Research Experience

Kaiming Liu

My primary interests are condensed matter experimental physics and its application to microscopic scales. As an undergraduate, I was fortunate to participate in several projects at both Xi'an Jiaotong University and UC, Berkeley, from which I realized the importance of condensed matter experimental physics, especially those related to nanostructures and novel materials.

I first became interested in condensed matter physics when I participated in the China Undergraduate Physics Tournament (CUPT). The competition itself is not a pen-and-paper competition but an enactment of a scientific discussion (or a defense of a thesis) where participants take the roles of Reporter, Opponent, and Reviewer. By collaborating with another undergraduate, I explored a phenomenon in fluid mechanics: A light cylinder will start to spin while being suspended near the edge of a water jet aiming upward. I used the Navier-Stokes equation and boundary layer theory to build a physical model. I found that this effect is caused by the pressure difference. Furthermore, we experimentally evaluated the stability of the cylinder. Our work led to a publication in a domestic physics journal, Physics Experimentation. I am the first author of this paper. This was the first time I went through the whole process of a research project, from identifying the problem to proposing a solution and finally writing a paper. This experience sparked my passion for condensed matter experimental physics and gave me confidence in my abilities to lead novel research and good collaborations.

To obtain more professional research experiences in condensed matter physics, in my third year, I was selected and fully financially supported by Xi'an Jiaotong University to study at the University of California, Berkeley. I entered Prof. Michael Crommie's group of condensed matter experiments to start research on scanning tunneling microscopy (STM) and nanostructures, such as Graphene nanoribbons (GNRs), with Dr. Peter Jacobse and graduate student Ziyi Wang.

In the first project, I studied the behavior of the magnetic ground state of dibenzoquateranthene (DBQA) on a gold surface. I learned to use Matrix-Assisted Direct (MAD) Transfer and Bottom-Up Approach to achieve an on-surface synthesis of poly-DBQA from precursor iodophenyl-bromobianthryl (PBA). By collaborating with my colleagues, I successfully scanned STM topographic image showing a poly-DBQA chain ("daisy chain"). I was fascinated by these delicate nanostructures when we finally overcame difficulties and got a clear image of daisy chains. This work led to a manuscript entitled "Decoupling localized modes in nanographene", which is prepared to be submitted to Nature Communication.

I was eager to explore more wonderful phenomena of condensed matter physics. Therefore, I started another project about the five-fold structure. In this project, I applied the Evaporation method and Bottom-Up approach to synthesize five-fold structures from five-membered ring molecules. I mastered many experimental skills in the first project, which enabled me to undertake some tasks independently, such as scanning probe measurements, molecular evaporation, and refilling liquid Helium and liquid Nitrogen. etc. Finally, we obtained STM topographic image showing five-point star structures. This project provided new ideas for the synthesis of 2D quasicrystals. More importantly, I learned to combine new theories with experimental tools to predict and synthesize new nanostructures.

In the third project, I discussed with my colleagues and proposed a possible pathway for the ordered synthesis of GNRs assisted by single strands of DNA which might enable us to precisely control the length, orientation, and order of nanostructures. I used MAD Transfer to complete the on-surface synthesis. Nevertheless, STM topographic images showed that single strands of DNA were all bent and twisted which were not good candidates for ordered synthesis. Therefore, we found that DNA single strands are not suitable as templates for the ordered synthesis of GNRs.

The research projects mentioned above sparked my interest in condensed matter physics. Therefore, I want to explore this field at a more fundamental level. Consequently, in the Spring 2022 semester, I joined a group about Cold Atoms at Xi'an Jiaotong University. Under the guidance of Prof. Yongchang Zhang, I performed a theoretical study on Rydberg atomic system and quantum nonlinear optics. My colleagues and I designed and co-proposed a scheme to realize the function of qubit gates through the interaction of Rydberg atomic systems coupled with photons. Specifically, I reproduced the derivation of the Hamiltonian matrix of the Rydberg atomic system by building a physical model of this system. I also conducted many numerical simulations of the Rydberg atomic system, such as the energy distance relationship of the two-atom model and the time evolution of the polyatomic system under the condition of dark-state polariton.

Throughout my two-year immersion in condensed matter physics, I have always been determined to pursue an academic career. I believe condensed physics is a promising topic with a myriad of unexplored research directions.