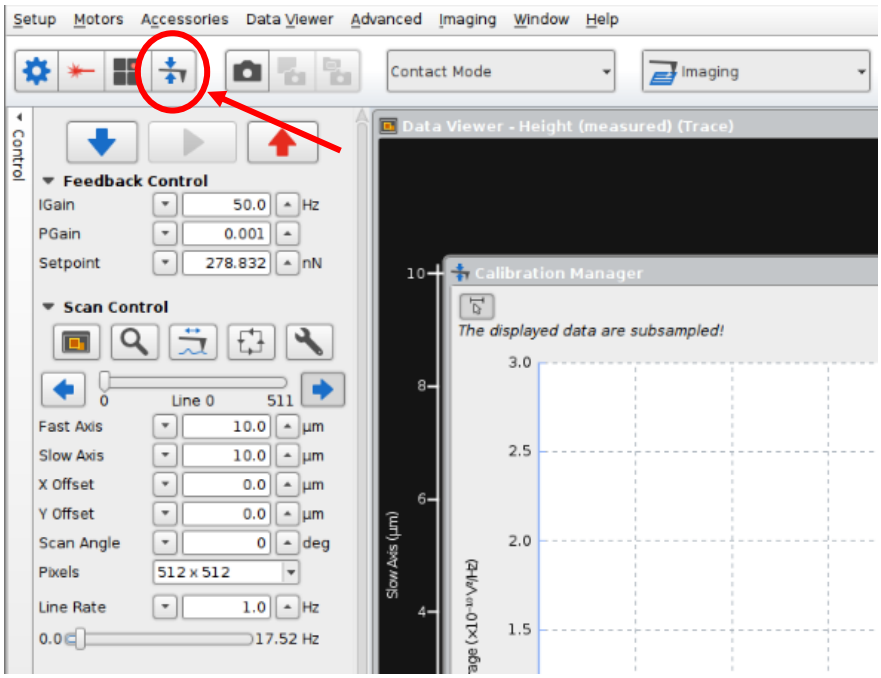
University of South Australia	**FUTURE INDUSTRIES INSTITUTE** **Standard Operating Procedure** ***JPK NanoWizard 3 AFM*** ***Lateral Force Microscopy manual***	MICROSCOPY AUSTRALIA
Location:	Laboratory Manager:	

JPK NanoWizard III analysis of Friction coefficient and Friction force (Lateral Force Microscopy)

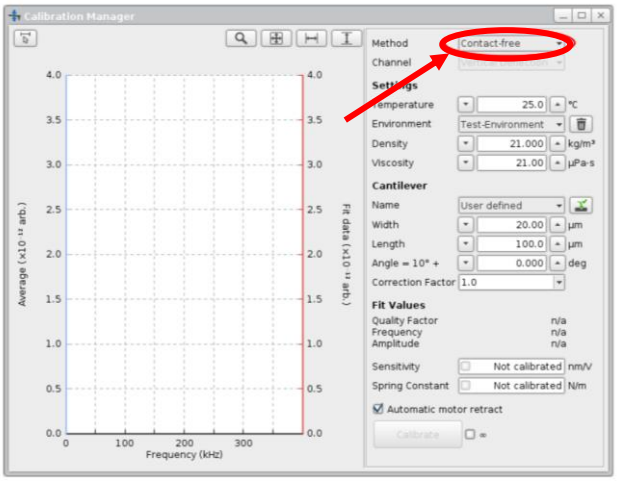
1. Tuning of the cantilever for contact mode does not necessarily need to be performed, but it is needed for accurate spring constant values for Lateral Force Microscopy conversion from friction coefficient to friction force. Also, it's advisable to check the physically tuned values against the manufacturer's parameters and to obtain a cantilever sensitivity.

   There are several tuning methods, the most straight-forward is non-contact tuning. On non-contact cantilever calibration in air, make a note of the cantilever sensitivity (nm/V) and spring constant. Follow these steps to tune:

   (a) Open the Calibration Manager.

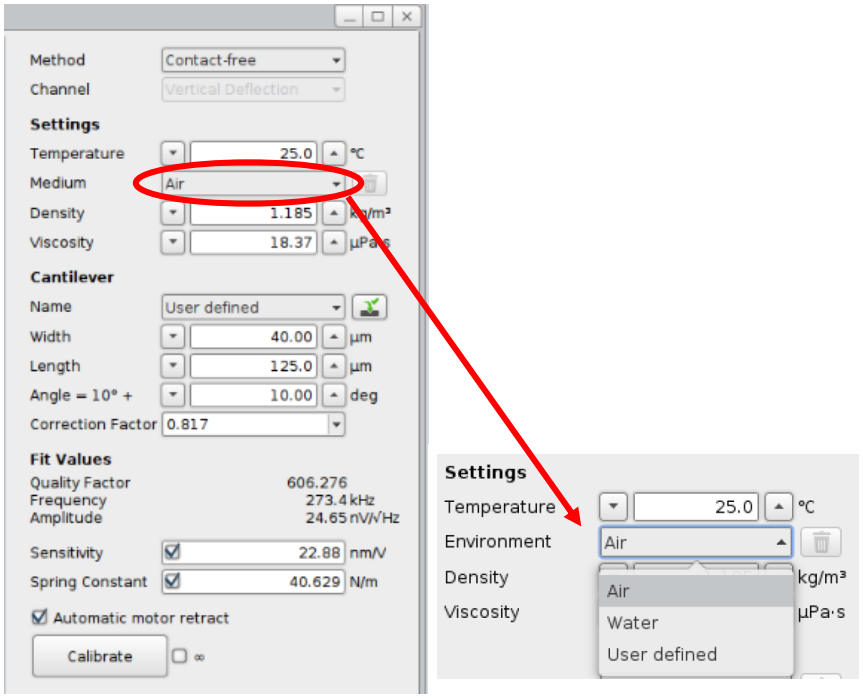


   (b) This pop-up window will open. Select 'Contact-free' from the method drop down menu.

