

AFM User Guide

Quick Reference Reminder Manual

by David Michalak
Version 1.1 (April 26, 2005)

Computers:

Please make sure the monitors and computers are shut down properly after each use. To log on to the computer, use the following username and password.

user: afmuser

password: (written on the monitor)

Don't forget to sign in to the log book at the beginning of each use!

Tapping Mode AFM:

1. Before you begin, make sure that the microscope mode toggle switch on the scanning probe microscope (SPM) is set to the right setting. For tapping mode AFM, you will want "TM-AFM." (See Picture 1)
2. Power on the switch at the back of the NanoScope controller on the floor; this will supply power to the SPM. (See Picture 2)
3. Manually raise the AFM head by adjusting the user-controlled screws on the SPM; this will prevent the tip from getting scratched or broken when removing the head. The screws should be turned counter-clockwise from above (clockwise from below) so that they screw into the scanner and lift the AFM head. (See Picture 3.)
4. Disconnect the cable connecting the head to the base, remove the two springs, and remove the head. Put your sample (glued onto the magnetic puck) down onto the magnetic region at the top of the scanner. Change the tip if necessary. See the section below on how to change AFM tips.
5. Plug the cable head back into the base so that the laser turns on. Hold the head over a sheet of paper or the rubber floor mat so that the laser spot can be easily seen. Align the laser spot on the tip using the central and right knobs on the top of the head. Make sure the V-shaped diffraction pattern is visible. (See Pictures 4 and 5 below.) Also see the section below on how to align the laser spot on the tip if you need a reminder.
6. Carefully put the head back onto the scanner making sure there is plenty of room between the tip and the sample. Hold the head in place while you reattach the springs; if you don't, the spring will flip the head over which could cause damage to the tip.

7. Rotate or move the sample puck so that the area you want to measure appears below the AFM tip.

8. Visually lower the AFM tip by retracting the user-adjustable screws so that the three vertical red dots get very close together. These dots correspond to the light bouncing off the probe tip, the light bouncing off the surface, and the reflection of the probe tip in the surface. While lowering the tip, make sure to turn both of the screws at the same rate so that the head does not tilt as you lower it (See Picture 6). Turning the screws clockwise as viewed from above (or counter clockwise from below) lowers the stage. Lower the stage until the three dots are very close together but not touching.

NOTE: If you keep lowering the screws but the spots do not appear to move any closer together, the screws have completely retracted into the scanner and the probe head is resting directly on the scanner. This can happen when the third, computer-controlled screw (located behind the other two) is too high, lifting up the rear of stage. You can visually check this by looking at the head and how it rests on the scanner (see Picture 6 below). If the front two screws are completely retracted, the head will be resting directly on the scanner up front, and the computer-controlled, screw will lift the rear of the head relatively high. To fix this problem, first *raise the front two screws* so that the head is level on the base (this is **critical** so that you don't crash the tips when you put the head back onto the base), then carefully remove the springs and the head, lift out the scanner, and reduce the height of the rear screw – just unscrew it a bit. The screw may need some minor adjustments to fit neatly back into its socket. (See Picture 7) Reattach the head and the two springs and proceed as usual with lowering the head.

9. Place the telescope about 2 inches from the head and focus on the three red dots. Continue to bring all three dots further together (by lowering the stage) until they just merge into one elongated blob. Keep in mind that the focus may need to be adjusted as the tip is lowered. Once done make sure that the head is evenly raised up by each of the screws above the scanner. If the head is not level, the image will look distorted.

10. Laser light reflected off the AFM tip is directed to the detector by bouncing it off a movable mirror. To align the mirror, adjust the lever on the back of the AFM head so as to maximize the number of dark hatches around the perimeter of the lower display on the base. The hatches move in a counter-clockwise manner and the more hatches the better as this represents the amount of light hitting the detector. Be sure to hold the head steady while moving the mirror lever as it is both stiff and sensitive. Getting a value somewhere between 2 and 3 is OK for regular silicon tips. (See Pictures 8 and 9)

11. With the cavity facing towards you, adjust the left-most screw on the top of the head to bring the number in the center of the lower display as close to zero as possible. This knob is only very sensitive when around zero, so you may be turning it for a while before you notice a significant change in the numbers. If you turn the knob too far in the wrong

direction you will notice that the dark hatches around the perimeter will start to decrease; simply just turn the knob in the other direction. Once you get the number to be 0 ± 0.5 you are all set to begin scanning. Take a breather, the hard part is over!

