

# MERIT Long-term Overseas Dispatch Activity Report

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Supported by MERIT Long-term Overseas Dispatch, I stayed in Jülich, Nordrhein-Westfalen, Germany from 8<sup>th</sup> March, 2015 to 31<sup>th</sup> May, 2015 to carry out a collaborative research with Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons (ER-C), Forschungszentrum under the mentorship of director of ER-C, Prof. Dunin-Borkowski, who is one of the world authorities on electron holography. ER-C is the distinguished research institution in the field of electron microscopy that named after the German physicist who won the Nobel Prize in physics for his research and development on electron microscopy. ER-C is known for their aberration-corrected ultrahigh-resolution electron microscopes, outstanding research using them by electron holography, scanning transmission microscopy and spectroscopy, and analysis and simulation related to electron microscopy.

My research theme in Ph.D. course is real-space observation of nanoscale magnetic vortices called skyrmions, and I have carried out it with using Lorentz transmission electron microscopy (LTEM). Although LTEM is easy to be carried out and useful for qualitative observation of magnetic moment distribution, spatial and phase resolution of LTEM are not high enough for quantitative analysis. Meanwhile, electron holography has much higher spatial and phase resolution than LTEM and can be used for quantitative analysis of nanoscale magnetic structures. I had been interested in electron holography and thinking about applying its high-resolution to skyrmions. On this occasion, I proposed the collaborative research named “Quantitative observation of magnetic skyrmion structure” to Prof. Dunin-Borkowski in order to apply electron holography to quantitative analysis of skyrmions which cannot be done with LTEM.

Dr. Kovács was kind enough to take care of me for our experiment project and staying issues in Jülich even though he was busy for other experiments and lectures. Fortunately, the quality of samples which I brought was good enough for electron holography. We could start experiment soon after the arrival. Although sometimes the experiment did not go straightforwardly, we could take proper steps to meet the situation thanks to sufficient machine time of microscopes and periodical discussions. During the discussion, the researchers also provided me constructive suggestions and chances to collaborate with researchers in the institute. Thanks to that, we could take more valuable experimental data than expected in the three-month stay. As a result, we could observe the structural change of magnetic skyrmion structure against magnetic field and temperature and we still need more analysis on the obtained data.

There were many researchers and students in ER-C. Some of them came to carry out collaborative research and to learn experimental techniques like me. Talking with them was very interesting because the subjects of study have a wide variety. I could also have deep discussions with researchers who are related to my research theme thanks to Prof. Dunin-Borkowski's introduction. During the stay, the international conference on the aberration corrected electron microscopy organized by ER-C, PICO 2015, was held and I participated in it. Many famous researchers from all over the world including Prof.

Ikuhara, other Professors and researchers from Japan participated in it. It was a great opportunity for me to talk to the great researchers in the field of electron microscopy. I also have opportunity of research exchange. I presented my research theme in the group seminar. I was asked many interesting questions about my research, and I was happy that many researchers in ER-C have an interest in my research.

Through the staying in the institute, I found that the researchers concentrate on research activity in the scheduled time and use the left time effectively to enrich private life. I had a good impression with their working style.

Before this dispatch, I was doubtful of my English skill, but now the fact that I could manage to live in foreign country by myself and carry out collaborative research gives me a certain confidence. Meanwhile, I also deeply realized the importance of English as a communication tool because I sometimes encountered the situation that I cannot understand conversation and say what I want to tell.

It was cold when I arrived at the beginning of March, but it soon became warm and comfortable. The daytime became longer day by day, and I had a good spring season. It seems that I was lucky to have sunny days because many people were saying that it was unusual there. I felt nervous about living since it was my first long stay in foreign country. Actually, I ran into some troubles, but thanks to the help of Dr. Kovács and others I could spend comfortable staying time in Jülich. At the beginning of the staying in Germany, I was surprised because less English was used on the street than I had expected, but that did not bother me because people in Germany are kind and speak English fluently. In the communication with non-Japanese people, I found that I don't know a lot about world-famous things of Japanese culture. I felt that I should have learned Japanese culture.

This dispatch provided me wonderful experience to plan and conduct research as a researcher in international scenes, and was the most significant three months of my research life. Prof. Dunin-Borkowski said that not only taking experimental data but also analyzing the data is very important part in electron holography study. I would like to have a close communication with them to analyze and publish the results and keep in touch ever after this project.

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