ESRF	**Experiment title:** X-ray Magnetic Scattering Study of TbMnO3 in applied magnetic field with full polarimetry analysis	**Experiment number**: HE 3181
Beamline: ID20	**Date of experiment**: from: 28/10/09 to: 03/11/09	**Date of report**: 15/03/10
Shifts: 18	**Local contact(s)**: Helen Walker	*Received at ESRF:*

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Report:

$TbMnO_3$ represents the canonical example of the special class of magnetolectric multiferroics in which the onset of a spontaneous electric polarisation is concomitant with an inversion symmetry breaking magnetic phase transition. This transition has been thoroughly invesitgated previously on ID20 using our recently developed technique of combining circularly polarised X-rays with a full polarimetry analysis of the scattered beam to learn details of the zero magnetic field structure [1]. A giant magnetoelectric effect is evidenced by the flopping of the electric polarisation from the c to a-axis on application of magnetic field along the b-axis, which is related to the flopping of the manganese spin cycloid from the b-c plane to the a-b plane. Clearly understanding the details of this microscopic mechanism is of vital importance for the development of these materials for potential technological applications. Whilst the magnetic structure has been determined in the high field phase using polarised neutron diffraction [2], as yet no mechanism has been deduced to explain the phase transition. ***In this experiment we continued our successful experiment HE3068 to investigate the evolution of the scattering as a function of applied magnetic field using the electric field and phase plate setups in an attempt to learn more about the flop transition mechanism.***

The single crystal sample used in these experiments was that prepared in Oxford, and cut to have an a-face such that it could be mounted to apply an electric field along the c-axis and a magnetic field along the b-axis using the ID20 electric stick in the Oxford Instruments cryomagnet. The experiment was performed using non-resonant scattering at E=6.16 keV (below the Mn K-edge), and this combined with the absorption from the sample environment and the diamond phase plate, made the high flux of ID20 essential. Polarisation analysis was undertaken using a LiF crystal.

In our previous experiment we discovered that application of H=3 T(< Hc=6 T) led to a marked change in the Stokes variation from that in zero magnetic field. We have further investigated this behaviour, by measuring the scattering for circular left and circular right incident for the reflection (4 τ 1) as a function of applied magnetic field. Figure 1 shows that the scattering in the pi channel remains approximately constant, whilst that detected with the analyser angle of 45 and 135 degrees varies smoothly and continuously for -2<H<6 T in a parabolic fashion. This continuous development is in sharp contrast with the phase transition, which is strongly first order.

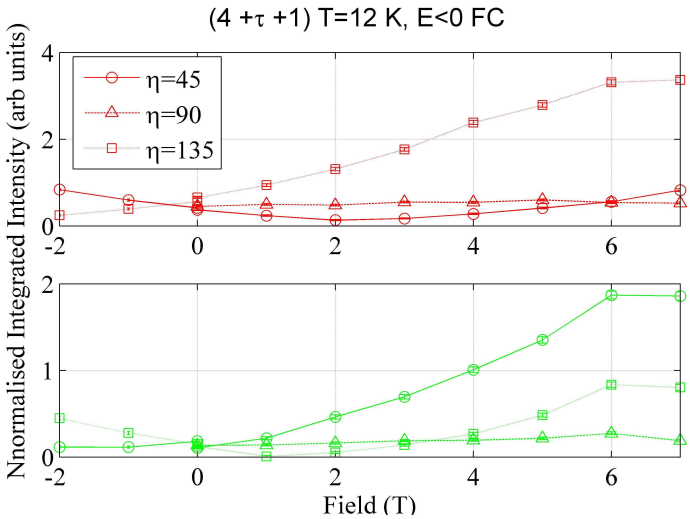

Figure 1: Variation in the scattered intensity of (4 τ 1) measured for circular left (top) and circular right (bottom) incident in three polarisation channels – η=45, 90, 135 degrees as a function of applied magnetic field. Discontinuities are seen in the data at H = 6 T, the critical magnetic field for the polarisation flop phase transition.

The experiment was very fruitful, providing an abondance of data, the analysis of which is ongoing and will, we believe, lead to a high quality, high impact publication.

[1] Fabrizi, Walker et al., *Physical Review Letters* **102** (2009) 237205, and ESRF Highlights 2009 pp74-75
[2] Aliouane et al., *Physical Review Letters* **102** (2009) 207205