

Statement of Purpose

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My research interest is strongly focused on the theoretical study of physics, especially condensed matter physics. Through my research on nonequilibrium statistical mechanics, I realized that theoretical study suits me very well. Meanwhile, I have become more interested in topics which are more relevant to real-world physics. With regard to this, the field of topological phases of matter is very attractive to me. To get a graduate degree in this field of study, I am applying to the University of California, Berkeley.

1 Toward condensed matter theory

I enrolled into Tokyo Institute of Technology through the presentation of my experimental research results on photocatalytic activity of TiO_2 , which I had been doing throughout high school. At that time, my interest was mainly phenomena themselves, and I had no preference in theory. After taking several classes, it gradually shifted to theoretical studies in physics. Since our university puts limitations on the number of credits that can be taken per year, I could not take advanced classes officially. However, my enthusiasm could not be stopped and I personally asked teachers for permission to attend courses beyond the curriculum. As a result, I had finished learning most of the physics courses by the middle of my third year.

The most striking experience that catapulted me into the world of theoretical physics is the research on nonequilibrium statistical mechanics under the guidance of Specially appointed Prof. Takahashi in Tokyo Tech. Though it is not within the standard physics curriculum, I had time after taking all the courses and was curious about how research is conducted, I personally asked him to research with his collaboration. Since August 2020, we have been studying the dynamical Lee-Yang zeros of the simple two-level system. Lee-Yang zeros are zeros of the partition function of a system with complex parameters. Though it is not present in the real-valued physical parameters, it is very useful to determine phase transitions in the thermodynamic limit and also recently experimentally utilized in a system where physical parameters can effectively be considered to be complex. These known results are for static systems without time dependence. Therefore, we are currently tackling the hitherto unknown periodically driven cases. In time-dependent cases, the situation changes drastically and the determination of the zeros itself becomes very difficult. I mainly did numerical calculations by Python and c++ and also came up with some general formulas for current distribution functions using dynamical Lee-Yang zeros. This research is still in progress and the results are not yet published, but not only did I learn a lot about nonequilibrium physics, but I learned a great deal about my perseverance and love for physics too. Combining it with my original interests in phenomena, I have decided to specialize in condensed matter theory.

2 Current research

I am investigating the topological phases of matter under the supervision of Prof. Murakami in Tokyo Tech now. My original theme was the theoretical understanding of the photovoltaic effect in a van der Waals interface, which has been experimentally observed recently. This effect is caused by the breaking of symmetry by stacking two sheets of materials with different rotational symmetries. This "symmetry breaking by symmetries" itself is not only an interesting idea from a theoretical point of view but also very important for future applications due to the variety of symmetries not included yet in the experiments. Like Moiré crystals, the lack of periodicity makes it difficult to understand this phenomenon. I am trying to construct a simple model which minimally captures the essence of this phenomenon. By graduation, I want to further understand the mechanism of this and hopefully publish the results.

Due to my enthusiasm to acquire as much research experience as possible, I have recently begun another research project. This project deals with a newly manufactured hexagonal boron-carbon-nitride sheet. By the Brillouin zone folding from that of the Graphene and change in the symmetry, the Dirac cones get gapped and localized states appear in the finite system. I constructed a tight binding hamiltonian of this lattice and confirmed the existence of the edge modes thus far. This work is also still in progress, but through this research, I acquired the ability to construct a tight-binding model for the desired system in both finite and infinite systems and analyze it analytically and numerically. I believe this would be very helpful in my research in graduate school and beyond.

3 Academic plan & Why UC Berkeley

After getting a Ph.D. degree, I want to get an academic position at a university. As a preparation for that, I have actively participated in activities apart from physics research. One of them is the university official survey team called "student survey". I was honored to be the president of that team for more than 2 years (currently vice president) and learned how to work, manage, and lead people in a team environment. For my hard work, I received a "student leadership award 2021". My leadership and collaborative skills will undoubtedly be a strength for me in the research field too.

UC Berkeley is a brilliant fit for me since it focuses on new phenomena and cross-disciplinary studies. Through research on topological matter, I know that fundamental things are extensively studied already. This situation is not limited to my field of study and can happen in the future too. In a somewhat matured physics society, where breakthrough is awaited, what can we do to revolutionize the situation? One answer I got is to combine various types of knowledge we have and, as a most important thing for natural science, make a theory based on physical phenomena. I really want to gain these abilities to survive as a researcher in the future. For that purpose, Prof. Moore, whose team actively collaborates with experimentalists is the best choice for me.