Experimental report

10/09/2022

Proposal: **4-01-1710** **Council:** 10/2020

Title: Magneto-elastic coupling in $Tb_3Ga_5O_{12}$ garnet

Research area: Physics

This proposal is a new proposal

Main proposer: **Sylvain PETIT**

Experimental team: Francoise DAMAY
Sylvain PETIT

Local contacts: Alexandre IVANOV
Andrea PIOVANO

Samples: $Tb_3Ga_5O_{12}$
KTb_3F_{10}

Instrument	Requested days	Allocated days	From	To
IN3	1	2	14/06/2021	15/06/2021
			16/06/2021	17/06/2021
IN8	6	7	14/06/2021	21/06/2021

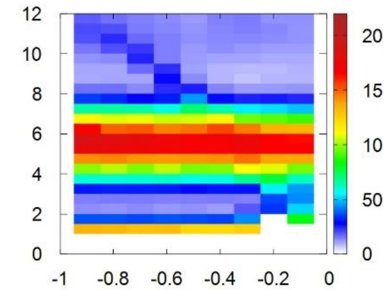
Abstract:

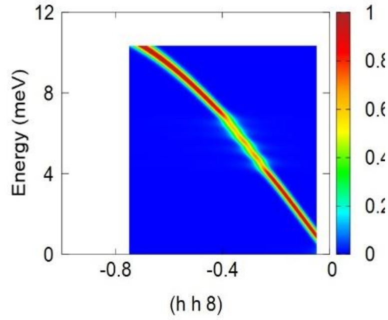
Aiming at shedding light on the intriguing phonon Hall effect recently reported in $Tb_3Ga_5O_{12}$, we wish to investigate the CEF and phonon spectrum in this particular material in an applied magnetic field. Previous measurements provide evidence for hybrid magneto-elastic modes, mixing CEF lines and transverse acoustic phonons. We plan to determine how this coupling evolves in a field and thus contribute to a better understanding of the magneto-elastic coupling and in turn of the phonon Hall effect.

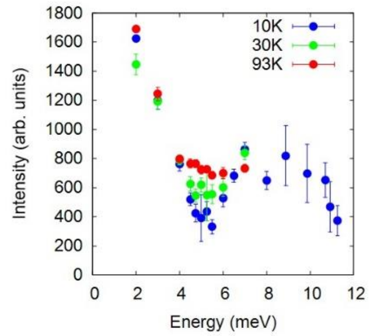
Exp report on 4-03-1710-IN8: spin lattice coupling in Tb3Ga5O12

Context: Aiming at shedding light on the magneto-elastic coupling in Tb3Ga5O12, we recently performed neutron scattering measurements at IN6-SHARP and on the thermal TAS 2T(@LLB) which revealed that the dispersion of transverse acoustic phonons is strongly coupled to CEF lines, resulting in hybrid magneto-elastic modes. Figure 1 displays raw data (showing the CEF and acoustic phonon mode) along with the analyzed spectral weight of this acoustic mode as a function of energy. As can be observed, a dip occurs when the dispersion crosses the flat CEF lines around 5 meV (the CEF has been analyzed in detail in ref [1]).

Figure 1





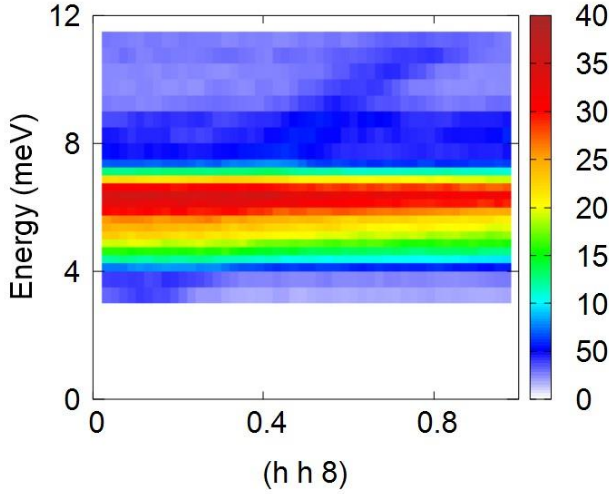


Raw data taken at 2T (LLB) along (hh8), at 10K. A strong CEF line is visible around 5 meV [10]. The dispersion of the transverse acoustic phonon propagating along (hh0) is also visible on this map.	RPA calculations taking into account the magneto-elastic coupling aiming at reproducing the dip in the dispersion of the acoustic phonon. The CEF line is not shown for the sake of clarity.	Spectral weight of the transverse acoustic phonon obtained from the analysis of the raw data.

