Report of Long-Term Overseas Dispatch

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1. Overview

I stayed at ELETTRA, synchrotron radiation facility, and at FERMI, free electron laser (FEL) facility, at Trieste in Italy from 7th/Jul. to 3rd/Oct. for long-term overseas dispatch program of MERIT. I conducted research under the supervision of Dr. Jun Fujii and Dr. Claudio Masciovecchio. I have joined a project for developing time- and spin-resolved photoelectron spectroscopy system, learned elemental technology for experiments using FEL and measured angle-resolved photoelectron spectroscopy on ultrathin Fe/graphene system using synchrotron radiation.

2. Research

1) Development of time- and spin-resolved photoelectron spectroscopy system

I joined a project for developing spin-resolved photoelectron spectroscopy system in which three dimensional spin polarizations can be detected at offline space of APE beamline in ELETTRA. In the system, two Mott-type detectors are used. This type of detector uses asymmetry, which is induced by spin-orbit interaction, of electron scattering depending on spin polarization (Figure 1). I was in charge of time-of-flight type detector unit that is used for energy analysis with the help of Prof. Vladimir Petrov who was staying there at the same time as a visiting professor. In my group in Japan, we have developed time-resolved photoelectron spectroscopy system combining time-of-flight detector at BL07LSU in SPring-8. We usually use it when we conduct experiment for tracing carrier dynamics in my group. However I had not designed or constructed the circuit unit of time-of-flight analyzer so far therefore this was a valuable experience for me. This system will be used for time-resolved experiment using FEL in the future so that I will keep in touch with the project team to continue the collaboration.

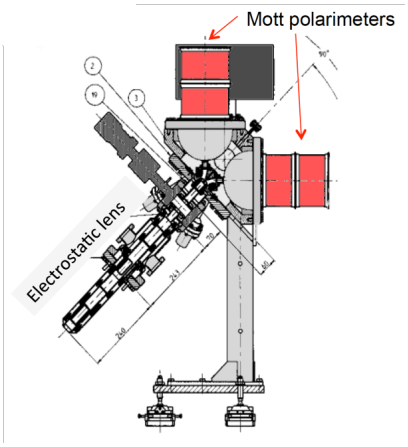

Fig.1 Three dimensional Spin detection system using two Mott-type detectors arranged at right angles to each other

2) Participation in time-resolved measurement at FERMI@ELETTRA

Regarding FEL that has recently emerged as a laser in X-ray region, currently (Apr. 2016), there are four facilities that are open to uses, LCLS in U.S., SACLA in Japan, FLASH in Germany, and FERMI in Italy (Fig. 2). Among them, only FERMI is available as a jitter-free light source with temporal coherence as well as spatial coherence. It was during the period that they tried to establish elemental techniques for time-resolved experiment in FERMI when I stayed there. I learned techniques such as temporal and spatial overlap between pump and probe light, which is core parts for time-resolved measurement. We determined delay zero between them with the resolution of tens of femtoseconds using FEL-pump and IR-probe experiment on Si_3N_4 or GaAs. In FERMI, data acquired during beamtime is stored in HPC because its amount is huge. I got accustomed to the way uses access to HPC and extract data needed for them. This style is also seen in Japanese FEL so that I think I learned generic data acquisition and reading techniques. After this overseas dispatch, beamtime for measuring time-resolved resonant magneto-optical effect at DiProI beamline in FERMI on Mar. 2014 had been planned so that I designed software for acquiring data and

Fig. 2 Experimental hall of FERMI (LDM, DiProI, TIMEX beamline from left)

measurement hardware using know-how I had learned through this program. In fact, I succeeded in observing ultrafast magnetization reversal of ferrimagnetic metal, GdFeCo on Mar. 2014 at FERMI in Italy [1].

3) Angle-resolved photoelectron spectroscopy at VUV photoemission beamline at ELETTRA

At VUV photoemission beamline at ELETTRA, it is possible to synthesize sample in under ultrahigh vacuum condition in preparation chamber, evaluate its structure using LEED and measure angle-resolved photoelectron spectroscopy after transferring the sample from preparation chamber to main chamber (Fig. 3). Firstly, I deposited a very small amount of Fe ranging from 0.05 to 1 atomic layer on graphene and measured angle-resolved photoelectron spectroscopy. This experiment would be preliminary one for understanding static properties before time-resolved measurement on surface magnetic atoms system. At certain Fe coverage, I observed dirac-cones of graphene and itinerant band structures of Fe at the same time. At the Fe critical thickness, both dirac-cones and itinerant structures are not modified from its original shape. This means that the coupling between Fe and graphene might be small. I also confirmed that if the Fe coverage is more than the critical thickness, itinerant band structure of Fe that is located close to Fermi level remarkably appears and band structure originated from graphene was not be observed. Investigation using STM about how Fe atoms position on graphene layer would be a future task.

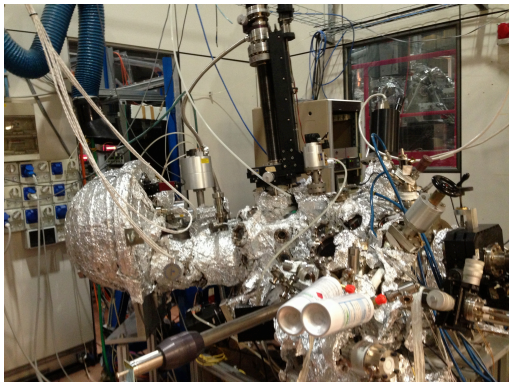

Fig. 3 Angle-resolved photoelectron system at VUV photoemission beamline endstation

3. Life in Trieste

They work with a proper sense of proportion, which they start working early and finish their work at 5 or 6 p.m. often seen in the style of European. There were lots of things I could learn from their active discussion and their attitude in which they enjoy their research. I could also fully enjoyed holidays. It was supposed that it was comfortable in Trieste because of its Mediterranean climate. However, in general, air-conditioner is not equipped in apartments so that I often had felt it was hot. In the case, I went to beach, 15 minutes using bus from Trieste central station, with colleagues or friends I made during my stay in Trieste and relaxed. I have also enjoyed gelato, especially after dinner. I learned this style from the local people. In Trieste, there is musical university so I have enjoyed jazz session with students of the musical university.

Fig. 4 Photo with colleagues

4. Acknowledgement

I would like to express my sincere gratitude to Dr. Jun Fujii, Dr. Giancarlo Panaccione, Dr. Claudio Masciovecchio and Dr. Maya Kiskinova. I am also indebt to Ms. Kaori Fujii for supporting life in Trieste. Finally, I heartily thank MERIT program, Prof. Hidenori Takagi and my supervisor Prof. Iwao Matsuda.

5. Reference

[1] Sh. Yamamoto *et al.*, Rev. Sci. Instrum. **86**, 083901 (2015)