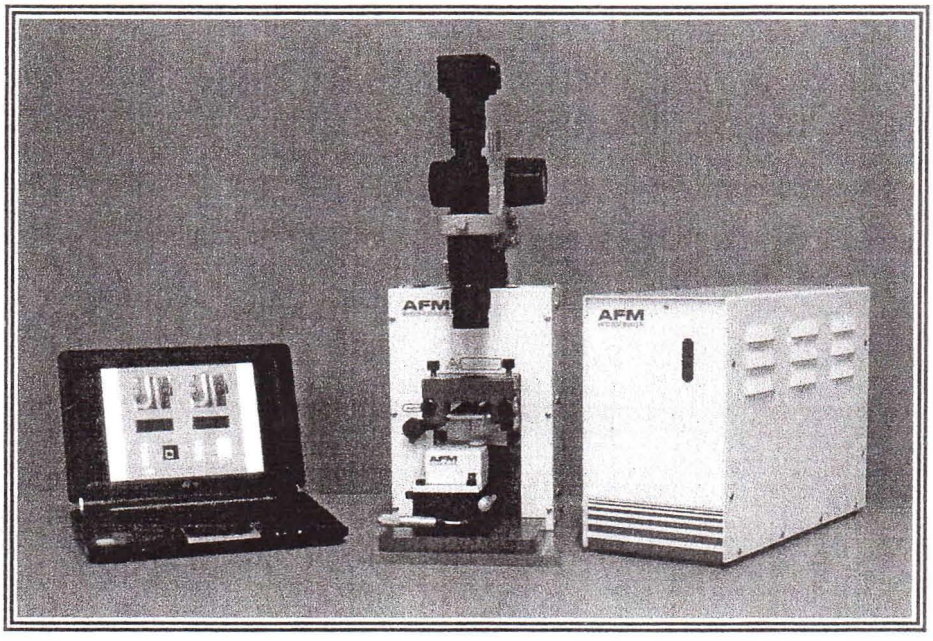
AFM WORKSHOP™

# TT-AFM

## Users Guide




Part # 10-4172-10

## Definitions and Symbols

The following terms and symbols are used in this document and also appear on the product where safety-related issues occur.

### General Warning or Caution

The exclamation symbol may appear in warning and caution tables in this document. This symbol designates an area where personal injury or damage to the equipment is possible.

### European Union CE Mark

CE

The presence of the CE Mark on AFM Workshop equipment means that it has been designed, tested and certified as complying with all applicable European Union (CE) regulations and recommendations.

### Warnings/Cautions/Notes

The following are definitions of the warnings, cautions and notes that may be used in this manual to call attention to important information regarding personal safety, safety and preservation of the equipment, or important tips.

WARNING
**Situation has the potential to cause bodily harm or death.**

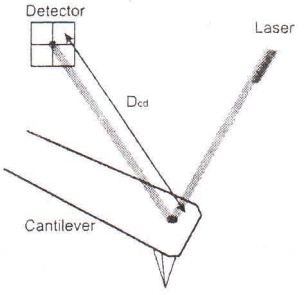
CAUTION
**Situation has the potential to cause damage to property or equipment.**

NOTE
**Additional information the user or operator should consider.**

# Contents

## 1. Introduction to Atomic Force Microscopy

In an AFM (atomic force microscope), a probe is scanned over a surface and the motion of the probe is monitored to create a three-dimensional image of the surface. Such microscopes are capable of measuring surface features of only a few nanometers in size. These unique instruments are capable of measuring high-resolution images in ambient air and liquids.

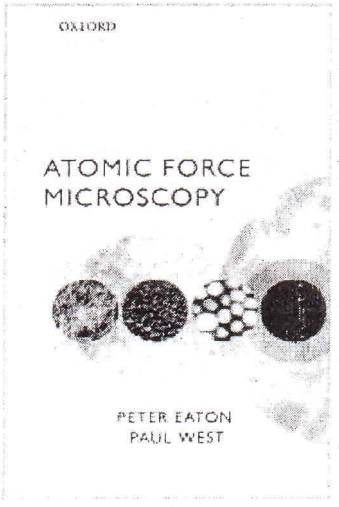



The three-dimensional motion of the probe (or sample) is generated with piezoelectric ceramics. With the piezoelectric ceramics, motions as small as a fraction of a nanometer are possible. Typically the sample (or probe) is moved in a raster pattern as the probe glides across the surface.

A light lever sensor is used for controlling the force of the probe on the surface while the sample is scanned. The light lever reflects a laser beam off the surface of a cantilever into a photodetector. As the probe interacts with a surface, the cantilever deflects and the motion is sensed with the photodetector.


With this light lever, forces as small as a pico-newton are possible. With such small forces, very small probes may be used. With micro-machining methods, probes can have diameters of only a few nanometers.

The light lever can be made more sensitive by vibrating the cantilever with a small piezoelectric ceramic and modulating the light. When the vibrating probe interacts with the surface, the amplitude of vibration may be monitored and used to control the probe's force on the surface.




Modern atomic force microscopes include not only a probe and piezoelectric scanner, but additional hardware for bringing the probe rapidly into the proximity of a surface. A video optical microscope is very helpful for operating an AFM. The video microscope helps with aligning the light lever and probe approach and for fining features for scanning.

For an in-depth description of AFM instrumentation, we recommend the book *Atomic Force Microscopy* by Peter Eaton and Paul West. This book provides a complete theoretical—as well as practical—explanation for the design and application of an AFM.

## 2. Introduction to the TT-AFM

When fully assembled, the TT-AFM comprises four sub-units. They are the control computer, the EBox, the stage and the video optical microscope.

### 2.1. Computer

The control computer is a standard IBM/PC-type computer with a Microsoft Windows operating system. There are two programs required to operate the TT-AFM: the first is the AFM control software and the second is the software for the color CCD camera.

### 2.2. Stage

Samples are held and scanned in the AFM stage. On the upright inside the stage is a linear translator which moves the LL-AFM sensor in a vertical direction. Also in the stage is the light lever force sensor, precision x-y stage and the piezoelectric scanner. Samples are held magnetically on a 1" diameter plate at the top of the piezoelectric scanner.

Optimal images are measured with the AFM stage if it is in a vibration- and acoustic-free environment. If necessary, a vibration and acoustic isolation system should be used. Appendix A provides more information on the best location for the AFM stage.

At the front left of the stage is a "modes" connector. Signals required for implementing additional modes such as conductive AFM, STM and EFM are provided. Additional information on the cable configuration is provided in Appendix C.

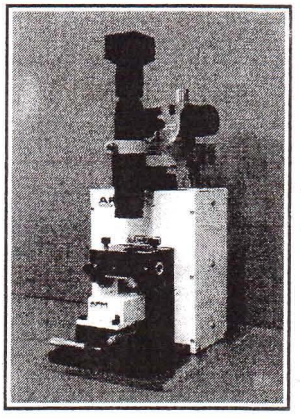


Figure 2.1. TT-AFM stage combined with the video microscope in rear mode

### 2.3. EBox

The EBox sends and receives signals from the computer through a single USB cable. Electronic signals are then sent to the stage trough a 60-pin ribbon cable. Additionally, a grounding cable is connected between the stage and the EBox. All cables are connected at the rear of the EBox. Besides the cable to the stage, there is a plug for an auxiliary 50-pin cable that gives access to the EBox's internal electronic signals. Appendix C provides additional information regarding the cables.

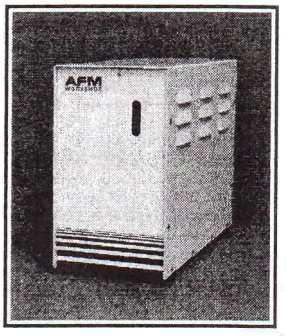



Figure 2.2. Front view of the TT-AFM EBox showing the indicator lights

### 2.4. Video Optical Microscope

Aligning the light lever force sensor is greatly facilitated by the aid of the video optical microscope. Also, the video microscope can help locate features on a surface for scanning. Finally, a tip approach can be undertaken much more rapidly with the aid of the video microscope. Images from the video microscope are displayed on a computers' video monitor.

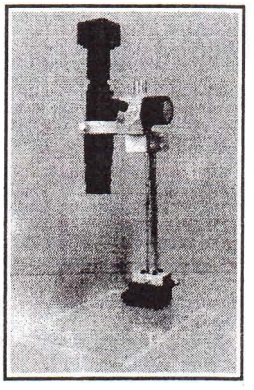


Figure 2.3. Video microscope

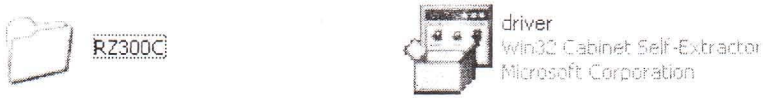
## 3. Software

The TT-AFM includes three separate software modules on a USB memory stick.

### 3.1. Loading Software

Video Microscope Software:

a) Plug USB memory stick into the computer and open the folder "CCD camera." The contents of the folder are:




b) Copy the folder "RZ300C" to the computer desktop.

c) Plug USB cable into the camera.

d) When prompted, load the camera driver from the memory stick.

e) Open folder and click on "RZS300C" to launch the program.

AFM Workshop Acquisition Software:

a) Plug USB memory stick into the computer.

b) Copy the contents of the folder "AFMWorkshop" to the desktop.

c) Once on the desktop, open the folder "AFMWorkshop" and select "setup.exe."

d) Follow the installation instructions.

Gwyddion Image Analysis Software:

Gwyddion is open-source software and the latest version of this image-analysis software is available on the Internet at: http://gwyddion.net/.