Meanwhile, magnetic interactions are also at play in $Tb_3Ga_5O_{12}$. This material is known to order below about 240 mK with moments aligned along the cubic crystal axes, as shown in Figure 1. This ordering is confirmed by our powder diffraction experiments carried out on G41@LLB, see also [1-2]). According to [1,3], it is well understood on the basis of a two singlets model and assuming a strong Ising character (with easy axis along the cubic axes) associated to the dipolar interaction.

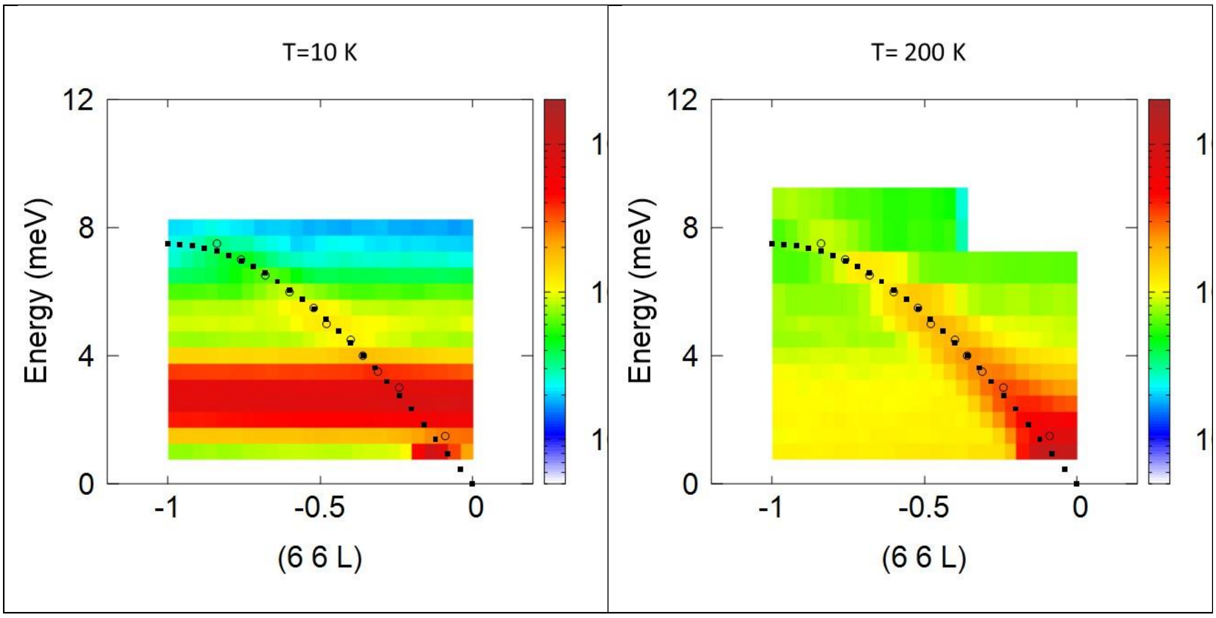
Proposed experiment: in this context, it remained to study the CEF-phonon mixing in an applied magnetic field. This should have unraveled how the CEF lines are affected, and how the crossing with the phonon dispersion is perturbed. To address this issue, we proposed to study the corresponding excitations while applying a magnetic field. This assumes being able to reach large wave-vectors to enhance the phonon response, while keeping a very good energy resolution. This double condition can be realized if one operates a thermal instrument like IN8, with a Cu002 monochromator (associated to a PG004 analyzer). This allows using large incident and scattered wave-vectors to close the scattering triangle at large Q, while take-off angles remain large, providing a good energy resolution. We planned to carry out several scans along the (hh8) direction using this set up, at different temperatures (1.5, 10, 30 and 100K) and for a number of fields ranging from 0 up to 2 T.

