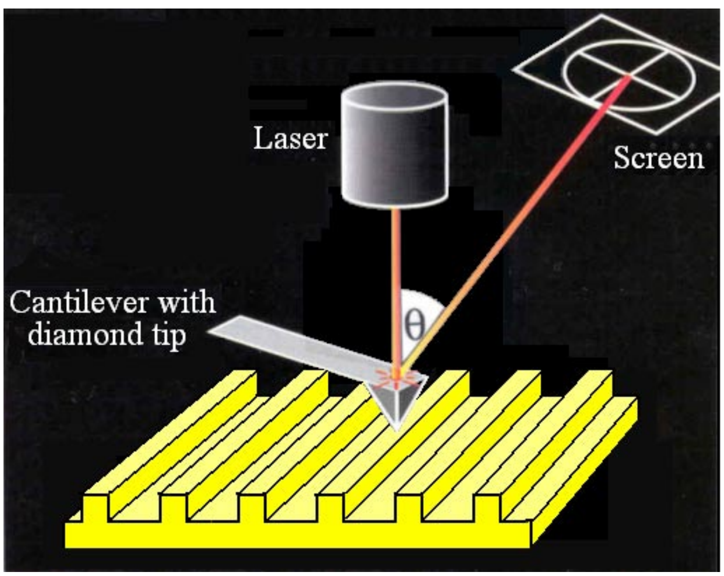
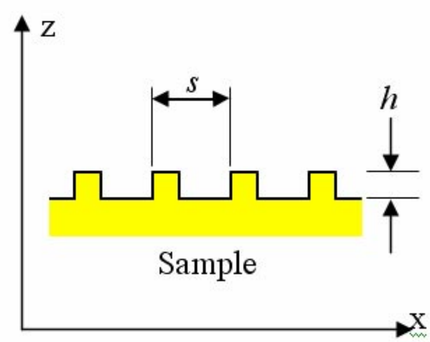
Experiment 11: Atomic Force Microscope Phys 431

In this lab you will use your optics skills to operate an atomic force microscope (AFM), and use it to examine surface topography. The AFM relies on the interactions of a sharp tip and a surface, the resolving power is not limited by the wavelength of any radiation. Our microscope consists of a sharp diamond tip mounted to a cantilever of length 400 μm. A small mirror is mounted behind the tip. We will use this instrument in the simplest mode, dragging the tip along the sample so that the surface features will deflect it. We will detect the deflection by monitoring the angle θ of the reflected laser beam, as shown below. The wavelength of the He-Ne laser is 632 nm.

You will examine two surfaces, a diffraction grating and a sample consisting of an array of square pits. We expect the cross section of each sample to be periodic, as indicated below. The main task of the experiment is to determine the height *h* of the topographical features of each surface.

For this lab we will use only two set-ups, one dedicated to each sample. So you may have more partners than usual.





Procedure:

The AFM tips are extremely fragile. Please be careful not to bump into the tip or the piezo tube which holds it. An instructor will perform the coarse positioning whenever the sample and tip are brought into contact.

A. Connect the function generator to the plastic coated electrical leads to make your tube scans horizontally. Hint: you can connect the signal to just one lead and ground all the rest. **Q1** What color is this lead? Please indicated with a sketch which electrodes are receiving a signal. When scanning, it is recommended that you set the function generator to 0.2-2 Hz. Moreover, choosing a triangular waveform will result in a constant tip velocity. The maximum output voltage of 20 V peak-to-peak results in a horizontal deflection of ~5 μm.

B. Align the laser and find the reflected beam on the screen. To do this, it will be helpful to first look at the tip and cantilever with the optical microscope. If you are standing near the path of the reflected beam, be careful not to look towards the tip. Take a picture of the laser spot as it appears on the screen, to be included in your write-up. **Q2** How would you describe the pattern that appears on the screen?

C. With the function generator set to zero, examine the effects of room vibrations. Because the measurement is so sensitive, events like bumping the bench are severe – this can even break the cantilever. In fact, even less direct vibrations can cause significant noise. Ask the instructor to put the tip in contact with the sample. Of course, be careful not to disturb the tip-sample support apparatus. You may notice that acoustical noises such as clapping your hands can significantly shake the tip. Try scooting a stool across the floor so that it makes a screeching noise. **Q3** What effect does this have on the signal? Estimate the magnitude of the noise (i.e., calculate the z-deflection that would give the same amplitude).

D. Now scan the tip. If the sample is not perfectly aligned with the scan direction, the tip will effectively be going up and down a sloped hill. **Q4** How can you differentiate this background signal from the topographical signal? From the amplitude of the topographical signal, calculate h (include an estimated uncertainty).

E. Switch to the other set-up, which has a different sample, and repeat the measurement. **Q5** In its current form, does your set-up have the required sensitivity to detect features at size scales less than the wavelength of the laser light?

<u>Extra Credit (+2 pts)</u>
The distance s, which describes the spatial period of the topographic features, is greater than the horizontal scan range. Nevertheless, the apparatus can be used to measure s. Can you think of the way to do it? Hints: it can be done without changing any part of our set-up, other than moving the screen. The answer does not involve scanning the tip; instead it relies on constructive and destructive interference effects (i.e., cool wave optics that we will be covering in the coming weeks).

Before you leave, please fill in your course evaluation and leave it with the designated student. For privacy, please do this in the computer room