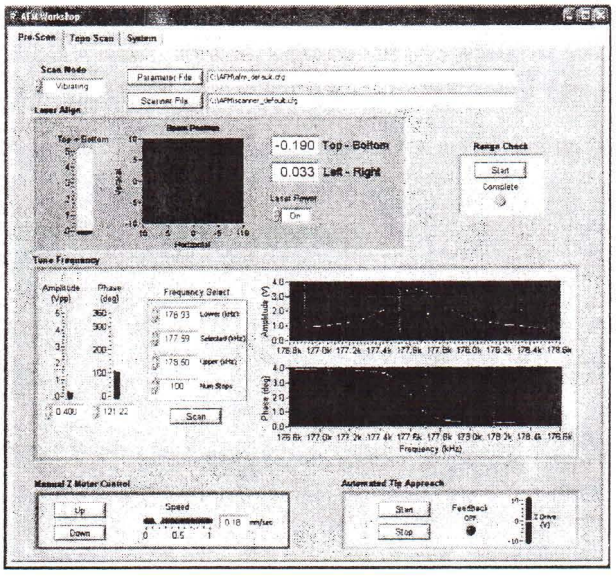
Additionally, there is a directory on the USB memory stick named "Gwyddion." The contents of the file are:

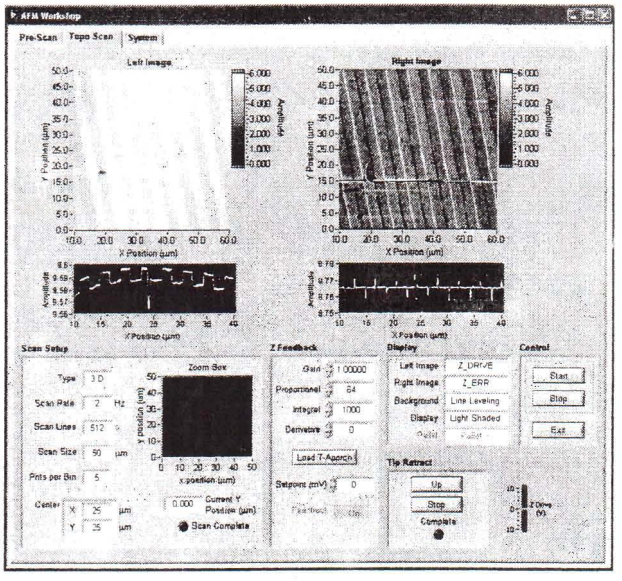

a) Launch and install the GK2.12.9 -win32 software.

b) Launch and install the Gwyddion 2.xx software.

### 3.2. AFM-View Software

Once launched, the AFM-View software has three screens that can be viewed by pressing the tabs at the top right-hand side of the screen. The first tab is for the "Pre-Scan" window and the second tab is for the "Scan" window. These two windows are all that are needed for measuring AFM images. The third tab labeled "System" is used for several functions such as measuring the Z noise floor and xyz scanner calibration.



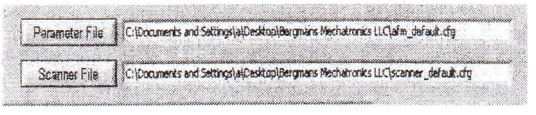




#### 3.2.1. Pre-Scan Window

The "Pre-Scan" window has all of the functions that are required before an image is measured. In this window, when a function is being used it appears with a green frame.

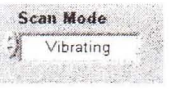
##### 3.2.1.1. Files

Two files are required to operate the AFM-View software. The "Parameter File" has parameters that are used to operate the microscope. The "Scanner File" has calibration parameters for a specific scanner. Upon launching the AFM-View software, default files are loaded into the software. Changing the files used by the program is possible with the "File" buttons. Also, these files may be edited to change parameters with a text editor such as Notepad. Appendix XX lists the contents of both the configuration and scanner file.



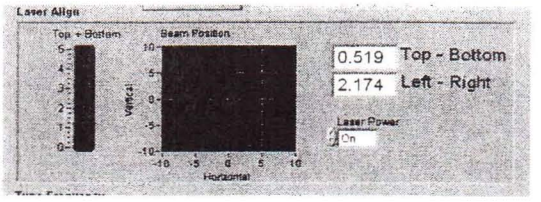
### 3.2.1.2. Modes

There are two TT-AFM modes: "Contact" and "Vibrating." The modes are selected by the "Scan Mode" button. When "Vibrating" mode is selected, the frequency sweep window is activated.




### 3.2.1.3. Laser Align

The position of the laser on the four-quadrant photodetector is presented numerically and visually with the "Laser Align" window. These two indicators are both updated in real time and are used for aligning the light lever in the force sensor. There is a switch for turning the laser "On" and "Off."




Note: After the TT-AFM light lever is set up for the first time, the thumb screws used for laser alignment do not need to be turned more than a few turns.

### 3.2.1.4. Tune Frequency

The "Tune Frequency" window is used for selecting the optimal conditions for making "Vibrating" mode images. There are several controls in the window. They are:

"Amplitude"

"Phase"

"Lower" frequency

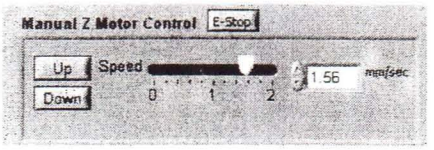
"Selected" frequency

"Upper" frequency

"Scan"

There are two oscilloscope windows in the "Tune Frequency" window. One shows the amplitude of the probe's vibration and the other shows the phase between the drive frequency and the measured frequency.

### 3.2.1.5. Manual Z Motor Control




The Z motor, which raises and lowers the LL-AFM sensor up and down, is activated with this window. The speed of the motion can be controlled with the speed slider. When the "Up" and "Down" buttons are held down, the motor slews. The motor is jogged by touching the "Up" and "Down" buttons.

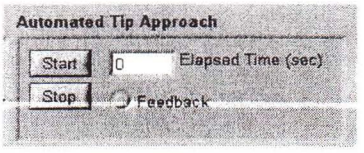
Caution: Always visually monitor the position of the Z motor. The Z motor can drive the cantilever into the xyz piezoelectric scanner and damage both the probe holder and the scanner.


### 3.2.1.6. Range Check

The usable range of the piezoelectric scanner is measured with the "Range Check" option. When "Started," the piezoelectric scanner is moved in a square motion which can be readily observed with the video optical microscope.

Caution: Before activating the "Range Check" function make sure that the probe is moved away from the sample surface. If the probe is too close to the surface, the probe may be broken.

### 3.2.1.7. Automated Tip Approach



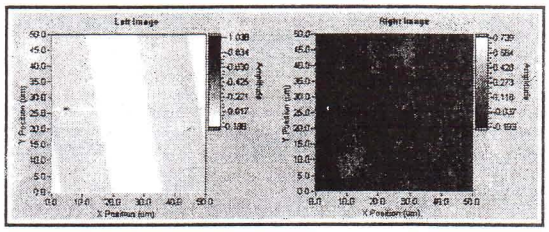

The "Automated Tip Approach" button starts the process of the probe moving toward the surface. A woodpecker motion is used, which results in noticeable clicking sounds from the microscope stage. This sound is from two sources: the stepper motor being energized and the Z piezoelectric ceramic being retracted.

### 3.2.2. Scan Window

After the instrument is set-up using the "Pre-Scan" functions, the "Scan" window is used for measuring AFM images.

#### 3.2.2.1. Image Window

Two images are displayed simultaneously while scanning. The type of images and their appearances are selected in the "Display" menu window. As the images are displayed, there is a constant normalization of the data so that the images appear in full scale.

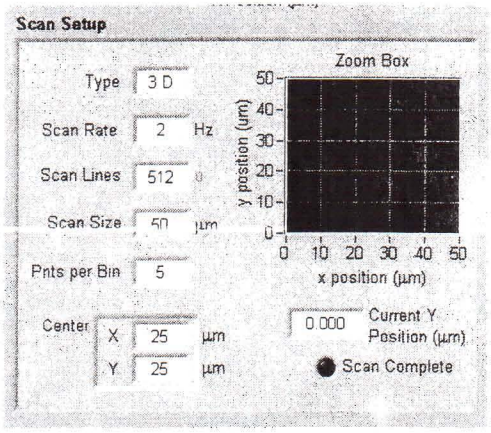


#### 3.2.2.2. Oscilloscope Window

A Z versus X position plot of the probe as it is scanned across a surface is plotted in two screens. The data plotted is selected in the "Display" window.

#### 3.2.2.3. Scan Setup

All of the parameters required for scanning are presented in the "Scan Setup" window. Once scanning is started, these parameters may not be changed. The parameters are:




"Type": The scan can be either 2-D, which scans just the X axis, or 3-D, which scans the X and Y axis.

"Scan Rate": The rate in Hertz that the probe is scanned across the surface in the X direction.

"Scan Lines": The number of lines in the Y axis and the number of pixels measured in the X axis.

"Scan Size": The range of the scan.

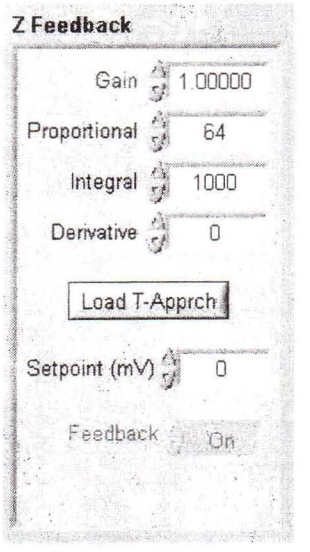
"Bits Per Bin": This is the number of data points signal averaged per pixel while a scan is being taken.

