Experimental report

21/07/2016

Proposal: **4-01-1429**

Council: 10/2014

Title: Magnetic Excitations in the Shastry-Sutherland Magnet Holmium Tetraboride

Research area: Physics

This proposal is a resubmission of 4-01-1400

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Samples: HoB4

Instrument	Requested days	Allocated days	From	To
IN5	6	6	21/07/2015	27/07/2015

Abstract:

We propose to investigate the magnetic excitations of HoB4 using IN5. Large single crystal samples of HoB4 have been prepared and characterised with magnetisation and specific heat measurements. Preliminary measurements of these samples using D10 and D7 at ILL have given some promising results. HoB4 shows a range of novel and unusual results believed to be due to the competition between the magnetic and quadrupolar interactions in this system, where the Ho ions form a lattice which is topologically equivalent to the Shastry-Sutherland lattice. This proposal is for the measurements in zero applied field. If successful we will extend them to investigate the nature of very intriguing field induced phases associated with the magnetisation pleateaux

The rare earth borides have garnered a great deal of attention for the diverse range interesting and unusual properties, ranging from various magnetic phase transitions, heavy fermion behaviour, mixed valence phenomena to superconductivity [1]. In recent years the rare earth tetraborides $R\mathrm{B}_4$ have been investigated extensively. $R\mathrm{B}_4$ is a rare experimental realisation of the Shastry-Sutherland lattice (SSL) [2]. $R\mathrm{B}_4$ crystallises into a tetragonal structure, where the R ions form a network of squares and equilateral triangles in the basal plane which topologically maps to the SSL [2]. It been suggested the competition between the magnetic and quadrupolar interactions is crucial to establishing a ground state, giving rise to a variety of properties observed in this family [3]. These properties include fractional magnetisation features [4], diverse phase diagrams in relatively small fields [5] and a plethora of magnetic structures [6, 7].

HoB_4 shows successive phase transitions at T_{N1} = 7.1 K and T_{N2} = 5.6 K [8]. The zero field structure has been investigated in detail by neutron and X-ray diffraction [3]. Between $T_{\mathrm{N2}} < T < T_{\mathrm{N1}}$ an incommensurate order is formed with **q** = $(\delta, \delta, \delta')$, where δ = 0.022 and δ' = 0.43. The low temperature phase, below T_{N2}, an ordered commensurate antiferromagnetic phase is formed.

We have carried out single crystal neutron scattering experiment on IN5 in order to look for and investigate any low lying magnetic excitations in HoB_4. Large single crystals of HoB_4 have been grown at Warwick using the floating zone technique. Isotopically enriched boron, $^{11}\mathrm{B}$ was used to reduce absorption of neutrons. The crystal was aligned and glued so that the [0K0] direction was vertical defining the horizontal $h0l$ scattering plane. We primarily investigated three temperatures (10, 6 and 1.6 K), allowing study of the paramagnetic regime and the two magnetic states. Two energies, $E_i =$ 3.3 and 6.8 meV, were used throughout the experiment. Fig. 1 shows the energy spectrum along the [H00] direction. As can be seen there are two dispersive bands of excitations. The higher energy band is most likely a low lying crystal field and was observed in a previous experiment (Expt No. 4-01-1457). There is a slight increase in intensity of the low energy band cooling from 10 to 6 K. Interestingly cooling down to 1.6 K we seen the excitation become gapped suggesting Ising anisotropy.

In order to investigate the low energy excitation we used a smaller incident energy ($E_i =$ 3.3 meV) and looked at the energy spectrum along the [00L] direction. As can be seen in Fig. 2, the excitation is gapless in the incommensurate phase and there is "pronged" structure which comes down to the incommensurate reflections in the elastic line. Increasing the temperature from 6 to 35 K, we see the excitation becomes gapped and the intensity decreases. The "prongs" are no longer visible from 20 K.

