

Design And Construction of A Cost-Effective Atomic Force Microscope

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Abstract

At Houghton College, a low-cost atomic force microscope (AFM) design is under development. This AFM will be equipped with an eddy current spring dampening system, a modified “Johnny Walker” sample mount which allows the sample to approach the cantilever tip in a controlled way, and a laser system to detect cantilever movement. Linear transistor amplifier circuits will yield a cost-effective means of driving piezo-electric crystal control elements.

Operation

The Houghton College AFM will be operated primarily in a dynamic mode, in which the cantilever is driven externally near its resonant frequency. As the sample approaches the cantilever tip via the “Johnny Walker” device (Figure 1), the interaction forces between the sample and tip affect the phase and amplitude of the cantilever oscillations. The cantilever reflects a laser (LDM150, wavelength: 650 nm) into a tetra-lateral diode position sensing detector (PSD) (Newport CONEX-PSD) which tracks the cantilever oscillations as shown in Figure 2.

Three piezo-electric crystals will drive the sample mount to approach and scan across the cantilever. Another crystal drives the cantilever near its resonant frequency.

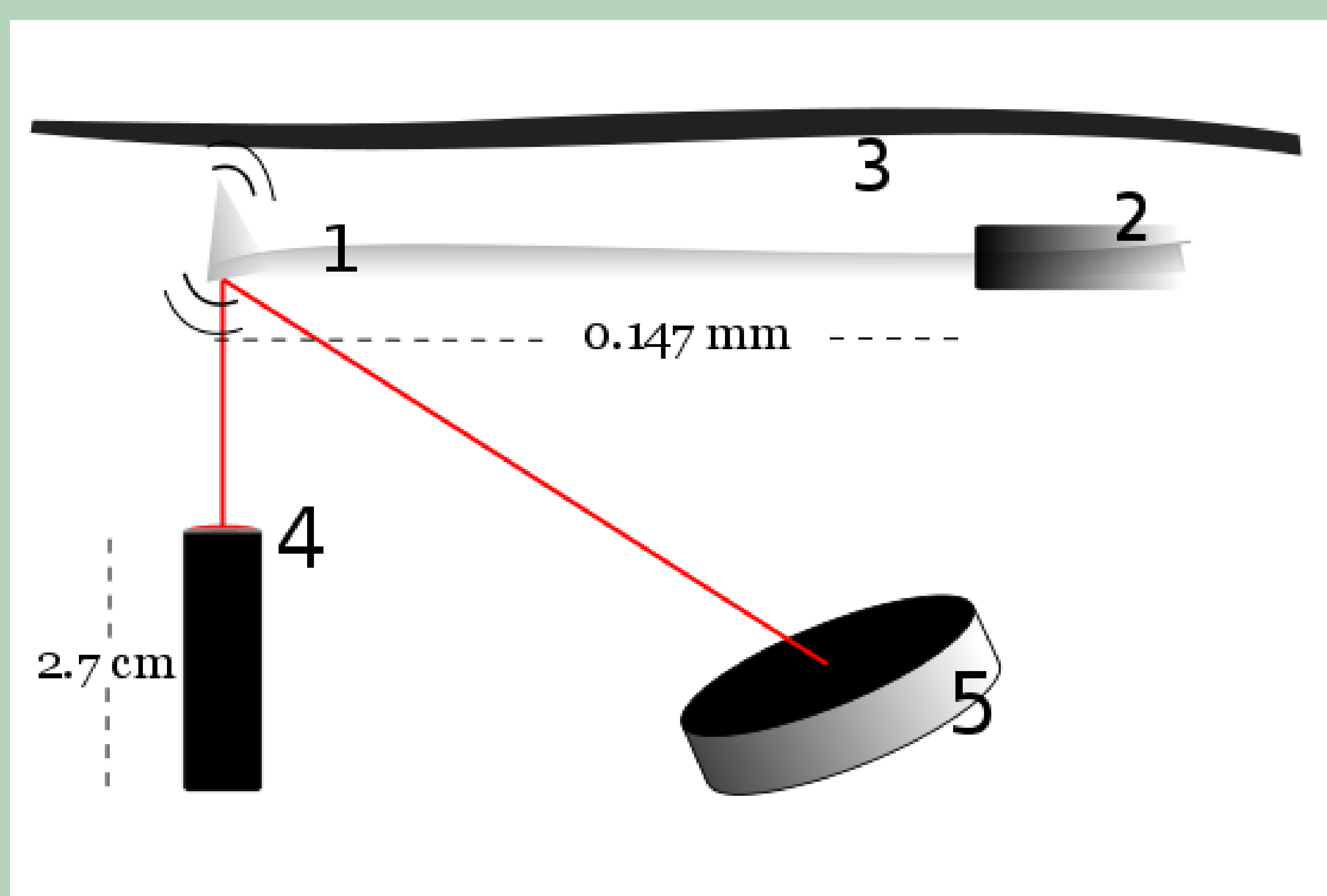


Figure 2. The cantilever (1) is driven at its resonant frequency by a piezo crystal in the holder (2), which is mounted to the stage as shown in Figure 1, toward the sample (3). A laser (4) is focused onto the cantilever and reflected into the PSD (5), which measures the position of the beam footprint. This allows the cantilever's oscillation parameters (amplitude and phase shift) to be measured dynamically.

Motivation

Atomic force microscopy is a powerful method of nano-scale imaging, often well below the optical diffraction limit. The AFM at Houghton College will be used to measure surface topography of thin films including roughness, grain coalescence, grooving, and the characteristics of crystallite formations during early deposition. A better understanding of the surface properties of thin films can improve the development of semiconductor and optical technologies.

