Experimental report

05/10/2018

Proposal: CRG-2565 **Council:** 4/2018

Title: Magnetic lattice dynamics in HoFeO3 - continuation

Research area: Physics

This proposal is a new proposal

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Samples: HoFeO3

Instrument	Requested days	Allocated days	From	To
IN20	0	6	11/09/2018	17/09/2018
IN22	6	0		

Abstract:

This experiment is the continuation of the granted one at IN12 spectrometer (# CRG 2500). We propose to broaden the transfer energy range at IN22 spectrometer to higher energies than at IN12 in order to obtain more complete measurements of dispersion spectrum, which will permit more explicit determination of the parameters of exchange and Dzyaloshinsky-Moria interactions. For this purpose we plan to experimentally determine the spectrum along the [H 0 0] direction centered at Q = (0 1 1) in the energy range 0~80 meV at base temperature (4 K). If time permits, we would also get additional information from temperature dependence measurements (25 K, 50 K). Therefore, we request for 6 days of beam time. The proposal is a part of the submitted joint German–Russian DFG project.

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* = [3 0 5] along *h* direction in the range from *q* = [1 0 5] to *q* = [3 0 5] and along *l* direction from *q* = [3 0 3] to *q* = [3 0 5]. We used the scans in "constant-q" mode, where the measurements were made in the energy range 7- 75 meV with the energy step ΔE = 1 meV along the scan. These scans were repeated along *h* or *l* with the step Δ*h*, Δ*l* = 0.1 rlu. In this way we obtained a maps of the intensity, reflecting different kinds of inelastic scattering.

First temperature of measurements was 65 K. At this temperature ordered magnetic moment on Ho subsystem is zero. On the resulting maps one can see the sets of points forming the dispersion curves reaching maximum at ~ 65 meV, which corresponds to the magnon excitations in Fe-sublattice (Figure 1). Dispersionless sets of points at 10 meV, 15 meV, 20 meV, 45 meV obviously correspond to the crystal field levels. In this case, the Hamiltonian of the system can be written as:

$$H_{Fe-Fe} = J_{Fe-Fe}\sum_{ij} S_i S_j + D_{Fe}\sum_{ij} S_i \times S_j + A_{Fe}\sum_{i} (S_i)^2$$

where J_{Fe-Fe} is an exchange interaction parameters, D_{Fe} – asymmetrical Dzyaloshinskii-Moriya (DM) exchange and A_{Fe} is a diagonal 3 × 3 matrix describing the effective single-ion anisotropy of the Fe moments.

At Figure 1 the measured maps for directions (h 0 5) - a) and (3 0 l) - b) are shown as well as results of simulation – c) and d).

The initial treatment within frames of assumed Hamiltonian leads to the following values of exchange parameters: $J_{Fe-Fe} = 4.8$ meV, $D_{Fe} = 0.08$ meV, $A_x = 0.005$ meV and $A_z = 0.003$ meV. Such values are in good agreement with the well-known parameters of exchanges in the Fe - sublattice in other orthoferrites [1,2].

