Experimental report

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Proposal: **4-01-1649** **Council:** 10/2019

Title: Magnon dispersion and polarisatin determination of a Dresselhaus magnet

Research area: Physics

This proposal is a new proposal

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Samples: Ba2MnGe2O7
Sr2MnSi2O7

Instrument	Requested days	Allocated days	From	To
THALES	8	5	12/05/2021	17/05/2021

Abstract:

Antiferromagnetic spintronics has attracted considerable attention recently reflecting several advantages over ferromagnets. Whereas a practical implementation of it is missing, several potential avenues towards future applications remain unexplored. A new theory has been recently proposed for insulating magnets. It predicts a rich spin texture arising from a specific combination of Dzyaloshinskii-Moriya interaction, magnetic anisotropy and an application of magnetic fields. Whereas the effects on the magnon dispersion due to broken spatial inversion symmetry have been observed in several noncentrosymmetric magnets, resultant spin texture stabilized by such a specific combination in the theory has so far eluded experimental observation. We have got interested in the 2D Dresselhaus antiferromagnet Ba2MnGe2O7 which can likely be a model compound for a critical test of the theory. We thus aim for understanding and studying magnon dispersion and polarization/handedness through observing the chiral term and propose a full polarization analysis inelastic scattering experiment on Ba2MnGe2O7 using ThALES.

Magnon dispersion and polarisatin determination of a Dresselhaus magnet
(4-01-1649)

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Antiferromagnetic spintronics has attracted much attention recently, since antiferromagnets have several advantages over ferromagnets for future applications like memory storage devices [1]. Antiferromagnets produce no stray fields, leading to robustness against external perturbations. Access speed in memory for writing and erasing—if achieved—is generally limited by the resonance frequency, which for antiferromagnets can be much higher than ferromagnets. While a practical implementation of antiferromagnetic spintronics is missing, several potential avenues towards this goal remain unexplored.

Quite recently, a new theory has been proposed for insulating antiferromagnetic spintronics [2]. The Rashba and Dresselhaus spin-orbit coupling in a metal combines the spin and motional degrees of freedom of electrons, resulting in a spin texture. In insulators, where the motional degree of freedom is quenched, the spin degree of freedom remains, and spin current can be carried by the collective motion of spin waves (quantised magnon) on momentum space The ordered moments in antiferromagnets are associated with a two-fold degeneracy in the magnon polarisations (precession motion direction of the magnetic moment) [3] that serve as internal degrees of freedom analogous to electron spins. The Dzyaloshinskii–Moriya (DM) interaction in the spatial inversion symmetry broken system couples these two magnon degrees of freedom as a function of the magnon momentum, i.e. spin-momentum locking, giving rise to a rich spin texture even in insulators. To experimentally observe such a texture, we performed an inelastic neutron scattering measurement on a model compound under magnetic fields, using the cold neutron triple-axis spectrometer ThALES.

As the target compound, we adopt the noncentrosymmetric antiferromagnet $Sr_2MnSi_2O_7$ (space group: P -4 2_1 m) with $S = 5/2$ [4]. The compound is known to be a 2D Dresselhaus antiferromagnet, and shows a transition at T_N = 3.4 K into an easy-plane type antiferromagnetic phase. Prior to this experiment, we have refined the magnetic structure through powder neutron diffraction, based upon the irreducible representation and magnetic space group analyses. The refined magnetic structure is depicted in Fig. 1(a).

Also, we conducted a zero-field inelastic study to estimate the superexchange interactions using BL14 AMATERAS at J-PARC. Figure 1(b) shows representative magnon dispersions together with our linear spin-wave calculation. The prime interaction in $Sr_2MnSi_2O_7$ is estimated to be J_1 = 23 μeV, which facilitates controlling the magnon dispersion relation with a few Tesla of the magnetic field.