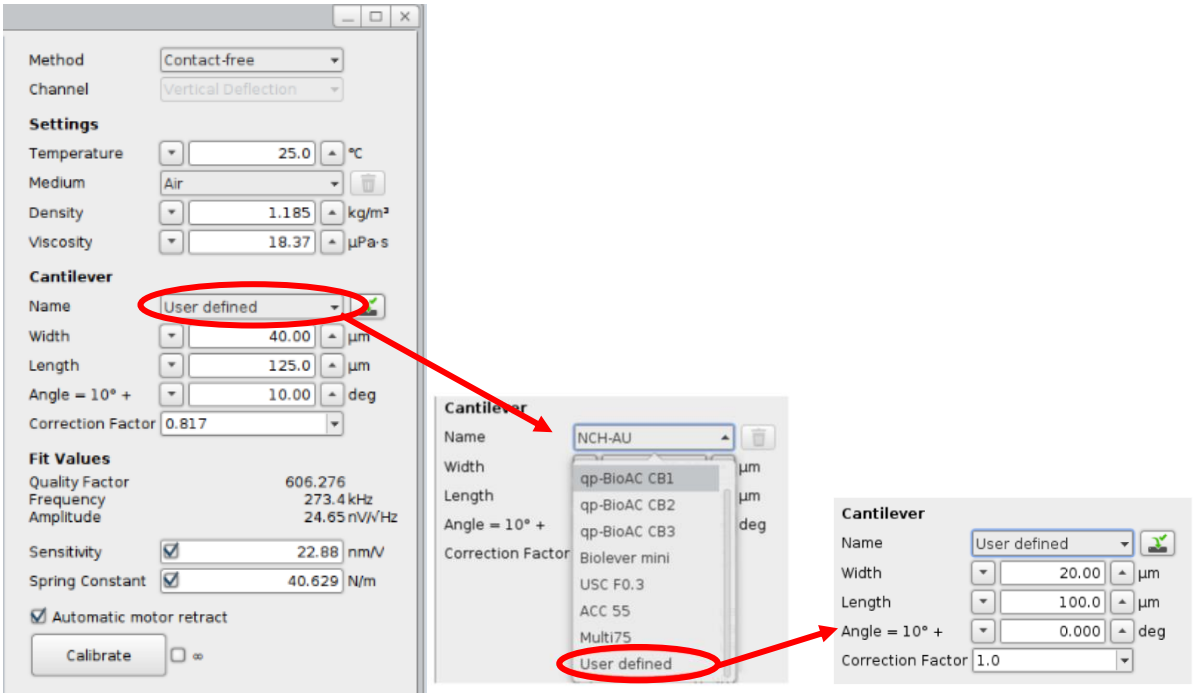


   (c) Set the Environment to 'Air'. The density and viscosity are prefilled but can be altered.

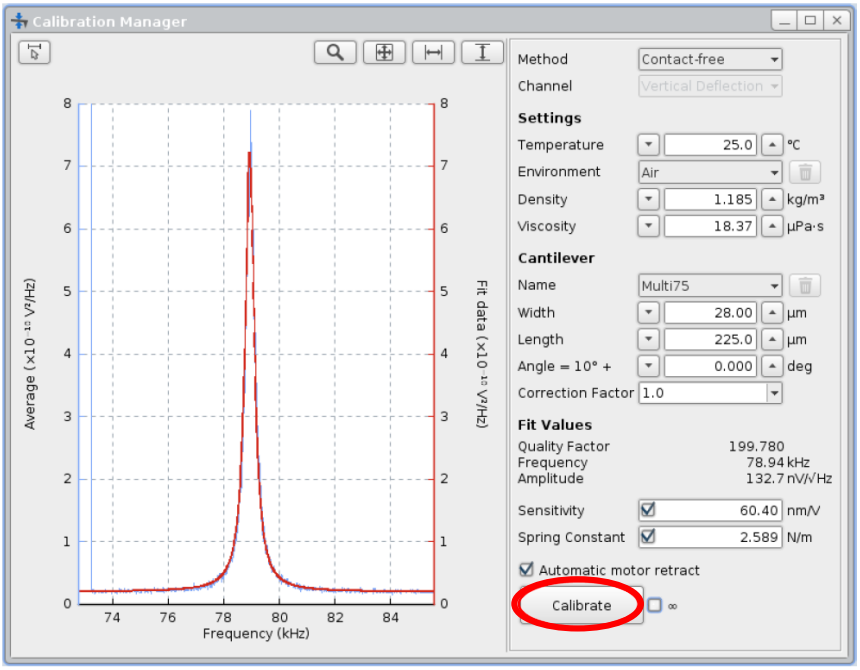
Unless you are scanning in liquid, which means you should set-up and calibrate the cantilever using the AFM liquid imaging manual.



