Activity report for MERIT Overseas Dispatch Program

Department of Applied Physics
Tarucha-Yamamoto Group
2nd year of Ph.D. cource
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1.Overview and background

Fig.1 Applied Physics department @TU Delft

I stayed and studied in the group of Prof. Lieven Mark Koenraad Vandersypen, Technische Universiteit Delft (TU Delft), Delft, Netherland from September 16th until October 15th. This group is leading the field of quantum science using semiconductor quantum dot (QD). The reason why I decided to visit Vandersypen group for overseas dispatch program is that my research theme and their theme have some common point and their recent product can help my project. Tarucha-Yamamoto group is also working on QD and I am working especially on multiple QD. In the experiment of multiple QD, initial tuning of QD is time-consuming process. But, recently, they published a paper about the computer automated tuning of QD and they need only 2 hours for forming double QD. It will help our project largely and I decided to visit Vandersypen group to learn about this tuning method and other techniques.

After Prof. Tarucha agreed with me about my one-month research trip to TU Delft, Prof. Vandersypen came to Japan for some meeting and I could talk with him about my visit. He accepted my visit and we discussed the plan in Delft. Unfortunately, I could not learn about computer automated forming of QD but they are also working on the automated tuning of other parameters. So we decided to work with a Ph.D. student, Sjaak van Diepen who is working on some automation of QD tuning and to decide detailed plan after the site visit of their laboratory.

2.Reseach in TU Delft

In 1st week, I had a look around the laboratory and was explained about the researches performed in Vandersypen group from the group members. I was surprised by the layout of their laboratory. They use 2 rooms for measurement that are arranged in ground and 1st floor and make holes between the rooms to embed their dilution fridges. They place the equipments that make noises in lower room and place measurement set ups and perform measurements in upper quiet room. That is a sensible way of measurement setting.

After that, I discussed with 3 guys working on multiple QD, Christian Volk, Sjaak van Diepen and Marija Zwerver. They were trying to demonstrate direct controll of QD parameters like chemical potentials of the dot and tunnnel couplings between the dots. In actual QD device, gate electrodes are used to tune them but we can not control each parameter independently due to capacitive couplings between the gate electrodes and the dots. Due to this problem, tuning and control of multiple QD get more difficult as the number of dots (the number of gate electrodes) increases. In order to solve this problem, they estimate all capacitive couplings between dots and gate electrodes and calculate the combination of gate electrodes that control parameters independently. They call this method “virtual gate” method. This method is an essential technique for the experiment in multiple QD and I asked them to let me learn about it. Considering my request, I started to learn about virtual gate method with numerically calculated virtual multiple QD systems. In that system, I worked on an automated addition of dot to already formed double QD. They already established the method to form single and double QD automatically but it is difficult to scale up this method to further scaled up QD system like triple QD. So they started to establish the method to form additional dot one by one. In this method, virtual gate method is also useful because we can change the voltage on the gate electrodes for additional dot without the effects on the parameters of existing dots.

At first, we checked this method manually in the QD device by applying voltage on gate electrode for additional dot with virtual gate method and the additional dot were formed correctly. Then I started writing the program for the automation of this method. At that time, I felt the difference between Tarucha group and Vandersypen group. In our group, the programs for measurement and analysis have to be written by oneself and there is no system to share the codes (we need copy & paste each program). In other hands, in Vandersypen group, they utilize common framework fabricated by some research groups including TU Delft and Microsoft and share the codes written personally by gitHub. In addition to this, there are the technical staffs for programming and they enable Vandersypen group to create high-grade measurement and analysis system. Actually, I was helped by the sharing system and the technical staffs to write programs. In the experiment of the spin qubit, the programs for measurement and analysis are needed to be sophisticated and it is a burdensome task. So the system in Vandersypen group looks very effective and I thought that our group should follow it.

At the end of the research dispatch, I could not finish the program to add a dot to multiple QD but the automatic detection of charge transition signal of the additional dot was realized. In the research visit, I got many chances to discuss not only what I worked on Delft but also my research at the University of Tokyo. In every discussion, I got new insights about the research and experiments because the people in the different group have the different mindset for research.

3.Acknowledgement

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