Terahertz STM Nano-Imaging of Topological Insulators

Rogelio Baucells, Keely Paul, Denis Le, Kersten Galeta , Guangxin Ni, PhD

Department of Physics, National High Magnetic Field Laboratory, Florida State University

Introduction:

Nano-imaging the elementary excitations found in the Terahertz range in solid materials permits observation of phase transitions and identification of topological surface states. Surface states cannot be directly visualized and their energy scales are often very small (in the FIR or THz range) (Bonnell, 2001, p. 34). Thus, in order to monitor phase transitions, we chose to couple an Edinburgh Instrument FIRL 100 gaseous far-infrared laser source to an in-house constructed Scanning Tunneling Microscope and controller. This version of microscopy is performed by bringing a sharp, wire tip very close to a surface and applying an electrical voltage to the tip or the sample (Chen, 1993, p. 4). With this, we can image the surface of the substance at an extraordinarily small scale–even down to individual atoms. Utilizing the functions of nano-imaging, we specifically aim to analyze the alpha to beta phase transition of Bi4I4 in attempt to capture signatures of the surface state changes that parallel this transition. Theoretically, if the high-order alpha topological phase appears in a superconductor, we can apply the generated hinge Majorana modes to fault-tolerant quantum computing which could enable testing more sophisticated protected circuits in small-scale quantum devices.

Methods:

- Constructed 3 power supplies with the following specifications: (Figure 2-5)
- Box 1: (+/- 250V)
    - 2 x U400Y20F (1/4 A) (250V)
    - 2 x VRB200GTIOR (1/2 A) (250V)
- Box 2: (+/- 16V)
    - 2 x VRB1GG500F (1/2A) (250V)
- Box 3: (+/- 16V)
    - 1 x VA5MT600F (1A) (250V)
    - 2 x VRB9G300F (1 A) (250V)
- Constructed a INA110 amplifier
    - 18V, and can be amplified by 50
    - Pin 3 was crossed with pin 11 in order to amplify the voltage by 500 (Figure 1)
- Constructed a digital-to-analog converter/ a analog-to-digital converter (DAC/ADC)

Results:

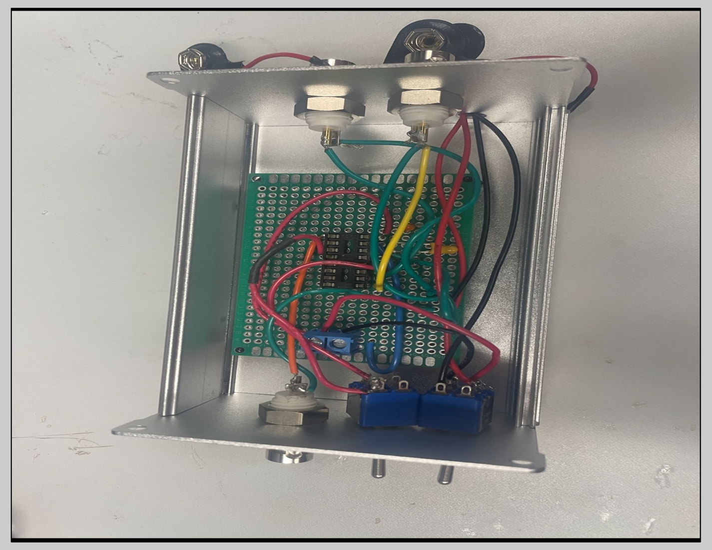
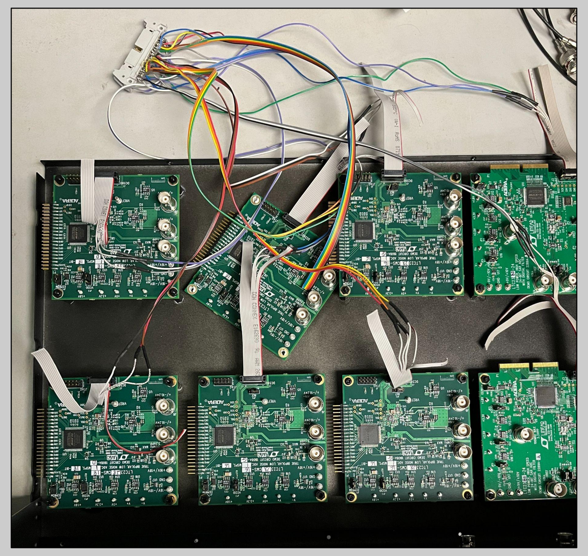


