ESRF	**Experiment title:** Room temperature electric field control of spin helicity in BiFeO3	**Experiment number**: HE 3193
Beamline: ID20	**Date of experiment**: from: 30/09/09 to: 07/10/09	**Date of report**: 06/04/10
Shifts: 18	**Local contact(s)**: Javier Herrero-Martin	*Received at ESRF:*

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Report:

The intention of this proposal was to study $BiFeO_3$, a room temperature multiferroic compound, which is of considerable interest for its potential technological applications. Sadly it quickly became apparent on checking multiple samples, that the quality was insufficiently high for our experiments. It was therefore decided to make the best use of the beamtime by investigating a different multiferroic compound $DyMnO_3$.

$DyMnO_3$ is an example of a magnetoelectric multiferroic material in which the onset of a spontaneous electric polarisation is concomittant with a magnetic phase transition resulting in a symmetry inversion breaking cycloidal magnetic structure. It bears many similarities to $TbMnO_3$, which we have previously very successfully studied on ID20 using circularly polarised incident X-rays and a complete polarimetry analysis of the scattered beam [1], but also presents some differences, for example the incommensurate ordering wave-vector is [0 0.36 0] as opposed to [0 0.28 0], and although it undergoes a flop of the electric polarisation in applied magnetic field, this is not associated with an incommensurate-commensurate transition [2].

Our experiments were performed using a single crystal grown by Tokura's group in Japan. Due to the larger value of ordering wave-vector it was necessary to mount the sample differently to the orientation used for our $TbMnO_3$ experiments. The sample was mounted to give a specular b-face, with the electric field applied along the c-axis, allowing us to access reflections of the type (0 K$\pm\tau$ $\pm$1). The sample was mounted in the ID20 electric stick which

was inserted into the orange cryostat (the larger beryllium window of the orange cryostat versus the Oxford Instruments cryomagnet giving us a larger region of accesible reciprocal space). The experiment was performed at an energy of 6.4 keV, lying well below the Mn K-edge so as to avoid any interference with resonant scattering, and using a LiF crystal for polarisation analysis.

We started the experiment by performing long k-scans to identify different incommensurate satellites in the rotated and un-rotated channels. These peaks were then classified and by measuring the temperature dependence of one of the magnetic peaks and comparing it to previously published data it was possible to accurately determine the phase transition between the higher temperature paraelectric collinear phase and the lower temperature ferroelectric cycloidal phase.

Then, using the phase plate to convert the linearly to circularly polarised incident X-rays, a full Stokes analysis was performed on the scattered beam in the two phases. The Stokes dependence in the collinear phase was as expected, see Figure, but the data for the cycloidal phase is a little more perplexing. An analysis of the data suggests that we might have some problems originating with the sample, since our data are not entirely consistent with those published by the group of Argyriou in Berlin. To try and rectify these problems and complete this study it might be necessary to suggest a collaboration with Professor Argyriou to perform the same experiment on one of his samples.

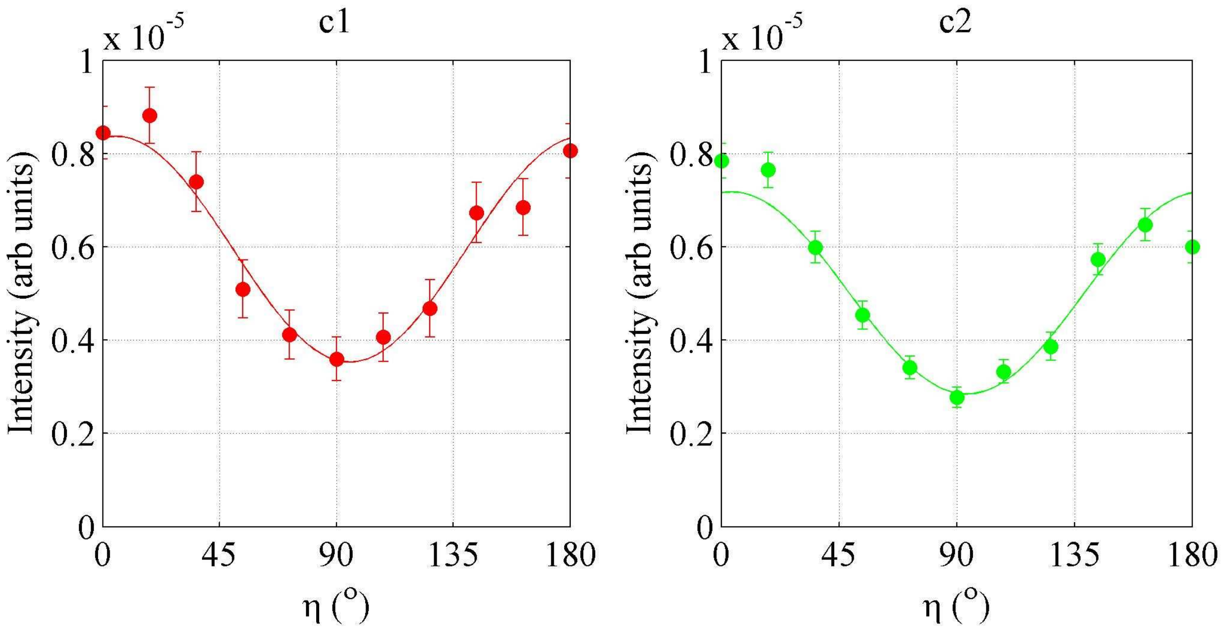

Figure: Stokes scans of the scattered intensity from (0 4-τ 1) with circular left (red) and circular right (green) incident, showing strong similarities as to be expected in the collinear phase.

References:

[1] Fabrizi, Walker et al., *Phys Rev Lett* **102** 237205 (2009)

[2] Strempfer, Argyriou et al., *Phys Rev B* **75** 212402 (2007)