaging at room temperature

19.2.4.1. Parts list

There are no associated parts. The stage comes by itself and has part number 901.748.



(a) Top Surface **(b)** Bottom View

Figure 19.5.: Cooler Heater Stage

19.2.4.2. Specifications

Exposed Materials:

Membrane: FFKM.

Stage surface: 316 Stainless Steel.

Sample Hold down: Embedded magnets.

Electrical: Stage surface is not grounded (floating) and sufficiently isolated to be safe for use with high voltage applications. .

Cleaning: When mounted to a CES cell body, it can be filled with nearly any solvent compatible with FFKM and Stainless steel and quartz. When disassembled, wipe with a solvent soaked swab or cloth, but keep liquids away from the back of the device and the circuit board connector.

Temperature range: 0ºC to 120ºC as measured by a sensor embedded several mm below the surface on which the sample sits.

Liquid use: Safe for use with samples in liquid droplets.

19.3. Tutorial: Disassembling the Sample Stage from the Cell Body

This tutorial will go through the steps of removing one sample from a cell body and replacing it with another. This tutorial starts with the combination of a gas cell body attached to an ambient stage, and replaces that ambient stage with a heater stage.

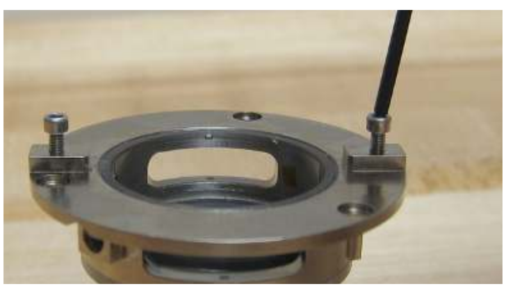
Your cell body and sample stage may differ, but the way the two attach is universal.

19.3.1. Separate Sample Stage and Chamber

1. Locate the 1.7mm slotted screwdriver and a pair of curved tweezers.

Figure 19.6.: Ambient stage / fluid cell body combination on the left. Heater stage / gas cell body combination on the right.

2.



Remove screws:

- Remove the two cantilever locking screws as shown and lay them aside.

3.

Extend the membrane:

- Place the assembly as shown.
- Pull on the sample stage bottom and extend the membrane as shown.

4.

Loosen all the screws:

- Using a 1.7mm flat tipped screwdriver, loosen all the screws.

NOTE: Be careful not to slip and possibly puncture the membrane with the screwdriver.

5.

Remove the ring:

- Remove the retaining ring and set it and the screws aside.

6.

Remove the sample stage:

- Lift off the sample stage.

7.

Finished:

- Your parts should now be as shown to the right.
- Store the sample stage as discussed in Section 19.5 on page 222.

19.3.2. Attach Cell Body and Sample Stage

1.

Prepare parts:

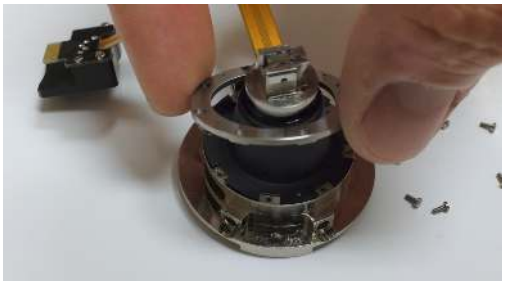
- Sample stage on the left.
- Cell body in the middle
- Membrane clamping ring and screws to the right. More screws (00-90 X 1/8”) can be found in the Environmental Scanner accessory kit (see Section 16.1 on page 163).

2.

Place the stage:

- Note the three small holes in the “petals” on the diaphragm perimeter.
- Align those with the three pins on the bottom of the cell. The parts can only go together one way.
- Assist the diaphragm so the pins go through the holes.

3.



Place the ring:

- As shown in the photos, place the ring.
- The ring has three small holes that line up with the pins.
- Seat the ring flush against the diaphragm.

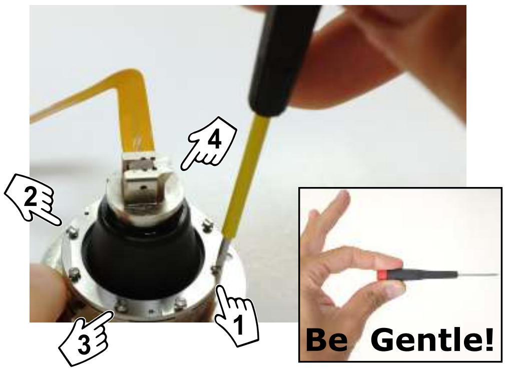
NOTE: The ring has a smooth side and a side with raised metal features. When the ring is properly placed, the smooth side is showing and the raised features face the diaphragm.

4.

Place the screws:

- As shown, place all the screws in the holes.
- Double check that the ring is not upside down!

5.



Tighten the screws:

- Using a 1.7mm flat tipped screwdriver, tighten all the screws.
- First tighten them in the pattern shown for the first four. When all 8 screws are snug, go around once more and tighten firmly while holding the tool only with fingertips to prevent over-tightening.

NOTE: Be careful not to slip and possibly puncture the membrane with the screwdriver.

6.

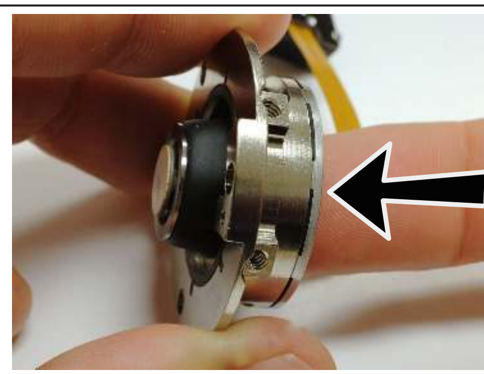
Finished:

- Your parts should now be as shown to the right.

7.

Preforming the diaphragm:

- Gently press the sample stage as shown so the diaphragm pops through to the other side.

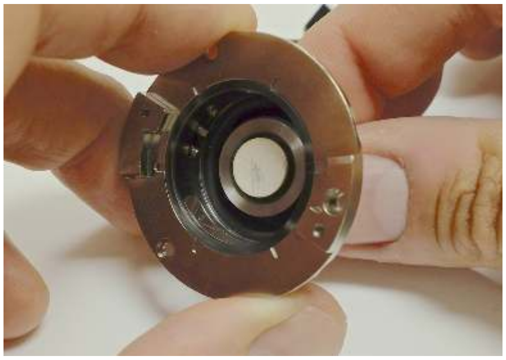


8.

Press back:

- Press the stage back a little until you can grab it from the back side.

9.



Finish preforming:

- Pulling from the back of the sample stage, move the stage back and forth until the membrane is formed as shown on the right.

At this point the stage is ready to be mounted on the Scanner (see Section 19.4.4 on page 218) or stored away it in its storage container (see Section 19.5 on page 222).

19.4. Tutorial: Exchanging the Sample Stage and Cell Body

This tutorial provides a quick path to learning the basics of changing cell bodies (see Chapter 19 on page 194 for various options) and sample stages (see Section 19.2 on page 207 for various options).

The Cypher is a research grade instrument and improper use of the instrument can cause damage to the instrument and/or injury to the user.

Before you start:

- We assume you understand the aspects of running this system safely: (Chapter 1 on page 3.)
- You are familiar with the basic names of the hardware components and software controls (Chapter 2 on page 14.)

This tutorial makes the rather arbitrary choice of starting with an environmental scanner equipped with an ambient stage / fluid cell body and replacing that with a heater stage / gas cell body combination (See Figure 19.7 on page 216). Depending on what you have available, please make the necessary substitutions.

Figure 19.7.: Ambient stage / fluid cell body combination on the left. Heater stage / Gas cell body combination on the right.

19.4.1. Required Materials

This tutorial is designed to be performed, not merely read. If possible, take the tutorial under the supervision of an experienced user (tell them to mostly sit back though, or you will not learn as much as you would by yourself).

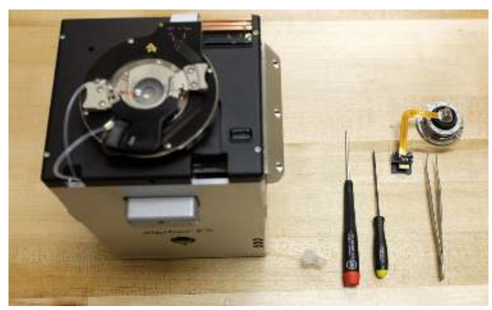
1. **Prepare your materials:** It will be necessary to gather a few items prior to beginning the tutorial:

   a) Tweezers, preferably with curved tip (for example, Asylum Part #290.102)

   b) 1/16” Hex Driver (Asylum Part #290.130)

   c) 5/64” (2mm) Hex Driver

   d) Sample stage already attached to a cell body.



19.4.2. Prepare the scanner

1. **Remove the cantilever holder:**

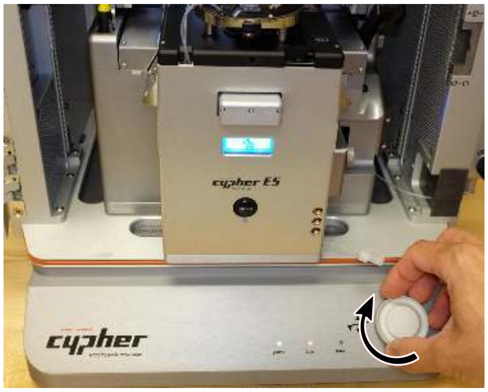
   • Remove the cantilever holder and place it, cantilever tip facing UP, to the side. See Step 6 on page 180 and the following few steps.

2.

Prepare scanner for Removal.

- RAISE THE COARSE ENGAGE STAGE by turning the Engage Control Knob *clockwise.*Raise the stage until it reaches its upper limit of travel.

This will prepare the engage mechanism for a later step of installing a heated temperature stage.



3.

Remove the scanner:

- Turn off the ARC2 controller power and remove the scanner from the Cypher Chassis (see Section 31.1 on page 338 for further details) and place it on a well lighted clean work surface.

19.4.3. Remove the Sample Stage and Chamber

1.

Loosen the sample stage clamping screw:

- Insert the 5/64” Hex Driver into the screw hole at the front of the scanner.
- Turn the Hex Driver *counterclockwise* at most **THREE** full rotations to loosen sufficiently.

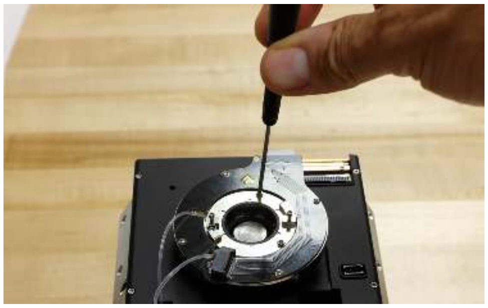
Note Turning the locking screw (114.576) more than three turns may cause the screw to come all the way out.

Note If the screw comes all the way out, you may need to lean the scanner forward until the screw slide out to a place where you can put it back on the wrench.

2.

Loosen the cell body screws:

- Use the 5/64” Hex Driver to loosen the screws at the top of the cell body.
- Set the screws aside.
- Extra screws are available in your kit. Replace old screws with Item 20, 2-56 x 1/8” long screws (Asylum Part #SHCS SS).



3. **Pull the cell body partway out:**

- Grasping the cell blocks, pull up on the cell body until the diaphragm is fully extended.

4. **Loosen fittings of gas in/out lines:** In this step, you will remove the gas in/out lines. Notice that the gas lines are sealed by a small O-ring (230.039) which may or may not come out when you pull out the gas lines.

- Grasp the cell body with your dominant hand.
- With the opposite hand, use ONLY YOUR BARE FINGERS to loosen the fitting by turning it *counterclockwise* to loosen it.
- Detach both gas lines.

5. Check the gas lines to see if small O-rings are stuck to the end. Usually the rings will stay inside the cell, but in case they are stuck to the gas lines, please unstick them and place aside.

6. **Lift out the sample stage:**

- Lift the sample stage out of the cell body.
- If you encounter resistance, you may need to further loosen the sample stage clamping screw (see Step 1 on page 217).

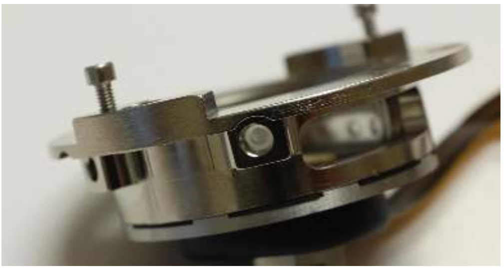
7. Store the sample stage / cell body combination it its proper storage container. See **??** on page **??**.

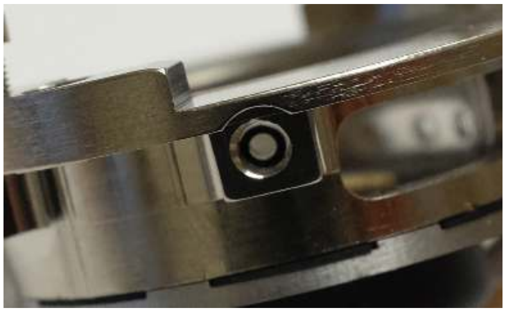
19.4.4. Mount the New Stage/Cell Combination

1. **Check the membrane shape:**

- Make sure the rubber membrane on the sample stage is properly formed as shown in the photo.
- If necessary, see Step 7 on page 214 on how do form the membrane.

2.





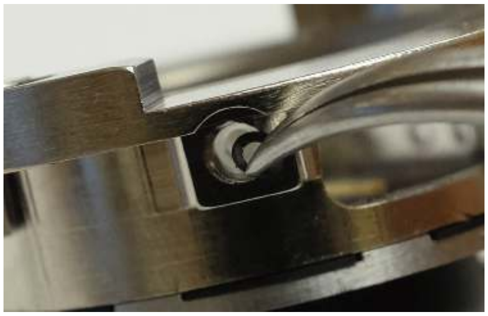
Check for O-rings:

- The cell body on the left has the O-ring (230.039) missing.
- The cell body on the right has a properly seated O-ring.

3.

Place O-rings if necessary:

- If no O-ring (230.039) is present, place it in the bottom of the port, up against the glass.
- If the O-ring is not properly centered, remove it (preferably with a sharp wooden stick) and replace it.
- If you are gentle with the cell, the O-rings should stay in place during the following steps.



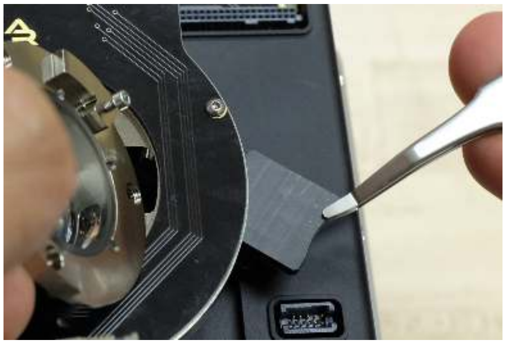
4.

Prepare to route the cable:

Note This step requires that the engage stage was fully raised before the scanner was unplugged.

- Hold the stage/cell as shown and tuck the cable connector under the engage ring using the “platypus” tweezers.

5.



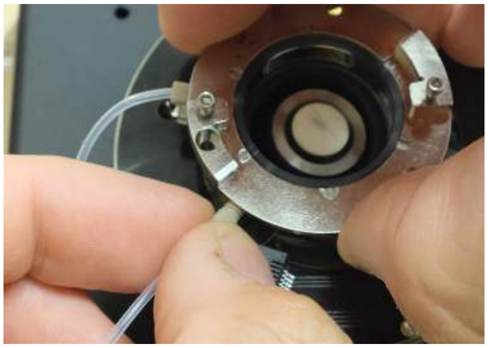
Guide the heater cable under the ring:

- As shown, guide the connector under the ring.
- Leave it sitting loose on the top of the scanner.

6.

Attach Gas Lines:

- Using only your fingers to tighten the screws, attach the gas lines to the cell body as shown.
- Tighten until snug, don't overdo it.



7.

Seat the sample stage:

- Lower the dovetail connection at the bottom of the stage into the receiving hole on top of the scanner.
- Press lightly onto the top of the sample stage until the sample stage sinks down into the hole.
- Check that the cell body is seated on the scanner engage ring.

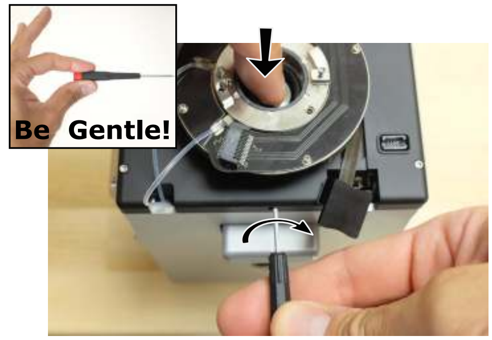
Note A properly seated sample stage is centered in the cell body and

BE GENTLE!

8.

Tighten sample stage:

- Press down on the sample stage to keep it flush against the scanner.
- Tighten the screw using the 5/64” driver. This will take about three turns before you feel resistance.
- Tighten snug, only using your fingertips to handle the tool.

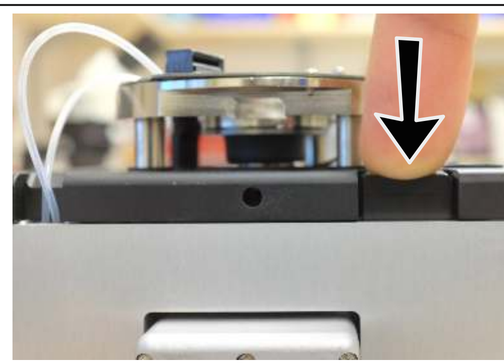


9.

Secure the cell body:

- Locate three 2-56 X 1/8” screws and the 1/16” hex driver tool.
- Fasten the screws as shown, using only your fingertips to hold the tool. This will prevent over tightening.

10.



Connect the heater cable:

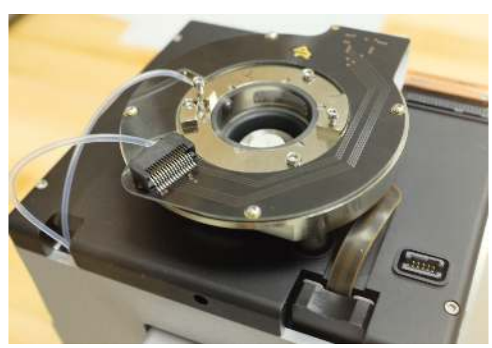
- As shown, insert the heater cable connector.
- Push it flush.

11.

Final checks:

- Your scanner should now look like the photo to the right.

CHECK The sample stage top surface sits quite deep as shown, below the glass sidewalls of the cell body. View the stage through the windows on the sides of the cell and make sure you cannot see it. If the sample stage was not seated properly, you will crush it when you go to insert the cantilever holder.



19.4.5. Replace the Scanner

1. Refer to 31.3.
2. When pressing the scanner against the back of the chassis, you should sense a hard stop of metal touching against metal. This requires a little extra pressure to compress some springs behind the copper plate at the back of the scanner. Not pressing the scanner all the way into the chassis may hamper thermal performance when using cooling or heating stages.

19.5. Storage

19.5.1. Storing Cell Bodies

Once a sample stage has been removed from a cell body (See 19.3.1), the cell body should be stored in the membrane container in which it shipped. See Figure 19.8 on page 223.

For cell bodies were recommend storing the membrane clamping ring attached tot the cell body with its eight screws and placing any other associated accessories such as cables with the cell in the box.Storing sample stage / cell body combinations

Since cell bodies must always be used while attached to a sample stage, we recommend storing them together when possible. For this purpose the cell body is shipped in a somewhat larger container and includes a plastic cap which is used when storing cell bodies and samples stages together in the box. It works as follows:

1.

Locate the box:

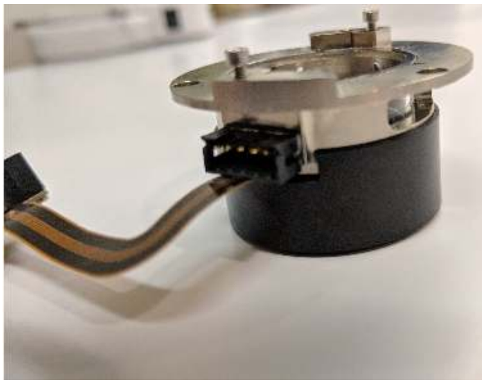
- Locate the cell body storage container.
- It should include the storage cup.

2.

Place the cap:

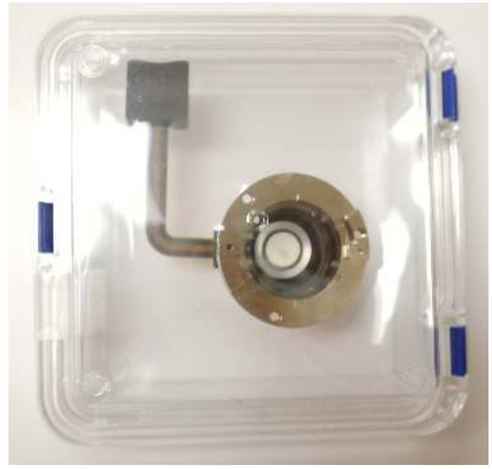
- Open the box and remove the cup.
- Place the cap on the cell body as shown.

Note The cutout on the cup should be placed where the cable exits the heater stage and where the electrical vias are located..



3. **Close the box:**

- Close the box and latch it.
- Inspect the other side to confirm that the diaphragm is not overly deformed.



19.5.2. Storing Disassembled Cell Bodies

Once a sample stage has been removed from a cell body (See 19.3.1), it should be stored in the membrane container in which it shipped. See Figure 19.8 on page 223.

(a) Heater Stage　**(b)** Gas Cell Body　**(c)** Passive Stage

Figure 19.8.: Various stages and cell bodies stored in their containers.

20. Gas Handling and Leak Testing

CHAPTER REV. 1912, DATED 03/03/2017, 08:49. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

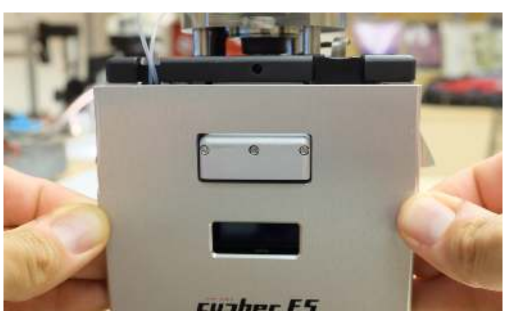
20.1. Gas Handling Overview

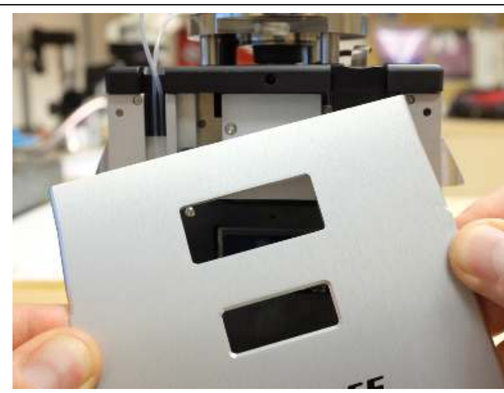
Figure 20.1 on page 225 shows the front of the scanner with the cover removed (see 20.2.1 to accomplish this). The two gas lines attached to the sample cell body are routed via tubing guides to the bottom left of the scanner. One of the lines branches off to a pressure sensor and then passes through a computer controlled valve. Depending on the application, this valve may be open or closed, and it may be manually or computer controlled.

20.2. Manifold Connections

20.2.1. Scanner Faceplate Removal

1.





Remove the scanner cover:

- Grip the cover as shown.
- Pull forward. The cover is attached magnetically.

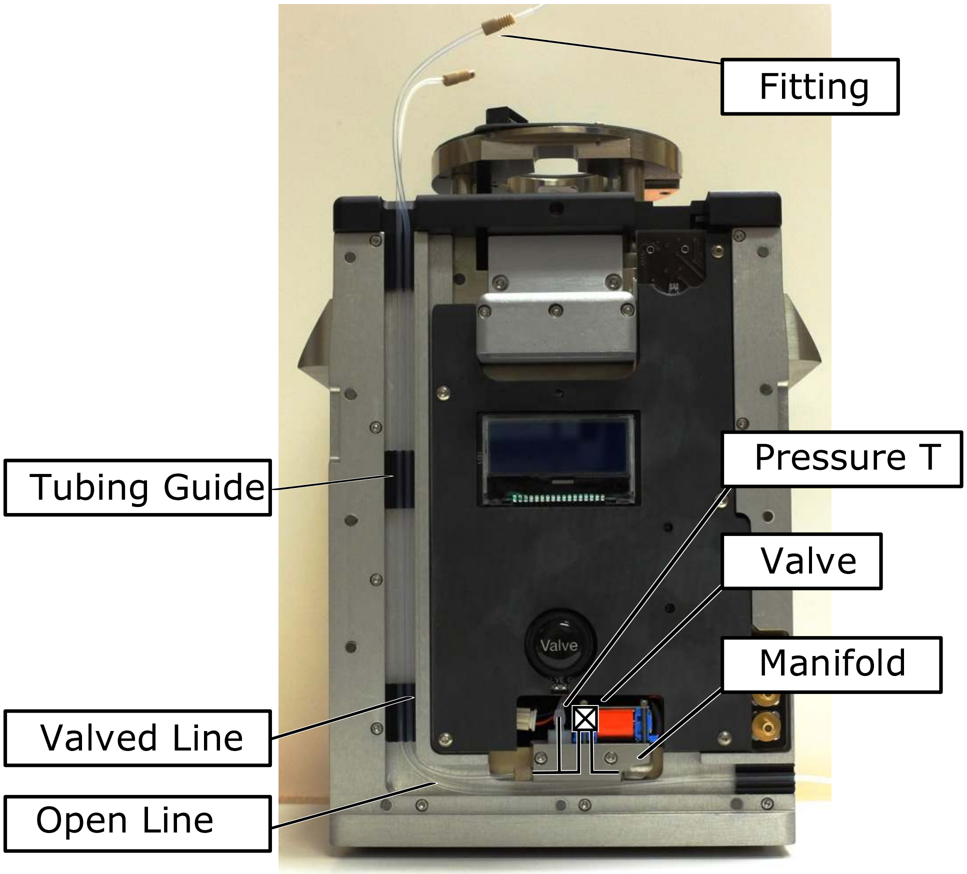
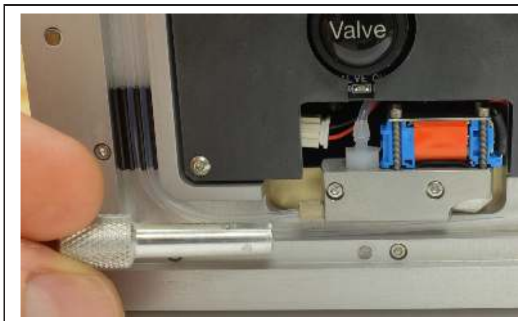


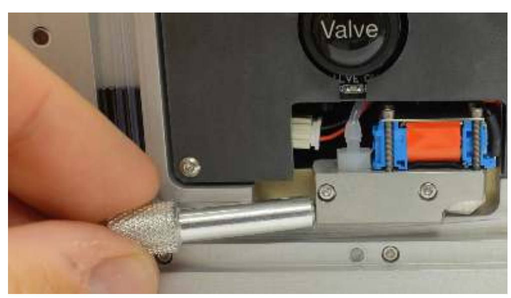
Figure 20.1.: Gas Handling Overview

20.2.2. Manifold Cell-side connection

Process for removing the tubing connected on the cell-side of the valve manifold.

1.





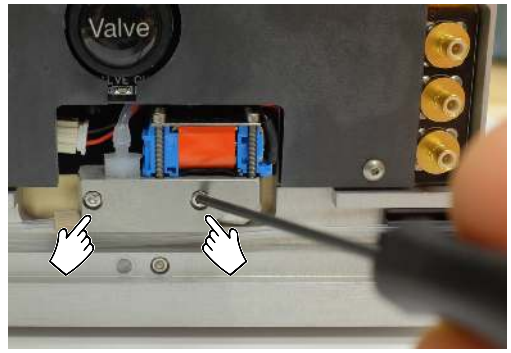
Remove the fitting using the tool:

- Place the tool on the fitting. The slot in the tool slides over the tubing.
- Unscrew until the fitting comes loose. An O-ring should stay attached to the tubing. If not, you may need to retrieve it from the port with tweezers.
- If it feels there is not enough room to complete this step, please follow to the next step:

2.

Remove the manifold (optional):

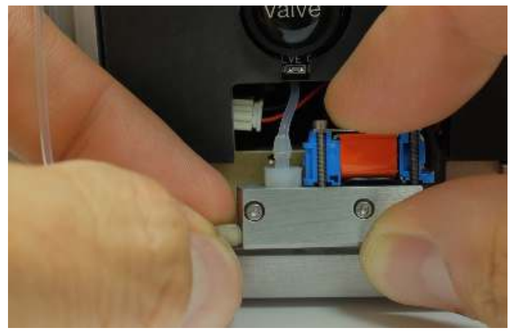
- ONLY IF there was not enough room to complete the last step, remove the two screws shown in the photo.



3.

Remove fittings while holding manifold:

- Pull the manifold forward a little. Pay attention not to apply tension to the tubing or the wires.
- Remove the fitting using fingers or the tool shown in previous steps.
- When the tubing has been replaced, reverse attach the manifold again with its screws.

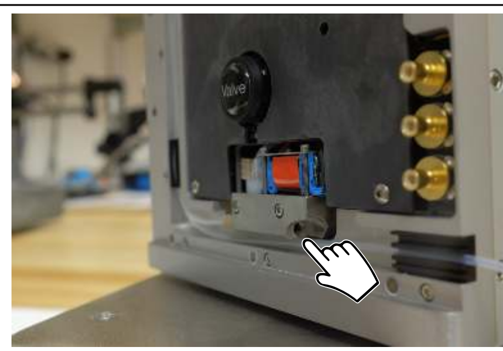


20.2.3. Manifold Lab-side connection

1.

Locate the manifold port:

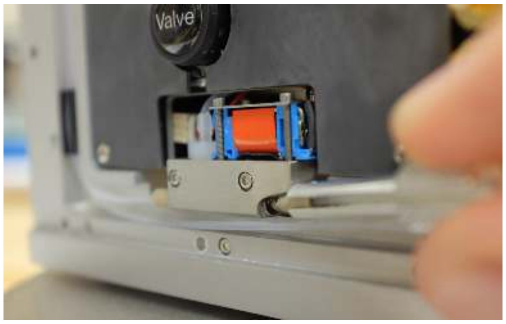
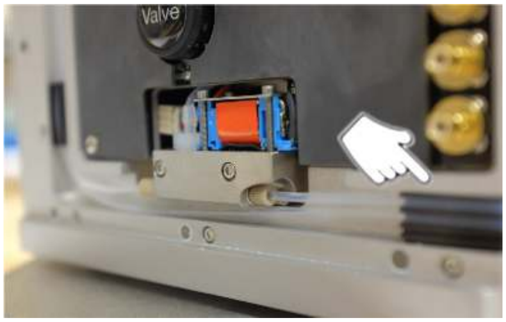
- The lab-side port of the valve manifold is shown in the photo.



2.

Prepare tubing:

- Attach the tubing with fitting to the fitting tool as shown.
- Note that the tubing should have a small bit extending beyond the ferrule. This space holds the O-ring (230.039)

3.	**Tighten fitting:** • Tighten the fitting as shown. • Do not over tighten. Holding the tool with fingertips only should prevent any damage to the fitting.	
4.	**Guide the tubing:** • Press the tubing into the guides. Note that the tubing is not perfectly round and it may fit better if it is twisted a bit.	

20.3. Gas Perfusion Imaging

20.4. Attaching Threaded fittings to tubing.

21. Tutorial: Fluid Imaging

CHAPTER REV. 2035, DATED 08/15/2018, 11:50. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

21.1. Tutorial: Fluid Imaging with Perfusion

This tutorial will walk through the simplest form of perfusion imaging, using two 1cc syringes to successively inject and withdraw small amount of fluid.

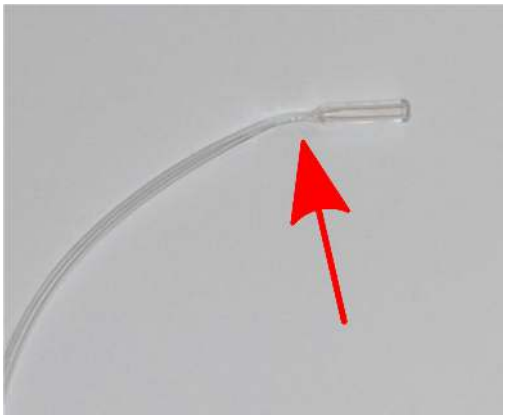
21.1.1. Prepare the tubing

1.

Prepare 1/32” tubing

- Think ahead of how much you need to move your reservoirs.
- Allow for enough tubing so the syringes can comfortably be placed outside the AFM enclosure.

2.



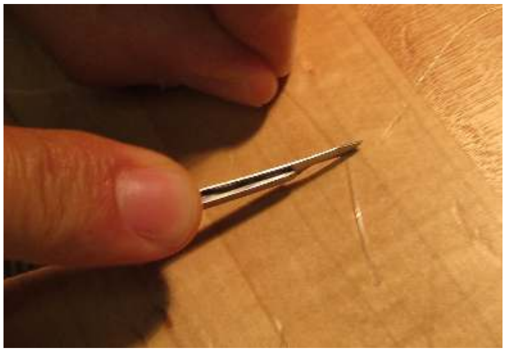
Stretch tubing:

- Thin out one end of each piece of tubing. If no pliers are around, just pinch between your fingernails

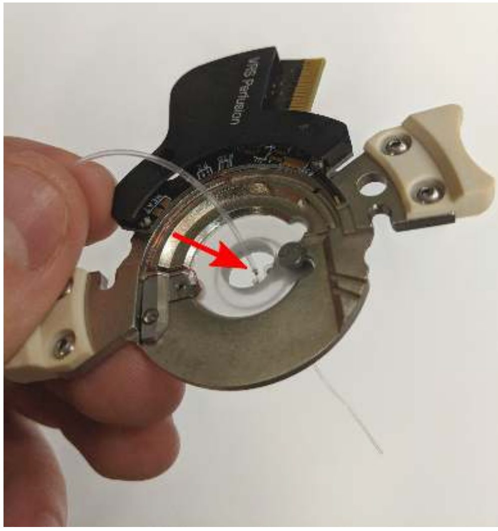
3.

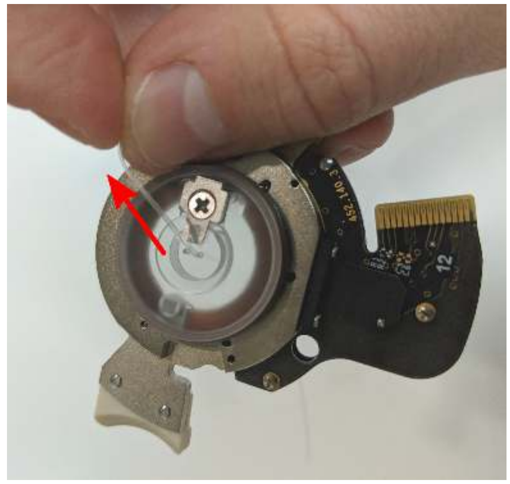
Trim tubing:

- With a fresh #15 scalpel blade, trim the tubing in the thin section. Leave as much thin tubing as possible.



4.





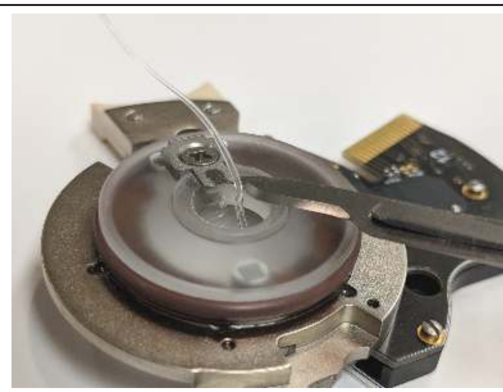
Insert the tubing:

- From the outside in, thread in thinned tubing.
- From the inside, pull it through until a few cm of unstretched tubing comes through the hole.

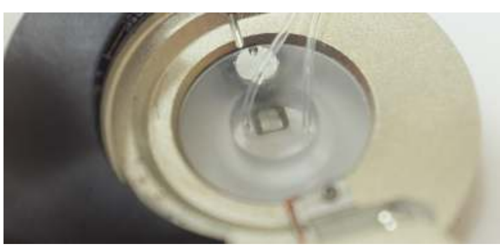
5.

Trim off excess tubing:

- Using a sharp #15 scalpel blade, trim the excess tubing flush with the glass.
- Repeat the process for the adjacent perfusion port and tubing.



6.



Finished:

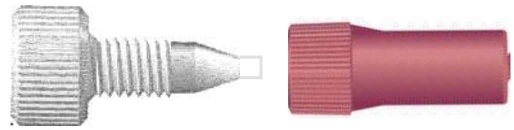
- The cantilever holder should look as in the photos.

21.1.2. Prepare for syringe attachment

1.

Gauge Plug:

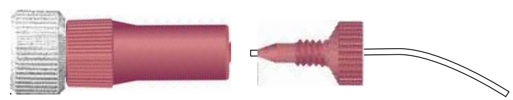
- Finger tighten the white Gauge Plug into the larger end of the Adapter.



2.

Insert the tubing:

- Thread the 1/32” tubing through the small fitting. Leave a small amount sticking out of the end.
- Thread the fitting into the adapter. Before it is tight, slide the tubing as far as it will go into the fitting. It will come to a stop against the white Gauge Plug.
- Finger tighten the fitting fully. Tug on the tubing to make sure it stays in place.
- Remove the white Gauge Plug and store it for later use.



3.

Attach the luer adapter:

- Finger tighten the luer adapter as shown.

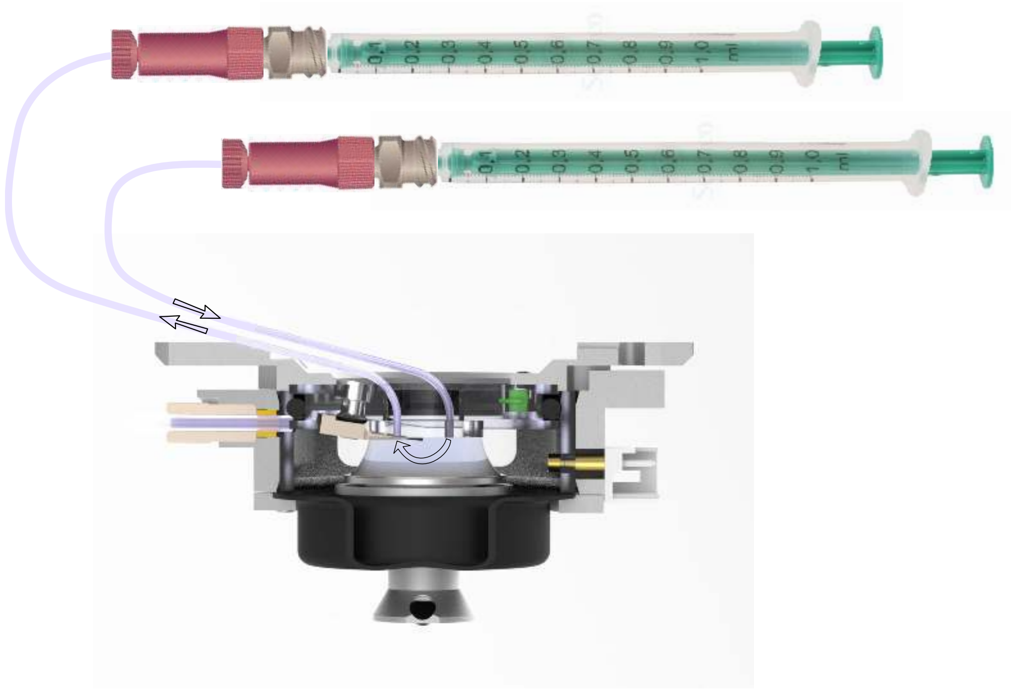
4.

Attach the syringe:

- For a non luer lock syringe, press and twist the syringe firmly into the fitting.
- For a luer locking syringe, twist the syringe in to place.

21.1.3. Prepare the cantilever holder for imaging

1.



Attach syringes:

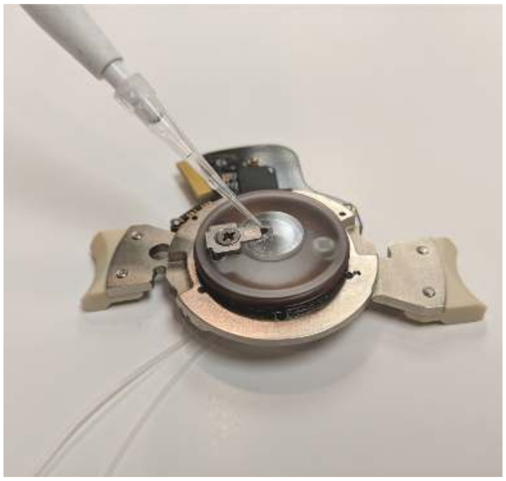
- At this point you should have two syringes attached as shown.
- The top syringe, connected to the port closest to the cantilever holder, should be filled with a very small amount of fluid, perhaps 0.1cc.
- The bottom syringe, connected to the port furthest from the cantilever, should be filled with fluid.

Note It is helpful to mark the syringes with IN and OUT, using little flags of adhesive tape. Halfway through the perfusion process it will be difficult to tell which is which.

2.

Prime the tubing:

- Push bubbles out of the tubing for both IN and OUT syringes.
- Suck up any excess fluid. In the photo a laboratory pipette is being used.
- Leave a small droplet on the cantilever.



21.1.4. Prepare the sample

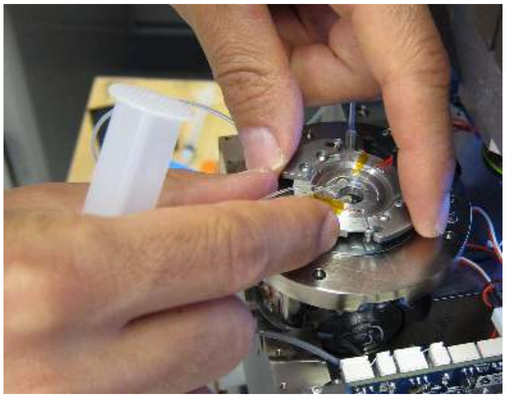
1. **Prepare the sample:**

   - Put sample in the chamber
   - Put about 100 uL of fluid on the sample. (necessary?)
   - Motor UP to a level a few mm below where the lever will crash.

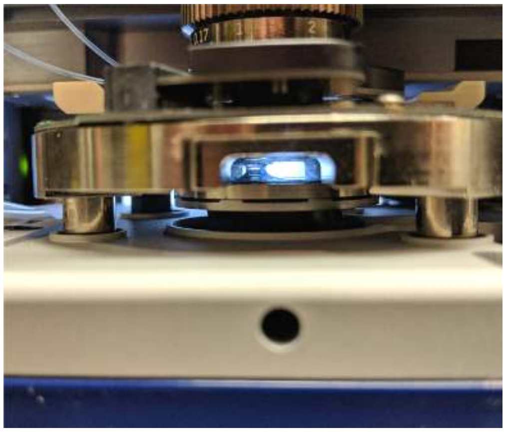
21.1.5. Sealing the chamber

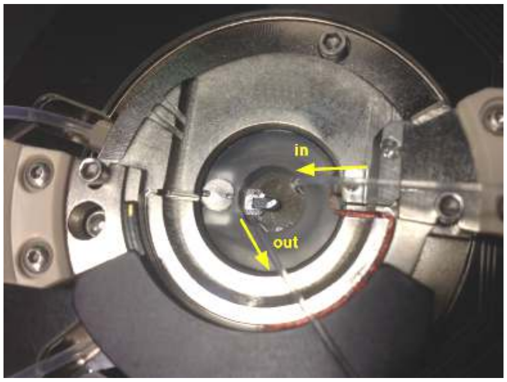
1. **Install the cantilever holder:**

   - As described in Section 17.2 on page 179, install the cantilever holder onto the chamber.



21.1.6. Imaging during Perfusion

1. 



Motor down:

- The valve on the front of the scanner should still be in the **OPEN** position.
- With the scanner still pulled out Motor Down manually.
- Inspect Droplet as it necks down. Don't **CRASH**!
- Stop before reaching the surface.

Note: A safe way to go about this is to engage first without any liquid and store the sample position in the software.

2. **Go to pre-engage height:**

- With all valves as they were, follow usual process of going to the pre engage height.
- We'll assume imaging will commence after fluid is flowing.

3. **Close gas valve:**

- While still at pre-engage height.. Close Gas Valve (button on scanner front).

4. Image as usual.

21.1.7. Perfusion

1. To perfuse fluid, depress the syringe marked "IN" by a modest amount: ~30 micro liters. This will cause the droplet to swell slightly.
2. Pull the plunger back on the syringe marked OUT by an equal amount.
3. Repeat the process a few times if desired.

21.1.8. Disassembly

1. **Remove the cantilever holder:**
   - Open Gas Valve (C).
   - Motor Up (E)
   - Remove the cantilever holder.
   - If all went well there should be no fluid in the membrane gutter and there should be about 150 microliters of fluid on the sample.

21.2. Perfusion Flow Characteristics

A perfusion experiment with two glass syringes, one filled with water and the other with dye and water. The two are connected to a valve, and about 1 foot of 1/32" tubing runs between the valve and the cell. Another foot of tubing runs from the cell to a balance to measure flow rate.

In perfusion experiment A, the flow is switched at about 1 minute. Flow rate ~1.3 uL / second.