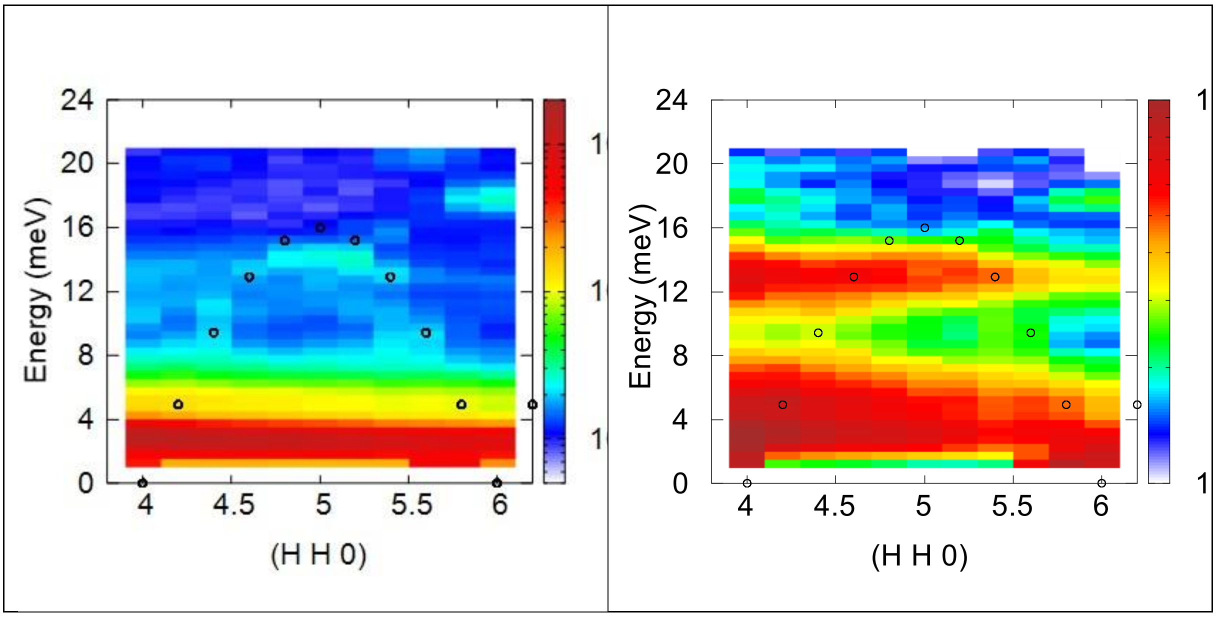
The experiment started in these conditions and we could take the reference map shown below:



Both the transverse acoustic phonon propagating along (hh0) and polarized along c as well as the set of CEF lines in the to 4-6 meV range could be clearly observed. However, as soon as we put the field on, the sample holder broke and the orientation was completely lost. The experiment had to stop; the radioactivity due to Tb prevented us from even touching the sample.

Instead, we decided (with agreement of our local contact) to go for another sample, KTb3F10, where the physics is very similar. The low energy dynamics is also governed by phonons in probable interaction with CEF lines (also a singlet ground state but a doublet first excited state). The latter appears at about 2.7 meV, according to previous experiments carried out at TASP@PSI. Since little is known about this material, we used standard condition, with Si111/PG002 and kf= 2.662. We could map out the dispersions of longitudinal and transverse acoustic phonon propagating along (hh0) and (00l) at 10 and 100K, with maps along (00L), (66L), (hh0) and (hh6). For the sake of illustration of the quality of those data, the (66L) map and (hh0) are reproduced below. Analysis is currently ongoing.





[1] J. Hammann and P. Manneville, J. Phys. Paris **34**, 615 (1973), J. Hammann and M. Ocio, J. Phys. **38**, 463 (1977), J. Hammann, Phys Letters Volume26A, number 6 1968

[2] R. Wawrzynczak, et al, PRB **100**, 094442 (2019).

[3] S. Petit, F. Damay, Q. Berrod, and J. M. Zanotti, Phys. Rev. Research **3**, 013030 – Published 12 January 2021