Thermal K 1.02 User Manual
Molecular Imaging Corp.
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Introduction

'Thermal K' is a program used in conjunction with PicoScan that allows the user to calculate the spring constant of an AFM cantilever.

The cantilever when far from a sample is treated as a simple harmonic oscillator with its kinetic energy equal to half its thermal energy (by equipartition). A power spectrum of the AC signal is then used to determine the mean-squared amplitude of the cantilever, which can then be used to solve for the spring constant. For more information on the method of spring constant calculation, see the references below.

Parts included in the package

- Data acquisition card (PCI-6013 or PCI-6070E)
- NI-DAQ software CD
- MI Thermal K software CD
- A 68-pin / BNC connector
- A 15-pin / BNC connector cable
- BNC coaxial cable

Setup

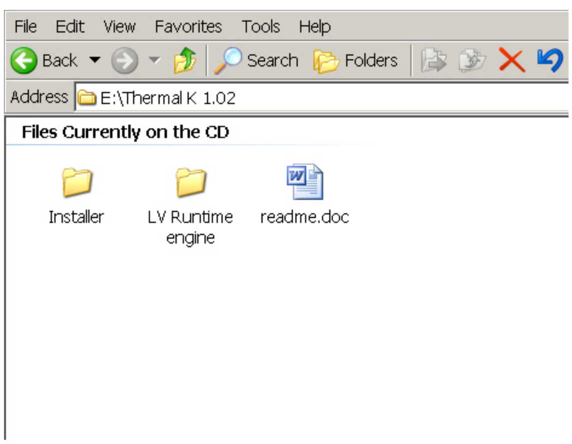
Hardware

- Install the data acquisition card in the PC you will be using.
- Plug the 68-pin connector onto the data acquisition card
- Plug the 15-pin connector onto the back panel of the ac mode box
- Connect the 68-pin connector and the 15-pin connector together with the BNC coaxial cable.

Software

Use the NI-DAQ software CD to install
- the device drivers for data acquisition card
- the NI-DAQ software

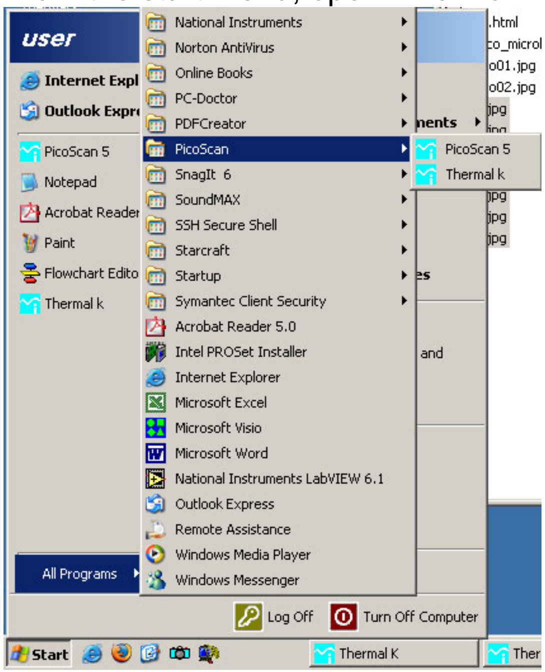
Use the MI thermal K software CD to install
- the LabVIEW Runtime Engine in the 'LV Runtime Engine' folder by running 'LVRunTimeEng.exe'
- the Thermal K software in the 'installer' folder by running 'setup.exe'

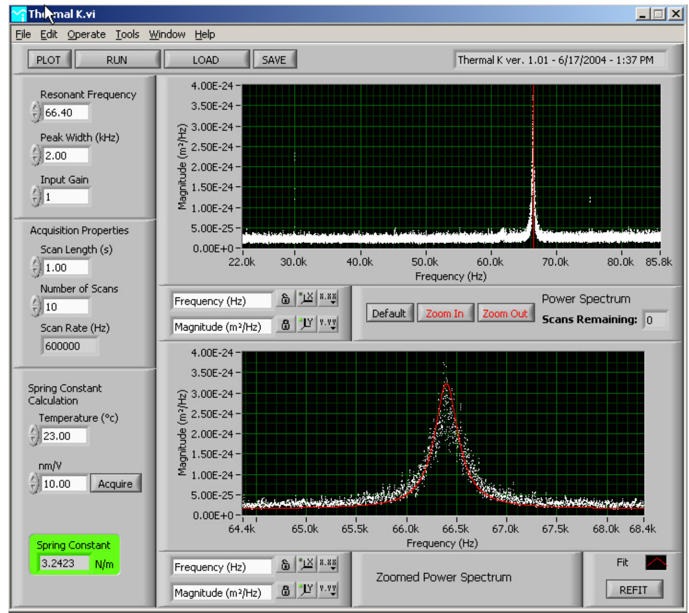


After the installation of the software, run the National Instruments Measurement and Automation software. Under 'Devices and Interfaces', ensure that the Data acquisition card that you are using says 'Device 1' next to it. If it says another device number, right click the card's name and choose properties. Under the system tab, change the device number to 1 and click OKAY. If another device is set as device 1, it will have to be changed to another number before this can be done.