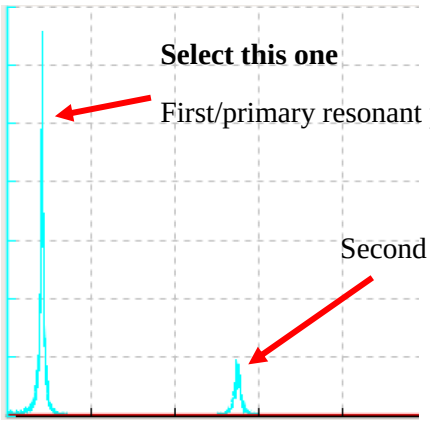
(d) Choose the model of cantilever. This will be on the box the cantilevers are in. If your cantilever model is not on the list (and it probably won't be as the list is very limited), select 'user defined' and put in the width and length of your cantilever. These values will be on the original cantilever box or on the manufacturer's website. If you know the angle and correction factor, put these in. If you don't leave them with the values they have. I not had to alter them with standard cantilevers. The cantilever holder places the tip at an offset of 10°, which is automatically put in.



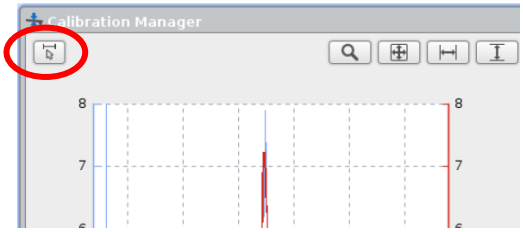
(e) Click calibrate (bottom of the window) to perform a thermal tune of the cantilever. The box next to it should be unticked (this will continually oscillate the cantilever until you uncheck it). All going well it will fit a red line trace over a significant peak that should be in the frequency range for your cantilever type. Look on the box or manufacturer's website to check the frequency range for the cantilever. If it is successful, values for Sensitivity and Spring constant will appear near the bottom of this window just above the calibrate button. If the Calibration Manager window looks similar to that below, calibration is finished, and you can load your sample, approach, and start scanning.



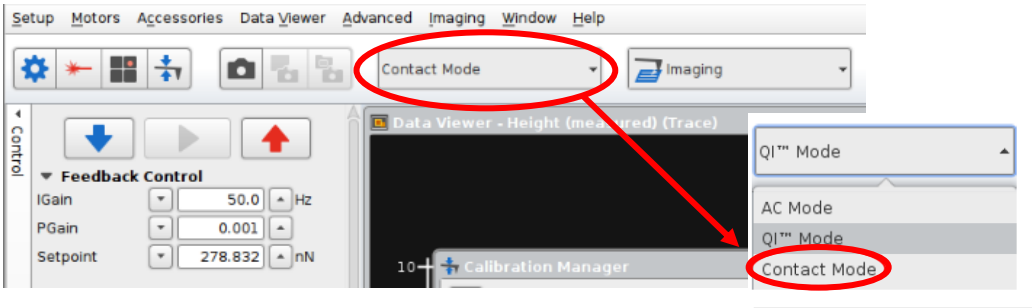
If the calibration fails. If it does not fit a peak within your cantilever's frequency range. You will need to manually select a peak. There should be a clear peak in the spectrum, within your cantilever's stated frequency range. It should be similar to below. If not see troubleshooting, in the Appendix.



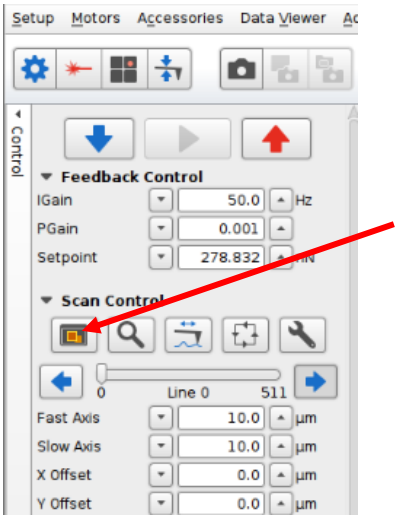
To manually fit a peak select the  icon on the top left corner of the window. Click and drag the cursor horizontally over peak area in the spectrum window. This should select the peak. If not try a wider region before and after the peak. If this does not work, you may need to try a different calibration technique. Consult the general set-up manual.



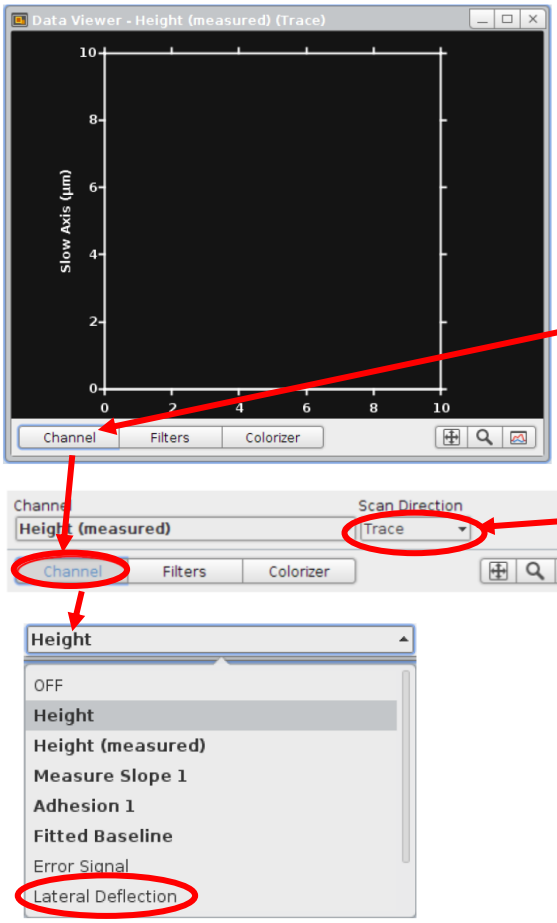
2. Make sure contact mode scanning is selected. Default mode when starting software is QI mode.



