Report on Long-term Overseas Dispatch

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In this Long-term overseas dispatch, I did the research with Dr. Marcin Konzcykowski at Ecole Polytechnique in France for three months.

His research topic is about the effect of electron irradiation on the strongly correlated electronic systems.

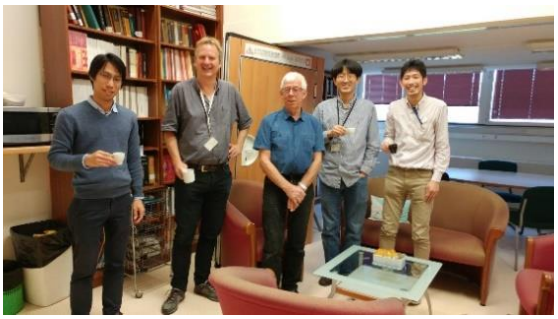

Figure1 At Laboratory of Irradiated Solids

According to previous studies, it is revealed that electron irradiation introduces homogeneous point-like defects in Fe-based superconductor $BaFe_2(As_{1-x}P_x)_2$ without changing the carrier concentration. The electron irradiation introduces carriers in topological insulators such as Bi_2Se_3, Bi_2Te_3 whose carrier concentration are originally small.

In this program, my research topic is about the effect of high-temperature annealing on the irradiated samples. After doing the electron irradiation on samples, we annealed them and measured the physical properties step by step. In the optimal doped $BaFe_2(As_{1-x}P_x)_2$(x=0.3) which have the maximum of superconducting transition temperature(T_c) in this system, we did the resistivity measurement. By increasing the value of electron irradiation, the absolute value of resistivity is increased. At the same time, T_c is suppressed. In this same sample, T_c and the absolute value of resistivity go back toward the pristine state by annealing. In Bi_2Se_3 and Bi_2Te_3, we measured the Hall coefficient. The carrier concentration is increased after irradiation. By annealing the sample, this carrier concentration is suppressed toward the pristine state. Although in the previous studies they did the electron irradiation and evaluated the physical properties step by step, now it is expected that after a large amount of irradiation at once, we can evaluate the effect of electron irradiation systematically by annealing the sample step by step. The electron irradiation experiments need a large apparatus. Due to the limitation of machine time for using this apparatus, that possibility of the annealing effect is very important to improve the efficiency of the experiments.

At Ecole Polytechnique, there was the simulcast lecture called “Frontiers of Condensed Matter Physics lecture” in every week during my stay. I had precious opportunities to attend the lectures by great researchers.

Dr.Marcin Konzcykowski has been collaborating with a lot of researchers. During my stay, His collaborators came to his laboratory and he visited his collaborator's laboratory with me. I got the opportunities to talk with the researchers. Dr. Kyuil Cho from Ames Laboratory in the USA was doing experiments on electron irradiation on another Fe-based superconductor. He told me his experimental results and talked about the academic careers in the foreign countries. Dr. Alexei Koshelev from Argonne National Laboratory in the USA discussed our results on the annealing effect of the Fe-based superconductor $BaFe_2(As_{1-x}P_x)_2$. We will continue the discussion about this result.

Furthermore, fortunately I had the opportunities to visit several research groups. Because I have been working on and I will continue to work on high pressure study, I would like to learn about the measurement technique under high pressure and I planned to visit other laboratories in this term.

Figure2 With SQUAP group at MPQ

First, I visited the Spectroscopy of quasi-particles (SQUAP) group of the Laboratoire Matériaux et Phénomènes Quantiques (MPQ) at Université Paris Diderot. I met Professor Yann Gallais at the Autumn Meeting of The Physical Society of Japan just before this dispatch, and ask him to give me a chance to visit his laboratory. Thankfully he allowed my visit. In this group, they do high pressure Raman spectroscopy measurement on superconducting materials and report interesting results. They showed me the system of optical measurement under high pressure and furthermore explained the recent research on high pressure Raman spectroscopy measurement of $NiSe_2$. Professor Yann Gallais suggested that I should attend the talk at the International Conference called Paris Edge 2017. Here, I was able to get the information on the recent topic in the research field of superconductivity.