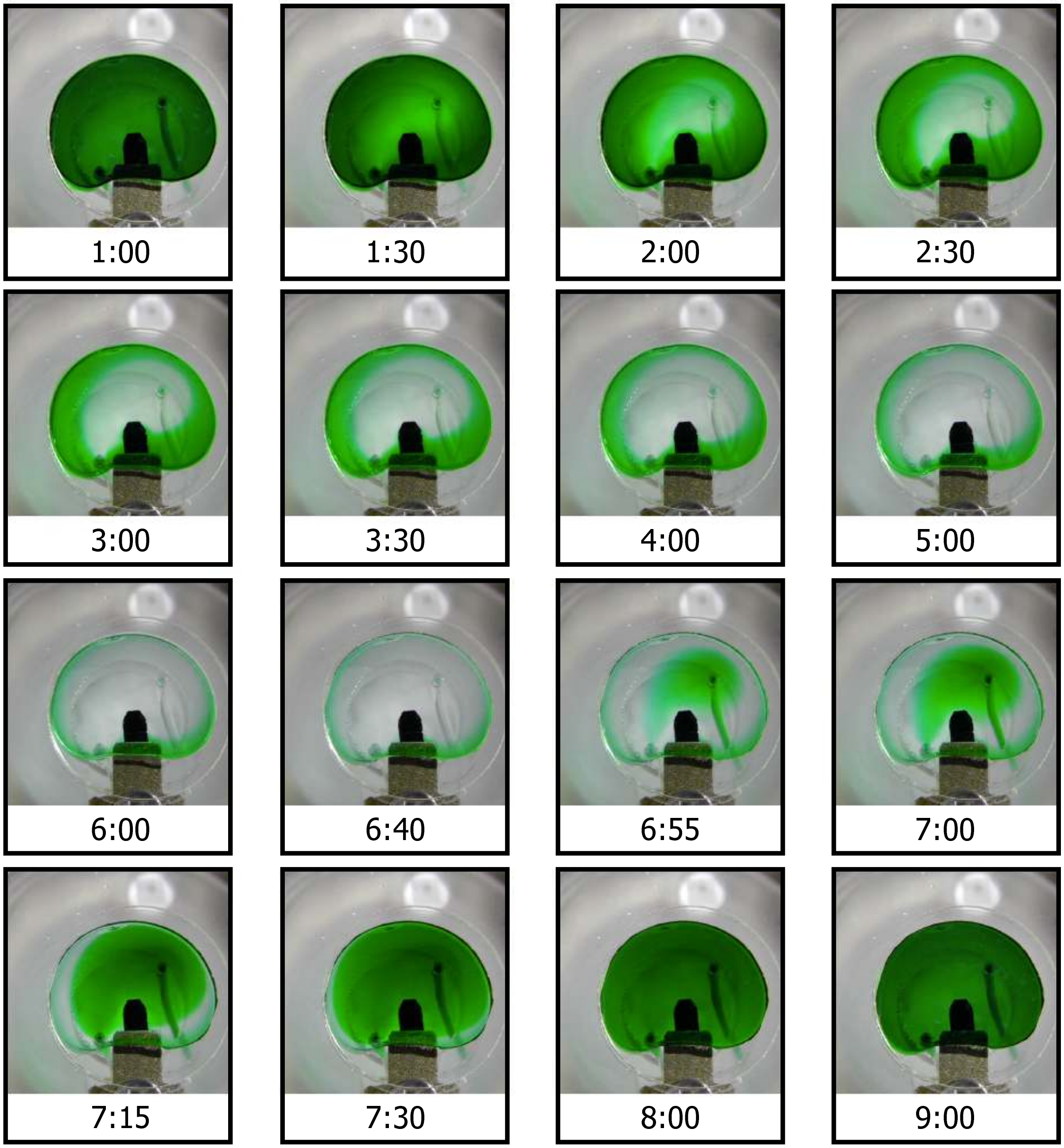


Figure 21.1.: Perfusion Experiment A

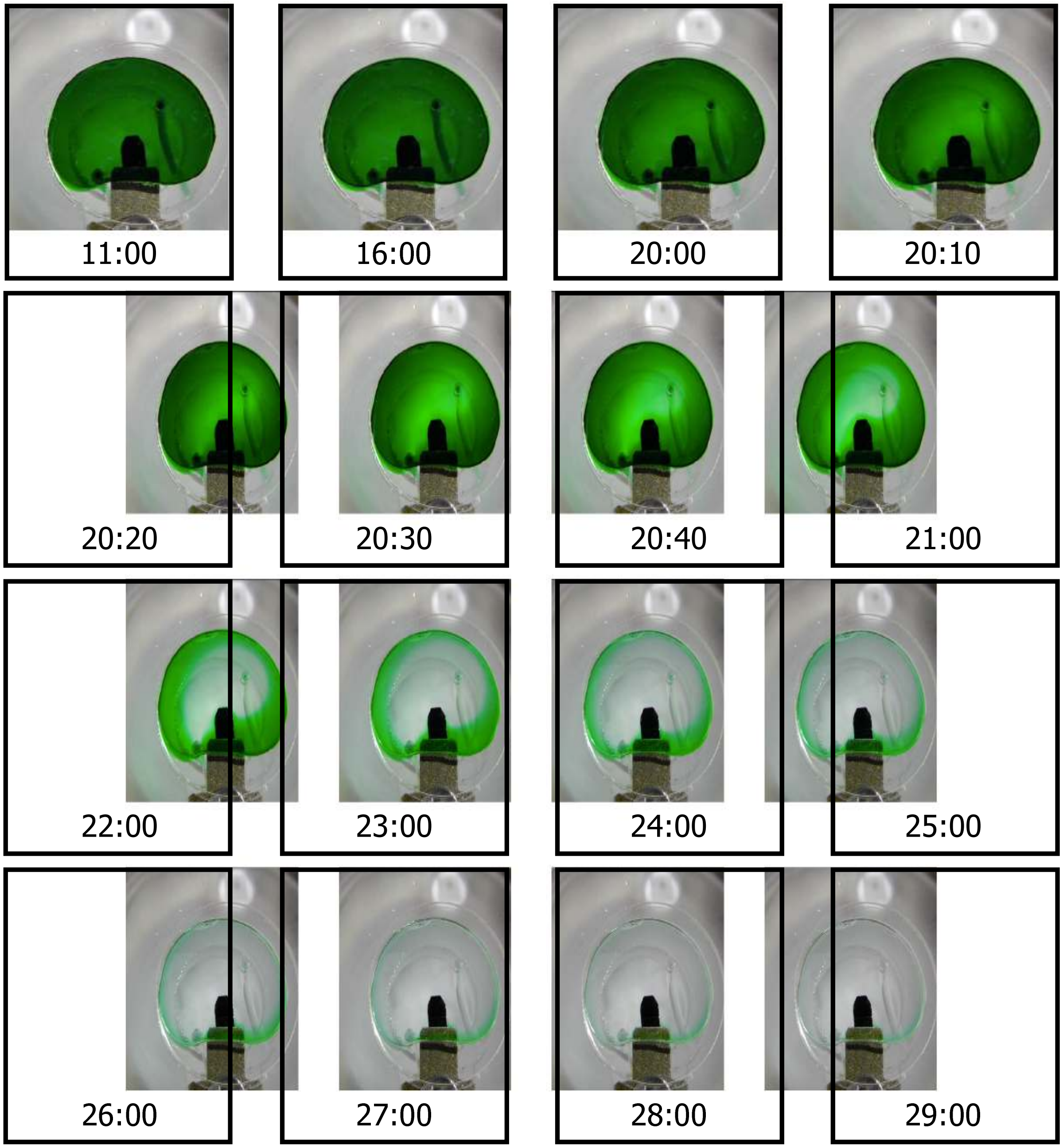


Figure 21.2.: Perfusion Experiment B

22. Tutorial: FM Mode Imaging in Fluid

CHAPTER REV. 2041, DATED 08/31/2018, 11:04. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

All new users should complete and understand the "AC Mode Imaging in Air" tutorial before attempting any imaging.

FM Mode imaging is fairly advanced and the user is considered to be quite proficient at AC mode imaging in air and fluid. This tutorial should be performed on a running Cypher, as opposed to merely read, and if possible should be done under the supervision of a user already familiar with the operation of the Cypher.

Before you start:

- We assume you understand the aspects of running this system safely: (Chapter 1 on page 3.)
- You are familiar with the basic names of the hardware components and software controls (Chapter 2 on page 14.)
- You have powered up the Cypher and launched the latest version 16 software: (Chapter 5 on page 33.)

22.1. Required Materials

This tutorial is designed to be performed, not merely read. If possible, it is advised to perform the tutorial under the supervision of an experienced user (ask them to watch you run the instrument - instead of showing you the steps - so that learn as much as possible).

Prior to beginning the tutorial, gather to following items:

1. Cypher instrument equipped with blueDrive photothermal excitation
2. Probes: You will need FS1500 AuD probe, which has a cantilever resonant frequency between 800 kHz and 2000 kHz, and spring constant is between 1.5 N/m and 10 N/m.
3. Samples: Freshly cleaved calcite and clean filtered DI water

22.2. Cleaving and Preparing the Calcite Sample

- Prepare a fresh and clean calcite surface

22.3. Prepare hardware

- Place the lowest possible blueDrive filter cube in the laser path - for ArrowUHF probe start by using 0.1x or 0.03x filter cube
- Clean a cantillever holder that will be used for imaging (either a liquid or a perfusion cantilever holder)
- Load a cantilever into the holder

22.4. Calibration and Approach

1.

C:/svn/rasy-svn/ConfigurationFiles/ModeMasterFigures

The Mode Master window:

- The software should now be showing the Mode Master window.
- If not, click the Mode Master button at the bottom of the screen: C:/svn/rasy-svn/ConfigurationFiles/ModeMasterFigures/Version 15/ModeMasterBu

2.

C:/svn/rasy-svn/Configu ▷ C:/svn/rasy-svn/ConfigurationFiles/ModeMasterFigures/Version 15/ModeMasterTabs_Stan

Select Mode:

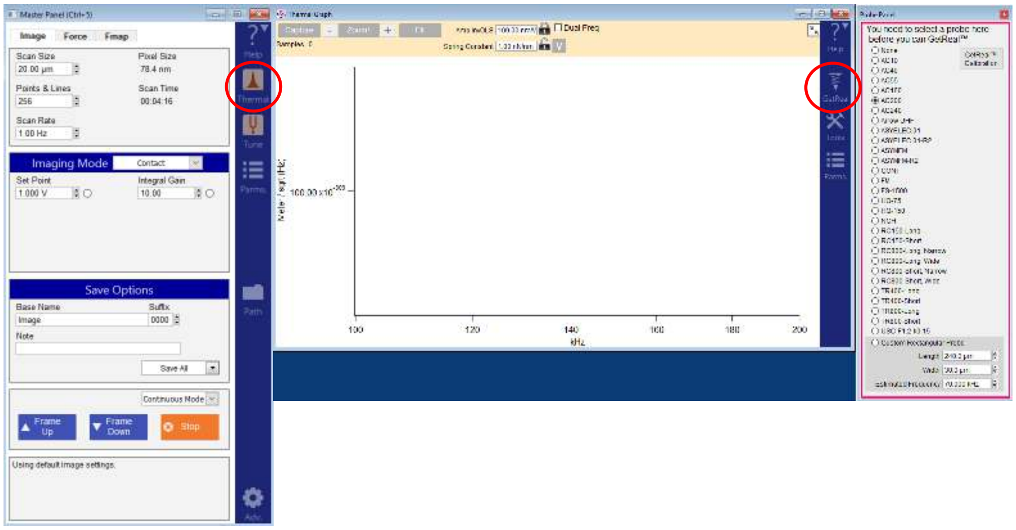
- Select *Standard tab* ▷ *Template*
- The screen will now re-arrange and present all the controls necessary for this type of AFM imaging.

3.

Align Laser

- Open the Video Panel
  - Use the arrows in the Video Panel to move the laser spot onto the cantilever and maximize the SUM signal

4.



Calibrate Probe

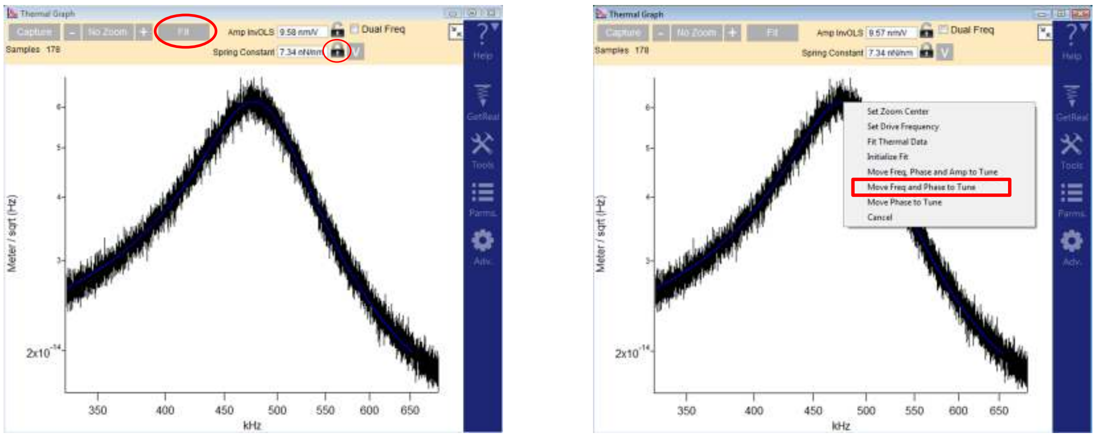
- Choose the Thermal icon in the Master Panel
  - thermal graph will appear
- Click on the Get Real icon which in trun will open a Probe Panel
- Choose the probe that is used for the experiment
- Click GetReal Calibration
- Once the calibration is compleated, the Amp InvOLS and Spring Constant values at the top part of the thermal graph will be updated

5. Remove the cantilever holder and place the freshly cleaved calcite sample on the scanner
6. Add a drop of water to the sample
7. Put a drop of water on the probe and place the cantilever holder back on the scanner
8. While looking at the distance between the probe and the sample, approach the sample to the tip so that both water drops join and the sample and lever are both in water environment

22.5. Software setup and liquid imaging in AC mode

1. Re-align the laser on the cantilever (now in liquid) - Sum should be ~ 6V

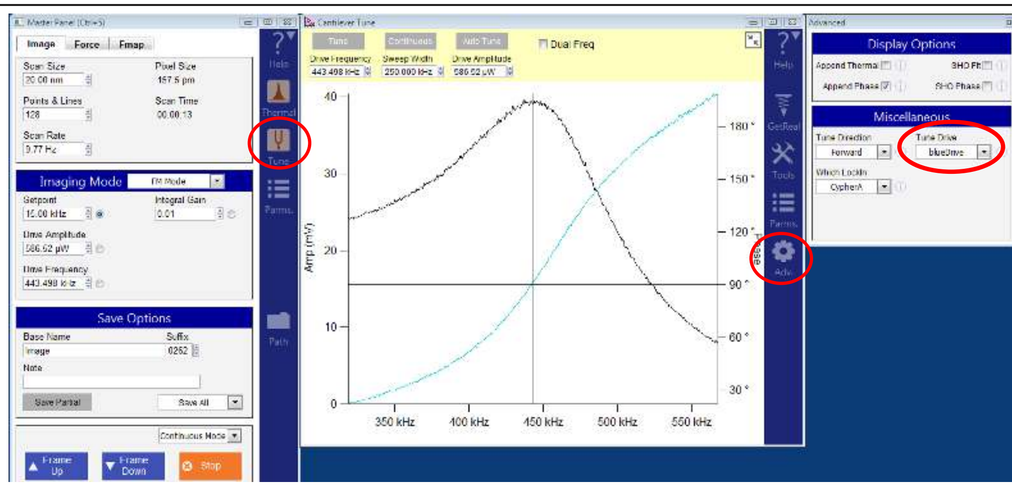
2.



Capture a thermal of the cantilever in liquid:

- Make sure that the padlock besides Spring Constant is locked
- Re-fit the thermal data to obtain the updated (water) InvOLS value
- Transfer the frequency of thermal peak to the tune panel
  - Right click on the peak of the Thermal Graph and choose Move Freq and Phase to Tune

3.



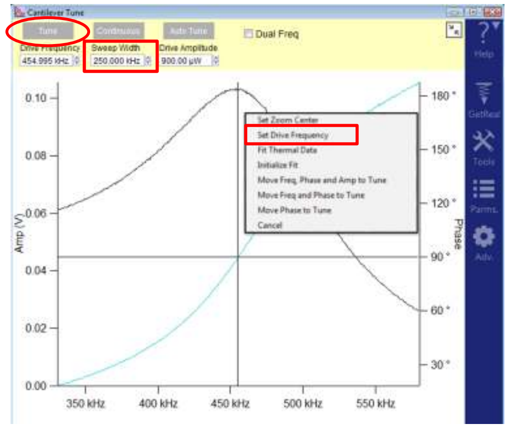
Turn on blueDrive photothermal excitation

- In the Tune graph, click on Adv.
- In the Advanced panel, choose blueDrive form the drop down menu of Tune Drive

4.

Tune panel

- Set the Sweep width to 250 kHz
- Click one Tune
- When tune is done, right click on the peak and choose set Drive Frequency
- Move the blue laser spot around the base of the cantilever to maximize the amplitude (see note below)
- Adjust the drive amplitude (in the Master Panel) until the amplitude of the tune reaches ~ 50 mV (visible on the graph and in the Sum and Deflection panel)
- Set the setpoint (in the Master Panel) to ~ 40 mV

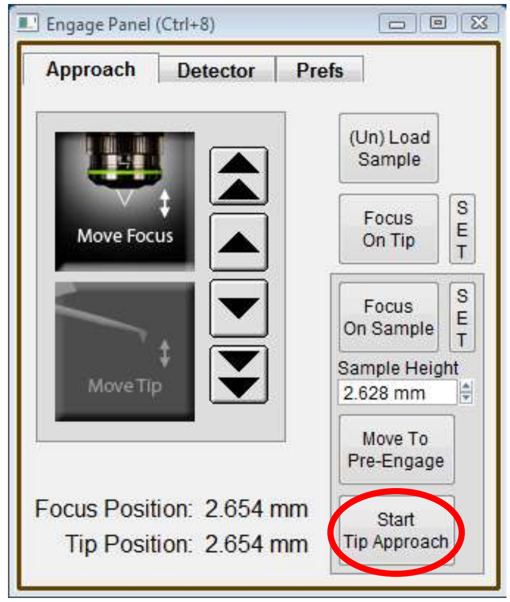


Tip Move blueDrive spot around to maximize amplitude

Note It is possible to attain a higher oscillation amplitude by moving the blueDrive spot to the side as shown in the image

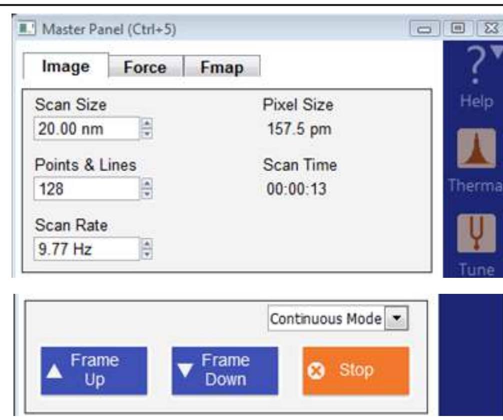
1. **Engage Panel**

   - Set the tip position while focused on the tip
   - Set the sample position while focused on the sample
   - Click on Start Tip Approach



2. Once the tip is in piezo range of the sample, capture another Thermal Tune with z-piezo at 0V (sample is 2-3 um from surface)
3. Lock padlock besides spring constant on Thermal Graph to re-calculate Amplitude InvOLS
4. Right click on the peak in Thermal Graph and Move Freq and Phase to Tune
5. When the tune is complete, verify that that the phase is set to 90 degrees
6. **Imaging parameters - Master panel**

   - Set the scan size to 20 nm
   - Set the scan rate to 10 Hz
   - Set the gain to ~60
   - Start imaging by pressing Scan Down



7. Start imaging

   a) decrease the free amplitude (by decreasing drive amplitude in the Master Panel)

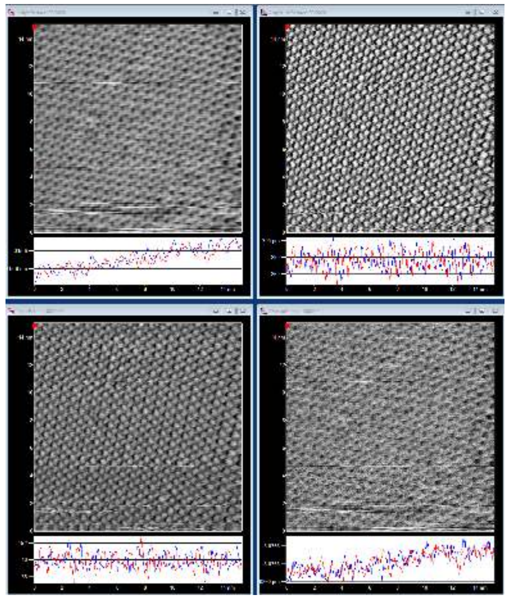
   b) then, decrease the setpoint unil trace and retrace overlap each other

   c) repeat several times to image with the lowest amplitude possible

8.

Imaging

- Acquire a 20 nm image and re-size the scan to 10 nm
- Once the imaging looks optimized, stop the scan and switch to FM mode

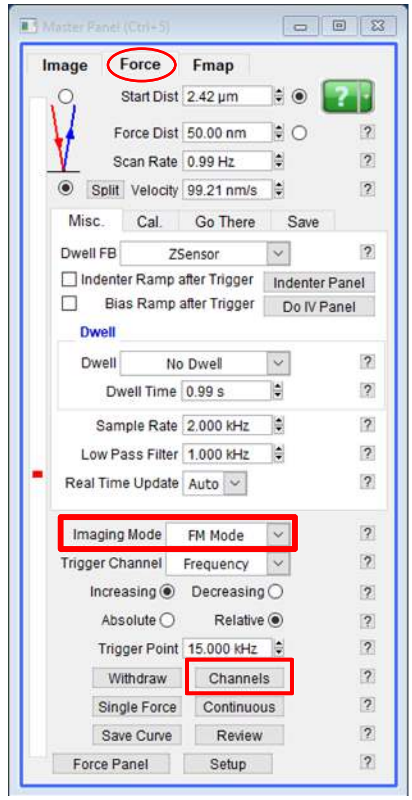


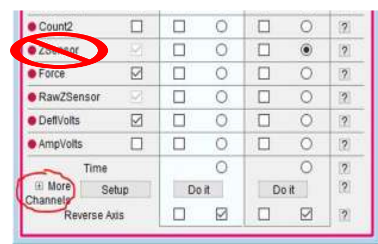
22.6. FM curves

1. In Master Panel, go to the Force tab

2.

- Choose FM Mode for Imaging mode
- Click on Channels button and select
  - Frequency
  - Dissipation
  - Amplitude
  - Phase
  - Make sure to plot versus DRIVE (not ZSensor) for short curve (tens of nm) as Drive is a quieter signal than ZSensor (which has 50 pm of noise in a1 kHz bandwidth)
- Choose trigger: Frequency
  - Increasing
  - Relative
- Trigger Point: 15 kHz is a good start

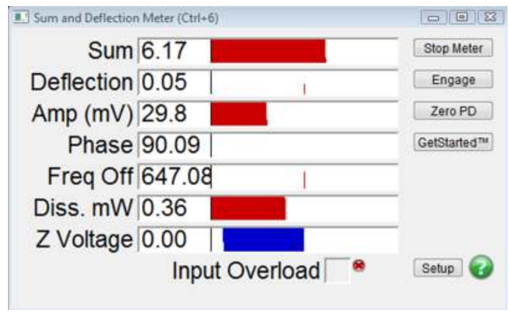


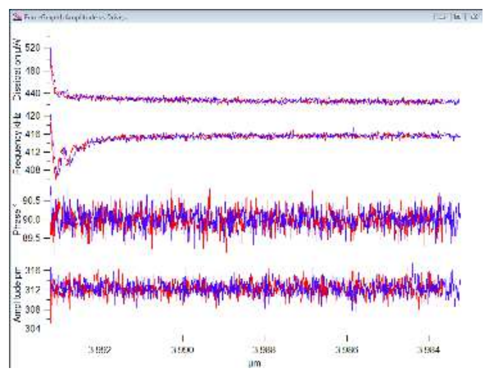


3. Locate the FM Panel (AFM Controls –> Other –> FM Panel)

4.

- Un-check and check the Auto Calculate Gains, the values should update
  - the gains can adjusted by the user
- Set the Drive Set Point to required amplitude
  - start with 3 Angstroms: 3A = 0.3nm;
  - Ex: 0.3nm / 10.25nm/V InvOLS = 0.0292V = 29.3mV
- Activate Feedback Loops by checking the boxes besides
  - FM feedback ON
  - Drive Feedback ON
- When the frequency and drive feedbacks are ON, the following values will appear in the SUM and Deflection meter
  - Amp (mV) = Drive SetPoint Value
  - Phase = 90
  - Freq Off = frequency offset compared to the value of drive frequency from tune, here 647 Hz
  - Diss mW = power (in mW) needed to keep the Drive Set Point Value at 30 mV

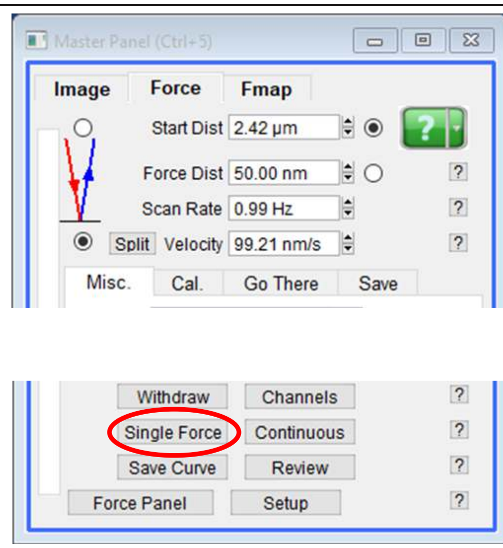




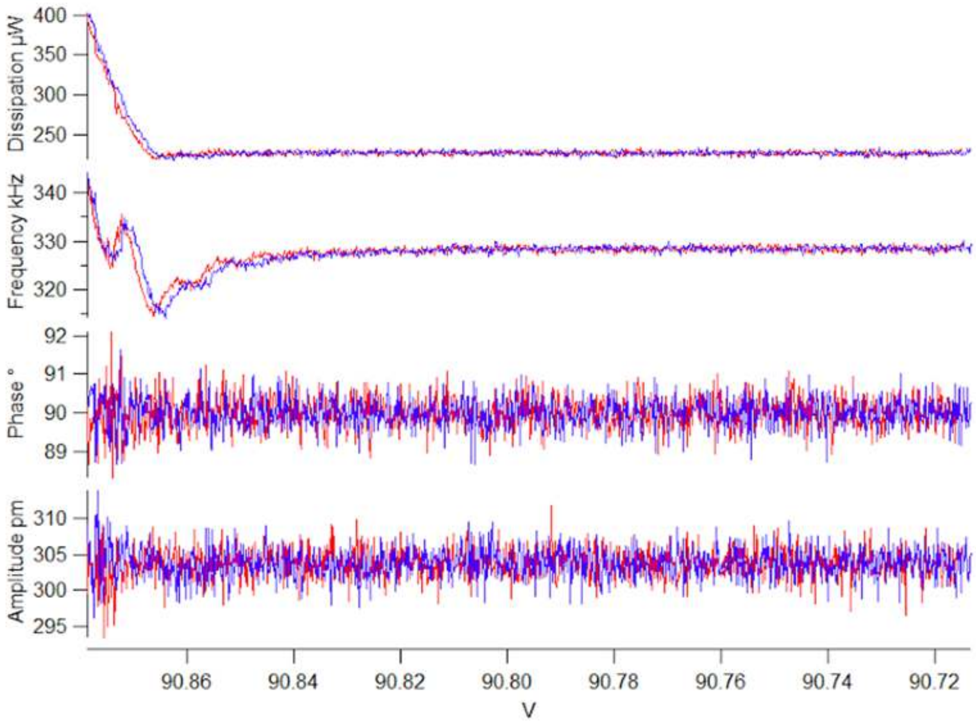
5.

Curve parameters - Master Panel; Force Tab

- Begin with the force distance set to ~100 nm
- Set the scan rate to 1 Hz
- Acquire a force curve by pressing Single Force
- Re-tune the cantilever to obtain the cantilever frequency close to the surface



6.



Optimize parameters for FM curves

- FM curves should ressemble the curves above
- Dissipation, Frequency, Phase and Amplitude plotted against Drive
- Click on Continuous and gradually decrease the force distance to 5 nm
- Adjust the FM gains in the FM Panel
  - Un-check the Auto Calculate Gains and adjust the values until extension/retraction curves overlap and no rigning is observed

7.

FM curves: absolute frequency trigger *versus* relative frequency trigger

- When *absolute trigger* is used, the frequency at the beginning of the curve is not taken into account. The trigger will be reached when the frequency value equals the trigger value added to the drive frequency (from the tune).
  - For example, if the drive frequency is 75 kHz and the absolute trigger value is set to 1 kHz, the trigger will be reached at 76 kHz.

  -OR-
- When *relative trigger* is used, it is the frequency at the beginning of the curve to which the value of trigger is added. Therefore, if the drive frequency differs from the frequency at the beginning of the curve, it's the frequency at the beginning of the curve that will be used.
  - For example, if the drive frequency is 75 kHz and the relative trigger is 1 kHz but the frequency at the beginning of the curve is 75.2 kHz, the trigger will be reached at 76.2 kHz

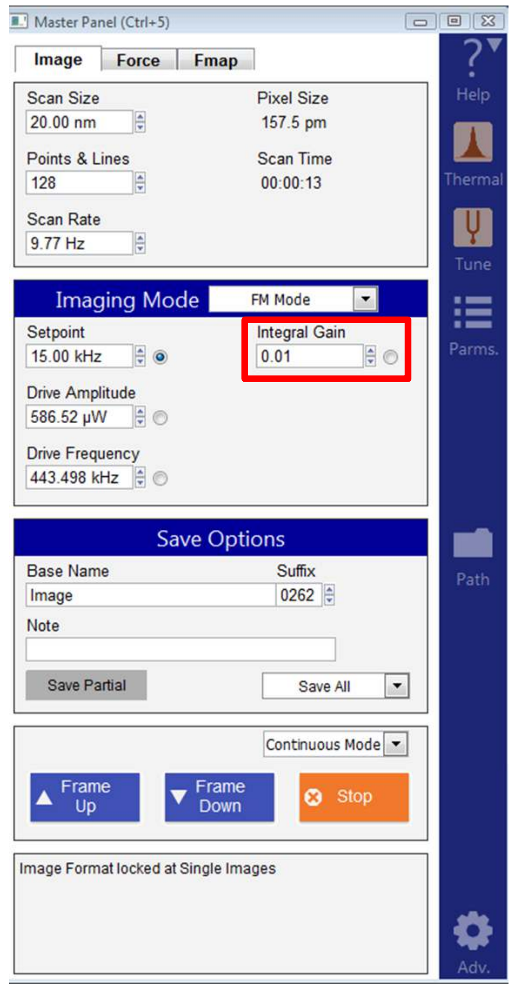
22.7. FM imaging

1. It is recommended to go through sections AC mode imaging and FM force prior to FM imaging. Doing so will allow the user to calibrate the cantilever, approach the sample and determine the FM gains for optimal imaging.

2.

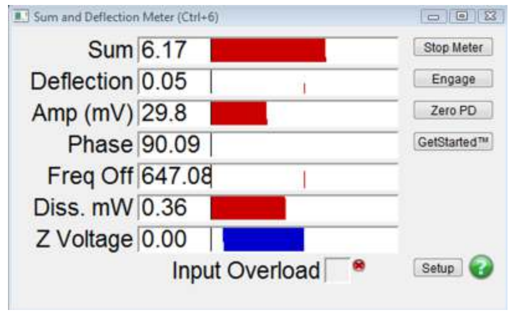
In Master Panel - Image tab

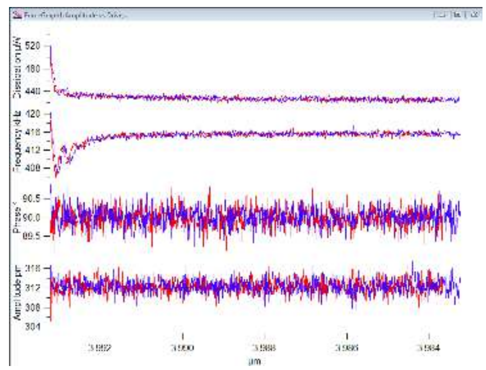
- Choose Imaging Mode: FM mode
- Set Integral Gain to 0.01 (when using blueDrive)
- Set the Setpoint to 10-15 kHz (or whatever value was used during FM curves)



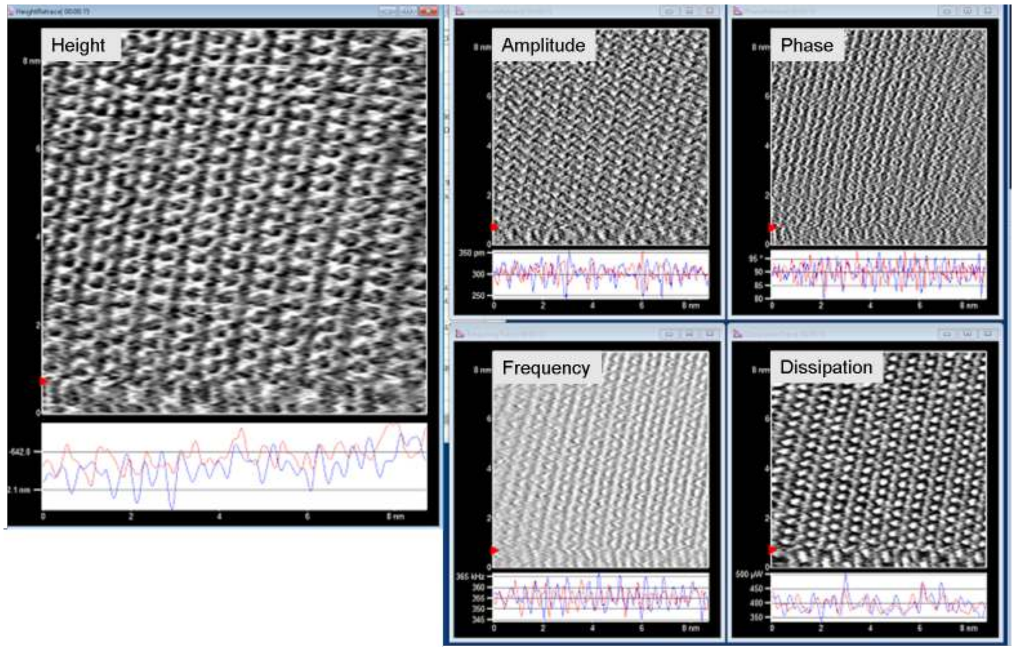
3.

- Set the Drive Set Point to required amplitude
  - start with 3 Angstroms: 3A = 0.3nm;
  - Ex: 0.3nm / 10.25nm/V InvOLS = 0.0292V = 29.3mV
- Activate Feedback Loops by checking the boxes besides
  - FM feedback ON
  - Drive Feedback ON
- When the frequency and drive feedbacks are ON, thefollowing values will appear in the SUM and Deflection meter
  - Amp (mV) = Drive SetPoint Value
  - Phase = 90
  - Freq Off = frequency offset compared to the value of drive frequency from tune, here 647 Hz
  - Diss mW = power (in mW) needed to keep the Drive Set Point Value at 30 mV or lower





4.



Start imaging

- Click Frame Down
- Height, Phase, Amplitude, Frequency and Dissipation channels should appear
- Adjust the following variables to optimize images
  - Drive Setpoint value
  - Setpoint
  - FM gains

23. Glovebox Protocols

CHAPTER REV. 1951, DATED 08/14/2017, 17:25. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

Cypher AFMs offer superb imaging performance inside of inert gas glovebox systems. While this solution offers the ultimate protection of the sample and cantilever from ambient conditions, it is not always practical to sequester an AFM inside of a glovebox for long periods of time. A decent alternative strategy is to assemble the cell inside of a glovebox and then to carry this assembly to the AFM which is located elsewhere. This chapter suggests a protocol for cell assembly inside of a glovebox.

While it is possible to leave the cell sealed during imaging, we suspect that oxygen and water vapor will find their way into the cell over the course of minutes and hours, driving the conditions inside of the cell away from the ~1ppm levels inside of the glovebox where the cell was first assembled. Therefore this protocol will suggest the attachment of an inert gas purge line as soon as the cell is mounted on the AFM.

Note	Imaging electrically insulating samples under conditions of very low water vapor can lead to unwanted forces on the cantilever due to static electric charge. With the whole AFM inside the glovebox, one can often mitigate these effects with devices (such as a static master) which locally ionize the air around the sample. Inside the sealed cell of the Cypher ES it may prove challenging to introduce static control devices.

23.1. Preparations

This section prepares you for imaging under inert gas purge conditions. This process will leave the AFM ready to accept the sealed cell as it comes out of the glovebox.

23.1.1. Prerequisites

- A Cypher ES outfitted with a rotameter device for regulating inert gas flow.
- Familiarity with basic imaging with the Cypher ES, described in Chapter 17 on page 178.
- Cypher ES with standard gas cantilever holder (901.758, See Section 18.1.1 on page 188).
- The sample stage can be ambient or heated or cooled. For this tutorial we chose the ambient sample mount (see Section 19.2.2 on page 207).

1. Start with a Cypher ES, fully prepared for imaging with gas perfusion. See Section 20.3 on page 227 for a tutorial on that subject.
2. Load a test sample and cantilever identical to what you plan on loading inside the glovebox.
3. Start imaging under the conditions (speed, scan size, etc.) you eventually plan to use on the sample which was mounted and sealed inside the glovebox.
4. Observe image quality while you experiment with the inert gas flow and note the maximum flow before imaging noise becomes noticeable.
5. Turn off the gas flow.
6. Stop imaging and disengage the tip.
7. Remove the cantilever holder.
8. Remove the entire sample cell from the AFM. For a tutorial on this subject see: Section 19.4 on page 215.

23.1.2. Preparing the cell and gas lines

We will completely bypass the gas valve and pressure manifold for this demonstration.

1. Start by removing and storing the gas lines that were already present on your Cypher AFM. See Section 20.2 on page 224.
2. Store the tubing sections in a safe place.
3. **Locate tubing and fittings:**

   - Consult the Cypher ES accessory parts list (Section 16.1 on page 163)_ and find the following:
   - 231.006 1/16” O.D. Tubing.
   - 231.008 Luer Fittings: 231.008.
   - 5cc Syringe: 080.010.
   - Threaded fittings: 232.015.
   - Scalpel knife with blade, 290.147 and 290.148
   - Ferrules: 232.016.
   - Extender Tool Fitting Wrench: 114.800.
   - Fitting Compression Fixture: 114.721

   Note A note over here on the left, using the list description type.
4. **Locate a three way valve:**

   - The luer-type valve at right is provided by Asylum.

5. Cut two sections of tubing long enough to reach from the scanner cell to the outside of the ES enclosure, perhaps half a meter.

6. At one end of each of these pieces of tubing, secure a threaded fitting and a ferrule. See Section 20.4 on page 227 for instructions.

7. At the other end of each piece of tubing, attach a female luer fitting, as shown in the following steps:

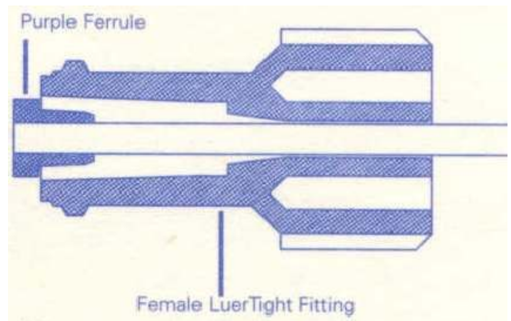
8. **Locate parts:**

   - 231.008 Luer Tight Fittings, which includes all the parts shown on the right.

9. **Attach purple ferrule:**

   - Slide the female Luer Tight fitting and purple ferrule, in that order, over the tubing.

   Note Make sure to keep the end of the tubing flush with the base of the ferrule, as shown in the diagram.



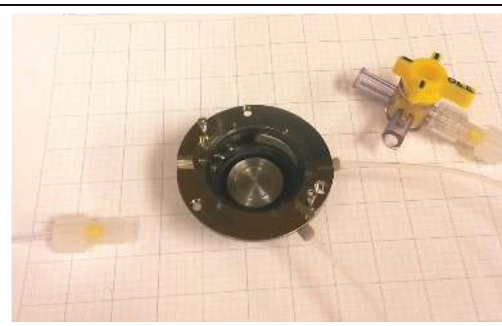
10. **Seat the fitting:**

    - Attach the red Luer Tight seating tool (has a piece of red plastic embedded into it) to the female Luer Tight fitting by screwing it firmly onto the female Luer Tight body. This will seat the ferrule into the luer fitting.
    - Remove the seating tool and store for later use.

11. Attach the two tubes to the two side ports of the cell. See Step 3 on page 219 and the following few steps.

12. **Attach valve:**

    - Attach a valve to one of the two tubing ends, as shown to the right.



23.1.3. Seal the cell

1. Read ahead through this section and collect all the tools, screws, tweezers, cantilever holders, etc. you will need to place inside the glovebox.

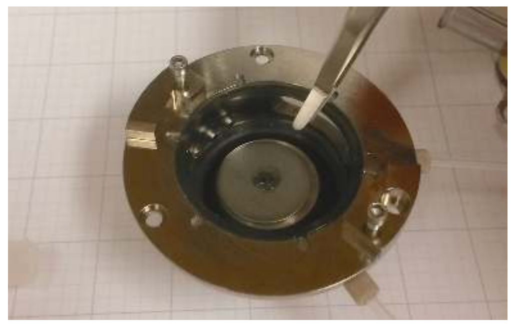
2. **Inspect the cantilever holder:**

- Ideally the cantilever holder has a hole in the position shown with the cartoon hand. This will allow for a tool to access a screw in a later step.
- If there is no hole here, you can proceed without using the screw, but should consider contacting support@asylumresearch.com to see if your holder can be updated.

3. Place all these items, and the cell body with tubing and syringe attached and the cantilever holder into the glovebox via the vacuum load lock. Evacuating the lock will not harm the cell since it has not yet been sealed.

4. **Place the sample:**

- With the sample mount in the position shown, place the sample.



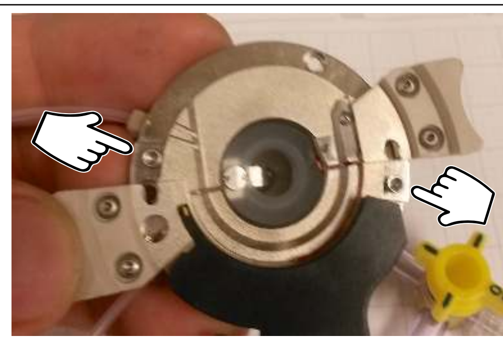
5. Load the cantilever into the cantilever holder and set that aside.

6. **Extend the membrane:**

- Pull down on the bottom of the sample stage to fully extend the rubber membrane, carefully, as shown.

7. **Place the cantilever holder:**

- Remove the two screws indicated and set them aside. You will need to take them out of the glovebox along with the cell later.
- Place the cantilever holder in the position shown. It should NOT be rotated clockwise as it usually is during use while imaging because this will interfere with the

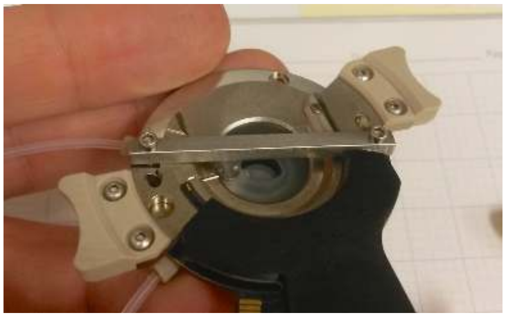


8.

Attach the bar:

- Using two longer screws (1-72 x ?”), attach the metal bar as shown.

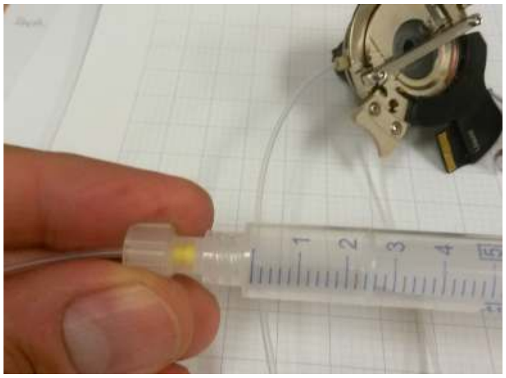
NOTE: Tighten the screws very gently and keep the bar from tilting. Tightly securing only one screw might cause the bar to tilt and tightening the other screw will cause the bar to press down too hard on the cantilever holder, possibly causing irreversible damage.



9.

Seal the tubes:

- Set the plunger of a 5CC syringe around the 2CC position.
- Attach the syringe to one of the tubes.
- Make sure the valve on the other tube is in the closed position.



10.

Close the valve:

- Make sure the valve is in the OFF position, if it was not already.
- The cell is now fully sealed on all sides.

11.

Take the assembled cell out of the glovebox:

- Place the cell and everything attached into the load lock and close it.
- DO NOT EVACUATE. There is no need for evacuation when taking things back into the ambient atmosphere.
- Open the door on the ambient side and take the cell to the AFM.

NOTE: some customers like to first place their cell and tubing inside of a jar, like the dessicator shown on the right. This gives you even more time and peace of mind when transporting the cell back to the AFM.

23.1.4. Mount the sealed cell onto the AFM

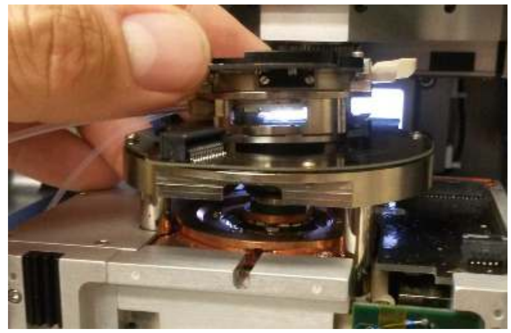
Chop Chop

The faster you work through the following steps, the smaller the chance of impurities diffusing into the sealed cell. The membrane is made of Kalrez and is quite impervious to water and oxygen. Nevertheless, it is best to get pure dry gas flowing through the cell as quickly as possible.

