

実験報告書様式(一般利用課題・成果公開利用)

(※本報告書は英語で記述してください。ただし、産業利用課題として採択されている方は日本語で記述していただいても結構です。)

 <p><b>Experimental Report</b></p>	承認日 Date of Approval 承認者 Approver 提出日 Date of Report
課題番号 Project No. 2017A0155 実験課題名 Title of experiment A polarized small angle neutron scattering study on a square skyrmion lattice phase in MnSi 実験責任者名 Name of principal investigator Taro Nakajima 所属 Affiliation RIKEN Center for Emergent Matter Science	装置責任者 Name of Instrument scientist Kazuki Ohishi 装置名 Name of Instrument/(BL No.) TAIKAN (BL15) 実施日 Date of Experiment 30 <sup>th</sup> Oct to 4 <sup>th</sup> Nov. 2017.

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。(適宜、図表添付のこと)  
 Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.
Manganese Silicide : MnSi (solid, single-crystal)

2. 実験方法及び結果 (実験がうまくいかなかった場合、その理由を記述してください。)
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.
<p>A metallic helimagnet MnSi exhibits magnetic skyrmion state, which is a topologically-nontrivial vortex-like magnetic order. These vortices are often arranged to form a triangular lattice, which can be observed as a hexagonal scattering pattern in small angle neutron scattering (SANS). In recent years, the magnetic skyrmions have attracted considerable attention because they can show unconventional coupling with conduction electrons (for example, topological Hall effect), and can be controlled by a variety of external stimuli, such as electric current, thermal gradient, laser pulse application and so on. However, in the H-T magnetic phase diagram of MnSi, the skyrmion lattice (SkL) appears only in a very narrow temperature and magnetic field window just below the transition temperature <math>T_c=29</math> K.</p> <p>Recently, Oike et al. have reported that the SkL state can be quenched to low temperatures, and can survive as a metastable SkL state at low temperature. Specifically, they applied an electric current pulse at a low temperature under magnetic field of 0.2 T. The sample was rapidly heated above the transition temperature because of the Joule heating, and then it was cooled to the base temperature passing through the equilibrium SkL state within a few seconds. Upon this rapid cooling, the phase transition from the SkL state to the conical state, which is the original ground state at low temperatures, was kinetically avoided. Finally, the metastable</p>

## 2. 実験方法及び結果(つづき) Experimental method and results (continued)

SKL state is realized at low temperatures.

Quite recently, we discovered that the metastable SkL state, which still has a triangular lattice form under magnetic field, turns into a square SkL state by removing magnetic field at 1.5 K. The original purpose of the present study was to observe polarized SANS pattern in the square lattice state. However, it was turned out that the maximum field of the horizontal-field electromagnet of BL15 was about 0.17 T, that is not enough to provide access to the metastable SkL state. Therefore, we had to change the experimental plan.

Instead of polarized SANS measurements, we performed stroboscopic SANS measurements on MnSi under application of pulsed electric currents, in order to elucidate ordering kinetics of the magnetic skyrmions during quenching. We consulted Dr. Inamura and Dr. Ito about frame-by-frame data acquisition of the neutron scattering data, and conducted pump-and-probe-like SANS experiment described as follows:

Figure 1(a) shows a picture of the sample. We have attached four electrodes, and the electric current pulse was applied through two of them (two thick wires attached on top and bottom). The electric current pulse was triggered by a kicker signal of MLF, and repeated with a frequency of 0.1 Hz (see Fig. 1(b)). Neutron scattering signals were recorded and divided into 250 frames, which correspond to stroboscopic picture with time interval of 40 ms. We repeated the application of the current pulse for about 1000 times, and accumulated the neutron signals for each frame. Note that we restricted neutron wavelength to 4–7.7 Å using UTSUSEMI software, to have a good Q-resolution. Taking into account the source-to-detector distance at TAIKAN, one neutron pulse passed through the sample within about 12 ms. This means that there is some dead time between two pulses. Therefore, we introduced delay times between MLF kicker and electric current pulse, and minimized the dead time.

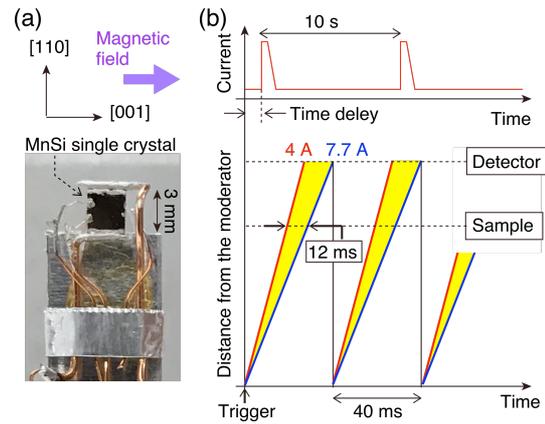


Fig. 1: (a) A picture of MnSi sample. (b) A schematic diagram showing the relationship between neutron TOF and the electric current pulse.

Typical results of the stroboscopic measurements are shown in Fig. 2. We successfully observed temporal changes of SANS patterns with a time resolution of about 10 ms. We are now working on further data analysis to elucidate time/temperature dependence of Q, intensity and widths of the Bragg peaks during the quenching process.

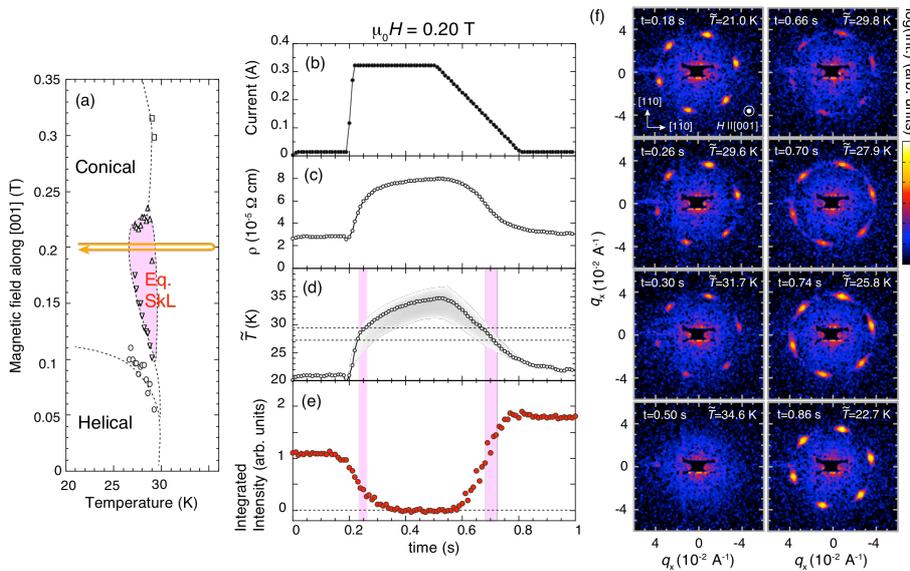


Fig. 2: Typical results of the stroboscopic SANS measurements on MnSi under magnetic field of 0.2 T.