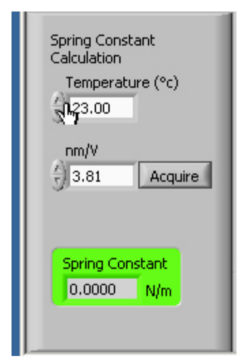
Measurement

From the start menu, open 'Thermal K' from the 'PicoScan' folder.





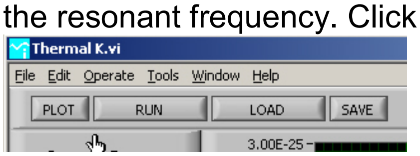
Setup AFM operation as instructed in the PicoPlus AFM manual. Prior to measuring the spring constant of a cantilever, one must calibrate a force curve. PicoScan provides a calibration script (Calibrate Deflection.vbs) to do this.

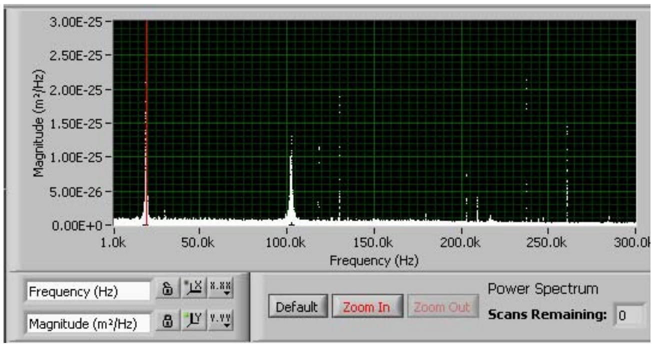


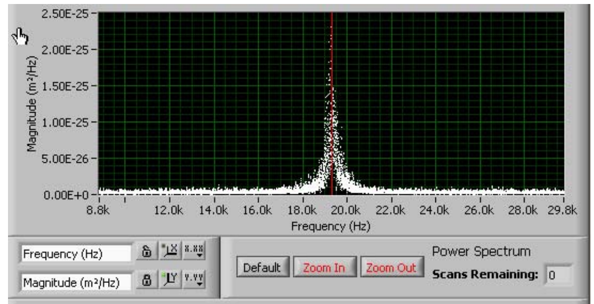
Once this is complete, either read the nm/V number from the setup in PicoScan (it is called the preamplifier conversion coefficient) and enter it manually into the nm/V field in Thermal K, or click the 'Acquire' button next to the nm/V field to have Thermal K read the value from PicoScan. Input the ambient temperature of the cantilever's environment into the temperature field in Thermal K.

Make sure the cantilever is withdrawn from the sample surface when performing the spring constant measurement.

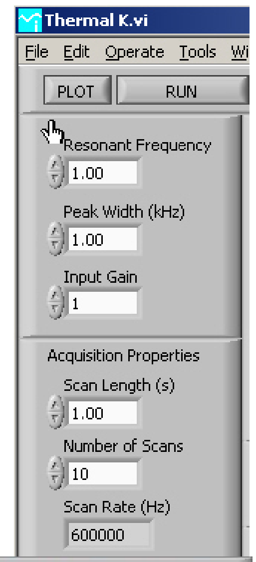
The Plot function in Thermal K provides the user with an easy way to estimate the resonant frequency. Click on the 'Plot' button to plot a single power spectrum.





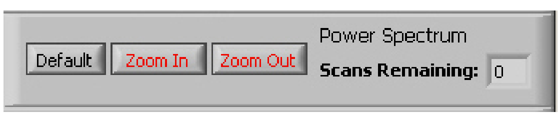


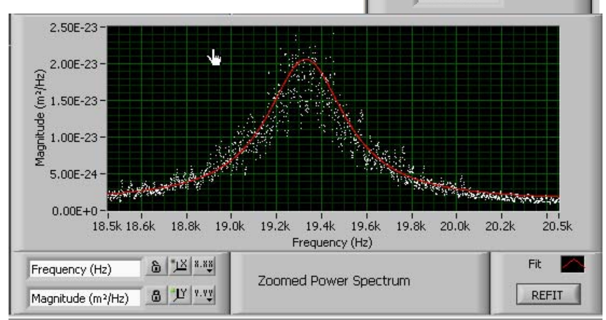
Once this is done, drag the red line to the resonant peak and click the ‘Zoom In’ button to better view the frequency. Enter the estimated resonant frequency in the program as the **resonant frequency**. After the calculation, the program will update this number to the calculated value. Enter the **peak width** with an estimated value from the plot. Peak width allows the program to only fit the necessary data. The input gain setting can be set to a larger value if the input signal is very small.



