Experimental report

13/09/2024

Proposal: **5-41-1217**

Council: 4/2023

Title: Field induced magnetic state of the ¿Faraday-rotator¿ KTb3F10

Research area: Physics

This proposal is a new proposal

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Samples: KTb3F10

Instrument	Requested days	Allocated days	From	To
D23	7	7	28/08/2023	04/09/2023

Abstract:

In recent years, the study of the coupling between the 4f electronic density and lattice degrees of freedom has aroused a lot of attention. Such interactions are suspected to play a key role in a number of issues, ranging from highly frustrated magnetism to the design of smart materials in optics. Preliminary single-crystal neutron diffraction experiments performed on the Faraday rotator KTb3F10 have revealed a decrease of the intensity on several Bragg reflections in a magnetic field up to 2 T, anomaly which can be interpreted as originating from a magneto-elastic coupling. To confirm this hypothesis, we need a more comprehensive study of the evolution of the crystal structure of KTb3F10 in an applied magnetic field. This will also lead to a better description of the Tb3+ environment, which will be used for crystal electric field modellings. For this study, we would require the D23 diffractometer, working in the 2-300 K range, up to 6 T.

Experimental report on
Magneto-elastic coupling in the "Faraday-rotator" KTb_3F_{10}
@D23

Scientific context: As is well known for non-Kramers ions, the crystal-electric field (CEF) splits the (2J+1)-fold degenerate J-multiplet into a series of doublets but also singlets. The class of magnetic materials whose CEF ground state is *such a singlet*, like in KTb_3F_{10} is quite remarkable. Depending on the precise value of the gap to the excited states, the singlet state could be either well protected, or much more subtle, (so called "induced magnetism") [1 -8].

In KTb_3F_{10}, the Tb ions occupy the vertices of a network of corner-sharing octahedra (cubic *Fm*-3*m* space group, see Ref [7]). Its CEF scheme encompasses a singlet ground state |O> = |J=6, J_z=0 > and an excited doublet |±> = |J=6, J_z=±1> at about 2.7 meV. Importantly, the z quantification axis changes from site to site, being one of the cubic axes [2]. Our modelling of the CEF levels leads to the fact that any field induced magnetic moment appears within the plane perpendicular to this local z quantification axis. Depending on the site, this plane is perpendicular to the local *a*, *b* or *c* axis of the cell. This experiment was dedicated to carry out diffraction measurements on KTb_3F_{10} to study the induced magnetism. The magnetic field was applied along the [110] direction.

The D23 diffractometer was operated at the wavelength of λ = 1.28 Å. It was equipped with a 6T cryomagnet. A high-quality single crystal (5x5x5 mm^3, commercial, Northrop-Grumman) was oriented with [110] vertical, along the magnetic field direction.

We spent 6 days to record data collections at various magnetic fields and temperature, ranging from 0 to 4.5 T at 1.5 K. We also ramped the field on a series of reflections to obtain a continuous evolution of the induced magnetic structure.

Representative results are shown in Figure 1. The direction of the field splits make non-equivalent the terbium sites. Indeed, the terbium sites with their 4-fold axis orthogonal to the field (4-fold axis parallel to [001]) have to be distinguished from other sites. On the figure 1, M_0 represents the magnetic moment component parallel to the 4 fold axis for sites having their 4-fold axis with a non-zero projection on the magnetic field direction. M_1 is the magnetic moments component parallel to the magnetic field and orthogonal to the 4-fold axis of the Tb with their 4-fold axis either parallel to [100] or [010]. Finally, M_2 represents the magnetic moments component parallel to the field of the terbium sites with their 4-fold axis along [001].

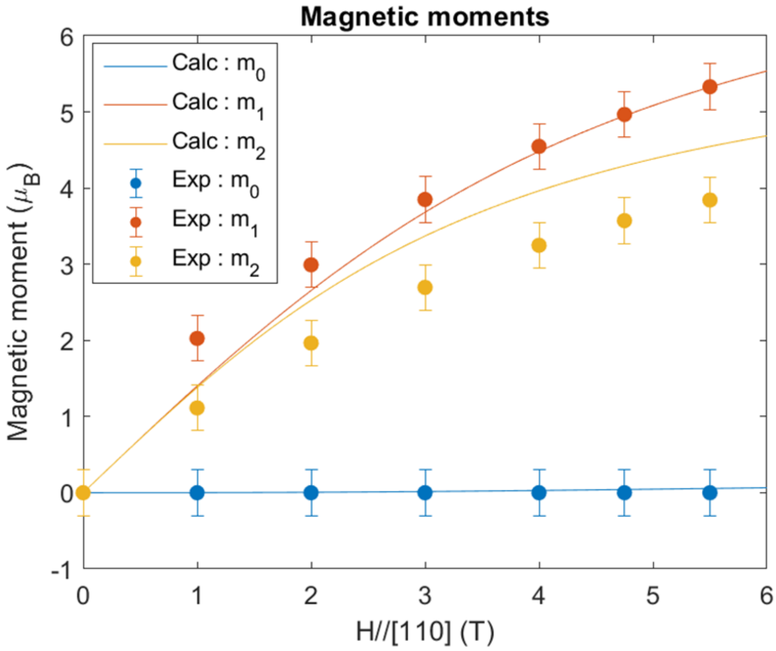

Figure 1 : Evolution of magnetic moments carried by magnetic ions.

[1] T. Fennell et al., Phys. Rev. Lett. **112**, 017203 (2014); S. Guitteny et al., Phys. Rev. Lett. **111**, 087201 (2013)

[2] L. Savary and L. Balents, Phys. Rev. Lett., **118**, 087203 (2017). O.Benton et al., Phys. Rev. Lett., **121**, 037203 (2018)

[3] N. Martin, et al., Phys. Rev. X, **7**, 041028 (2017).

[4] S. Petit et al., Phys. Rev. Research **3**, 013030 (2021)

[5] M. J. Weber et al., J. App. Phys. **49**, 3464 (1978).

[6] S. L. Chamberlain and L. R. Corruccini, Phys Rev B **71**, 024434 (2005)

[7] D. N. Karimov, et al., Crystals **11**, 285 (2021)

[8] M. Mujaji and J.P.R. Wells, J. Phys.: Condens. Matter **21** 255402 (2009)