Experimental report

20/01/2021

Proposal: **CRG-2695** **Council:** 10/2019

Title: Magnetic lattice dynamics in TbFeO3

Research area: Physics

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Samples: TbFeO3

Instrument	Requested days	Allocated days	From	To
IN12	6	5	25/08/2020	28/08/2020

Abstract:

The aim of the proposed work is to investigate the low-energy and high-energy spin wave excitations in TbFeO3 orthoferrite by means of inelastic neutron scattering. The studies will permit to obtain the parameters of the exchange interactions Fe3+ - Fe3+, Fe3+ - Tb3+, Tb3+ - Tb3+. The anisotropy parameters as well as the parameters of DMI also will be studied in the proposed experimental work. This will give valuable contribution to the elucidation of the microscopic mechanism(s) responsible for the emergence of ferroelectricity in RFeO3 orthoferrites family.
First, the measurements of low-energy spin excitations at IN12 spectrometer planned. For this purpose we plan to experimentally determine the spectrum along the [0 0 L] direction centred at (0 1 2) and along the [0 K 0] direction centred at Q = (0 2 3) in the energy range 0 ~ 10 meV at temperatures 15 K, 6 K, 2.5 K. For that, we request for 6 days of beam time at IN12 cold neutron spectrometer.

Crystal structure of TbFeO3 is described by space group Pnma (#62, Pbnm in another setting), Below T_N=650K Fe sublattice has antiferromagnetic order with the strongest component along c-axis, and weak ferromagnetic component along b axis. Compound have two spin-orientation transition at T_{sr1}=8.5K from the magnetic phase Γ4 to the phase Γ2 where moments of Fe^{3+} rotate in directed along b axis. At T_{sr2}=3.5K where the Fe magnetic moments return to phase Γ4 and Tb sublattice describe by magnetic representation Γ8. Tb order happens at temperature T_{NR}=3.3K [1].

At the beginning of the experiment, the crystal was oriented. Cell parameters a = 5.578 Å, b = 7.813 Å, c = 5.413 Å [1]. Then the measurements of the inelastic scattering were made. The scans were performed around node [0 0 1] along k direction, where k from 0 to 0.8 with step 0.1 at temperature T=2K. During the experiment we used the scans in "constant-q" mode, where the measurements of scan were made in the energy range 0 - 2 meV with the energy step ΔE = 0.05 meV along the scan.

At q = [0 0 1] the crystal field level is around E~0.75meV [2] and the peak corresponding to the magnon is around E~1meV (see fig 1.). Next, the magnon energy decreases. At q= [0 0.3 1] – [0 0.5 1], the energy of the magnon is close to the CEF and we hardly distinguish them. Then the magnon peak is close to the elastic peak and it can be difficult distinguished. This behavior is in agreement with our model of exchange interactions. Figure 2a shows the calculated energy map and dispersion curves. The exchange values inside the Tb sublattice are J=0.18(1). The appearance of this exchange interaction leads to a redistribution of the balance of exchange interactions. A phase transition occurs in the system, where Tb sublattice is described by irreducible magnetic representations Γ8 and Fe sublattice – Γ4.

In addition, the temperature dependence of the energy gap of Fe subsystems was measured in temperature range 2-10K (see fig. 2b). We may see the sharp increase in the energy of the gap after $T_N^{Tb} = 3.5K$. It shows the competition between energy of exchange interactions inside Tb sublattice and easy axis anisotropy of Fe ions.

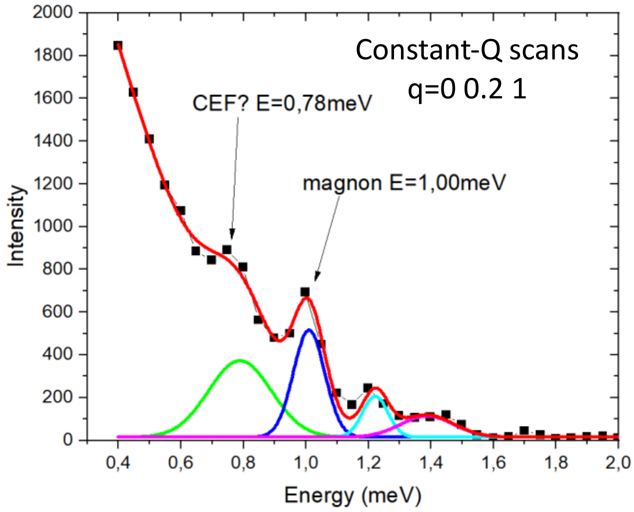

Figure 1. Constant-q scan at q=[0 0.2 1]. Black dots – measured intensity, red line – cumulative fit of peaks.

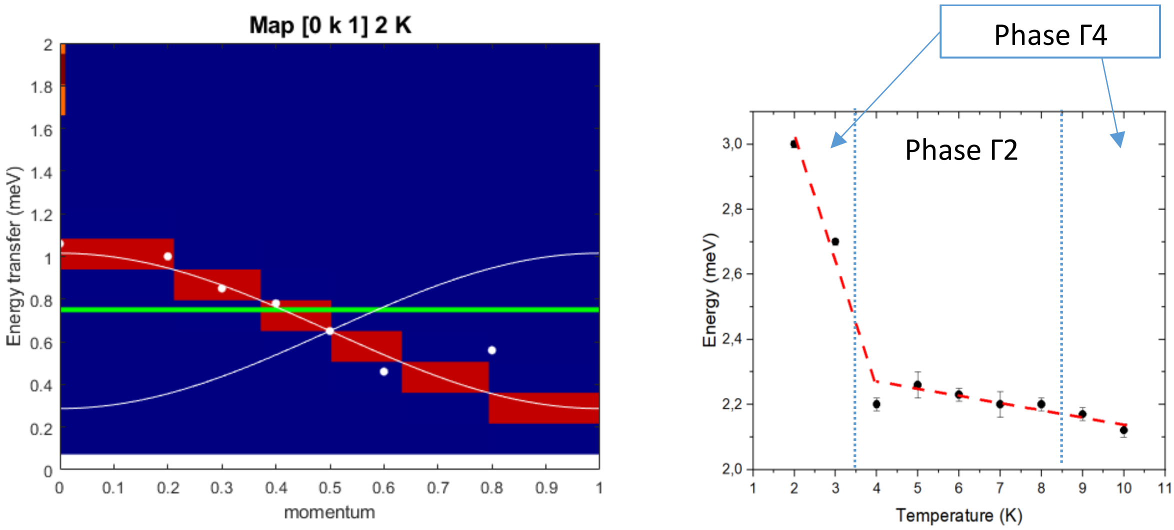

Figure 2. a) Model. White lines - dispersion curves, white dots - the position of the peak corresponding to the magnon, green – CEF, color – intensity. b) The temperature dependence of the energy gap of Fe subsystems. Red line – guide for the eyes.

References

1. Artyukhin, S., Mostovoy, M., Jensen, N. et al. Nature Mater 11, 694–699 (2012).

2. John C. Walling and Robert L. White Phys. Rev. B 10, 4737 (1974)