（別紙様式５）

変革を駆動する先端物理・数学プログラム（FoPM）

国外連携機関長期研修　報告書

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I visited Professor David Penneys at Ohio State University from January 18 to March 23, 2026. I joined a research project with Professor Penneys and his student, Anupama Bhardwaj. I also attended seminars and gave a talk.

In our research project, we have been investigating the extension theory for nets of algebras—families of properly infinite von Neumann algebras indexed by posets with involutions (such as cones in R^2). These objects generalize conformal nets, but here we focus on cases without group actions. While a one-to-one correspondence is known between irreducible finite index extensions of conformal nets and Q-systems in the category of DHR endomorphisms, our aim is to generalize this to nets of algebras and the category of their superselection sectors. We are working to define “finite index extensions” for nets of algebras and to establish a correspondence with Q-systems in their superselection sector categories. The main challenge is the Haag duality, which we include as an axiom for nets of algebras, although for conformal nets, it can be deduced from weaker assumptions.
We had meetings with Professor Penneys and Anupama every Monday. Anupama and I also had frequent discussions, aside from the Monday meetings. I enjoy having discussions with Professor Penneys and Anupama. I had been interested in Q-systems and tensor categories arising in mathematical physics, but I hadn’t had much opportunity to study these before this project. I appreciate Professor Penneys for letting me join this project and Anupama for giving me plenty of time for discussions. We will continue our work after my stay.

I participated in three types of seminars in Professor Penneys’ group: the Quantum Symmetry Seminar on Tuesdays, the Thursday student seminars, and Friday progress reporting meetings.
The first one is the Quantum Symmetry Seminar on Tuesdays. In this seminar, we have speakers from other affiliations. We had various talks related to quantum symmetries: operator algebra theory, knot theory, category theory, and mathematical physics. I presented the progress of my research project on nets of algebras on March 3, titled “Inclusions of nets of algebras and Q-systems”. It was a great opportunity to hear the latest research topics around quantum symmetries.
The second one is the seminar by the students of Professor Penneys on Thursdays. His students are working on category theory, operator algebra theory (namely, von Neumann algebras), and mathematical physics. It was great to attend these discussion-based seminars. In our lab in Tokyo, the student seminars are more like practice in giving lectures. I realized that I had been too passive to ask questions during the seminars.
The third one is the progress reporting meetings by the students of Professor Penneys, who are working on operator algebraic topics on Fridays. In Professor Penneys’ group, students have both collaborating projects with other students and their own projects. It was very nice to hear what they are working on.
It was great to communicate with Professor Penneys’ students before and after the seminars.

I also enjoyed my stay in Columbus, Ohio. The city is very convenient and comfortable to live in. In January, we had a terrible winter storm in the eastern parts of the United States. Columbus also got very cold, such as -25 degrees Celsius, which was said to be the worst in several decades. I had never experienced that cold in my life. After the snow, snowplows piled up the snow on sidewalks, so I needed to make my way through knee-deep snow to get to supermarkets for a while. Also, once the heater in my room broke, I needed to change my room. However, I could concentrate on my work during that period. I also enjoyed cooking in my room with American ingredients.
The weather became better in March, and I visited Anupama’s home with Chumeng Di, a student of Professor Penneys. We enjoyed Indian food by Anupama and her roommates, and we talked a lot. It was interesting to hear

about the campus life at Ohio State University.
I also visited several sightseeing spots, such as the Wexner Center for the Arts, Columbus Museum of Art, Franklin Park Conservatory and Botanical Gardens, Columbus Short North Art District, and Center of Science and Industry (COSI). I particularly enjoyed the modern art exhibitions. It was interesting to know the perspectives of the American people on culture and science.
This was my second visit to the States, and the first one was to Berkeley, California. I enjoyed the difference in the culture of the western and eastern areas of the United States.

In closing, I would like to express my gratitude to Professor Penneys and his students, especially Anupama, for their warm support during my stay. I had a great time and learned a lot during my stay. Namely I realize the importance of communication. I would like to utilize this experience for the rest of my PhD, and I hope to visit Ohio State University again.



(Ohio Stadium in the snow)



(with Professor David Penneys (center) and Anupama Bhardwaj (right))