"Center": The center of the scan in X and Y coordinates.

"Current Y Position": This is the position of the probe in the Y axis as a scan is taken.

"Scan Complete": This indicator turns green when a scan is completed.

### 3.2.2.4. Z Feedback




All of the parameters for maintaining Z feedback are provided here. The parameters are:

"Gain": Scale factor for the feedback control signal.

"Proportional": Scale factor for the proportional term in the PID feedback controller.

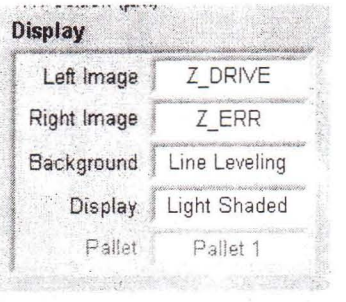
"Integral": Scale factor for the integral term in the PID feedback controller.

"Derivative": Scale factor for the derivative term in the PID feedback controller.

"Setpoint": Parameter that controls the magnitude of interaction between the probe and surface.

Caution: If the "Z Feedback" parameters are too high, the Z ceramic can begin to oscillate and potentially cause damage to the ceramic.

### 3.2.2.5. Display




There are several options for changing the appearance of the images displayed in the "Scan" window. They are:

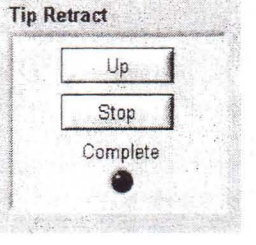
"Left Image": The source of the image displayed in the left image window.

"Right Image": The source of the image displayed in the right image window.

"Background": When "Line Leveling" is selected, the background is subtracted from the image one line at a time.

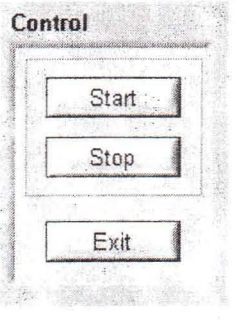
"Display": Two types of displays may be selected: "Color Map" and "Light Shaded."

### 3.2.2.6. Tip Retract




After scanning a sample, this function is used to move the tip away from the surface. The "Tip Retract" function should always be used to assure that the probe does not get damaged after scanning.

### 3.2.2.7. Control



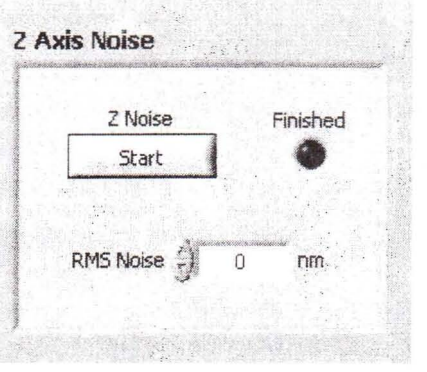

These functions start a scan, stop a scan and exit the AFM-View software.

### 3.2.3. System Window

The "System" window includes functions that are used for optimizing the TT-AFM.

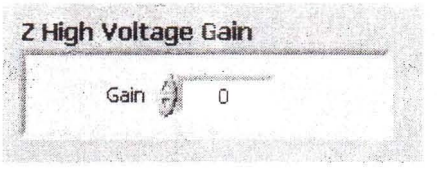
#### 3.2.3.1. Z Noise

Resolution in an AFM depends critically upon the noise in the Z direction. This function permits measuring the system's Z noise under the same conditions used for measuring images. However, the probe is not scanned while making the Z noise measurements.




#### 3.2.3.2. Z High Voltage Gain

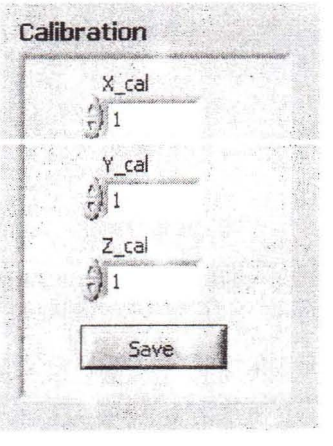
The high-voltage amplifier that drives the Z ceramic in the xyz scanner can have 14 gains. This function allows reducing the Z gain of the high-voltage amplifier. Reducing the gain reduces the dynamic range of the ceramic, but reduces the noise floor of the instrument.



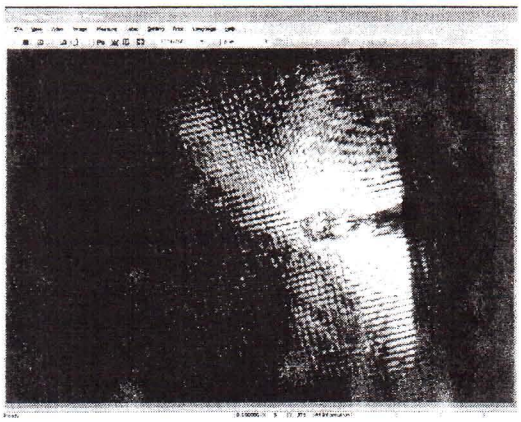

#### 3.2.3.3. Xyz Calibration

When scanning a standard test pattern, the values in this sub-window are changed. Appendix C explains how to calibrate the TT-AFM.

Note: Changing the calibration values will change the scale on images measured with the TT-AFM. Only change the values when calibrating with a reference sample.



### 3.3. Video-View Software



Software for visualizing images from the video optical microscope allows real time visualization of the probe and surface. Additionally, the software allows real time capture of images as well as videos. Operation of the video software requires substantial computer processing speed; when computers with slower processing speeds are used, the image can often change contrast. The change in contrast is triggered by other programs using the computer's processing capacity. Below is a brief description of the function found in the software package. We recommend optimizing the parameters for the particular type of sample you want to visualize. Before operating the video camera, it must be properly aligned; see Appendix A

To launch the video view software:

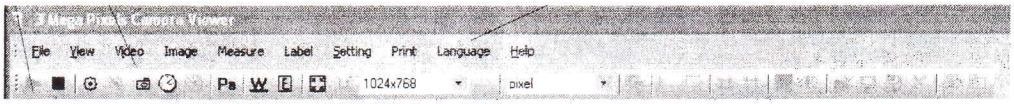
a) From the desktop, open folder "RZ300C."

b) Click on the "RZ300C" icon to launch the software.

Start Image Display

English/Chinese

Capture Image




Pause Image Display

Image Pixel Density

Signal Average Images

The quality of the image viewed with the video microscope depends directly on the reflectivity of the sample being viewed. Thus it is not possible to give instructions for optimizing the video microscope images. It is recommended that operators experiment to find the best parameters.

## 4. Measuring Images With the TT-AFM

Once put together, you can expect to take a few hours to learn how to measure images with the TT-AFM. It is very important that you learn how to:

a) operate the video microscope.
b) change samples.
c) change probes.
d) align the light lever force sensor.
e) perform video-microscope-assisted probe approach.

Once these techniques are learned, measuring images is relatively simple.

### 4.1. Operating the Video Microscope

Operating the video microscope is essential for efficient operation of the TT-AFM. We suggest that you practice operating the video microscope before attempting to replace probes or measure images.

XY Position Translator: At the base of the support pole is an XY position translator used for centering the probe in the video microscope window.

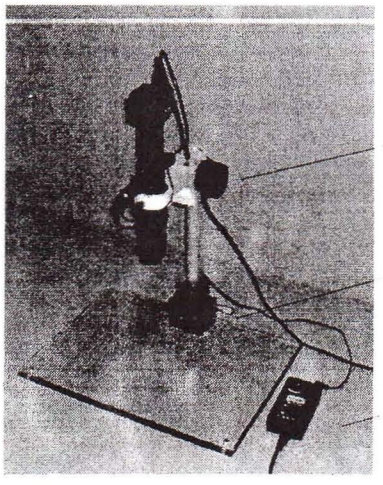
Zoom Adjust: The zoom lens allows viewing a surface at high or low magnification. The light intensity must be adjusted when using the zoom lens.

Light Intensity Adjust: It is often critical to adjust the intensity of the light on a sample to get the best image.

Focus Adjust: Adjusting the location of the microscope's focus is very important.

Note: If you are not familiar with the operation of a video optical microscope, please review the contents of Appendix A, section 2.

Zoom Adjust



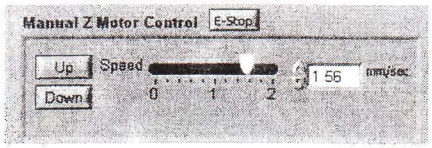
Focus Adjust

XY Position Translator

Light Intensity Adjust

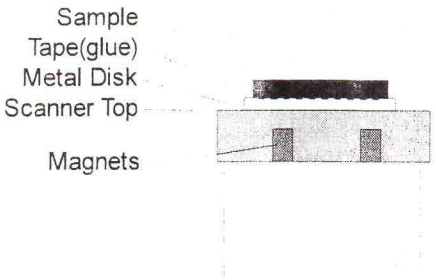
### 4.2. Exchanging Samples

Metal disks serve as the sample holders for the TT-AFM. Samples may be attached to the disks with double sticky tape or with glue. Once a sample is attached to the disk, it is held on the microscope's sample holder magnetically. It is critical that the sample be tightly bound to the sample disk. If it can vibrate, then the image resolution will be substantially degraded.



