Experimental report

12/10/2018

Proposal: **CRG-2500** **Council:** 4/2018

Title: Magnetic lattice dynamics in HoFeO3

Research area: Physics

This proposal is a new proposal

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Samples: HoFeO3

Instrument	Requested days	Allocated days	From	To
IN20	6	6		
IN12	6	6	05/09/2018	11/09/2018

Abstract:

Rare-earth orthoferrites $RFeO_3$ represent interesting and important family of magnetic compounds. Their crystal and magnetic structures were studied by the neutron powder diffraction technique several decades ago.

Recently, interest to this family has been greatly renewed because of discovery of their multiferroic properties in some compounds of $RFeO_3$ series with R = Dy, Gd and Sm. There is an indication that Dzyaloshinsky-Moria interaction is responsible for the emergence of ferroelectricity in $RFeO_3$ at relatively high temperatures (above T_{sr} ~ 50-60 K).

Therefore, more precise and detailed studies of crystal and magnetic properties of the $RFeO_3$ compounds are essential in complex studies of coupling between the magnetic and ferroelectric order parameters in multiferroic materials. In this regard, knowledge of the magnetic exchange interaction parameters is of great importance.

We propose the inelastic neutron scattering measurements on IN12 spectrometer in order to determine the parameters of Heisenberg exchange and Dzyaloshinsky-Moria interactions in single crystal $HoFeO_3$.

At the first stage of the experiment, the orientation of the crystal and the parameters of the unit cell were refined at the temperature 65 K. The obtained structure corresponds to space group Pbnm with cell parameters a = 5.302 Å, b = 5.598 Å, c = 7.623 Å.

Then the measurements of the inelastic scattering were performed. They include series of scans along *h* and *l* directions in the reciprocal space. Scans were made in the vicinity of node q = [1 0 1] along *h* direction in the range from q = [0 0 1] to q = [2 0 1] and along *l* direction from q = [1 0 0] to q = [1 0 2]. During the experiment we used the scans in "constant-q" mode, where the measurements were made in the energy range 0 - 7 meV with the energy step $\Delta E = 0.1$ meV along the scan. These scans were repeated along *h* or *l* with the step Δh, $\Delta l = 0.2$ rlu. In this way we obtained a maps of the intensity, reflecting different kinds of inelastic scattering. For a more accurate determination of the energy gaps, some of the measurements were made with better energy resolution $\Delta E = 0.05$ meV.

Measurements were performed at the following temperatures T=2.5, 15, 35 and 65K, which correspond to different phases of magnetic alignment. At 4 K a large gap in the magnon spectra $\Delta \approx$ 4 meV is observed (see Fig. 1(a)), which indicates an easy-axis character of the dominating anisotropy constant at low temperature. Figures 1 (b) and (c) shows the measured maps for directions (h 0 1) at 2.5K and 35K respectively. Sets of points below 1.0 meV, which represents weak dispersion most probably correspond to the splitting of ground state energy level of Ho^{3+} and the dispersion curve of the Ho-sublattice. According to data obtained in works on absorption spectroscopy [1, 2] the energy levels of Ho^{3+} show splitting of 0.88 meV at T=20K, which decreases to 0.6 meV when extrapolated to 0 K. On the other hand, as the temperature decreases, the magnetic moment of Ho^{3+} increases and, therefore, the energy of the dispersion curve of the Ho-sublattice increases also. This situation is observed on the measured maps and our models, where at the 35K the dots around 0.9 meV correspond to the energy splitting of the groundstate level of Ho^{3+} and dots around 0.5 meV is the dispersion curve of Ho-sublattice (Fig. 1(b)). At a temperature 2.5K the dispersion curve of Ho-sublattice goes higher – to ~ 0.7 meV and the dots around 0.6 meV correspond to the splitting of the groundstate of Ho^{3+} (Fig. 1(c)). Such values of the splittings and the energies of the dispersion curves are in good agreement with our calculations (Fig. 1(d)).

At the same time at temperatures T=65K and 35K, we observe scattering around 4.5 meV (Fig.1b) which do not correspond to the energy levels obtained in the works [1, 2] and they cannot be described by dispersion curves obtained with reasonable exchange parameters. At the temperatures T=15K, 2.5K these scattering was not observed. This experimental result should be considered and discussed later on.