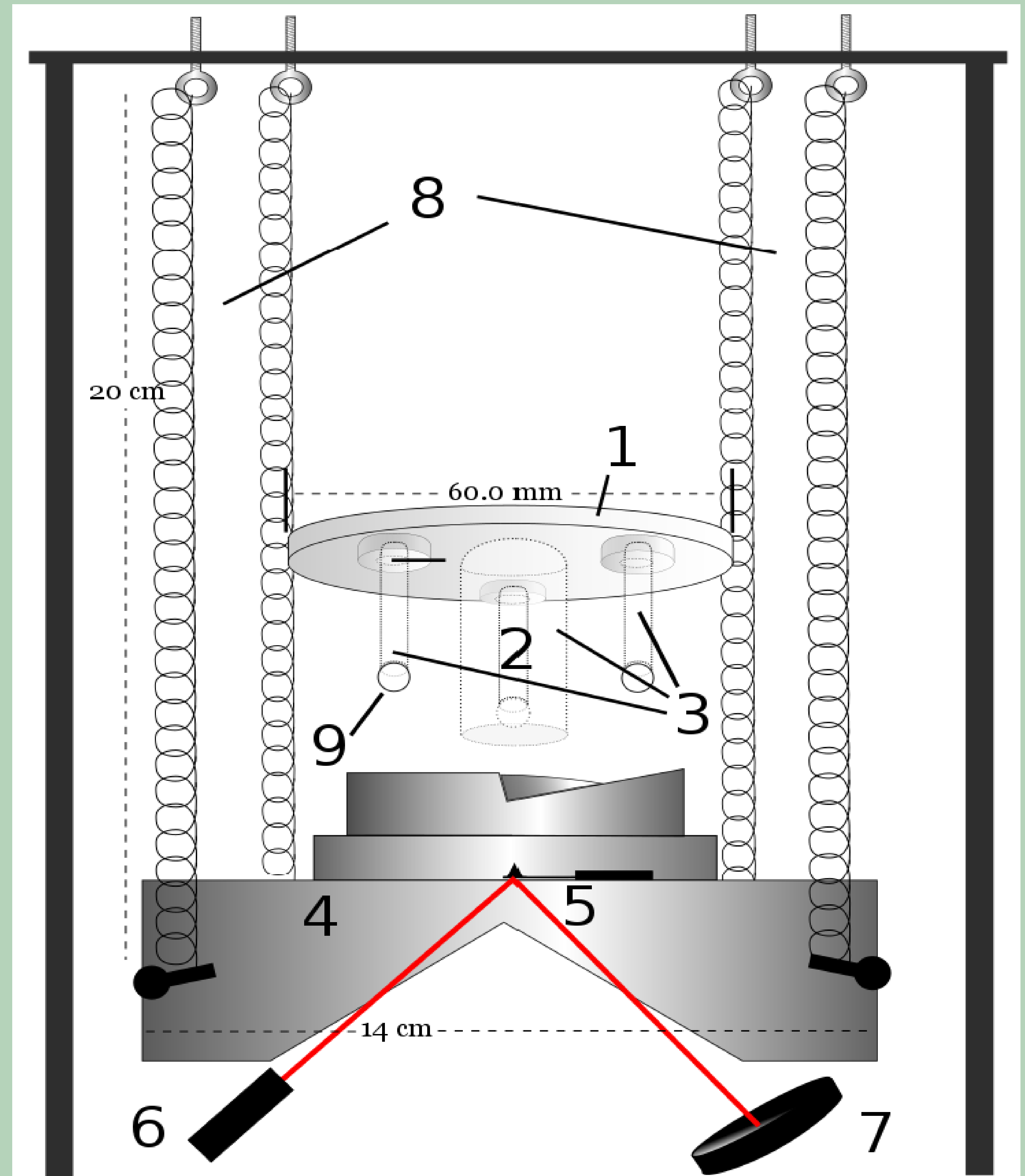


Figure 1. A circular mount (1) holds the sample mount (2) and sample and piezo crystals (3) in place. This device is the “Johnny Walker”. This mount can walk up and down the circular ramps on the sample stage (4) towards and away from the cantilever (5). The cantilever's movement is detected by a laser (6) and diode position sensor (7). The stage is suspended with springs (8) to reduce vibrations. Sapphire balls (9) on the crystals provide the static friction necessary for the legs to undergo controlled slipping to “walk” up and down the ramp.