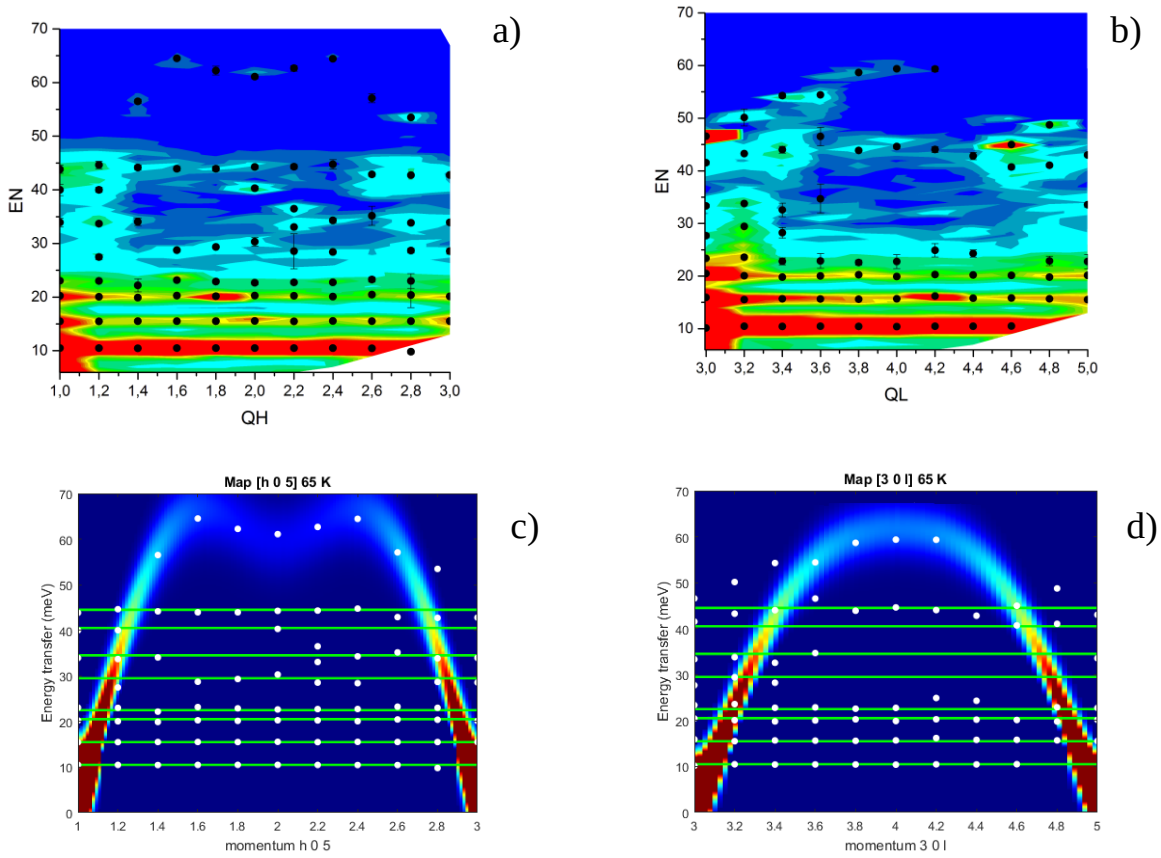

Figure 1. Measured spin wave dispersion along a) (*h* 0 5) and b) (3 0 *l*) and calculated spin wave dispersion along c) (h 0 5) and d) (3 0 l). Dots -positions of inelastic peaks. Green lines - energy levels of Ho.

In the last part of the experiment, we repeated measurements of the dispersion of spin waves at 2.5 K. At this temperature the magnetic moment of Ho $m_{Ho} = 8.6\,\mu_B$ which implies that dispersion curves corresponding to the Ho-sublattice oscillations should be clearly seen. In this case total system Hamiltonian can be written as $H = H_{Fe-Fe} + H_{Fe-Ho} + H_{Ho-Ho}$. However, during the measurements new excitations did not discover. This suggests that the dispersion curves are in the lower energy region.

References

1. S. E. Nikitin, L. S. Wu, A. S. Sefat, K. A. Shaykhutdinov, Z. Lu, S. Meng, E. V. Pomjakushina, K. Conder, G. Ehlers, M. D. Lumsden, A. I. Kolesnikov, S. Barilo, S. A. Guretskii, D. S. Inosov, and A. Podlesnyak. Decoupled spin dynamics in the rare-earth orthoferrite YbFeO3: Evolution of magnetic excitations through the spin-reorientation transition. Phys. Rev. B 98, 064424 (2018).

2. S. E. Hahn, A. A. Podlesnyak, G. Ehlers, G. E. Granroth, R. S. Fishman, A. I. Kolesnikov, E. Pomjakushina, and K. Conder. Inelastic neutron scattering studies of YFeO3. Phys. Rev. B 89, 014420 (2014).