Progress Report

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In lab, I have spent the past year contructing our new Low Temperature Scanning Probe microscope. The big advantage of this new microscope is that it is a smaller diameter than the previous microscope (25 mm down from 36 mm), and will be compatible with our Oxford top loading dilution fridge. This will allow us to measure the properties of electrons using our capacitance probe technique at unprecedented temperatures. Since the microscope is built on the end of a standard Oxford stick, we will also be able run this in any of our cryogenic systems, giving us a temperature range of 30 mK to 300 K in magnetic fields of 0 to 11 Tesla. The new microscope also has interchangable scan tubes, giving us a wide range of scan ranges and resolutions.

The original design of the microscope is based was a copy of the old one, and is shown in figure 1(a). In scanning probe experiments, one needs to get the tip very close to the surface, often within 10 angstroms. To do this, two separate motion mechanisms are used: one provides coarse steps (∼1000 angstrom) and a large range (∼mm), and one that provides fine control of the tip (∼1 angstrom) but a short range (∼5000 angstroms). The process of approaching the tip consists of taking a coarse step, checking for the surface using fine positioning, and repeating until the sample is in range. Firgure 1(a) shows a schematic of our original design. The tip is attached at the end of a long scan tube that extends from above, and which provides the fine tip positioning. The sample is mounted on a disc that has three tilted ramp surfaces machined onto the bottom. This disc sits atop a tripod of walking scan tube piezos mounted from below. Coarse z approach is attained by moving the walking piezos in a rotating pattern shown in figure 1(b) using a a waveform shown in figure 1(c). The entire mechanism relys on static and dynamic friction forces between sapphire balls mounted on top of the walking piezos and the ramp surfaces on the sample holde disc. The idea is that the sapphire balls will slip on the falling edge of the pulse, but stick on the gentle rising

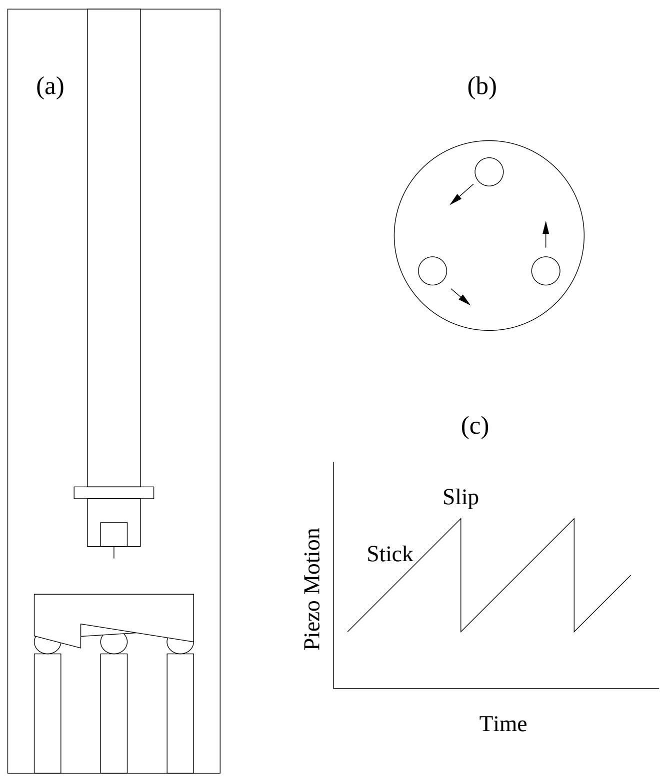

Figure 1: (a) A schematic of the old microscope design. (b) shows the rotation pattern for walking the sample up and down, and (d) shows the waveform applied to the walking piezos.

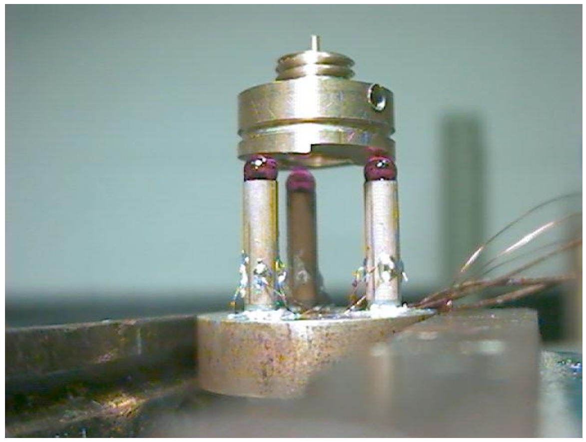

Figure 2: A picture of the walking piezos I built.

edge. In this way, a net rotation of the sample disc is attained, walking the ramps up the sapphire balls moving the sample towards the tip.