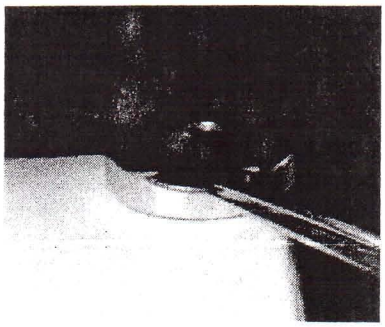

To Exchange Samples:

a) Raise the Z motor all the way up with the "Z Motor Control" function in the "Pre-Scan" window.



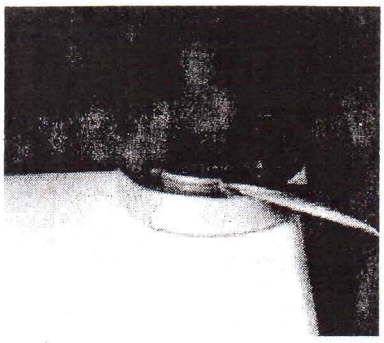

b) Remove the probe holder (see section 4.3.)

c) Place the sample disk on the top of the sample holder.



Caution: Do not place excessive force on the sample holder, as it could break away from the piezoelectric ceramic.

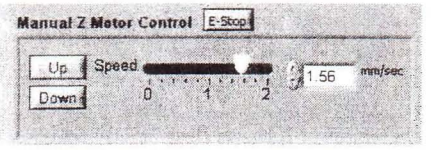
d) Slide new sample disk/sample onto the sample holder.



e) Replace the probe holder.

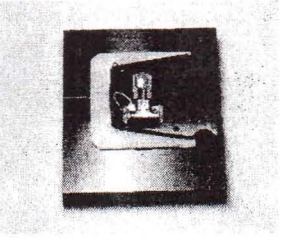
### 4.3. Exchanging Probes

Exchanging probes takes less than three minutes in the TT-AFM if the following steps are used:



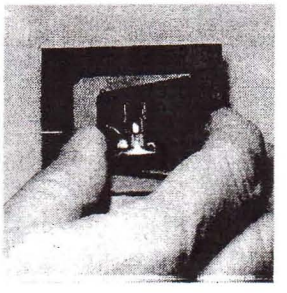

a) Raise the Z motor until the probe is about ¼ " from the sample's surface.

b) Remove the probe holder.

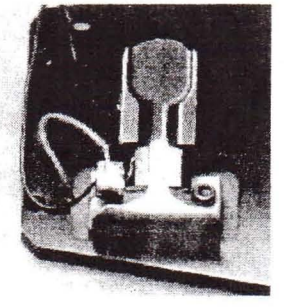


c) Place the probe holder upside down on the probe exchange tool.

d) Put the probe that you want to install on the pedestal of the probe exchange tool.



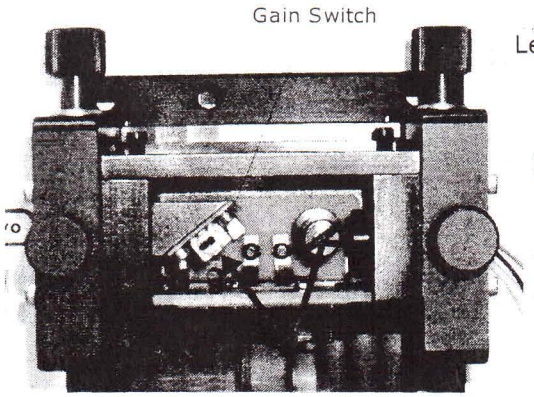
e) Push down on the probe module such that the spring is moved up and then slide the probe into position. To slide the probe into the spring, use a sharp pair of tweezers.



f) Place the probe holder back into the microscope.

### 4.4. Aligning the Light Lever Force Sensor

Aligning the light lever force sensor is greatly facilitated by understanding the optical path of the light in the sensor. The following figure shows the light path and the effect of turning the adjustment knobs on the light lever.




Red Dot in Pre-Scan

Motion of the red dot in the "Pre-Scan" window when the detector adjust knobs are turned clockwise.

Video Microscope View

Motion of the laser spot when the laser adjust knobs are turned clockwise.

Tips for aligning the laser in the light lever force sensor:

a) After replacing a cantilever, the laser and photodetector adjustments are usually less than a single turn.

b) It is often difficult to see the laser spot on the cantilever because the cantilever reflects the light.

c) Bringing the cantilever within a mm of the sample's surface can help because you can see the laser on the sample's surface.

d) If the cantilever does not alight within a few minutes, try another cantilever.

e) The adjustment screws have backlash, so sometimes the motion is not perfectly linear.

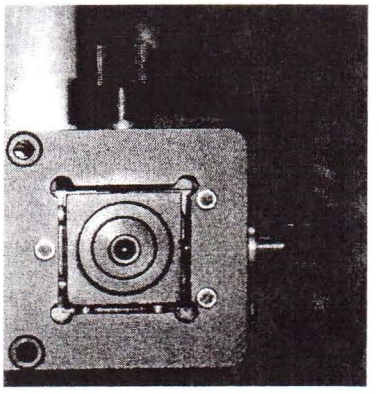
f) When in "Vibrating" mode, if the resonance peak appears inverted at the top, move the detector gain from "High" to "Low."

Light Lever Alignment Procedure:

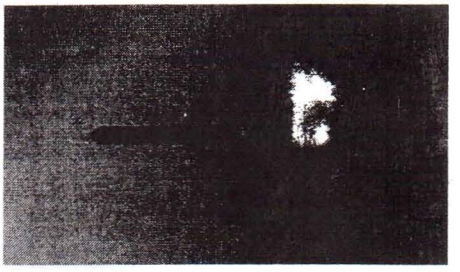
These instructions assume that the light lever is already set up and aligned. If not, please see the instructions in Appendix A.6.

a) Make sure that the laser light is turned on.

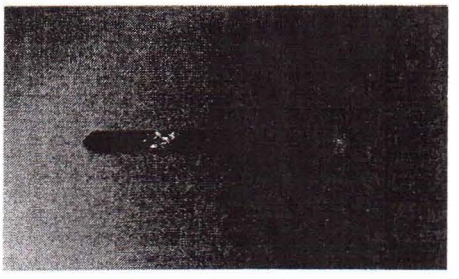
b) Position the laser and detector position mechanisms at the center of their range.



c) Turn the detector knob at the top of the sensor counter clockwise (to the left) until light is visible on the cantilever substrate. This should only require one or two turns.



d) Use the two laser alignment knobs to "walk" the laser onto the cantilever.



5) When the laser is on the cantilever in the right position (contact position is different the vibrating position), move the two photodetector adjustment knobs until the red dot is in the correct place.

### 4.5. Optical Assisted Tip Approach

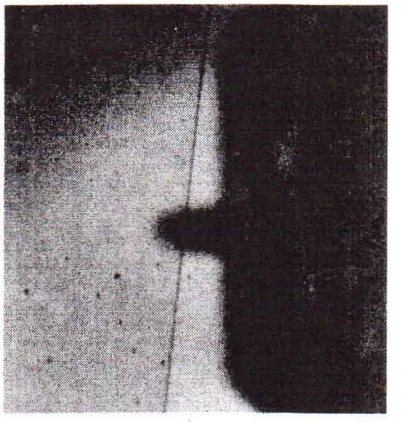
Tip approach in the TT-AFM is achieved using a woodpecker algorithm activated in the "Pre-Scan" window. Before activating the "Automatic Tip Approach" function it is desirable to move the probe as close to the surface as possible. The video microscope can be helpful.

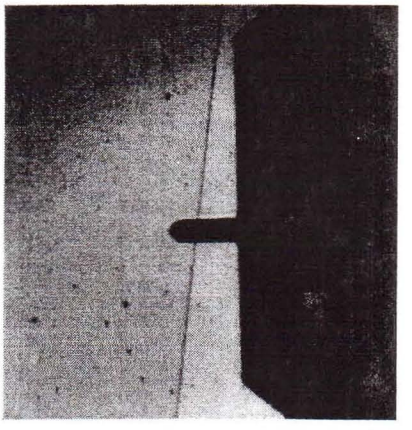
a) Focus the video microscope on the sample's surface.

b) With the manual motor control, move the tip down until it can be seen in the video microscope image.

c) Slowly use the "Jog" function in the manual motor approach and move the probe down until it is also in focus.

At the right are two images of a probe as it moves toward a surface. Care must be taken not to hit the surface with the probe.



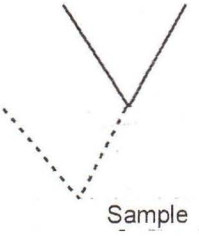


Note: If the tip touches the surface before the "feedback" is activated, the tip may be damaged or even broken.

Typically when doing tip approach with the AFM, the laser is on. The laser focus spot can be seen on the cantilever when the cantilever is a sizable distance from the surface. As the probe gets close to the surface, a second laser spot is seen on the surface. As the probe gets closer to the surface, the two spots appear to merge. This effect is useful for judging the distance of the probe from the sample.

Tip Away From Surface

Tip Near Surface



### 4.6. Contact Mode Imaging

These instructions assume the AFM-View software is properly loaded and working, and that you have reviewed the features of this program presented in section 4.2.

1) Follow the instructions in section 4.2. and place sample in instrument.

2) Follow the instructions in section 4.3. and place a contact mode probe in instrument. See Appendix D for a probe recommendation.

3) Focus the video optical microscope on the AFM probe.

4) Follow the instructions in section 4.4. to align the laser on the probe. The laser spot should be about halfway down the cantilever; the T-B signal must be greater than one.