3. Select scanning parameters such as scan size, etc. Approach surface by pressing  icon. If you are unsure how to approach and contact surface. Look at general topography manual.
4. Before scanning or just as scanning starts, open two more scan windows: Lateral deflection trace and retrace, as shown below.



Click twice to open two new scan windows



Scan window

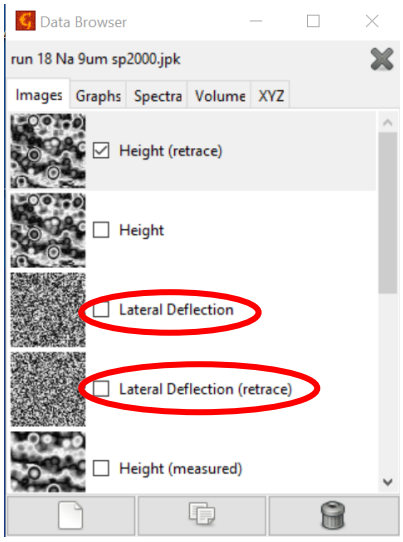
Click ‘Channel’ and select Lateral deflection

Select one scan window as ‘Trace’, the other as ‘Retrace’

Data Processing

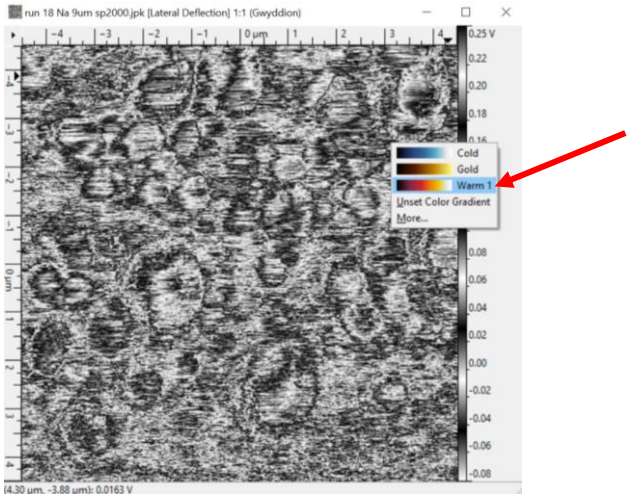
After the height, Lateral Deflection Trace and Retrace images have been saved into a folder, they need to be processed to gain Friction coefficient and Friction force values and plots. Processing can be partially performed using the JPK data processing software. Some external software is required. In this manual Microsoft Excel and Gwyddion freeware will be used for data processing due to their ease of use and functionality.

1. Open Gwyddion , File → Open and choose the file you wish to open
2. In the Gwyddion data browser, under the Images tab select Lateral Deflection and Lateral Deflection (Retrace). These are the Trace and Retrace windows. These will open the image windows.



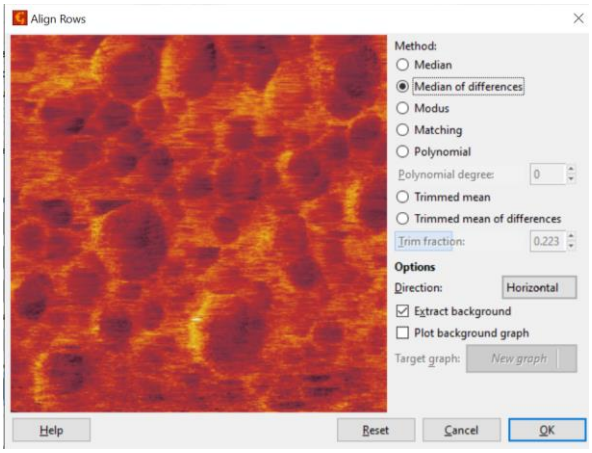
3. To Image correct and colour these images, in this example I will use the colour pallet 'Warm'. For each image, select by clicking the top toolbar, in the main Gwyddion toolbar go through the following steps:

   -Right click on edge of scan (to the right of the scale bar), select Warm, or More if not on list.