12. Logon to the computer and start up the DI-nanoscope program. Under the “di” menu, select “realtime.” Under the “di” menu select “microscope select” and then select the appropriate scanner that you are using (*e.g.*: “multimode TMAFME”). You will want to make sure that the correct calibration settings are loaded. To do this go under the “Microscope” menu, select “scanner” and make sure the right setup files is used (*e.g.* select “450ezse....E” for the E head.)



13. While in “realtime” click on the tuning fork icon to go to the auto-tune window. To begin the autotuning process, click on the “Autotune” button. This may take some time to find the resonant frequency. If you do not find resonance this may mean one of two things: you have not scanned over the range where the tip has a resonance, or the tip is broken off. Hopefully it is the former, and you can just increase the range of the frequency sweep. For example, for the AFM tips located in the drawer use:

start frequency = 200.000 kHz
end frequency = 400.000 kHz
target amplitude = 2.00 V
Peak offset = 5.00%

Special tips may have a mechanical resonance outside of this range so try a wider range if this does not work. Otherwise you probably have a broken tip and it should be replaced. In which case, go back to the beginning and do not collect \$200. To go back to the previous scan window from the “autotune” window, either click the “Back to Image Mode” button or go to the “view” menu and select “image mode.”

14. Set the scan rate and scan size to appropriate values: *e.g.* a 13 micron scan size and 1 Hz scan rate. (If you want some settings for measuring the standard sample see the Appendix at the end of this manual.) Lower scan rates will generally yield better-looking pictures, but sometimes it’s useful to use faster scan rates to quickly see what things look like. If voltage units appear instead of distance units go the “other controls” window (that should already be open on the right side of the screen - if not, select “Panels” and “Other”) and click on the field “Units” to change from “Voltage” to “Metric.”



15. Click the engage tip icon (or press ctrl E). The program will now lower the tip until it engages the surface and it will immediately begin scanning when engaged. While the computer is lowering the computer-controlled screw, the distance it has moved will be displayed in the bottom of the screen. This number will disappear once scanning

begins so watch it carefully. REMEMBER THE DISTANCE THE MOTOR HAS MOVED SO THAT YOU CAN RETRACT THE TIP THE SAME DISTANCE WHEN DONE. This will keep the probe head flat and not tilted for future use. (Typical distances are less than 50 microns, though a little longer is OK. If the motor scans distances of more than 100 microns the tip will likely be tilted and your images may look weird. Click the tip-retract button several times and then using the eyepiece, bring the AFM tip closer to the surface.)



16. During scanning you can click the camera button to record images. Before you do, you should first go under the “capture” menu and select “capture filename” to name your files. Take advantage of the note field, since it is often very handy for recording specifics about a given sample. When the computer actually decides to capture an image is a bit tricky. When you push the camera button to start a capture, it won’t just download the scan that appears on the screen, it only captures data as it is acquired. If you have started a capture, you will notice that it says “capture next” at the bottom of the screen, meaning that the data from the next scan will be captured and saved. After the tip has reversed its direction, the capture will begin and it should say “capture on” at the bottom of the screen. During capture DO NOT change any of the settings or the capture will be postponed until the next full scan is completed that does not involve any changes to the settings. If you have changed any settings during a “capture on” period, you will notice that “capture next” appears again at the bottom of the screen. See the section below on how to obtain your captured files.

17. You can zoom in and move the scan rate around in two methods. The first way is to describe scan are by the coordinates given in the “scan size,” “Aspect ratio,” “X offset,” and “Y offset” fields. This is often not too intuitive unless you’re really good with numbers. You can also click on “Zoom In” on the second monitor (above the scans). You will now be able to move a square around the picture; center this square over the desired region. If you click once more this will allow you to increase or decrease the size of the zoom rectangle (its dimension determined by the Aspect ratio file) by moving the mouse. Once you’ve selected the right placement and size of the zoom area, right click and the mouse should appear at the execute button. Click execute and the new scan lines will be at the desired magnification and position.



18. When finished, raise the tip by clicking the tip-retract icon (or by pressing ctrl W) several times. Each click retracts the tip 5-7 microns. Please retract the tip as much as the computer-controlled screw motor moved to initially to engage the tip. For example, if you noticed that the tip motor moved about 40 microns during the tip engage cycle, then click the tip retract button about 6-7 times. Doing this will keep the head flat for the next user. Retracting the tip in this manner also prevents you from

accidentally crashing the tip into the surface if you turn the screws the wrong way when trying to raise the AFM head further.

