

**Operation of MRL's Veeco Dimension 3100 SPM
in Tapping Mode: Version 5 software**
els 180906

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

Turn on the two display monitors. Check that the upper yellow air supply handle is in line with its copper pipe. Turn on the Huff n' Puff if it's off (green power switch).

Start the software by clicking on the top left icon on the Control screen (labeled Nanoscope V530r3sr3). Then click on the **yellow microscope icon** when it shows up.

Wait patiently. When the Real Time menu finally appears, check the bottom left of the screen. If it doesn't say Quadrexed D3100, pull down the **DI** menu, click on **Microscope Select** and select the option **Quadrexed D3100**.

In the Other Controls panel, check the grayed-out field labeled "Serial number" to make sure the correct scanner calibration file is loaded. The standard open-loop scanner serial number ends in "g" or "g-z". (The less-used XY closed loop scanner number ends in "cl".)

To load the default Tapping Mode parameters *and default parameter values*,
Pull down **Microscope** and click on **Profile**,
Click once to select **MRL Tapping AFM**,
Click once to select **Load Master**. (Answer OK to confirm deletion)

Warning: clicking on **Load** rather than **Load Master** loads the last user's parameter values, not the recommended default values. This can cause complications.

Inspecting and Preparing Your Sample

Don't load your sample on the D3100 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. If the sample is larger than about a half-centimeter square and has a clean, flat underside, you'll be able to use the vacuum to secure it to the microscope platen. If for some reason you can't use the vacuum to hold your sample, mount the sample with adhesive or with silver paint onto a smooth substrate, for instance a steel "puck", a piece of silicon, or a glass slide.

Do not contaminate the vacuum platen surface with adhesive, silver paint, or grease.

Installing a Cantilever

The previous user should have left the Dimension scanner installed but unlocked,

raised up about a centimeter from the platen,
power cord unplugged,
cantilever mount installed.

If necessary, unlock the scanner (i.e. turn the locking screw all the way clockwise).

Dismount the scanner by 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 mount platform.

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

Install your cantilever on the cantilever mount, making sure the silicon chip is level, aligned straight, and all the way back in the slot. Bring the spring finger fully forward and make sure it is not touching metal on either side of the silicon chip. Stow components and tools safely away as soon as you've finished with them. Close your cantilever box to protect your unused cantilevers.

Carefully align the cantilever mount with the four gold contact pins in the scanner and *gently* press it in place, *visually inspecting* to make sure all four pins are fully seated.

If it's a dry day, always touch a grounded metal surface immediately before you touch the D3100 again.

Slide the scanner *smoothly* all the way down to the bottom of the slot on the D3100. Plug in the scanner power connector, 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). If the laser is not on, select **Microscope/Reset** to reset the controller. If the LED is still dark, select **Stage/Initialize** and answer all the prompts "OK" until initialization is complete. Initialization takes about a minute.

Step 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.

First, adjust the illumination so that you see a spot of white light on the platen. Then:

- 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 that red spot for now -- watch instead the laser reflection on the platen surface.

If the scanner is too close to the platen to let you see the laser reflection, click on the "Withdraw" icon (red up-arrow) to raise the scanner. One click = 1 mm rise.

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 shift!) 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.**

Step 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 reflected laser on the oval glass window (the exact position varies from scanner to scanner). Then, watching the red dot on the Laser Signal display on the monitor, use the same two knobs to move the red spot 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. Then select **Auto Tune**.

Software Response: First the Auto Tune routine homes in on the dominant peak in the amplitude vs frequency graph (white line). That peak is the natural resonant frequency of your cantilever.

Next it adjusts the drive amplitude so that the detector voltage output matches the Target Amplitude, lowers the center of the frequency range 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 amplitude response for three characteristics: 1) stability, 2) symmetric shape, and 3) drive amplitude less than 10% of the target amplitude. If these conditions aren't met, then return to the Real Time menu, dismount the scanner, and reseal the cantilever. Remount the scanner, realign the laser and the photo detector mirror, and retune the cantilever.

When the amplitude response meets specs, **Zero Phase**, return to the Real Time menu, and note the free amplitude value. This value should stay fairly stable during your session.

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

Select the **Locate Tip** icon (**magnifying glass over yellow <**).

What's Happening: The XY piezo will spiral itself briefly and the optical microscope focus will automatically move to the focus position the previous user set for his/her cantilever.

Use the two black knobs on the optical microscope to position the optical CRT crosshair precisely where you believe your cantilever's probe is. You may need to adjust the Illuminator intensity to see the cantilever. If the cantilever tip is not then in focus, press the large lower left trackball button and roll the trackball to adjust the optical microscope focus until the tip is in focus. Then **exit** the Locate Tip routine.