Moreover, I contacted Dr. William Knafo from Laboratoire National des Champs Magnétiques Intenses (LNCMI) in Toulouse and got an opportunity to see his

experiments. During my visit, he was doing a study on the electronic conductivity properties of heavy fermion superconductors under high magnetic field and high pressure, which is a collaborative work with Dr. Yosuke Hirose from Niigata University. The pressure cell used for this measurement was developed by Dr. Daniel Braithwaite of IMAPEC (Instrumentation, advanced materials, physics of correlated electrons). I was learning about ceramic high-pressure cell used in high magnetic field and sample setting for the measurement under high magnetic field. In addition, Dr. Atsuhiko Miyata who is postdoctoral fellow at the facility kindly explained the measurement technique under high magnetic field to me and introduce laboratories in the facility. At that time, I met Dr. Cyril Proust and he talked about study on ultrasonic measurement in high-T_c cuprate and explained the measurement system to me.

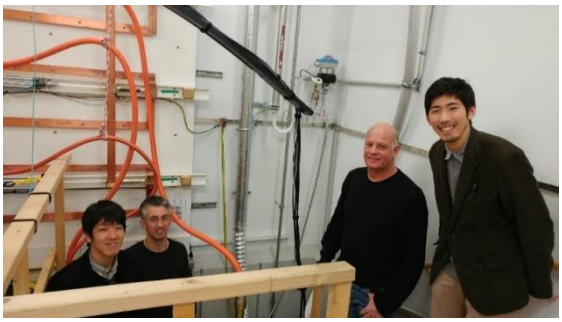

Figure3　At LNCMI in Touluse

During this period, I also had precious experiences. They are not directly related to the research, but are important when working overseas in the future. There were opportunities to interact with students in various fields. They gave me a lot of motivations.

There are students who joined the Internship program of Ecole Polytechinique as I was. One of them was working on the theme of machine learning and he gave me the information on machine learning. In addition, we exchanged opinions about how to apply machine learning to the field of experimental physics research in the future. I will keep in touch with him and seek out the ways to apply it.

I was also able to interact with Chinese students who join the Innovation and entrepreneurship management double Master degrees program which is organized by Zhejiang University in China and Ecole Polytechnique. Most of them already had their job in the industrial companies and the ministries. They joined that program to improve their skill and they were learning about the management skill and the latest technology related to IT. In talking with them, I was able to learn about not only what they are learning at Ecole Polytechnique but also what they do and recent projects in their companies. I got information on the situation and the trend of Chinese companies.

In addition, Ecole Polytechnique has a Japanese class. The students who want to work for the things related to Japan or who want to study in Japan are learning Japanese. Some of them plan to go to graduate school in Japan this year. I also had the opportunities to interact with them on holidays. They were very interested in Japan and asked me questions about various things. I think that the ability to grasp the Japanese culture and society and to explain such a topic in foreign languages, especially English is very important to expand the network when working overseas.

Figure4 With people from Japanese class

Finally, I would like to express my sincere gratitude the people who supported me in this long-term overseas dispatch. My supervisor Professor Shibauchi introduced me an internship program at Ecole Polytechnique and gave me the opportunity to experience overseas, Dr. Marcin Konzcykowski kindly allowed me to join the internship program in Ecole Polytechnique and organized the experiments. As Professor Shibauchi recommended me, Professor Uwatoko from Institute for Solid State Physics of the University of Tokyo also recommended me to the internship program. Professor Nakamura who is my assistant supervisor in the MERIT program allowed me to apply for this MERIT long-term overseas dispatch. Professor Gallais and Dr. Knafo gave me a chance to visit their group. Thanks to the supports from Ecole Polytechnique and MERIT program, I spent this precious time. I also would like to thank all those who I met during this stay.