Experimental report

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Proposal: 4-05-649 **Council:** 4/2016

Title: Search for magnetoelastic spin liquid state in terbium gallium garnet(Tb3Ga5O12).

Research area: Physics

This proposal is a new proposal

Main proposer: Rafal WAWRZYNCZAK

Experimental team: Rafal WAWRZYNCZAK
Tom FENNELL
Goran NILSEN

Local contacts: Hannu MUTKA
Jacques OLLIVIER

Samples: Terbium gallium garnet Tb3Ga5O12

Instrument	Requested days	Allocated days	From	To
IN5	7	6	15/09/2016	21/09/2016

Abstract:

Magnetic frustration, the phenomenon of being unable to satisfy all magnetic interactions in a system, draws a lot of attention as it is the source of exotic behavior in many magnetic materials. Although it has been thoroughly studied in various groups of compounds, little progress has been made in its examination in the half-garnet lattice family, particularly terbium gallium garnet(TGG/Tb3Ga5O12). TGG hosts an array of magnetoelastic effects e.g.: anomalous acoustic Faraday effect and thermal Hall effect, the microscopic origin of which has not been experimentally investigated yet. Moreover, as it has a strongly frustrated lattice, a non-Kramers doublet groundstate and low-lying excited states within the bandwidth of acoustic phonons, so it strongly resembles the pyrochlore terbium titanate(Tb2Ti2O7). It is therefore a promising candidate for hosting an exotic magnetoelastic spin liquid phase, as recently observed in Tb2Ti2O7. We propose a detailed study of the low energy excitations of TGG, on IN5, to look for coupling of crystal field levels and acoustic phonons resulting in exotic magnetoelastic excitations and to propose a Hamiltonian describing magnetic interactions in TGG.

Search for magnetoelastic spin liquid state in terbium gallium garnet($Tb_3Ga_5O_{12}$).

R. Wawrzyńczak,[1] T. Fennel,[2] G. Nilsen,[3] J. Ollivier,[1] and M. Kenzelmann[4]

[1] *Institut Laue Langevin, FR-38042 Grenoble, France*
[2] *Laboratory for Neutron Scattering, PSI, CH-5232 Villigen PSI, Switzerland*
[3] *ISIS Facility, STFC, UK-OX11 0QX Didcot, United Kingdom*
[4] *Laboratory for Scientific Developments and Novel Materials, PSI, CH-5232 Villigen PSI, Switzerland*

IN5 direct geometry time-of-flight spectrometer with dilution fridge inset was used for examination of terbium gallium garnet ($Tb_3Ga_5O_{12}$, TGG) single crystal sample. The main objectives were to provide information for modelling magnetic interactions in TGG by analysing two lowest-lying crystal field (CEF) quasi-multiplets. Ground state quasi-doublet (split by ~ 0.17 meV), whose higher level exhibited splitting into rich scheme of dispersive exciton levels revealing behaviour exceeding one expected for ordinary single-ion effects. Observed anomaly persisted even above ordering temperature (T_N ~260 mK). Second group of CEF excitations in scope of our interest consisted of 4 singlets having energies in the range 4-7 meV. As in the previous case experimental results exposed dispersive character present exclusively in the ordered phase.

Experimental details Single crystal of length $\sim$ 45 mm and mass $\sim$ 10 g was mounted and oriented on copper sample mount (ORIENT EXPRESS and IN3). TGG is a cubic crystal system and scattering plane in prepared orientation was spanned by [110] and [001] vectors. Additionally, in order to provide better thermal contact of the sample with sample environment to facilitate faster thermalization crystal and part of holder was wrapped in copper foil and copper wire. Two instrumental setups with different λ_i were used during the measurements: 7 Å and 2.55 Å with 13000 and 9000 rpm chopper speeds respectively. Measurements were performed at 4 different temperatures: 40, 240, 500 mK and 1 K.

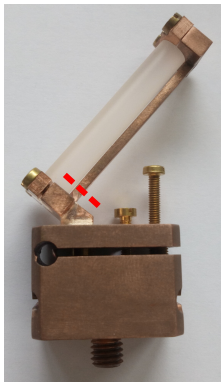

FIG. 1. Sample on copper mount.

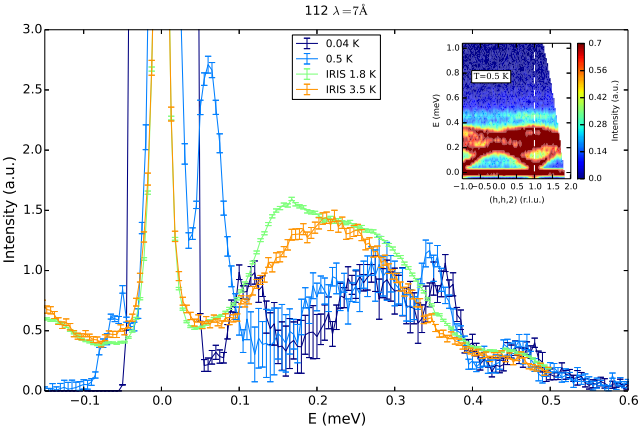

FIG. 2. Q-cuts through the dispersive excitons (inset) resulting from higher level of ground state quasi-doublet compared with powder data from IRIS spectrometer(ISIS).

Results of the measurements In Fig. 2 there are presented constant Q-cuts at various temperatures made through the spectrum of excitons emerging from higher out of two crystal field levels constituting quasi-doublet ground state. Out of 6 modes which can be distinguished in 2D colour map 2 of them seem to be dispersionless (~ 0.1 and ~ 0.5 meV). One of the dispersing modes, while crossing the $T_N \sim 260$ mK, is softening significantly and reopening when departing from transition temperature. However, closing of the gap was not observed. The dispersive excitons persist in $T > T_N$.

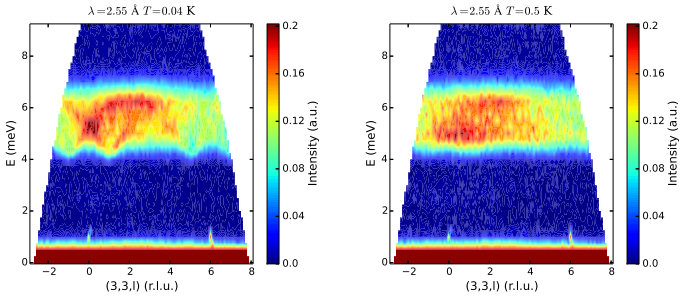

FIG. 3. 2D cuts through $S(Q,\omega)$ along $(33l)$ direction at 40 mK and 0.5 K.

Fig. 3 shows plot of 2D cuts through $S(Q,\omega)$ volume along $(33l)$ direction. 2.55 Å incoming neutron wavelength allowed reaching energy transfers covering the higher crystal field quasi-multiplet. Consisting of quasi-triplet and singlet grouped together at energies in range 4-6 meV. This group of excitations display Q dependence which seem to correspond with the possible lattice excitations emerging from elastic line. The dispersive features of the excitations vanish over the ordering temperature.