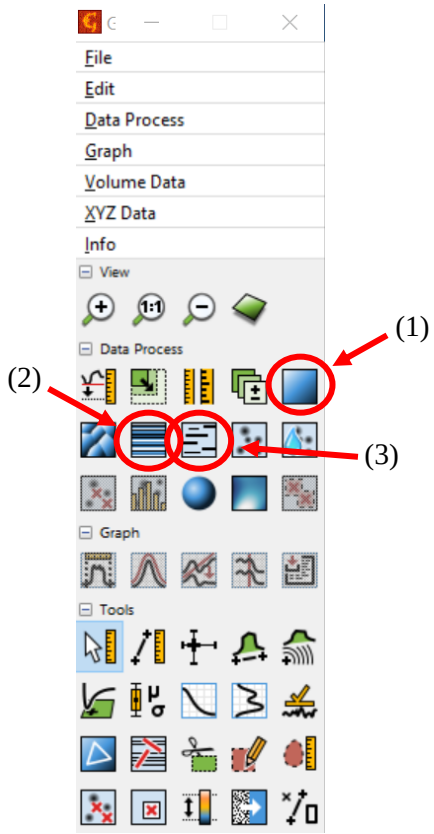


   -Level data by mean plane subtraction (1)

   -Align rows using various methods (2). I usually select Median of differences under Methods and Extract background box ticked.

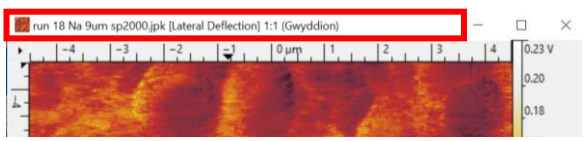


-Correct horizontal scars (strokes) (3)

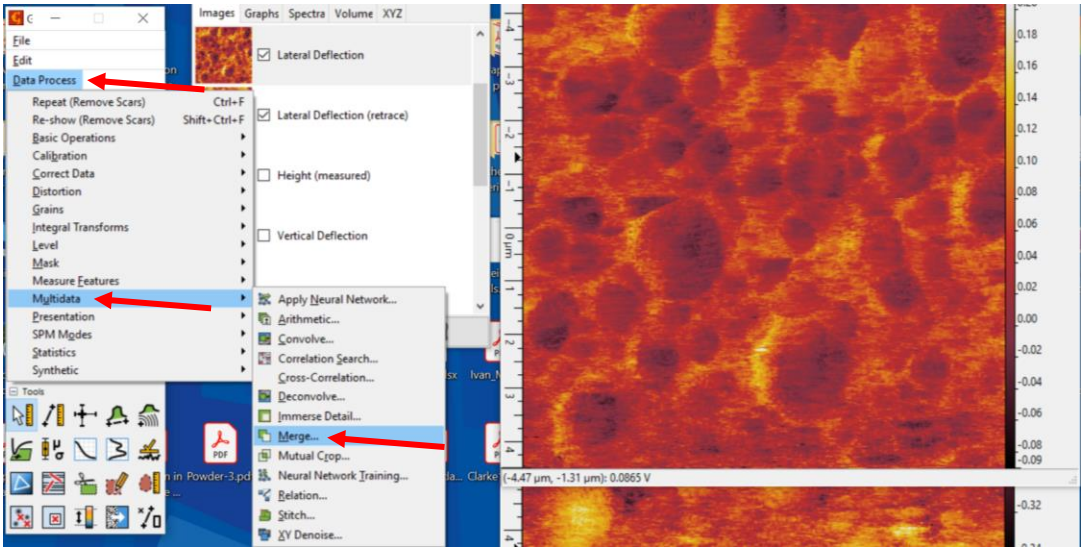


4. Merge the Lateral Trace and Retrace images, by the following steps:

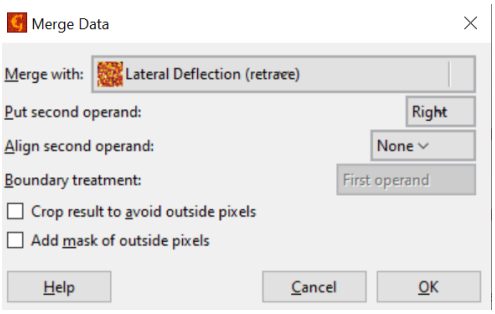
-Select the Lateral Deflection image by clicking on the top of it (where file name is)



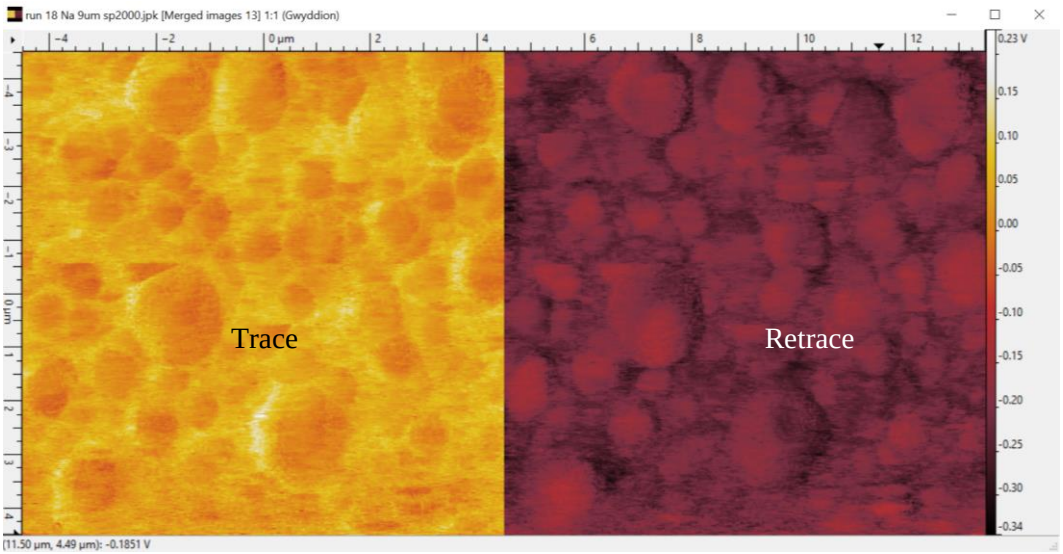
-Click on ‘Data Process’ in main Gwyddion toolbar, then ‘Multidata’ ondrop down menu, then ‘Merge’ on next dropdown menu.



