Experimental report

10/09/2019

Proposal: **4-01-1584** **Council:** 4/2018

Title: Low Energy Excitations of SkyrmionLattice in Mn1-xCoxSi

Research area: Physics

This proposal is a new proposal

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Samples: Mn1-xCoxSi x=0, 0.02

Instrument	Requested days	Allocated days	From	To
IN15	7	7	17/10/2018	24/10/2018
			24/10/2018	28/10/2018

Abstract:

Topological spin textures have been extensively investigated both experimentally and theoretically. Among them, a vortex-like spin-swirling texture of so-called magnetic skyrmions has attracted much attention. A helimagnet MnSi possesses a magnetic skyrmion phase in a small magnetic field and temperature region. However, the dynamics of magnetic skyrmions has not been clear because inelastic neutron scattering measurements with an energy scale of 1~5 μeV in a small q region is not easy. Recently, a theoretical study on the magnetic skyrmions has been carried out and then not only the difference between the magnetic dispersions for the helical and skyrmion structures but also the different q dependence of magnetic excitations have been predicted.

For Mn1-xCoxSi (x=0 and/or 0.02), an energy scale and a Q range of interest are about 0.1~50 μeV and 0.02<Q< 0.1 A-1, respectively, and q resolution of necessity is an order of ~0.01 A-1. IN15 allows us to search such (q,E) region. Therefore, to clarify the asymmetric dispersion of the magnetic skyrmion dynamics of Mn1-xCoxSi, we would like to propose inelastic measurements at IN15.

Low Energy Excitations of Skyrmion Lattice in MnSi

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Introduction

Topological spin textures have attracted great attention both experimentally and theoretically. Among them, the vortex-like spin-swirling texture of magnetic skyrmions has attracted much attention [1]. Since the magnetic skyrmions in MnSi have a long periodicity (~18 nm), the structure has been examined using small angle neutron scattering (SANS) in momentum space and Lorentz Transmission Electron Microscope (LTEM) techniques in real space. On the other hand, the dynamics of the magnetic skyrmion lattice has not been clear because an inelastic neutron scattering measurement in which the dynamic structure factor $S(q,\omega)$ can be estimated is not easy with an energy scale of μeV in a small q region.

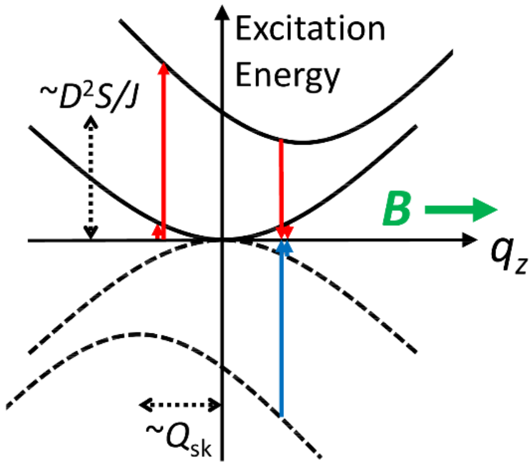

Fig. 1 Schematic dispersion curves of the magnetic skyrmion lattice. The red arrows show the two processes giving momentum $+q_z$ to a neutron.

A theoretical study of magnetic skyrmion dynamics has been carried out by our collaborators [2]. Figure 1 shows schematic dispersion curves for propagation vector (q_z) parallel to the magnetic field (z-axis), which is the direction of the skyrmion strings. A different q dependence of the magnetic excitations along $+q_z$ and $-q_z$ is predicted. The purpose of our experiment is to confirm the predicted asymmetry of the dynamics of the skyrmion phase.

Fig. 2 Aligned MnSi single crystals.

Experimental Details

We have carried out the inelastic measurements on IN15 in MnSi by the ferromagnetic spin-echo technique. We prepared the aligned MnSi single crystals, as shown in Fig. 2. The MnSi single crystals were set with the [1 1 0] axis vertical in a cryostat with a magnet, as shown in Fig. 3. Incident neutrons with wavelength λ=6 Å were used. In the skyrmion phase, we rotated the sample around the vertical axis until one of the Bragg reflections from the skyrmion lattice appeared on the horizontal axis of the 2D detector. The spin-echo measurements were performed after cooling in a field B = ±0.17 T, and those performed in the skyrmion phase were carried out at 28.4 K. Background data were also taken at 70K.

