Development of a Multipurpose Ultrahigh Vacuum System for Electrical and Optical Measurements of Surface-Modified Quantum Materials

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REU Program: 2018 Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials Research Experience for Undergraduates Program at Cornell (PARADIM REU @ Cornell)

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Abstract:

The goal of The Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM) is to discover and characterize quantum materials, specifically superconductors. The challenge with synthesizing and characterizing most quantum material samples is that they are extremely air sensitive, meaning that exposure to atmospheric pressure will damage the sample making it unable to be characterized. At one atmospheric pressure, particulates in the air (dust) deposit onto the sample's surface making it impossible for instruments to characterize the sample. To combat this challenge, samples are synthesized and characterized in ultra-high vacuum (UHV). UHV is defined as any pressure below 10^{-9} torr. At low pressures, samples can be used for longer since they are not being ruined by air particulates. PARADIM has created a lab in 308 Duffield Hall at Cornell University that integrates molecular beam epitaxy (MBE) with material characterization instruments all connected in UHV, keeping the sample clean as they transport it from synthesis to characterization. During this summer, PARADIM was beginning to implement another UHV synthesis and characterization system at Cornell University. The goal of our project this summer was to help coordinate the layout of chambers in the PARADIM lab, as well as design UHV chambers that would be used by PARADIM Researchers.

Design Process:

Lab CAD Modeling. In order to achieve the goal of helping PARADIM users construct the layout for the lab and designing UHV Chambers, we first have to create an extremely accurate model of the PARADIM Lab. In Autodesk Inventor 2018, we created a model for the PARADIM lab that was accurate down to less than an inch. This step was important because it allowed PARADIM users to take models of chambers they designed and find where those chambers could fit.

Using a tape measure and a laser measuring tape, we first measured and modeled the general room dimensions and floor plan. After that, we measured the space objects such as cabinets and pipes take up and their relation to the walls of the lab. For the chambers that already existed in the lab (MBE), we used a computer aided design (CAD) model that had already existed in Shen's lab group's Dropbox and placed them in the model.

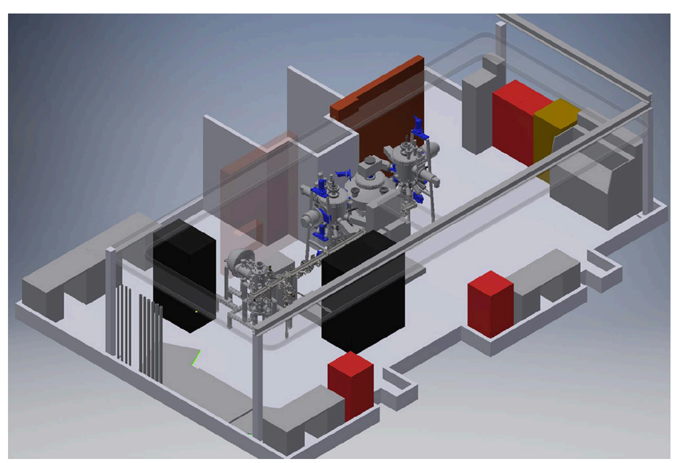

Figure 1: PARADIM lab model, proposed layout.

Upon completion of the model, we were tasked with helping Ed Lochocki and Luca Moreschini with placing chamber designs they were working on. Ed was working on a transfer tube that would allow users to transfer samples between chambers without taking them out of UHV and Luca was designing an ARPES chamber. We took suggestions from PARADIM users including PI, Professor Kyle Shen, and PARADIM director, Professor Darrell Schlom, and created a mock layout of the lab in Inventor Model. The current layout of the PARADIM Lab can be seen in Figure 1.

Sample Garage Design. In addition to creating the CAD model of the PARADIM Lab, we also worked on designing chambers that would be used by PARADIM users. The first design we worked on was a Sample Garage. One of the big limitations of the current system in Duffield 308 is the lack of samples that can be inside at a given time. Without a chamber dedicated to storing samples, users must grow their sample and measure them immediately. A storage chamber would allow users to have more flexibility when they characterize their samples. By having a sample garage, samples can be stored in UHV and can be used longer than what can be achieved currently.

For the sample garage design, we had several things we had to consider. The goal was to create a chamber that could store as many samples as possible in the smallest amount of space. Using a body that was 25 inches tall and 8 inches in diameter, we were able to design a sample garage that can hold up to 80 samples.

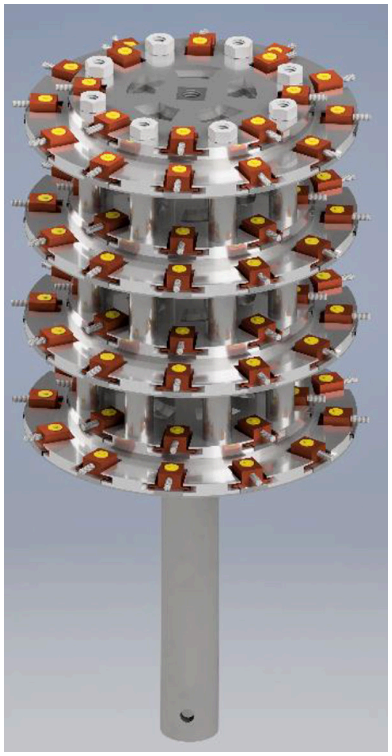

Figure 2: Storage sample garage.

Inside the chamber, there are four stacks of disks that each hold 20 samples. Each stack has two layers, a larger layer that can hold 12 samples and a smaller one that can hold 8 samples. Each disk will be made of aluminum, which will be waterjet cut at a machine shop. Within each sample holder space, there is a spring that secures the sample holder in place. The sample garage can be seen in Figure 2.

Aside from the design of the sample garage, we also had to design viewports and locations of transfer arms. We decided to place the transfer arm responsible for controlling the sample garage on the bottom of the chamber, so users could easily reach it. Since this sample garage would be attached to the transfer tube designed by Ed, a second arm was added which would be responsible for transferring samples in and out of the sample garage. we also added viewports that pointed to allow users to easily watch their sample as they were performing a sample transfer.

Future Work:

Towards the end of the summer, we began working on a surface science chamber. This is a characterization chamber that will be responsible for measuring the resistivity of a sample with respect to its temperature. This chamber is still in development and we will continue to work on it throughout next semester. The goal is to have this chamber to be part of the PARADIM Lab.

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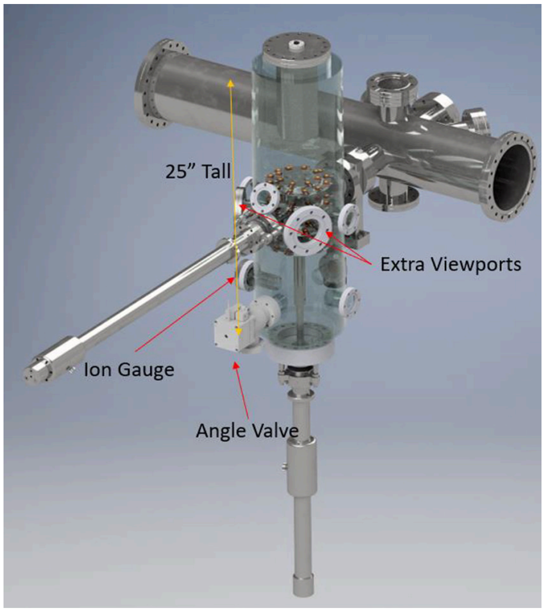

Figure 3: Storage sample chamber.