19. Before removing the head, raise it up a bit more by turning user-adjustable screws counter clockwise as viewed from above (or clockwise from below). Make sure you can clearly see each of the three red dots separated by a considerable distance. This will protect the head from inadvertent damage during removal. Take off the springs and remove the head.

20. Remove your sample and reattach the head by plugging in the cable and attaching both springs. Place the dark felt cover back over the AFM, turn off the computer on the the floor. Log off the AFM computer and turn off both monitors.

Tips for aligning the laser on the AFM tip:

Aligning the laser onto the AFM tip is easiest to do with the lights off. This will allow you to see the laser spot and the final V-shaped diffraction pattern when the tip is properly aligned. Remove the head from the scanner and hold it over a piece of paper or over the floor mat so that you can clearly see the laser spot and its shape.

Orientation:

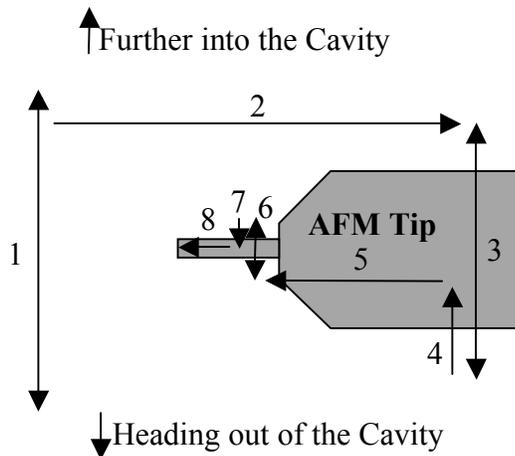
Hold the head so that the cavity faces toward you. The knob on the right (closer to you) moves the laser spot left and right (turning clockwise makes the laser spot turn to the right) and the knob in the middle (further from you) moves the spot further into the cavity or closer towards you. See Picture 4 below.

Finding the AFM tip:

The best and easiest way to align the laser spot on the apex of the AFM tip is to follow a certain path as outlined in the diagram below. When the laser spot is not shining on the anything, it will hit the ground in the shape of a hamburger (See Picture 5). Now move the central knob around to see if, through the course of the laser moving into or out of the cavity (arrow 3 in the diagram below), it passes across the AFM tip. You will know if you've passed over the AFM tip because it will obstruct the laser spot and the hamburger will disappear. If you see no obstruction from the AFM tip, you may be at position 1 (in the diagram below) where the spot is to the left of the AFM tip, so turn the right knob clockwise a bit to move the spot to the right (arrow 2). Once you have located the AFM tip, move the spot about halfway onto it (arrow 4). Now turn the right knob counterclockwise to make the laser spot move to the left until it is off the side of the probe (arrow 5); you should see the hamburger again. Now move the laser spot with the central knob into and out of the cavity to find the AFM probe tip extension (arrow 6). It should take only about 1 full rotation (360°) of the central knob to pass from one end of the probe tip to the other. When the laser is over the probe extension you should see a tall diffraction pattern. Again back the laser spot onto the center of the AFM probe tip extension using the central knob (arrow 7) and then move the laser spot along the probe tip extension (by turning the right knob counterclockwise) until you reached the end of

the tip (arrow 8). When you reach the end of the tip you should start to see the bunny-ears V-shaped diffraction pattern. To make this diffraction pattern look nice you may need to tweak both knobs a little bit and, once done, you have successfully aligned the laser spot on the AFM tip. A properly aligned laser spot, and the bunny-ears V-shaped diffraction pattern is shown in Picture 5.

Top View Picture of the AFM Tip



Arrows indicate the direction to move the laser spot

If you haven't changed a tip, it's unlikely that the laser position will need to be moved much. However each time you use the AFM, you should check that the laser is indeed aligned with the tip and that it gives a nice V-shaped diffraction pattern.

Obtaining files that have been captured:

1. Under the di menu, select "offline."
2. Your saved files will show up under a fake "!" directory. Don't ask me where that directory is, or why it has been named as such.
3. Select the files you're interested in by double clicking them. They should then appear on the second screen. Select the "Utility" menu and select "JPEG Export." Select the export options you desire and please select the default c:\temp folder as the file destination folder. Your files should now be in the "temp" folder within the c: drive. At the end of each run, you should take all your files with you (either by Zip disk or by USB drive). We are not responsible for any data lost if the computer crashes – take it with you immediately!