1.

Place the cell onto the scanner:

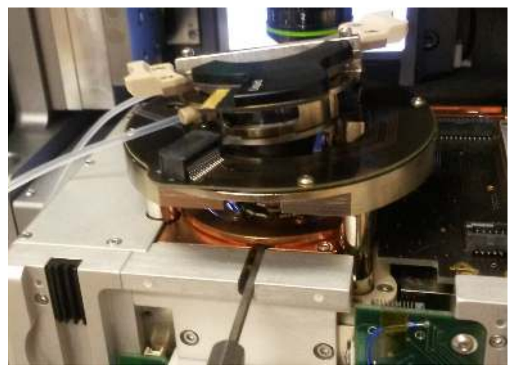
- Seat the foot of the cell onto the receptacle located on top of the scanner.
- The trapped air inside the cell will prevent sample will prevent the tip from colliding with the sample.



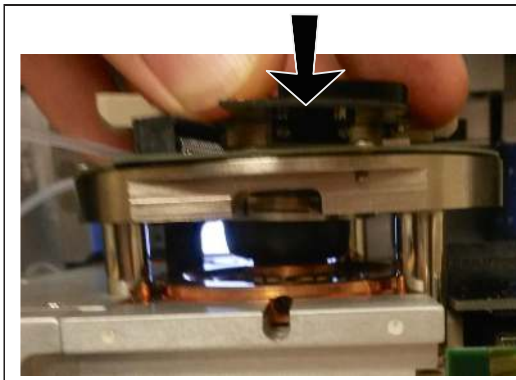
2.

Lock the foot:

- Lock the foot of the using the tool as shown. Do not over tighten. This is discussed in more detail in Step 8 on page 220.



3.



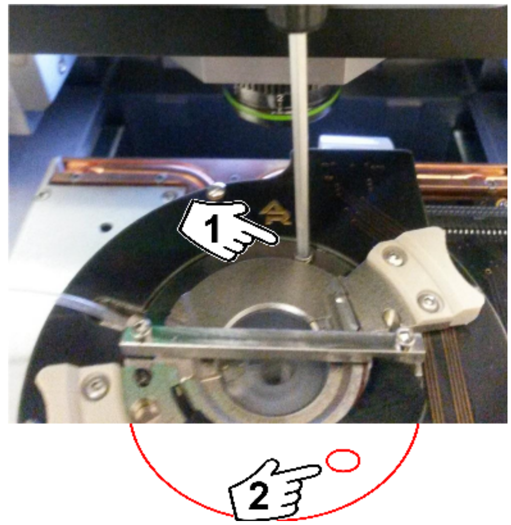
Press down and seat the cell body:

- Press down on the sample stage as shown on the left. You will see the membrane bulge a bit under the building pressure. This pressure will assist the proper forming of the membrane.
- During this process, retract on the syringe to relieve the pressure as the cell lowers.
- About 3CC of gas should be removed to properly seat the cell body. A little overpressure is better than a slight vacuum in terms of keeping contaminants out of the cell.

4\.

Secure sample chamber to scanner with two screws:

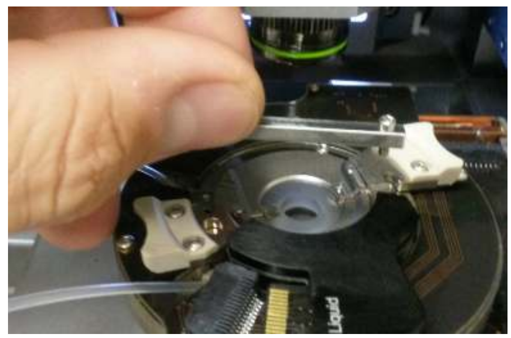
- Secure the sample chamber with screw number 1. Do not over-tighten.
- If your cantilever holder has a hole in the position marked (2), secure that screw also. Some older equipment does not grant access to (2). In that case, skip this screw.



5\.

Remove the bar:

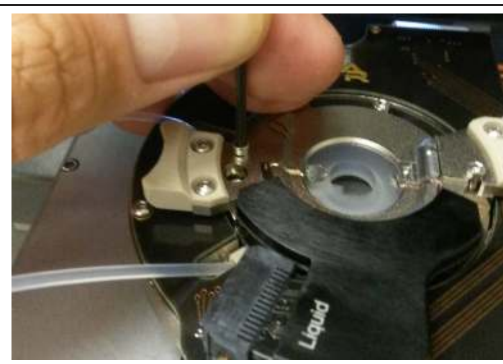
- Unscrew the bar and remove it as shown.
- Ensure the fastening screws are in place but not screwed all the way down, as they will be used to secure the cantilever holder in the next step.
- TAKE CARE: During these steps, the cantilever holder could now be pulled loose, exposing your sample.



6\.

Rotate the cantilever holder into position and secure:

- While pressing down to maintain the O-ring seal, rotate the holder clockwise so that the circuit board seats with its connector and the screws line up with their grooves on the holder.
- Tighten screws.



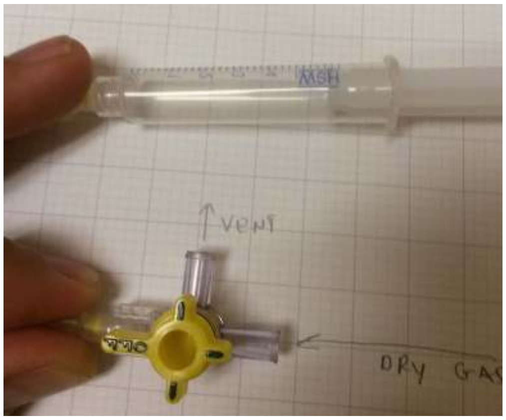
7\.

Put the final screw into place securing the cell body to the scanner:

- With the holder in place and fastened to the sample chamber, tighten the third and final screw that fastens the sample chamber to the scanner.

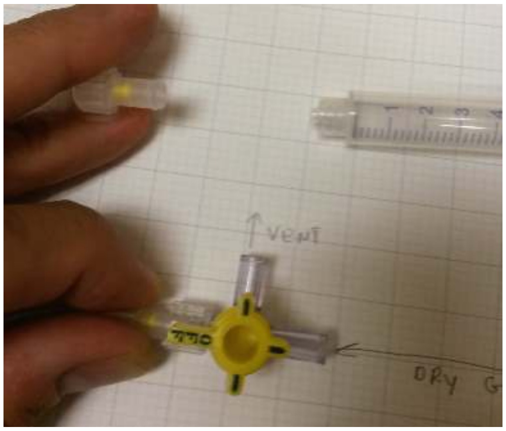
8. **Attach the gas line to the valve, and turn on the gas flow to purge the interior of the valve:**

- Gas flow rate is chosen by the user
- Gas will flow to atmosphere



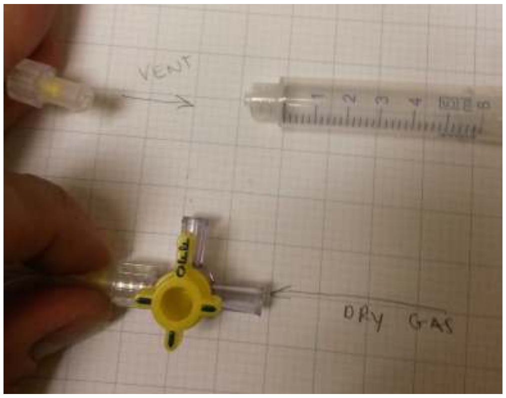
9. **Remove the syringe from the tubing at one end:**

- This very briefly breaks the seal to atmosphere, but there is NOT sufficient time to contaminate the sample chamber, and the next step creates gas flow that continuously purges atmosphere.



10. **Turn the valve clockwise to divert gas flow through the sample chamber:**

- The gas will now flow into the sample chamber and out of the tube where the syringe was just removed.
- CAUTION: if there are organic or toxic fumes contained in the sample chamber, the vent line should be routed to a fume hood.



24. High Voltage

CHAPTER REV. 2039, DATED 08/30/2018, 11:02. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

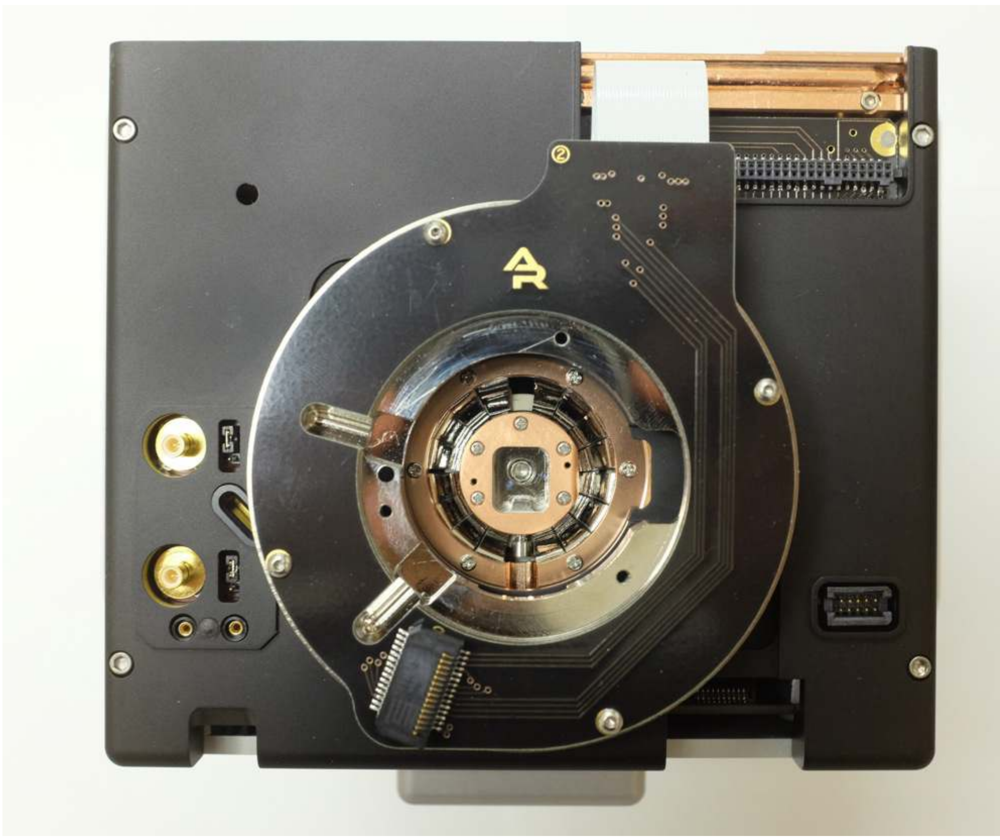


Figure 24.1.: High Voltage Scanner seen from above.

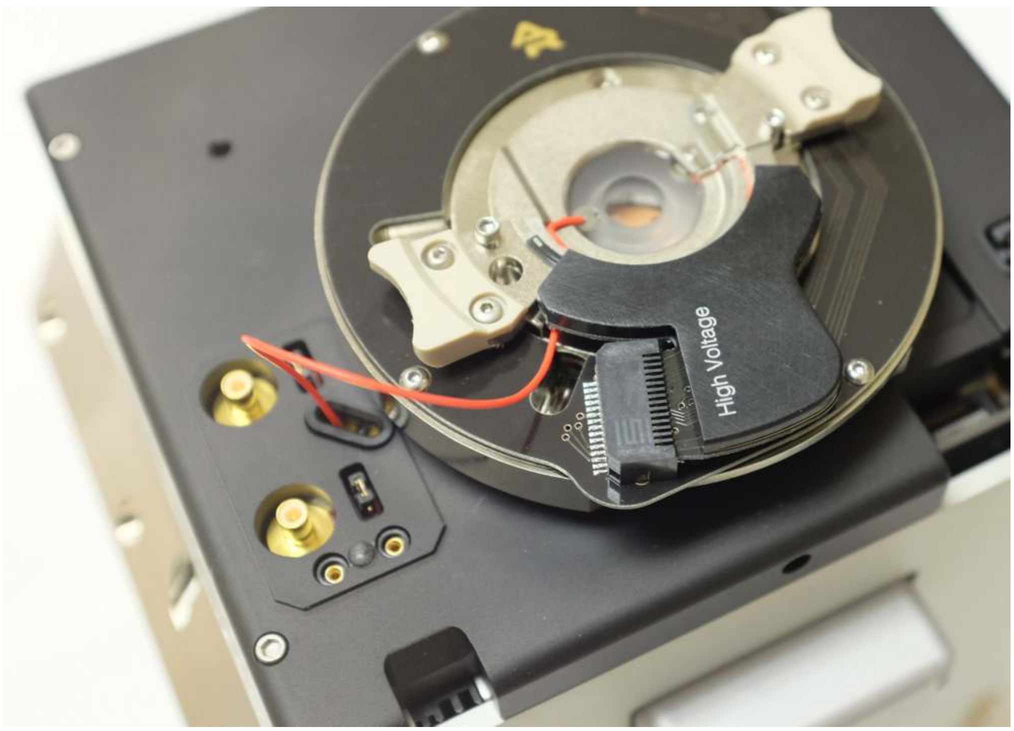


Figure 24.2.: High Voltage Scanner with High Voltage cantilever holder and its fly wire connected to the high voltage contact.

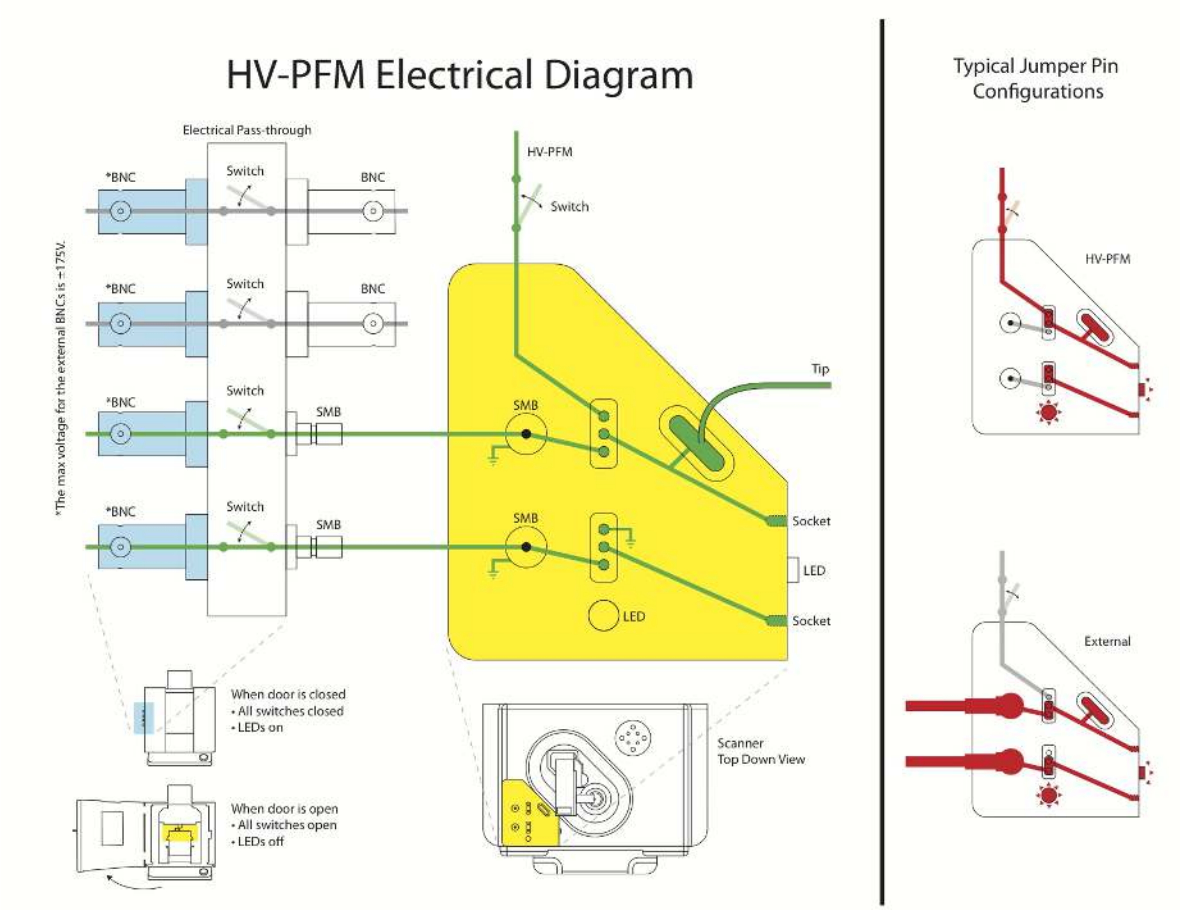


Figure 24.3.: The Cypher High Voltage Option

25. Electrochemistry Cell

CHAPTER REV. 2095, DATED 08/12/2019, 21:54. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

25.1. Requirements and Prerequisites

Electrochemical AFM is considered an advanced technique. One should have mastered these basic techniques before attempting to use the EC AFM accessory:

- Familiarity with the Cypher ES system and AFM imaging of a basic sample in air, covered in Chapter 16 on page 163 and Chapter 17 on page 178.
- Mastery of basic imaging in fluids, covered in Chapter 21 on page 228.

It is also assumed that the user:

- Has a Cypher ES AFM
- Has blueDrive photothermal excitation equipped in order to image in tapping mode

25.2. Overview

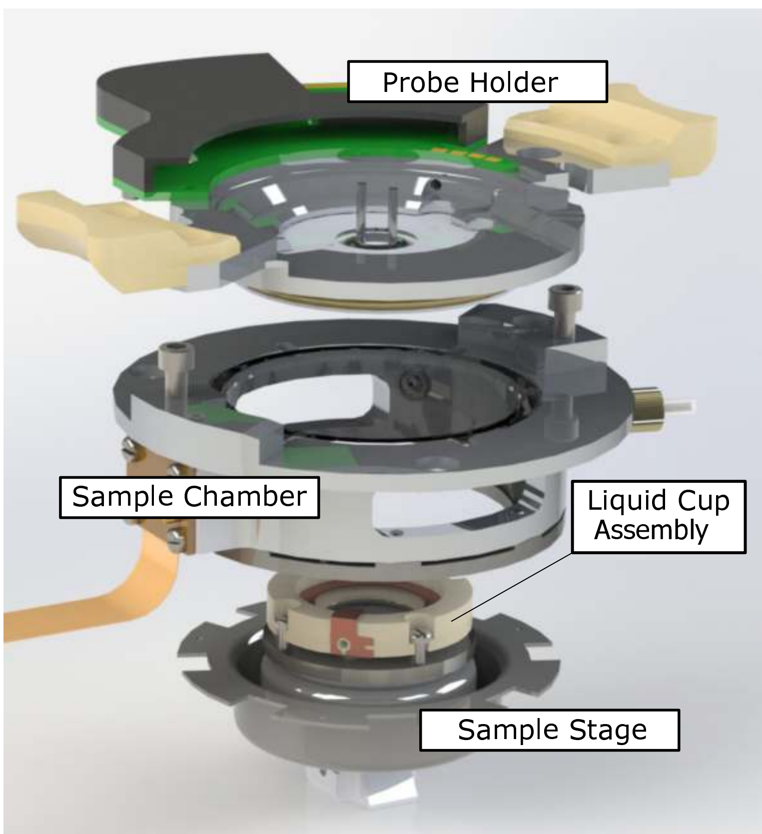


Figure 25.1.: The four major components of the Cypher ES electrochemistry cell

The Electrochemistry (EC) Cell for the Asylum Research Cypher ES Atomic Force Microscope (AFM) has been designed to perform EC-AFM with the Cypher ES. It enables study of, for example, deposition, oxidation, corrosion, and mass transfer of metals and other materials. Simultaneously, the nanoscale topographical changes induced by these electrochemical reactions can be precisely monitored with the AFM. Please note: this manual does not cover any hardware or applications where voltage or current are applied or measured through the probe tip.

Electrochemical experiments with the Cypher ES EC Cell are conducted in a standard three-electrode configuration with the sample as the working electrode (WE), a geometrically concentric counter electrode (CE), and a reference electrode (RE) that enters the cell through the probe holder. Virtually infinite combinations of materials may be used for these electrodes. The cell can be operated in a sealed configuration, and the electrolyte is contained in a liquid containment cup that both seals to the sample to define the working electrode area and provides support for the counter electrode in solution. All components contacting the electrolyte solution are chemically inert.

The connection between an external potentiostat and the electrodes is established through an EC-specific electric-blue-colored circuit board and related connector cables. This circuit board interfaces with the top of the Cypher ES Scanner, and it is conveniently labeled with the orientation of the magnetic working (sample), ground, and counter electrode contacts inside the Sample Chamber.

The probe holder for the Cypher ES EC Cell is provided either with or without perfusion capability, and is designed so that the cantilever may be lowered to the sample surface in the electrolyte in the liquid containment cup. The probe clip is made of inert PEEK or PPS and holds the probe in place by friction for use in tapping or contact mode. For tapping mode, note that there is not a shake piezo, so the cantilever must be photothermally excited with Cypher's blueDrive laser.

25.2.1. List of Abbreviations Used Throughout This Chapter

AFM Atomic force microscope/microscopy

CE Counter electrode

EC Electrochemistry/electrochemical

FEP Fluorinated ethylene-propylene

FKM Fluoroelastomer (equivalent to Viton®)

FFKM Perfluoroelastomer (P-Rex®, equivalent to Kalrez®)

PCB Printed circuit board

PEEK Polyetheretherketone

PFA Perfluoroalkoxy alkane

PH Probe holder

PPS Polyphenylenesulfide (Ryton®)

PTFE Polytetrafluoroethylene (Teflon®)

RE Reference electrode

WE Working electrode (sample)

25.2.2. Quick Start Guide

The following order of operations is suggested to optimize your work flow in setting up and using the Cypher ES EC Cell. Additional details related to these steps may be found in 25.6:

1. Turn on Cypher, start software, calibrate position and blueDrive motors.

a) For best performance, allow the instrument to equilibrate for a few hours.

2. Clean all parts as desired, and make solutions. The cleaning cylinder (114.820) may prove to be useful for this. See Table 25.1 on page 272.

3. Assemble Standard Probe Holder Subassembly (901.933) without probe (see Section 25.3.2 on page 267 for additional detail).

   a) Install RE through top port (1 mm diameter) in probe holder. If atmospheric control is needed, ensure that the RE is fully sealed into the top port as described in Section 25.7 on page 284 to prevent inward diffusion of external gases.

   b) Install probe clip on probe holder; ensure clip strap is aligned with the bevel on the optical window so that when the probe is mounted the cantilever will be centered on the optical window (see Figure 25.3 on page 268 for rendering).

   c) If using the Perfusion Probe Holder Subassembly (901.939), ensure perfusion tubes are set up. See Section 25.6.1 on page 282 for further details on installing these tubes.

4. Install the Enclosure Bulkhead Subassembly (901.937) and connect its SMB cables to the lower right front connections on the Cypher ES Scanner inside the enclosure. **Top**: WE. **Middle**: RE. **Bottom**: CE. Related images may be found in Figure 25.7 on page 270.

5. Affix the Generic Potentiostat Cable Subassembly (448.172) cables to the Bulkhead subassembly, and connect your potentiostat to the free ends of these. Note: Specifically for CH Instruments potentiostats, we offer a Potentiostat Cable Subassembly (Table 25.1 on page 276) that plugs directly into the back of the potentiostat from the enclosure.

6. Install the EC AppMod Printed Circuit Board (PCB) Subassembly (458.293.1) circuit board on top of the scanner, ensuring the ribbon cable from the Sample Chamber seats into the receiving port on the PCB. See Figure 25.9 on page 271 for picture and additional description.

7. Test electrical connections from the Potentiostat Cable leads to the sample chamber magnets with a multimeter to ensure proper signal pathways.

8. Mount the WE (sample) in the Liquid Cup Subassembly (901.934) as shown in Figure 25.5 on page 269.

   a) Affix CE and its magnetic jumper wire to liquid cup with lateral screw (00-90 x 3/32” or shorter).

   b) Locate four screws (00-90) of equal length to mount your sample, and thread one of the screws 1-2 turns into base plate.

   c) Locate desired number of shims of desired material to support WE.

   d) Locate O-ring of desired material (Viton or FFKM) for sealing the liquid cup to the WE.

   e) Place the liquid cup on the base plate so that the previously inserted screw (b) seats into the side of the cup. Thread a second screw of same length 1-2 turns into base plate in an adjacent screw groove in the liquid cup. This fastens the cup to the plate loosely, leaving room for the sample to be inserted between. (Note also that the assembly can be cleaned in this state.)

   f) Locate another jumper wire, and if possible, solder it to the conductive surface of the WE.

   g) Place O-ring on sample/WE, and with tweezers slide the sample/O-ring into the cup-plate assembly from steps (e-f). Ensure that the O-ring aligns with the recessed edge in the bottom of the liquid cup.

   h) Insert shims (generic plastic sheet of any tipe is sufficient) below the sample substrate if desired. This has two effects: making the sample effectively thicker, and electrically insulating the sample from the base plate (important for fully conductive samples).

   i) Thread the remaining two screws 1-2 turns into their holes in the base plate via grooves in the liquid cup.

j) If soldering was not used in (f), create electrical contact to the WE by inserting a free jumper wire lead between the liquid cup and the WE surface (screws are not fully tightened yet).

k) Evenly tighten all screws, simultaneously compressing the O-ring to seal the WE and clamping the jumer wire to the WE surface.

l) Ensure the sample is properly aligned and test electrical connections with a multimeter to ensure that no electrical leads are shorted.

9. Place the EC Cell Liquid Cup in the Sample Chamber Subassembly (901.935) and, with tweezers, contact magnetic jumper wires from the Liquid Cup to the inner wall contacts of the Sample Chamber. The WE contact is closest to the front, while the CE contact is furthest back, and the middle contact is ground.

10. Mount probe of choice on the probe holder. Further detail may be found in Section 25.6.4 on page 283.

11. Optionally expose liquid cup assembly and mounted probe/cantilever to UV irradiation for a few minutes to decompose any remaining organics.

12. Add 200-300 μL electrolyte to liquid cup and a small droplet of electrolyte to the probe to prevent bubble formation

    a) Optionally, you may perform a “calibration” EC experiment (such as cyclic voltammetry with 5 mM ferro-/ferricyanide redox couple in 100 mM KCl) to confirm electrical continuity and electrochemical performance. For specifically this experiment with ferro-/ferricyanide, the blueDrive laser should not be used because its 405 nm wavelength is strongly absorbed by the molecules and can result in photochemical transformations; this is only used as an electrochemical test.

13. Affix the probe holder with mounted probe to the sample chamber; tighten screws to finger tightness.

14. Lower probe until electrolyte wicks onto probe, clip, RE and laser window.

    a) If using the perfusion probe holder, optionally perfuse electrolyte into/out of the liquid cup.

15. Ensure objective is set to 2 for liquid imaging.

16. Tune cantilever, approach surface, and start imaging with EC-AFM! Note that if the tip is far from the surface, approaching may require several iterations of maximizing the objective’s z-position followed by lowering the tip and repeating. Sometimes, this also makes the deflection laser become misaligned with the cantilever, and is simply fixed by re-aligning it to maximize the sum signal. (Please refer to Cypher ES manual for additional information regarding any of these steps.)

25.3. EC Cell Kit (901.800) Description and Parts List

The EC Cell is an accessory for the Cypher ES scanner, and may be purchased separately and immediately integrated with the the system. **Part number 901.800 specifies this entire accessory kit, consisting of all of the parts listed in** Section 25.3.9 on page 271. Note: the EC Cell is **not** compatible with the Cypher S scanner.

25.3.1. Items Included in the EC Cell Kit

- Probe Holder, standard (901.933) or with perfusion (901.939)
- Liquid Cup subassembly (901.934) with base plate for mounting sample/WE
- Sample Chamber subassembly (901.935)
- Remaining accessories including:
    - Probe clips in PEEK (116.086) and PPS (116.129)
    - EC AppMod Circuit Board, light blue (458.293.1)

- An electrical connections bulkhead assembly (901.937) for facilitating use of an external potentiostat of the user's choice and routing electrical signals out of the instrument enclosure
- A reference electrode wire in Teflon (PFA)-coated Ag, with the option to use any other type of metal wire as the RE
- A concentric counter electrode in Cu, with the option to use other types of metal or a simple loop of wire as the CE (116.070)
- Tubing, O-rings, connectors, PTFE tape, and various fittings
- Essential tools such as screwdriver, tweezers, scalpel

Note that all of these items are thoroughly specified in Section 25.3.9 on page 271.

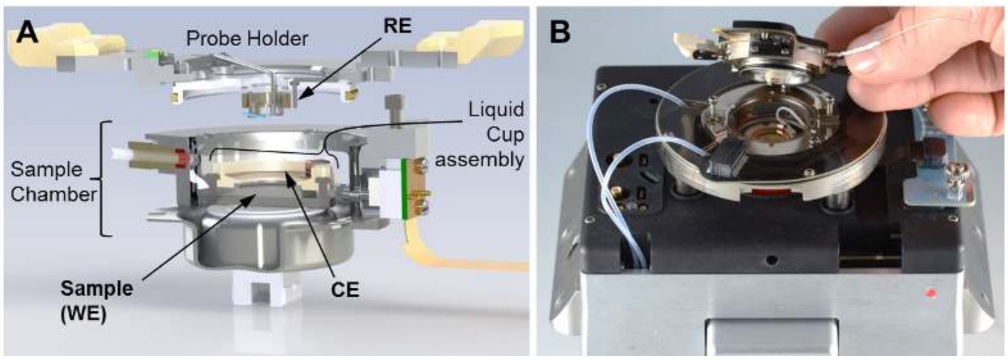


Figure 25.2.: The EC Cell. (A) Exploded cutaway schematic rendering of the major EC Cell components. (B) Photograph of the EC Cell in place inside the Cypher ES scanner. Securing the probe holder completes assembly and completes the 3-electrode circuit in the electrolyte (see Section 25.6 on page 282 for full assembly instructions).

25.3.2. Standard Probe Holder Sub-assembly (901.933)

The probe holder comes in two flavors: regular and perfusion. The "moving parts" of this component that the user will modify/exchange/replace are:

- Probe
- Probe clip
- RE wire

Any brand or type of probe may be used; however, keep in mind that no current or bias can be applied to the tip in the Cypher ES EC Cell. The probe clip uses spring force and friction to hold the probe in place (see Figure 25.3 on page 268). It has been designed to be easy to manipulate and easy to clean without sacrificing imaging performance in contact or tapping mode (please see Section 25.8 on page 285 for cleaning instructions).

25.3.3. Perfusion Probe Holder Subassembly (901.939)

This probe holder is identical to the standard probe holder, save for the features that provide perfusion capability. Namely, the optical window that supports the probe has two offset holes (~0.029" diameter) bored in it, and FEP tubes (~0.031" diameter) have been inserted in these. The hole closer to the cantilever is intended as the inlet in order to maximize solvent flow at the tip-surface locus. Please see Figure 25.4 on page 268 for further detail.

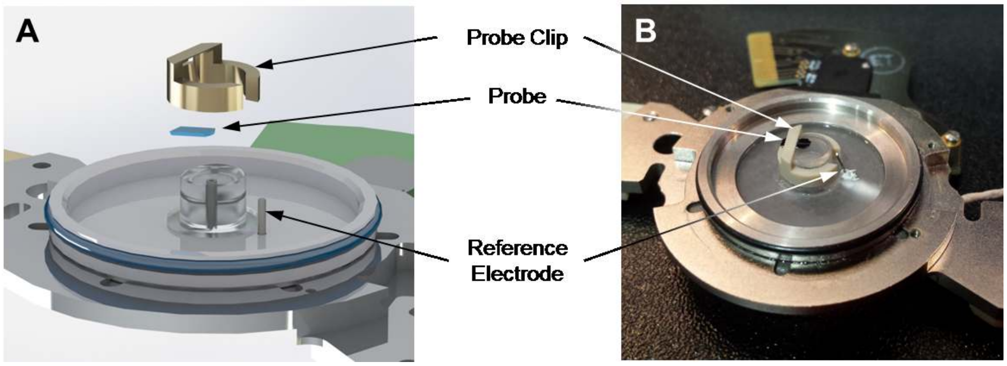


Figure 25.3.: Standard Probe Holder. (A) Schematic upside-down view of the probe holder. (B) Upside-down view photo of the assembled probe holder showing probe, probe clip, and reference electrode in recommended orientation.

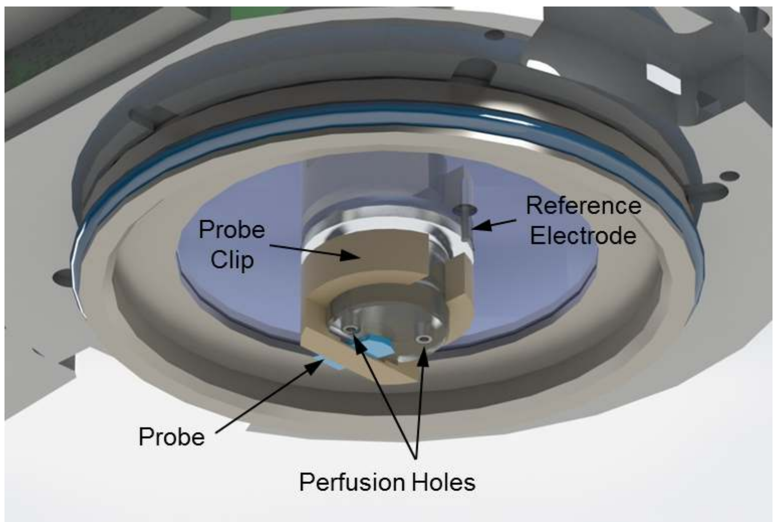


Figure 25.4.: Bottom view rendering of the fully assembled Perfusion Probe Holder (901.939)

25.3.4. Liquid Cup Subassembly (901.934)

The liquid cup assembly may be seen in Figure 25.5 on page 269. It is used to simultaneously:

- Contain the electrolyte for EC
- Support the CE
- Support the WE (sample) for imaging
- Seal the WE (sample), providing a consistent surface area defined by the O-ring

A working volume of electrolyte inside the cup of 225 µL fills the liquid cup full to the brim with the tip engaged. Any volume in the range 150-300 µL will work well, and larger volumes in that range aid the user in visually confirming that the liquid wicks onto the probe and probe holder. The standard CE is a concentric annulus made from Cu or Pt with a bent protrusion for electrical contact; please keep in mind that a loop of any metal wire will also work. The liquid cup accommodates samples (WEs) that are 0.9–1.5 cm in circular diameter or square edge, with a range of >0–5 mm thickness. Users typically find square samples to be more convenient due to the ease of contacting the jumper wire to a corner of the sample. A conductive WE sample surface should have a non-conducting substrate or otherwise be insulated from the base plate (e.g. with plastic shims). Contact between the sample and the potentiostat WE lead is achieved by either soldering a free jumper wire to an exposed sample edge/corner or clamping a free jumper wire lead lightly between the liquid cup and the sample (as shown in

Figure 25.5 on page 269). Two gas perfusion ports in the sample chamber (see C in Figure 25.9 on page 271 for the entry points of the tubes into the Sample Chamber) allow for atmospheric exchange and control around the electrolyte (gas blanket).

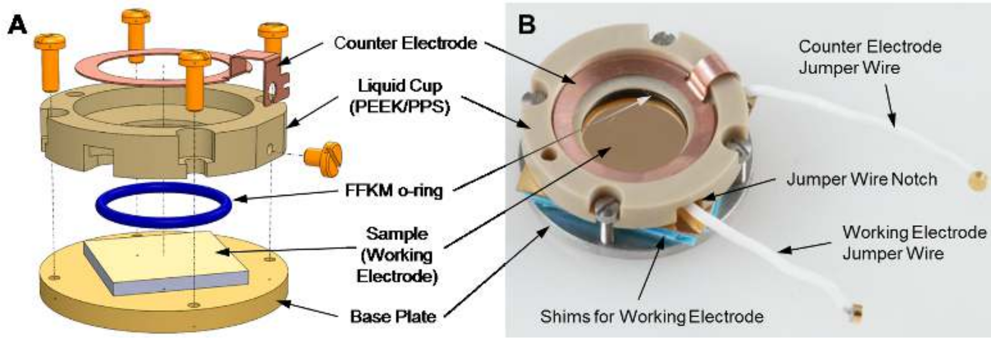


Figure 25.5.: EC Cell Liquid Cup Subassembly. (A) Exploded schematic of the liquid cup. (B) Photograph of the assembled Liquid Cup including sample shims and WE and CE jumper wires. For scale, O-ring inner diameter is 8.4 mm, and base plate diameter is 18.5 mm. Notice the blue platic shims in use, as well as the notch that is provided in the liquid cup to aid in physically clamping a jumper wire to the sample surface.

25.3.5. Sample Chamber Subassembly (901.935)

Typically, this subassembly comes pre-installed in the Cypher ES scanner. It is worth pointing out that a few small changes have been made to the design so that it is compatible with the design of the EC Cell as well as previously offered functions. First, the metal contacts that feed through the glass cylinder enclosure are now made of nickel, which is rust-proof and yet still ferromagnetic for making contact to the WE and CE jumper wires. Second, the permanent ribbon cable replaces the former removable black 3-wire cable that used to exit the sample chamber. This ribbon cable connects directly to a female adapter on the light blue EC AppMod PCB (458.293.1) that routes WE, CE, and RE (and eventually a second WE for SECM and EC-STM type applications) through the scanner to the external potentiostat.

Figure 25.6.: Sample Chamber Subassembly.

25.3.5.1. Sample Chamber Electrical Connections

Please refer to Figure 25.9 on page 271 for the magnetic contact pin location assignments inside the sample chamber that are depicted on the blue AppMod PCB.

25.3.6. Enclosure Bulkhead Sub-assembly (901.937)

This sub-assembly allows electrical signals to pass from the potentiostat to the scanner to the EC Cell through the Cypher ES enclosure. As can be seen in Figure 25.7 on page 270, the SMB ports at the bottom right front of the Cypher ES Scanner are labeled for Working (Top), Reference (Middle), and Counter (Bottom) electrodes. These labels correspond to the same labels in the EC Cell and the AppMod PCB.

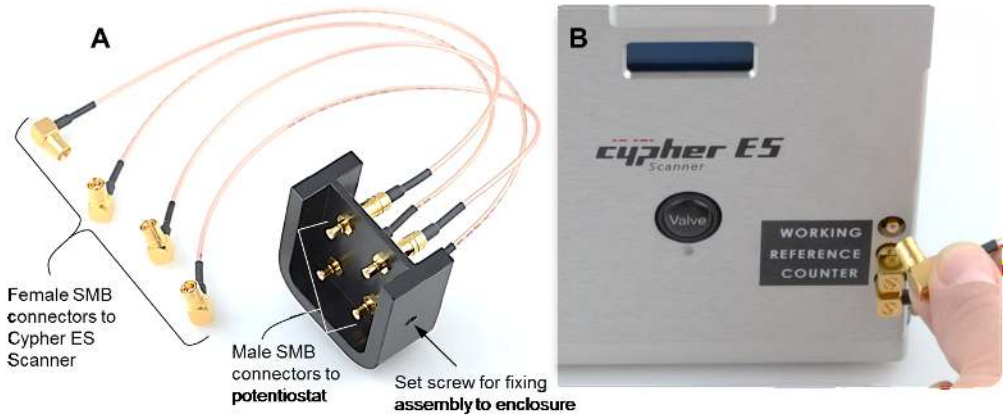


Figure 25.7.: (A) Enclosure bulkhead subassembly depicting SMB type connectors. (B) SMB connections and labeling corresponding to the electrical path to the pins inside the sample chamber.

25.3.7. Generic Potentiostat Cable Sub-assembly (448.169)

This assembly is comprised of coaxial cables with SMB connectors. It interfaces with the SMB barrel connectors on the outside of the bulkhead assembly (901.937), allowing for the user to connect an external potentiostat to the EC Cell while the Cypher enclosure door is sealed (see Figure 25.8 on page 270).

Figure 25.8.: Generic 5-lead potentiostat cable showing SMB connectors (to attach to bulkhead assembly) and free contacts for alligator clips.

25.3.8. EC AppMod Printed Circuit Board (PCB) Subassembly (458.293.1)

This sub-assembly is a light blue circuit board that plugs into the top of the Cypher ES scanner. It has a port for connecting the ribbon cable from the sample chamber (901.935) that routes the electrical signals out of the

EC Cell. This part is necessary for routing electrochemical signals through the provided hardware. Note that the labels for the magnetic pins are printed on this board for reference.

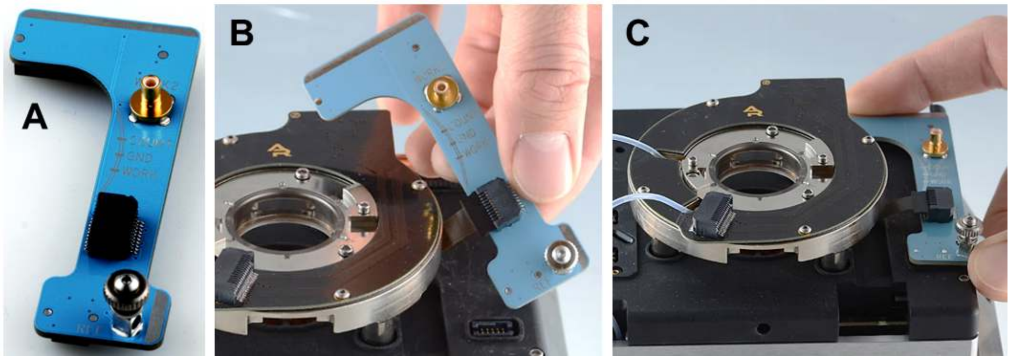


Figure 25.9.: EC AppMod PCB. (A) Circuit board as an independent part. Note the labels “COUNT,” “GND,” and “WORK” that correspond to CE, ground, and WE for the nickel pins on the inside of the sample chamber. The RE contact is the knurled silver knob, allowing for the RE wire to exit the top of the probe holder and be clamped for connection to the potentiostat. (B) View of the sample chamber ribbon cable installed into the port on the circuit board. (C) View of the proper installation site of the circuit board, which is easily connected with fingers.

25.3.9. Full Parts List

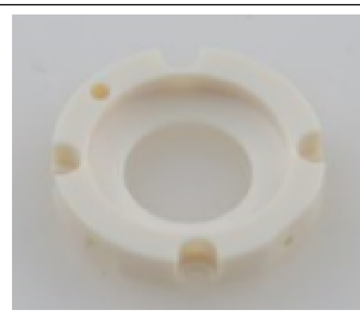
Below is a list of all components contained in the EC Cell kit (901.800). Please always refer to the relevant six-digit (###.###) Asylum Research part numbers during support calls or when buying replacements. Note that only inert components come into contact with the electrolyte: glass, glass-filled PEEK, PPS, and FKM or FFKM.

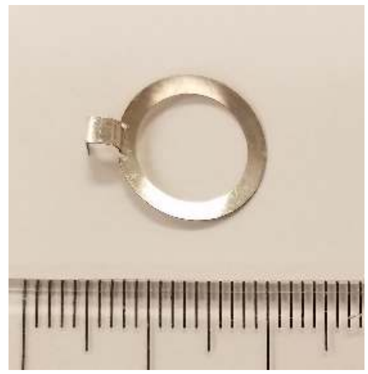
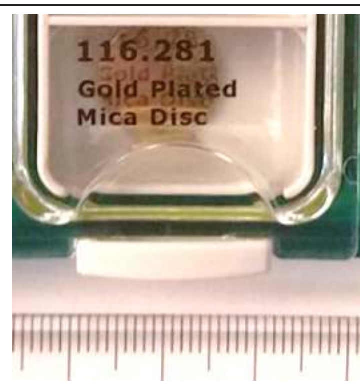
The part numbers for the major components of the EC Cell kit are

- 901.800 (Entire Accessory Kit)
- 901.933 (Standard Probe holder) or 901.939 (Perfusion Probe Holder)
- 901.934 (Liquid Cup)
- 901.935 (EC Sample Chamber)

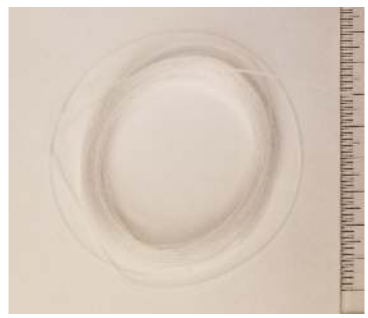
Itm	Part #	Item Description	Qty	Picture
1	n/a	Screws and fittings in Meiho box	1	
2	080.165	Syringes, Norm-Ject, 1 ml, tuberculin	5	
The scale in the photos is in cm and mm.				

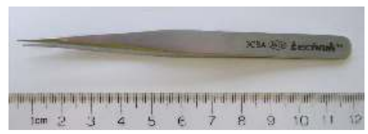
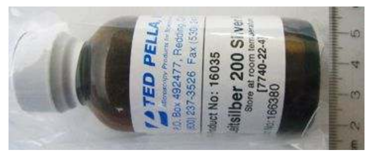
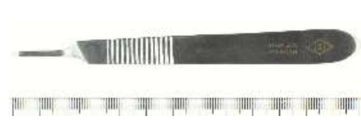
Itm	Part #	Item Description	Qty	Picture
3	010.106	PFA-coated silver wire for reference electrode; OD 0.010" uncoated, 0.013" coated	12”	
4	010.107	PFA-coated silver wire for reference electrode; OD 0.025" uncoated, 0.030" coated	12”	
5	114.820	Probe holder cleaning cup. Used to rinse and clean the probe holders while not causing damage to the circuit board.	1	
6	116.046	Base Plate, EC Liquid Cup (included in liquid cup assembly)	1	
The scale in the photos is in cm and mm.				