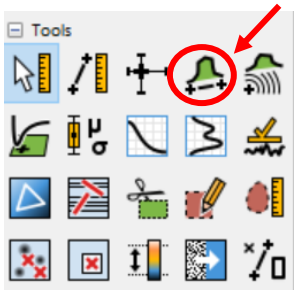
-In Merge with, select Lateral Deflection (retrace), then OK

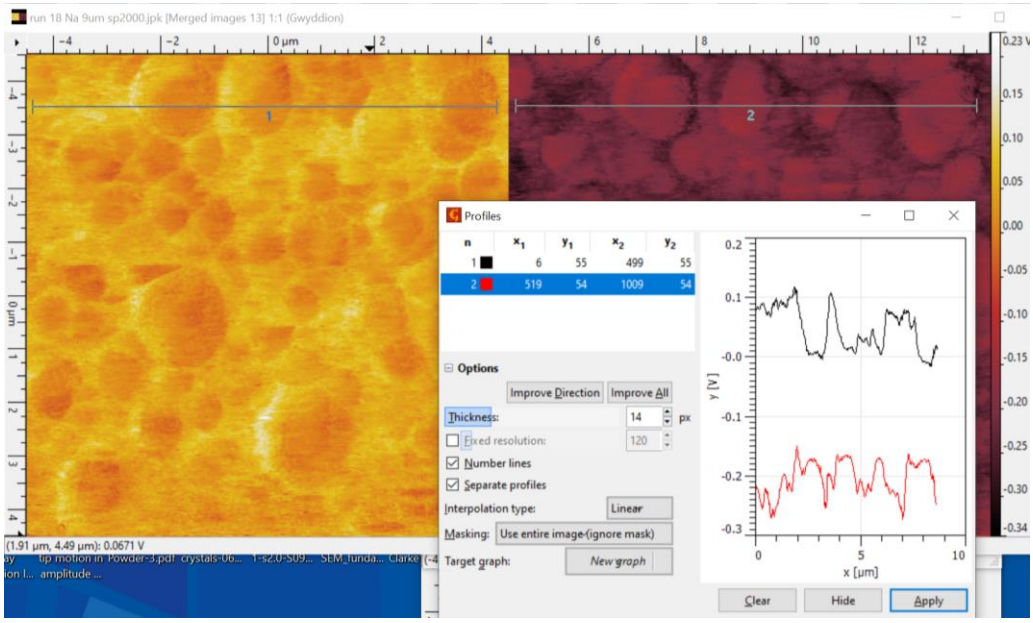


-This will combine the Lateral Deflection Trace (LHS) and Retrace (RHS)

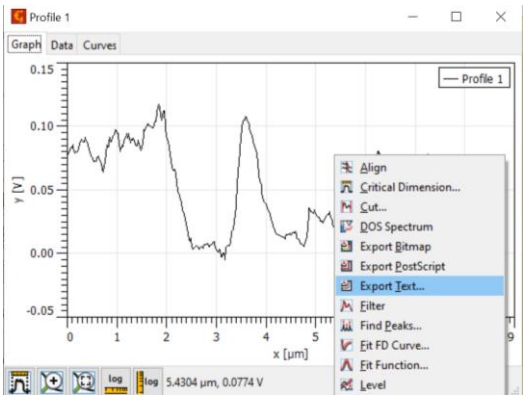


-Select ‘Extract profiles along arbitrary lines’, then Click and drag along an area in both images to gather a 2D plot. A plot of the Trace (black) and Retrace (red) will appear.