5) Select "Contact" in the "Scan Mode" window.

5a) Focus video microscope on sample's surface.

5b) If this is the first scan since opening the AFM Workshop software, click on "Start" in the "Range Check" window.

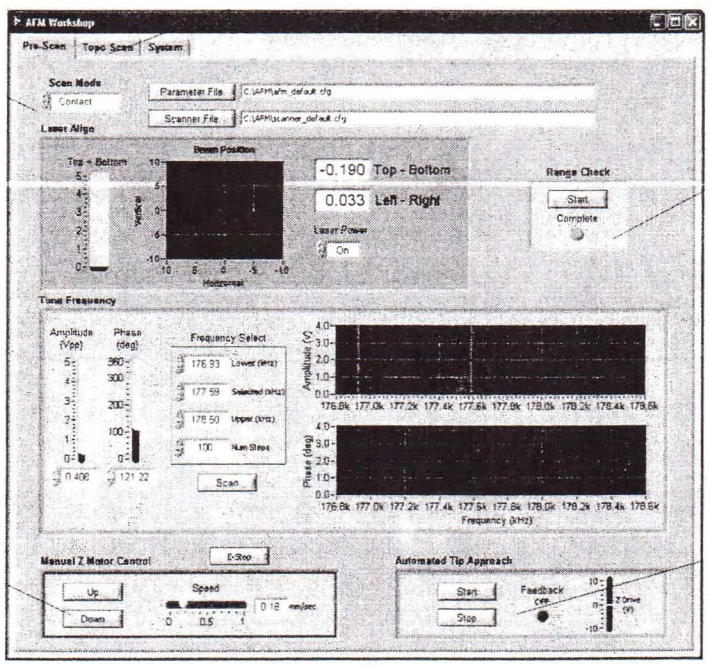
6) In the "Pre-Scan" window, use the "Manual Z Motor Control" to move the motor to the sample, probe just out of focus.

7) In the AFM-View "Pre-Scan" window, initiate "Automated Tip Approach." Wait for the green light to indicate that feedback was achieved.

7a) If the the "Z Drive" indicator is not near the center of its range, start the automated tip approach again.

8

5




5b

6

7

9) Select scan parameters such as "Scan Size," "Scan Rate" and the number of lines.

10) Select the 2-D scan option in the "Scan Setup" window.

11) Press "Start" in the "Control" window.

12) Optimize the GPID and set point parameters (instructions in Appendix F).

13) Once the parameters are optimized, stop the 2-D scan using the "Stop" function in the "Control" window.

14) Select 3-D scan in the "Scan Setup" window.

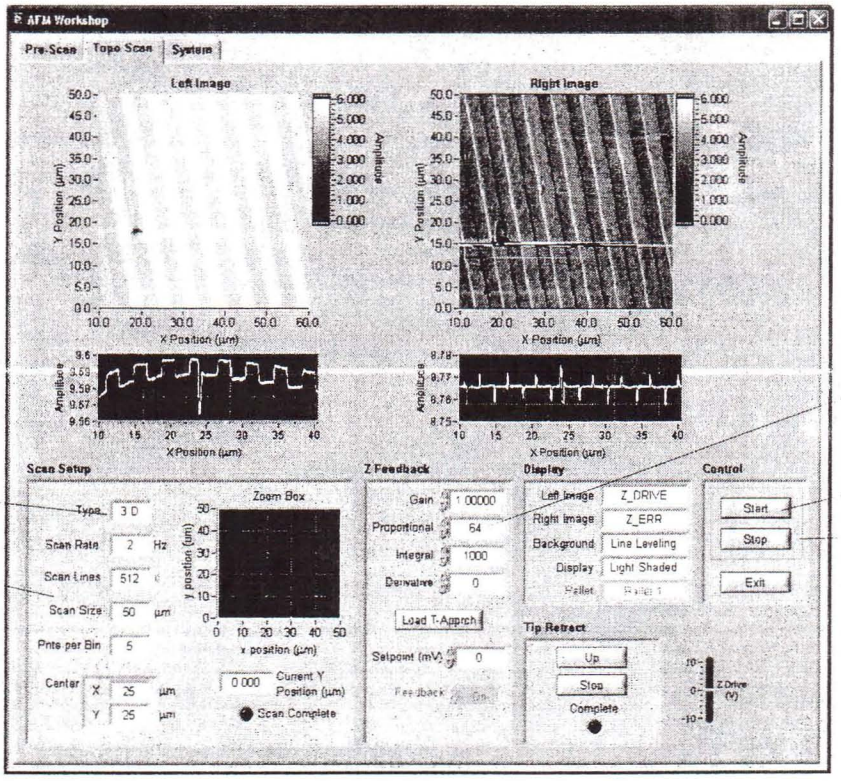
15) In the "Control" window activate "Start."

16) When the scan is completed, the light turns green.

17) If desired, select a different zoom box and start the scan.

18) When finished scanning, press "Tip-Retract."

Note: At the end of every scan, data is automatically stored in a pre-selected directory.



### 4.7. Vibrating Mode Imaging

These instructions assume the AFM-View software is properly loaded and working, and that you have reviewed the features of this program presented in section 4.2.

1) Follow the instructions in section 4.2. and place sample in instrument.

2) Follow the instructions in section 4.3. and place a vibrating mode probe in instrument. See Appendix D for a probe recommendation.

3) Focus the video optical microscope on the AFM probe.

4) Follow the instructions in section 4.4. to align the laser on the probe.

5) Select "Vibrating" in the "Scan Mode" window.

5a) Initiate the "Range Check" function.

6) Select the frequency:

6a) Set the lower limit to the number on the probe box.

6b) Set the higher limit to the number on the probe box.

6c) Set the number of points to 100.

6d) Scan the frequency.

6e) Move the red and green cursors to the resonance peak.

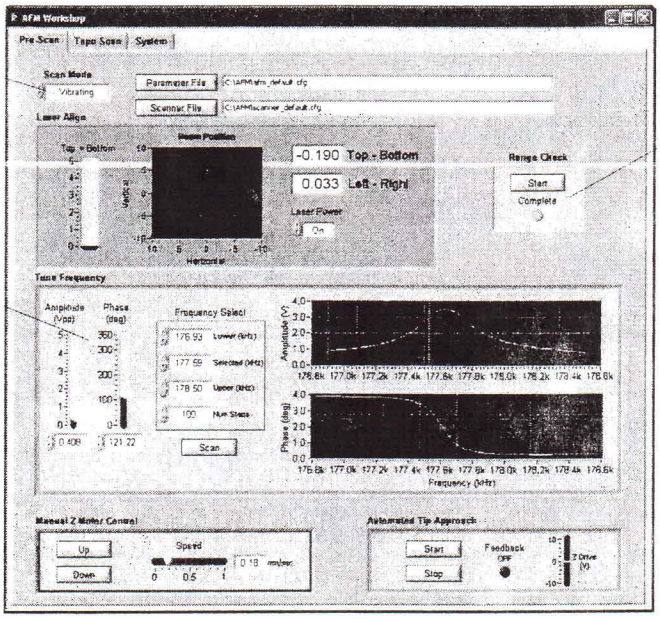
6f) Scan again.

6g) Drag the blue line to the left of the peak.

5

5a

6



7) Focus video microscope on sample's surface.

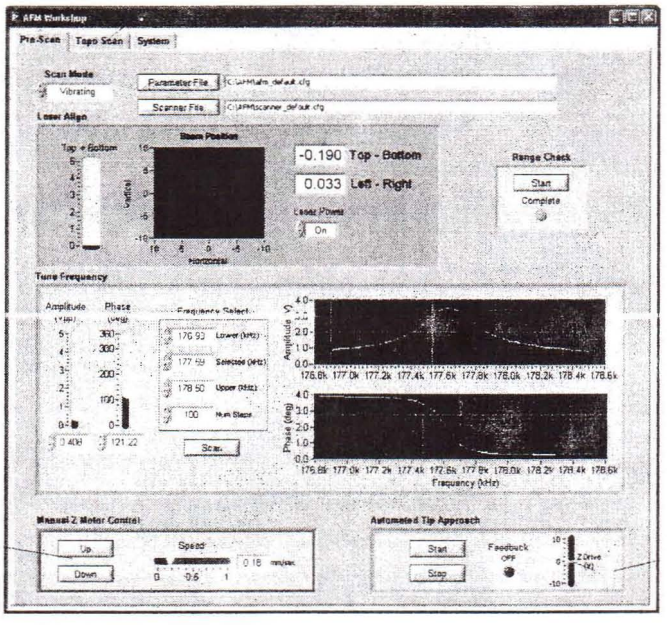
8) Using the "Pre-Scan" software "Manual Z Motor Control," move motor to sample, probe just out of focus.

9) In the AFM-View "Pre-Scan" window, initiate "Automated Tip Approach." Wait for the green light to indicate that feedback was achieved.

9a) If the "Z Drive" indicator is not at the center of its range, start tip approach again.

10) With the "Scan" tab at the top of the AFM-View window, open the "Scan" window.

10




8

9

11) Select scan parameters such as "Scan Size," "Scan Rate" and the number of lines.

12) Select the 2-D scan option in the "Scan Setup" window.

13) Press "Start" in the "Control" window.

14) Optimize the GPID and set point parameters (instructions in Appendix F).

15) Once the parameters are optimized, stop the 2-D scan using the "Stop" function in the "Control" window.

16) Select 3-D scan in the "Scan Setup" window.

