Theoretical Study of Nano Force Measurement Systems

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Background & Objectives

The objective of this project was to experimentally and theoretically demonstrate the nano-forces reflected by sample materials using a probe-based atomic force microscopy system [1]. The study of these forces hold applications throughout astronautics and electronics in nanoparticle repellant self-cleaning capabilities. This project sought to configure and characterize an AFM using a tuning fork and laser-cantilever systems to measure the force reflected from different materials sensitive to nanoparticles (solar panels, space suits etc.) [2].

Experimental Set Up

The experiment was conducted with two probe-based force measurement systems, one of which was tested experimentally. An Akiyama probe was placed the preamplifier board which was connected to the tuning fork sensor controller to change the gain and amplitude. This system was connected to an oscilloscope to visualize the readings. Either a function generator or the interior generator was used to set the sweeping function. The probe was tested in an open-air environment but has the capability of being moved into different settings (i.e. a vacuum).

Theory and Conclusions

Theoretical calculations of the force measurement as a function of the frequency shift were able to be solved for the tuning-fork system, given by this equation: $F = \frac{-\Delta f * 2kx}{3f_0}$. The equation relating a change in voltage from the PSD to a force measurement is highly variable due to the different cantilever and probe models and thus is still being processed. The amplitude versus frequency graph obtained represented a semi-accurate measure of the force deflected off the probe, this is due mainly to the lack of an enclosure to reduce external forces. Further testing with a software-based controller system and a proper protective shell would increase the accuracy of the measurements.

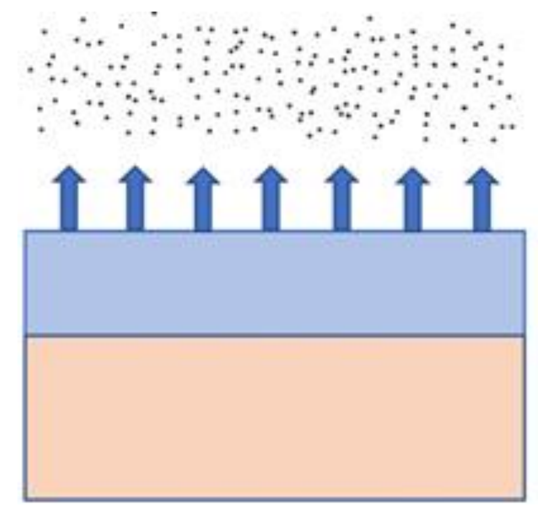
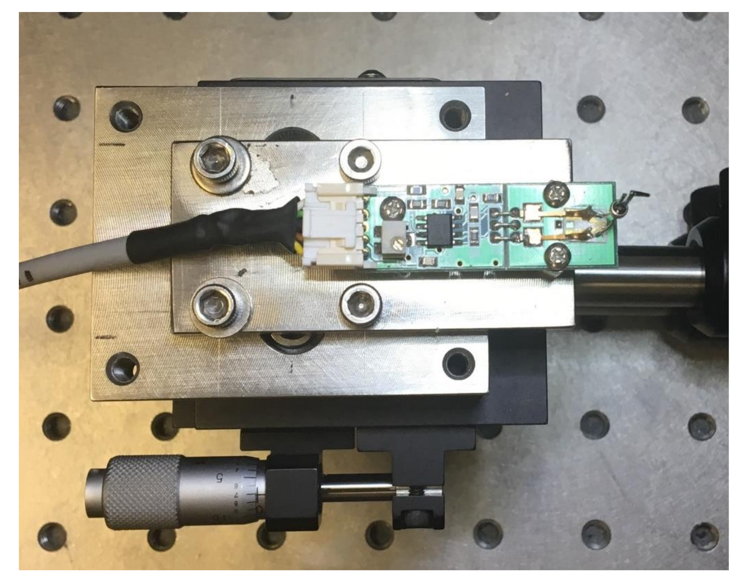
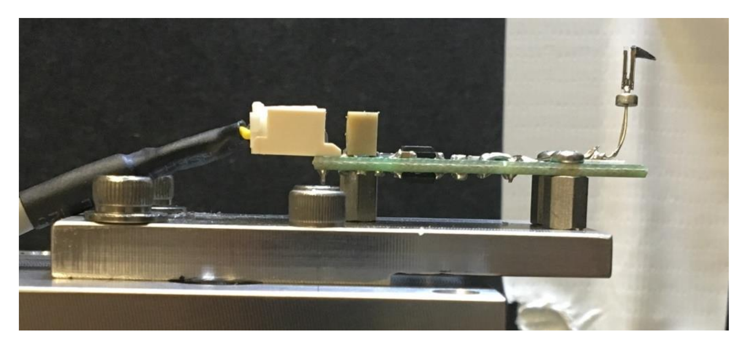


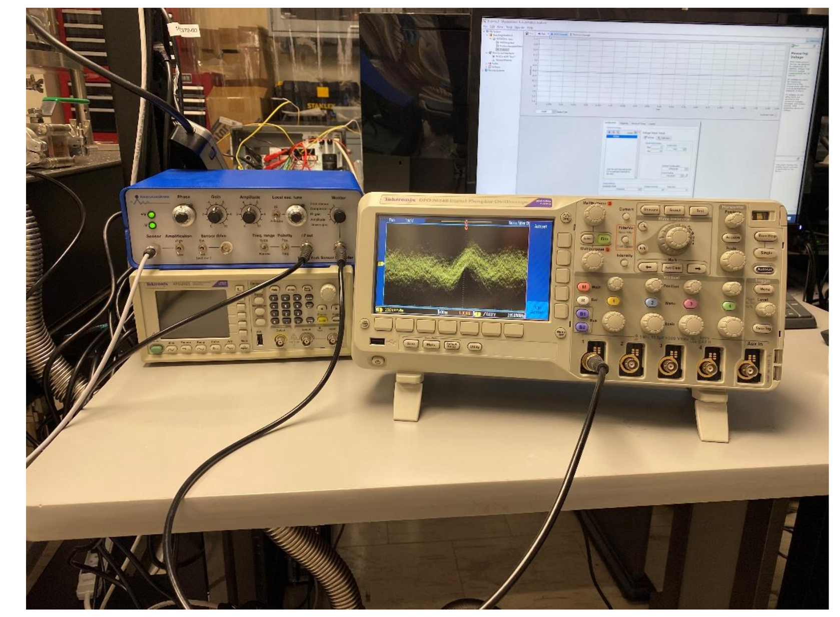
Illustration of self-cleaning by optical force repelling capabilities.