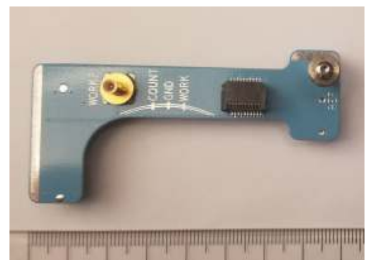
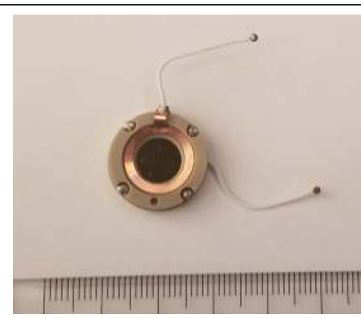
Itm	Part #	Item Description	Qty	Picture
7	116.070	Counter electrode, Copper ring	3	
8	116.071	Cup, EC Liquid, PEEK; included in liquid cup assembly	1	
9	116.086	Probe clip, PEEK (cantilever clamp); 7 mm OD; included in Probe Holder assembly	1	
10	116.119	Cup, EC Liquid, PPS	1	
The scale in the photos is in cm and mm.				

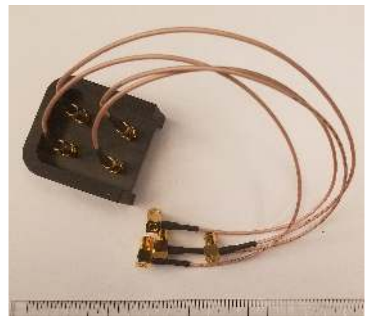
Itm	Part #	Item Description	Qty	Picture
11	116.129	Probe clip, PPS (cantilever clamp); 7 mm OD	1	
12	116.173	Counter electrode, Platinum ring	1	
13	116.281	Gold Plated mica disc; 0.5" diameter	1	
14	230.059	O-ring; 0.930" ID, 0.040" CS; Viton (FKM); for Probe Holder seal to Sample Chamber	1	

The scale in the photos is in cm and mm.

Itm	Part #	Item Description	Qty	Picture
15	230.060	O-ring; 0.332" ID, 0.031" CS; P-Rex (FFKM) durometer 75; For Liquid Cup seal to Sample/WE	2	
16	230.061	O-ring; 0.332" ID, 0.031" CS; Viton (FKM) durometer 70; For Liquid Cup seal to Sample/WE	5	
17	231.028.1	Tubing, FEP, natural, 0.016" ID, cut	20’	
18	232.019	Female luer to 10-32 Male	1	
19	232.020	Adapter, 1/16" to 1/32"	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
20	279.160	Tape, TaegaSeal PTFE 3/8" wide	1	
21	290.103	3C Tweezer, Extra Fine Sharp, Standard Grade.	1	
22	290.109	Leitsilber Conductive Paint. Used for mounting samples. Can be purchased from Asylum Research or directly from Ted Pella (16035).	1	
23	290.110	WIHA Screwdriver, Flat Tip 260 1.5 X 40.	1	
24	290.147	Scalpel Handle. Used to attach liquid perfusion tubing to the cantilever holder. Also useful when trimming thicker tubing for gas exchange.	1	
25	290.148	No. 15 scalpel blade. Used to attach liquid perfusion tubing to the cantilever holder.	10	
26	448.169	Potentiostat Cable; CH Instruments specific Cypher EC Cell.		
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
27	448.171	4 Jumper wire and magnet assembly for EC Cell contacts	18	
28	448.172	Cypher EC Cell generic potentiostat cable	1	
29	458.293.1	Cypher EC AppMod PCB Assembly	1	
30	901.934	Liquid Cup Assembly, PEEK	1	
31	901.933	Electrochemistry Probe holder assembly, Standard	1	
The scale in the photos is in cm and mm.				

Itm	Part #	Item Description	Qty	Picture
32	901.935	Cypher ES Electrochemistry Chamber Assembly; includes three 2-56 x 1/8" SHCS S/S	1	
33	901.937	Cypher enclosure bulkhead assembly	1	
34	901.939	Electrochemistry Probe holder assembly, Perfusion	1	
The scale in the photos is in cm and mm.				

25.4. Chemical Compatibility

Descriptions of the materials comprising the three major components of the Cypher ES EC Cell are provided below. Please refer above to the Full Parts List for additional detail for these EC Cell parts.

The Cypher ES EC Cell probe holder (901.933 or 901.939) comes into direct contact with the electrolyte during normal operation and is comprised of:

- Monolithic fused silica (quartz) downtube probe support and optical window
- Glass-filled PEEK and PPS probe clips (both provided)
- Reference electrode of user’s choosing (Ag wire provided), sealed as appropriate
- **For perfusion probe holder only**: PTFE tubes that enter through the probe holder for liquid perfusion/exchange in the liquid cup

The Cypher ES EC Cell liquid cup (901.934) comes into direct contact with the electrolyte and is comprised of:

- Glass-filled PEEK and PPS (both provided)
- O-ring seal in FFKM or FKM (both provided)
- Copper or Platinum concentric CE (both provided), or a wire/sheet of metal user's choosing
- Sample (WE) of customer's choosing

The Cypher ES EC Cell sample chamber (901.935) does not come into direct contact with the electrolyte during normal operation, and is comprised of:

- Fused silica inner wall (makes contact with chamber atmosphere).
- Rust-proof magnetic nickel contacts for WE, CE, and ground connections (make contact with chamber atmosphere). Optional: Ground contact can be permanently substituted for a humidity sensor (must be submitted as a Special Request prior to ordering).
- PTFE tubes for gas perfusion/exchange in the Sample Chamber.
- FFKM bellows for emergency liquid containment and mechanically-adaptive atmosphere isolation.
- Stainless steel chassis

Below is a table of the compatibility levels between the materials used in the EC cell and some common chemicals. Depending on your sample, electrode, electrolyte, and any additional materials used for sample mounting, this list may not be comprehensive. Please use additional resources to look up the chemical compatibility of more specialized materials (e.g. https://www.coleparmer.ca/Chemical-Resistance or https://www.burkert.com/en/content/download/9318/334992/file If you have any doubt about chemical compatibility, we recommend that you soak a piece of material in your electrolyte solution and notice any change in the material aspect (e.g. use the AFM to image the surface, or measure the dimensions before and after to measure dissolution or swelling). As a key example, PEEK will swell when in prolonged contact with concentrated sulfuric acid. Please contact Asylum Research with any additional inquiries about chemical compatibility

25.4.1. Chemical Compatibility Table

Compatibility Legend details:

- 1. **Excellent**: prolonged high performance; negligible corrosion/discoloration/swelling
- 2. **Good**: minor effect; very slight corrosion/discoloration/swelling; elevated temperatures increase effect
- 3. **Fair**: moderate effect; discouraged for continuous use; softening, loss of strength, swelling may occur
- 4. **Poor**: severe effect; not recommended for ANY use
- Blank. **Information not available**: not found or not tested

Chemical	PEEK	PPS	FKM	FFKM	PTFE	Quartz*	Copper	Platinum
Acetaldehyde	1	1	4	4	1	1		
Acetate solvents	1	1	4	1/2	1		1	
Acetic Acid 20%	1	1	2	2	1		2	1
Acetic Acid 80%	1	1	3	3	1	1	2	1
Acetic Acid, Glacial		1	4	3	1	1	2	1
Acetic Anhydride		1	4	2/3	1		2	
Acetone	1	1	4	1	1		1	
Alcohols, Amyl	1	1	1	1	1	1	1	
1: Excellent 2:Good 3:Fair 4:Poor blank:Unknown.								

Chemical	PEEK	PPS	FKM	FFKM	PTFE	Quartz*	Copper	Platinum
Alcohols, Benzyl	1	1	1	1	1		2	
Alcohols, Butyl	1	1	1	1	1		1	
Alcohols, Ethyl	1	1	1	1	1		1	
Alcohols, Hexyl			3		1			
Alcohols, Isobutyl	1	1	1	1	1			
Alcohols, Isopropyl	1	1	1	1	1		2	
Alcohols, Methyl	1	1	3	1	1		2	
Alcohols, Octyl			2				1	
Alcohols, Propyl	1	1	1	1	1		1	
Amines	1	2	4	1 (MeNH2: 4)	1			
Ammonia	2	1	4	3	1		4	
Aromatic hydrocarbons	1	2	1	1	1			
Aqua Regia (80% HCl / 20% HNO3)	4	4	2	1	1	1	4	4
Benzaldehyde	1	1	4	1	1		2	
Benzene	1	1	4	1	1		2	
Benzene Sulfonic Acid	4	1	1	1	1	1		
Bromine	4	4	1	1	1			3
Butyl Amine	1	4	4	1	1			
Carbolic Acid (Phenol)	4	1	1	1	1		4	
Carbon Disulfide (aka Bisulfide)	4	1	1	1	1			
Carbon Tetrachloride (dry)	1	2	1	2	1			
Chlorine (dry)	1	4	1	2	1		1	4
Chlorine, Anhydrous Liquid	4	4	1	2	1			4
Chlorine Water	4	4	1	1	1		4	4
Chlorobenzene	1	4	4	1	2			
Chlorosulfonic Acid	1	4	4	1	1			
Chromic Acid 10%	4	1	2	1	1		4	
Chromic Acid 30%	1	1	1	1	1		4	
Chromic Acid 50%	4	1	1	1	1		4	
Chlorox (Chlorine Bleach, Sodium hypochlorite)	2	4	1	1	1			1
Diethyl Ether	1	1	4	1	1		1	
Diethylamine	1	3	4	1	4		1	
Dimethyl Sulfoxide (DMSO)	3	1		1	1			
Ethanolamine		2	4	1	1			
Ethylene Diamine	1	1	2	2	1		4	
Ethylene Oxide	1	4	4	3	1		4	
Ferric salts	1	1	1	1	1		4	
Fluorine	4	4	3	2	4		3	
Fluosilicic Acid		4	2	1	1			
Formaldehyde <40%	2	2	2	1	1		2	
Formic Acid	3	1	3	2	1		3	
Furfural		1			1		1	
Glycerol (Glycerin)	1	1	1	1	1			
Gold Monocyanide					4			3
Hexane	1	1	1	1	1		1	
1: Excellent 2:Good 3:Fair 4:Poor blank:Unknown.								

Chemical	PEEK	PPS	FKM	FFKM	PTFE	Quartz*	Copper	Platinum
Hydraulic Oil (Petro)	1	4	1	1	1		1	
Hydrobromic Acid, 20-100%	4	1	1	1	1		4	3
Hydrochloric Acid, 20-100%	1	4	1	1	1		4	1
Hydrofluoric Acid, 20%	4	1	1	1	1	4	2	1
Hydrofluoric Acid, 50%	4	1	2	1	1	4	2	1
Hydrofluoric Acid, 75%	4	2	2	1	1	4	2	1
Hydrofluoric Acid, 100%	4	4	2	1	1	4	2	1
Hydrogen Peroxide, <30%	1	3	1	1	1		4	
Iodine	3	4	2	1	1		4	1
Iodoform					3		2	
Lye: KOH Potassium Hydroxide	2	1			1	4	2	
Lye: NaOH Sodium Hydroxide	2	1			1	4	2	
Magnesium Chloride	2	1	1	1	1		1	
Magnesium Hydroxide	1	1			1		2	
Morpholine		3	2	2	1	1		
Nitrating Acid (<15% HNO3)		3			1	1		
Nitrating Acid (>15% H2SO4)		4			1	1		
Nitric Acid, 5-10%	1	2	1	1	1	1	4	
Nitric Acid, 20%	1	3	1	1	1	1	4	
Nitric Acid, 50%	3	3	1	1	1	1	4	
Nitric Acid (Concentrated)	3	3	1	1	1	1	4	
Oxalic Acid	1	1			1	1		
Petrolatum	1				3	1		
Phenol (Carbolic Acid)	4	1	3	1	1	1	4	
Phosphoric Acid	1	1	1	1	1	2	4	2
Potassium Hydroxide (Caustic Potash)	1	3	4	1	1	4	2	2
Sodium Hydroxide, 20-80%	1	1	1	1	1	1	2	2
Sulfides	1	1	2	1	1		4	1
Sulfuric Acid, <10%	1	1	1	1	1	1	3	1
Sulfuric Acid, 10-75%	3	1	1	1	1	1	4	1
Sulfuric Acid, 75-100%	4	1	2	1	1	1	4	1
Sulfuric Acid (cold concentrated)	4	1	1	1	1	1	4	1
Sulfuric Acid (hot concentrated)	4	4	1	1	1	1	4	2
Water, Deionized	1	1	1	1	1	2	2	1
1: Excellent 2:Good 3:Fair 4:Poor blank:Unknown.								

25.5. Fluid Volume Guidelines

Do not fill the entire sample chamber with liquid. This will cause electrical shorting between contacts, or worse (e.g. electrochemical corrosion of the instrument). The liquid cup can be operated successfully with liquid volumes in the range 150-300 μL. Based on experience and excluded volume calculations, a volume of 225 μL will completely fill the liquid cup with a tip engaged; however, capillary forces will also cause some liquid to wick up onto the probe holder glass and electrodes, so some user may find 300 μL more intuitive to work with.

25.6. EC Cell Assembly

This section provides additional detail for the following tasks:

- Installation of perfusion lines (for perfusion probe holder only)
- Installation of the EC AppMod PCB
- Connecting SMB cables for routing electrical signals from the sample chamber out of the Cypher enclosure to an external potentiostat
- Connecting a potentiostat
- The process of mounting electrodes, AFM probe, and sample (WE).

IMPORTANT: In order for the EC Cell to function properly, all of the electrical connections must be robust and correct, and the electrodes must contact the electrolyte solution.

25.6.1. Installing and Using Liquid Perfusion Lines (For Perfusion Probe Holder Only)

The process of installing and using the perfusion lines is fully analogous to the same procedure for the non-EC droplet imaging perfusion probe holder found in Section 21.1 on page 228. One subtle difference is that the distance between the perfusion line ports and probe are all much smaller for the EC probe holder, as can be seen in Figure 25.10 on page 282, but this does not affect the procedure.

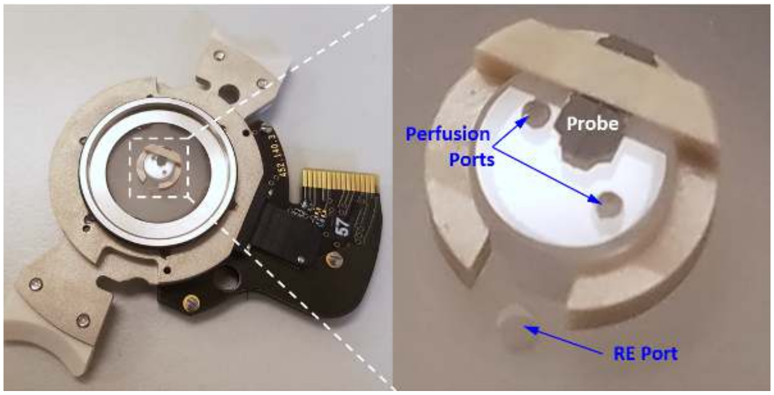


Figure 25.10.: Cypher ES EC Perfusion Probe holder. (Left) Full probe holder. (Right) Zoomed in view of the optical window showing clip, probe, and perfusion ports. Note the position of perfusion tube ports relative to the probe chip and RE port. For scale, the optical window is 5 mm in diameter.

25.6.2. Installing the EC AppMod PCB

The EC AppMod PCB, shown in Figure 25.9 on page 271, must be plugged into the top of the scanner in order to use the EC Cell in its designed configuration. In order to do this, first plug the the ribbon cable extending from the sample chamber into the socket on the PCB, and then with two fingers, press the circuit board into its corresponding sockets in the top of the scanner. Please refer to the same figure for visual cues. Note that the PCB may be left installed on the scanner without interfering with normal operation (e.g. if standard imaging techniques are desired without electrochemical control). It is also possible to use the EC Cell concurrently with the Heater or HeaterCooler stages that both plug into a different socket on the top of the scanner.

25.6.3. Connecting SMB and Potentiostat Cables

On the bottom right of the ES Scanner, there are three male SMB connections for use with the EC Cell that correspond to the working, reference, and counter electrodes. These receive female SMB connectors, as can be seen in Figure 25.7 on page 270, that connect to the bulkhead feedthrough (the astute user will note that there are four SMB leads in this figure, which belies the future intent to enable tip bias for techniques such as SECM and EC-STM). Then, the the potentiostat cable (Figure 25.8 on page 270) is connected to the male SMB leads on the outside of the bulkead feedthrough, with free ends now available for further electrical connections. The free ends may be clipped with alligator clips from the potentiostat, completing the connection between the potentiostat and the electrical contacts in the sample chamber. It is now important to ensure that these signal lines are properly routed from the scanner through the Cypher enclosure to the potentiostat.

One qualitative check for this is to color coordinate the leads and ensure that the same colors propagate from the potentiostat to the scanner, but we note that potentiostats vary a bit between brands as to how the electrical leads are labeled for working, reference, and counter electrodes. (For CH Instruments, the WE is green, RE is white, and CE is red, so we have chosen these as our standards.)

A multimeter set to resistance measurements should now be used to test electrical continuity of the system. If the leads are routed appropriately, the user should obtain resistances <10 ohm between the potentiostat alligator clips and the corresponding lead (WE and CE are magnetic pins inside the sample chamber, while the RE is the knurled knob affixed atop the EC AppMod PCB).

25.6.4. Mounting Electrodes and AFM Probe

Recall that the WE and CE are connected to the liquid cup and base plate, while the RE enters through the probe holder independently of the WE and CE. Through many trials, and as described in Section 25.2.2 on page 264, it has become clear that it is easiest to first install the RE on the probe holder, followed by mounting the CE to the liquid cup, followed by mounting the WE/sample to the liquid cup, followed by mounting the probe to the probe holder. This order of operations may be modified, but serves to:

- Minimize opportunities for inadvertent contamination of the sample via accidental contact with gloves, tweezers, etc., and
- Minimize the amount of time required to mount the sample, which may be of concern for certain time-sensitive experiments.
- Minimize risk of damaging or contaminating the probe

25.6.4.1. Mounting Reference Electrode (RE)

The RE enters through the top of the probe holder through a 1 mm diameter hole that accommodates a wide variety of reference electrode options. A wire of any diameter less than 1 mm may be inserted through the hole and optionally sealed in place with teflon tape or epoxy (depending on the permanence of a given experimental setup), as seen in Figure 25.11 on page 284. Additionally, a 1 mm OD, leak-free, PEEK-based, fritted Ag/AgCl (saturated KCl) reference electrode constructed by Innovative Instruments is compatible and shown in Figure 25.11 on page 284. It is stable in all experimental conditions that the EC Cell components withstand (see Section 25.4 on page 278 for chemical compatibility of PEEK). If the system requires full hermetic seal, the RE should be sealed into the RE port with epoxy or equivalent to prevent gas exchange.

25.6.4.2. Mounting Counter Electrode (CE)

The CE is mounted inside the liquid cup, as shown inFigure 25.5 on page 269, and can be either a ring electrode as provided (see Table 25.1 on page 273 or Table 25.1 on page 274) or simply a piece of wire of any type bent into

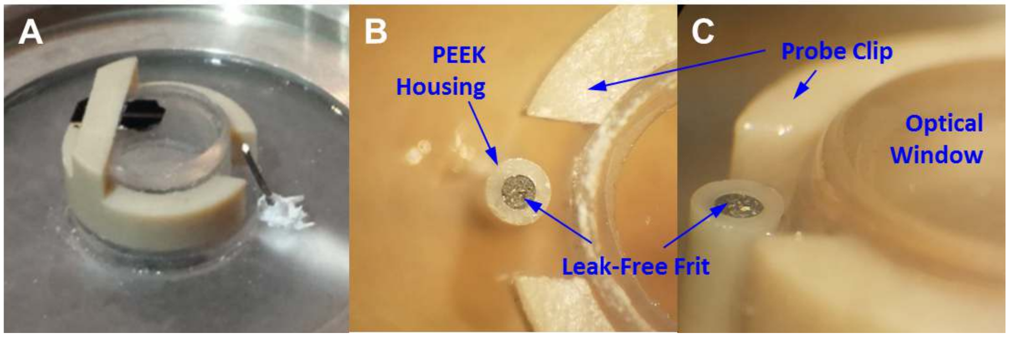


Figure 25.11.: (A) Probe holder with mounted probe showing an Ag RE wire sealed in place with teflon tape. (B) Top down view of 1 mm OD leak-Free PEEK fritted Ag/AgCl (sat. KCl) RE manufactured by Innovative Instruments inserted through RE port. (C) Zoomed side view of 1 mm OD leak-Free PEEK fritted Ag/AgCl (sat. KCl) RE manufactured by Innovative Instruments inserted through RE port.

an appropriate ring. The CE is fastened to the liquid cup with a lateral 00-90 screw (3/32" or shorter), to which a magnetic jumper wire is also fastened to provide electrical connection to the contact in the sample chamber. Care should be taken to ensure that the CE is as flush with the liquid cup surface as possible to avoid introduction of mechanical noise or errant electrical contact with other components.

25.6.4.3. Mounting Working Electrode (WE, sample)

As described in the order of operations in Section 25.2.2 on page 264, it is advised that the sample be mounted after the RE and CE in order to minimize the risk of accidental WE contamination or damage. The WE is mounted to the liquid cup with an O-ring seal, insulating shims (optional), and four screws. If possible, solder a jumper wire that extends laterally from your sample prior to mounting.

25.6.4.4. Mounting Probe

The probe is mounted by lightly raising the probe clip from the optical window using tweezers, sliding a probe under the strap of the probe clip, and pushing the clip back into its fully-seated position. Note that this holds the probe in place with spring friction force of the clip upon the glass tube, and there are no screws or fasteners involved. This requires very little force to accomplish.

25.6.5. Testing Electrical Connections

Similar to the description in Section 25.6.3 on page 283, the full electrical connections from potentiostat to mounted CE, WE, and RE should now be tested. The simplest way to do this is to attach sharp contacts to your multimeter and touch the CE, WE, or RE with one contact while simultaneously contacting the same connection at the potentiostat alligator clip. Continuous connections provide resistance of <10 ohm, while non-continuous connections provide overload resistance.

25.7. Sealing the EC Cell Sample Chamber for Environmental Control

The EC Cell probe holders are designed to function the same way as standard probe holders for the Cypher ES, and they should therefore be able to maintain an internal inert atmosphere inside the sample chamber without having to be inside a glovebox. This has proved to be of high utility for some customers desiring to conserve laboratory space.

One of the key spots that the sample chamber may allow diffusion of gas is through the RE port (see Figure 25.10 on page 282 and Figure 25.11 on page 284 for reference). This is a hole in the top glass of the EC probe holder, where the RE lead enters. Depending on the type of RE used, this hole will need to be sealed with something like epoxy surrounding the RE. Note that 5 minute epoxy is sufficient, and also compliant enough that it can be removed if the electrode needs to be replaced.

Another spot that the sample chamber may allow gas diffusion is through the gas tube and perfusion tube seals. The gas tube fittings may be seen in Figure 20.1 on page 225, and are the connections that seal into the sample chamber. The perfusion lines are installed into the Perfusion Probe holder, and that process is outlined in Section 25.6.1 on page 282; if these are not fully seated into the perfusion ports, gas may leak.

25.7.1. Outside of a Glovebox: Maintaining Strict Inert Gas Atmosphere

Once the above considerations have been accounted for, the procedure outlined in Chapter 23 on page 251may be followed in order to generate and maintain a temporary inert atmosphere for imaging of sensitive samples outside the glovebox. Additional comments are provided below It is worth mentioning that the probe holder O-ring for the EC Cell probe holder (see Table 25.1 on page 274) has different cross sectional dimension than other designs of the Cypher ES probe holders, making it easier to damage the O-ring if lots of force is applied. Care should be taken during the glovebox procedure to avoid such damage.

For experiments beyond ~1 hour, continuous flow of inert gas will likely be needed because the sample chamber depressurizes at < 1 mbar/min. The incoming gas can be provided an extremely low flow rate. One useful trick is to bubble the incoming gas through the same solvent as is used for the electrolyte solution so that the incoming gas stream is saturated with solvent and therefore won't slowly evaporate the electrolyte. The idea is that while the EC chamber remains sealed, the gas input line is purged on low flow of your inert gas (Ar, N2, etc.) for at least 15 min (sufficiently long to displace the volume many times over, depending on flow rate) by having the 3 way valve turned to allow gas flow to atmosphere (step 1). Then, without breaking the flow of gas, the valve is turned 90 degrees so the gas stream is redirected to the chamber (step 2) and the pressure regulating syringe is simultaneously removed (step 3). This outlet stream that now flows out where the syringe was will contain solvent vapor and should be directed to a fume hood if needed. This process is also discussed in Section 23.1.4 on page 256.

25.8. Cleaning and Storage

Components of the EC Cell are designed for chemical inertness and may therefore be cleaned with a variety of solvents of different composition and polarity. Please refer to Section 25.4.1 on page 279 for considerations of the proper solvent for your needs.

WARNING: The probe holder should never be fully immersed in solution, nor sonicated, due to its electrical contacts and external glue bonds. Instead, please use the probe holder cleaning cup as described in Table 25.1 on page 272.

25.9. Troubleshooting

25.9.1. General EC-AFM Considerations

25.9.1.1. Incorrect Electrical Connections

Poor electrical contacts between the elements of the EC Cell, the external potentiostat, and/or the controller may cause malfunctions. If a problem arises that may stem from the electrical wiring, electrodes, and connectors, please check all electrical connections (a multimeter set on resistance mode should show <10 ohms between connected elements). Connections may be found between:

- The controller and scanner
- The potentiostat and the bulkhead feedthrough on the Cypher enclosure
- The bulkhead feedthrough and the base of the scanner
- The scanner and the EC AppMod PCB
- The EC AppMod PCB and the sample chamber cable
- The EC AppMod PCB and the RE wire
- The Sample Chamber magnetic contacts and the jumper wires to the liquid cup
- The jumper wires and the sample (WE) or CE
- The electrolyte solution and the RE, WE, and CE

25.9.1.2. Chemical Reactivity of EC Cell Components

Please refer to 25.4 to verify that your experimental conditions are compatible with the EC Cell materials in use. For examples: very caustic chemicals such as HF or concentrated NaOH will slowly etch the quartz window of the probe holder, and concentrated H2SO4 is not compatible with the PEEK liquid cup and probe clip (so the PPS versions should be used). Generally, solutions in the range 1 < pH < 13 (i.e. 0.1 M strong acid to 0.1 M strong base) will not cause problems. Whenever possible, the concentrations of reactants in the electrolyte should be kept low, and special attention should be paid for concentrations above 0.2 M. For proprietary solutions (e.g. ionic liquids, deep eutectic solvents, etc.), for which it is less likely to find documentation of material reactivity, one may place a small drop of the solution on a part of the liquid cup outside of the liquid containment area and monitor for changes. **We also sell a chemical compatibility test kit (Asylum P/N 901.813)**. Please call Asylum Research if you are uncertain about the chemical compatibility of the EC Cell and your electrolyte, or would like to purchase.

25.9.1.3. Leaks in the EC Cell: Predicting and Identifying

Check that the O-ring is level and properly sealed against the sample surface and that the jumper wire is not pinched between the sample and the liquid cup. Verify that the sample has no cracks or divots that could let electrolyte flow out of the liquid cup. If these precautions fail to prevent leaks, please take into consideration the composition of your electrolyte: Low surface tension of the electrolyte will contribute to its ability to flow out, so eliminating surfactants (for example) from the solution will help. If such surfactants are essential, we recommend coating the O-ring with Dow Corning High Vacuum Grease, provided this is compatible with your solvent (refer to product information at www.dowcorning.com).

25.9.1.4. Colloidal Electrolyte Solutions (such as Bacterial Suspensions)

Colloidal components present in an electrolyte may diffuse and/or block either the reflected laser beam for measuring cantilever deflection or the blueDrive laser for driving cantilever oscillations. Colloidal particles can adhere to the cantilever, tip, optical window, liquid cup, sample (WE), or counter/reference electrodes, thus modifying the optical path, tip-sample interactions, effective concentrations, or electrochemical signals.

Even for electrolytes that are completely chemically compatible with the EC Cell, high concentrations of solute/analyte can promote surface crystallization on the cantilever, tip, optical window, liquid cup, sample (WE), or counter/reference electrodes and cause similar problems as above.

25.9.1.5. blueDrive Laser Electrolyte Absorption

The output wavelength of the blueDrive laser is 405 nm. If the electrolyte solution or solute has a strong absorption band at this wavelength, unwanted photoinduced reactions such as polymerization, crosslinking, lysis, oxidation, deposition, etc., may occur. It is recommended that an absorbance spectrum of the electrolyte solution be obtained prior to use in the EC Cell, as this aids in troubleshooting photoinduced effects.

25.9.2. EC-Specific Considerations

25.9.2.1. Unexpected or Transient Peaks in Electrochemical Signals

Trace contaminants adhered to the EC Cell components or mixed into the electrolyte solution may be one predominant contributor to errant signals in electrochemical experiments due to their chemical or surface interactions. The cleanliness of not just the liquid cup, but all electrodes, tubes, connectors, tweezers, etc., that contact the electrolyte during preparation will affect the purity of your electrolyte and resulting experimentally detected currents.

Additionally, external mechanical vibration (e.g. construction, music, slamming doors, etc) may cause anomalous signals during electrochemical measurements due to shaking of the sample (perturbs the electrochemical interface) or vibration of the electrical contacts (may cause intermittent breaks in electrical continuity—especially for magnetic contacts—or intermittent unwanted contact between the electrodes in the electrolyte).

For some experiments where material is electrochemically deposited on the sample/WE surface, and in particular if the deposit is conductive, an electrical pathway may be formed between the sample and the counter electrode, causing large transient spikes in the current and/or saturating the current signal. If cleanliness and mechanical vibration have been ruled out, it may be worth removing the probe holder and visually inspecting the liquid cup.

All electrodes should be making electrical contact with the electrolyte in the EC Cell (but not with each other). Sometimes the electrolyte volume will decrease over time due to evaporation from heat or current running through the solution, causing an electrode to lose contact with the solution. One technique for mitigating this is to add a small volume of the solvent to the Cypher ES sample chamber bellows to help saturate the atmosphere inside the sample chamber; if gas is being flowed through the sample chamber, a pre-stage where the gas is bubbled through the solvent will help saturate the gas entering the cell and slow the evaporation of the solution.

Check that the reference and/or counter electrodes have not been covered by solids, oxidized, or changed properties significantly during the electrochemical reaction. In the case of these occurrences, try cleaning or refurbishing or replacing these electrodes. Platinum is well cleaned in an oxygen-free hydrogen flame, or by dipping in Piranha solution (3:1 H2SO4:H2O2) until clean. Storing Pt in a 10% HNO3 solution keeps it contaminant free. Ag/AgCl reference electrodes can often be refurbished by replacing the internal electrolyte (saturated KCl) as well as replacing the AgCl wire with a fresh wire (Ag wire in chlorine bleach or biased in KCl may do the trick); the frit can often be refurbished by heating to 80 °C in dilute H2O2 to remove organic contaminants from its porous microstructure.

25.9.2.2. Electrochemical Topography not Imaged with Probe

Sometimes the electrochemical experiment will indicate that reductive deposition, oxidative stripping, or otherwise redox-mediated conformational changes are occurring on the electrode surface, and yet the probe does not detect these topographical changes where it is scanning. Some but not all of the effects that may contribute are:

- The reduced/oxidized species deposited on the surface are so loosely-bound that the lateral force of the tip sweeps them out of the scan area
- The reaction is occurring in a location on the sample away from the tip. This could occur due to a weak electrolyte (<0.1 M) creating a strong or non-uniform electric field, or if the counter electrode is mounted in an asymmetric position around the exposed area of the sample/WE. Another possibility is that the Probe Holder and/or probe and/or Probe Clip are shielding the diffusion of the electroactive species at the site of imaging, preventing the reaction from occurring there; this may be evaluated by raising the probe several microns from the surface, running the same electrochemical experiment (while also monitoring the surface with the optical microscope), and re-engaging the tip and imaging to observe if the surface changed.
- The signal detected electrochemically is not correlated to the sample/WE. The assembly should be checked for shorted connections and cleanliness.

26. Scanning Tunneling Microscopy

CHAPTER REV. 1777, DATED 06/19/2014, 11:17. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

26.1. Introduction

This chapter discusses the use of the STM tip holder with the Cypher ES Scanner. The chapter assumes that you are familiar with operating the Cypher ES using basic AFM scanning techniques.

26.2. Required Equipment

- Cypher ES
- Cypher ES STM tip holder
- Cypher ES stage equipped with a Gas Cell body

- STM probes - A box of Platinum Iridium STM probes is included in the accessories kit
- Appropriate STM sample - A HOPG sample is included in the accessories kit
- ES electrical sample pucks - Supplied in the accessories kit
- Conducting paint - Supplied in the accessories kit
- Voltmeter
- Tweezers

26.3. About the Cypher ES STM tip holder

The ES version of the STM tip holder is designed around the same concept as the ES AFM tip holders. The closed cell of the ES is sealed by Viton O-ring surrounding the edge of the holder. The tip holder tube is sealed to the glass window with epoxy. The tip tube is sealed at the top of the tube with RTV silicone glue.

Warning	The tip holder tube is sealed with a drop of RTV silicone glue at the top. Inserting probes more than .2” (5mm) into the tube will push the silicone glue “plug” out of the tube and cause a gas leak. The seal is repairable by the user and may be ignored if the user is not concerned about a sealed sample chamber.

The ES STM holder is currently designed as an air only holder. Although STM experiments are possible they have not been tried on this design. The main risk of scanning in liquids is a fluid leak through the top side of the tip holder tube due to capillary forces drawing fluid into the tube and causing a leak to the top of the holder. Liquid scanning requires that the bottom of the tip holder tube be sealed so that the inside of the tube is not contaminated causing poor electrical contact to the STM probe. Please contact Asylum Research if your experiment involves STM scanning in fluids.

Warning	The tip holder tube is sealed with a drop of RTV silicone glue at the top. Inserting probes more than .2” (5mm) into the tube will push the silicone glue “plug” out of the tube and cause a leak.

The tip tube is connected to a current to voltage converting preamplifier built into the tip holder body assembly. Currently, the sensitivity of the amplifier is 1nA/V meaning that 1nA of current flow into the tip generates 1v of output signal from the amplifier circuit. The total detectable current range is 10nA where the absolute current is 10nA and the sign of the flow is determined by the polarity of the bias voltage applied.

Warning	The electrical connection between the tip tube and the preamp circuit is made using small gauge magnet wire. The wire is delicate and if broken, is difficult to repair. Please be careful when using sharp tools or other objects around the top of the STM holder near the tip wire.

Due to the inherent design of the Cypher’s video system which is optimized for AFM use, some of the features are not possible to perform as an STM so they have been deactivated. Please see the section on using the video system for detailed information. The engage sequence is primarily affected where the tip and sample focus cannot be determined. The tip must be lowered to the surface by eye and then the engage routine is initiated.

26.4. Using the Video system

The video system on the Cypher ES equipped with an STM holder is different from AFM.

- The “Set” button for saving the tip focus location has been deactivated. The view of the tip is from the top down so it is not possible to see the actual end of the tip.
- The “Set” button for saving the Sample Focus position has been deactivated in software. It is possible to move the focusing objective to view the sample surface prior to engaging as long as the tip length is less than 3mm from the bottom side of the glass window.
- The “Move to Preengage” button has been deactivated. Since the Tip and Sample locations cannot be stored, it is not possible to quickly move to a close distance prior to engage.

26.5. ES Cell electrical connections

The sample bias in the STM is generated by the system and located on the front magnet inside the gas cell body by way of an interconnect cable.

See section 18.1.2 Gas cell body for details.19.1.2

26.6. Preparing an STM sample

An STM sample must be electrically conductive between the sample puck and the top surface to be scanned. The sample may first be fixed to en ES electrical sample puck with a drop of 5 minute epoxy. Silver paint is used to create an electrical connection from the puck to the sample surface. Bias voltage is made to the sample by way of a wire lead magnetically attached to the front most magnet in the gas cell body.

See Gas cell body, Applying a sample bias for details.19.1.2.4

1. Mount your sample to an ES electrical sample puck.
2. Use silver paint to connect the sample puck to the top side of the sample.
3. Install the sample into the ES fitted with a Gas cell body. Make sure that the gas cell cable is installed.
4. Use tweezers to connect the bias lead from the sample puck to the front magnet in the gas cell body.

26.7. Loading and preparing an STM tip to engage

26.7.1. Loading an STM tip

The tip holder tube is slightly curved and is designed to be used with STM tips made from straight wire. The reason for this is to reduce lateral drift in the system caused by stress in the tip wire if it is bent during installing. Inserting the tip wire into the curved tube allows the tip to be secured and also make good electrical connection without the stress of bending the wire.

1. Use tweezers to grab an STM probe from the probe box. Be sure not to touch the end of the probe with the tweezers otherwise the probe tip will be damaged.
2. Insert the probe into the tip tube.
3. Gently push the probe into the tube until you feel resistance.

4. Continue to push the probe into the tube until about 2mm of the probe wire is protruding from the tube.

Attention	The STM probes supplied in the acessory kit are cut to .2” (5mm). This is a suffecient length to allow the tip to extend about 2mm from the tip holder tube while being short enough to not extend out the top of the tube which will compromise the gas tight seal of the tip holder.

26.7.2. Preparing the STM to engage

The optics in the view module was intended for use with an AFM cantilever. Due to the tip position pointing down below the STM probe wire, it is necessary to bypass the normal AFM alignment process and simply bring the tip down manually close to the surface and then click the *Engage* button.

1. Use the coarse adjust wheel on the front of the Cypher to raise the cell high enough to allow the STM probe to clear the sample surface.
2. Install the STM tip holder onto the ES and secure it in place with the two locking screws.
3. Use the wheel on the enclosure to move the tip to the sample. Get the tip to the desired engage distance of about 0.5 to 1 mm above the sample. Use the tip and the reflection of the tip in the sample surface as a guide to bring the probe close.

26.8. Zeroing electrical offsets in the system

Due to multiple circuits in the signal path, it is necessary to adjust the zero points of the system for both the STM current amplifier and the sample bias. Each Cypher system is different and should be characterized as part of the initial system setup. Once the offsets are known, the offset values typically do not change over time so this is a one time adjustment to your system.

Hint	The software will save the offsets in the experiment but not carry them over if a new experiement is started. You might want to record the current and sample bias offsets once they have been determined.

26.8.1. Zeroing the STM current amplifier

Zeroing the current amplifier signal is mainly necessary to normalize the current signal to 0A for the feedback signal during scanning. Zeroing the offset does not modify the electrical offset present in the Current signal path.

1. Install the ES STM tip holder into the scanner. It is not necessary to install an STM probe.
2. If the system does not automatically detect the holder type, use Mode Master to select STM operation or select STM mode in the Main tab of the Master Controls panel.
3. Monitor the current signal in the Sum and Deflection meter panel.
4. Note the value being displayed in the Current signal.
5. Enter the value only with the opposite sign into the ’Current Offset’ menu item on the Main tab of the Master Controls window.
6. You may also use the “zero” button next to the current offset menu item in the DoIV control panel.

Once the offset is entered, you should see that the Current signal has changed to 0A in the Sum and Deflection window.

Note A typical offset current is around +/- 200pA

26.8.2. Zeroing the Sample Bias voltage

Zeroing the sample bias ensures that the voltage you are applying matches the voltage in the sample bias menu item. The S bias offset adjustment is added to the Sample Bias menu item so the electronics is actually adjusted.

1. Install the ES STM holder into the scanner and allow the software to detect it. The operating mode should change to STM mode but if doesn't, use the mode master buttons to select STM or change the mode to STM in the Main tab in the Master Controls window.
2. Once the software is set to STM mode, remove the ES STM holder.
3. Set the Sample Bias to 0V in the Main tab of the Master Controls window.
4. Set the S bias Offset to 0V.
5. Use a voltmeter to measure the sample bias located on the front most magnet inside the gas cell body. Use the gold ground shell of one of the three SMB connectors on the front of the ES as the ground reference for the voltmeter.
6. Enter the voltage measured on the meter with the opposite sign into the S. Bias Offset menu item.
7. Remeasure the bias voltage on the magnet. It should now be 0v.
8. Enter a voltage in the Sample Bias menu item and confirm that the correct voltage appears on the magnet.

Note A typical offset voltage is around +/- 50mv

26.9. Basic scanning parameters

26.9.1. Atomic scale scanning on HOPG

The following parameters are used as a starting values to get atomic resolution imaging using the supplied HOPG sample and the supplied PtIr STM probes.

- Scan size 10nm
- Scan rate 20Hz
- Resolution 512 line x 512 pixels
- Integral gain .5 to 1
- Setpoint current 1nA
- Sample bias 20-50mv
- Feedback bandwidth 2-5KHz
- Scan mode Hybrid. This parameter may be hidden in the main scan controls tab. Click on the setup button to expand the tab to see all the settings.

1. Cleave the surface of the HOPG sample by using a strip of adhesive tape. Stick the tape to the the surface and pull it off. A thin layer of graphite will peel off the surface and reveal a clean sample. Often times the layers of the graphite tear and leave small flaps of material pointing up. Try another cleave and possibly adjust the direction you peel the tape to create a smooth surface.
2. Install the sample and connect the bias lead to the front magnet the cell body. Don't forget the interconnect cable from the cell to the scanner.
3. Install a probe and lower the tip to the surface.
4. Set the initial scan parameters and engage the tip.
5. Begin scanning.

Once the tip is engaged and scanning, pay attention to the current signal in the sum and deflection meter panel. It should match the setpoint current and be stable. Also monitor the current signal. initially the lattice may appear distorted due to the system settling. The settling time may be immediate or take several minutes. Typically from 5-30 minutes.

If the current signal appears to be noisy or low quality, don't give up. The tip may be passing through a bad location on the sample. The tip may also be alternately tunneling from several places as the actual end of the probe cannot be that well defined. One trick we use is to "clean up" the tip by abruptly crashing it into the surface. To do this, gently give a sharp tap on the view module with a small tool like your tweezers. The mechanical disruption to the system often knocks off neighboring tips on the end of the probe and make them less likely to be in the tunneling distance to the surface.

Adjusting the integral gain helps increase the tracking of the height signal while also showing good resolution in the current signal. Raising the the gain too high will reduce the current signal which is normal but may end up causing the feedback loop to oscillate which may blunt the tip.

Depending on the quality of the current signal, you may want to adjust the feedback bandwidth to filter out higher frequencies or increase it for better tracking.

26.9.2. Larger scan sizes on HOPG

The same scanning parameters are typically used to scan the HOPG sample at a larger scan area like 1-5um with the exception of the scan rate.

- Scan rates for larger scan sizes are typically .5 to 2Hz. The tip velocity increases with scan size so you need to allow time for the feedback loop to track the sample surface.
- For optomiozing the image, try increasing the integral gain and/or then the bias voltage. Raising the gain will increase the feedback adjustment rate to the Z piezo while increasing the bias voltage makes the tunneling current easier to achieve although spatial resolution may be reduced. The effect will be negligible.

26.10. STM Probes

The Cypher ES STM kit is supplied with 20 mechanically formed (i.e. carefully clipped with super sharp wire cutters) probes. Additional probes can be purchased from Asylum Research. If you wish to make your own probes the material and dimensions for making the supplied probes are:

Material: 80%/20% Platinum Iridium. Wire should be drawn straight. Wire cut from a roll has a small radius and may not hold tightly into the tube on the STM holder. The tube is bent with a large radius. This is intentional to help reduce drift due to the stress of bending the probe wire upon insertion into the holder.

Wire size: 0.01" diameter (0.25mm) , cut approximately .2" (5mm) long.

Contact Asylum Research about further tools and techniques required to make the proper cuts.

Attention	Longer probes can be used but may introduce image distortion from drift due to the length.

Attention	The approximate range of the camera focus is about 3mm below the underside of the tip holder tube. Tips that extend below 3mm will not allow the sample to be viewed.

26.11. STM holder Testing and Maintenance

26.11.1. Testing

26.11.1.1. Using the test resistor

A 500M Ω resistor is supplied in the STM accessories kit. The resistor is soldered to a short length of wire terminated by some Pt Ir probe wire. The other end of the resistor is soldered to a magnet which allow connection to the sample bias terminal in the gas cell body.

1.

To use the test resistor

a) Insert the platinum wire into the tip tube.

b) Connect the magnet on the test resistor to the front magnet in the gas cell body.

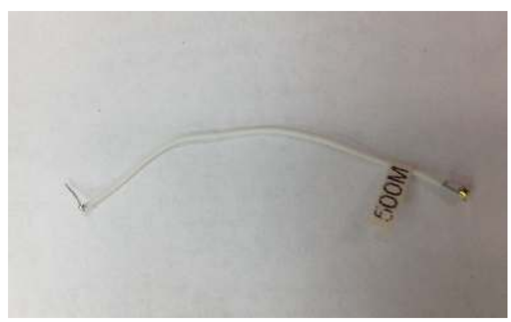
c) Install the STM tip holder into the ES while making sure not to pinch the test resistor lead in between the cell body and the O ring on the STM tip holder.

d) The software should detect the STM holder and change the operating mode to STM. If this does not happen then use Mode Master to change to STM or change the operating mode to STM in the main tab of the Master control window.

e) Set the surface bias to 1V

f) Note the measured current on the Sum and Deflection meter display window. It should be 2nA (1/500e6 Ω)

Note You can also use the DoIV controls to ramp the bias voltage and observe the current relationship of 2nA per 1V applied bias.



26.11.1.2. Testing the STM preamp noise level

1. Install the ES STM holder into the scanner.

2. Push the scanner into the chassis and close the enclosure door to shield the scanner from stray electrical interference.
3. In the upper command bar, select Programming ->Load test procedures. The word “testing” will be added to the command bar and the test controls window will appear.
4. Click on the Noise tab.
5. Current is not typically a choice in the noise panel so type the word ’current’ into the source field in channel 1. The software will automatically add the current channel as a data choice.
6. Set the Resolution to 1Hz
7. Set the filter cutoff to 1KHz
8. Go to programming->Filter panel and deselect the ’1 pole’ filter in the feedback channel.
9. Click on the Start button to start recording the STM current noise.
10. The typical noise should be ~1mV (~1pA) Adev from 1hz-1kHz with little perceivable periodic noise in the spectrum.

