Experimental report

29/09/2016

Proposal: **4-01-1521** **Council:** 4/2016

Title: Resolving helimagnon excitations in the long-pitch helimagnetic insulator Cu2OSeO3

Research area: Physics

This proposal is a new proposal

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Samples: Cu2OSeO3

Instrument	Requested days	Allocated days	From	To
IN5	5	5	03/06/2016	09/06/2016

Abstract:

In the multiferroic Cu2OSeO3 system, the interplay of interatomic exchange and the Dzyaloshinskii-Moriya (DM) interactions leads to the formation of a spin-spiral ground state. An exotic skyrmion-lattice arrangement can be further stabilized by the application of magnetic field. Our recent time-of-flight (TOF) and triple-axis (TAS) neutron spectroscopy experiments revealed a complicated structure of magnetic excitations in Cu2OSeO3, confirming recent theoretical predictions. However, the long pitch of the spin spiral in its zero-field ground state makes high-resolution measurements necessary to resolve individual helimagnon branches. It is impossible with a conventional thermal-neutron spectrometer. Here we propose to employ the cold-neutron time-of-flight spectrometer IN5 with magnet to map out low-energy helimagnon excitations around the (000) wave vector.

Introduction

The long-pitch helimagnetic insulator Cu_2OSeO_3 is a good candidate to observe helimagnons [1] — recently proposed continuum-like dispersive bands, formed by low-energy excitations of a noncollinear spin spiral. In the follow up experiment at PUMA thermal triple axis spectrometer we have successfully mapped out dispersion of magnon branches along high symmetry directions at the low-energy region (Fig. 1). Near the Γ(222) point, a strong Goldstone mode was observed that presumably consisted of multiple unresolved helimagnon bands. Our goal was to resolve very closely spaced ($\Delta E \approx 10.5\,\mu$eV) individual helimagnon branches in Cu_2OSeO_3 using the cold-neutron time-of-flight spectrometer IN5 and to study their evolution with temperature across T_C.

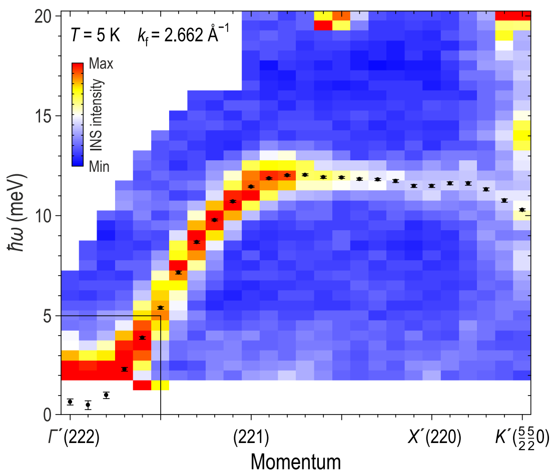

Fig. 1: Resolving helimagnon excitations in the long-pitch helimagnetic insulator Cu_2OSeO_3

Experimental configuration

We have used the same pre-aligned array of Cu_2OSeO_3 single crystals with the total mass of ~ 1 g, which we already used for PUMA experiment shown in Fig. 1. To reach the single-domain state the 2.5 T vertical magnet was used. We have mounted the sample in the cryomagnet with its $(1\bar{1}0)$ axis vertical, i.e. parallel to the direction of the magnetic field. The sample was cooled down to 1.5 K in the magnetic field of 0.07 Tesla. We performed measurements with the following wavelengths: 8.5, 6 and 4 Å.

As a backup sample we used co-aligned single crystal mosaic of $ZnCr_2Se_4$ with the total mass of ~ 1 g. The sample was mounted in such a way that its $(11\bar{2})$ axis was vertical. This sample was measured in the last days of the experiment after it was clear that we could not reach sufficient resolution to resolve the helimagnon bands in Cu_2OSeO_3. We cooled down the sample to the 1.5 K in a vertical magnetic field of 1.5 T to chose only one helimagnetic domain with propagation vector pointed along (001) direction. Measurements performed with 5 Å wavelength of the incoming beam.

Experimental results

Original sample Cu_2OSeO_3

First, we performed an overview scan around (000) point. However, we realized that the stiffness of the magnon was too high to reach it at low q, so we observed no signal in the vicinity of (000).