Changing the tip:

1. Carefully unscrew the knob in the center of the back of the probe head, opposite the cavity, to retract the three gold-colored probes that hold the stage in place. (See Picture 8)
2. Remove the tipholder stage. When turned upside down, you can see the gold clip that holds the AFM tip in place. Loosen the small screw that holds the gold clip in place and swap the tips. Keep in mind that the laser will need to be realigned with the new AFM tip. (See Picture 10_
3. Place the stage carefully back into the cavity of the head and finger tighten the screw on the back of the head to let the three gold-colored tips press the stage back into place. Align the laser spot onto the tip of the AFM cantilever.

PHOTOGRAPHS

1. Microscope Mode Toggle Switch:

Before you begin, make sure that the microscope mode toggle switch is set to the correct position. The photograph shows the case you will most likely use: Tapping-Mode Atomic Force Microscopy (TM-AFM). But remember that if you will be doing either contact mode AFM or Lateral Force Microscopy, you should change the switch to “AFM & LFM.”



2. Power Switch for the NanoScope Controller:

This photograph shows the rear of the NanoScope controller that is resting on the floor. This provides the power to the SPM. The power switch is the black toggle switch in the upper left corner on the back of the instrument.



3. Screws For Raising/Lowering the Stage:

The two user-adjustable screws shown below can be turned to raise or lower the stage. Turn the screws in the direction of the arrows to raise the AFM probe head. Sometimes it's confusing to remember how the screws work, just remember that the screws are like lightbulbs: screw them clockwise (as seen from below) to screw them in, this lifts the stage higher since the stage rests on screws. Turn the screws counter clockwise (as viewed from below them) in order to unscrew them. Since they are being unscrewed, they lower the stage that rests on them.

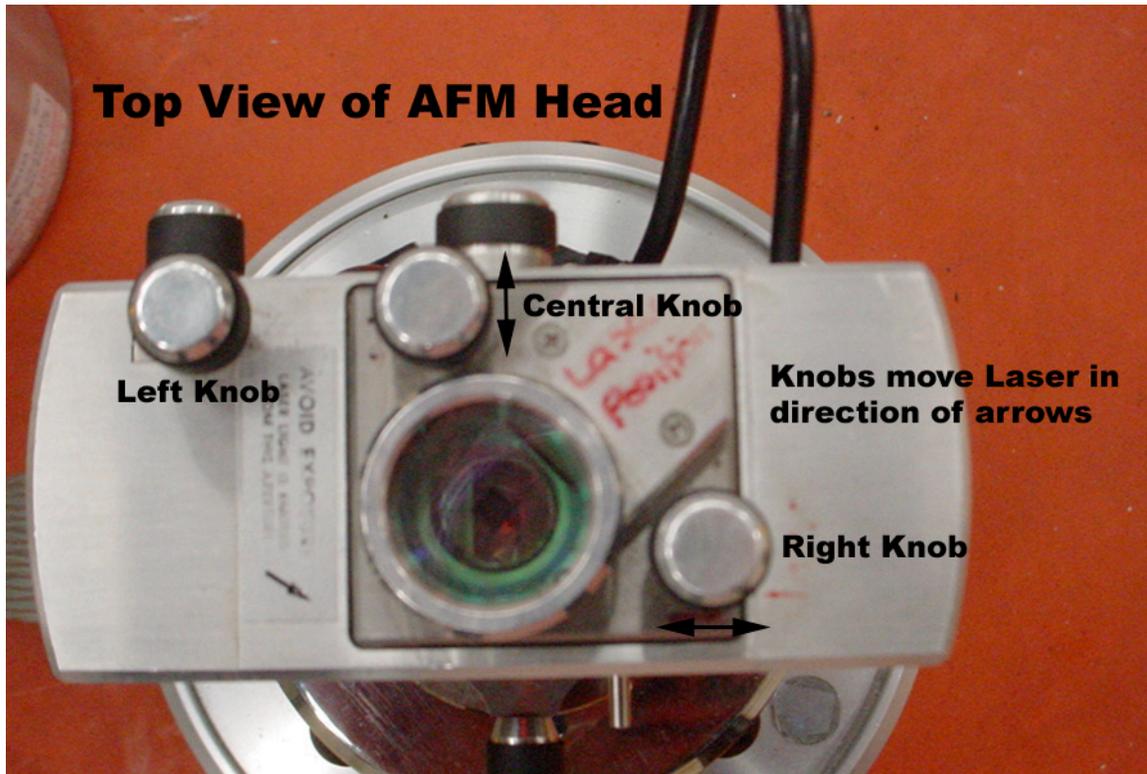
Make sure that you turn both screws equally when you are raising or lowering the stage. This is critical so that the stage doesn't tilt and give you bad AFM images. (Notice that the screw on the right is a bit more unscrewed from the one on the left – this is bad! Be careful.)



