X-ray magnetic scattering studies on multiferroicHo$_{0.5}$Nd$_{0.5}$Fe$_3$(BO$_3$)$_4$

D. K. Shukla, C. Mazzoli$^1$, J. Strempfer$^2$, L. N. Bezmaternykh$^3$, I. A. Gudim$^3$, V. L. Temerov$^3$

UGC-DAE Consortium for Scientific Research, Khandwa Road, Indore 01, India
$^1$CNR-SPIN and Dipartimento di Fisica, Politecnico di Milano, I-20133 Milano, Italy
$^2$Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg, Germany
$^3$L.V. Kirensky Institute of Physics, Krasnoyarsk 660036, Russia

Rare earth iron borates show a combination of exotic properties, such as multiferroic behavior, and are therefore a suitable platform for studying complex f-d exchange interactions, and unveil different magnetic anisotropies at low temperatures when R differs [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13]. Among this family, HoFe$_3$(BO$_3$)$_4$ exhibits magneto-electricity and spontaneous electric polarization below $T_N$ and a spin-reorientation at $\sim 4.5$ K [7, 1]. However under application of external magnetic field ferroelectric polarization is suppressed in HoFe$_3$(BO$_3$)$_4$ [7]. Interestingly, replacing 50% Ho by Nd in this compound increases the spin reorientation transition temperature, $T_{SR}$, from $\sim 4.5$ K (for HoFe$_3$(BO$_3$)$_4$) to $\sim 9$ K for Ho$_{0.5}$Nd$_{0.5}$Fe$_3$(BO$_3$)$_4$. The Nd doped compound has the additional advantage that under application of an external magnetic field the induced electric polarization is amplified [7].

We have performed resonant x-ray magnetic scattering studies on a flux grown Ho$_{0.5}$Nd$_{0.5}$Fe$_3$(BO$_3$)$_4$ single crystal. Measurements have been performed in the EH1 of the resonant scattering and diffraction beamline P09 at PETRA III[14]. Resonant scattering experiments have been performed at the Nd L$_2$-edge, Fe K-edge and Ho L$_3$-edge. The crystal was mounted on a cold finger of the low temperature Joule-Thomson cryostat, capable of reaching down to 1.7 K, so as to match the a$^*\cdot$c$^*$ plane with the scattering plane. The incident beam was $\sigma$ polarized. For polarization analysis of the scattered beam, a Cu (220) crystal was used at the Nd L$_2$ and Fe K edges and a PG (600) crystal at the Ho L$_3$-edge.

Fig. 1 shows representative plots of measurements of magnetic (0 0 7.5) and charge (0 0 6) reflections at the Nd L$_2$ absorption edge. Below the antiferromagnetic transition temperature ($\sim 32$ K) of Ho$_{0.5}$Nd$_{0.5}$Fe$_3$(BO$_3$)$_4$, reflections corresponding to the magnetic wave vector (0 0 3/2) have been observed (see Fig. 1a and 1c). For comparison, energy scans as well as intensity as a function of temperature for the charge (0 0 6) reflection are shown in Fig. 1b and 1d. Magnetic reflections have been measured at the absorption edges of all three magnetic elements (Ho, Nd and Fe) present in the compound. The intensity of the magnetic reflections as a function of temperature and azimuth has also been investigated.

References

Figure 1: (a) Resonance at the Nd L$_{2}$-edge in the energy scan of the (0 0 7.5) reflection in the $\sigma$-$\pi'$ channel confirms the magnetic origin of this reflection. Resonance energy matches well with the Nd L$_{2}$-edge energy. Energy scans presented here have not been corrected for the absorption. (b) Energy scan of charge (0 0 6) reflection in $\sigma$-$\sigma'$ channel across the Nd L$_{2}$-edge exhibiting the expected dip due to absorption. (c) L-scans of the magnetic (0 0 7.5) reflection at the Nd L$_{2}$-resonance energy at selected temperatures, below the Néel transition temperature ($\sim$ 32 K), measured in the $\sigma$-$\pi'$ channel. (d) Temperature dependence of the charge (0 0 6) reflection in the $\sigma$-$\sigma'$ channel, showing no effect on the crystal structure through the magnetic phase transition.