While this stick-slip motion may sound unreliable, it forms the basis of the coarse approach mechnism in most compact scanning probe microscopes. In order to function well, it requires clean, smooth surfaces and favourable normal forces. If the normal forces are too small, there will be insufficient traction during the stick phase to move the object, and if they are too large, the surfaces wont slip.

Figure 2 shows a picture of the ramps and walking piezos I built. Unfortunately, we ran into trouble: in making the microscope smaller, the ramps had become too light. The normal force from the weight of the ramps did not provide enough traction to walk the ramps upwards. I confirmed this by balancing washers and nuts on top of the ramps to add weight: the ramps were able to walk up slowly once the weight had increased from 6 to 18 grams. (The ramps on the old microscopes were 18 grams.) Adding this much weight to the ramps in the confined space we have to work with was inpractical, and I decided to redesign the microscope.

The design I chose to base my new microscope around is a that of S. Pan (RSI 66 1077). Figure 3 shows a drawing of my design, and figure 4 shows the principle of the coarse approach mechanism. The idea is that you clamp the object you want to move in a sandwich of multiple shear piezos. You then apply sharp steps to the piezos one at a time, causing them to slip while th others are holding the object in place. Once they have all moved, they are brought back their starting posistions at the same time using a smooth waveform, moving the object by one step in the desired dirction.

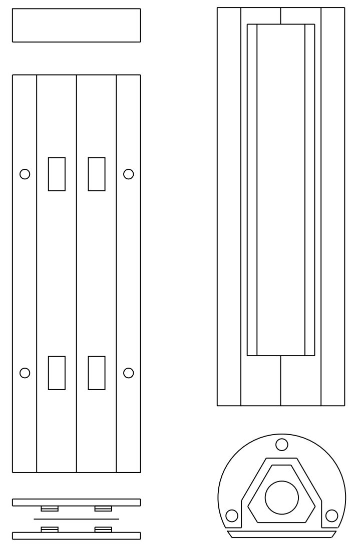

Figure 3: My new microscope design, based around the design of S. Pan.

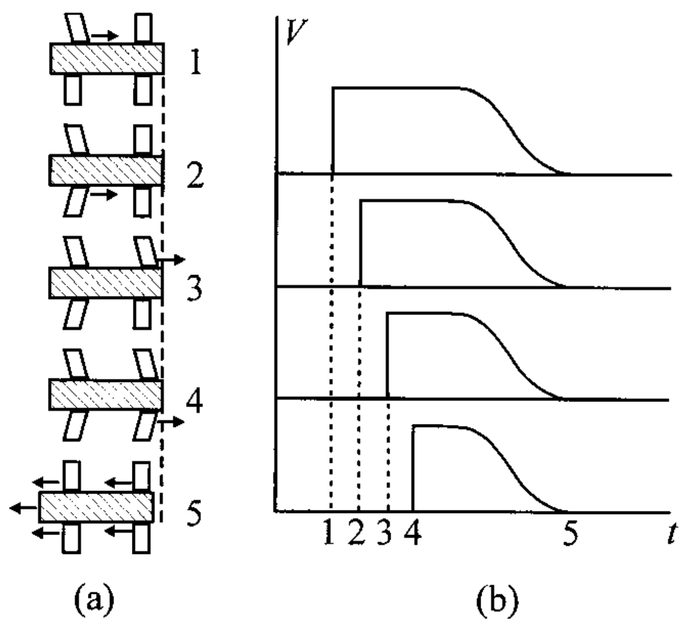

Figure 4: The method of coarse approach with the new design.

The big advantage of this design is that you are able to tune the normal force at the surfaces by varying the clamping force: you are not relying on gravity. This is also used in a separate set of piezos to attain x-y translation of the sample. By decoupling the x, y, and z motion, we also eliminate another flaw of the old design where when trying to walk sideways, the sample would walk downwards. Yet another advantage is that the entire assembly is rigid: the old design was very sensitive to any bumping of the microscope, which could cause the sample to become misaligned, or evey cause the ramps to fall off of the walking piezo tripod.

Since the conception of the new design at the end of February, I have designed and built controller electronics for the stepping wavefunction, and have machined the parts for the new microscope. The piezos have arrived this week, and I anticipate the microscope will be ready by early June.