4. Top View of the AFM Head:

Three knobs are visible on the top of the AFM head. The left most knob controls the number in the center of the lower display of the base and the goal is to get this number as close to zero as possible. This knob raises and lowers the position of the quadrant photodiode. Turn this knob until the laser spot hits the center of the detector; in this case the difference between the top and bottom quadrants becomes zero.

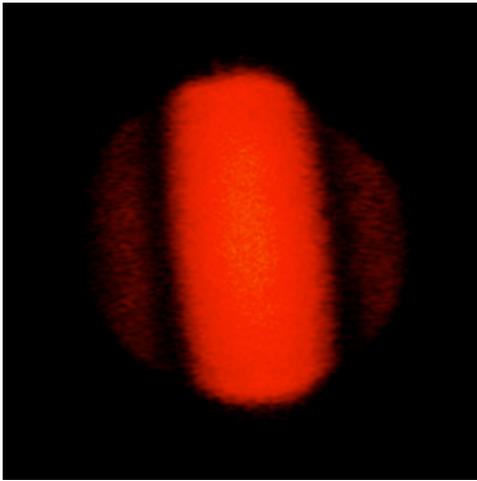
The central and right knobs control the laser position. It's like an Etch-A-Sketch if you've ever used one. The central knob moves the laser further into or out of the cavity, the right knob moves the laser left and right.



5. Laser Spot Shapes:

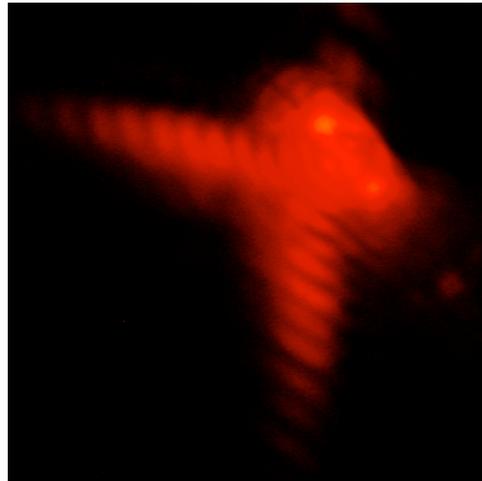
The Hamburger-shaped spot, shown below on the left, is obtained when the laser is not shining on or diffracting off anything. The V-Shaped Bunny-ear diffraction is observed when the laser spot is properly oriented on the tip of the AFM tip. See the section above on how to align the laser spot on the AFM tip.

HAMBURGER-SHAPED SPOT



The Hamburger-shaped laser spot is observed when the tip is not shining on anything.