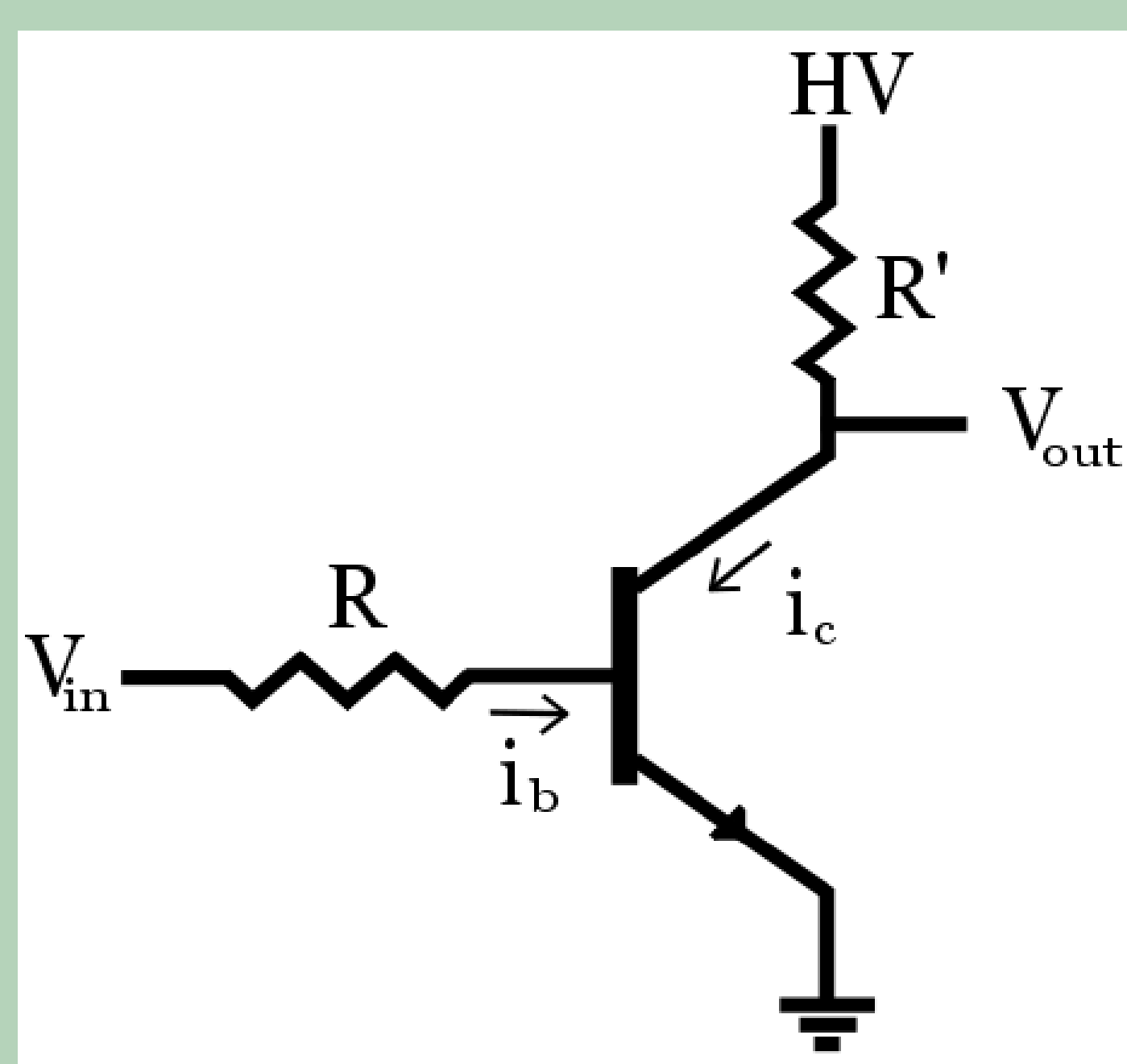


Figure 4. A linear transistor amplifier used to drive the piezo-electric crystals. This amplifier uses the linear property

$$\beta i_b = i_c$$

of transistors to amplify a low voltage input signal (V_{in}) to a high voltage output signal (V_{out}).

The crystals must be driven ≈ 1500 volts, so high voltage BJTs will be used. Since each walker leg requires four leads (and one common floating ground) this simple design is a cost-effective way to control many high voltage signals at once.

Progress

The motion detection system is under construction with recent substantial progress (see Figure 3). The entire laser beam must be reflected from the cantilever into the PSD in order for the oscillations to be recorded. Due to the size of the cantilever, extreme precision is needed to focus the laser and to center the PSD.

Electrical arcing was observed on the walker mount. This problem is difficult to overcome as air breaks down electrically at about $3 \cdot 10^6 \text{V/m}$. Because the leads on the piezo crystals are separated by $\approx 1 \text{ mm}$, electrical arcing occurs within the mount if care is not taken.

The Houghton College AFM is designed to be cost effective as major components are designed to be built by undergraduates using tools and materials found in the common laboratory and shop. Expensive components of the Houghton AFM are limited to the piezo-electric crystals and cantilever.

