# Nanoimaging of Superconductors

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## Abstract

In this lab, we will be using various nanoimaging, cryogenics, absorption, and photo conducting instruments to test three samples. The samples are bismuth bromide, bismuth Iodide, and tellurium oxide to test the superconductivity at very low, near 1 Kelvin temperatures. We know the bismuth bromide is a superconductor under high pressure $Bi_4Br_4$ which stabilizes the bond structure (Xiang Li, et al.). In our project we will try to see if electrons from our FIR laser will stabilize the bond structure instead of the high pressure. To continue on to their experiments we will see if bismuth iodide will work as well by studying the resistivity in the STM under cryogenic and low pressure conditions with the high current as well as bismuth bromide. We also decided to test the oxide of tellurium to see how it relates to aluminums' oxidized state which acts as a buffer protecting the aluminum structure. Meanwhile in iron, the oxidation will erode the structure. The instruments we will be using are STM, TEM, FIR laser, and FTIR. This will allow us to view the structure, conductivity, and absorbance of light of our samples. By finding these more practical ways to create superconductors we can then get closer to a broader use for more efficient energy transfer.

## Methods

In this experiment we will be scanning and analyzing samples in an STM.

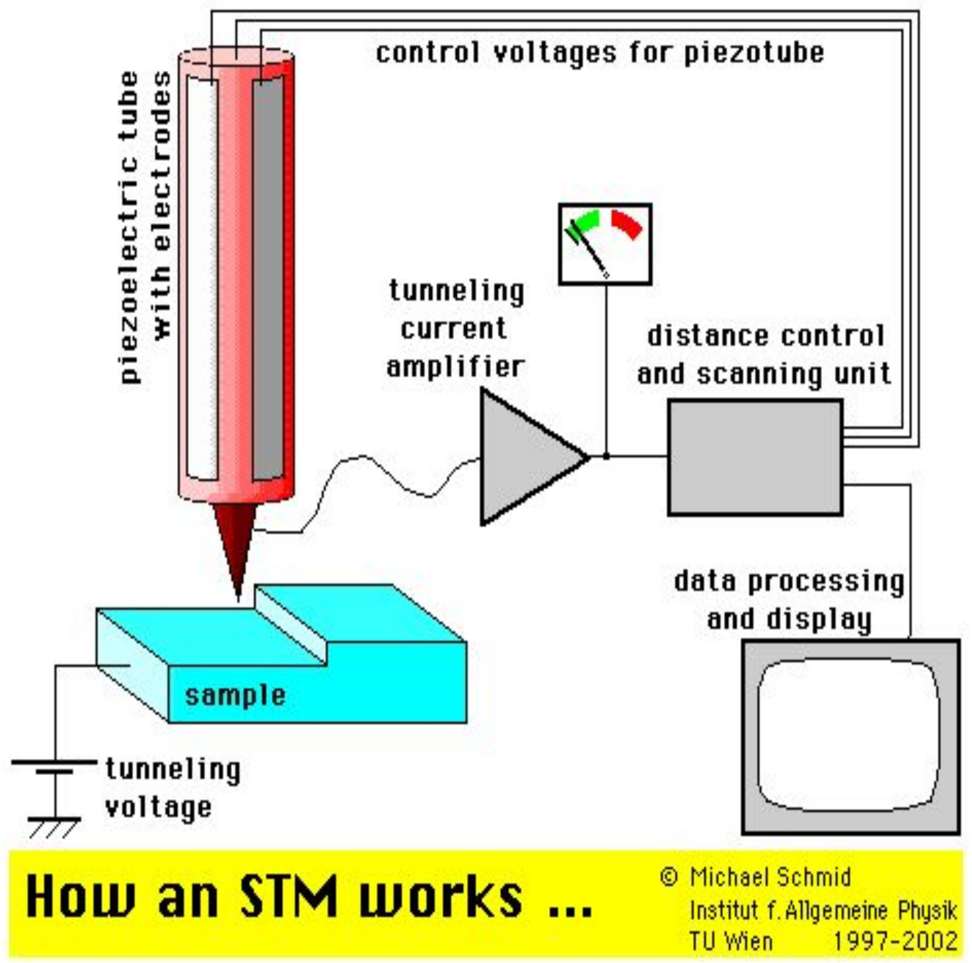
To use this we will:

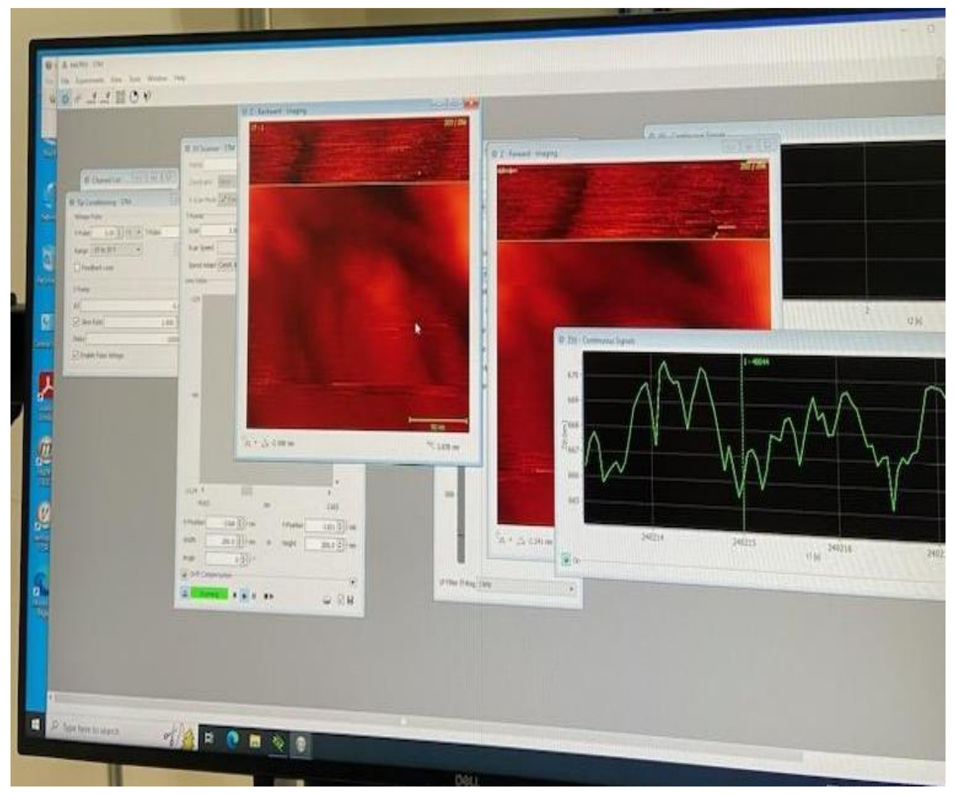
- initially prepare our samples we want to study
- Place the sample in our vacuum chamber with gate closed and turbo pump off
- Use linear translator to put sample in sample receiver
- Begin the turbo vacuum pump and wait 3-6 hours
- open gate, use translator to put inside chamber
- Use wobble rod to grab sample and put on the mount
- Use stage holder to lower stage into the dampener magnets
- Use the camera with the manual controller to get tip close to sample (course)
- Use the computer software to get the tip to a micrometer away from sample setting the Voltage to 2V and the amp range to 2nA.
- Once the tip is in place and fine movement is calibrated we will be sending an electrical signal into the sample and allowing the tip to move from a micrometer to a nanometer continuously until an entire section is observed.
- If blurry, increase voltage to "clean" the tip of STM.
- Not higher than 5V to protect sample
- Repeat steps until clear pattern of atoms on screen
- Move the sample area around to scan other parts of sample
- We then can analyze the physical properties and further understand the chemical properties of our sample

## Background Information

The current research of the lab is on the structure of two-dimensional van der Waals (vdWs) heterostructures. In order to study these low-dimensional quantum materials, methods of observation called Scanning Tunnel Microscopy and Atomic Force Microscopy (STM/AFM) are used to obtain images of these structures. Time-scales for these materials are in the femtosecond range, and multiple quantum devices are used in order to control the IR probes which are in turn used in order to observe the vdWs structures under nano-light in extreme conditions. The controller program for the STM/AFM machine is split into a firmware section, a kernel section, and a client software section. This controller program will auto detect currents and aid in calibration of instruments.

- The STM controller is housed on a Xilinx XC7A100TCSG324-1 model FPGA with 3 modules:
  - The firmware (written in Verilog) which has three significant functions
    - Auto-approach: This module aids the STM operator in approaching the sample by keeping the selected voltage in the tip within an acceptable range for the current, which depends on the resistance of the sample
    - Raster scan: This module reads the data given by the STM and transmits a bitmap image of the results from the STM to a monitor.
    - Control Loop: This module ensures that values in the system stay within a certain range
  - The software (Written in C)
  - The client software



## Discussion

In this research project we have finally recently started to begin STM runs on our samples to see if everything works correctly. Once the tip has been accessed to see if it will give accurate non distorted views, we will use the found set point for contracted and extended to speed up calibration for the other two samples bismuth bromide and Baged at the nano level before. In the future once we construct the instruments, we will be using a FIR (far Infrared) laser to do proton probing to study the current then created on the sample. We will also be using a TEM to get a better image of the sample and determine if our sample is in the Left or Right conformer due to the molecule's chirality. We will then be seeing if the Oxidation will erode the Tellurium like what happens to Iron or will it remain protected by the oxygen similar to aluminum. The two Bismuth compounds should be much more simple just viewing the structure and seeing how the oxide affects it in known superconductivity temperatures (-273.15°C) for the pure compound.

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## Reference

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