Hint	You can change the units of the noise measurement by selecting Custom in the Sensitivity display item. Enter “A” for the units and 1e-9 for the scale. The sensitivity should change to 1nA/V.

26.11.2. Maintenance

26.11.2.1. Cleaning the STM tip tube

Normal operation does not require that the tip tube be cleaned. If for some reason debris has gotten into the tip tube, the ES STM accessories kit is supplied with a length of 0.01” diameter tungsten wire. The wire is very stiff and will allow you to push the wire through the tube to force out the obstruction through the top of the tube.

Warning	Be aware that the top end of the tube is sealed with a small drop of silicone glue so this seal will also be removed.

Warning	Be very careful of the tip wire soldered to the top of the tip tube. It is very fragile and can break if hit. Please observe caution when handling sharp tools or objects around the top of the STM holder assembly.

26.11.2.2. Sealing the tip tube

The tip tube is sealed with a small drop of silicone glue. If for some reason you wish to reseal the tube, use RTV silicone glue that is thick enough not to flow into the tube. In particular, we use Dow Corning 3545 RTV silicone glue.

1.

To seal the tip tube

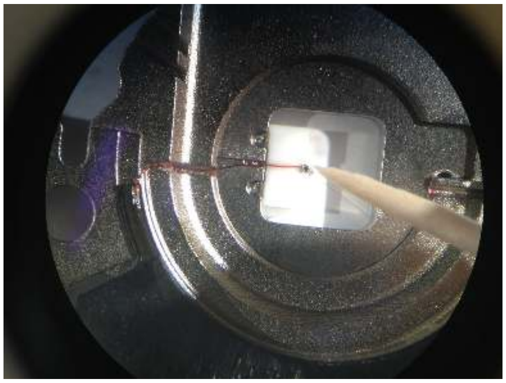
a) View the top of the ES stm tip holder under an optical microscope.

b) Collect a small amount of glue onto the end of a wire or small tool such as the point of a broken wooden cotton swab.

c) Touch the glue to the top of the tube and deposit a small amount on the tube.

d) Allow glue to dry.

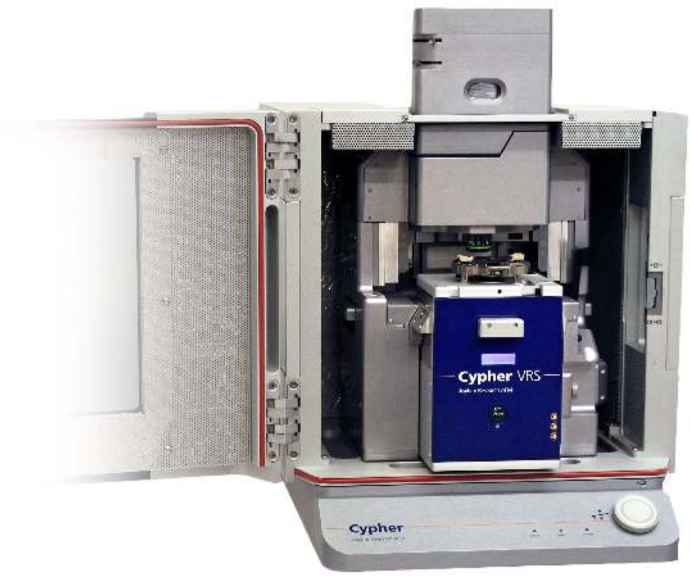
Warning Be very careful of the tip wire soldered to the top of the tip tube. It is very fragile and can break if hit. Please observe caution when handling sharp tools or objects around the top of the STM holder assembly.



26.11.2.3. Replacing the bias lead on the electrical sample pucks

The wire lead on the electrical pucks can fatigue and break during use. The ES STM tip holder accessory kit is supplied with 6 replacement puck bias leads. Additional replacement wires can be purchased from Asylum.

1. Use a screw driver to loosen the screw on the puck.
2. Remove the small 1/2 washer from the broken lead that may be trapped under the head of the screw.
3. Slip the new lead under the screw.
4. Gently tighten the screw to capture the new lead. It is not necessary to tighten the screw very tight. Light pressure is all that’s necessary.



Part IV

Video Rate Scanner (VRS)

Who is this part for? After the Cypher VRS AFM has been installed in your lab and you (or someone in your facility) have completed the initial training, this part of the user guide will be the principal reference for operating the instrument. Although written with the novice user in mind, experienced SPM users should complete the basic imaging tutorial at least once before attempting to use this instrument.

Part Contents

27. Cypher VRS Overview

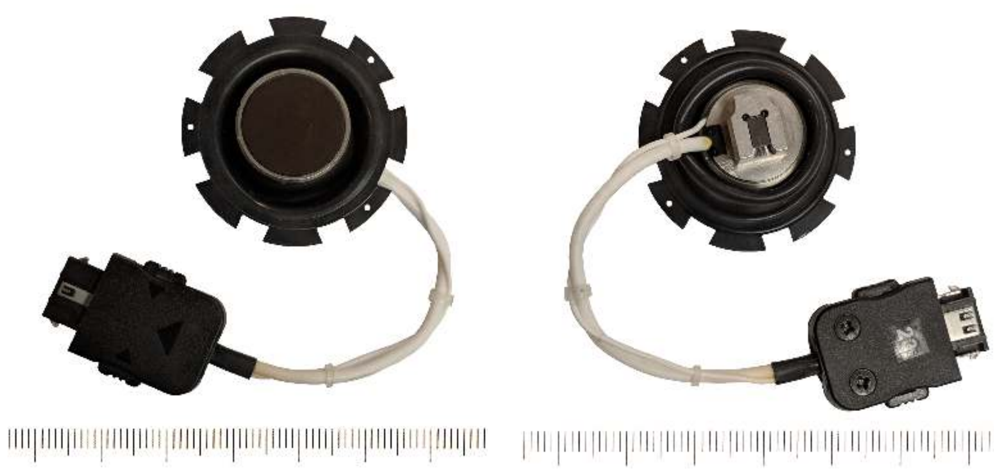
CHAPTER REV. 2030, DATED 07/26/2018, 13:29. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

27.1. Cypher VRS AFM

Cypher VRS is the third AFM in the Cypher family, where VRS stands for “video rate scanner.” It is based on platform of the Environmental Scanner (ES) where the sample is placed in a sealed cell. Cypher VRS allows for maximum scan rate of 625 lines per second in tapping and contact modes. Cypher VRS has a dedicated VRS sample stage as well as updated electronics in the: Backpack, Controller, and Scanner. Cypher VRS is compatible with all of the existing ES sample stages, therefore allowing imaging in all the modes already available with the Cypher ES.

27.1.1. VRS Hardware



(a) Top Surface **(b)** Bottom View

Figure 27.1.: VRS Stage

VRS Sample Stage The VRS sample stage is different from all existing ES sample stages in that it contains an additional Z-actuator. The Z-actuator is in the center of the VRS stage and has ~2 µm z-range and is not sensored. It is located underneath a 15 mm diameter sapphire disk (black shiny surface visible to the user). There is a high voltage wire that connects the sample stage to the Scanner though the VRS application module connector on top-right of the Scanner.

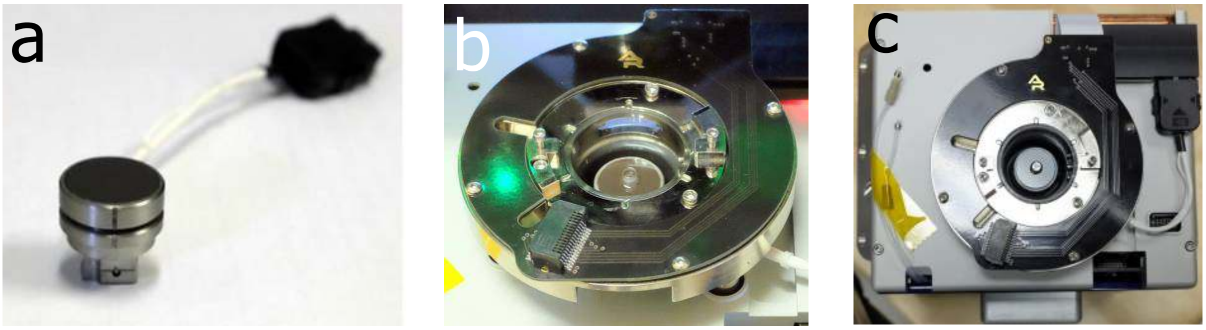
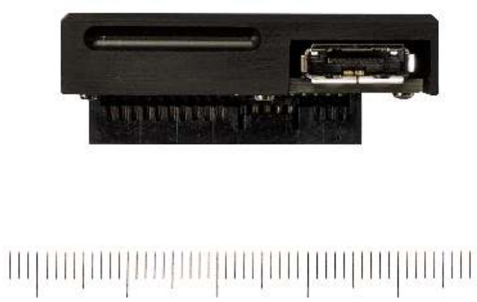
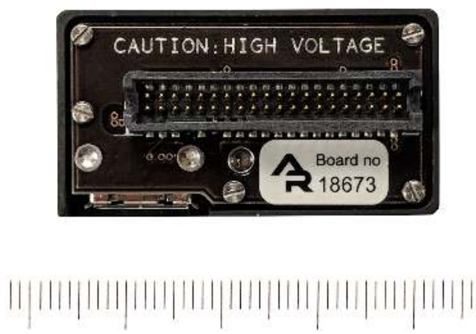


Figure 27.2.: VRS sample stage a) by itself, b) mounted in the cell, c) top view of the VRS scanner with the VRS stage plugged into the high voltage connector located on the top right side of the scanner



(a) Front Connector

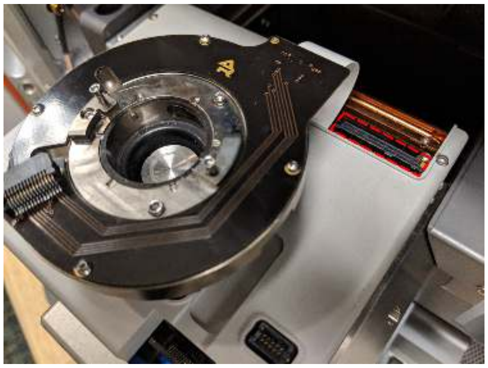


(b) Bottom Connector

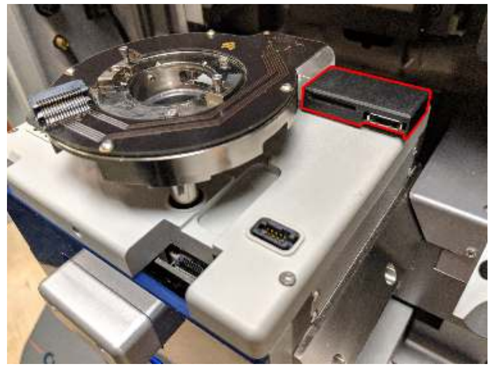
Figure 27.3.: VRS Application Module

VRS Application Module For VRS use, a connector called the "VRS application module" must be installed into the port at the top-right side of the VRS Scanner (as seen in 27.4). This serves at the connection point for the high voltage VRS stage connector. Typically this module is always left attached, however it is required to be removed or reattached, the ARC2 controller **MUST** be powered **OFF** when doing so.

VRS Perfusion Cantilever Holder For VRS use, the Standard Gas and Liquid cantilever holders can be used just the same as for Cypher ES. However, specifically for liquid perfusion experiments, a new VRS Perfusion cantilever holder was developed to accommodate the reduced sample size requirement. The same tubing as for a Standard ES Perfusion cantilever holder can be used with this holder.



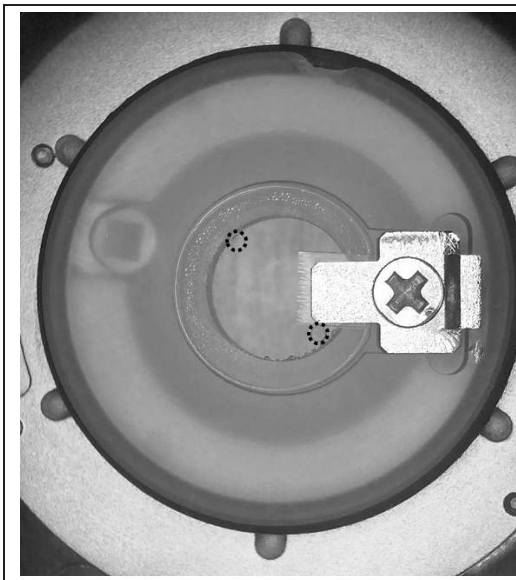
(a) Empty Top-Right Port

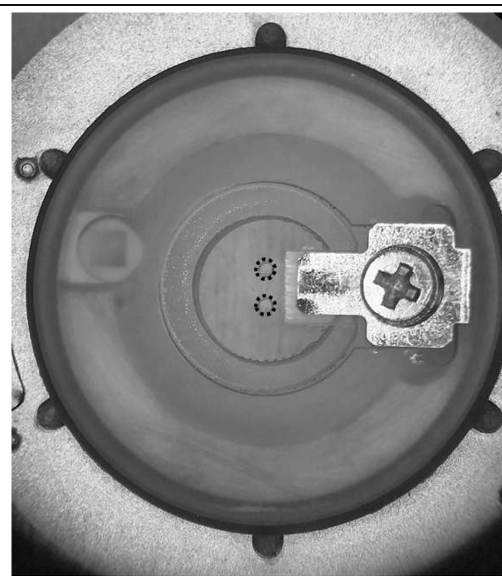


(b) VRS Application Module Attached

Figure 27.4.: VRS Application Module Installation

1.





ES perfusion holder (left)

- The image shows the location of the inlet and outlet holes on the perfusion holder. The distance separating the holes is optimized for a 15 mm diameter sample.

VRS perfusion holder (right)

- The inlet and outlet holes are very close to each other to accommodate the smaller 3 mm diameter sample size.

27.1.2. VRS Software

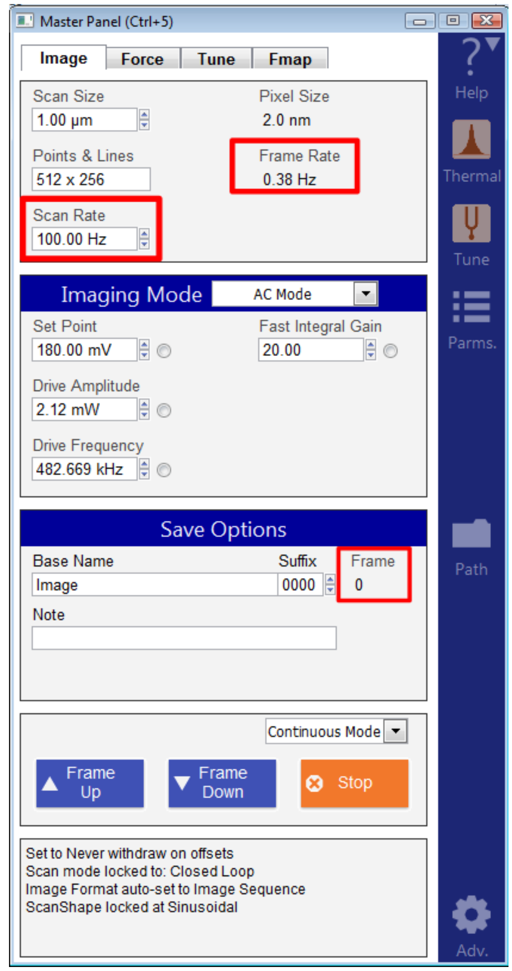
Cypher VRS can only be used with software version 16. The reason is that the imaging data is acqurired in a new format, Asylum Research Image Sequence with the file extension ARIS. Each ARIS is a file composed of x number of frames.

There are several new parameters that have been added to the already existing panels.

1.

Master Panel, Image tab

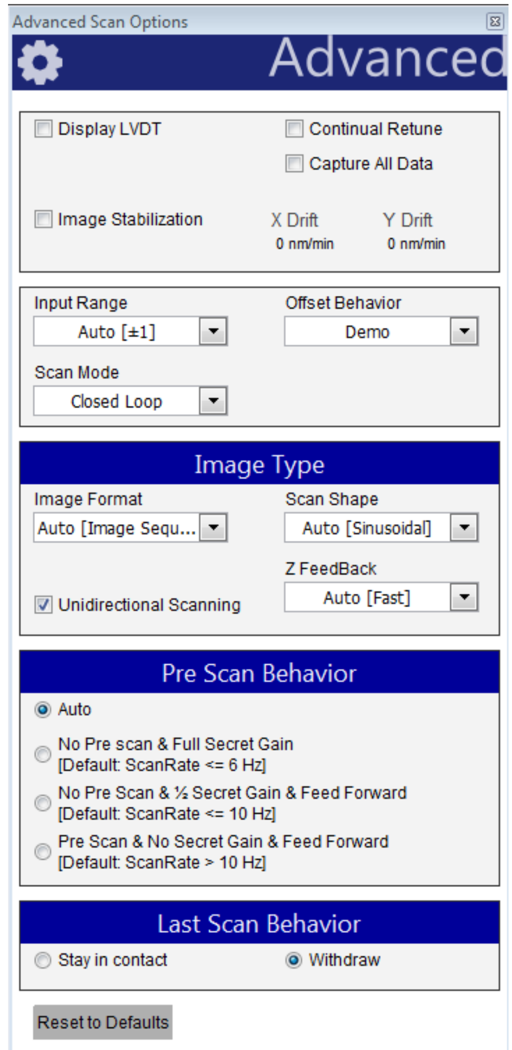
- Scan Rate
  - indicates how many lines are scanned per second
- Frame Rate
  - indicates how many frames are acquired per second
  - Frame Rate = Scan Rate/ [number of lines in the image + # Return + # Skip lines]
    * Frame Rate = 100 Hz/[256 + 6 +2] = 0.38 Hz
- Frame
  - indicates the number of frames in an individual ARIS file



2.

Adavnced Scan Options Panel

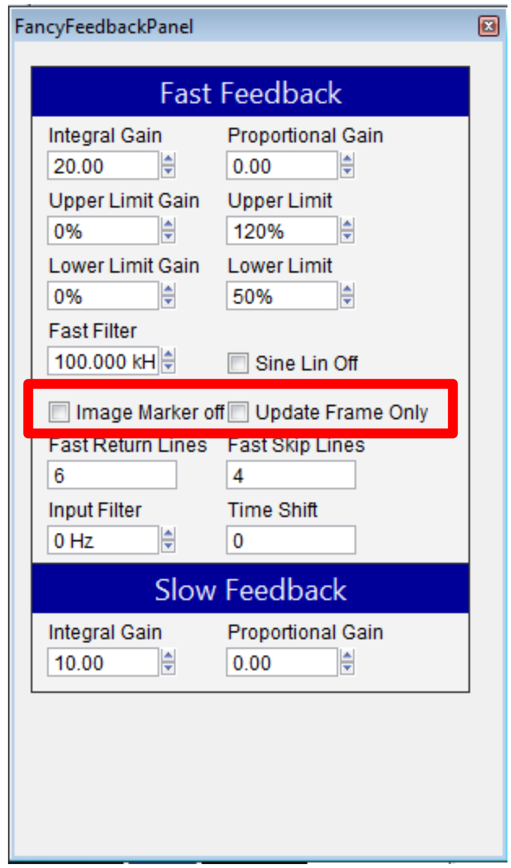
- Image Format
  - when the VRS sample stage is plugged in, the images are acquired as image sequence (instead of ibw files)
- Scan Shape
  - can be sinusoidal or triangular
  - sinusoidal scan shape is automatically set at scan rates of 101 Hz and higher
- Z Feedback
  - feedback can be set to Fast or Standard
  - at scan rates of 101 Hz and higher, it is automatically set to Fast
- Unidirectional Scanning
  - images are acquired line by line in one direction only (top to bottom or bottom to top)
  - Fast Return Lines in the Fancy Feedback panel indicate how many lines are used to move from the end of an image to the beginning of the next one
  - when the scan shape is set to sinusoidal, scanning is automatically set to unidirectional



3.

Fancy Feedback Panel

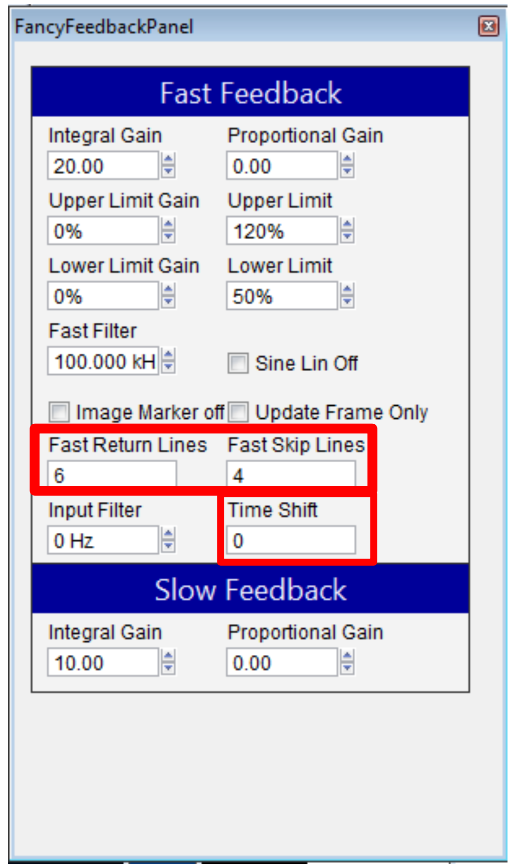
- There are several parameters that are not active for now, however the ones that can be set are:
- Image Marker Off
  - during imaging, the red marker on the left side of the image shows the location of the trace and retrace that appears in the scope
  - when scanning fast, the marker can be distracting so check the box “turn marker off” to hide it
- Update Frame Only
  - instead of updating the image line by line, it can be updated every frame
  - this setting is set automatically when the scan rate reaches 101 Hz



4.

Fancy Feedback Panel

- Fast Return Lines
  - during unidirectional scanning, once an image is acquied, we need to move to the beginning of the next image
  - Fast Return lines is the number of lines that are used to do that movement
- Fast skip lines
  - number of lines that are skipped (are not shown) in the image
- Time shift
  - it is a scanner specific value in milliseconds
  - when left at 0, a lag between trace and retarce may be visible in the scope (it is scanner dependant)
  - this value is calculated and put into the software automatically, however it can be asjusted by the user



28. Sample Preparation

CHAPTER REV. 2041, DATED 08/31/2018, 11:04. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

28.1. Imaging in Liquid

The Z-actuator inside the VRS stage is located in the middle of the sample stage and as a result of that, the sample must be placed directly on top of it. Additionally, when working in liquid, the sample needs to be mounted some distance away from the surface of the VRS stage to prevent the excitment of resonances in the cantilever chip when the sample is moving fast in z direction. For this reason, we use a sapphire rod onto which we secure the sample to. The sample should be immobilized on the sapphire rod using epoxy glue (ex: 5 Minute epoxy in DevTube No. 14250 from Devcon). It is also important to image the very edge of the sample (not the middle) for the same reason.

Mica, HOPG or coverslips should be mounted on pilars with inert glue such as Epon.

28.2. Imaging in Air

When performing VRS experiments in air, there are no major restrictions on sample size or shape compared to conventioal scanning. The sample can mounted to a puck, however it must still be fixed directly on the stage using wax (ex: SS-66 Red sticky wax from Universal Photonics) or epoxy.

29. Cypher VRS Tutorial

CHAPTER REV. 2041, DATED 08/31/2018, 11:04. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

This tutorial will guide the user though the steps necessary to image DNA on mica in buffer environment.

Prior to starting the tutorial please read the Environmental Scanner section of the manual Part III on page 160.

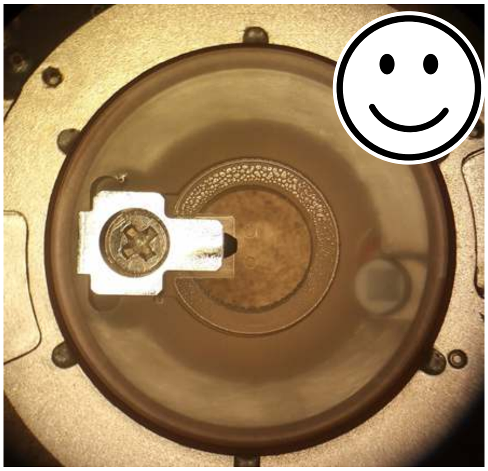
29.1. Loading the Cantilever

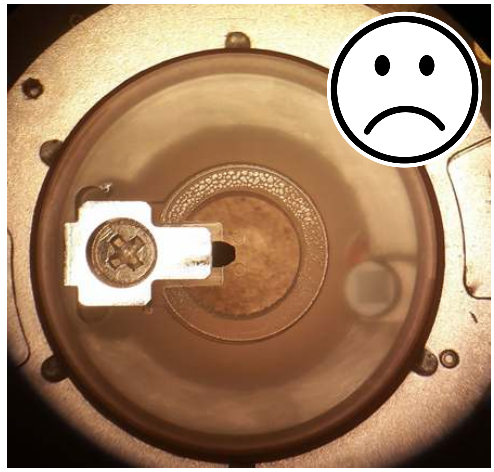
The cantilever chip is held in place by a metal clamp. Step by step instructions can be found in section Section 17.2 on page 179.

1. **Mount a cantilever**

- Use the Liquid Cantilever holder
- Choose a short probe, AC10DS works well for this experiment
- Place the cantilever chip all the way in under the clamp
- Tighten the clamp and check that the chip is well held in the holder

2.





Check tip position

- Appropriate cantilever probe placement is shown on the left side.
- On the right side image, the probe is pulled out too far.

29.2. Mounting Mica Posts on the VRS stage

1.

Glue the mica pillar to the VRS stage

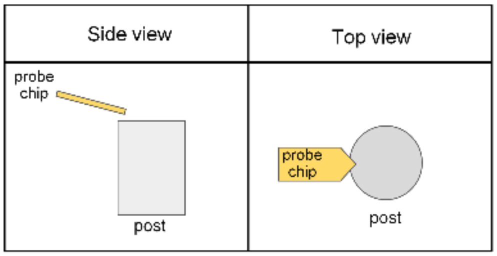
- Prepare 5-minute epoxy glue by mixing the two components vigourously for at least 1 min
- Dip the bottom of the mica pilar in the glue so that the bottom of it is covered in glue
- Place the pilar in the middle of the VRS sample stage

Warning	It is crucial for the probe to be aligned at the very edge of mica post!

1.

Align the Post with the Cantilever

- RAISE THE COARSE ENGAGE STAGE by turning the Engage Control knob clockwise
- Carefully place the cantilever holder mounted with a cantilever on the scanner while checking that the cantilever does not crush into the pilar
- Look through the top of the cantilever holder to check the alignment of the cantilever relative to the pilar
- Take the cantilever holder off, realign the pilar, place the holder back on the scanenr and check for alignment
- Repeat until the cantilever is right at the edge of the mica
- IF THE PROBE CHIP IS NOT AT THE VERY EDGE OF THE MICA PILLAR YOU WILL NOT BE ABLE TO IMAGE FAST
- Let the epoxy solidify completly (~20 min)



29.3. Sample preparation

1.

DNA deposition on the mica

- Cleave a layer of mica with adhesive tape to expose fresh mica surface
- Place ~15 µL of 0.5 µg/ml DNA solution onto mica
  - use Tris buffer* to prepare the DNA solution, for rinsing and for imaging
    - 40 mM Tris, 100 mM $MgCl_2$, pH: 7.6, filtered with 0.2 µm syringe filter
- Let DNA incubate for 15 minutes
- Rinse the mica surface by adding and removing a total of ~200 µL of Tris buffer (use pipettor)

Note To prevent any contamination, keep the liquid on top of the mica so that it does not touch the sides of the glass pilar nor the VRS stage

29.4. Software setup

1.

The Mode Master window:

- The software should now be showing the Mode Master window.
- If not, click the Mode Master button at the bottom of the screen: C:/svn/rasy-svn/ConfigurationFiles/ModeMasterFigures/Version 15/ModeMasterBu

C:/svn/rasy-svn/ConfigurationFiles/ModeMasterFigures

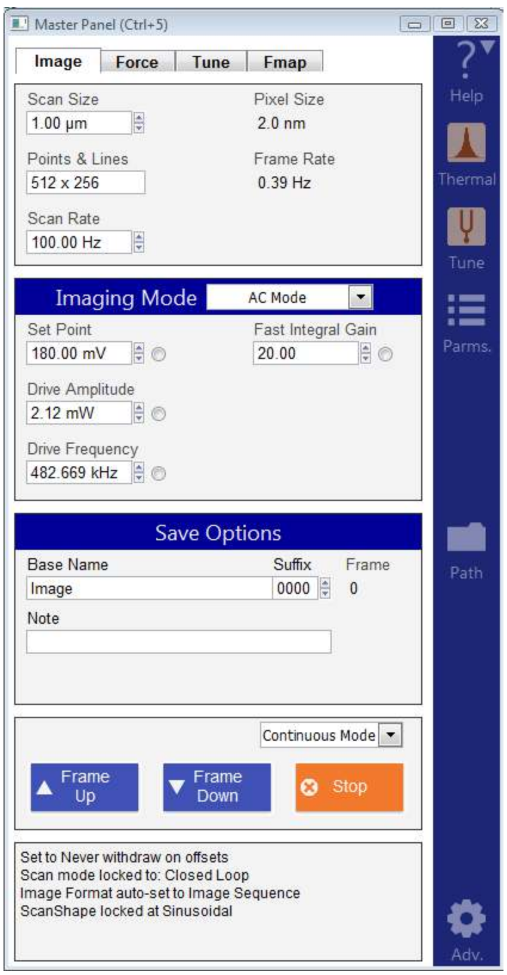
C:/svn/rasy-svn/Config ▷ [illegible]

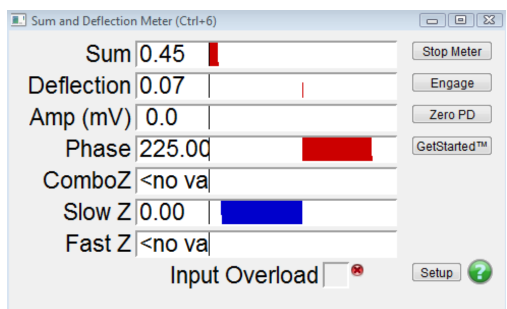
2.

Select Mode:

- Select *Cypher tab* ▷ *Video Rate AC Water*
- The screen will now re-arrange and present all the controls necessary for this type of AFM imaging.

3.



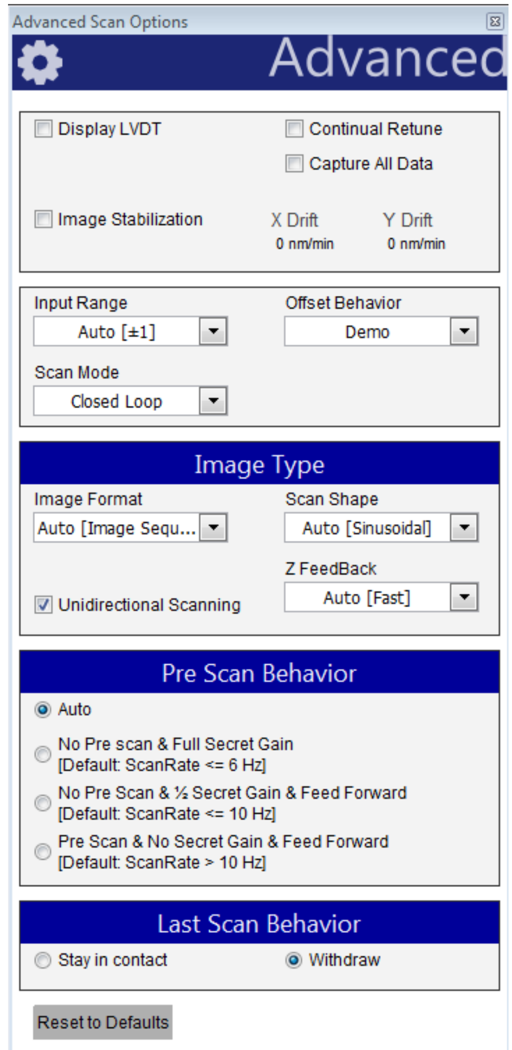


- In the Master Panel, set the Scan Rate to 100 Hz
- The Sum and Deflection meter will update and will show the voltage values for Fast Z and Combo Z

4.

Adavanced Scanning Options Panel

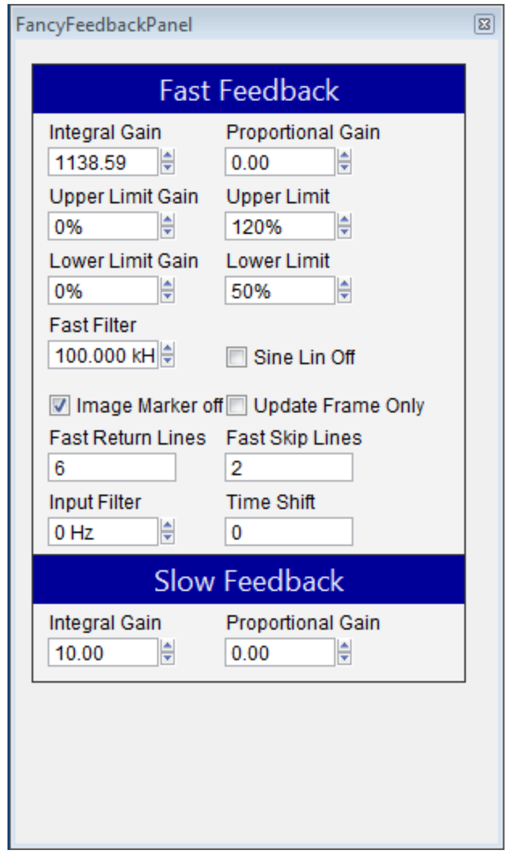
- Open this panel by clicking on the gear icon in the Master Panel, Image tab.
- Offset Behavior should be set to Demo
- Scan Mode should be set to Closed Loop
- Image Format should be set to Image Sequence
- Scan Shape should be set to Sinusoidal
- Z Feedback should be set to Fast
- Unidirectional Scanning checkbox should be checked



5.

Fancy Feedback Panel

- Open Fancy Feedback Panel from AFM Controls
- Set the Fast Return Line to 6
- Set the Fast Skip Lines to 2. (It is the number of lines skipped at the beggining of each image)
- Time Shift is scanner dependant and affects the overlay of trace and retrace. This value is calculated automatically but can be adjusted to improve the trace and retrace overlap.

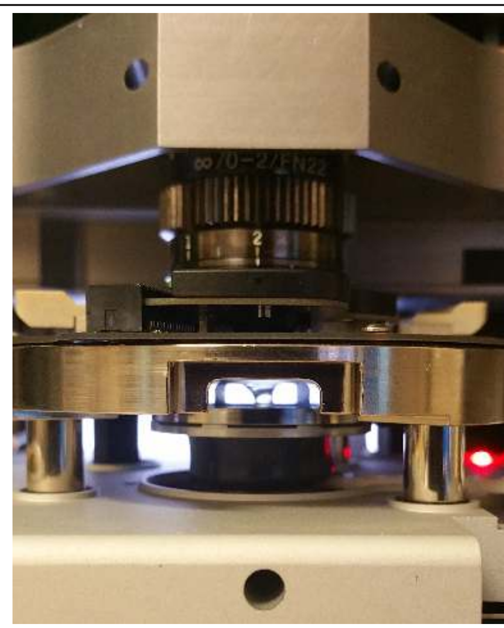


29.5. Align laser and tune

1.

Seal the imaging chamber

- Place a drop of buffer onto the probe that is mounted in the liquid cantilever holder
- RAISE THE COARSE ENGAGE STAGE so that you don't crush the cantilever when you mount the holder
- Carefully place the cantilever holder on the scanner
- Gently thighten the screws to seal the imaging chamber
- Look through the cell body window (see figure) and slowly motor up the stage until a meniscous forms between the cantilever and sample
- Set the correction collar on the objective to 2



2.

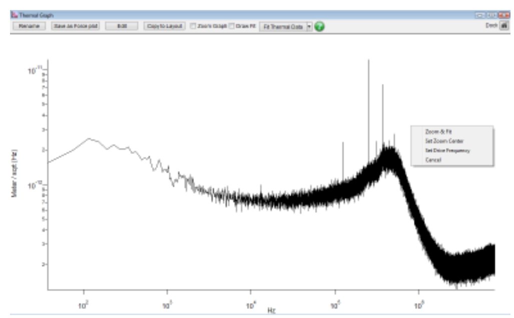
Align the red laser

- Use the controls of the Engage Panel to locate and bring the cantilever into focus
- Click on SET
- Place the cursor on the cantilever, right click and choose SpotOn
- The Sum should be around 3 V
- For smaller steps during alignment, hold shift key when pressing on laser controls in the Video window
  - AC10DS cantilever is 10 um long and might be difficult to locate for the first time

3.

Capture a Thermal

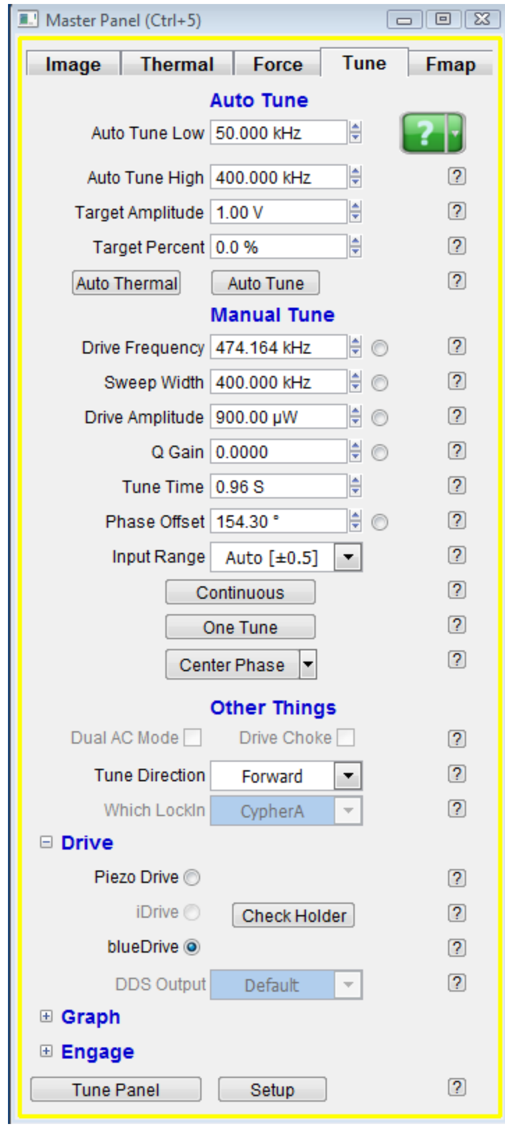
- In the Master Panel, choose Thermal icon
- Click on Capture Thermal Data
- Acquire ~250 samples
- Click on Stop Capture Data
- In the Thermal Graph, place the cursor over the resonance peak
- Right click and choose Set Drive Freqeuncy
  - For AC10DS cantilever, the frequency should be around 500 kHz in liquid



4.

Turn ON and align blueDrive

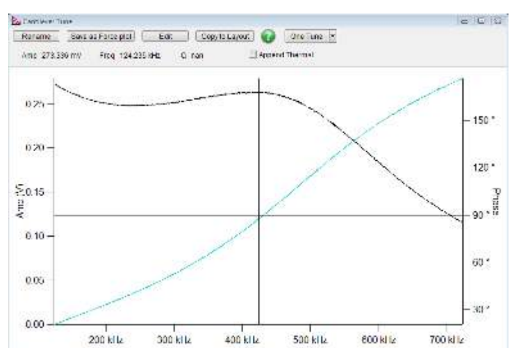
- For this experiment and AC10DS probe, place the 0.1x filter cube on the blueDrive unit
- In the Master Panel, choose the Tune tab
- In the Drive section of the Tune tab, choose blueDrive
  - The unit of Drive Amplitude should now be Watts
- Controls for blueDrive alignment will be visible in the top right corner of the Video window
- Place the cursor on the cantilever, right click and choose Blue SpotON to align the blue laser on the cantilever
- Move the blue laser around the base of the cantilever to maximize Amp value visible in the Sum and Deflection Meter



5.

Tune the Cantilever

- In Master Panel, choose Tune icon
- Drive Frequency should be set to 500 kHz (from Thermal Data)
- Set Sweep Width to 400 kHz
- Click One tune
- Tune Graph should show a clean broad peak at ~500 kHz
- Adjust Drive Amplitude until Amp on the Sum and Deflection Meter indicates 250 mV

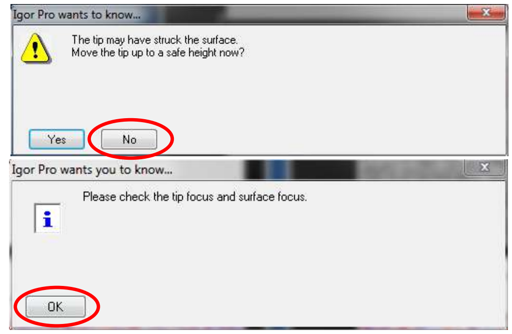


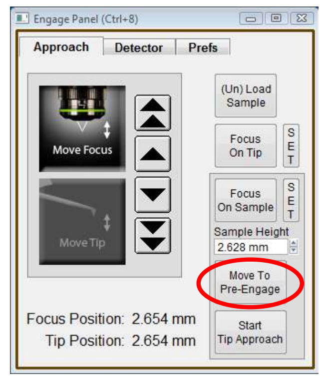
29.6. Approaching the sample

1.

Bring the sample close to the probe

- The height of the sapphire pillar with mica is ~ 2.5 mm
- In the Engage Panel, set the Sample Height to 2.8 mm
- Click Move to PreEngage
- It is possible that a warning message will appear “Tip may have struck the surface..”
  - The reason for this message is that the laser spot moves off the cantilever which results in a Sum signal drop
- Click No when prompted to “Move the tip up to a safe height now?”
- Realign the red laser on the tip to maximize the Sum and click Move to PreEngage

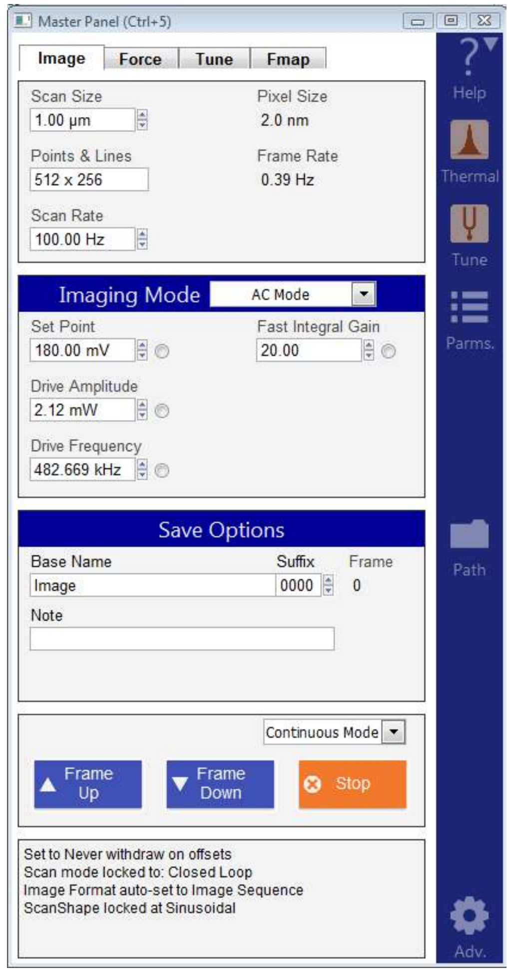




2.

Approach

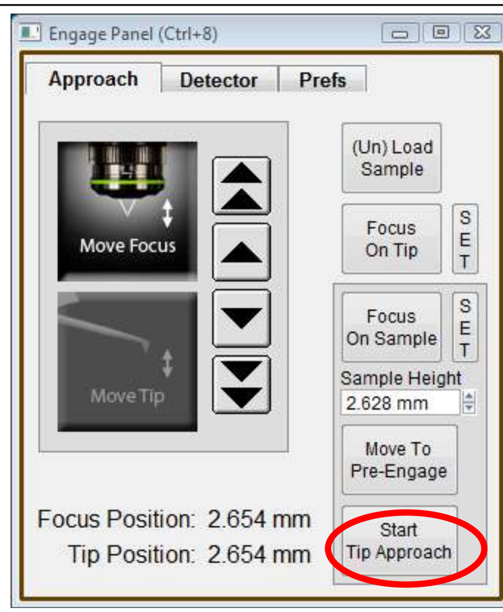
- In Master Panel, Image tab set the parameters to:
  - Scan Size: 1 um
  - Points & Lines: 512 x 256
  - Set Point: 180 mV
  - Scan Rate 100 Hz
  - Fast Integral Gain: 20



3.

Approach tip

- In the Engage Panel click on Start Tip Approach

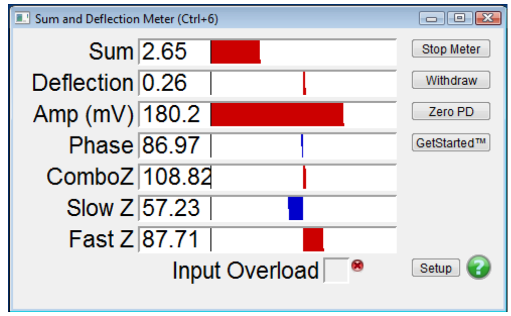


0

Engage

4.

- When the Set Point is reached click Engage
- If the tip is at the surface, Sum and Deflection Meter will read:
  - Amp (mV): 180
  - Combo Z, Slow Z and Fast Z should be somewhere in the middle of their ranges
- If either Combo Z, Slow Z or Fast Z are out of range, withdraw and:
  - Realign laser
  - Set Drive Amplitude to 250 mV
  - Click on Start Tip Approach
- When the Set Point is reached click Engage and check if the surface has been reached



29.7. Imaging Settings

Start Scaning

1.