V-SHAPED DIFFRACTION

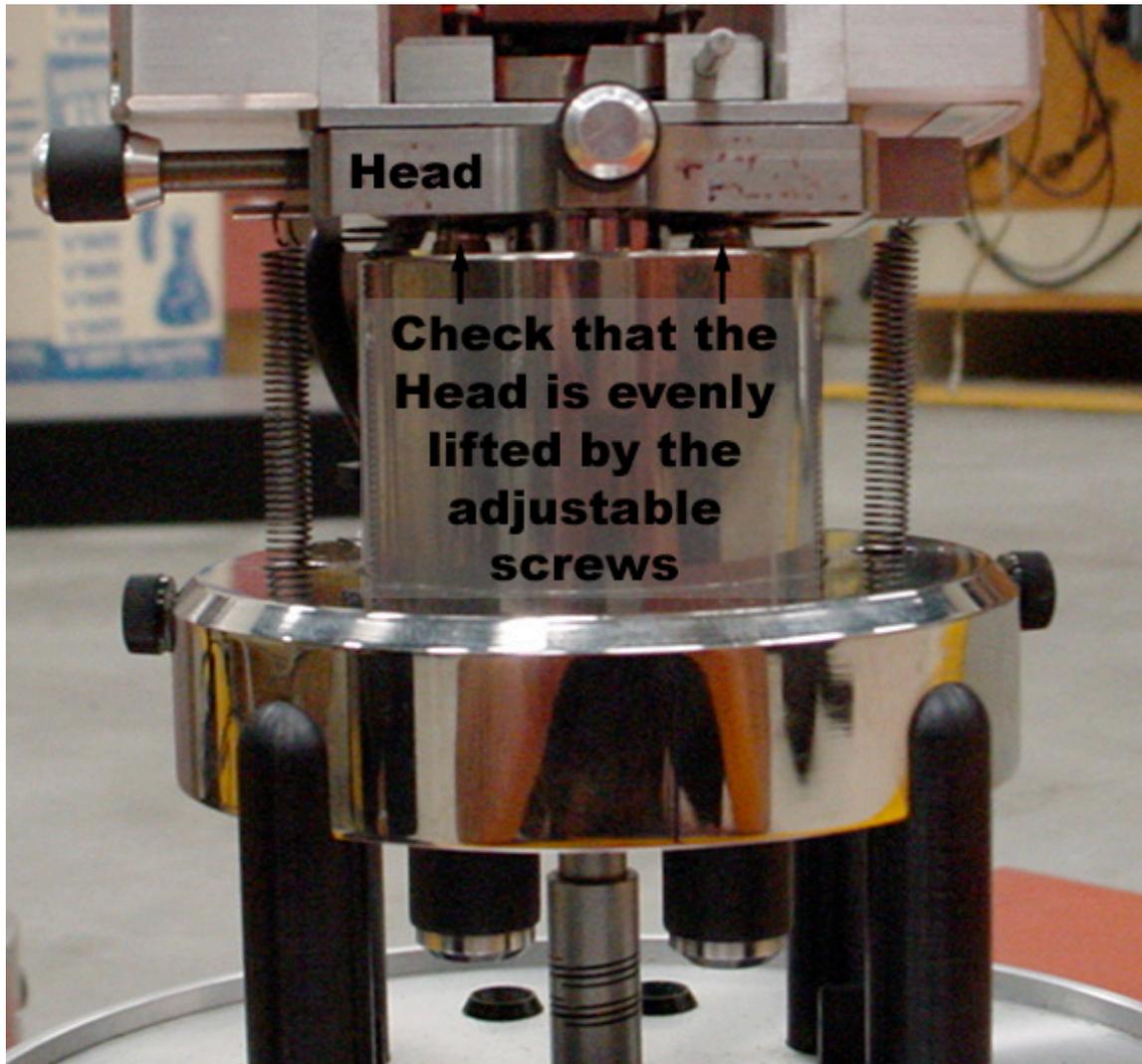


The V-shaped, Bunny-ear diffraction pattern is observed when the laser is properly focused on the AFM tip.

6. Making sure the AFM Head is level:

In order to get nice images that aren't tilted, it's important to make sure the AFM head is not tilted. The picture below shows the AFM head resting on the front two, user-controlled adjustment screws. The head looks pretty level (perhaps the left screw could be brought down a little). As shown here the AFM head is lifted pretty high up off the surface of the scanner (in this position the AFM tip is usually pretty far from the surface.) The screws will be much more retracted into the scanner when the tip is lowered into position. Once lowered into position, it is even more important that the head is level. Don't forget to check that the AFM head is flat/level relative to the rear, computer-controlled adjustment screw as well.

If you continue to lower the user-adjustable screws and the three red dots do not continue to get closer together, it might be that these screws are fully retracted into the scanner and the AFM head is resting directly onto the surface of the scanner. Further retracting of the screws will not further lower the AFM tip. See the next picture for help.



7. The Computer-Controlled Stage Screw:

You may need to adjust the computer controlled screw if the two user-adjustable screws on the front have been fully retracted into the base and the AFM tip is still not close enough to the surface. To do this, carefully remove the springs and the AFM head. You should now be able to remove the scanner as shown in the diagram below. The computer controlled screw will now be free for adjustment.

There are a couple reasons why the computer-controlled screw may need adjustment. It could be that previous users had retracted the AFM tip too many times at the end of a run – the net result is that this screw gets raised. This screw could also require adjustment if your sample is significantly thicker or thinner than those of previous users.

In all cases, the idea is that the rear computer-controlled screw should be adjusted so that all screws are about the same height when the AFM tip is lowered onto the surface. Before running a scan, make sure that all screws are about the same height so that the AFM head is resting evenly on the screws and is not tilted.