The user can change the acquisition properties to optimize the measurement. **Scan length** defines the time (in seconds) to acquire data for the power spectrum. The **number of scans** defines the number of scans to perform and average. The scan rate is pre-set by the data acquisition hardware.

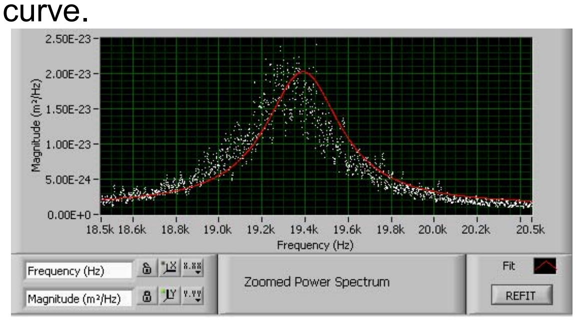
After getting the estimated resonant frequency, click the ‘Run’ button.

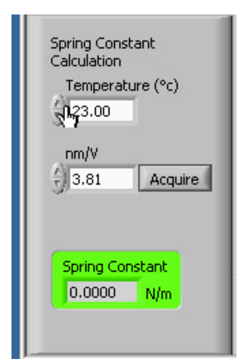




The scans remaining counter will count down. Once the given number of scans are finished, the program will fit the data and display the resonant peak in the lower window with a red curve fit.

If the curve fit in the bottom graph is not on the peak (as shown below), change the value in the ‘Resonant Frequency’ field and click the ‘Refit’ button to refit the curve.





The spring constant will be displayed in the green box after each fit.

To save the data, click the save button and type in a name for the file. You can look at it again by clicking the ‘Load’ button and choosing that file.

<u>List of Controls:</u>

- Plot: produces a quick PSD plot without any data analysis so the user can determine the approximate spring constant.
- Run: begins data acquisition.
- Stop (appears in place of 'Load' after clicking 'Run'): stops the current acquisition. During acquisition, allow a few seconds for the current average to finish.
- Load: loads a saved spectrum.
- Save: saves the acquired spectrum in ASCII format.
- Resonant Frequency: the approximate resonant frequency (in kHz) of the resonant thermal peak. This value is updated with the calculated resonant frequency after a run is completed.
- Peak width: the approximate full width at half max of the thermal peak. This controls the frequency range over which the peak is isolated in the zoomed power spectrum.
- Input Gain: the gain factor applied to the acquired AC signal. This can be used to improve resolution. A gain of 1 corresponds to an input range of ±10 V, a gain of 2 to ±5 V, etc. If the gain is set so that the deflection signal is out of the input range, the spectrum will appear to be zero.
- Scan Length: the length of time of each data acquisition.
- Number of scans: the number of times to acquire data. This is equivalent to setting the number of averages on a spectrum analyzer.
- Temperature: the ambient temperature of the cantilever's environment.
- Nm/V: The Z sensitivity of the piezo. This number, if set correctly in the preferences window in Picoscan, can be acquired from Picoscan by pressing the 'Acquire' button. (Picoscan must already be open for this feature to work.)
- Default: changes the x-scale values of the power spectrum plot back to default, and reacquires the scan rate.
- Zoom In: zooms the power spectrum plot in around the red cursor line.
- Zoom Out: zooms the power spectrum out to the previous range.
- Scale legends: these are the boxes at the bottom left of the plots. The text fields show the plot names. The middle button auto-scales the axis once, and the lock button auto-scales continuously. The button on the far right controls other options for the axis, including formatting and mapping modes. The scales can be changed by inputting numbers on the scales as well.
- Refit: refits the zoomed power spectrum curve fit with a given resonant frequency as indicated in the resonant frequency field, then recalculates the spring constant.

<u>Indicators</u>

- Scan Rate: the number of samples acquired per second. The maximum frequency of the power spectral density plot is half of the scan rate.
- Spring Constant: the calculated spring constant of a cantilever.
- Power Spectrum: a plot of the entire power spectral density of the AC signal.
- Zoomed power spectrum: a graph of the power spectral density isolated to twice the chosen peak width around the resonant frequency, as well as a Lorentzian curve fit.
- Scans Remaining: the number of scans left to complete in the current run.

References

Jeffrey L. Hutter, John Bechhoefer. Calibration of atomic-force microscope tips. *Review of Scientific Instruments*, Volume 64, Number 7 (July 1993), pp. 1868-1873.

N A Burnham, X Chen, C S Hodges, G A Matei, E J Thoreson, C J Roberts, M C Davies and S J B Tendler. Comparison of calibration methods for atomic-force microscopy cantilevers. *Nanotechnology*, Volume 14, Number 1 (January 1, 2003), pp. 1-6.

H -J Butt, M Jaschke. Calculation of thermal noise in atomic force microscopy. *Nanotechnology*, Volume 6, Number 1 (January 1, 1995), pp. 1-7.