Loading Your Sample on the Platen Before Engaging

Make sure the platen and the underside of your sample are clean before using the vacuum to hold your sample. Make sure that the only vacuum ports open are the ones you'll be using. Be careful not to strip any vacuum screws when you're installing them. **Store unused vacuum screws safely away in the box provided.**

Don't use sharp tweezers to position your sample on the platen surface. The platen must be scratch-free or its ability to hold samples with vacuum will be compromised. Don't touch the platen surface with your fingers unless you're wearing gloves. Never use anything but the vacuum to secure your sample on the platen (i.e. no glue!).

DO NOT ROTATE THE VACUUM PLATEN UNDER VACUUM, or you may scour the mating surfaces of the platen and vacuum chuck and eventually their ability to hold a vacuum will be destroyed.

Check that the vacuum is holding your sample, then turn OFF the vacuum, then rotate the platen to move your sample into position, then turn ON the vacuum again.

Positioning the Sample and Scanner Before Engaging

Select the **Focus Surface** icon (**magnifying glass over red IC**). The optical microscope will refocus to a point 1 millimeter below the cantilever.

Check the height of the cantilever over the platen. If it looks too low to move your sample into position without crashing into the cantilever, press the FOCUS trackball button and push the trackball **away** from you to raise the scanner until the cantilever is out of harm's way.

Then rotate your sample to the back of the platen. Remember to turn OFF the vacuum before rotating the platen. Handle the platen only by its knurled edge, and remember to turn the vacuum back ON after finishing rotating the platen.

Then, still in the Focus Surface routine, use the trackball to translate your sample into position under the cantilever. Translation is done by holding down either of the upper LOCK trackball buttons and rolling the trackball in the direction you want the stage to go.

Next, 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 surface.* Roll the trackball smoothly to adjust the height of the scanner until the sample surface is in sharp focus.

Warning: the tip should NOT come into focus during the Focus Surface routine. If the tip starts to come into focus, move the scanner back up! You risk crashing the tip into the surface. Finally, translate the stage a little to confirm that you are not bringing the tip down on a piece of dirt.

Engaging the Microscope

If you expect acoustic vibration may interfere with your analysis, close the acoustic hood NOW, before engaging. Do not lock it.



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

Software response: The optical microscope will focus on the tip, the motor will move the scanner to about 100 μm from the sample surface, and then the motor will 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

Click on the **Scope Mode** icon (**oscilloscope screen**). This shows a live graph of cantilever response vs. the distance the tip is traveling in the fast-scan direction (usually X direction), in both the Trace (white) and Retrace (yellow) 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.

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

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). But 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. And **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.

Raise the acoustic hood if you need to see the sample surface while you're finding the new area to scan (generally a good idea). Click on **Focus Surface** to enable the trackball controls. If your sample is not uniformly level, use the large FOCUS trackball button and the trackball to raise the scanner until it is high enough to clear the sample while the sample is being moved. Use either of the small LOCK trackball buttons in conjunction with the trackball to translate the stage until the new area you want to scan is under the CRT crosshair. Then use the FOCUS trackball button in conjunction with the trackball to refocus the microscope on the surface. **Exit Focus 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**.

If you are working with a large wafer, a convenient way to change or remove samples will be to 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.

With other samples, use the trackball in Focus Surface mode if you need to raise the scanner to avoid hitting the tip as you remove your sample. Then rotate the platen and exchange/remove your sample.

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, use the Focus Surface routine to raise the scanner well 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 media. Warning: do not expect your files to exist on the computer after your session. Copy your files either to a USB drive or to a WCD. The USB socket is on a grey cable on the desktop.

Using Focus Surface mode, raise the scanner until the cantilever is about a centimeter above the platen surface. If you've 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.

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, turn off the isolation air supply, Huff n' Puff and monitors.

DO NOT turn off the Nanoscope controller.

Leave the Nanoscope computer and controller on.

Sign out your time, cantilever use and disk use in the Instrument Use Log. Round the time to the nearest half-hour (with a half-hour minimum) and record every tip you bought as a consumable (example: 1 TM for "one tapping mode tip"). Correct the Lab Calendar if you stayed longer or shorter than your original reservation. Enter any

helpful observations of instrument performance in the AFM Performance Log. If there were any problems, report them directly to Libby as well.

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

Standard TM start-up settings for the D3100

SCAN CONTROL PANEL

Scan size	:	1.00 μm
Aspect ratio:	:	1:1
X offset	:	0.00 nm
Y offset	:	0.00nm
Scan angle	:	0.00 deg
Scan rate	:	2.00 Hz
Tip velocity	:	4 $\mu\text{m}/\text{sec}$
Samples/line	:	256
Lines	:	256
Slow scan axis	:	Enabled
CL Scanner	:	OFF

FEEDBACK CONTROL PANEL

Integral gain	:	0.15
Proportional gain	:	0.20
Amplitude Setpoint	:	**
Drive frequency	:	*
Drive phase	:	*
Drive amplitude	:	*

CHANNEL PANELS

Realtime Planefit	:	Line
Offline Planefit	:	Full

OTHER CONTROLS PANEL

Units	:	Metric
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.