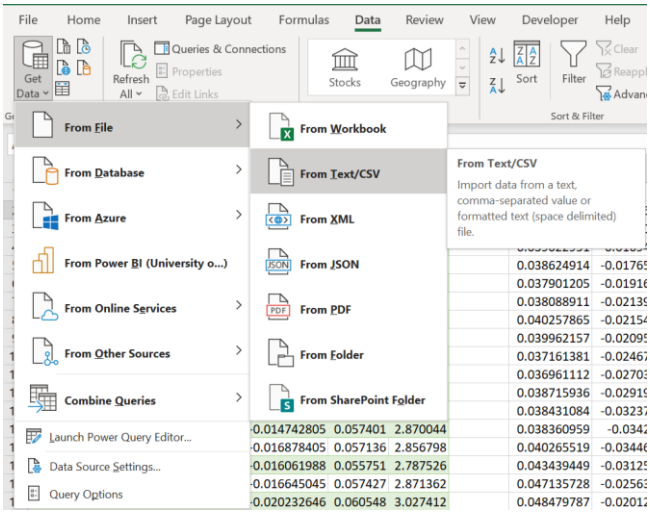




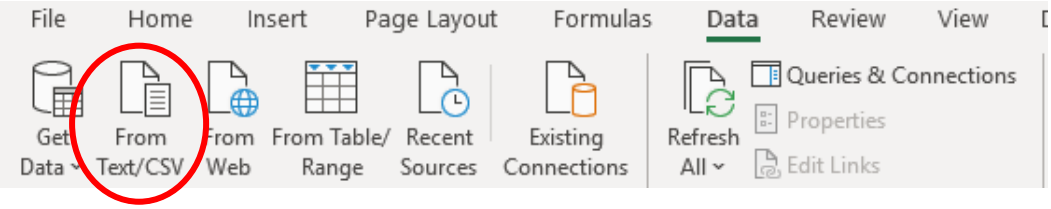
-Click ‘Apply’ and two pop-up windows will appear, Profile one in black for Trace, Profile two in red for Retrace. Right click on plot and select ‘Export Text…’, choose file name and place to store it.



5. Open an Excel spreadsheet. Select ‘Data’ on the top toolbar, then ‘Get data’ on the LHS → From File → From text/CSV, then select your trace and retrace files.

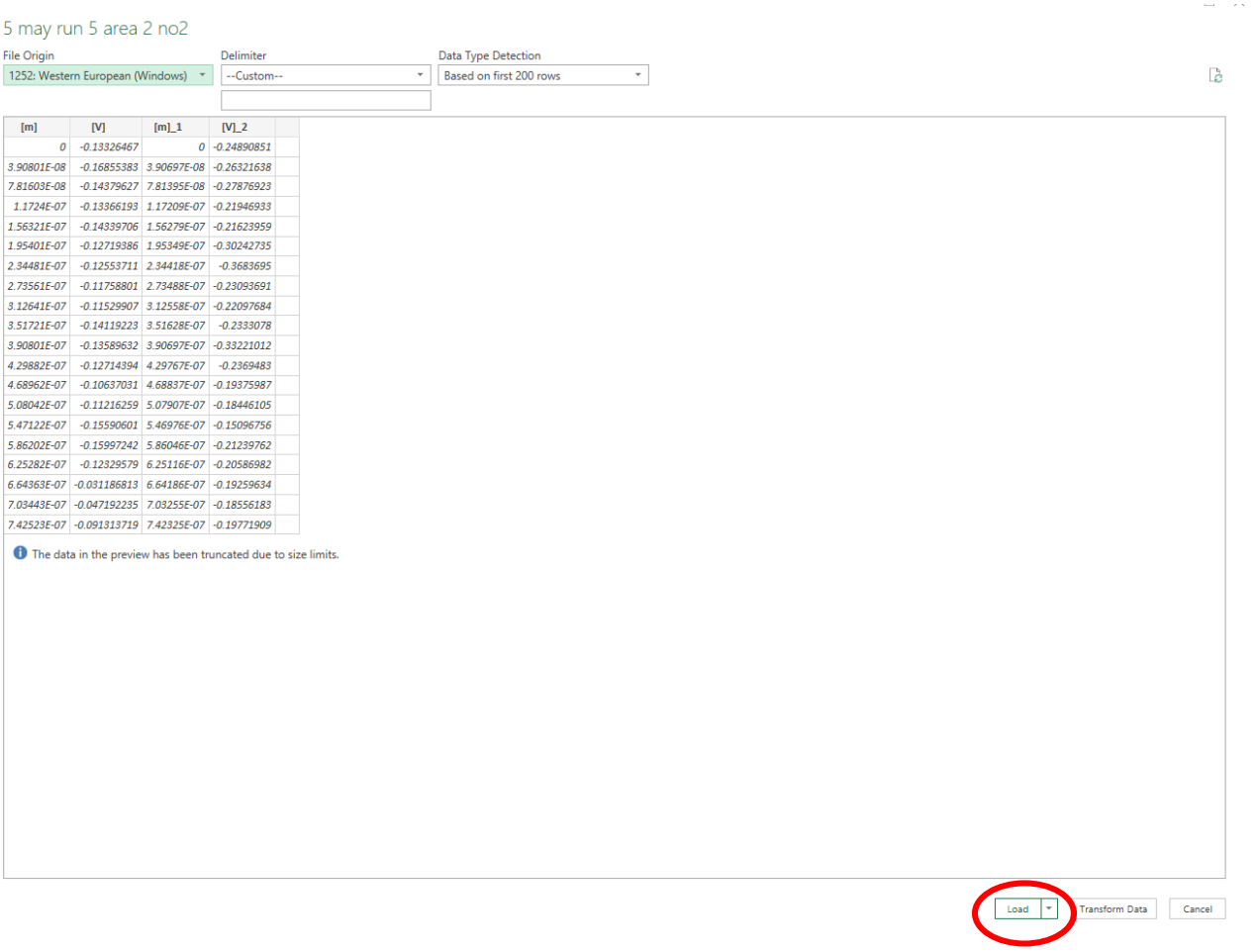


-Saved data as text: This can be opened in Microsoft Excel or Origin software. In Excel, click on 'Data' on top toolbar, then 'From Text/CSV'.



Then import data from where you saved it. On the bottom RHS of screen, may need to change from 'Text Files' to 'All Files' to show the files.