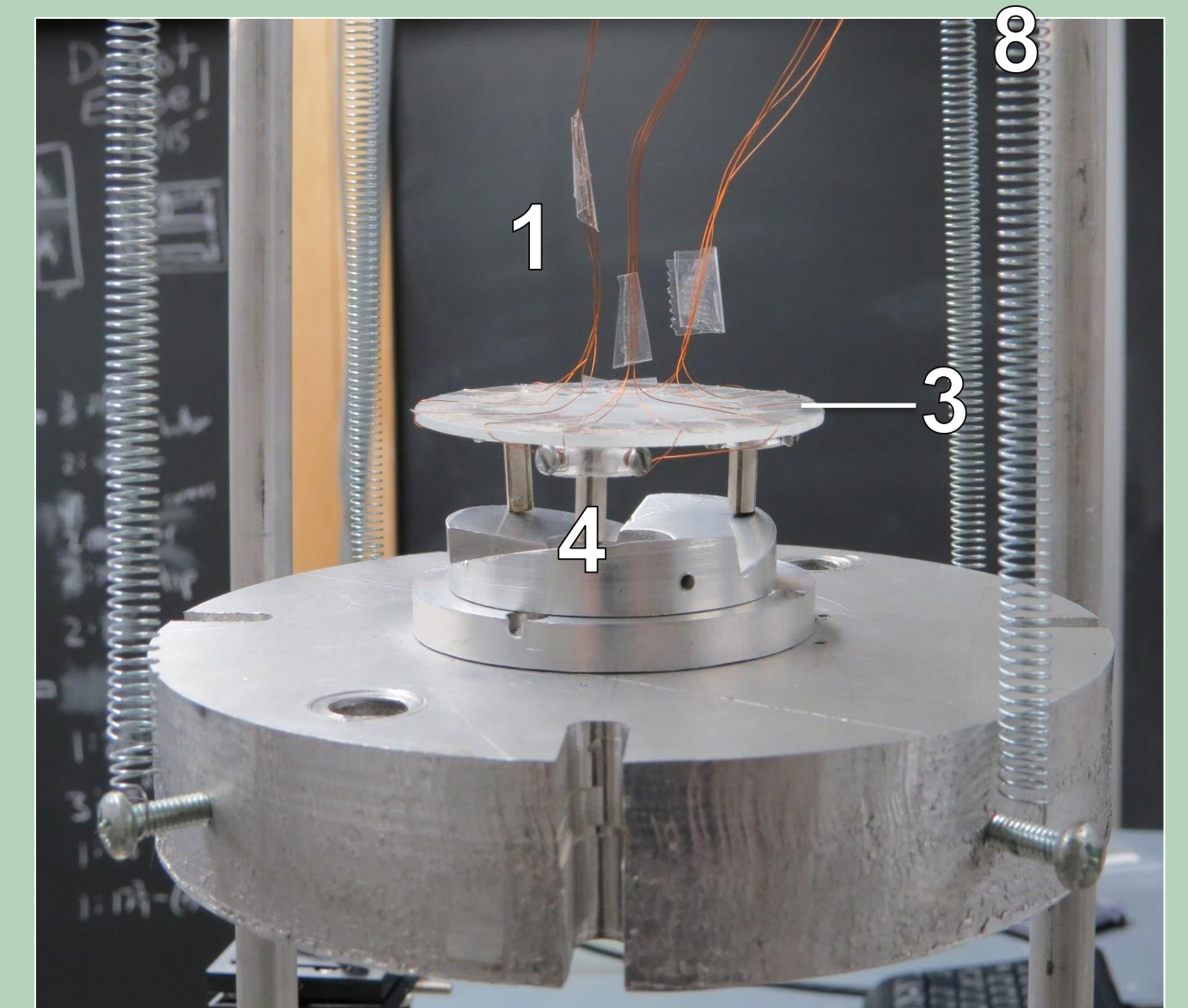
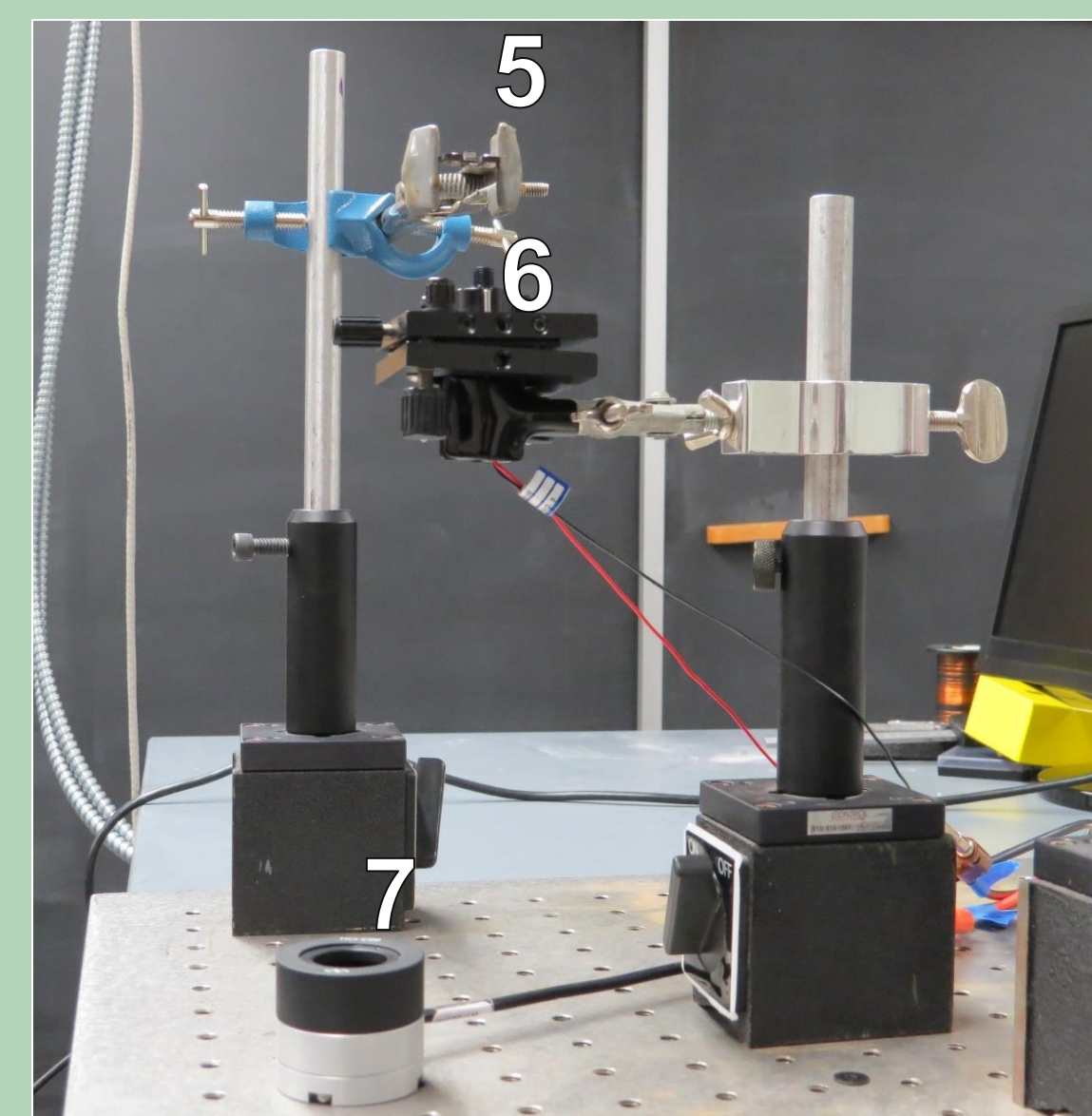


Figure 3. (Labels correspond with those in Figure 1) Progress on the movement detection system (left) and walker mechanism (right). The laser beam has been successfully focused onto and reflected from the cantilever into the PSD. A redesigned walker mount has reduced problems with electrical arcing. Currently, the sapphire balls and sample mount are detached from the walker.

Conclusion

By implementing cost-effective designs, as well as tools and materials found in many undergraduate laboratories, a cost effective atomic force microscope is under construction at Houghton College. Once the walker is successfully controlled and the movement of the cantilever is understood via the movement of the beam footprint on the PSD, work to obtain images can begin. First; however, modifications (Figure 1) to the stage must be made.

The atomic force microscope will be an excellent tool in the study of the surface topography of thin films at Houghton College.