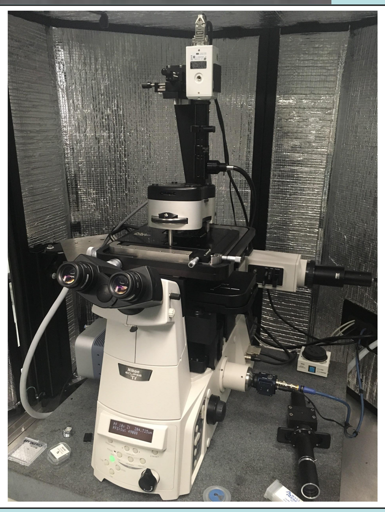
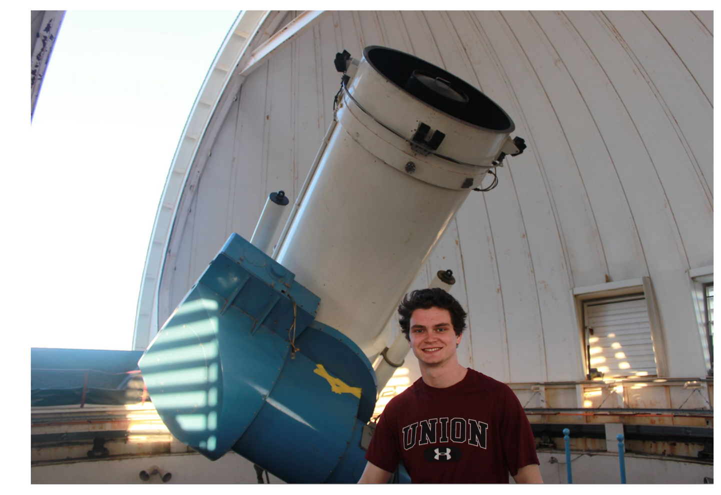
Senior Capstone - Computer Engineering - 2018



Module Design for AFM Tip Impulse Response

Garrett Fitzgerald

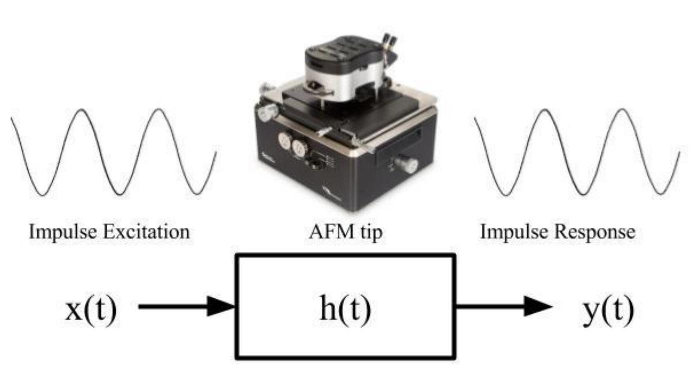
Advisors: Prof. Catravas & Prof. Dovidenko



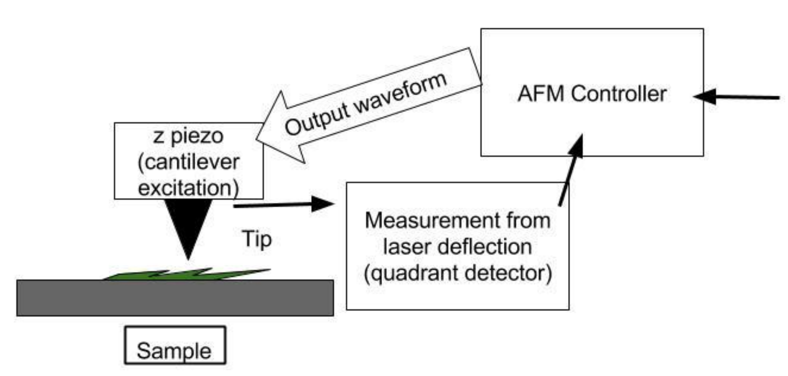
Abstract:

Union College's Asylum Research MFP-3D Atomic Force Microscope (AFM) is utilized for studies in nanoscale materials science. The accessibility of the sensitive and powerful machine is enhanced with the implementation of user defined functions, which this project explores. The development and testing of a software module to study the impulse response of the AFM's tip demonstrates the customizable nature of the machine's software and serves as the first steps in a systematic study of the impulse response. The software module's development is in testing stage and components are reacting appropriately to user defined functions which drive the tip with a sinusoidal or a step response. Further testing of system parameters will lead to more data collection with different waveforms to study system response.