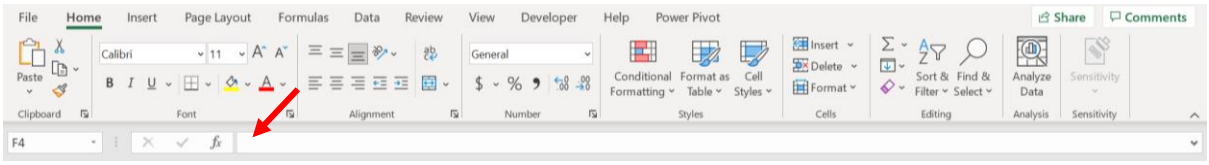
Double click on file you want to open. A window will pop-up. If the data looks good and is separated into individual columns, click 'Load', down the bottom RHS. This will load the data into an Excel spreadsheet. From there you can create a 2D plot from the 'Insert' menu in the top toolbar. If more than one set of data is in the one space, the delimiter drop-down menu may be needed to separate data if separated by colon, semicolon, etc.



-Saved data as .jpk file: This can be opened and processed in post-processing software such as Gwyddion, WSxM, or SPIP.

-Place data in Excel like this. Calculate the Friction coefficient by typing the sum into the formula window in the top toolbar. For friction coefficient '=(B2-C2)/2' and for the Friction force which is the SetPoint force multiplied by the friction coefficient value '=(10*D2)'. Adjust these sums as required, such as for the SetPoint value of 10 nN.

	A	B	C	D	E	F
1	Scan distance (m)	Lateral Deflection trace	Lateral Deflection Retrace	Friction coefficier	Friction force (nN)	
2	0	0.067346366	-0.03527511	0.102621476	5.1310738	
3	9.75099E-09	0.06786462	-0.02777533	0.09563995	4.7819975	
4	1.9502E-08	0.068340027	-0.020397332	0.088737359	4.43686795	
5	2.9253E-08	0.067253002	-0.017753309	0.085006311	4.25031555	
6	3.9004E-08	0.061625898	-0.019003396	0.080629294	4.0314647	
7	4.8755E-08	0.055607927	-0.02064294	0.076250867	3.81254335	
8	5.8506E-08	0.052151345	-0.019712229	0.071863574	3.5931787	
9	6.8257E-08	0.048693115	-0.018259825	0.06695294	3.347647	
10	7.8008E-08	0.046004846	-0.016751432	0.062756278	3.1378139	
11	8.7759E-08	0.045069306	-0.01642458	0.061493886	3.0746943	
12	9.75099E-08	0.044696052	-0.015114246	0.059810298	2.9905149	
13	1.07261E-07	0.04404116	-0.013293794	0.057334954	2.8667477	
14	1.17012E-07	0.04265808	-0.014742805	0.057400885	2.87004425	
15	1.26763E-07	0.040257548	-0.016878405	0.057135953	2.85679765	
16	1.36514E-07	0.039688537	-0.016061988	0.055750525	2.78752625	
17	1.46265E-07	0.040782193	-0.016645045	0.057427238	2.8713619	
18	1.56016E-07	0.040315595	-0.020232646	0.060548241	3.02741205	
19	1.65767E-07	0.038545264	-0.023740114	0.062285378	3.1142689	
20	1.75518E-07	0.038044884	-0.025544244	0.063589128	3.1794564	
21	1.85269E-07	0.039723391	-0.025162897	0.064886288	3.2443144	



Rearrange this equation $F_f = \mu \times F_N$

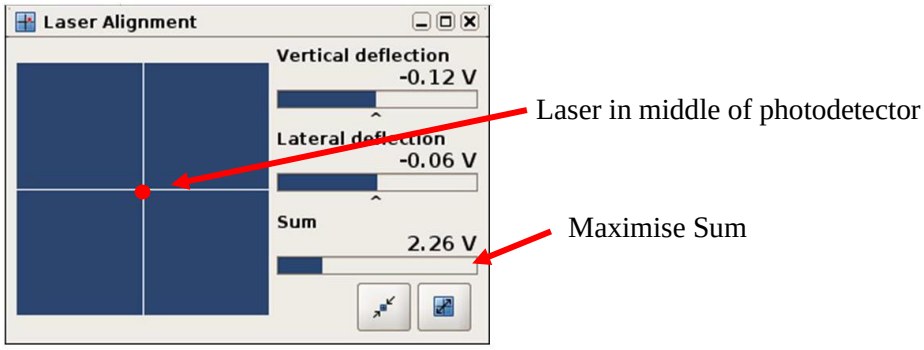
Friction coefficient equation $\mu\ (friction\ coefficient) = \frac{F_f(friction\ force)}{F_N(friction\ load)}$

Appendix

Calibration troubleshooting

There should be a clear peak in the spectrum. If there isn't, troubleshoot as follows:

1) Ensure laser spot is completely on cantilever. Readjust and ensure maximum Sum and that red laser dot is in the middle of the photodiode window. If the laser spot is not completely on the back of the cantilever, it will be partially on another non-oscillating surface which will cause coupling.



2) Take the cantilever holder out and readjust the cantilever. The cantilever may not be sitting in an ideal position. You will then need to readjust the laser on the back of the cantilever and photodiode, as per previous step.
3) If this fails, take the cantilever holder out, take the cantilever out, and clean the optical window with a little bit of ethanol on a Kim wipe. Replace the cantilever. It is rare that a new cantilever is bad, but it can happen.
4) If this all fails, consult with an AFM specialist on campus to further troubleshoot.