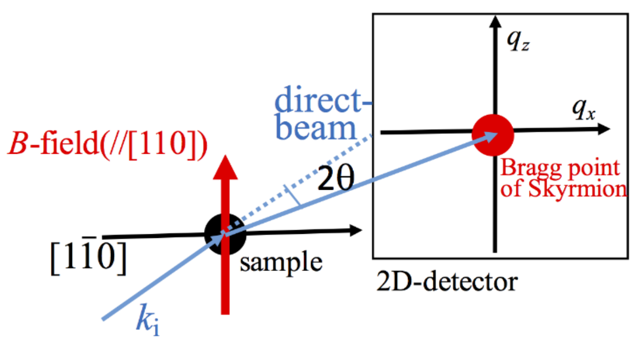

Fig. 3 Experimental set up.

Results

We carried out neutron spin-echo measurements at 28.4 K and 70 K with the field at the sample either + 0.17 T (Field Up) or - 0.17 T (Field Down). A large phase-shift in the spin-echo-signal has been observed in the skyrmion phase, as shown in Fig. 4. The value of the phase shift was reversed on changing the magnetic field direction. Figure 5 shows the average energy transfer estimated from the phase shifts as a function of q_z along the magnetic field direction in the skyrmion phase. The phase shift of the spin-echo profile is expected to correspond to the average of the gain and loss energies shown in Fig. 1. Our results mean that the skyrmion has an asymmetric dispersion, which is predicted to arise as a topological effect of the Berry phase of the skyrmions. Furthermore, the asymmetric dispersion becomes opposite on changing the magnetic field direction.

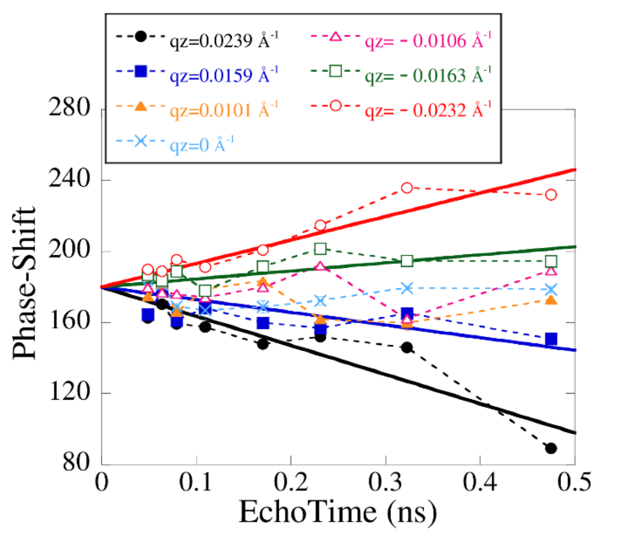

Fig. 4 The phase shift of the spin-echo profiles in the skyrmion phase as a function of echo time.

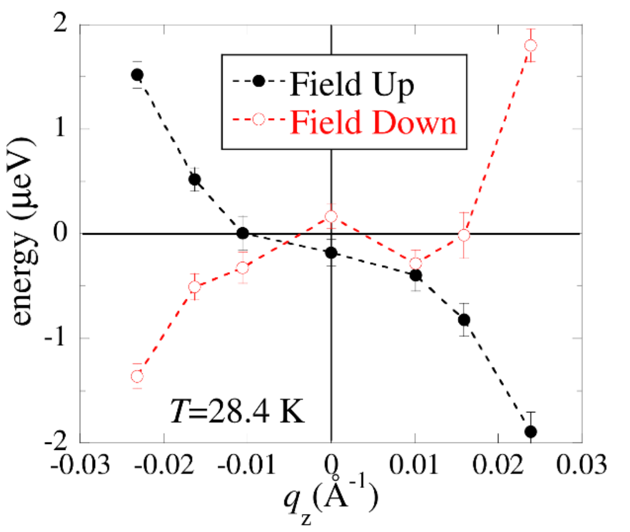

Fig. 5 Energy transfer as a function of q_z, estimated from the phase shift in the skyrmion phase.

We clarified the asymmetric dispersion of excitations along the strings of a skyrmion lattice by using the neutron spin echo technique. The dispersion is different for *q*-vectors parallel and antiparallel to the magnetic field direction. Our results have been written up for publication [3] and are in the final stages of discussion between the authors. According to theory [4], the asymmetric dispersion should be realized only in the skyrmion phase. Therefore, we need to carry out an additional spin-echo experiment in another magnetic phase in the future.

References:

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