# Design and Construction of a Variable Temperature Atomic Force Microscope Emilie Ocock, Brandon Hoffman, Dept. Physics, Houghton College, One Willard Ave, Houghton, NY 14744

# Abstract

A variable temperature atomic force microscope (AFM) is being built at Houghton. The AFM will use a spring vibration isolation system with eddy current dampening in order to remove mechanical vibrations from both the machine and external sources. To approach and scan a sample, a modified "Johnny Walker" beetle will be built to move up, down, and across a ramp. Liquid nitrogen and resistive heating will be used to create a range of  $\sim$ 100K – 500K to measure in and increase the temperature range of the AFM.

# **Motivation**

An AFM at Houghton College would be useful primarily for making topographical scans of thin metal films. It would also be useful for scanning biological and chemical materials, thus creating a wide range of research opportunities for all of the science departments

Figure 1



# Theory

#### Modes of Scanning

There are two effective scanning methods for the typical AFM:

- Tapping mode In this mode, the cantilever tip is dragged across the sample in such a way that the atomic forces between the sample and the tip remains constant. The forces are kept at a constant level through the use of feedback loop that uses the position of the sample and optical force detector to make the topographical image.
- Contact mode In this mode, the cantilever tip is put on a resonant frequency. As the tip comes closer, or farther, to the sample, it changes the forces and frequency of the oscillation. To compensate for this, the sample is then moved (through the use of a feedback loop similar to the one for the tapping mode). This movement of the sample creates the topographical sample.

# **Measurement of Movement**

To measure the movement of the cantilever, a laser system will be used. A laser will be shone onto the bottom of cantilever tip (Figure 1 & 5). As the tip oscillates, it will reflect onto a quadrant detector (4) that reads the movements into a computer that converts them into a topographical map of the sample.

# The "Johnny Walker"

The "Johnny Walker" (Figures 1 & 2) is used as a descent and scanning mechanism because of its ability to move up and down the ramp (1 & 3) and side to side. It is able to do this because of the three piezoelectric crystal tubes it uses. They allow the walker to move incrementally by using voltages changes to alter the shape of the tubes (Figure 4).



# Drawn by Bethany Little

# FFigure

#### Figures 1-3 – The AFM

In the figures 1-3, **A** is the frame of the AFM, and is made primarily of aluminum. **B** is the ramp system for the "Johnny Walker" (**C**). It is made of two aluminum rings. There is a hole cut into the inside of the ramp for the cantilever tip (**E**) to fit into. On the "Johnny Walker," there are three piezo legs (**G**) with sapphires on the bottom in the center of these, the sample is attached for scanning (**F**). All of this is then attached to the top of the frame with four springs (**D**)that act as a Spring Vibration Isolation System.





#### Figure 4 – Piezoelectric Tube movement

Figure 5 is an example of the movement of a piezoelectric tube using the stick-shift method. On the right, we see the voltage in the tube over time, while on the left we see what happens with the indicated voltage.



#### Figure 5 – Laser System

Figure 4 is a representation of how the laser system works in reference to the cantilever tip. As the tip moves across the surface, it bounces, making a significant change in place for the laser on the quadrant detector.

# Design

#### The Dampening System

There are two main parts of the dampening system:

- The microscope is mounted on a heavy base which then hangs from four springs that are suspended over an optical table (Figures 1&3).
- There are four N42 neodymium magnets that are placed into the heavy base.

These together will dampen the oscillations caused by external forces. If oscillations start, the springs will counteract with them and cause the base to move through the magnetic field caused by the magnets. This implements Lenz's law, creating a current in the metal which will create an opposing magnetic field. This generates a force that opposes the motion thus creating an eddy current dampening system

#### LabVIEW

The student edition LabVIEW 8.2 is being used to make a program that effectively runs the microscope. Within the program, there will be several methods:

- A method of approaching the sample the program tells the computer to output the necessary voltages to move the "Johnny Walker" down the ramp in
  a circle (using the stick-slip method) until the sample is in contact with the cantilever tip
- A method for moving around the sample the program tells the computer to output the necessary voltages to move the walker (again with the stick-slip method) to the desired location on the sample. It does this via a user input for direction.
- A method for scanning and creating a map of the sample here, the program implements the use of the laser system along with the feedback loop and

converts that data into a map of the surface.

# Progress

The "Johnny Walker" has been completed as well as its descent platform. The circuitry for descent (Figure 6) from the computer (with exception of the DAC) is also complete. The frame of the AFM (Figures 1 & 2) is nearly complete. It requires a few minor adjustments (e.g. a laser-holder apparatus, weighting down, etc.). Some things that are currently in progress include the program for decent and scanning, the calibration of the laser system, and the DAC for the computer to piezo legs circuit. The biggest parts of the AFM that have both been started are the cantilever tip and the apparatus that contains it, as well as the scanning circuitry (Figure 7) for the "Johnny Walker." Besides that, all that needs to be started is the assembly of the various parts.



#### Figure 6 – Approach

The approach circuitry uses five voltage amplifiers (A-E) which are connected to the inputs of the three piezo legs (1-3).



#### Figure 7 – Scanning

The scanning circuitry uses four voltage amplifiers (X Positive, X Negative, Y Positive, and Y Negative). They are then connected to the inputs of the piezo legs (1-3) with one of the inputs also being connected to ground.