- Click on Scan Down
- Adjust Setpoint until trace and retrace overlap
- Increase Fast Integral Gain to improve image quality
  - if the sapphire pilar and mica have been well imobilized on the VRS sample stage, the Fast Intergral Gain should reach values of 60 and higher
  - if the Fast Intergral Gain value is low (20-30) and ringing is visible, consider re-mounting your sample

Start Scanning

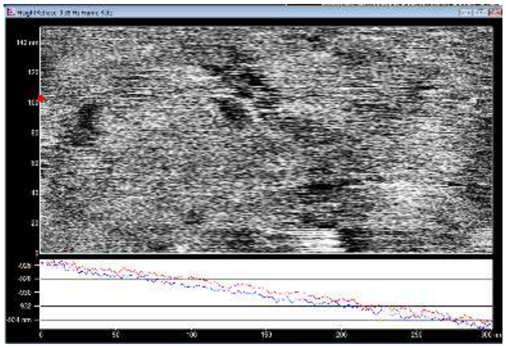
- Click on Scan Down (or Up)
- Adjust Setpoint until trace and retrace overlap
- Increase Fast Integral Gain to improve image quality

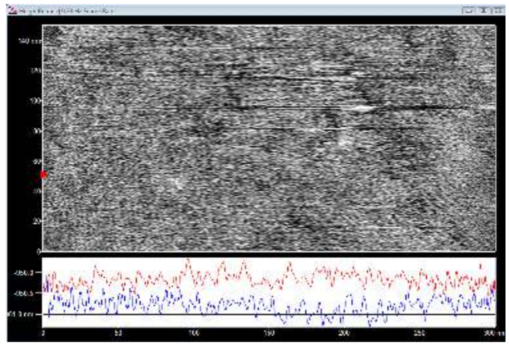
2.

If the sapphire pilar and mica have been well imobilized on the VRS sample stage, the Fast Intergral Gain should reach values of 60 and higher

Note If the Fast Intergral Gain value is low (20-30) and ringing is visible, you probably have poor sample mounting or loose probe. RE-MOUNT YOUR SAMPLE and CHECK PROBE PLACEMENT in the holder.

3.





- If there is any tilt in the Trace and Retrace scope (left image) change the scan angle by increments of 10 degrees until the traces are level (right image)

4.

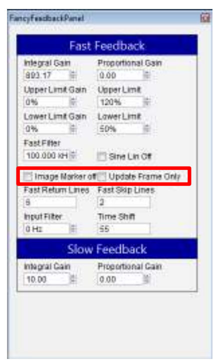
Adjust Scan Rate and Scan Lines

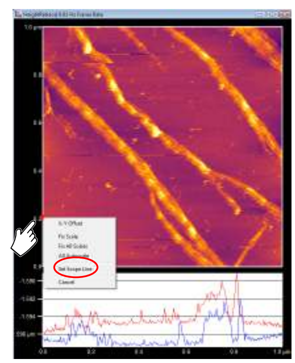
- To increase Frame Rate
  - Increase Scan Rate (Maximum = 625 Hz) or
  - Decrease the number of Scan Line

5.

Image and Scope update

- Images are updated line by line up to 1 Hz frame rate
- When imaging at a Frame Rate of 1 Hz and higher, images are automatically set to update every frame
- Red Image Marker on the left side of the image moves continuously to show where the tip is scanning
- When images are updated every frame, the position of the Image Marker is static and can be set by the user
  - Right click on the position where the marker should be placed
  - Set Scope Line





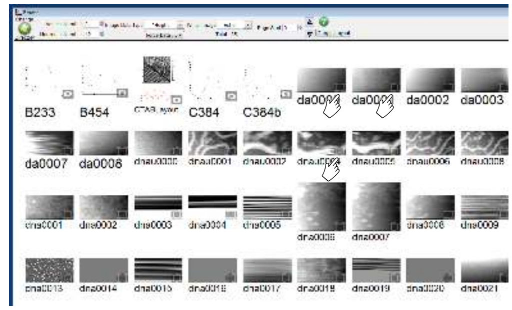
29.8. Data Analysis

Data is acquired in **A**sylum **R**esearch **I**mage **S**equence format (file extension ARIS). ARIS files can be opened directly form data browser.

1.

Opening Saved Files

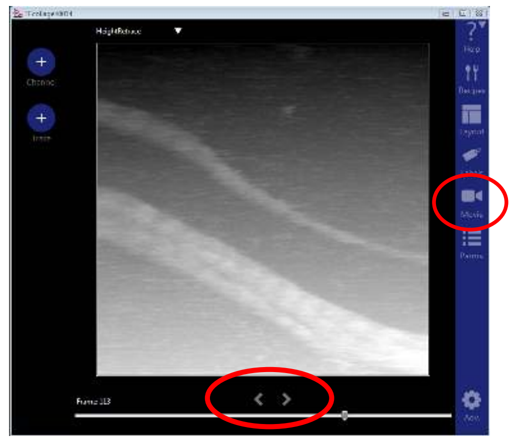
- From AFM Analysis choose Browse Saved Data
- Browse window will open with thumbnails of all the saved files
- Each file contains all the individual frames that were acquired for this file
- To open the file, simply double click on a thumnail that has a filmstrip on it



2.

Offline Movie Viewer

- File opens at the first frame
- User can *step* though the frames by clicking on the arrows below the image (slow)
- User can *slide* though the frames (faster) by keeping the arrow pressed down
- User can make a movie out of the file

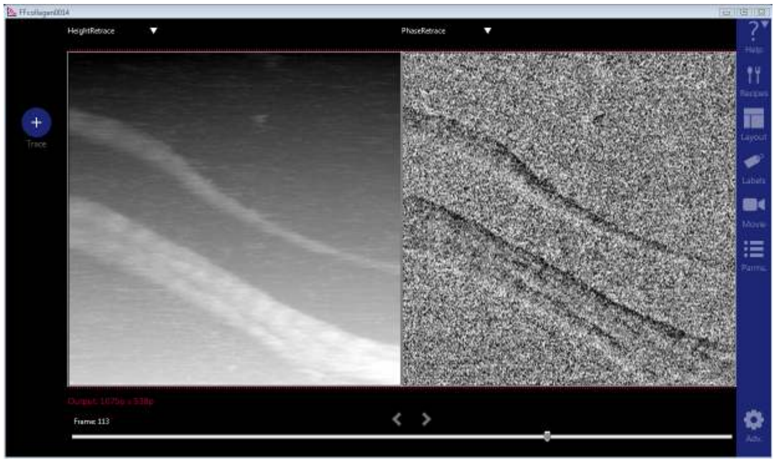


3.

Adjusting Data Scale

- By clicking on the top of the frame, a hidden section with options will appear
- The section contains different color scheme, data scale range and offset
- To hide this section click on it

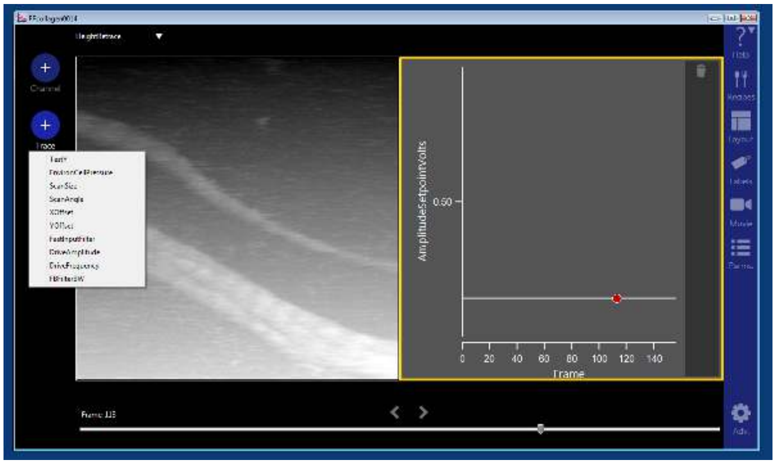
4.



Channel button

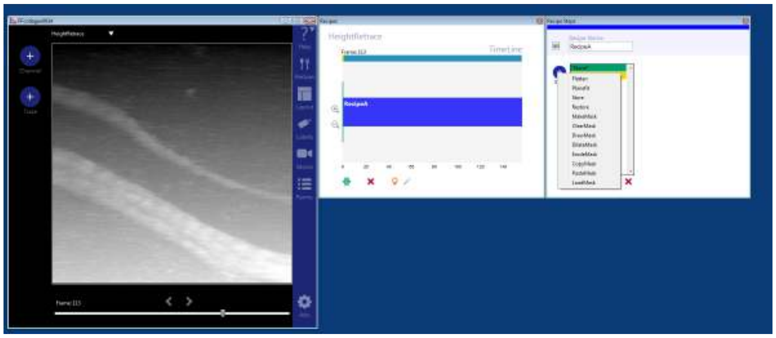
- This button adds channels that were acquired during imaging
- In this case it is the Phase image, Amplitude is also available
- To close one of the channels, click on the garbage can that appears at the top of the image

5.



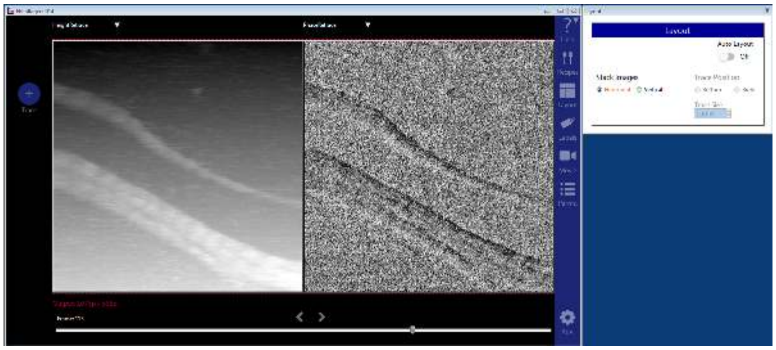
Trace button

- This button adds any information that was collectd during imaging
- If collected, choices include
  - Cell pressure
  - Scan Size
  - X and Y offsets
  - Filter inputs
  - Drive Amplitude
  - Drive Frequency
  - Feedback Filter Bandwidth
- To hide the additional information, click on the garbage in the top right corner of the image



6. **Recipes**

- Recipes allow for modification of batches of frames
- Receipes include the following function that can be used together
  - Flatten
  - Planefit
  - Store
  - Restore
  - Mask
- User can choose to apply a recipes with a given number of modification functions on either all or chosen frames



7. **Layout**

- Layout lets the user choose the display of the two channels that are being viewed

8.

Labels

- By using this button, user can append differnt labels to the image
- Labels include
  - Title
  - Chanel type
  - Scale bar
  - Additional parameters
    - pressure
    - time
    - scan size
    - scan angle
    - x and y offset
    - ...

9.

Movie

- When making a movie out of an ARIS data file, the user decides which frames should be used
  - In this case the movie will start at frame 0 and will end at frame 156
- Other options include
  - Size of the movie window
  - Output type
  - Playback rate
    - movie can be played back at real time rate, faster or slower

10.

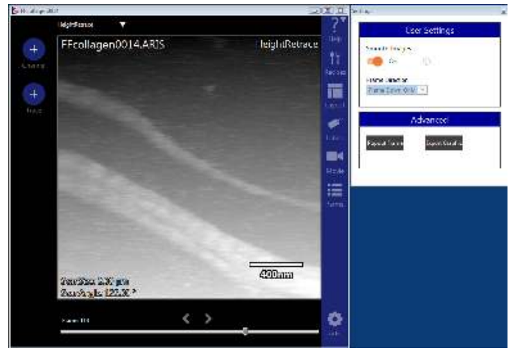
Parms.

- Parms. is short for Parameters
- Parameters relating to the movie will apprad besides the image window
  - Frame Rate
  - Scan Rate
  - Scan Size
  - Points & Lines

11.

Adv.

- Adv. is short for Advanced
- Popout Frame allows for extraction of a frame out of the ARIS file
- This extracted frame can be processed and saved as an IBW file



30. Cypher VRS Experimental Protocols

CHAPTER REV. 2041, DATED 08/31/2018, 11:04. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

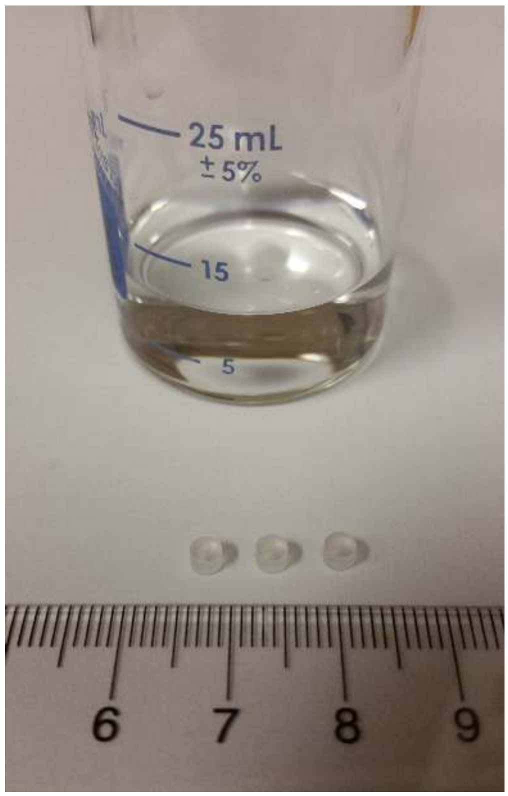
Chapter Contents

30.1. Preparing Mica Substrates

1.

Clean the Sapphire Posts

- Sonnicate the posts in ethanol for 10 min
- Rinse the posts with clean water several times
- Let the posts air dry

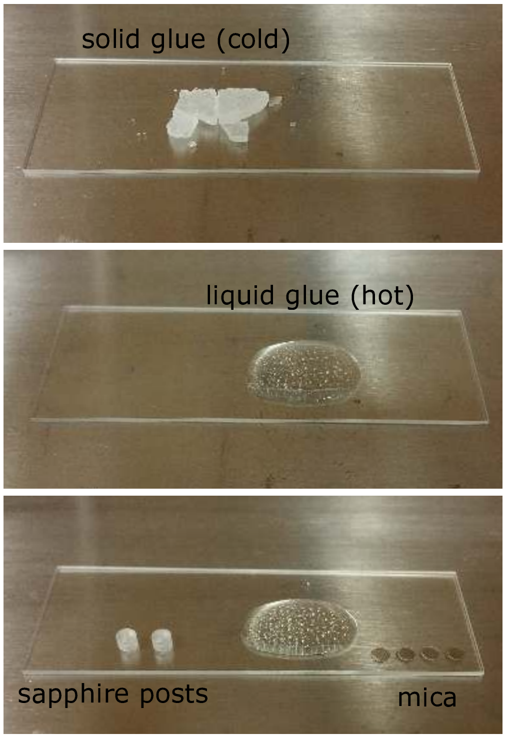


2.

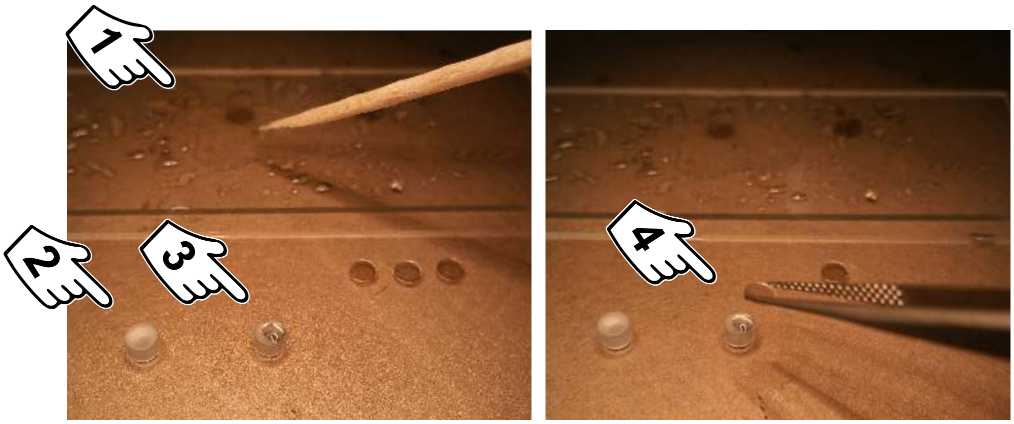
Prepare Glue

- Place some EPON1004F glue crystals on a glass slide and heat it up on a hot plate
- Place several clean sapphire posts on a glass slide and heat them up besides the glue
- Have mica ready for gluing beside the sapphire posts

Note Mica can be bought from various suppliers. It is important to have high quality mica with nice sharp edges devoid of cracks. Avoid flaky mica.



3.



Adhering Mica to Sapphire Posts

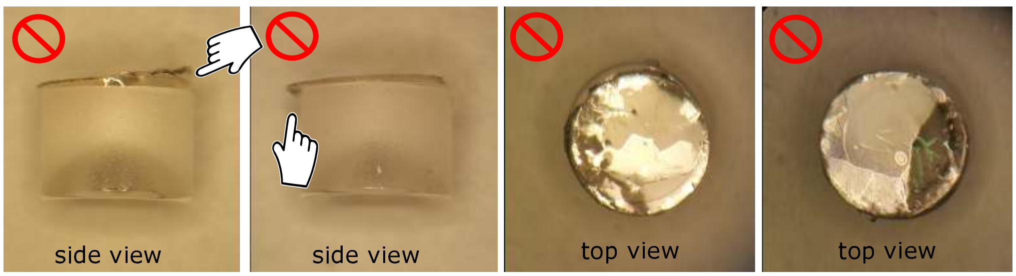
- Step 1: Wait for glue to melt (~140 degrees C)
- Step 2: Keep sapphire posts on the hotplate so that they are at the same temperature as the glue
- Step 3: Put a drop of glue onto the post using a wooden applicator
- Step 4: Place mica on top of the glue and let the glue spread under the mica. Do not press on the mica as the glue might from moving on top of the mica

4.

Mica Quality is Key

- The edges of the mica disk must be sharp and as flat as possible (two left images)
- Choose the side with sharpest edge of the mica when approaching the probe
- Flaky and delaminated mica will result in unstable imaging (two right images)

5.



Care must be taken when preparing sample substrates

- Too much glue will result in a tilted sample (left image)
- Mica should be placed in the middle of the pilar, overhangs should be avoided
- Uneven or flaky mica is easy to see under the microscope and shoudl be avoided

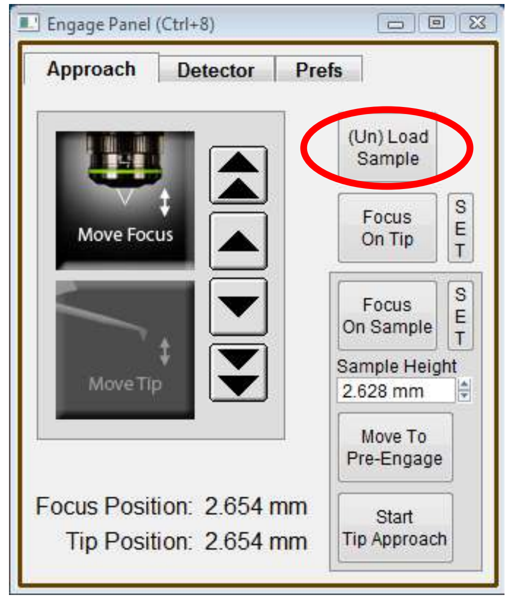
30.2. Removing Mica Pilars from VRS Sample Stage

When there is no more mica on the sapphire pilar, the user will need to remove the used pilar and glue on a fresh one.

1.

Unload the sample

- Stop imaging by pressing STOP on the Image Tab of the Master Panel
- Move the sample away from the tip by pressing the (Un)Load Sample button on the Engage Panel
- Remove the cantilever holder from the scanner



2.

Turn Controller OFF

- Turn controller OFF by pressing the Power button
- Green LED light will turn OFF

3.

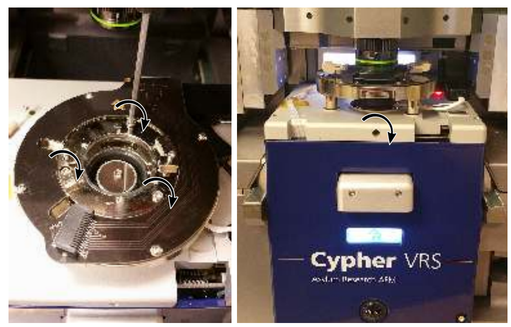
Unplug the VRS stage

- Gently pull on the connector to unplug the VRS stage

4.

Remove the VRS stage from the scanner

- Unscrew the 3 screws on top of the stage
- Unlock the VRS sample stage form the scanner by turning the from screw 3 full turns
- Remove the cell body from the scanner slowly



5.

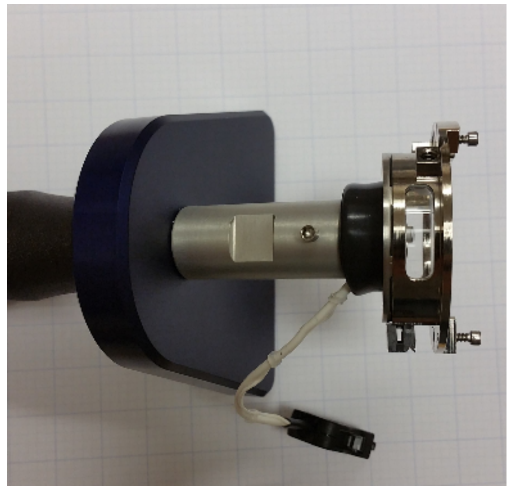
VRS sample stage holder

- The holder has the same screw lock-in mechanism as the scanner
- Place the dove tail of the stage in the holder and gently tighten the screw

6.

Place the VRS stage on the holder

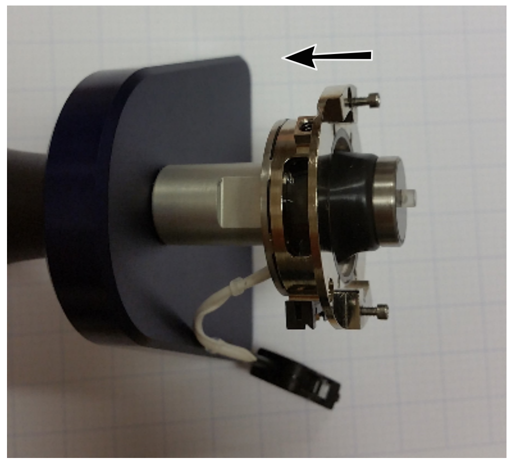
- Place the stage on the holder
- Fasten the screw so that the stage is firmly attached to the holder



7.

Expose the sample stage

- Pull the cell body away from the sample stage



8.

Cleave off sapphire pilar

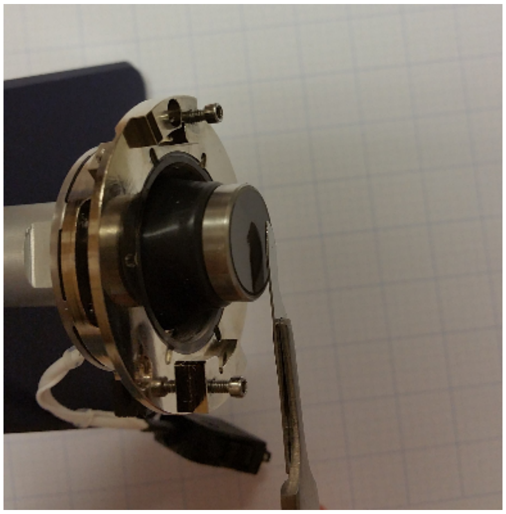
- Use a scalpel or a blade
- Place the blade parallel to the sample stage and apply pressure
- The pilar should pop off

9.

Clean off residual glue

- Scrape any residual glue off the sample stage

Note The sample stage is made of sapphire so do not worry about scratching it



10.

Refold the cell body membrane

- Press on the sample stage until you can grab onto the back side of it
- Pull from the back of the sample stage, move it back and forth until the membrane folds into place and looks like the image to the right

11.

Place the VRS sample stage in the scanner

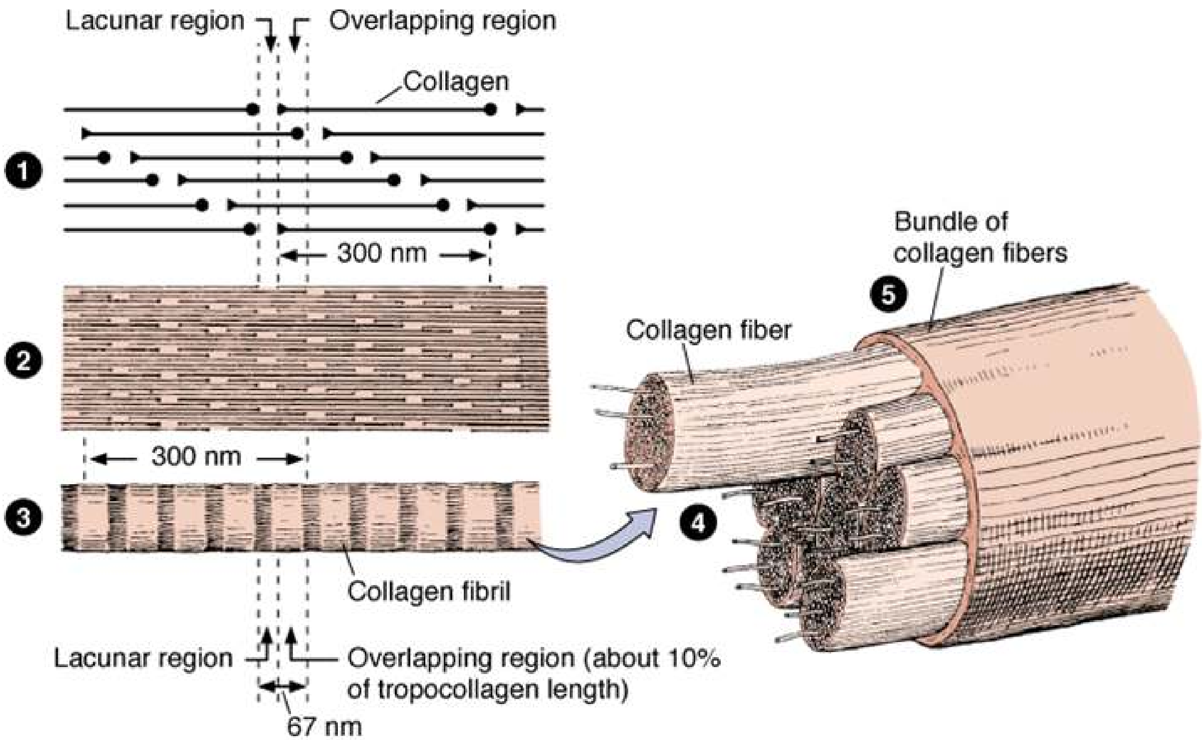
- Lock the stage in place with the screw in the front of the scanner (finger tight)
- Tighten the 3 screws on top of the cell
- Plug the VRS sample stage to the connector on top of the scanner
- Turn the controller ON
- Follow the steps in the Cypher VRS Tutorial to glue a new mica pilar on the VRS stage

30.3. Collagen on Mica in Liquid - Perfusion experiment

Collagen molecules aka procollagen: measures 300 nm each. Smallest thickness of molecule: 1.3 nm -1.5 nm (part 1 in figure). Each procollagen is composed of two alpha1 peptide chains and one alpha2 peptide chain (100kDa each). It is a right handed helix held together by hydrogen bonds and hydrophobic interactions. Each complete turn of the helix is 8.6 nm.

Collagen fibril: diameter ranging from 20 to 90 nm and several micrometers in length. They have striations (banding) with a periodicity of 64-68 nm. (part 3 in figure) - Collagen fiber: composes bundles (part 4 in figure) - Collagen bundle: biggest (part 5 in figure).

The goal of the experiment is to follow the dynamic process of collagen molecules assembling into fibrils on mica surface. The experiment is performed as follows: 1) clean mica is imaged (in buffer pH 10); 2) a small amount of concentrated solution of collagen molecules (solution is pH ~4) is added using a perfusion holder and 3) the assembly of collagen molecules into fibrils is observed by scanning the mica surface at ~ 1 frame/sec.



Source: Mescher AL: *Junqueira's Basic Histology: Text and Atlas, 12th Edition*: http://www.accessmedicine.com

Figure 30.1.: Structure of collagen

- **What's needed for the experiment**
  - 300 mM potassium chloride/ 10 mM sodium phosphate dibasic buffer pH: 10
  - Concentartaed collagen solution (3100 ppm = 3100 mg/mL)
  - AC10 probes
  - VRS perfusion holder
  - Tubing and tools to set up the perfusion holder
  - Plastic syringes 1 mL
  - Posts with mica

1. **Preparing the substrate**
   - Use Devcon epoxy to glue a clean sapphire/mica post onto the VRS sample stage

2.

Preparing the perfusion holder

- Wash and dry the holder
- Thread the tubing through the perfusion holder
- Make sure the tubing is well connected by gently pulling on it

3.

Preparing the perfusion setup

- Attach syringe adapters to the other end of the tubing that is connected to the holder
- One syring will be used to inject buffer or collagen
- The other syring will be used to remove solution from the tip-sample area

4.

Experiment

- Place an AC10 probe in the holder
- Cleave mica using adhesive tape to expose fresh mica surface
- Add a drop of buffer (~10 μL) onto the mica surface
- Fill 1 syringe with buffer and connect the syringe
- Push the buffer through the tubing until it reaches the probe
- Pull some of the buffer away from the probe using the other syringe
- Place the holder on the VRS scanner
- Bring the sample close to the probe while watching the two approach
- A meniscus will form between the holder and the sample
- To keep the experiment free of contamination, keep the liquid on the pillar

5.

Experimental settings

- Use AC10 probes
- Align laser on the cantilever
- Use blueDrive to tune the cantilever
- Free Amplitude: ~250 mV
- Setpoint: ~200 mV
- Fast Integral Gain: 50
- Scan Size: 1-2 µm
- Points and Lines: 512 x 256
- Scan Rate: 250 Hz

6.

Imaging mica

- Approach the mica surface and image it
- The surface should be clean and flat
- It there are any features, it is probably contamination: consider recleaving the mica

7.

Preparing collagen

- Stop imaging
- Prepare a syringe with 400 µL of buffer
- Add 4 µL of concentrated collagen (3100 mg/mL) to the buffer
- Exchange the pure buffer syringe with the collagen syringe
- Take care to not introduce bubbles into the tubing (look at figure)

8. **Imaging collagen**

- Start scanning again
- Slowly add collagen by pushing on one syringe
- At the same time, remove buffer with the other syringe (a pump could be used for this step)
- As the collagen is assembing on the surface you will start seeing strands
- Adjust the setpoint so that the stratnds are not being moved off the surface by the tip

Part V

Chassis & Enclosure

Who is this part for? This part covers general topics relating to the “frame” of the instrument, such as scanner exchange, laser module exchange, and air temperature control.

Part Contents

31. Tutorial: Scanner Exchange

CHAPTER REV. 1912, DATED 03/03/2017, 08:49. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

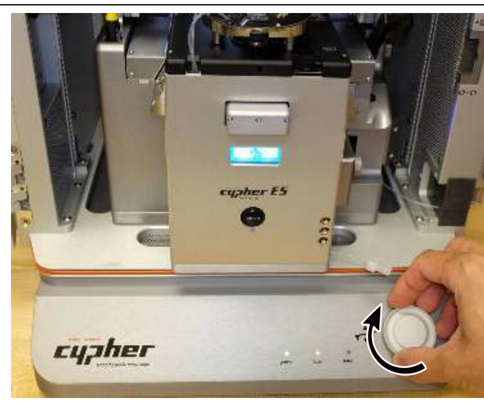
The Cypher AFM can be purchased with various scanner modules. This tutorial describes how to safely swap from one scanner to another.

31.1. Removing the scanner

The photos show the removal of the Environmental Scanner. The steps are the same for any other model.

1. **Raise the coarse engage stage:** It's likely you'll need to change a cell body after scanner removal, so it's best to raise the stage now to make those later actions possible.

- Rotate the Engage Control Knob on the Cypher **clockwise** and hold it until the cantilever is at its highest position.



2. **Open the enclosure:**

- Lift the door latch and open the enclosure door.

3. **Power OFF the ARC2:**

- Turn the ARC2 off before proceeding.
- Press the button as shown and verify the green light is OFF.

NOTE: The light behind the display on the scanner front will not turn off because it's powered by a different power supply. It is OK to unplug the scanner with this power supply active.

4. **Unlock scanner:**

- Lift the lever to the right of the scanner.

5. **Begin to pull the scanner out:**

- Pull the scanner out about halfway.

6. Now go and clear out a place to set the scanner down once you remove it. We recommend you first place the scanner right in front of the AFM system, and then grip the scanner again to move it elsewhere. If the scanner is dropped it might become irreparably damaged.

7.

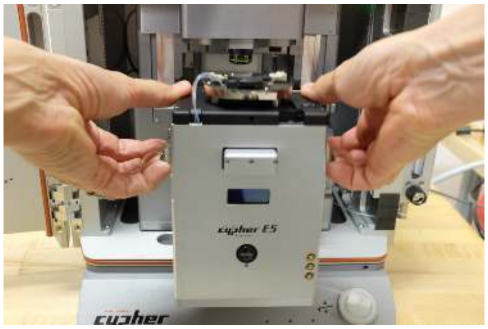
Detach the scanner from the chassis:

- Check that the light behind the scanner is off. This confirms the controller was turned off.
- The light behind the display on the front of the scanner will remain on. This is OK. It is powered by an alternate power supply.
- Turn the knob on the right side of the scanner *counterclockwise* to unscrew.
- The knob will disengage and retract back towards the chassis. If the knob does not disengage readily, make sure the scanner body is pulled out sufficiently from the chassis.

8.

Remove scanner:

- Use two hands to grasp both sides of the scanner and remove. Place your fingers under the two dovetail rails as shown in the photo.
- Use care because the scanner is HEAVY.
- Preferably place the scanner right in front of the AFM and then pick it up again to move it to its storage location.



31.2. Scanner Storage

The scanner should be stored under basic laboratory conditions, preferably in a locked cabinet or drawer where it will not collect dust, be accidentally knocked over, or be “borrowed”. At the very minimum, place it on a shelf and cover it with a soft cloth.

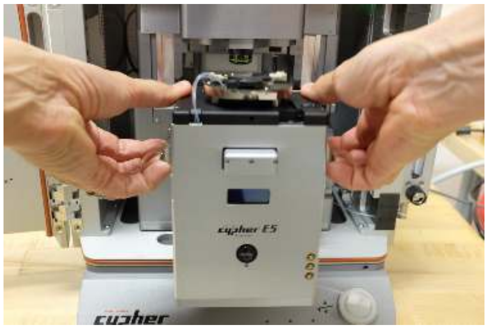
31.3. Replacing the Scanner

1. **Verify that the ARC2 is off:**

   - Double check that the ARC2 power light is indeed off. If not, turn off the controller.

2. Clear a space in front of the AFM.
3. Set the scanner down in front of the AFM.
4. Swing the scanner connector to the side so it does not block the scanner's insertion.
5. Make sure the locking lever on the chassis is in the RAISED position.
6. **Set the scanner on the rails:**

   - Use two hands to grasp both sides of the scanner and remove. Place your fingers under the two dovetail rails as shown in the photo.
   - Use care because the scanner is HEAVY.
   - Lift the scanner as shown and set it on the rails.
   - Push it in far enough so it sits stably on the rails.



7. **Secure the scanner connector:**

   - Press the connector into its mating socket.
   - Turn the knob on the right side of the scanner *clockwise* until firmly tight.

8. **Push the scanner in:**

- Push the scanner all the way into the chassis until it connects with the chassis.

9. **Lock the scanner:**

- Continue to apply pressure against the scanner.
- Lower the lever to the right of the scanner to lock it into place.

10. **Turn the AC2 back on:**

- Press the button as shown. The light must remain green.

11. Sometime during the following steps you may be asked to re-home the motors. Please do so when the software requests it.

12. When the process completes and click the  button and the popup list of attached hardware should include the scanner.

32. Optical System

CHAPTER REV. 2029, DATED 07/25/2018, 15:56. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

32.1. Overview

The Cypher AFM has an excellent optical system. A high quality microscope objective sits at the heart of this system. It affords an excellent optical view of the sample but also guides laser beams for the cantilever detection system.

A camera and white light source are embedded in the “view system” which protrudes from the top of the cypher enclosure.

32.2. Microscope Objective

The objective is not user replaceable. The magnification is fixed. Only digital zooming is possible within the software.

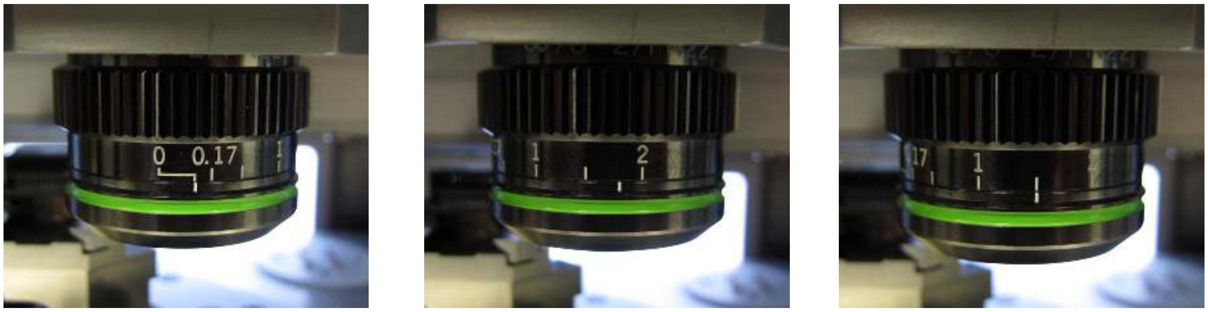
Depending on the imaging conditions (air, fluid) a correction collar on the objective must be adjusted. The tutorials in this user guide will always indicate the correct setting. An overview of these various settings is given in the table below.

Collar setting	Cypher S Cantilever Holders	Cypher ES Cantilever Holders
0	Any “Air Only” cantilever holder.	Never
1.5	Any “Droplet” cantilever used WITHOUT liquid.	Any cantilever holder used with Gas.
2	Any “Droplet” cantilever holder used WITH water.	Any cantilever holder used with water.

32.3. View system

The view system protrudes from the top of the AFM enclosure. It contains a software controlled white light source and camera. It also has three user controls. Two levers for adjusting image brightness and contrast, and a focus ring.

The focus ring is typically set at its detent position, in which case the optical view in the camera is focused in the same plane as the laser spot used to detect cantilever motion, which usually brings the back of the cantilever into



(a) Zero **(b)** 2 **(c)** 1.5

Figure 32.1.: Some examples of correction collar settings.

focus. In most cases a focused view of the sample, and not the back of the cantilever is desirable. During imaging, use the focus ring on the view system to bring the sample into focus.

During the engage process, the ring should be returned to the neutral (detented) position. A sensor will inform the software if this is not the case and you will be warned before engaging to adjust the view system focus if necessary.

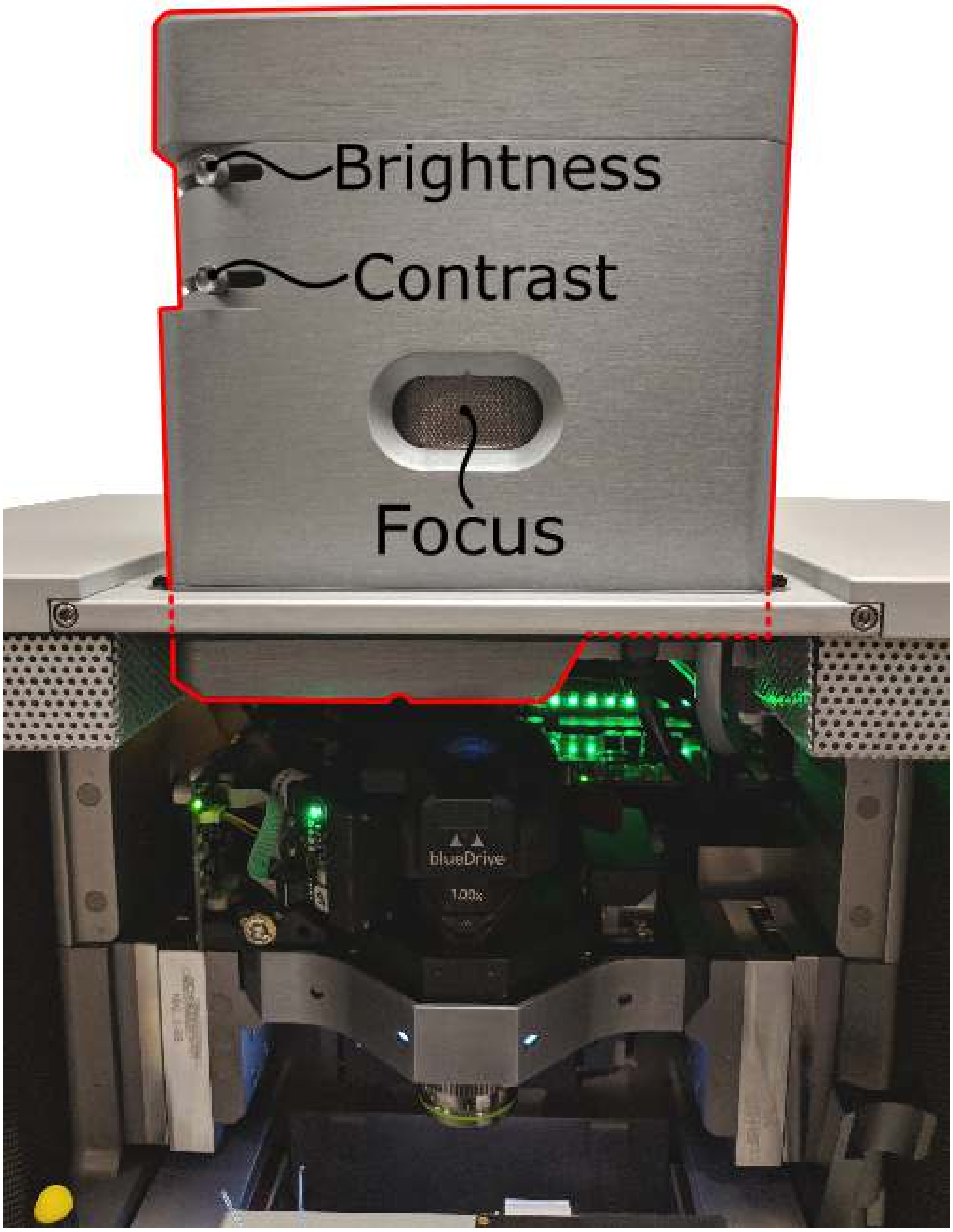
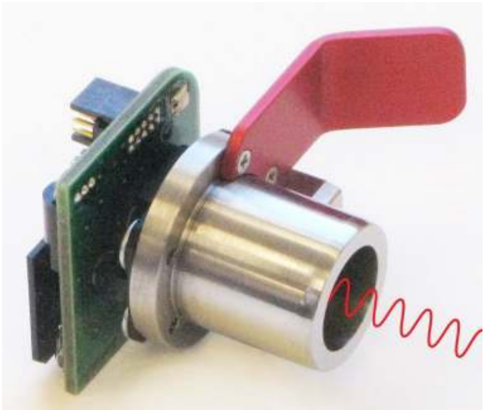


Figure 32.2.: Frontview of Cypher view system and controls.

33. Laser Source Modules

CHAPTER REV. 2101, DATED 09/04/2019, 16:15. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents



The following instructions describe exchanging laser source module assembly in the Cypher AFM. The Laser Source Module can be exchanged without disassembly through the front of the instrument with a little familiarity of the process. For the reason of clarity the instructions describe exchanging the Laser Source Module by disassembling the enclosure followed by the process done through the front of the instrument.

33.1. Types of Laser Source Modules and How to Identify Them

The Cypher can be equipped with interchangeable light sources. Some of the nomenclature:

Laser Diodes: Best all around choice for AFM imaging. Lower noise for imaging techniques, but with some interference effects which can lead to background oscillations when performing force curve measurements.

Super Luminescent Diodes: Also known as SLDs. Best all around choice for force curve measurements. Slightly higher noise than the laser diode sources, but remarkably lower oscillating background for force curve work.

Small Spot: 3µm by 9µm spot size. Mandatory for cantilevers smaller than the large spot, to prevent light from spilling over the sides.

Standard Spot: 10µm by 30µm spot size. Preferable for larger (traditional) cantilevers since a spot that fully fills the cantilever leads to lower imaging noise..

Part #	Item Description	Picture
901.601	SLD Source Module, standard spot size.	
901.602	SLD Source Module, small spot size.	
901.603	Laser Diode Source Module, standard spot size.	
901.604	Laser Diode Source Module, small spot size.	

33.2. Tutorial: Laser Source Module Exchange

As noted at the beginning of this procedure, it is possible to exchange the Laser Source Module without removing the top of the enclosure. It is highly recommended that you first familiarize yourself with the system by removing the top cover once so that you are certain of the location of the components involved.

1. Remove your sample from the scanner.

2.

Lower the cantilever holder:

- Rotate the ‘Engage Control Knob’ on Cypher *counter-clockwise* to lower the tip to a close distance ~1mm) above the top of the scanner. This will allow easy access to the top of the head assembly where the Laser Source Module is located.

Note Although it is not required, for safety reasons we recommend making motor moves with the door closed. Beware of pinch points (Figure 1.1 on page 5).

3. Turn the ARC2 controller power off. This will shut off most of the Cypher’s power. It is not necessary to disconnect the motor power supply when exchanging the Laser Source Module assembly.

4.

Remove optics cover:

- Grip the cover at its lower edge and gently pull forward. It is attached magnetically and will detach of smoothly.

Note This will expose the head assembly and allow access to the Laser Source Module from the front.