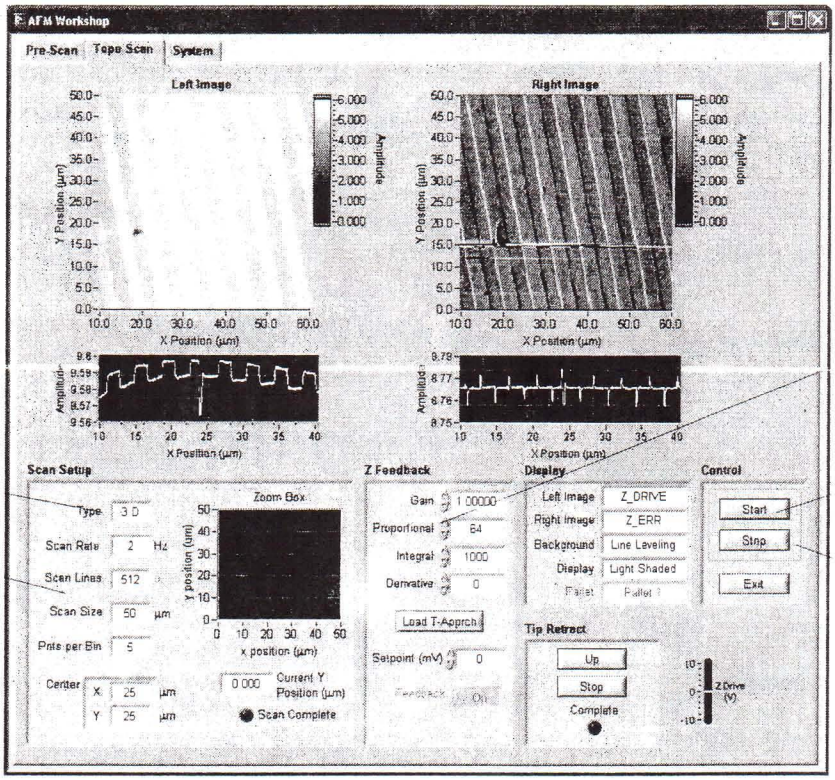
17) In the "Control" window activate "Start."

18) When the scan is completed, the light turns green.

19) If desired, select a different zoom box and start the scan.

20) When finished scanning, press "Tip-Retract."

Note: At the end of every scan, data is automatically stored in a pre-selected directory.




14

12,16

13,17

11

15

## Appendix A: Setting Up the TT-AFM

A.1. Selecting a Location:

Structural vibrations from a building's floor and acoustic vibrations can greatly reduce the resolution of an AFM. Ideally, the AFM would be placed in a vibration-free environment, but this is typically not possible. A few tips:

- Set the AFM up in a building's basement or lower floor near a bearing wall.
- Avoid setting the AFM near fans or other sources wind turbulence.
- Avoid locations where there are elevators, a lot of foot traffic or freeways.
- If you must place the AFM in an undesirable location, consider purchasing a vibration table and/or acoustic enclosure.
- A simple test to see if a location has a problem is to fill a coffee cup with coffee and set it in the potential location. If there are ripples in the coffee's surface, there are going to be problems.

A.2. Setting Up the Optical Microscope:

The video optical microscope is essential for efficient operation of the TT-AFM. After setting up the microscope, we recommend spending some time to operate it by viewing some samples.

a) Assemble the video microscope:

1) Attach the post to the X-Y translator using four screws and a hex wrench.

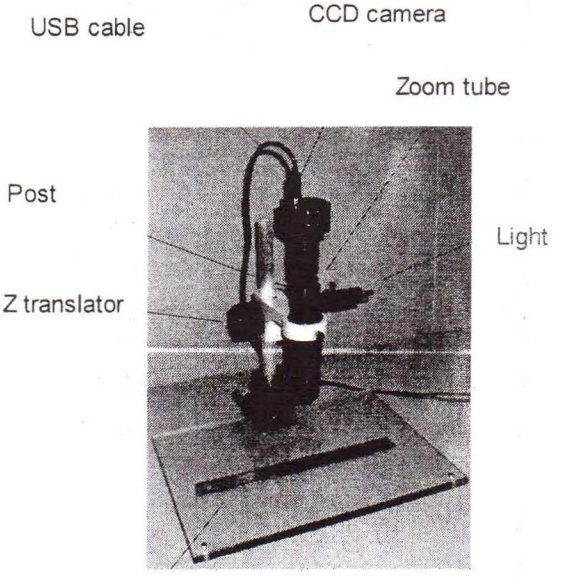
2) Place the Z translator on the post and tighten.

3) Install the zoom tube/CCD camera.

4) Attach the USB cable to the CCD and computer.

5) Plug the light power into the plug.

6) Remove the black cap at the bottom of the zoom tube.




Ruler in place for test of video optical microscope

b) Test the microscope and verify its operation:

1) Launch the "Video View" software (see section 3.1. ).

2) Turn on the light and adjust the intensity now to its mid-range.

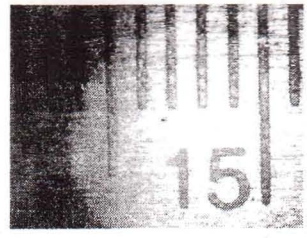
3) Adjust the height of the zoom tube so that the bottom of the tube is 115 mm from the surface of the Plexiglas.

4) Place a coin or other metal object under the objective. You should see the light on the object.

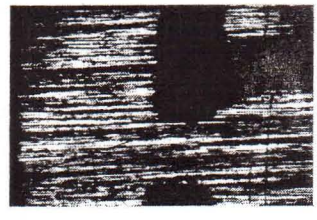
5) On the zoom tube, turn the zoom adjustment counter clockwise all the way, thus reducing the magnification.

6) At this time you should see an image on the computer screen; use the focus adjust on the video microscope to sharpen the image.

7) Increase the magnification with the zoom tube adjuster and increase the light intensity as needed.







A.3. Connecting the TT-AFM to the Cables:

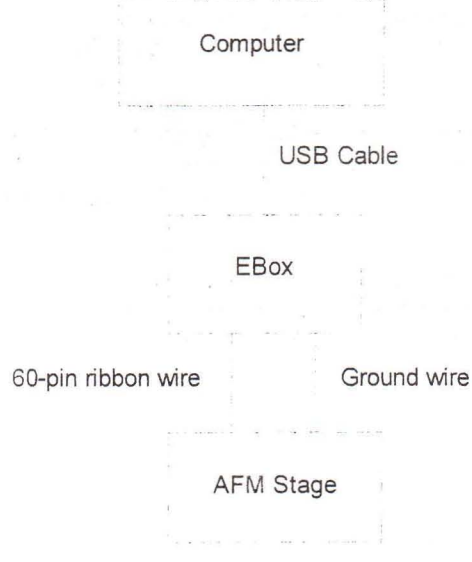
a) Connect the USB cable between the computer and the EBox.

b) Connect the 60-pin ribbon cable between the EBox and the TT-AFM stage.

c) Connect the grounding wire between the EBox and the TT-AFM stage.

Warning: Failure to connect the ground wire can cause damage to the stage and/or EBox electronic circuits.

Warning: Always turn off the master power to the EBox before plugging or unplugging any of the cables on the TT-AFM.



A.4. System Check:

a) Turn on the computer and the EBox.

b) Launch the "Video View" software.

c) Open the "Pre-Scan" software window tab.

d) Move the Z motor a few steps.

e) If the Z motor makes a sound and you can see the LL-AFM sensor going up or down, the system is working.

A.5. Aligning the Video and TT-AFM Microscopes:

a) Raise the zoom tube on the optical microscope so that the LL-AFM sensor can fit under the bottom of the zoom tube.

b) Move the micrometers on the video microscope support to their central position. Move the micrometers on the TT-AFM stage to their central position. If not installed already, install a xyz piezo scanner.

c) Place the TT-AFM stage under the zoom tube such that the hole in the LL force sensor is directly below the zoom tube optical objective.

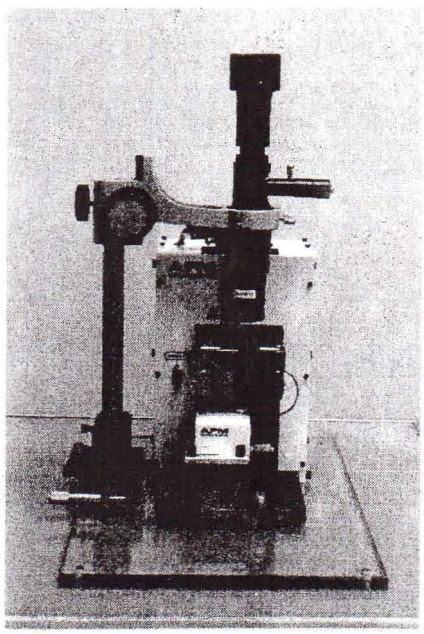
d) Adjust the height of the zoom tube so that the bottom of the tube is about 115 mm from the top of the AFM sample holder. Move that stage by hand and adjust the optical focus.

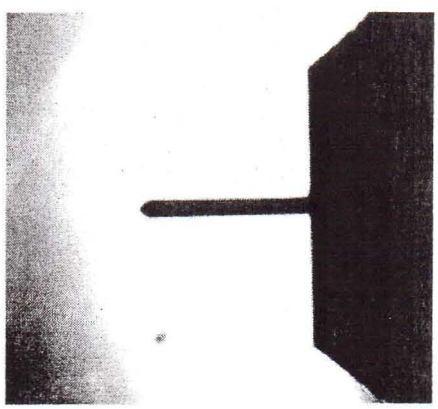
1) Place a probe in the probe holder (see section 4.3.) and place it into the microscope.