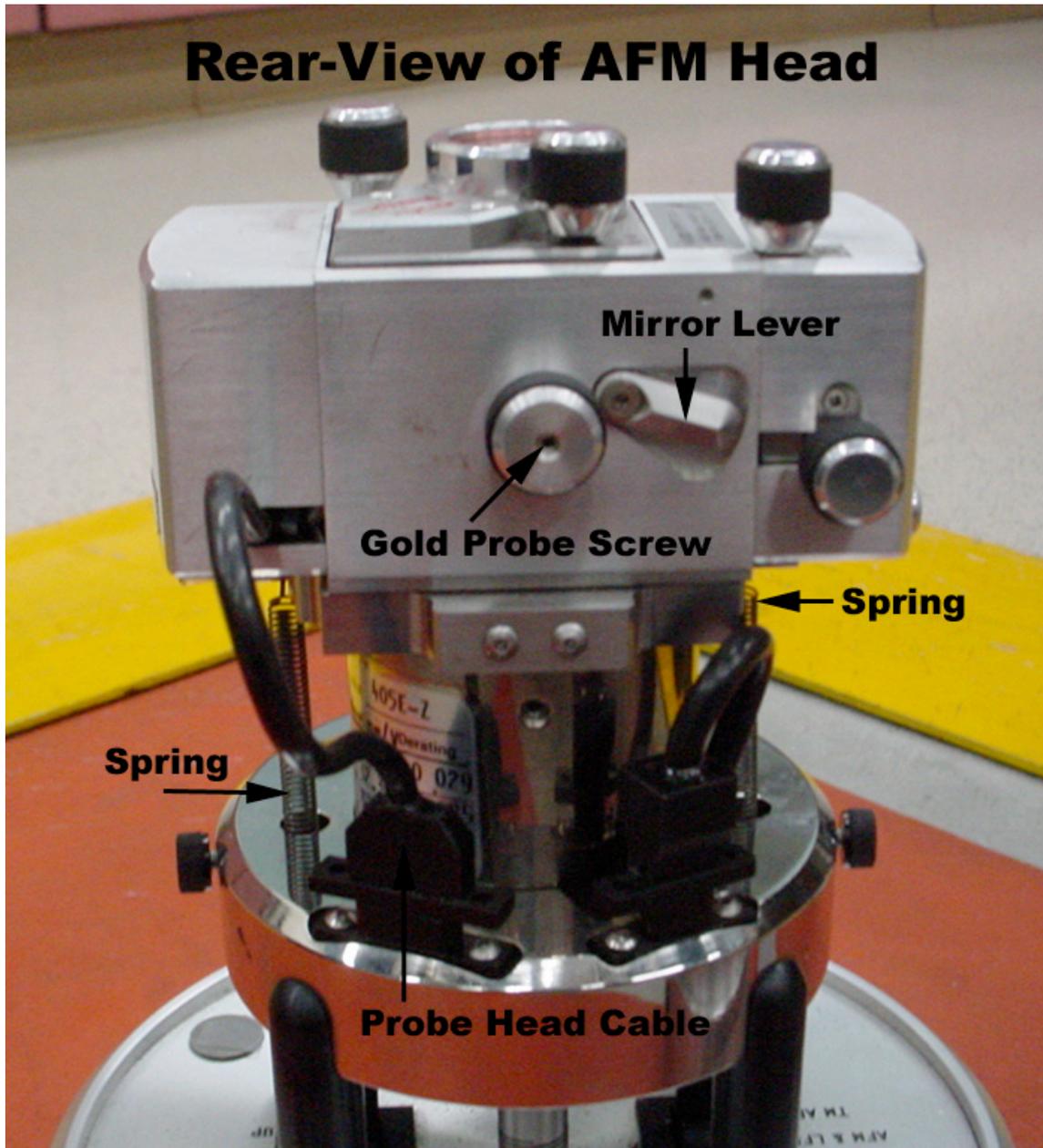


8. Rear View of the AFM Head:

The knob in the center of back of the AFM head loosens and tightens the 3 gold-colored probes that clamp the AFM tip-holder stage into the cavity. Loosen this screw if you need to release the AFM tip-holder stage to change the AFM tip.

The mirror level is also found on the back of the AFM head. It is used to adjust the number of dark hatches that move around the perimeter of the lower display on the front of the AFM base. It is stiff and sensitive which can make the job a little tough.

The two springs that hold the probe head securely on the base can also be seen in this photograph as well as the probe head cable.



