Implementing a Functional ARPES System

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Abstract:

Over the past decades, angle-resolved photoemission spectroscopy, or ARPES, has become a leading characterization tool in condensed matter physics. ARPES is an extremely valuable method for probing and mapping out the electronic structure of crystalline materials. The Platform for Accelerated Realization, Analysis, and Discovery of Interface Materials, or PARADIM, is currently in the process of designing and procuring a new APRES system. The challenge of this design is due to the nature of the technology which requires that all procedures and measurements within the system are performed under ultra-high vacuum (UHV) conditions. Our goal was to design and build a load lock and sample storage roundhouse within the UHV system for inserting and storing samples. These two components are critical for the operation of the new ARPES setup.

Summary of Project:

ARPES supplies vital information on the physics behind unique electronic and optical properties of materials through creating an image of the momentum-resolved electronic structure. ARPES has proven to be an essential tool in recent efforts to understand novel materials, whether fitting to one-electron band descriptions, such as topological insulators [1], or more complex correlated systems, which are challenging to predict with band theory and better described by a many-body picture [2]. The technology works through exploiting the basic principle of photoemission to eject electrons from the top atomic layers of a material. These photoemitted electrons pass through an electron analyzer and eventually reaching a 2D detector and camera. This process provides the emission angle and kinetic energy of the electron. Taking these two quantities, the binding energy and momentum of the electron prior to its photoexcitation can easily be extracted and the electronic band structure mapped [1].

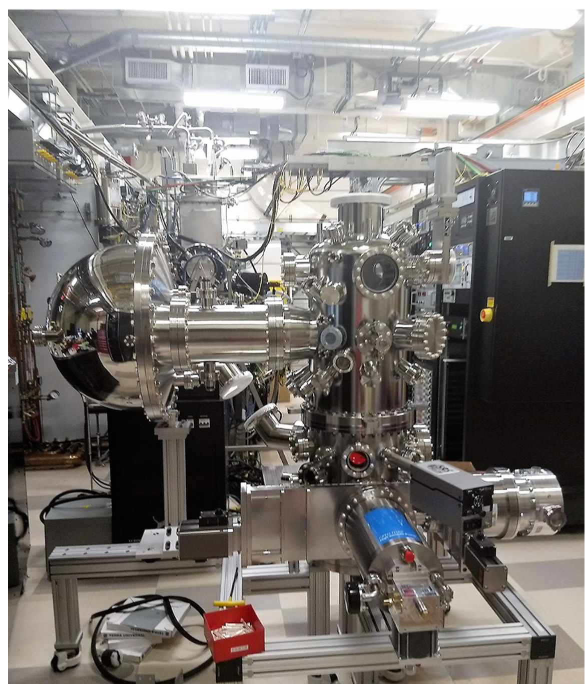

Figure 1: Image of the current state of new ARPES setup.

The novel ARPES system being commissioned is part of a user facility that will be utilized by researchers across the globe. Consequently, it is imperative that the design is functional, robust, and intuitive. Figure 1 illustrates the anticipated arrangement of the lab. The molecular beam epitaxy (MBE) presently exists and is functional, whereas the ARPES system is fully designed but only partially installed. Figure 2 depicts the current state in mounting the new ARPES. MBE and ARPES are frequently used in conjunction with one another, therefore it is necessary that they communicate within UHV through a transfer system. The next step in commissioning the new setup is to design and build a load lock and sample storage roundhouse off of this transfer system.

Load Lock Design. Electrons cannot travel through air at atmospheric pressure, therefor photoemission requires vacuum. For assuring a reasonable stability of the sample surface, ARPES measurements are typically performed at a pressure < 10^{-10} torr. The load lock, whose design is shown in Figure 3, permits users to insert and remove samples without venting the entire apparatus. It operates through a sample being inserted into the sample garage, the chamber pumping down, and then the gate valve opening. Once the gate valve is open, the sample garage travels upwards to meet a second transfer arm that picks up and pushes the sample into the main chamber to be measured. The sample garage is cut out of aluminum with a stainless steel leaf spring to secure the samples in place. The garage's capacity is six samples which maximizes the number of samples for the given length. Key features of the overall design include that the garage motion is easily motorized, it requires primarily stock parts, and the operation is simple and user friendly.

