Development of an Inexpensive Scanning Tunneling Microscope

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Scanning tunneling microscopy is a modern technique which creates images of atoms on a material surface, the invention of which won a 1986 Nobel Prize in Physics. The importance of a scanning tunneling microscope (STM) branches across many industries and fields of study, but a cost on the order of $100,000 makes it impractical for undergraduate lab courses. Development of an inexpensive STM gives chemistry, physics, materials engineering, and electrical engineering students at “Learn by Doing” schools hands-on experience with modern imaging techniques, inspiring them and further preparing them for a successful career. Cal Poly and many other colleges, could implement the open source device into lab sections of many courses across various majors, including solid state physics, quantum mechanics, physical chemistry, and electronics manufacturing.

**Introduction**

Scanning tunneling microscopy (STM) is a modern technique that creates images of atoms on a material surface. The invention of STM won a 1986 Nobel Prize in Physics. The cost of an STM, typically around $100,000, makes it impractical for undergraduate laboratory courses. Development of an inexpensive STM allows students to gain hands-on experience with modern imaging techniques.

**Mechanical Design**

**Unimorph Disk Scanner**
- Coarse approach: Front two ¼ inch thick aluminum disks are separated by a ³/₁₀₄ inch thick brass disk.
- Fine approach: 
  - Front two ¼ inch thick aluminum disks are separated by a ³/₁₀₄ inch thick brass disk.
  - Rear thumbscrew on the scanner center by 30mm in opposite direction.

**Coarse Approach**
- Front two ¼ inch thick cylinders are separated by a ³/₁₀₄ inch thick brass disk.
- Rear thumbscrews allow the motor to move 30m in opposite directions.
- No micro-steps to avoid signal sampling on the motor encoder.

**Vibration Isolation**
- Standard concrete blocks separated by Viton rubber gaskets achieve vibration dampening with f ≈ 2Hz.
- Viton gaskets pieces glued to 3D printed housing for balance.
- A 3µm optoelectro-pendulum creates a low frequency dampening system with L = 160µm.
- A ³/₁₀₄ inch thick 3 inch diameter aluminum cylinder is glued with Viton gasket pieces to the holder.
- It interlocks with misalignment magnets which provides magnetic dampening.

**Tip Locking**

Constant current STM image by locking the tip at a specific tunnel current and recording the voltage across the x axis of the scanner. The tunneling current approaches the surface. This current is amplified and transformed to a voltage through a transimpedance amplifier. It is then compared to a setpoint and the difference is integrated. The resulting voltage is then buffered and sent to the piezo z axis.

Typical locking currents are 1 – 10 nA.

**Power Supply**

The low-cost STM requires rails of ±15 VDC for the transimpedance amplifier, piezo drivers, ADC, DAC, and control circuitry. Main voltage is stepped down by a 10:1 transformer and rectified producing ±18 VDC, which is then regulated to ±15 VDC. The STM draws 60 mA during normal operation excluding the stepper motor. A separate buck converter will supply the 12 V required for the motor.

Next Steps:
- Remove the solder mask on the TIA guard ring for proper operation.
- Add buck converter for stepper motor.
- Measure piezo movement with Michelson interferometer.
- Create a GUI for the STM in python.
- Create instruction and post them on Polyatom.com

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