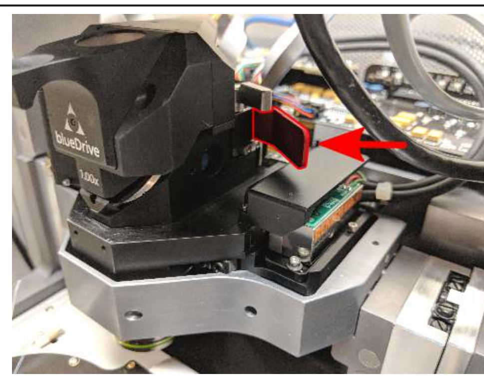
5. Locate the Laser Source Module container for the one you are removing now. You will need to store it properly as soon as it is removed from the SPM.

6. Locate the Laser Source Module (hopefully in its container) which you will be installing.

7.

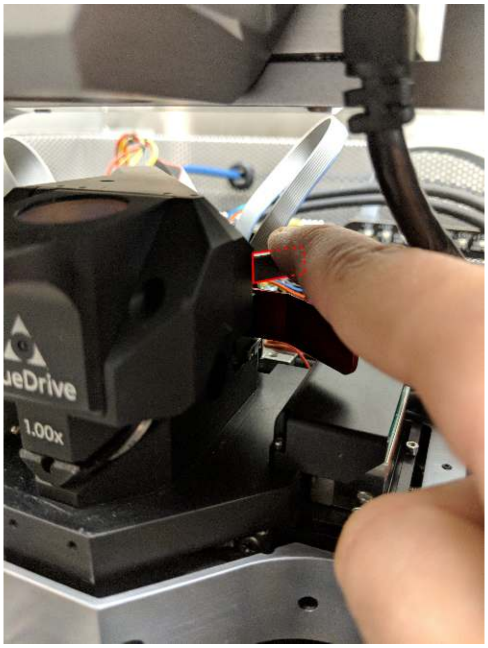
Locate the Laser Source Module:

- Look in the area where you just removed the optics cover.
- The Laser Source Module is easily identified by its red handle.
- Above that note the metallic silver cross shaped clamping knob.



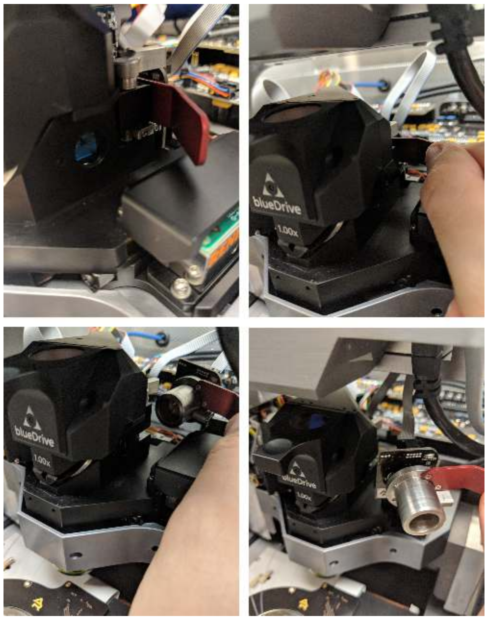
8. **Loosen the clamp:**

- Turn the clamping knob about ½ turn *counter-clockwise* or until it feels loose.



9. **Pull the Laser Source Module out:**

- Touch a metal part of the SPM instrument to ground yourself.
- Grip the Laser Source Module’s red handle.
- Gently push straight back. The Laser Source Module should slide out very smoothly. If not, further loosen the knob.
- Once the tube clears its cradle, move it to the right and pull it forward and out.



10. Unplug the power cable.

11. **Store the Laser Source Module immediately:**

- Place the Laser Source Module in its pink anti static bag (IMPORTANT!)
- Place the bag and Laser Source Module inside its plastic enclosure.
- Store in a safe place. The Laser Source Module is fragile and can be damaged or knocked out of focus if it is dropped.

12. Connect the new Laser Source Module to the power cable.

13. Install the Laser Source Module (reversing the removal process) into the head making sure that the tube is fully seated. The tab on the left side of the tube will key the rotation of the tube in the head.

14. Tighten the clamping knob to secure the Laser Source Module.

15. Replace the optics cover (See Step 4 on page 348)

16. Turn theARC2 power back on.

17. Power the system back up and align the laser spot on the cantilever. If you are unsure of this process, follow these steps

a) Power up the system as described in Chapter 5 on page 33.

b) Follow the "AC Mode in Air tutorial" (Chapter 7 on page 40) up to Step 12 on page 52.

c) If the 'Spot On' process does not perfectly center the laser, then please see Section 33.3 on page 350.

33.3. 'Spot On' calibration

A small amount of misalignment in the light spot position is normal after the Laser Source Module is exchanged. Great care is taken at the factory to ensure that the "spot on" calibration is correct but due to subtle position shifts in the relationship of the optical components, the light may settle in a new location. Once the Laser Source Module is installed and any corrections are made to the calibration, the spot accuracy of the "Spot On" routine is very repeatable. If the "Spot On" software routine appears to misalign the light on the back of the cantilever, it may be for the following reasons:

- The Laser Source Module you installed may be clamped in a different position from when it was tested at the factory. With the Laser Source Module powered on, loosen and jiggle the Laser Source Module to allow it to re-seat in the head. Re-tighten the clamp. If the light moves back to the same (unwanted) location repeatedly then consider recalibration.
- If the Laser Source Module was purchased at a later time from when the system was delivered or it was exchanged due to a repair then the "spot on" parameters were calibrated on a different Cypher and small system to system differences make the spot on calibration parameters in the Laser Source Module incorrect for your system.

33.3.1. Readjusting the 'Spot On' calibration.

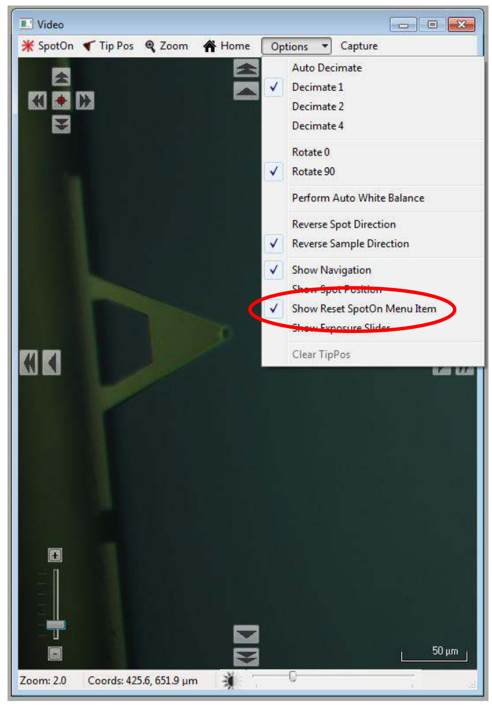
The spot on software routine relies on two parameters stored in the Laser Source Module calibration information block (info block). These parameters are set at the factory but may need to be changed if the Laser Source Module is exchanged.

If you find that the Spot On position is still off after re-seating the Laser Source Module and allowing it to warm up:

1. Allow the Laser Source Module to come to operating temperature. Subtle changes in the relative position of the optical emitter and focusing lenses inside the Laser Source Module can occur during warm up after installation. Allow an hour for the Laser Source Module to come to thermal equilibrium with the system. You may find that the error in the "Spot On" positioning will reduce. If the Cypher is left powered off for an extended amount of time, i.e. overnight or for a day, you may find that the Spot On position may be off. Allow ample time for the system to reach thermal equilibrium before deciding to make adjustments

2. **Prepare to reset:**

   - Click on "show reset spot on menu item" in the options pull down selection.



3.

Reset the spot position:

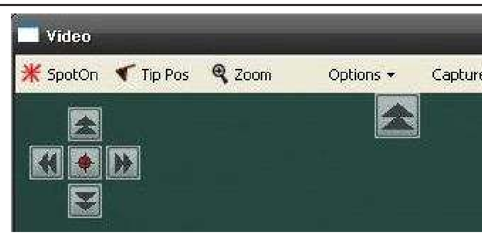
- Zoom in at least once.
- Point the mouse cursor to the center of the laser spot. Right click and click on "reset spot on position".
- The new XY spot centers will be stored in the Laser Source Module's infoblock.

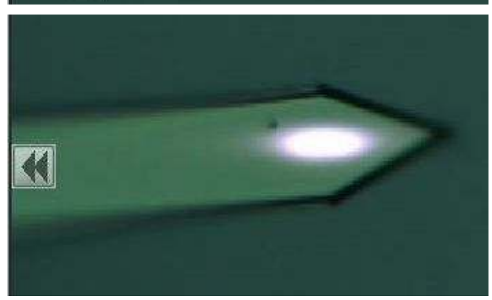
Note The photo shows a laser spot which did not quite center onto the cantilever holder, hence the need for the recalibration.

4.

Test 'Spot On':

- Use the arrow markers at the top of the video window to steer the spot off the cantilever.
- Click the Spot On button at the top left of the video window.
- Click in the center of the cantilever and confirm that 'Spot On' is properly calibrated.





From now on this light module should be properly calibrated for use (and re-use) in your Cypher SPM, since each Laser Source Module has a small memory element which stores the calibration values.

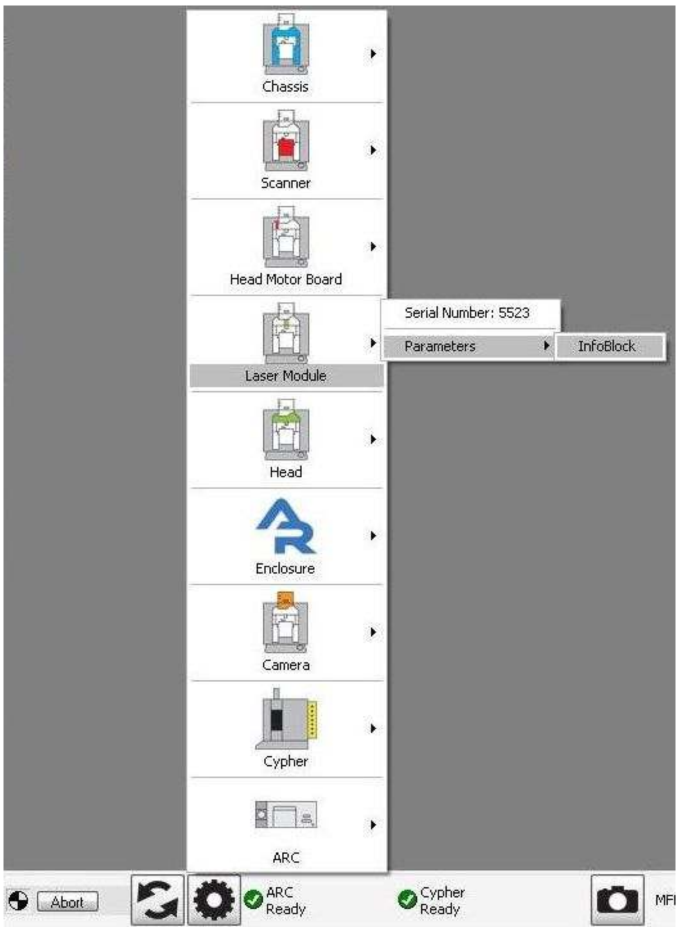


Figure 33.1.: To open the Laser Source Module infoblock, click on the "gear" icon at the bottom of the screen, then mouse up to the Laser Module and over to the infoblock. Then release the mouse button.

34. blueDrive™ Photothermal Excitation

CHAPTER REV. 2101, DATED 09/04/2019, 16:15. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

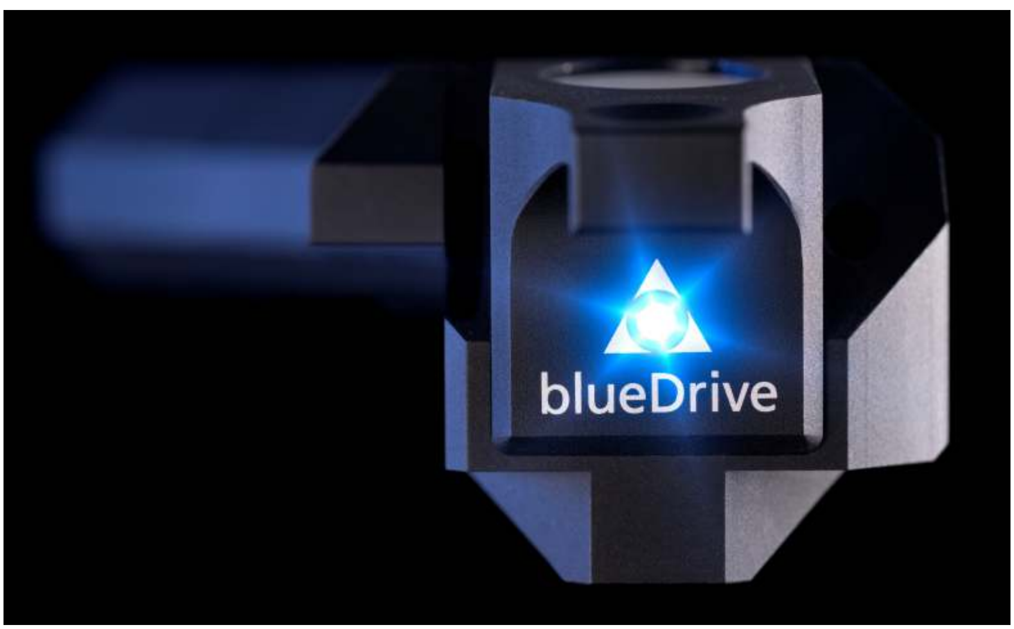


Figure 34.1.: blueDrive optomechanical unit that mounts onto the Cypher Head

34.1. Overview

blueDrive is an optional accessory mounted onto the Cypher Chassis which focuses a blue laser spot onto the cantilever. The blue laser provides an alternative drive mechanism to the standard piezoacoustic drive mechanism used to excite the cantilever (a.k.a piezo drive).

34.1.1. The principle of photothermal excitation

In addition to the infrared detection laser (850 nm), a blue laser (405 nm) is focused on the base of the cantilever which causes photothermal excitation: local heating of the cantilever leads to a thermal stress that changes the cantilever deflection proportionally to laser power. High frequency modulation of the laser power up to 8 MHz allows the excitation of cantilevers of all sizes, as well as excitation of higher eigenmodes.

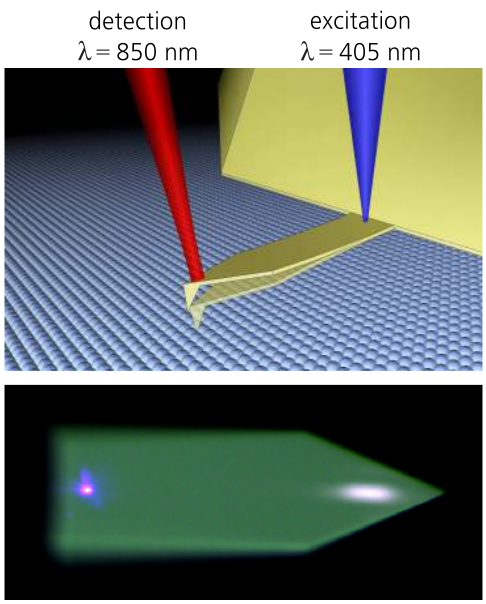


Figure 34.2.: Schematic of photothermal excitation

The benefits of such a direct drive mechanism are similar to those of magnetic actuation (iDrive), but with the advantage of being applicable to cantilevers of all shapes and sizes. Photothermal excitation allows quantitative imaging in all environments, and the benefits are especially noteworthy in liquids, where blueDrive enables stable imaging for hours. The only drawback is that cantilevers **may** require a gold coating to achieve high amplitudes with photothermal excitation.

Much more details about the benefits of blueDrive are described in the following webinar:

“AFM Imaging and Nanomechanics with New blueDrive™{} Photothermal Excitation”

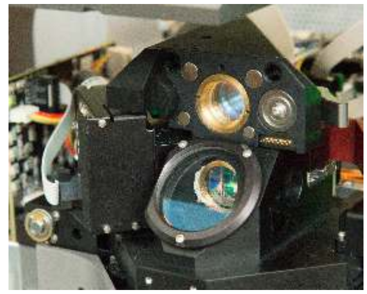
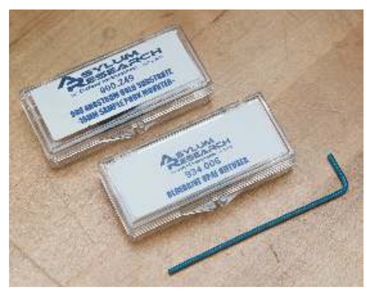
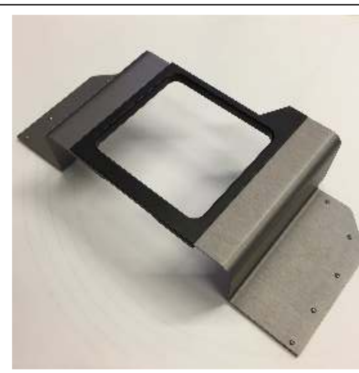
34.1.2. How much light power do you need?

As shown in the Figure below, there are 5 Filter Cubes that can be selected. The purpose of the Filter Cubes is to attenuate the blue light power to a desired level. Depending on the cantilever shape, the coating, or the imaging environment, up to 10 mW of blue light might be necessary to drive the cantilever substantially, or as little as 0.1 mW may be enough. Choosing the right Filter Cube ensures that the right amount of blue light power reaches the cantilever in order to avoid having excess blue light hitting the cantilever. This minimizes cantilever heating and maximizes the performance of blueDrive.

Figure 34.3.: blueDrive unit with 5 Filter Cubes for setting the power level of the blue laser

34.2. Hardware components

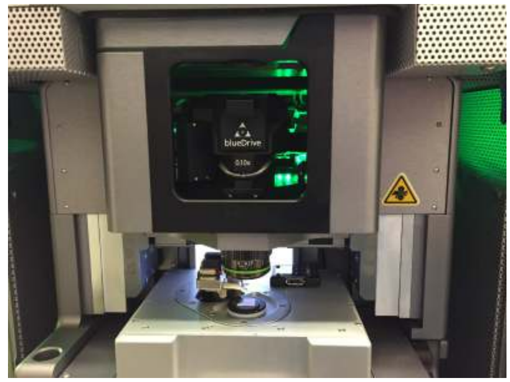
34.2.1. Table of parts

Itm	Part #	Item Description	Qty	Picture
N	934.001	The main blueDrive optomechanical unit comes premounted onto the Cypher head	1	
N	900.266.01-05	Filter Cubes (900.266.01-05), labelled by their gain factor: 0.01x, 0.03x, 0.10x, 0.30x, or 1.00x	5	
N	934.005	blueDrive Accessory Kit 290.169 Hex Key, 2mm 900.249 Gold sample 934.006 Opal Diffuser	1	
N	901.803	blueDrive Optics Cover	1	

34.3. Switching Filter Cubes

34.3.1. blueDrive Optics Cover (optional)

The blueDrive Optics Cover (901.803) magnetically attaches to the View Module bridge as shown in the photograph to the right. It serves an aesthetic purpose, and therefore is not required for proper functioning of the Cypher system.



34.3.2. Changing Filter Cubes

The standard blueDrive package comes with 5 Filter Cubes (900.266.01-05), labelled by their gain factor: 0.01x, 0.03x, 0.10x, 0.30x, or 1.00x. The spare Filter Cubes dock on the Cypher door when they are not in use, as shown in Figure 34.4 on page 358.

Figure 34.4.: Spare Filter Cube docked on the Cypher door.

Changing Filter Cubes is easy. Simply grip the Filter Cube mounted to the blueDrive unit as shown below. Pull on the Filter Cube directly away from the blueDrive unit, towards the front of the Cypher, as shown by the red arrow.

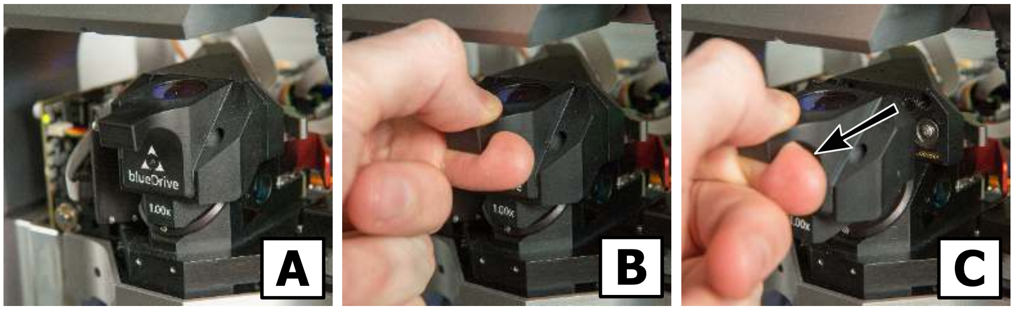


Figure 34.5.: Remove the Filter Cube by pulling directly towards the front of the Cypher.

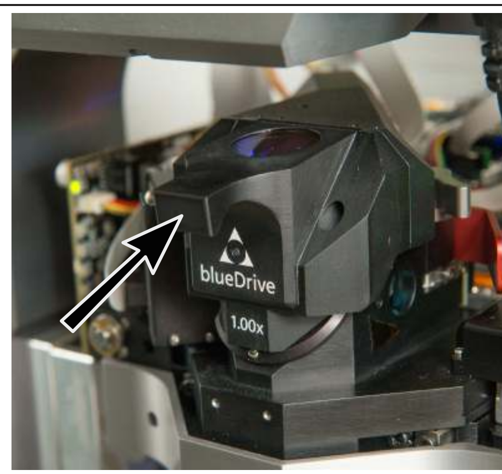
NOTE DO NOT apply torque on the Filter Cube.

To install a new Filter Cube, simply locate the Filter Cube in proximity to its final position. Make sure that the gage pins line up with the holes on the blueDrive unit. Once the Filter Cube is close to being in place, let go of the Filter Cube and let the magnetic force position the Filter Cube appropriately.

Igor automatically recognizes the Filter Cube and scales drive amplitude (in mW) in the software accordingly.

Tip Ensuring high accuracy blue spot positioning.

In some cases, the locating pins may have some friction that prevents proper indexing of the Filter Cube (e.g.: if some dust gets into the indexing holes). This may lead to a laser spot positioning error of several tens of microns. In order to ensure high accuracy positioning of the blue spot between changing Filter Cubes, apply a small force with your finger onto the Filter Cube after installation. As shown to the right, the force should be slightly upwards to makes sure the Filter Cube indexes properly.



34.4. Cantilever and Filter Cube Selection

34.4.1. Choosing the right cantilever

As a general rule, gold-coated cantilevers have the best photothermal response and lead to the highest amplitudes for the least amount of blue light power. We recommend the use of gold coated cantilevers to achieve the largest amplitudes with blueDrive.

However, other cantilevers may be used, especially in applications which require small amplitudes. The best way to determine if a cantilever will work with blueDrive is to simply test it out by acquiring a cantilever tune with blueDrive and noting the maximum attainable amplitude.

34.4.2. Choosing the right Filter Cube

The maximum cantilever oscillation amplitude that is attainable for a particular cantilever scales with the Filter Cube gain factor (0.01x, 0.03x, 0.10x, 0.30x, or 1.00x). For example, if a 0.10x Filter Cube results in a maximum amplitude of 100 nm on some cantilever, it is expected that a 0.30x Filter Cube will result in a maximum amplitude of 300 nm.

However, some cantilevers are very photothermally sensitive and provide large amplitudes, such as 100 nm, even with the lowest Filter Cube (0.01x). Using a 1.00x Filter Cube on such a sensitive cantilever could cause overheating and permanent damage to the lever.

As such, it is always best to start with a low Filter Cube when testing a new type of cantilever. If the desired amplitude is not attained with the 0.01x Filter Cube, one can scale the Filter Cube up to attain the desired amplitude. Once the right Filter Cube has be defined for a particular cantilever, all cantilevers with the same model number are expected to achieve similar amplitudes (within a factor of ~2), such that the Filter Cube test can be avoided in future experiments.

Importantly, blueDrive has the best performance when the lowest Filter Cube required to attain the desired amplitude is used. For example, it is better to use the 0.30x Filter Cube to drive the cantilever with 2 mW of drive amplitude, rather than using the 1.00x Filter Cube with 2 mW of drive amplitude. Both of these Filter Cubes allow a drive amplitude of 2 mW; however, the 0.30x Filter Cube has only 3 mW of DC light power at the cantilever, as opposed to the 1.00x Filter Cube which has 10 mW of DC light power. In other words, the same cantilever amplitude will be attained in both scenarios, but using the 1.00x Filter Cube will lead to roughly 3x more heating of the cantilever.

Filter Cube gain factor	DC power @ cantilever	Max (AC) drive amp.	Min (AC) drive amp.
1.00x	10 mW	9 mW	1 mW
0.30x	3 mW	2.7 mW	0.3 mW
0.10x	1 mW	0.9 mW	0.1 mW
0.03x	0.3 mW	0.27 mW	0.03 mW
0.01x	0.1 mW	0.09 mW	0 mW

Table 34.2.: Blue light power output for blueDrive as a function of Filter Cube

The Minimium (AC) drive amplitude, which is fixed in software, is there to remind the user to switch the Filter Cube to a lower value when requiring lower cantilever amplitudes, rather than simply turning down the drive amplitude electronically via the Tune Panel in Igor.

The Figure below explains why its better to change Filter Cubes rather than significantly lowering the drive amplitude in the Tune Panel. The DC power of the blue light at the cantilever is fixed, according to Table 34.2 on page 360. Meanwhile, the drive amplitude, which is the AC power modulation of the blue light at the drive frequency, can be adjusted continously on Tune Panel as with conventional piezo drive. It is the AC power, not the DC power, which determines the oscillation amplitude of the cantilever.

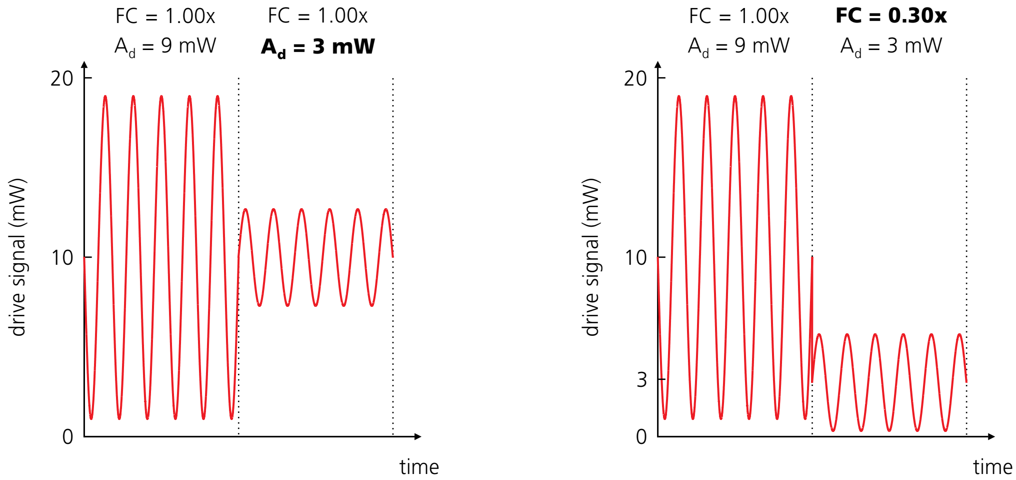


Figure 34.6.: The AC and DC power of the blue light are illustrated with respect to (left) changing the amplitude on the Tune Panel versus (right) changing the Filter Cube (FC), which is the preferred option because it lowers the amount of blue light shining on the cantilever.

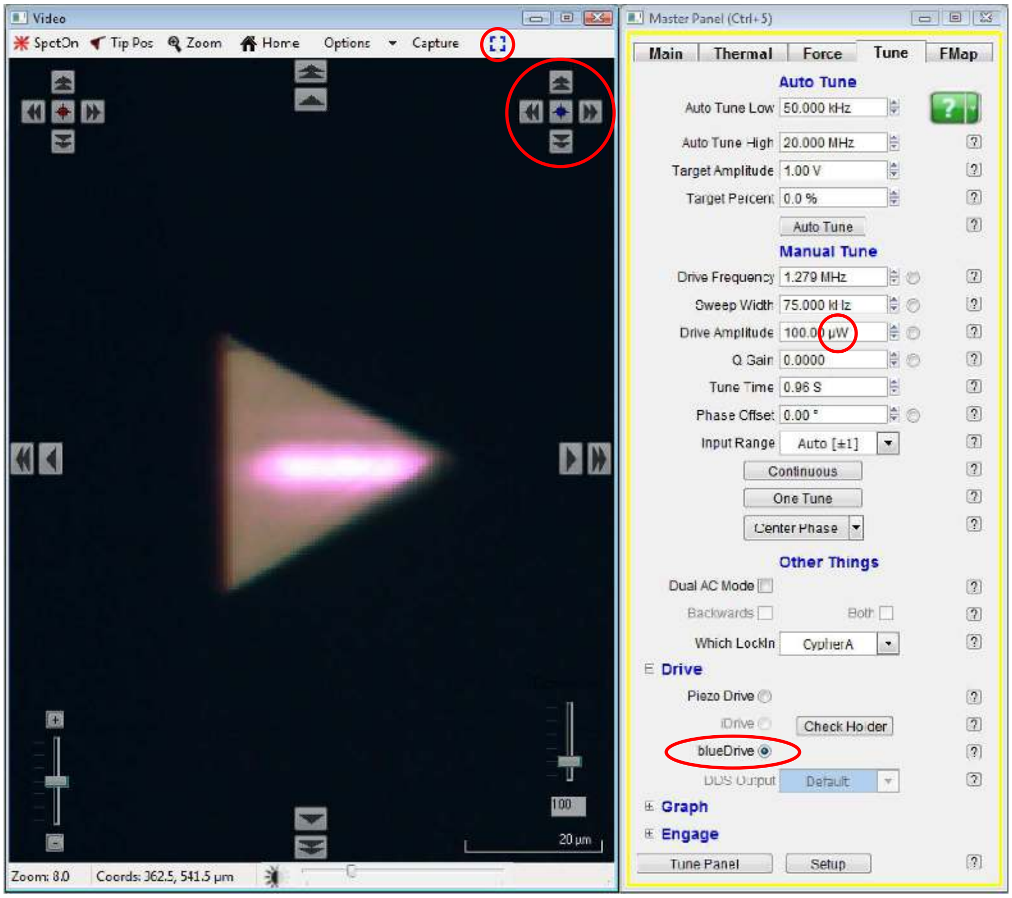
34.5. Software interface

34.5.1. Software requirements

blueDrive requires version 13 or above of the AFM software. The latest version can be downloaded here: https://support.asylumresearch.com/forum/content.php?4-Software

34.5.2. Turning on blueDrive

1.



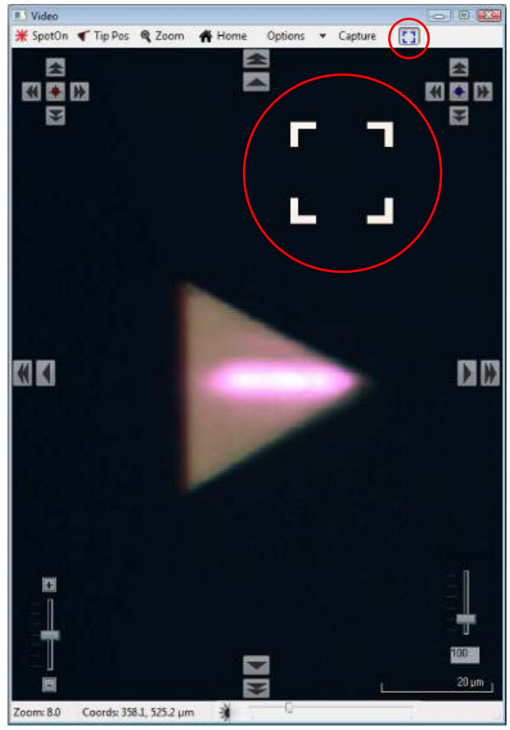
- blueDrive can be turned on by selecting the “blueDrive” option on the Tune Panel, as an alternative to the conventional “piezo drive” - see above.
- In blueDrive mode, the drive amplitude changes from units of “V” to units of “mW” to remind the user that the cantilever is driven by blue light power.
- Also note that there are new View Module controls that appear in the Video Window when blueDrive is selected. These will be used in the following section.

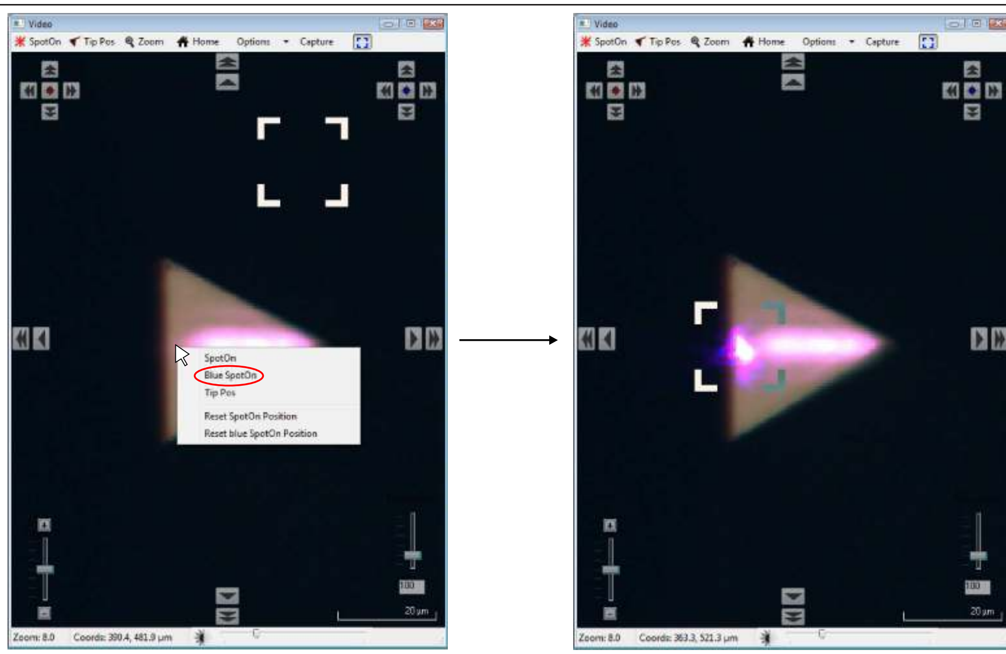
Tip: Reducing sample exposure to blue light When blueDrive is turned on, the blue light spot **may** be directed at the sample inadvertently. If sample exposure to blue light is potentially problematic, it is advisable to retract the cantilever from the sample as far as possible before turning blueDrive on. Then, the cantilever should be approached towards the surface only once the blue spot is positioned at the base of the lever in order to avoid unnecessary exposure of the sample.

34.5.3. Positioning the blue spot

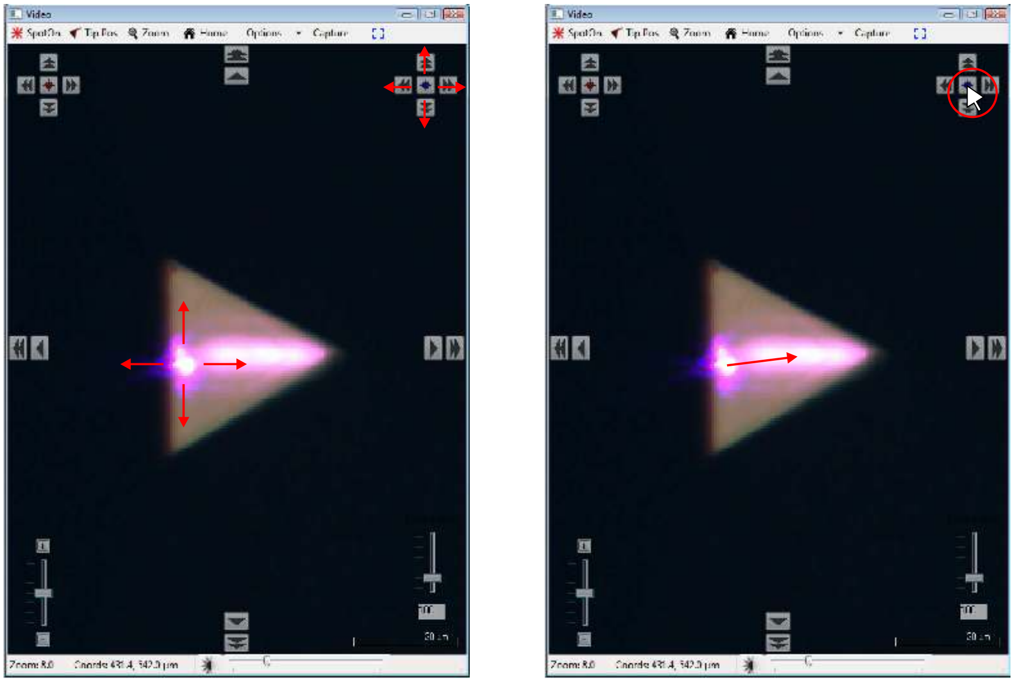
The blue spot may be positioned in several ways using the new controls that appear on the View Window once “blueDrive” is selected on the Tune Panel, as shown in previous section.

The blue box can be toggled. When enabled, the blue box displays the blue spot location on the View Window, as shown to the right. If the blue spot is not incident on a reflective surface, such as the cantilever, it may be impossible to see the blue spot. However, the blue box indicates the position of the blue light spot, which is known to Igor because of a photodetector inside the blueDrive unit which measures the location of the blue spot **before** it reaches the cantilever and sample.





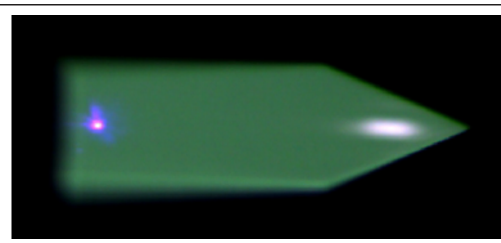
- Right-clicking on a partiular location of the View Window and clicking “Blue SpotOn” automatically moves the blue spot to that location.

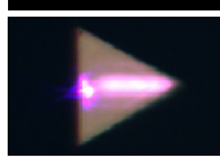


- (left) The blue arrows on the top/right of the View Window can be used to move the blue spot position in all directions. If enabled, the blue box follows the location of the moving blue spot.
- (right) Clicking on the center circle in between all four arrows commands the blue light to move on top of the infrared detection light spot.

34.5.4. Acquiring a cantilever tune

- The optimal location for the blue spot for best photothermal performance is the base of the cantilever, along the axis of the cantilever. An example of the optimal location for several levers is shown on the right.
- For hollow triangular cantilevers, the blue spot should be placed at the base of either of the cantilever legs.





bio mini

triangular lever

Although it is not necessary to fine-tune the blue spot location, it may be beneficial in certain cases to move the blue spot with the arrows near the cantilever base in order to find the position with the maximum amplitude.

34.5.5. Operating on the thermal resonance

The true resonance of the cantilever is best determined from a fit to the thermal spectrum of the cantilever. This ensures that the cantilever is being driven at its true resonance, where the phase response is 90 degrees. For ultimate accuracy, the thermal should be acquired with the blue light positioned where it will reside during imaging.

So, note that it is not actually necessary to acquire a cantilever tune before imaging. Taking a thermal and fitting it to set the drive frequency to the cantilever resonance may suffice. That being said, cantilever tunes are very useful in determining whether everything is functioning appropriately.

35. Air Temperature Controller (ATC)

CHAPTER REV. 1912, DATED 03/03/2017, 08:49. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

35.1. Overview

This chapter covers the installation and operation of the Cypher ATC (Air Temperature Controller).

If the temperature of your laboratory varies by more than a few tenths of a degree over time (almost all labs do), your SPM images may be suffering from distortion due to differential thermal expansion and contraction of the entire instrument. The Cypher ATC can improve the situation by gently forcing filtered temperature controlled air through the AFM enclosure.

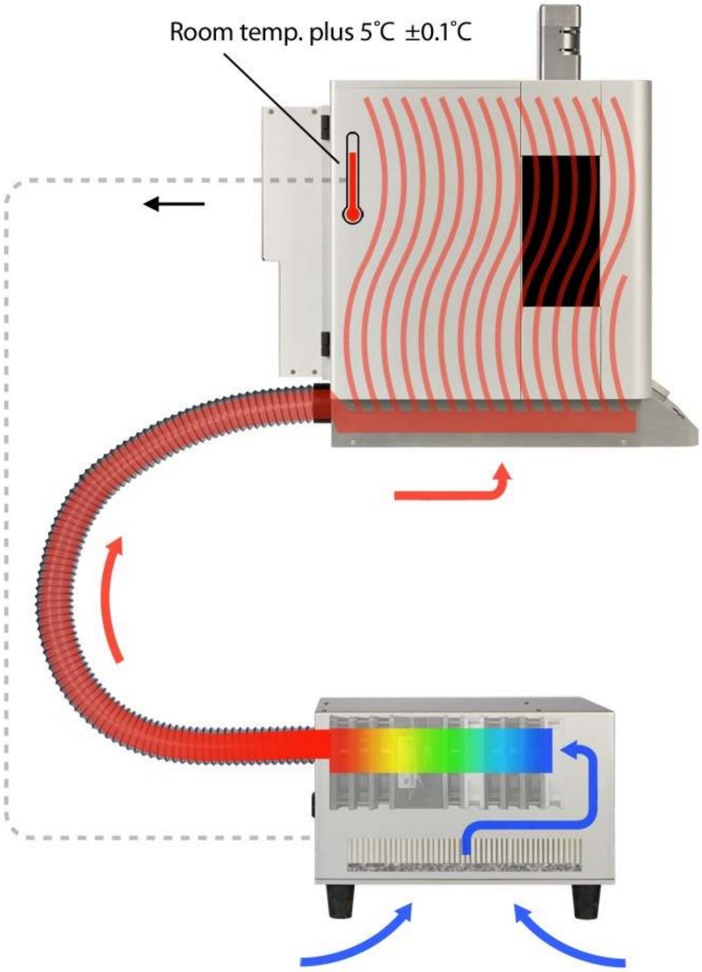


Figure 35.1.: Basic Diagram of ATC airflow. Cool lab air enters via a HEPA filter at the bottom of the Cypher ATC and then passes through fans and heater coils and travels via corrugated hose to the Cypher enclosure. Temperature signals travel from the Cypher back to the ATC (dotted line). Air exits the Cypher from the bottom rear.

The Cypher ATC is a box containing a heater/fan sub-assembly and an electronics board for controlling the amount of heat generated and the volume of air flowing into the Cypher SPM enclosure. The interior temperature of the Cypher enclosure is regulated by a software driven feedback loop that controls the ATC system's heater to maintain the temperature of a thermal sensor located on the back of the Cypher SPM chassis.

The temperature in typical labs will vary by a few degrees during the course of the day, often oscillating due to the turning on and off of air conditioning. The ATC will counter these temperature swings by adding more of less heat to counteract these temperature swings. Since the ATC can only add heat, the temperature setpoint must be set above the maximum temperature swing of the laboratory, typically 2-5 C above the average room temperature.

The ATC is not designed as an environmental controller to drive the working temperature of the sample.

35.1.1. Good Practices

To get the most out of your Air Temperature Controller, please follow these guidelines (even if you don't own an ATC, they will improve your imaging stability):

- A laboratory with decent temperature control will always lead to improved imaging stability. Typically a windowless room with air conditioning operating at all times is preferred.

- Do not place your Cypher AFM in strong air currents, such as from an air conditioning vent. If you have no choice, fashion some sort of air deflector panel.
- It can take between 6 and 12 hours for all the metal and components of the cypher AFM to thermally stabilize. Therefore the best approach is to always leave the Cypher AFM turned on and the ATC regulating the instrument temperature. If you wish you can turn off the laser at night to extend its lifetime, but note that there may still be a period of thermal drift even from turning on the laser.
- Keep the enclosure door closed as much as possible. Only open it briefly when exchanging samples or cantilevers.
- Keep critical items, such as spare cantilever holders, somewhere inside the Cypher enclosure. This will ensure all parts are at the same temperature. Some people also leave the cantilever holder changing station (see Step 9 on page 43) inside the enclosure to prevent the cantilever holder from cooling down during tip exchange. Needless to say, work quickly when replacing tips.

35.2. Parts List

Itm	Part #	Item Description	Qty	Picture
1	901.901.1	ATC Unit.	1	
2	330.002	Air Hose.	1	
3	113.407	Hose Fitting.	1	
4	279.066	Hose Clamp.	1	

Itm	Part #	Item Description	Qty	Picture
5	409.002	AC power Cable.	1	
6	449.025	ATC Control Cable.	1	
7	448.088	Auxiliary Temperature Sensor.	1	
8	290.118	5/64” Hex wrench.	1	

35.3. Hardware Setup

35.3.1. Power requirements

The ATC has a fixed power input for use with either 100/120VAC or 220/240VAC. In all cases the power should be single phase power where the mains supply has a load and neutral line in addition to an earth ground.

During normal ATC operation the voltage on the load line is “chopped” with a circuit to supply pulses of current to the heater coils in order to vary the amount of heat generated. The return path of the current from the heater flows to the neutral line which is essentially at 0V relative to earth ground. The chopping circuit is only on the load line and cannot operate correctly with 2 phase power.

The ATC has built-in sensors on both the load and neutral lines to monitor their condition. If the sensor on the neutral line detect a voltage higher than 10VAC, the system will detect a fault state and the software will display an error message indicating that 2 phase power is present.

Please consult your facilities personnel to establish weather or not you have the proper supply voltage in you lab.

35.3.2. Connect the ATC air hose

The hose feeding the ATC air connects to a fitting on the lower half of the enclosure. If the ATC was purchased with the Cypher, the fitting will be attached. If the ATC was a separate purchase after the Cypher, the fitting will need to be attached using the following instructions.

1. Shut the ARC2 controller power off.

2. **Disconnect Cypher cables:** Disconnect:

- The Motor Power
- The Main controller cable
- The USB cable
- The Fire wire cable

Note For ease of installation only. If you have unobstructed access to the back of the Cypher then you may choose to leave the cables connected.

