Experimental report

14/02/2017

Proposal:	**5-54-236**	**Council:**	10/2016
Title:	Dilution-induced ground state selection in the Seff=1/2 XY pyrochloreantiferromagnet Er2Ti2O7		
Research area:	Physics		

This proposal is a new proposal

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Samples: (ErY)Ti2O7

Instrument	Requested days	Allocated days	From	To
D3	6	6	02/02/2017	08/02/2017

Abstract:

Er2Ti2O7 is the most prominent candidate for order-by-disorder, a ground state selection mechanism whereby magnetic order is selected by purely quantum mechanical effects. However, one alternative scenario exists that could also possibly explain the ground state selection in Er2Ti2O7. We propose an experiment which aims to find conclusive evidence of the order-by-disorder in a derivative of Er2Ti2O7 diluted with 20% non-magnetic yttrium. Theoretical works have shown that if a change of ordered state occurs in the diluted sample, it is strongly in favor of the order-by-disorder scenario. However, the change in ordered state can only be directly observed with polarized neutron diffraction, which we propose to carry out using the D3 spectrometer and CRYOPAD.

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From Feb 2nd to 8th 2017, we performed an experiment on a single crystal of $Er_2Ti_2O_7$ and $Er_{1.6}Y_{0.4}Ti_2O_7$ using the CRYOPAD setup on the D3 diffractometer. The goal of this experiment was to investigate the effect of magnetic dilution on the magnetic structure of $Er_2Ti_2O_7$. Indeed, it has been theoretically predicted that substitution of Er^{3+} atoms with non-magnetic Y^{3+} atoms should induce a magnetic transition from a pure ψ_2 state to a pure ψ_3 state [1,2]. The observation of such a transition is important as it would be driven by order-by-disorder, an exotic phenomenon where long-range order is driven by entropic selection instead of energetic selection.

Earlier unpolarized elastic and inelastic neutron scattering data collected on single crystals of $Er_{(2-x)}Y_{(x)}Ti_2O_7$ (x=0,0.2,0.4) has shown that their respective magnetic structure are all consistent with the k=0 Γ_5 representation manifold [3]. However, an unpolarized neutron experiment cannot distinguish between any magnetic structure that is comprised of states within the Γ_5 manifold. In a more technical terms, an unpolarized experiment cannot distinguish between the ψ_2 and ψ_3 basis vectors that make up the full Γ_5 representation manifold.

For pure $Er_2Ti_2O_7$, this problem has been solved by A. Poole et al. using the polarization setup CRYOPAD at the ILL [4]. Refinement of the measured polarization matrices for various Bragg peaks allowed the authors to conclude that $Er_2Ti_2O_7$ orders into a pure ψ_2 state. In our experiment, we remeasured the polarization matrices of $Er_2Ti_2O_7$ and found that it is consistent with the finding of A. Poole et al [4]. This result will serve as a good reference for the magnetic structure of a pure ψ_2 state in comparison with the results obtained on diluted single crystals. During our experiment, we also measured the polarization matrices of several Bragg peaks for the 20%-Y dilution, $Er_{1.6}Y_{0.4}Ti_2O_7$, and found that the polarization matrices are different than the ones obtained for the pure sample. Our preliminary analysis suggests that the structure is consistent with a linear combination of both the ψ_2 and the ψ_3 states. However, further analysis is needed to determine the magnetic structure of $Er_{1.6}Y_{0.4}Ti_2O_7$, as the experiment was performed only a week before the ILL proposal deadline.

Finally, since the goal of this proposal is to map out and understand the magnetic phase diagram of the $Er_{(2-x)}Y_{(x)}Ti_2O_7$ as a function of Y^{3+} concentration, we are interested in continuing this project by measuring the polarization matrices of two other single crystal of $Er_{(2-x)}Y_{(x)}Ti_2O_7$ with an yttrium concentration of 5% and 10%. Unfortunately, we were not able to measure these two single crystals in the previous experiment as we lost about 2 days of beam time due to a problem with the dilution fridge. Also, since the first experiment was successful and the method is well suited for such experimental question, we request another 6 days of beam time to measure the polarization matrices of several Bragg peaks for a single crystal of $Er_{1.8}Y_{0.2}Ti_2O_7$ and $Er_{1.9}Y_{0.1}Ti_2O_7$. The continuation of this project will be important to accurately determine the phase diagram of the magnetic structure in the $Er_{(2-x)}Y_{(x)}Ti_2O_7$ system and for detailed comparisons to the very topical theoretical arguments that have been made [1,2].

[1] V. S. Maryasin and M. E. Zhitomirsky, Phys. Rev. B 90, 094412 (2014)
[2] A. Andreanov and P. A. McClarty, Phys. Rev. B 91, 064401 (2015)
[3] J. Gaudet *et al.*, Phys. Rev. B 94, 060407(R) (2016)
[4] A. Poole *et al.*, J. Phys. Condens. Matter 19, 452201 (2007)