System Design:



General system signal delivery

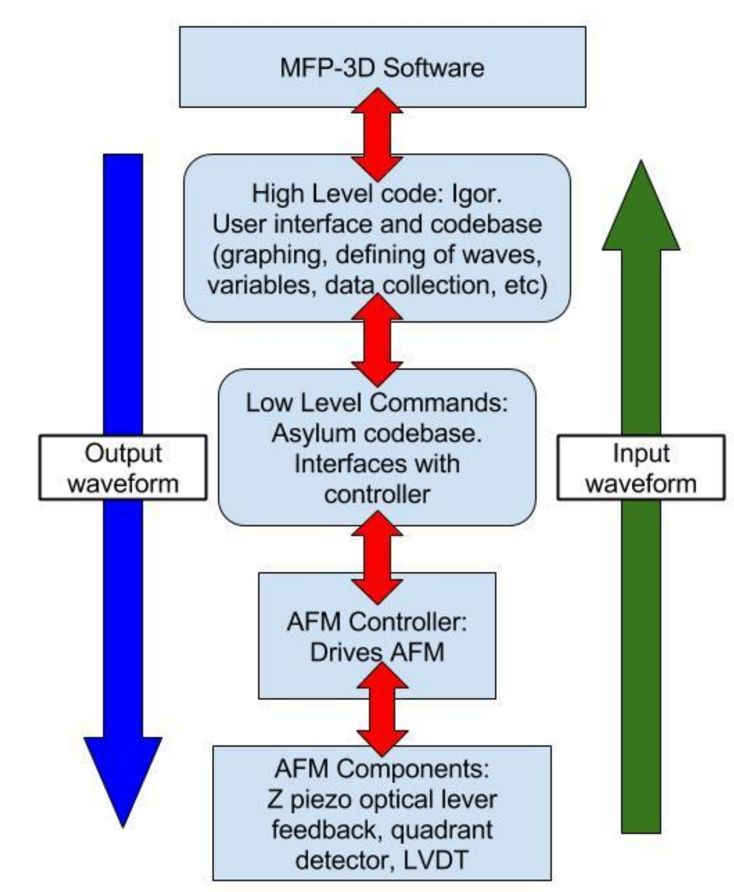


Major system components involved

- **Output excitation signal delivered to AFM tip via z-piezo.**
- **Input system response waveform of tip deflection recorded on quadrant detector photodiode.**
- **User should be able to define system parameters such as impulse duration, sampling rate, and type of impulse (ie, square wave, noise, chirp, etc).**

Software Design:

- **Must be run from the MFP-3D AFM's main software in parallel with other processes.**
- **Custom programs written in IGOR programming language which interact with low level machine functions**
- **Asylum controller functions drive machine components with specified parameters.**
- **Output and input waveform data can be viewed and saved for analysis.**



Results:

A & B- confirmation of component reaction

Using AC240 cantilever with resonant frequency of 70 kHz

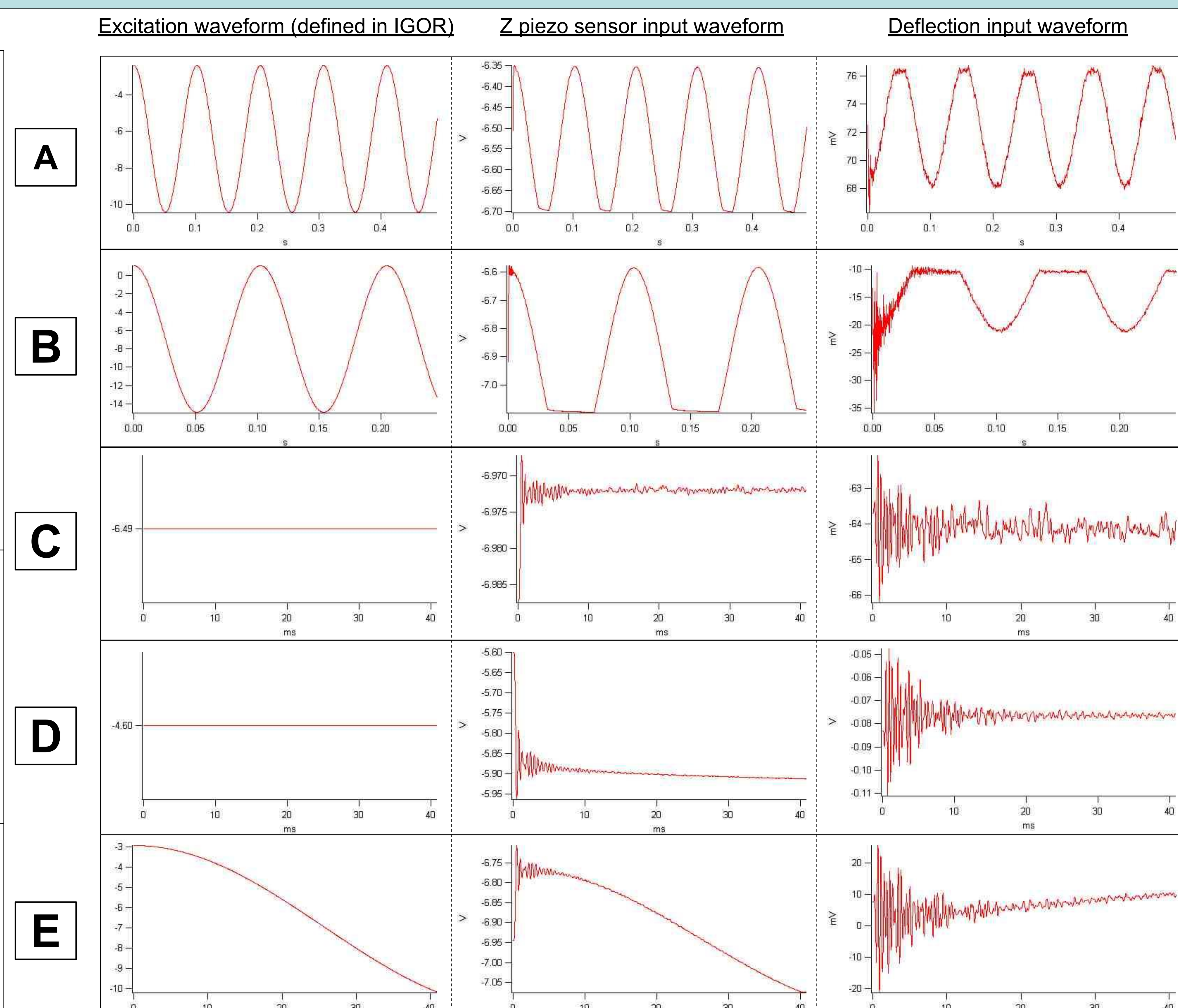
- ***A- 4V cosine excitation***
  - Note that the z piezo sensor is reading nearly the exact same values as the output waveform.
  - The deflection of the cantilever and tip matches the waveform, but is an inverted signal. There is a small amount of clipping, which is explored in B.
- ***B- 8V cosine excitation***
  - More pronounced clipping is observed in both the z-piezo sensor and cantilever response
  - The z-piezo has a voltage input limit ranging from -10V to 150V. When the input waveform goes below -10V, we the tip should no longer move. Clipping is expected.

C, D, & E- impulse response in free space

- ***C- 0.5V step response (discrete, singular voltage change)***
- ***D- 1V step response***
  - *For both C and D, transient behavior is observed in both the z-piezo and cantilever deflection waveforms.*
- ***E- 4V cosine excitation***

Conclusions

A software module has been written that allows for sinusoidal and step excitation of the Asylum AFM z-piezo with readout of cantilever deflection and z-sensor response. The output tracks the input frequency correctly and shows transient effects.



Future Work:

- **Finalize system parameters and perform calibrations (voltage of impulse to nm of movement, deflection value to magnitude of displacement, etc).**
- **Record and study impulse response in attractive and repulsive regimes (as a function of height relative to the sample).**
- **Perform a systematic study of impulse response on different types of samples in attractive and repulsive regimes.**
- **Make software module more user friendly.**

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