Next, we performed measurements around covering both the (111) and (222) Bragg peaks with the corresponding low-energy magnon bands (Fig. 2 b,c). In order to reach the (222) wave vector we had to reduce the wavelength of the incoming beam to 4 Å. We had no possibility to resolve helimagnon branches in this configuration, but we have obtained a high-resolution spectrum of the parabolic dispersion stemming from (222) and (111) Bragg peaks (Fig. 2b). As the next step, we increased the wavelength of the incoming beam to 6 Åto improve resolution without significantly sacrificing the intensity. In this configuration, we could reach only the (111) wave vector, where the magnon intensity is approximately twice weaker than at (222), but still sufficient to obtain a clear signal. We observed a gapless parabolic dispersion stemmed from (111) Bragg (Fig. 2d), again with no signatures of individual helimagnon branches at low energies.

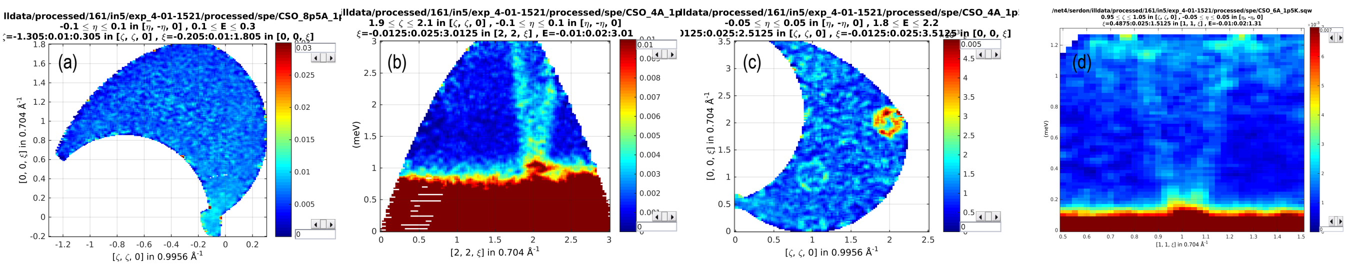

Fig. 2: Representative cuts for Cu_2OSeO_3.

Backup sample — $ZnCr_2Se_4$

As we were not able to resolve helimagnon branches in our initial sample, we decided to change the sample to another helimagnetic compound $ZnCr_2Se_4$. It is a magnetically frustrated spinel compound with an incommensurate ground state. At low temperatures it displays a spin-spiral structure propagating along the (100) direction.

We applied the magnetic field of 1.5 T vertically, along the $(11\bar{2})$ direction, to choose one helimagnetic domain with propagation vector pointed along (001) direction (Fig. 3a). We found that despite of the difference in the Bragg intensities, the magnon branches stemming from "allowed" and "forbidden" Bragg peaks have almost the same intensity (Fig. 3b,c,d).

This result was unexpected, but confirmed later using spin-dynamical calculations in the isotropic J_1-J_2-J_3-J_4 Heisenberg model. We have shown that the selection of a single helimagnetic domain does not suppress helimagnons propagating in directions orthogonal to the propagation vector of the spiral.

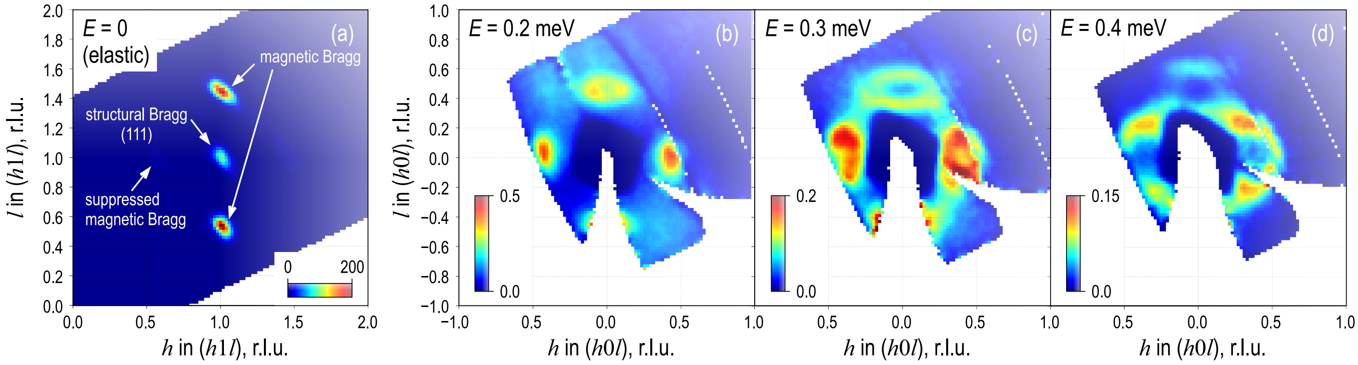

Fig. 3: Constant energy cuts for $ZnCr_2Se_4$.

[1] M. Janoschek *et al.*, PRB **81**, 214436 (2010).
[2] S. K. Choi *et al.*, PRL **108**, 127204 (2012).