An optical image of our high-quality single-crystal sample for the experiment oriented with [HK0] zone in the scattering plane, is shown in Fig. 1(c). The sample was mounted in the horizontal field cryomagnet, and a magnetic field (*H*) of 2.2 T within the *ab*-plane was applied. To examine textures in separate combinations of the DM interaction and the magnetic field direction, we pointed the field in [100], [110], and [1-10] directions. Figure 1(d) summarises results from accumulated grid scans with *H* // [100], and the magnon is clearly dispersing with increasing energy. We have mostly analysed experimental data and are now trying to compare it with numerical study to confirm the possible textures.

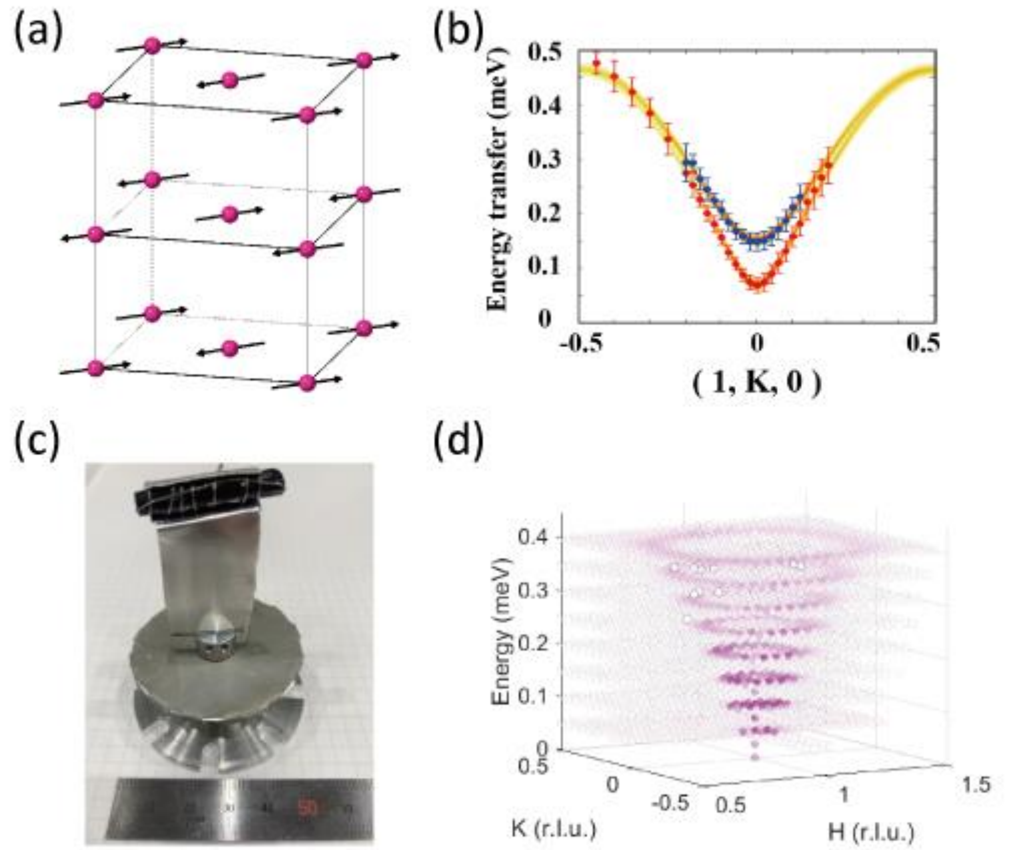

Fig. 1 (a) Magnetic structure, and (b) magnetic excitations in $Sr_2MnSi_2O_7$. (c) A single-crystalline sample used for the ThALES experiment, and (d) magnon dispersion relations from accumulated grid scans with the magnetic field parallel to the *a*-axis.

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[3] Y. Nambu *et al*., Phys. Rev. Lett. **125**, 207201 (2020).
[4] T. Endo *et al*., Inorg. Chem. **49**, 10809 (2010).