X-ray Resonant Magnetic Scattering Study of Spin Ice $Dy_2Ti_2O_7$

J. Park and G. Aeppli

London Centre for Nanotechnology, University College London, 17-19 Gordon Street WC1H 0AH London, United Kingdom

A pyrochlore oxide $Dy_2Ti_2O_7$ (DTO) has attracted considerable interest due to magnetic frustration resulting in spin ice behavior. The magnetic moment of Dy^{3+} residing on a pyrochlore lattice of corner-linked tetrahedral is well described by Ising spins constrained to point along the local <111> type crystallographic axes, analogous to the disordered network of hydrogen bonds in water ice. This spin structure gives rise to Pauling's residual entropy of (R/2)ln(3/2) [1] where two spins point into and two out of each tetrahedron with no long-range ordering. However, it has been theoretically predicted that long-range dipolar interactions between the spins can drive a unique and ordered ground state of the pyrochlore oxide [2] and recently a deviation from the Pauling's entropy with a very large magnetic relaxation time has been observed [3] raising questions about the true ground state of the spin ice.

We carried out a resonant x-ray scattering experiment on a DTO single crystal at the beamline P09 of the PETRA III. The x-ray scattering cross sections of magnetic moments depend on the helicity of circular polarization whereas charge contributions are the same for both circular polarizations and, therefore, the difference between for two helicities provide useful magnetic information. Fig. 1 shows a peak appearing at the (0 0 4) reflection near Dy L_3-edge as we increase the applied field along the [1 1 0] crystallographic axis at low temperature. In our scattering geometry where the field direction is in the scattering plane, magnetic moments induced directly by the field with the spin ice ground state do not contribute to x-ray resonant magnetic scattering and therefore the peak is speculated to originate from ordering of orbitals or components of the spins which are not collinear with the magnetic field along the [1 1 0] direction induced by the applied magnetic field of which a transition temperature is around 15 K. For better understanding of the magnetic structure of spin ice under magnetic field more studies are required.

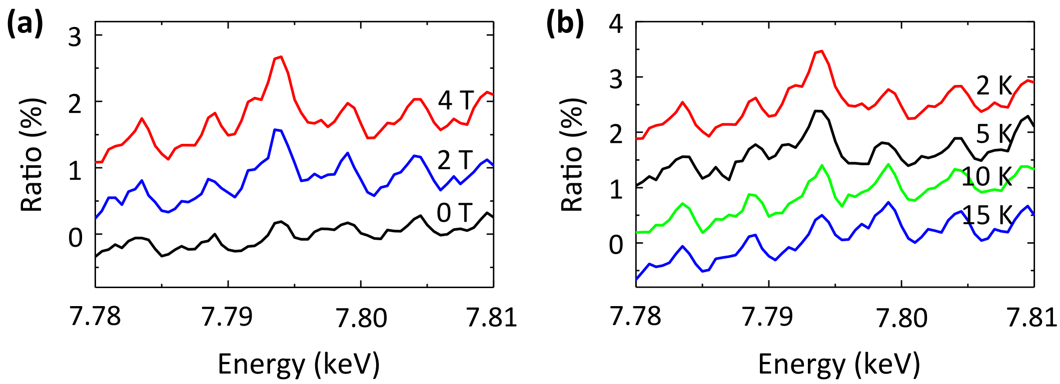

Figure 1: The ratio of the difference between the intensities of the (0 0 4) reflection for right- and left-circular polarizations to the sum. (a) All data were measured at a temperature of 2 K and red, blue, black lines represent data at 4, 2, and 0 T, respectively. (b) Red, black, green, and blue lines present data measured at 2, 5, 10, and 15 K under a magnetic field of 4 T, respectively.

References

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[2] R. G. Melkoet *al*., Phys. Rev. Lett. **87**, 067203 (2001).
[3] D. Pomaranskiet *al*., Nature Phys. **9**, 353 (2013).