Sample Storage Design. Samples exposed to air can rarely be successfully measured by ARPES, thus it is critical they are stored within the UHV system after growth. The sample storage roundhouse serves as a long-term holding cell to protect samples if they are not immediately measured after growth in the MBE or if they need to be analyzed again later. The design, exhibited in Figure 4, consists of three sample carousel disks mechanically coupled to a solid aluminum pole. Each carousel layer holds eight samples, resulting in a total system capacity of twenty-four samples. However, extra mounting holes in the center pole allow additional sample carousel layers to be added as needed to increase storage capacity. The sample carousel is approximately 3.5 inches in diameter and placed within a 4-inch diameter chamber. Similar to the load lock garage, the sample carousel employs thin stainless-steel leaf springs to clamp in samples and the carousel body will be waterjet cut out of aluminum. Three viewing ports are located at different angles and positions on the sample system chamber to maximize visibility of the transfer of samples into the storage carousels. Lastly, there is a gate valve that can be shut to isolate the system from the main measurement chamber in case of a leak or required maintenance.

Present Status and Future Directions:

The load lock garage has been machined, assembled, and is currently undergoing testing. Next, the stock pieces of the design will be ordered and then the assembled load lock will be attached onto the main chamber. The sample storage design is presently in the process of fine-tuning and optimization. After the final design is approved, it will follow a similar process to the load lock where custom parts are machined, and stock parts are acquired. Once both the load lock and sample storage are attached onto the ARPES system they will be tested and refined.

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References:

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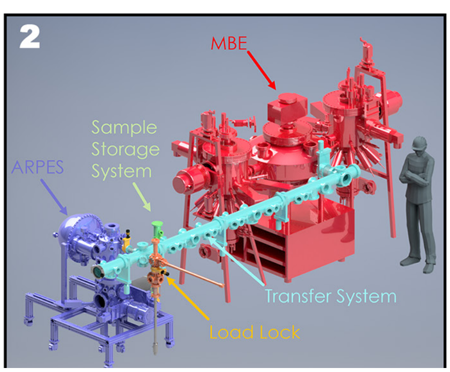
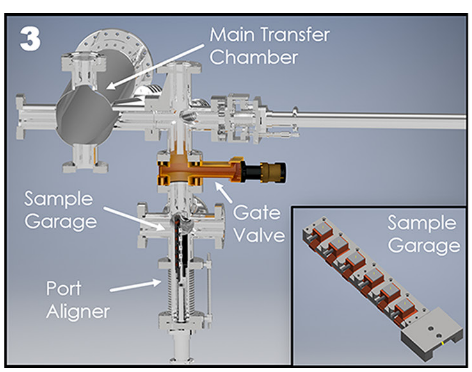
[2] A. Damascelli, Z. Hussain and Z.-X.Shen, "Angle-resolved photoemission studies of the cuprate superconductors", Rev. Mod. Phys. 75, 473 (2003).





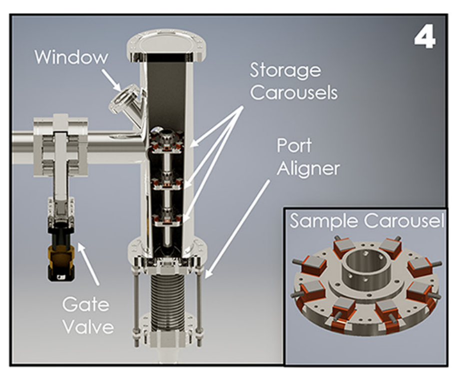


__Figure 2, left:__ 3D AutoCAD model depicting the ARPES/MBE system. __Figure 3, middle:__ AutoCAD model of the load lock. __Figure 4, right:__ AutoCAD model of the sample storage.