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[4] S. Matas *et al.*, J. Phys.: Conf. Series **200** (2010) 032041
[5] R. Watanuki *et al.* Physica B **378-380** (2006) 594
[6] K. Semensmeyer *et al.* Phys. Rev. Lett. **101** (2008) 177201
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[8] J. Y. Kim, B. K. Cho, and S. H. Han, J. Appl. Phys. **105** (2009) 07E116

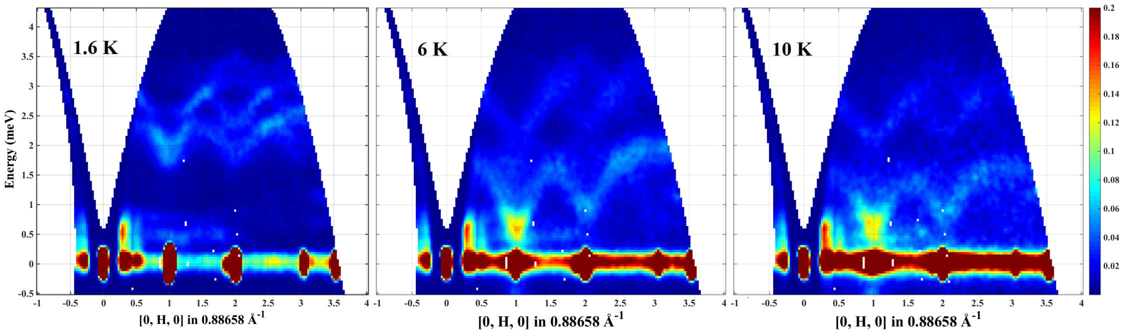

Figure 1: Intensity maps of the energy spectrum along the [H00] direction for 1.6, 6 and 10 K obtained using an incident energy of E_i = 6.8 meV.

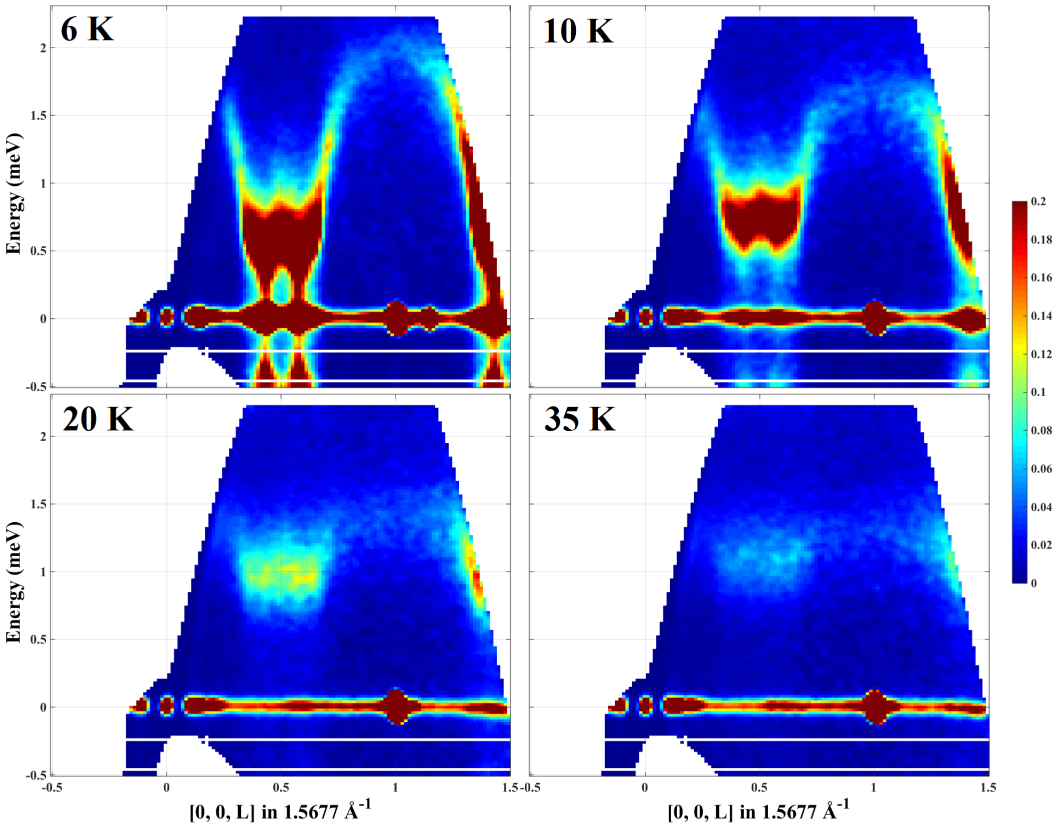

Figure 2: Intensity maps of the energy spectrum along the [00L] direction for 6, 10, 20 and 35 K obtained using an incident energy of E_i = 3.3 meV.