2) With the Z motor control, move the probe such that is about ½ " above the sample plate.

3) With the focus adjustment knob, raise the zoom tube approximately ½ ".

4) Slowly move the stage with your hands until the probe is viewed in the video microscope window. As required adjust the focus, the lighting and the position of the stage until the probe is in the center of the optical view.





A.6. First Alignment of the Light Lever:

a) Place probe in holder in the light lever sensor with a contact or vibrating mode probe installed.

b) Adjust optical microscope until probe/substrate can be viewed on screen.

c) Center the laser and detector translation mechanisms with thumb screws.

d) Turn on the laser.

e) Use screwdriver to rotate the mirror until the laser spot is on the back side of the cantilever.

f) Place sample disk on the sample holder.

g) Move the Z translator until the probe is just above the sample disk.

h) With the upper thumb screw move the laser light until it is visible on the sample disk.

i) Loosen the set screw that is holding the laser.

j) Slide the laser in or out until it is focused.

k) Tighten the set screw holding the laser in place.

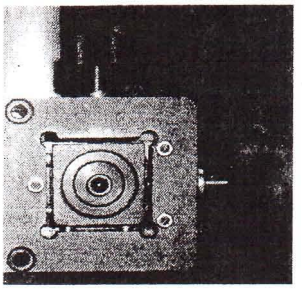
l) Move the light out to the cantilever.

m) Place the two photodetector translators is the center of their range.

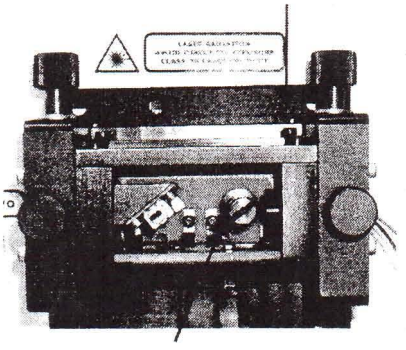
n) Use a small piece of paper to make sure that the light is hitting the photodetector.

o) Release the screw that holds the photodetector in place.

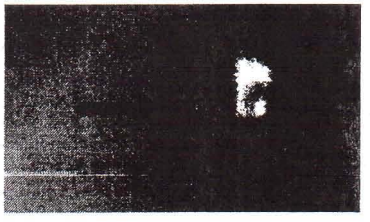
p) Move the photodetector in and out until the T-B signal is zero.



Set screw holding laser

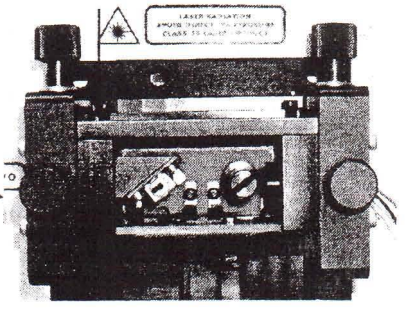


Rotating mirror mechanism



Set screw holding photodetector

Move photo-detector in and out by pushing and pulling on socket head



A.7. Installing an xyz Piezoelectric Scanner:

a) If not already turned off, turn off the EBox electronics.

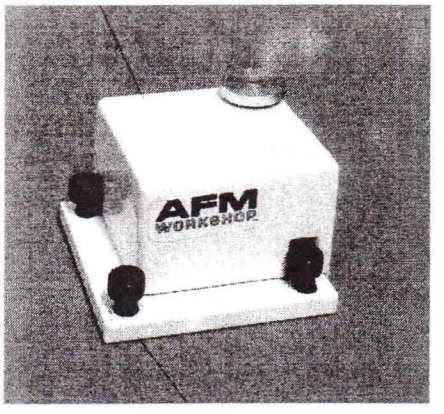
b) Place the scanner on the TT-AFM X-Y translator and locate the ribbon cable that plugs into the scanner.

c) Plug in the ribbon cable.

d) Screw in the three socket screws that hold the scanner onto the XY translator.

Caution: Do not twist the ribbon cable. Doing so will damage the TT-AFM electronics.

Connector on back of scanner




Hold down screws (3)

## Appendix B: TT-AFM files

The TT-AFM software has three separate files that it uses. The first is a parameter file which stores all of the parameters used for operating the microscope. The second is a scanner file, which is unique for each scanner and has range and calibration information. Finally, data files contain images measured by the microscope.

B.1. Parameter Files:

When the microscope software is launched, the default parameter file is used to set all of the parameters that are displayed on the screen. A new parameter file may be created from the default parameter file and stored with a different name. The new parameter file can be loaded in the "Pre-Scan" window. Below is a list of all the functions in the parameter file.

```
************************************ =
*                                  * =
*         AFM Workshop             * =
*     Atomic Force Microscope      * =
*                                  * =
*       Configuration File         * =
*                                  * =
*        April 27, 2010            * =
*                                  * =
************************************ =

[debug_flag]
debug_flag = 0

[Scan Mode]
Scan Mode = 0

[Motor]
Drive (%) = 50
Acceleration (microsteps/sec^2) = 50000
Velocity (microsteps/sec) = 582

[Tune Frequency]
Amplitude (V) = 0.408163
Phase (deg) = 121.224490
Lower Freq (Hz) = 176927.884615
Upper Freq (Hz) = 178496.394231
Selected Freq (Hz) = 177587.500000
Num Steps = 100.000000

[Z Piezo Control]
Tip Approach | Gain = 2048
Tip Approach | Proportional = 64
Tip Approach | Integral = 1000
Tip Approach | Derivative = 0
Scan | Gain = 2048
Scan | Proportional = 64
Scan | Integral = 1000
Scan | Derivative = 0

[Scanning]
scan type = 1
state = 0
first_flag = 0
new_line_scan_data = 0
Current Vertical Position (um) = 44.444443
line_index = 7
num_lines = 0
X_A (um) = 0.000000
X_B (um) = 50.000000
Y_A (um) = 50.000000
Y_B (um) = 0.000000
delta_Y = 0.793651
scan_rate (Hz) = 2.000000
size (um) = 50.000000
points_per_bin = 5

[Display]
Left Image = 1
Right Image = 2
Background = 1
Display = 0
Pallet = 0
```

B.2. Scanner Files:

Every scanner has its own corresponding file. These files have the calibration and range information used by the AFM-View software. The contents of the file are:

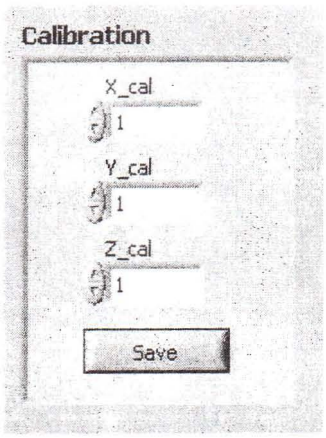
```
****************************************
*                                      *
*          AFM Workshop                *
*      Atomic Force Microscope         *
*                                      *
*          Scanner File                *
*                                      *
*         April 27, 2010               *
*                                      *
****************************************

[System Information]
Serial_No = A-001

[Range Check]
Max X = -1960968193.000000
Max Y = -1973551105.000000

Min X = 1456078849.000000
Min Y = 1003094017.000000
Margin (%) = 3.000000

[Cal Size (um)]
Cal Size (um) = 50.000000

[Calibration]
X_cal = 1
Y_cal = 1
Z_Cal = 1
```

B.3. Data Files:

TT-AFM data files are stored in a text format. At the top of the data file are the parameter used for the scan. The format for the data files is a text format.

## Appendix C: Calibration

Calibration of the TT-AFM requires scanning a standard sample that has known X,Y and Z dimensions. If a sample with squares is used, the pitch in X and Y should be around 10 microns. The height of the features in Z should be around 0.1 micron. The calibration procedure is:




a) Scan a standard sample with known dimensions in X,Y and Z.

b) To calibrate in the X and Y axis:

1) Measure the actual distance across the image by physically measuring the distance.

2) Adjust the parameters for calibration in the "System" window and rescan the standard sample.

c) To calibrate in the Z direction:

1) From the data file measure the number of volts required to scan over a feature.

2) Divide the distance by the number of volts to get a calibration coefficient in microns/volt.

d) When the calibration parameters are correct, activate the "Save" button in the "Calibration" window.

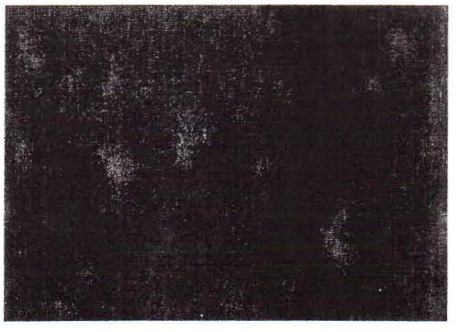
## Appendix D: Probes

There are two major types of probes, non-vibrating-probes and vibrating-mode probes.

