MERIT report for long term overseas stay

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Duration of stay: 2019/01/15~2019/07/15

- Overview

I stayed in University of Basel for 6 months in order to do collaborative work with Prof. Daniel Loss. In this report, I would like to give a brief summary of my stay and the research projects.

- Background

When I started a PhD course, I decided to work on the theory of spin waves in magnetic materials as a completely new research theme. Spin wave (magnon) is a propagation of small deviations from classical ground states in magnetic materials. My research interest lies in the combination of magnons and Floquet engineering, which allows us to control a system externally by introducing the laser field. The idea of Floquet engineering has been applied to many other systems, such as electrons, cold atoms, spins and so on. There are also several attempts on magnonic systems, but it is a rather new topic and there were not so many groups working on this field. Fortunately, Prof. Loss's group works on magnons and Floquet theory in electronic systems. Thus, I thought that it was an ideal place to start a new project and Prof. Ogata kindly introduced me to Prof. Loss. I was able to receive a financial support from "Young researcher's exchange program between Japan and Switzerland".

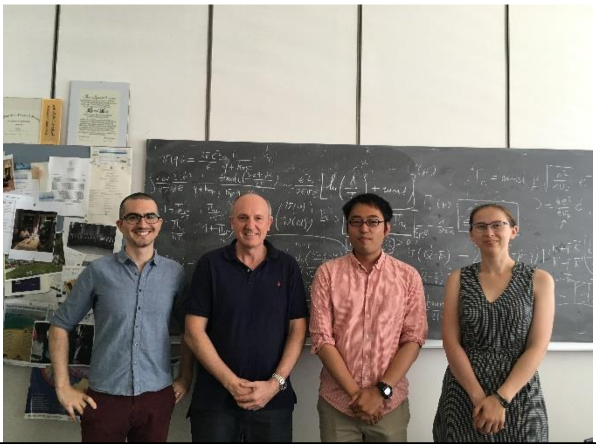

Photo 1 ：They are my collaborators. From left, Sebastian (postdoc), Prof. Loss, me, Prof. Klinovaja.

- Research

I studied magnon excitation in skyrmion lattice under a static magnetic field, followed by the study of Floquet magnons with laser fields. Skyrmion is a vortex realized in magnets (Fig 1). There are many technological advantages in skyrmions. One important property is the stability due to the topological protection. It is also possible to manipulate them using electric currents and creates them by short pulses of laser. Instead of single skyrmions, I focused on a periodic structure formed by skyrmions in thin films, known as skyrmion lattice.

Firstly, I learned how to obtain magnon spectrum in skyrmion lattice. Skyrmion lattice has a long periodicity in comparison to other spin systems. In Cu_2OSeO_3, the size of skyrmion was found to be as large as 50 nm or larger [1]. For such a complex and large periodic system, we need a classical Monte Carlo simulation for each magnon band rather than assuming a particular classical ground state. Supervised by Sebastian, I investigated the properties of skyrmion lattice under a static magnetic field. Initially, I regarded this process as a preparation for Floquet magnons, but I was fortunately able to obtain interesting results. I am hoping to present them in future publication.

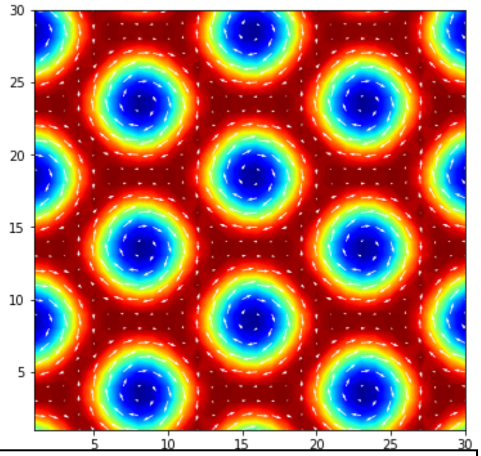

Figure 1 ：It shows spin textures of skyrmion lattice. White arrows indicate the direction of spins in xy-plane and the color plot shows the z-component of spins.

After learning about magnons in skyrmion lattice, I started to work on Floquet magnons generated by lasers. While this project is not finished yet, I think that important theoretical foundations were made during my stay in University of Basel. The advantage of our approach is that we can incorporate the time-dependence of magnetic unit cell under time-periodic field. In order to find the time-dependence of magnetic unit cell, we made use of the multiferroics of Cu_2OSeO_3 [2]. Since there are still several unresolved issues, I will keep work on this project in Japan with communicating my collaborators in Basel.

Photo 2 : Basler Fasnacht in March.

● Acknowledgement

Through a 6-month stay in Basel, I was able to learn many things about my research theme. In addition, it was a great experience to work with international people. Lastly, I would like to thank for support from members of Prof. Loss's group, Prof. Loss and Prof. Klinovaja, Prof. Ogata and MERIT.

● Reference

[1] S. Seki *et al.*, Science **336**, 198 (2012). [2] Seki, et al. PRB **86**, 060403 (2012)