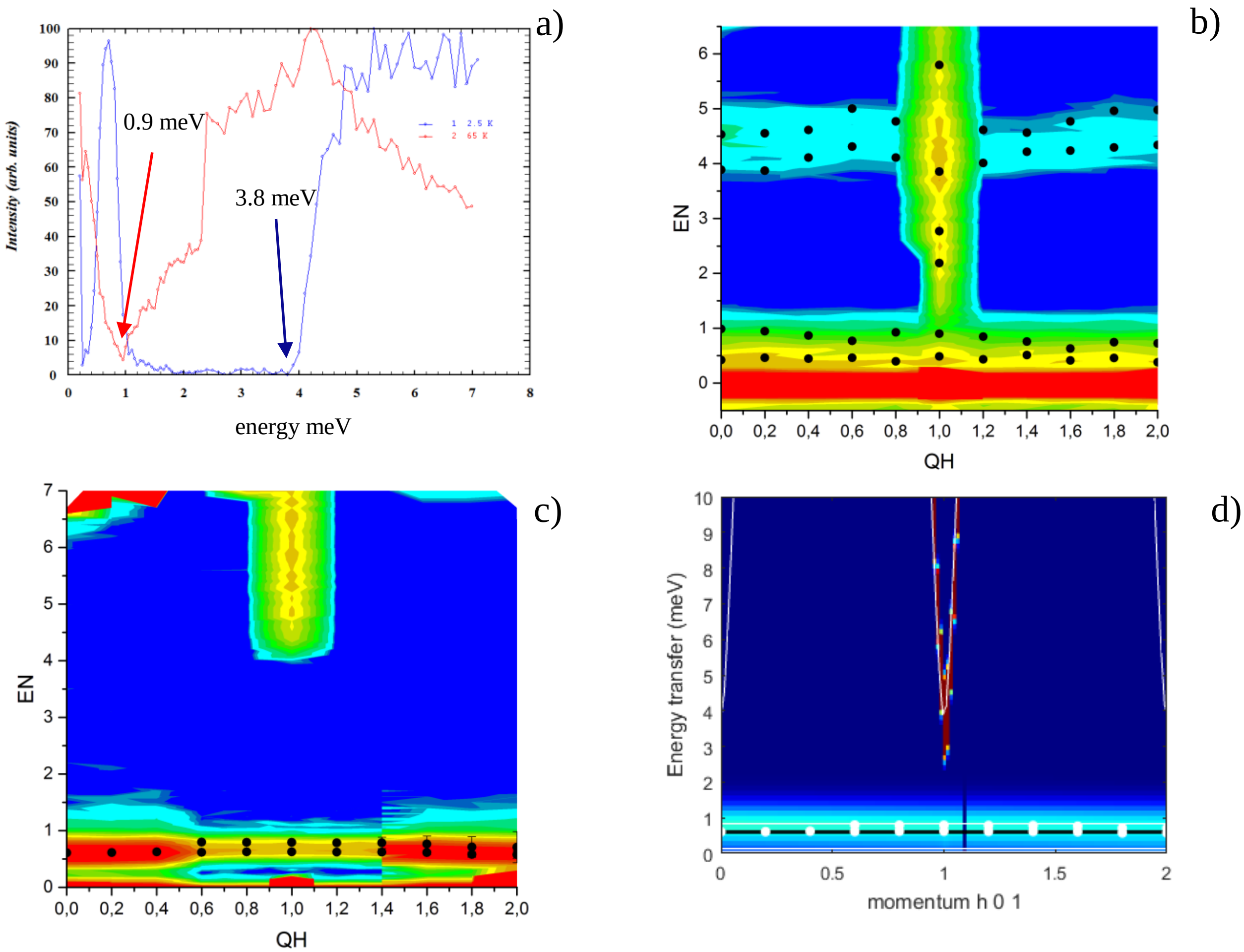

Figure 1. (a) Energy cuts at *q* = (101), taken at *T* = 2.5 – blue line and 65 K – red line to show the gap in the excitation spectrum of Fe3+ magnons. (b) and (c) Measured spin wave dispersion along (*h* 0 1) at *T* = 35K and 2.5K respectively. Dots - positions of inelastic peaks. (d) Calculated spin wave dispersion along (h 0 1) at *T* = 2.5K. The white line is the calculated dispersion curve. Black line - energy level of Ho.

References

[1] Schuchert, H., Hüfner, S. & Faulhaber, R. Z. Physik (1969)

[2] Optical-absorption Zeeman spectroscopy of HoFeO3 John C. Walling and Robert L. White Phys. Rev. B 10, 4737 – (1974)