Vibrating Mode (VM) Probes:

Typically, vibrating-mode probes are in the shape of a rectangle. VM probe specifications:

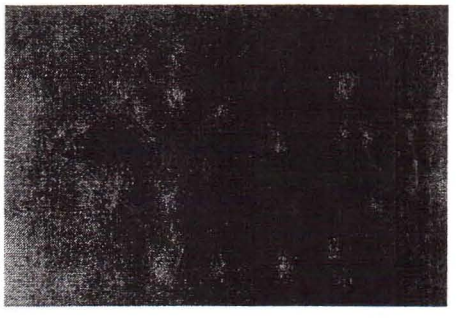
| | |
|---|---|
| Resonance Frequency | 150 – 350 Khz |
| Length | 125 – 225 micron |
| Width | 30 – 40 micron |
| Thickness | 0.5 – 1 micron |
| Force Constant | 30-50 N/M |



Non-Vibrating-Mode (NVM) Probes

Non-vibrating-mode probes can be in the shape of a V or rectangular. Typical NVM probe specifications are:

| | |
|---|---|
| Resonance Frequency | 150 – 350 Khz |
| Length | 225 – 450 micron |
| Width | 30 – 40 micron |
| Thickness | 0.1 - 0.5 micron |
| Force Constant | 0.1 – 0.5 N/M |

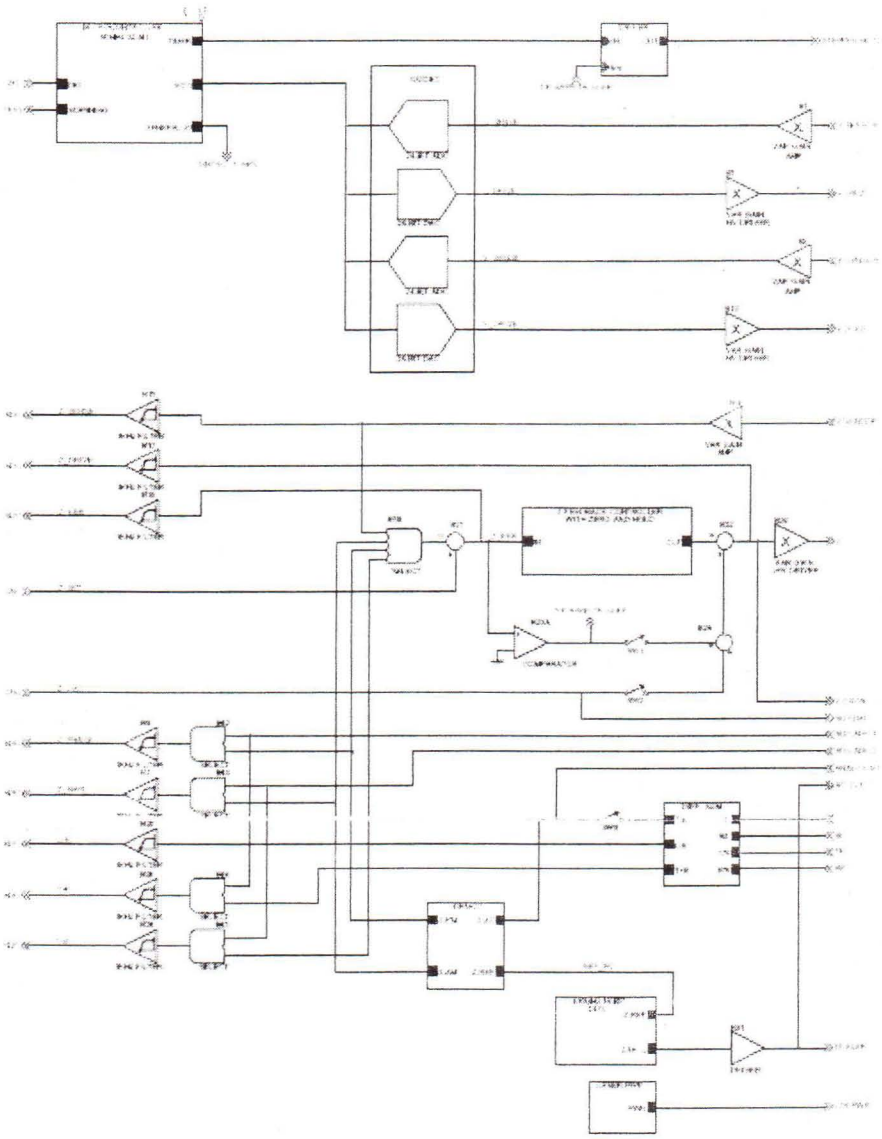


Each of these probes may have a coating, which makes them more reflective.

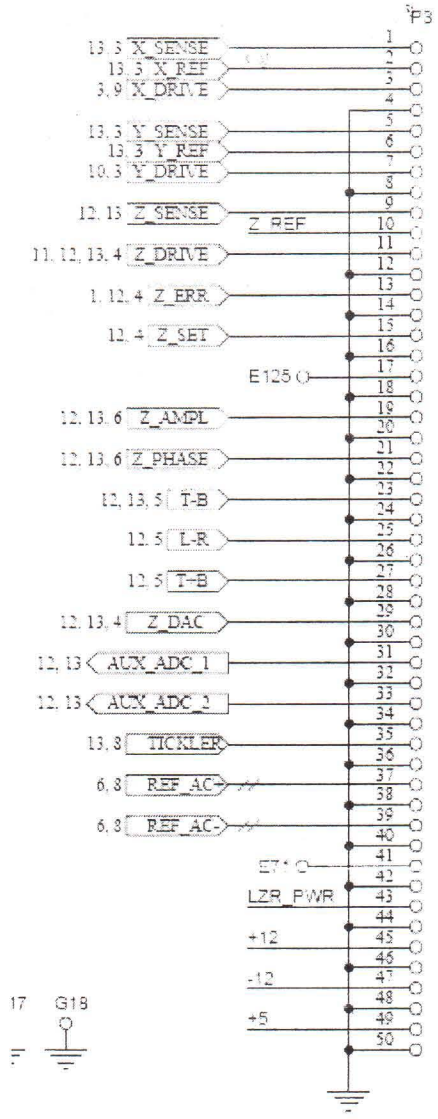
**Appendix E: Technical Information**

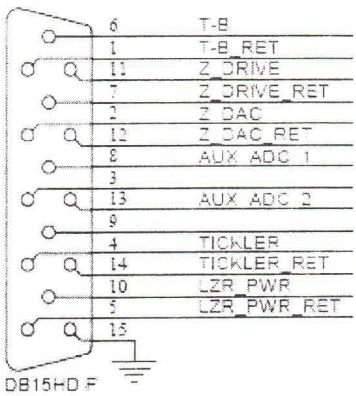
This appendix has technical information that may be useful for creating customer instrumentation with the TT-AFM. Additional information is available in the TT-AFM technical guide.

E.1. Electronic Bock Diagrams:

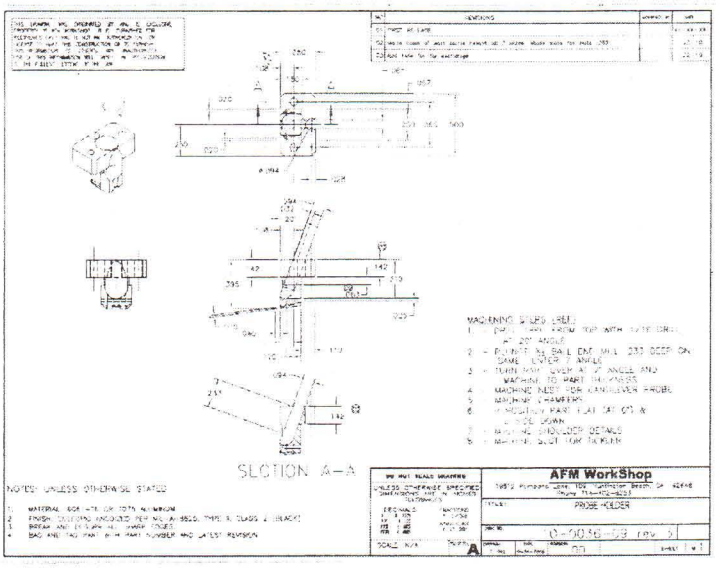


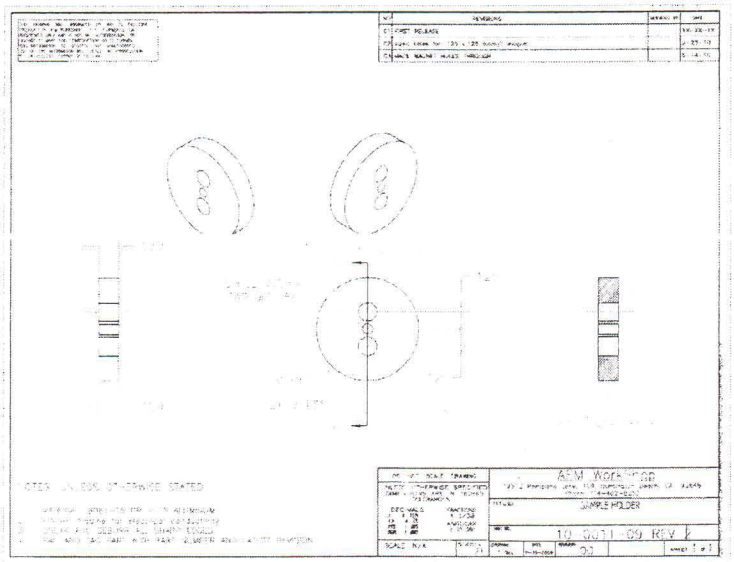
E.2. EBox and Modes Pin Assignments:



E.3. Sample and Probe Holder Mechanical Drawings:



## Appendix F: Optimizing GPID Parameters

The scan parameters such as the set-point voltage and the PID parameters are adjusted as the line scan is being made. The goal in adjusting the scan parameters is to have the probe track the surface. The probe is tracking the surface when the Z error signal image has a minimal signal. Establishing the optimal conditions requires practice and some intuition.

When first learning to operate an AFM, it is helpful to operate with a test sample and adjust the PID settings to see the effect on the Z voltage and the Z error signal, as shown in figure below.