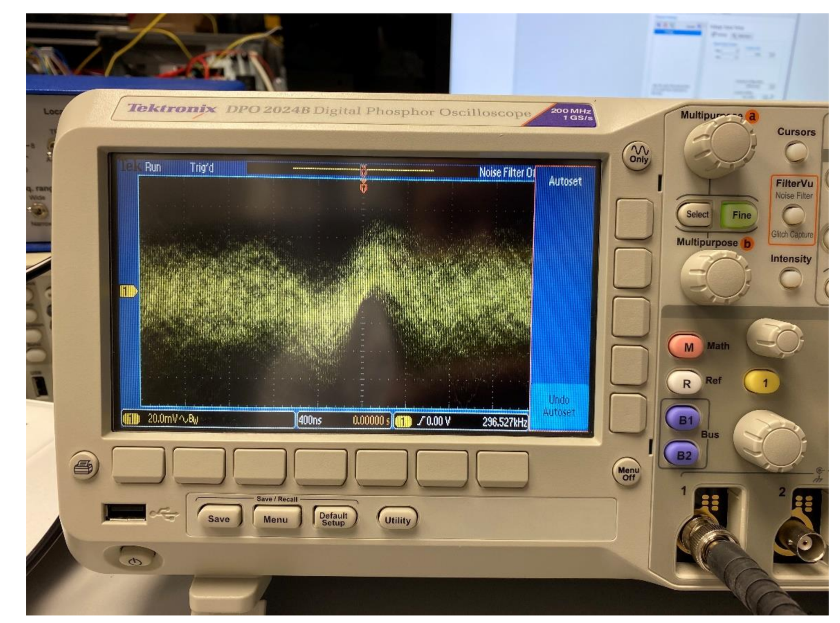
Preamplifier board on mount (top).



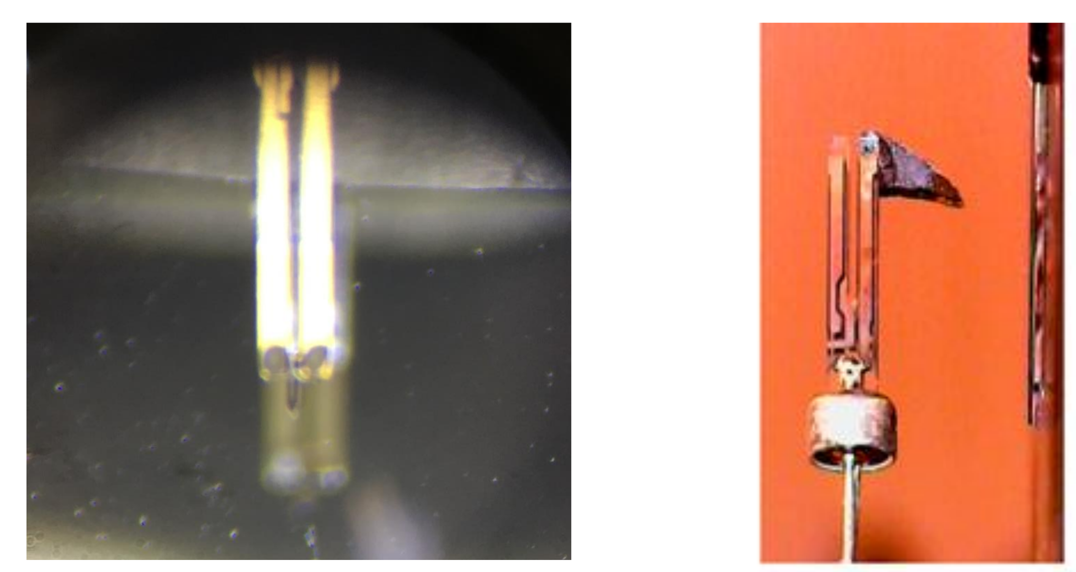
Preamplifier board on mount (side).



Setup of the TFSC , AFMVIew, and oscilloscope used to characterize the Akiyama probe.



Oscilloscope reading of the probe characterization. Note excess noise due to lack of enclosure.



Akiyama Probe fixed on a tuning fork (L) under a microscope and a silicone tip probe on a tuning fork (R).

Methods

Using the controller, a low amplitude sensor drive was selected and connected to the AFMView software. The interior wave generator in the TFSC was used to excite the probe to a specific degree at which the frequency was read using an oscilloscope. The parasitic capacitance was finely adjusted using the small knob on the preamplifier board in order to characterize the probe. Note this method is only for the tuning-fork AFM system.

Additional Information

References

[1]. Mai, Wenjie. "Fundamental Theory of Atomic Force Microscopy." Fundamental Theory of Atomic Force Microscopy, Professor Zhong L. Wang's Nano Research Group.

[2]. Karrai, Khaled, and Robert D. Grober. "Piezoelectric Tip-Sample Distance Control for near Field Optical Microscopes." AIP Publishing, American Institute of Physics.

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