9. The Lower Display:

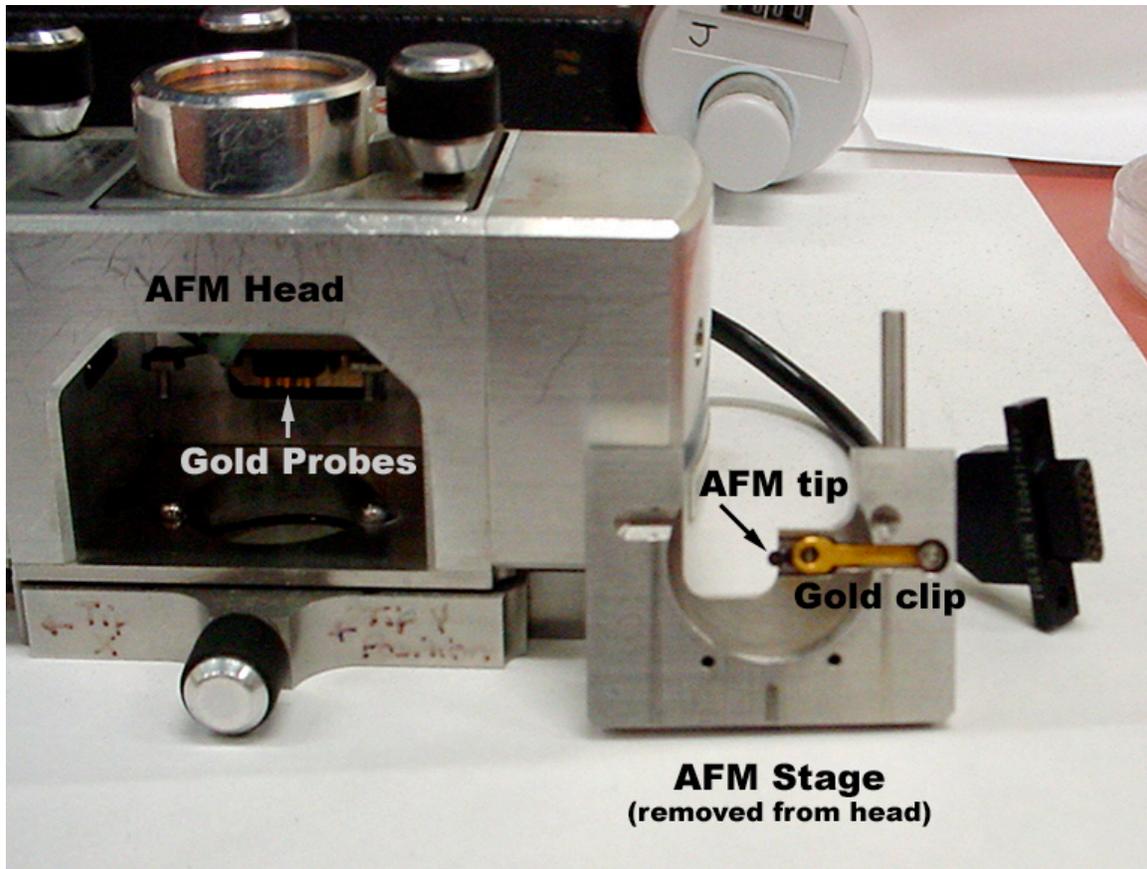
The lower display on the AFM base shows two important values. The first is the number of dark hatches that increase around the perimeter of the display in a counter clockwise manner starting at about 11 o'clock. The manual has a much fancier name for this display: it's called the "elliptical bar graph." Names aside, the idea is to maximize the number of dark hatches you see going around the perimeter; the number of hatches corresponds to the amount of laser light hitting all four quadrants of the detector (hence SUM signal). This number is maximized by adjusting the mirror lever so that the laser light is directly hitting the detector. Just so you know, the units on the "elliptical bar graph" are not in steps of 1 volt; they are in steps of 1.2 volts, don't ask me why.

The second important thing is the "difference value" in the center of the lower display. This number gives you a feeling for how well the laser is centered on the detector. Technically speaking it is the voltage difference between the four quadrants of the detector (hence DIFF signal). By minimizing this value (ideally to zero), it means that each quadrant is receiving the same amount of light (*i.e.* there is little difference between them). This number can be reduced by turning the left knob on the top of the AFM head.



10. The AFM Head and Stage:

The AFM head is seen to the left in the picture below. The gold-colored probes that make contact with the AFM stage can be seen at the back of the cavity in the AFM head. The AFM tipholder stage that holds the AFM tip has been removed and positioned so that the bottom (underneath part of the stage) is facing the viewer. The gold clip and the AFM tip that it holds can be seen.



The NanoScope Control Panel:

This is the main control panel of the di NanoScope when in real-time. It shows the tip engage button (with the green downward facing arrow), the tip retract button (with the red upward facing arrow) and the the tuning fork auto-tune button on the far right. Also on this control panel, but that are not shown, is the image capture button with looks like a camera.



Appendix

Scan Parameters For Measuring the Standard:

