**Operation of MRL's Veeco Dimension 3100/NanoscopeV SPM
in Tapping Mode: Version 7 software**
els 190204

**Please train yourself to always touch grounded metal just before touching the D3100
if there's ANY chance of static discharge when you touch the microscope.**

Startup

Before you begin to use the AFM, engage in CORAL and create an appointment in BusyCal. If you're using a special applications module, remember to indicate that both in your CORAL log and in your BusyCal entry.

Float the air table by turning the yellow air supply handle so that it is in line with its copper pipe. Turn on the two display monitors. Turn on both the Nanoscope V controller and the Huff n' Puff box if they're off.

Start the Nanoscope software by clicking on the icon at the top left of the Control screen (labeled Nanoscope V7etc).

Click on File/Open Workspace... and select the correct workspace (probably "CMSEtapping in air .wks").

Click on any one of the top three icons in the left hand column to start up the software. If any sub-window is full-screen, minimize it. Initialize the stage if the software indicates that is needed.

Inspecting and Preparing Your Sample

Don't load your sample on the D3100 platen just yet. It'll be easier to get the cantilever set up first. But now is a good time to mount your sample on a substrate if you need to.

Your sample surface ideally should be flat, level, and dust-free.

Do not contaminate the D3100 platen surface with adhesive, silver paint, ink or grease. If the sample needs to be secured or grounded, pre-mount the sample with adhesive or with silver paint onto a flat smooth substrate, for instance a steel "puck", a piece of silicon, or a glass slide.

Installing a Cantilever

The previous user should have left the Dimension Hybrid scanner
      installed but unlocked (locking screw all the way clockwise),
      raised up about a centimeter from the platen,
      power cords unplugged,
      cantilever mount installed.

Dismount the scanner by raising it using the two-finger handle and sliding the dovetail *smoothly* out of its vertical slot.
Don't touch the laser optic on the left underside of the scanner.

Gently unplug the cantilever mount from the four gold contact pins, put the scanner safely down, and gently plug the cantilever mount onto the black mounting platform. Don't force it; just secure it.

If there's a cantilever installed, remove it now. It's probably a dead one.

Install your cantilever on the cantilever mount. Make sure the silicon chip is level, aligned straight, and all the way back in the slot. Bring the spring finger fully forward. Carefully place the spring finger so that it is *centered* on the chip. Stow components and tools safely away as soon as you've finished with them. Close your cantilever box to protect your unused cantilevers.

Remove the cantilever mount from the black mounting platform and place it on the tabletop. Then pick the mount up with the tips of your fingers. Carefully align the cantilever mount with the scanner's four gold contact pins and *gently* press it in place, *visually inspecting* to make sure all four pins are fully seated.

When you go to install the scanner, remember to touch the copper pipe on the wall immediately before you touch the D3100.

Using just the two-finger handle, slide the scanner *smoothly* all the way down to the bottom of the slot on the D3100. Plug in the scanner power connectors, and lock down the scanner by turning the locking screw *counterclockwise*. Stop turning as soon as the screw feels *loose*.

Aligning the Laser

First make sure the laser is turned on (small red LED on the scanner is lit).

Part One: Align the *Incident* Laser Beam on the Cantilever Tip

Following is a procedure for using the two laser alignment knobs on top of the scanner to move the incident laser beam so that it is reflecting off the very tip of the cantilever.

The steps to align the incident beam:

1. **Turn the lengthwise laser alignment knob** *clockwise* **until the laser is fully on the silicon chip. (**If there's a red laser reflection on the platen surface, it will disappear when the laser is fully on the silicon chip.)

    If you see a red spot on the oval window of the scanner, ignore it for now -- watch instead the laser reflection on the platen surface.

    If the scanner is too close to the platen to easily view the laser reflection, raise the scanner using the software Z control.

2. **Slowly turn the lengthwise alignment knob back** *counter-clockwise* **to move the laser** *just* **off the silicon chip.** Stop turning as soon as all of the red laser light is hitting the platen directly below the cantilever.

3. **Crank the crosswise laser alignment knob side-to-side to locate the cantilever** (this should require very little turning!) When the laser crosses the cantilever you'll see the red laser spot flash *briefly* on the oval glass window on the scanner. Position the laser on the cantilever.

If you don't see the flash, turn the crosswise alignment knob back to its starting position, then repeat Steps 2 and 3. If you still can't see the brief flash from the cantilever, use the **Locate Tip** function to check to see if perhaps the cantilever is broken off.

4. **Next step is to put the laser on the very tip of the cantilever.** Turn the lengthwise knob *counterclockwise* until the red spot on the oval glass disappears, i.e. the laser has dropped off the tip of the cantilever, then turn the knob *clockwise* until the red spot reappears and *first* reaches maximum brightness.

5. **Finally, crank the crosswise knob to center the laser laterally on the cantilever.**

Part Two: Align the *Reflected* Laser Beam on the Photodetector

Use the two mirror alignment knobs on the side of the scanner to approximately center the red spot on the oval glass window (the exact position varies from scanner to scanner). Then use the same two knobs to move the red Laser Signal dot on the graphics monitor to the center of the green crosshair.

Tuning the Cantilever

Select the blue tuning fork icon (or select View/Cantilever Tune)

and observe the cantilever frequency response graph.   Set the Target Amplitude and Peak Offset to values appropriate for your sample. Set the Drive Amplitude to 50 mV. Then select **Auto Tune**.

What's Happening: First the Auto Tune routine homes in on the dominant peak in the amplitude vs frequency response curve (white line). That peak is the natural resonant frequency of your cantilever.

Then it adjusts the drive amplitude so that the detector voltage matches the Target Amplitude, lowers the Center Frequency until the amplitude matches the Peak Offset value you have specified, and zeroes the phase difference vs frequency curve (yellow line) at the resonant frequency.

When the Auto Tune routine is finished it will display the resonant peak just off center in a short frequency range.   The frequency response curve will continue to be "live", updating every second.

When the auto tune routine is finished, inspect the frequency response for three characteristics: 1) amplitude stability, 2) symmetric shape, and 3) drive amplitude less than 200 mV. If there is more than one dominant peak in the frequency response curve, or if the amplitude response is unstable, then return to the Real Time menu, dismount the scanner, and reseat the cantilever in its mount. Then remount the scanner, realign the laser and the photo detector mirror, and retune the cantilever.

When you determine that the frequency response is satisfactory, return to the Real Time menu and note the free amplitude reading. The free amplitude should average about 400 mV.

Locating the Tip (necessary when you install a new cantilever)

Select the **Locate Tip** button. The XY piezo will spiral itself briefly, and the optical microscope focus will automatically move to the tip-focus position set by the previous user.

Use the two black knobs on the optical microscope to position the optical CRT crosshair about 1 cm below where you believe your cantilever's probe is. You may need to adjust the illuminator intensity to see the cantilever. Adjust the optical microscope focus until the tip is in focus. Then **exit** the Locate

Tip routine. When you exit, the optical microscope will refocus itself to a point 1 millimeter below the cantilever.

Loading Your Sample on the Platen Before Engaging

Make sure the platen and the underside of your sample (or sample substrate) are clean.
Use the software or trackball to bring the platen straight out from under the scanner. Do NOT rotate the platen.
Put your sample down on a flat metal area on the far side of the platen.
DON'T use sharp tweezers to position your sample on the platen surface. The platen must be scratch-free or its ability to hold a vacuum will be compromised.

DON'T touch the platen's top surface with your fingers. Do not contaminate the platen with adhesive, silver paint, ink or grease.

Use the software or trackball to drive the platen back under the scanner.

Positioning the Sample and Scanner Before Engaging

Use the stage software or trackball to translate your sample into position under the cantilever. Translation is done with the trackball by holding down either of the upper LOCK trackball buttons and rolling the trackball in the direction you want the stage to move.

If you need to rotate the platen to bring your sample into position, remember to turn OFF the sample vacuum before rotating the platen. Handle the platen only by its knurled edge.

Next, make sure the optical microscope image is zoomed fully out, then use the stage software, or press the FOCUS trackball button and spin the trackball toward you, to lower the scanner. Watch the gap between the cantilever and sample surface until the gap is about a millimeter.

Then transfer your attention to the video monitor. *Make sure the illumination is adjusted so that you can see your sample surface.* Adjust the height of the scanner until the video image of the sample surface is in focus.   Use the stage control to center the area you want to analyze, then zoom in the optical microscope and adjust Z for sharpest focus.

Next: go back and repeat the Locate Tip routine and the Focus Surface routine. Sorry about that silly necessity.

Warning: the tip should NOT come into focus during this Focus Surface routine. If the tip starts to come into focus, move the scanner back up! You risk crashing the tip into the surface.

Engaging the Microscope

If you expect acoustic vibration may interfere with your analysis, close the acoustic hood NOW, before engaging.

Make sure the Z limit is **NOT** reduced. Click on the **Engage** icon.

What's Happening: The optical microscope will focus on the tip and the XY piezo will rapidly spiral the scanner. The Z motor will lower the scanner to about 100 μm from the sample surface, and then step the scanner down toward the surface in micron-sized steps until the RMS amplitude is damped in a way the SPM recognizes as true engagement. That final RMS amplitude will automatically be entered in the Feedback panel as the Amplitude setpoint when the piezo begins scanning.

Optimizing Feedback Parameters

The **Scope Mode** graph shows the Z piezo response vs. the distance the tip is traveling in the fast-scan direction (usually X direction), in both the Trace (blue) and Retrace (red) directions. In the Main Controls menu, set **Slow scan axis** temporarily to **Disabled**, in order to eliminate the changes in topography due to scanning in the slow scan direction.

Optimize the scan and feedback parameters so that the trace and retrace lines mimic each other. The primary parameters used for optimizing surface tracking are the **Setpoint**, **Integral gain** and **Tip velocity**. In most cases it is best to minimize the force on the sample surface, so the amplitude setpoint should be decreased (i.e. the force increased) only if the scope trace exhibits false engagement behavior or if adjusting other parameters does not improve tracking. In general, the rougher the sample surface and/or the larger the area being scanned, the slower the required scan rate.

More on Real Time Parameter Settings

Reducing the **Z limit** will improve height resolution on extremely smooth surfaces (where the Data scale is 10 nm or less). Don't drop the Z limit if your surface has tall features that you may be scanning over; the reduction in Z scanner range prevents the scanner from raising the tip out of harm's way.   Remember to return the Z limit to its maximum setting if there's any chance the reduced Z piezo range may not be adequate for new conditions, and always before you re-engage the microscope. **Never drop the Z limit below 500 nm.**

Once you get used to using this instrument you should feel free to experiment with other Real-Time scanning and feedback parameters to learn how to get the best image of your sample. A *fractional* drop in drive frequency, or a small increase or decrease in drive amplitude, will sometimes improve tracking. Be careful with these latter two parameters, however. Type in a small numerical change rather than using the arrow keys. It's safer to set these two parameters with the tip disengaged than with it actually tapping on the sample.

Moving to a Distant Area on the Surface

If the area you want to translate to is out of range of the scanner, you must use the motor control to move the sample relative to the tip.

Click once on the **Withdraw** icon . The SPM will go out of feedback mode, the tip will withdraw and the optical microscope will refocus on the sample surface. If you offset the scan in X or Y previously, reset those offsets back to zero now. Also make sure the Z Limit is set to its maximum value.

If you're moving far from the previous point, raise the acoustic hood to see the sample surface while you're finding the new area to scan. If your sample is not uniformly level, raise the scanner to protect the probe while the sample is being moved. Translate the stage until the new area you want to scan is centered under the CRT crosshair. Then refocus the microscope on the surface.

Close the acoustic hood now. Make sure the X and Y offsets are set to 0 and the Scan size is 1 μm, then reengage (click on **Engage**).

Changing or Removing Samples

Warning! before you lift the acoustic hood, withdraw the tip and ensure that the message at the bottom of the control screen says Tip: Secured.

Raise the scanner if you may need to protect the probe as you remove your sample. Then rotate the platen manually and exchange/remove your sample.

If you are working with a large wafer, select **Stage/Load** to raise the scanner and bring the stage all the way out from under the cantilever. Select **Load** again to reposition a new wafer.

If continuing with a new sample, reposition the new sample under the cantilever, use the **Focus Surface** routine to position the tip as described above, and **Engage**.
If ending your session, raise the scanner to a centimeter above the platen for the next user.

Ending a Session

Allow enough time at the end of your session to copy the files you want onto your own USB storage device. Plug your USB device into the side of the left monitor. Warning: do not expect your files to exist on the computer after your session.

If you had to move the platen out from under the scanner to unload your sample, please move it back again so that the pool of white light is centered on the back outer edge of the platen. You can move the XY stage motors manually if need be.

Unplug the scanner power plug (grab the plug, not the cable).
Dismount the scanner and remove your tip if you want to keep it.
Leave the spring finger on the cantilever mount retracted.
Reinstall the cantilever mount on the scanner and leave the scanner mounted,
unlocked and unplugged, on the microscope.
Reinstall any stage screws you removed to hold your samples.
Exit the Nanoscope software.
Close the acoustic hood, and turn off the isolation air supply, Huff n' Puff, Nanoscope controller and monitors.
Leave the Nanoscope computer on.

Sign out your time in CORAL and remember to report any cantilevers you bought during your session. Correct the BusyCal Lab Calendar if you stayed longer or shorter than your original reservation.

If there are any instrument performance problems, report them directly to Libby (it's most productive to report these **while** you're using the AFM, not afterward).

Turn off the light, lock the door, bye! See you next time!

Standard TM start-up settings for the D3100

SCAN CONTROL PANEL			FEEDBACK CONTROL PANEL		
Scan size	:	1.00 μm	Integral gain	:	0.15
Aspect ratio:	:	1:1	Proportional gain	:	0.20
X offset	:	0.00 nm	Amplitude Setpoint	:	**
Y offset	:	0.00nm	Drive frequency	:	*
Scan angle	:	0.00 deg	Drive phase	:	*
Scan rate	:	2.00 Hz	Drive amplitude	:	*
Tip velocity	:	4 μm/sec			
Samples/line	:	256			
Lines	:	256			
Slow scan axis	:	Enabled			
CL Scanner	:	OFF			

CHANNEL PANELS			OTHER CONTROLS PANEL		
Realtime Planefit	:	Line	Units	:	Metric
Offline Planefit	:	Full	Color table	:	[anything]
			Illumination	:	***
			Engage setpoint	:	1.00

* = these parameters will be set using the Cantilever Tune routine.
** = initial setpoint will be set by the automatic Engage software.
*** = manually set the illumination as needed.

GENERAL ADVICE:

Double-check that the Real-time menu says "Tip: SECURED" before doing anything that could interfere with the feedback loop, such as blocking the laser beam, dismounting the scanner, or unplugging any cable. **Unreported instrument damage suffered during your session will be charged to your account**.

Confirm your AFM tip is acceptably sharp by imaging some material with stable features of a similar size and scale to the ones you'll be measuring.   Rescan that sample whenever you suspect tip damage.

Before you capture an image, optimize your feedback parameters and make sure that the image is not drifting excessively. With the slow scan axis disabled, the image should look like vertical columns.

Capture images early and often -- the tip will eventually degrade. Compare the live trace and retrace topographic images to help you decide whether the data is "real" enough to save. If you capture multiple channels to a single file it is easy to resave the images separately later.

Some software bugs occasionally act up in the Version 5 software. Here's how to deal with them:

The stage keeps moving after I move the trackball, even when I exit the Focus Surface routine.
Solution: Exit the Nanoscope software and restart it.

When I go to exit the Locate Tip routine, I get a warning to "reteach the tip position".
Solution: Ignore the message and hit OK.

When I hit Engage the optical microscope doesn't focus on the probe as it's supposed to, and the surface is out of focus when the instrument starts scanning.
Solution: Let the microscope engage, then use the Focus Surface routine to focus on the sample surface
          while scanning. The next time you hit Engage the optical microscope should focus normally.

After engaging I get a "null signal" message and Engage stops, even though there's still a laser signal.
Solution: Put your sample on a substrate in order to raise it up a bit.