3. Position the Cypher so you have access to the back of the enclosure.

4. **Remove cover:** The air inlets and outlets need to be uncovered.

- Locate the 5/64” hex wrench.
- Remove the six screws holding the cover onto the enclosure
- Remove the cover and save with the other Cypher accessories

5. **Install the air inlet fitting:**

- Insert the fitting into the hole in the enclosure. The end with the short flange goes in the hole.
- Secure the fitting onto the enclosure using four of the screws you removed with the cover.

6. **Install the air hose:**

- Adjust the hose clamp so it fits loosely over the hose.
- Slide the hose clamp onto the hose.
- Push the air hose over the fitting on the enclosure.
- Tighten the hose clamp to secure the hose to the enclosure.

7. **Connect the air hose to the ATC:**

- Place the ATC on the floor below the table under the Cypher.
- Move the Cypher back to its normal location.
- Route the air hose over the edge of the table and down to the ATC.
- Push the hose into the exhaust hole on the back of the ATC. Start by guiding the end of the spiral wire inside the hose into the hole. Gently push the hose and allow the wire to go into the hole on the ATC until about 1 to 1 1/2 turns of the wire is inside the ATC.

Note You may need to install the ATC next to the Cypher if your instrument position does not allow you to have the ATC on the floor. Be aware that the ATC has two small fans which can possibly induce vibration into the system.

35.3.3. Connect the ATC

1. **Connect the ATC control cable:**

- Connect the cable to the connection labeled ATC on the backpack.
- Route the cable over the table and down to the ATC unit.
- Connect the ATC Control cable to the ATC.

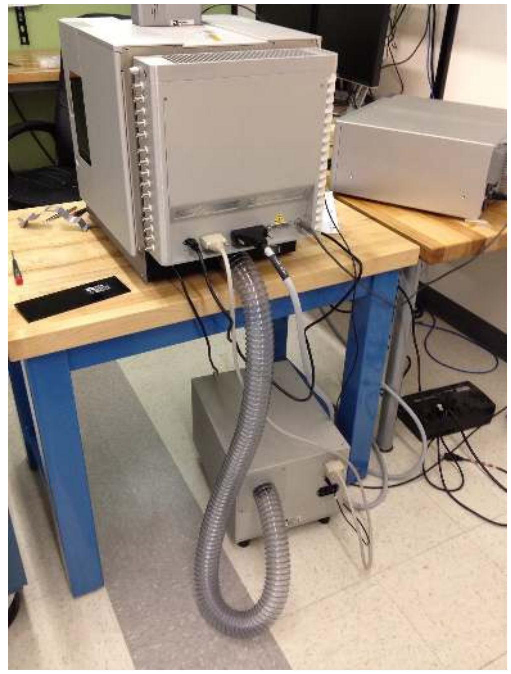
2. Connect the AC power cord to the ATC and plug it into wall power.

3.

Reconnect the Cypher cables: Reconnect:

- The Motor Power
- The Main controller cable
- The USB cable
- The Fire wire cable

The final result is shown in the photo to the right.



4.

Plug in remote temperature sensor:

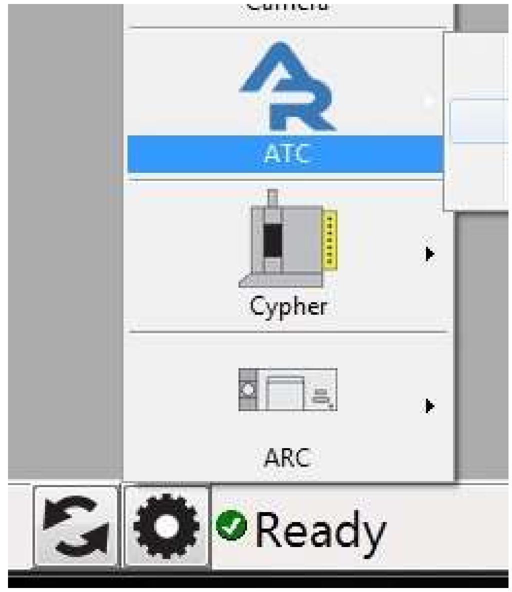
- As shown to the right, connect the auxiliary temperature sensor.
- Locate the sensing end in a place where it is sampling the room temperature. Choose a location away from warm instrument enclosures or plumes of warm instrument exhaust air.

35.3.4. Power-up and Software Initialization

1. Turn the ATC power on.
2. Turn the ARC2 controller on.
3. Re-Start the AR SPM software and home the Cypher motors.

4. **Check connectivity:**

- In the status bar of the software, click on the “gear” icon and confirm that the ATC is indeed in the list of attached instruments. If not, please check all the cable connections and click on the “recycle arrows” and then the “gear” again.



35.4. Operation

With the ATC connected and software running, from the main menu bar select *AFM controls* ▷ *ATC* to open the ATC control panel. The control panel is broken into sections containing controls grouped together based on function. Like all the other control panels in the software, a detailed explanation for each menu item can be seen by clicking on the “?” button to the right of the item of interest.

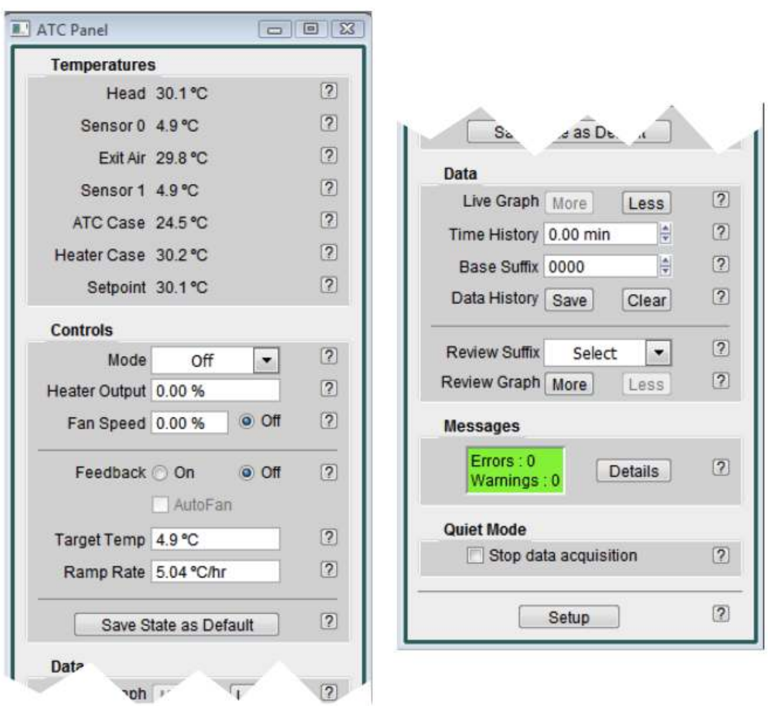


Figure 35.2.: Typical View of the ATC control panel.

The ATC control panel (Figure 35.2 on page 373) allows you to control every aspect of ATC operation. allow the user to adjust the conditions for both heating and air flow. There are two basic mode settings:

Manual Temperature control feedback operates based on values typed into the ATC panel. When the AR SPM software is exited or restarted, temperature control quits. This mode is typically used for the first few days when optimal parameters are being determined. Once these parameters are saved into ATC firmware, auto mode will likely become the typical ATC setting.

Auto The ATC operates autonomously based on values stored in its firmware. It will continue operating as long as the ARC2 controller is turned on, regardless of what the software is doing. This will likely be the typical mode of ATC operation.

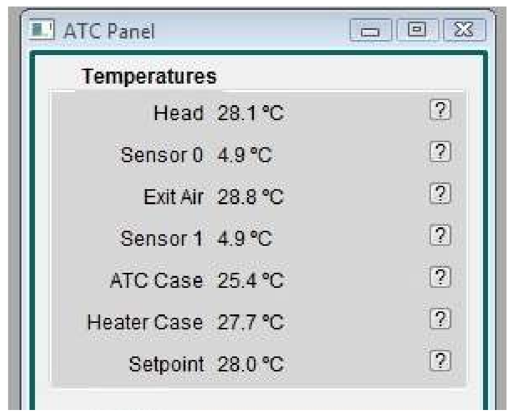
Please read on for more details.

35.4.1. Manual Control

1.

Note the room temperature:

- From the ATC control panel, note the 'sensor 0' temperature. This is the room temperature based the external sensor connected in Step 4 on page 372.

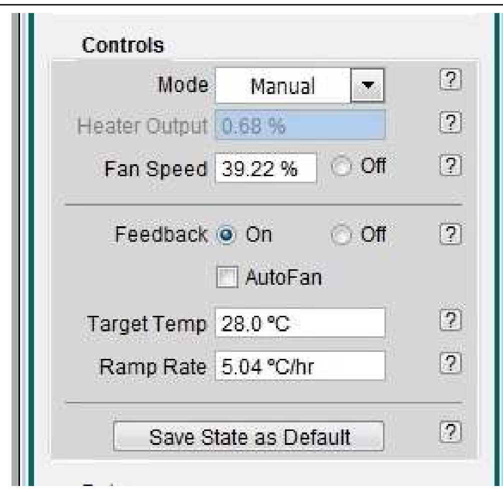


2.

Choosing the temperature setpoint:

- Make sure the feedback is set to off.
- Make sure the mode is set to manual.
- Set the 'Target Temp' to ~3 degrees C above the room temperature recorded in the previous step.
- Check that the ramp rate is 5C/sec and change if necessary.

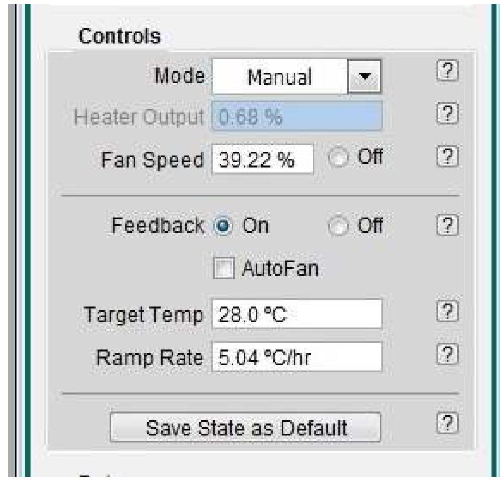
Note Target Temp is the temperature setpoint for the ATC temperature feedback control.



3.

Set fan speed:

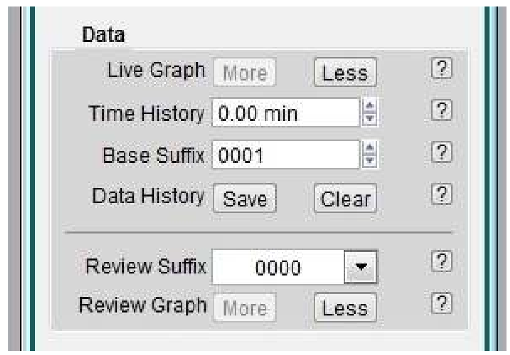
- Start with a fan speed of 100%.
- If you find imaging artifacts related to the fan, consider lowering the speed.



4.

Display datalogging: It's important to be aware of how well the temperature feedback is operating so you should get used to monitoring the temperature data history:

- Live graph - Click on the 'More' button once to display the graph. Click on the 'More' button multiple times to add sensors to the data plotted.
- For more information on datalogging, please see Section 35.7 on page 379.

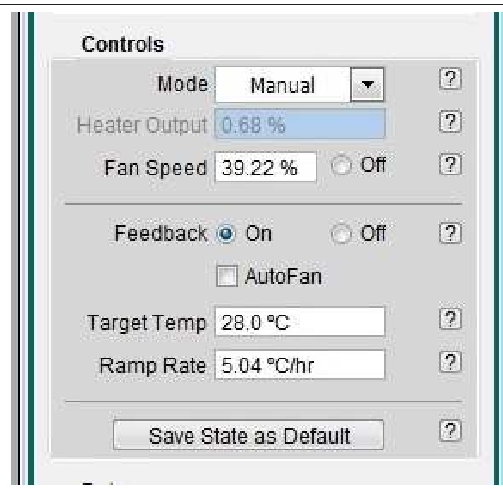


Note Even if you don't display the data, it is logged nonetheless for later inspection.

5.

Turn the feedback on:

- Click the feedback control to ON.
- Over the next hours observe the heater power variation and the head temperature converging on the temperature setpoint.
- A properly operating system will apply between 5% and 15% heater power to keep the head temperature within 0.1C of the setpoint.



35.4.2. Further Description of ATC Controls

Heater Output This controls the amount of power provided to the heating coils. The power can be adjusted to 50% power. Typically the amount of power required to maintain temperature stability is under 5%. Although not recommended, you can use this control to briefly send a burst of hot air into the enclosure to accelerate initial warm up time.

Fan Speed Has a range of 0% to 100% and is variable from 39-100%. In cases where you are scanning near atomically flat surfaces, you may see periodic noise from the fans. Reducing the fan speed will eliminate this but be aware that you need to circulate air through the Cypher in order to maintain thermal stability. In most cases, reducing the speed to 39% for a few hours will not be a problem as long as the lab temperature is sufficiently below the Target Temperature. Noise levels from the fans at 39% show negligible to no effect on the Cypher's performance.

Feedback On/Off. Enables the feedback loop which controls the heater power to maintain a constant head sensor temperature.

Target Temp. The final temperature to be maintained by the feedback loop.

Ramp Rate Rate at which the ATC adjusts the current Setpoint Temperature to achieve the Target Temp.

Note The Setpoint Temperature is located the Temperatures display area. This is a transition temperature based on the ramp rate parameter changing the feedback loop's current operating point to the Target Temp

35.4.3. Explanation of Temperature Sensors

There are three temperature sensors located inside the ATC that are primarily used to monitor the operating temperature of the unit while it's being used.

ATC Case This sensor is attached to the inside wall of the ATC box. It is used to monitor the incoming air from the room which is essentially the room temperature.

Heater Case This is a sensor mounted directly on the portion of the heater/ fan assembly containing the heating coils. Typically used for diagnostic purposes in case of overheating.

Exit Air This sensor is mounted directly in the path of the outgoing air just inside the hole where the air hose is connected to the ATC. Used for diagnostic purposes.

Head Temperature This sensor is located on the back of the Cypher Chassis about 1 inch above the rear air vent in the enclosure floor. This sensor is used by the ATC as the primary feedback source. Its location allows the sensor to be shielded from abrupt thermal changes when the door is opened.

Sensor 0 Input connection on the outside of the ATC unit. For auxiliary use.

Sensor 1 Second input connection on the outside of the ATC unit. For auxiliary use.

The ATC is shipped with 1 remote temperature sensor. This sensor can be used as the feedback sensor or to simply monitor some specific place in your setup, or, as suggested above, to monitor room temperature.

The ATC Case sensor is a reasonable second choice indicator of the lab temperature if you have are using the auxiliary sensor (see Step 4 on page 372) for another purpose.

35.4.4. Automatic Operation

After a few days of data logging you will have characterized the temperature swings in your laboratory and will have chosen an ATC temperature setpoint which is a few degrees above the maximum daily room temperature.

Tip	Your goal is to run the Cypher AFM as cool as possible since this minimizes thermal shock to the instrument when the door is opened. Ideally you choose this setpoint so that the ATC is producing heat at about the 5% level when the room temperature is maximum.

Now is a good time to store the values of the ATC panel in the firmware of the ATC unit itself with the following single step:

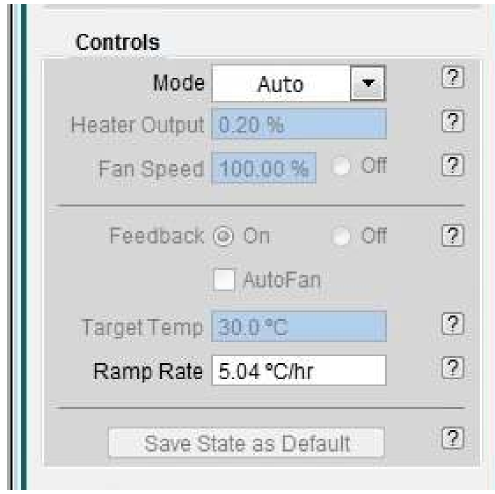
1. Under the ‘controls’ section of the *ATC Panel*, click on the ‘Save State as Default’ button.

Setting the ATC to automatic mode is also easy:

1.

Setting the mode to Auto:

- From the ‘Mode’ pulldown in the ATC Panel, select ‘Auto’.
- You will notice that some values will become “grayed out” since they are now controlled by values stored in the ATC firmware.



During operation, the ATC feedback will be maintained as long as the power to the ARC2 controller and ATC unit are left on. Exiting the software will not interrupt the ATC operation.

35.5. Enclosure Door Function

When the enclosure door is open, the ATC cannot realistically attempt to control the temperature inside the Cypher enclosure. Therefore the ATC senses the opening of the door and temporarily freezes the feedback process but keeps the fans running and also keeps the air heater power at the same level when the door opened.

Once the door is closed again (we urge you do this quickly, see Section 35.1.1 on page 367) the air keeps blowing for about a minute and then the feedback automatically resumes. You will see the LEDs on the front of the ATC change colors while this is happening. More on the LEDs in the next section.

35.6. ATC Front Panel LEDs

The LEDs on the front of the ATC unit provide a basic visual cue regrading the condition of the system.

Summary	If all three lights are green, the ATC is functioning properly and attempting to control the temperature inside the Cypher enclosure. For any other combination of colors, please read further.

ATC temperature control OFF: The ATC power is on, the Cypher enclosure door is closed and the ATC Feedback is OFF.

- This is a normal condition until the feedback is activated in the software.

Normal Operation, ATC ON, and controlling temperature. The ATC is on, The door is closed and the ATC Feedback is ON.

- Normal condition where the system should be.

Note If the ATC was just activated, the lights do not indicate if stable feedback has been reached.

Feedback ON, but door open: The ATC is on, the door is OPEN and the ATC feedback loop is in Standby mode.

- This is a typical condition when the Cypher door is opened during use.
- When the door is opened, the feedback loop is paused and the software holds the fan and heater power steady. Feedback resumes a few minutes after the door is closed again.

Note Be aware that the longer you keep the door open the more unstable the interior will become due to heat loss. It is good practice to open the enclosure door only long enough to remove the cantilever holder or exchange samples in the instrument.

Note Close the door when exchanging the tip in the cantilever holder or when you are prepping a sample.

Door just closed, but feedback still on hold: The ATC power is on, the door is CLOSED and the ATC Feedback is in Standby mode.

- The is a typical condition when the Cypher door is opened and closed.
- The Feedback loop will stay in standby mode for an additional 30 seconds and then reactivate automatically, turning all three lights to green again.

35.7. Data Logging

The data logging area allows you to monitor the temperature sensors as well as the fan speed and heater power over time. You already encountered it in 4 and we'll follow up here with some more detail.

Please refer to the data section of the ATC panel (see Figure 35.2 on page 373).

Live graph Click on the 'More' button once to display the graph. Click on the 'More' button multiple times to add sensors to the data plotted.

Data History Click on the 'Save' button to capture the history of the data.

- The data history is saved with the experiment. To review the data click on the pull down arrow attached to the 'review suffix' menu item. Select the particular data set you wish to review and hit the 'more' button to load the data into a graph.

Clear Erases the data in the graph and restarts the data acquisition. Be sure to use the 'Save' button first or those data will be lost.

Note Remember to click on the '?' button to the right of any menu item for a description of its function.

Some example logged data are shown in Figure 35.3 on page 380. These particular data log shows an ATC unit under feedback set for 29 degrees C. The fan was set to 100%

Notice:

- The data between the green lines. The feedback loop has shut the heater power off. The Cypher was already warmed up so all that needed to happen was for the fan to cool the head sensor down. At this point the ambient temperature is rising high enough so that the fans can not cool the enclosure temperature down to maintain 29 degrees. This is indicated by the head temperature increasing above the Target Temperature

Note This is an example where the Target Temperature should be raised a degree to allow the ATC to regulate the enclosure air temperature better. Ideally the target temperature is set so that the ATC never applies 0% power. That means when your lab is at its maximum daily temperature swing, that the heater is still able to control temperature.

This is an example of the ATC running with the Target Temperature set to 30 degrees C.

Notice:

- The head temperature is now equal to the target temperature.
- The heater power is between 2 and 15%. The ATC fan is still at 100% so air flow is constant.

Note This is an example where the Target temperature is set high enough above the room temperature to allow the head temperature to remain constant.

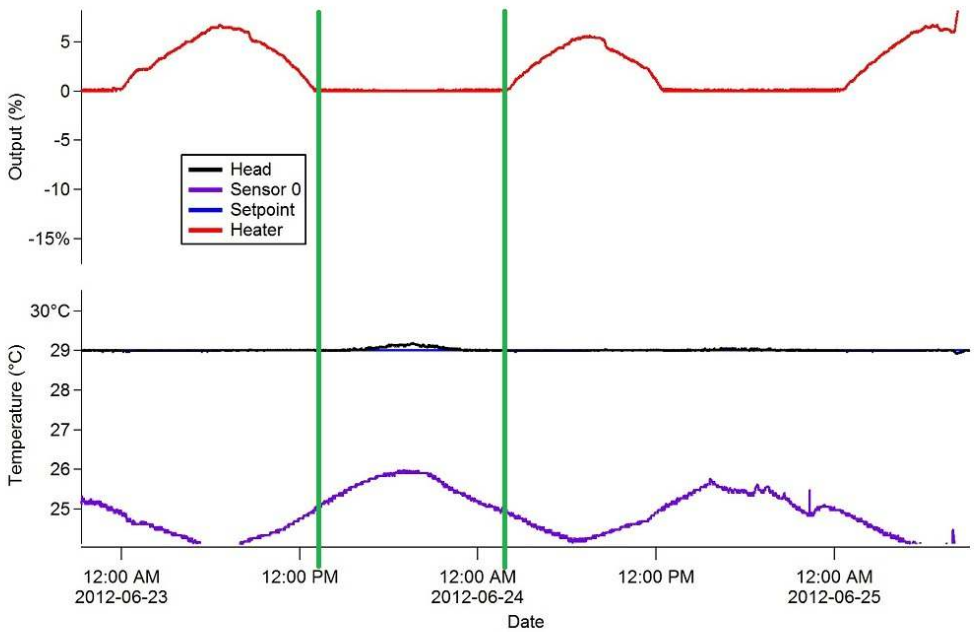


Figure 35.3.: Sample Data Log

35.8. Using the Remote Temperature Sensor

35.8.1. Inserting the Sensor Inside the Cypher Enclosure

Step 4 on page 372 already suggested using the remote sensor for measuring room temperature, but there are other uses.

The Remote Temperature Sensor can be used to monitor the temperature of a particular location inside the Cypher enclosure and can even be used as a feedback source for the ATC.

1. Turn off the power to the ARC2 controller and the ATC box.

2. **Connecting the Sensor** Plug the remote temperature sensor into either Sensor input connector on the back of the ATC unit.

   - The temperature will displayed on the corresponding sensor channel in the ATC control window.
   - Hold the sensor between your fingers and watch the temperature rise as a test.
   - Log the sensor data in the data logger as an additional channel.

   Note Additional sensors can be purchased from Asylum Research.

3. Remove the top of your Cypher enclosure by following these instructions: **??** on page **??**.

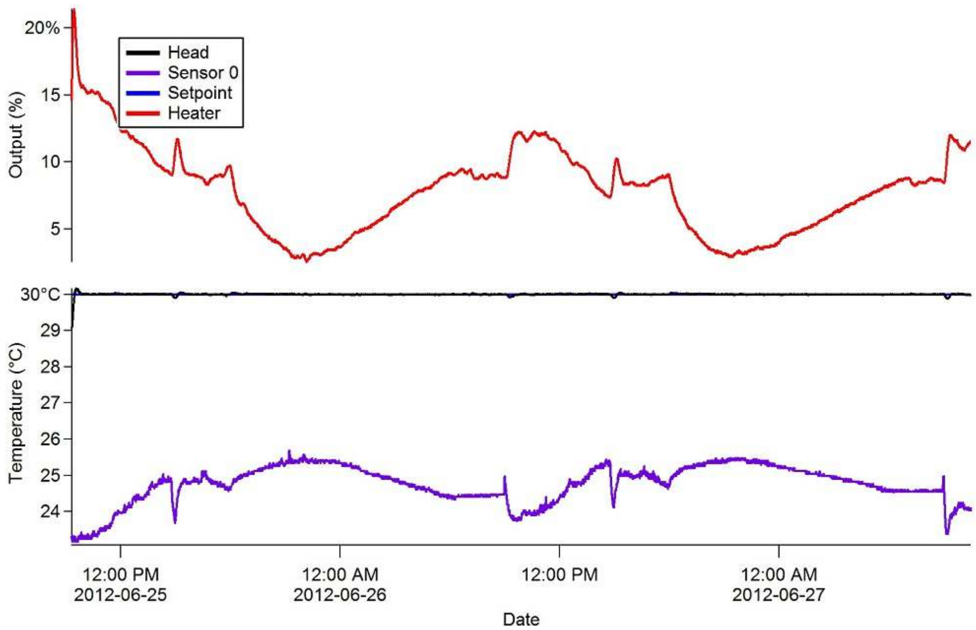
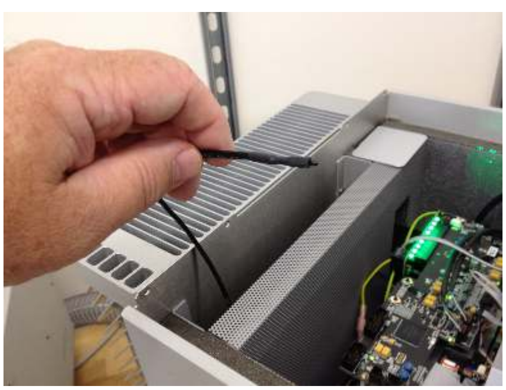


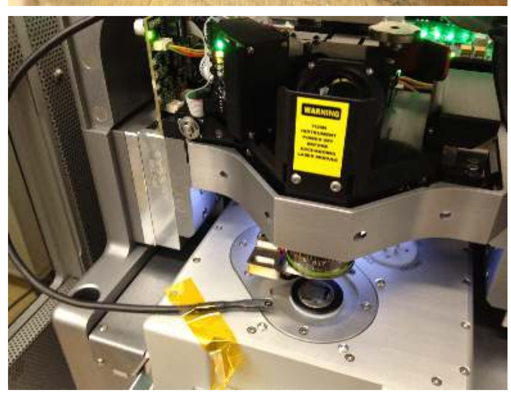
Figure 35.4.: Sample Data Log

4. **Insert Sensor inside the Cypher enclosure:**

   - Insert the sensor into the exhaust port on the back of the enclosure.
   - Pull the sensor cable up through the space in the back of the enclosure.
   - Locate and secure the sensor in the position you wish to monitor.

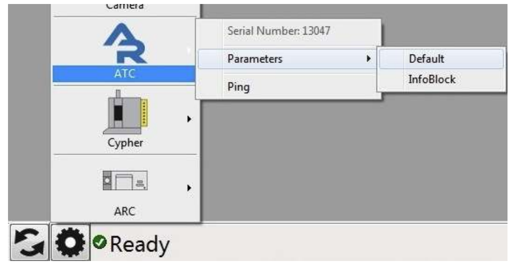
5. Replace the top of the enclosure. See **??** on page **??**.
6. Turn the ARC2 and ATC power back on.
7. You can now monitor the sensor from the ATC control panel or its data logging function.

35.8.2. Using the remote sensor for temperature feedback control

1.

Open the ATC default parameter window:

- Click on the device list (Gear Icon).
- Select *ATC* ▷ *Parameters* ▷ *Default*.

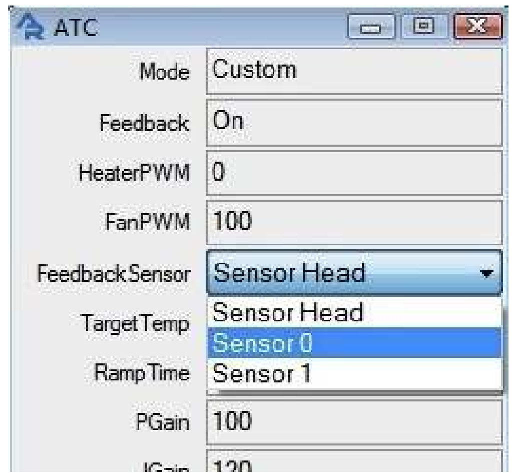


2.

Select the feedback sensor:

- Change the feedback sensor to the sensor input channel you are using.
- Set the change by clicking on the 'Write' button.

NOTE: This will change the feedback sensor temporarily. The software will default to the Head Sensor when you exit the software.



35.8.3. Permanently assigning feedback control to the remote sensor

NOTE: This change is not advised in a multi-user facility or for long term use. If you feel strongly that the location of the standard head feedback sensor should be different, it can be relocated. The sensor is on a 12” cable and can be moved or a replacement sensor can be purchased and substituted leaving the original one in place. Please contact Asylum Research for additional information.

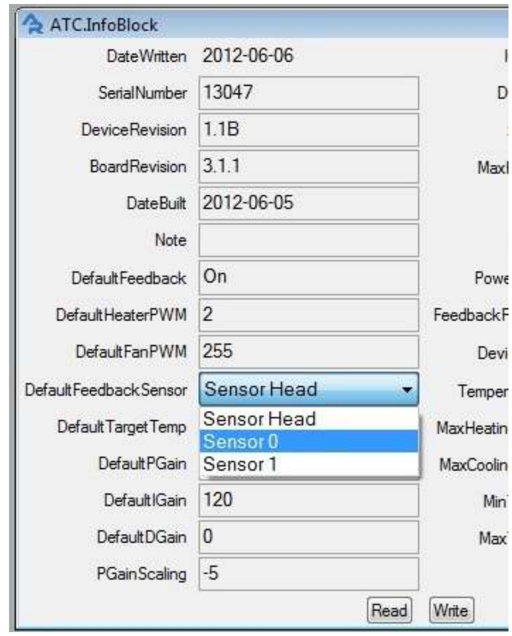
1.

Open the ATC default parameter window:

- Click on the device list (Gear Icon).
- Select *ATC* ▷ *Parameters* ▷ *InfoBlock*.

2. **Permanently select the remote feedback sensor:**

- Change the feedback sensor to the appropriate input channel.
- Click on Write to save the change.
- Rescan the smart start bus by clicking on the blue spiral button or close and open the software.



35.9. Error messages

35.9.1. ATC Messages

The **messages** area on the ATC control panel (see Figure 35.2 on page 373) shows the current operating state of the ATC. The window is typically green indicating normal operation with no errors. If an error occurs, the message box will turn red. Clicking on the 'Details' button will pop up a window with a description of the error.

35.9.2. Critical Error messages

Any time a critical error is generated, the ATC will go into a state where all heating capability is disabled. A critical error requires that a service technician reset the system. In the event of a critical error, please contact Asylum Research for assistance. A report log is generated by the system computer which can be sent to us to help diagnose the reason for the error. Please go to: my documents\asylumresearch\devices\ATC. In the ATC folder you will see a file called ERRORDUMP.PXP. If there is more than one error dump file, please send us the newest one along with a brief description of any events that may be helpful in troubleshooting the problem.

35.9.2.1. Error: Overheating

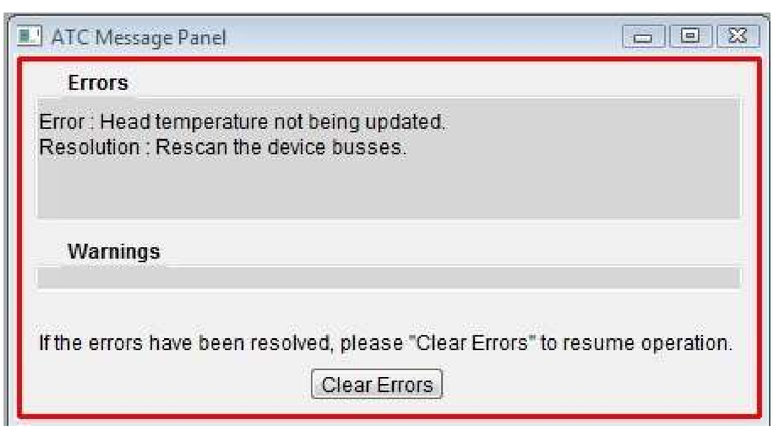
This error is the result of the ATC overheating internally which has caused one of the two thermal switches to trip. A high pitched audible alarm will also sound. The possible reasons for this error to happen can be:

- The Heater power is set too high for too long in the manual mode. This will cause the heater case to overheat and trip its safety switch. To avoid this, do not drive the heater power at max power for more than a minute or keep the heater case temperature below 50C
- The exit air is too hot causing the thermal switch in the exit air to trip. It is possible to run the heater at max power with the fan set to 100% for a longer period of time. This will keep the heater case cool but will generate too much hot air and will over heat the heater hose. The exit air switch trips at about 70C.
- The door on the enclosure is not latched completely. If the door is left ajar, it may be closed enough to keep the door detection switch closed. This essentially allows the air to escape and forces the ATC to ramp up the heat to try to compensate for the heat loss.
- The ATC air hose has fallen off or is disconnected. Same situation as above. The interior of the Cypher enclosure is cooling down while the ATC continues to heat up trying to compensate.

35.9.3. Noncritical Error messages

Noncritical error messages indicate a problem with the setup and can be cleared after the fault is corrected. After the error is cleared, the message box will turn green and full function of the ATC is restored.

35.9.3.1. Error: Head Temperature Not Updating

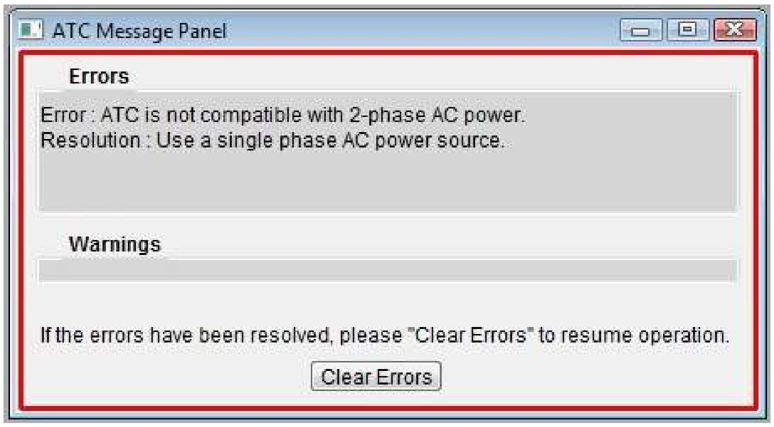


This error is caused by the Feedback Sensor (Head Sensor) not being read. The possible causes can be:

- The ATC power was shut off for more than a minute while the software was running.
- A change was made to the ATC's infoblock programming.
- The software was started with the ATC off and then the ATC power was turned on.

Note Click on the blue spiral button to the left of the device list. This will rescan the smart start bus. Alternately, you can power cycle the ARC2 controller to force a smart start rescan. Finally you can exit and reenter the software.

35.9.3.2. Error: Reverse AC Power Polarity



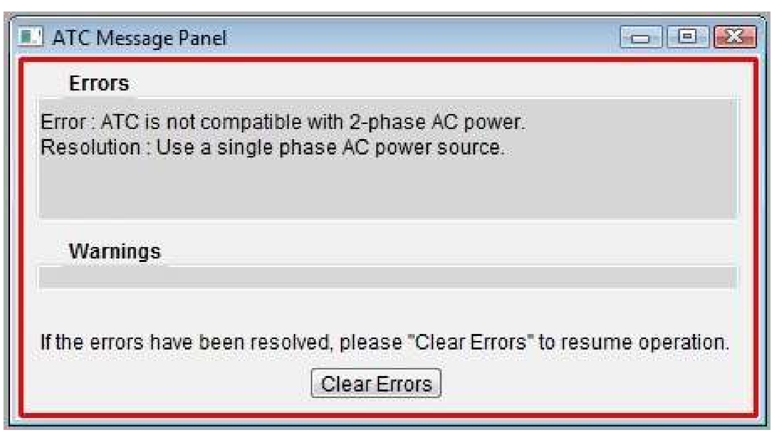
This error is caused by faulty wiring in the wall receptacle.

Usually only happens on new installations or if you've relocated the instrument to a new location.

Reverse plug on non-polarized receptacles.

Note Contact your facilities personnel to confirm correct wiring exists. Once repaired you can clear the error.

35.9.3.3. Error: 2 Phase Power



The ATC requires single phase power. This error is typically caused by the wrong type of wall power or:

- The earth ground connection may be faulty

- There is current flowing in the neutral power line which may indicate a disconnected neutral line and the return path is though the earth ground connection.

Note Contact your facilities personnel to confirm correct wiring exists. Once repaired you can clear the error.

35.10. Alarms

The ATC has two thermal switches that will trip an audible alarm when their respective temperature is reached. The alarm is an indication that an unsafe temperature has been reached inside the ATC. This condition will generate a critical error to display in the status box and cause the ATC to go into a disabled state until the error is cleared by a factory service technician.

In the event that the alarm sounds and the ATC does not shut the heater power off, an additional thermal switch on the main AC power will activate turning the unit completely off. This switch will reset after the ATC has cooled down but will reactivate if the unit continues to overheat.

Part VI

Set-up,Shipping, Maintenance and Troubleshooting

Who is this part for? Every new user should read the safety section at least one. If you need to move your AFM or ship it to Asylum Research for any reason, please consult this manual. Beyond that, this portion of the manual will probably not see much day to day use.

Part Contents

36. Shipping or Moving

CHAPTER REV. 2089, DATED 07/26/2019, 17:44. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Warning	Please contact your nearest Asylum Reseach office or distributor, or send an e-mail to support@asylumresearch.com in case you are contemplating moving or relocating your Cypher AFM. The inustrument can be damaged if moved improperly or taken apart incorrectly. Opening the enclosure may also lead to unsafe situations as the enclosure protects the user from potentially harmful electronics and laser radiation.

37. Cypher Setup

CHAPTER REV. 845, DATED 03/06/2012, 20:12. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

37.1. Facilities Requirements

37.2. Cable Connections

38. Troubleshooting and Maintenance

CHAPTER REV. 2106, DATED 09/18/2019, 12:37. USER GUIDE REV. 2110, DATED 09/20/2019, 16:35.

Chapter Contents

38.1. Maintenance

Cypher is a maintenance free instrument. The exterior housing can be cleaned with a damp cloth using a non agressive solvent like isopropyl alchol.

There are no user maintainable or user serviceable parts inside the instrument.

If necessary, fuses in the AFM controller can be replaced as needed. See Chapter 3 on page 21

38.2. Using a USB drive causes Cypher to lose communication

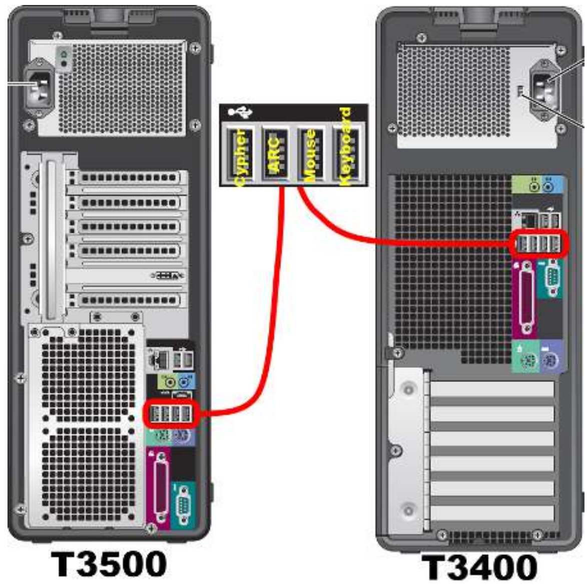
38.2.1. Problem Summary

A USB memory stick or portable USB drive is plugged into the front panel of the computer, causing all sorts of communication errors to show up in the Igor log window. A customer may report only the communication errors, not remembering they were using a portable USB device at the time.

38.2.2. Workarounds

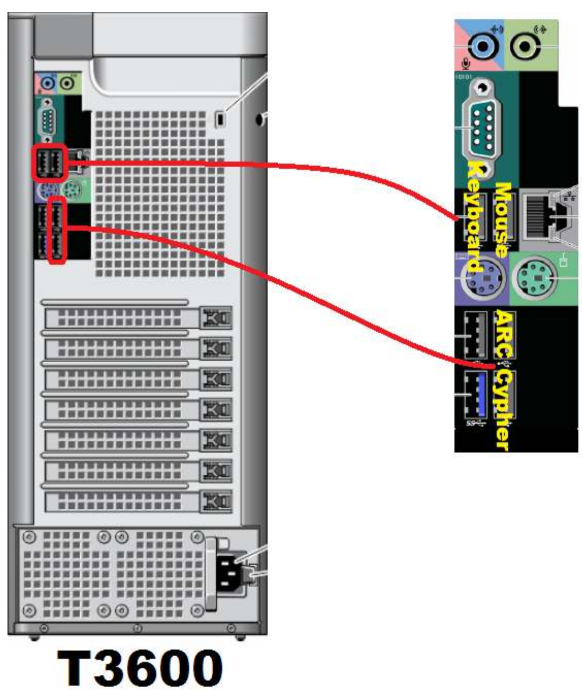
38.2.2.1. Dell T3400 and T3500

- Plug Cypher, ARC, mouse and keyboard into the **bottom USB ports** as shown in the picture below.
- USB 2.0 devices like USB drives and printers and LCD monitor hubs may now safely be plugged into the remaining non-circled ports, including the two USB ports on the front of the computer.



38.2.2.2. Dell T3600

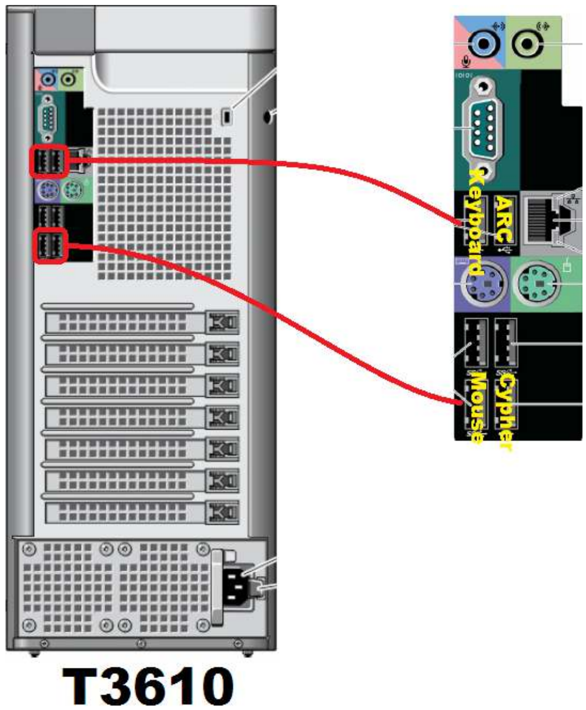
- Plug Cypher and ARC into the **bottom-right USB ports** as shown in the picture below. Do not plug Cypher or ARC into the USB 3.0 ports (marked SS for SuperSpeed).
- Plug mouse and keyboard into the **top USB ports** as shown below.
- USB 2.0 and 3.0 devices like USB drives and printers and LCD monitor hubs may now safely be plugged into the remaining non-circled ports, including the four USB ports on the front of the computer.



38.2.2.3. Dell T3610

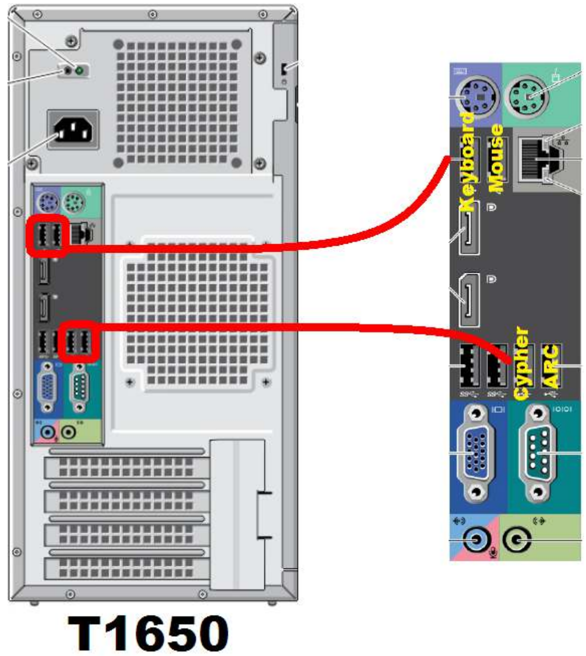
- Plug ARC into the **top-right USB port** as shown in the picture below.

- Plug Cypher into the **bottom-right USB port** as shown in the picture below.
- Do not plug Cypher or ARC into the USB 3.0 ports (marked SS for SuperSpeed).
- Plug keyboard into the **top-left USB port** as shown below.
- Plug mouse into the **bottom-left USB port** as shown below.
- USB 2.0 and 3.0 devices like USB drives and printers and LCD monitor hubs may now safely be plugged into the remaining non-circled ports, including the four USB ports on the front of the computer.



38.2.2.4. Dell T1650

- Plug Cypher and ARC into the ***bottom-right USB ports*** as shown in the picture below.
- Plug mouse and keyboard into the ***top USB ports*** as shown below.
- USB 2.0 devices like USB drives and printers and LCD monitor hubs may now safely be plugged into the remaining non-circled ports, including the four USB ports on the front of the computer.



38.2.2.5. Computers that do not have two USB 2.0 host controllers

Buy another USB 2.0 host controller on a card. Plug Cypher and only Cypher into it.

Part VII

Bibliography, Glossary, and Index

Part Contents

Bibliography

Cited Scientific References

Cited Asylum Research Documents

Applications Guide, Chapter: AC Mode Imaging in Air.

Applications Guide, Chapter: Conductive AFM.

Applications Guide, Chapter: PFM Using DART.

Applications Guide, Chapter: Single Frequency PFM.

Applications Guide, Chapter: Thermals.

MFP-3D User Guide, Chapter: Tutorial: AC Mode Imaging in Air.

Index

About the index:

- Page numbers are preceded by the user guide part. The two are separated by a dash.
- **Bold** printed page numbers are references to the definition of terms.
- Other page numbers indicate the use of a term.