Figure 1: INA110 Amplifier



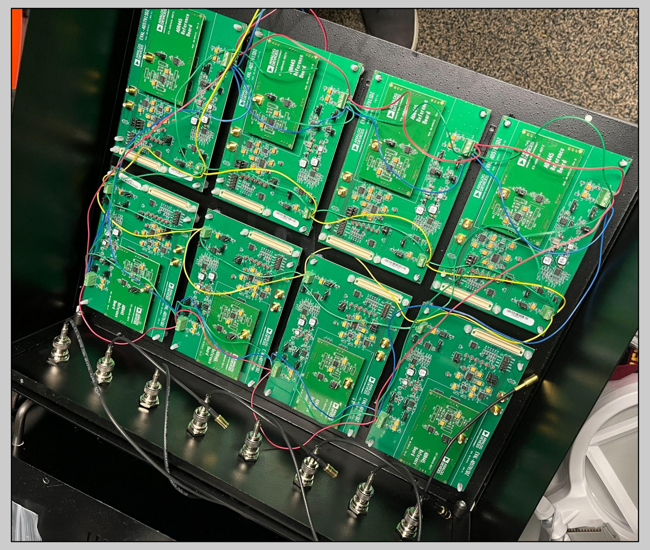


Figure 2 & 3: DAC/ADC Converter

Figure 4: Power Supplies

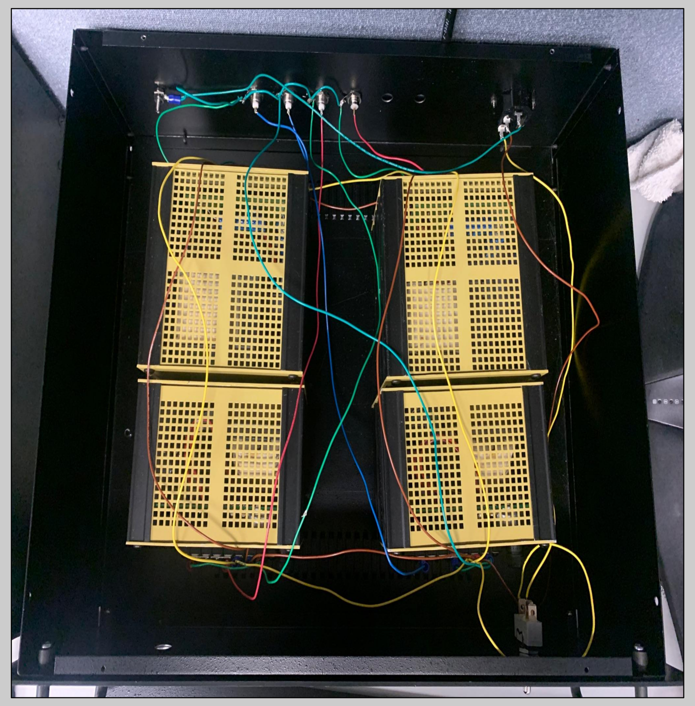


Figure 5: Box 1

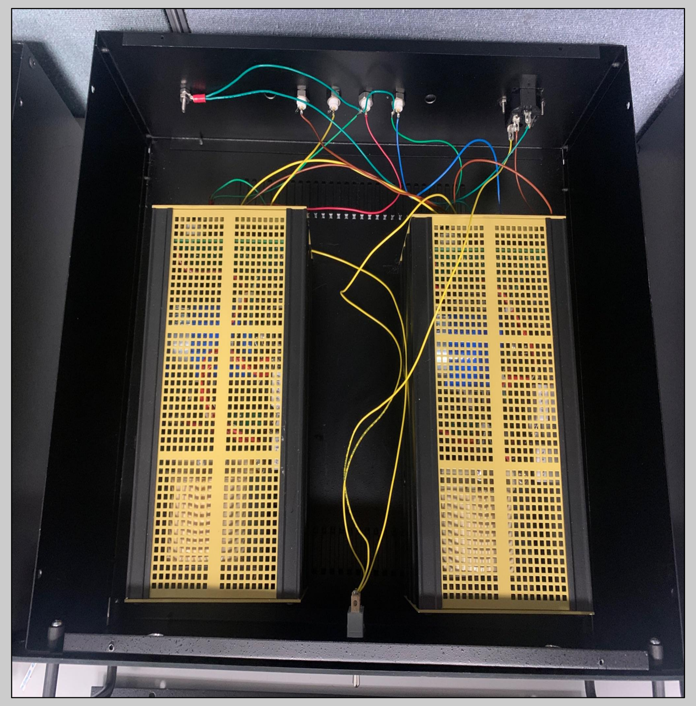


Figure 6: Box 2

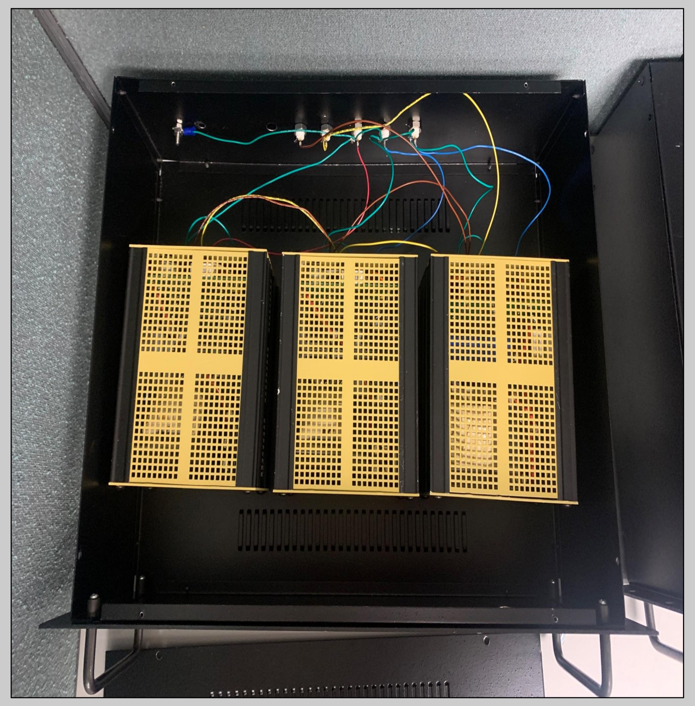


Figure 7: Box 3

- Figure 1: This figure shows the wiring for the INA110. In order for it to be amplified pin 3 and pin 11 are connected to either sides of the switch.
- Figure 2-3: These figures display the DAC/ADC converter. One converts a digital signal into an analog signal, and the other one vice versa.
- Figure 4: This shows the general look of the power boxes, with 2 of them having switches (Box 1 & 2) while the other (Box 3) will be connected to Box 2
- Figure 5-7: This shows the inside of each power supply and how the wires were connected to give a stable, noise-reducing, connection to the instrument
    - Box 1 is unregulated giving an output of +/- 250V while Box 2 and 3 are regulated to give an output of +/- 16V

Conclusion:

- Once these parts for the STM microscope were completed, they were tested and were working successfully with little interference.
- The Power Supplies are able to supply a stable flow of current with little noise
- The INA110 Amplifier was successful in amplifying the signal making it sufficient to operate the STM microscope for a long period of time.
    - It can amplify the voltage by 500 or to keep it at 18 volts.
- The Amplifier experiences low noise and will minimize the vibrations allowing for a clearer and more precise image.
- The STM microscope requires a Digital current in order to be operated, and then it sends information back to the computer in a more complete and precise manner via Analog currents.
- The AC/DC convertor will transform the Alternating current to Digital current, allowing for the flow of electricity to be stable and usable with this instrument
- The only components missing to fully assemble the STM microscope is the Isolator.
- The isolator will stabilize the instrument as it uses ultra-low frequency that cause vibrations which interfere with the imaging.
- Once this is completed, it will be tested and if successful, will be assembled together to form the STM microscope.

References:

- Bonnell, D. A. (2001). *Scanning probe microscopy and spectroscopy: Theory, techniques, and applications*. Wiley-VCH.
- Chen, C. J. (1993). *Introduction to scanning tunneling microscopy*. Oxford University Press.