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Mysterious incommensurate Dy^{3+} magnetic ordering in $DyFeO_3$. Spherical neutron polarimetry study.

$DyFeO_3$ is the only known rare-earth orthoferrite with an incommensurate magnetic ordering of the rare-earth element without an external magnetic field [1,2]. $DyFeO_3$ establish the ordering of the Fe^{3+} sublattice, according to the Γ4 representation (magnetic space group $Pb'n'm$) below T_N = 645 K. Below the spin-reorientation temperature T_{SR} ≈ 65 K magnetic moments rotate into the Γ1 ($Pbnm.1$) Fe^{3+} structure with symmetry forbidden ferromagnetic component, making it suitable for spherical neutron polarimetry studies.

Our unpolarized single crystal neutron diffraction (IN12, ILL) measurements show the temperature evolution of $DyFeO_3$ satellites at zero magnetic field below 4 K [3]. It is worth comparing it with $TbFeO_3$ [4] which orders incommensurately in a solitonic lattice in the applied magnetic field (~ 3 K and H > 1 T). Both show long modulation periods ($DyFeO_3$ 280 Å and $TbFeO_3$ 340 Å) and higher order satellites ($DyFeO_3$ up to 7^{th} order, $TbFeO_3$ up to 11^{th} order). However, in $DyFeO_3$ the intensity ratio between satellites suggests triangular modulation ($1/n^2$), while for $TbFeO_3$ it is square-like (1/n), where n is the satellite order. $DyFeO_3$ and $TbFeO_3$ have different modulation vector directions, [00l] and [0k1], respectively. The formations of incommensurate order in $DyFeO_3$ and $TbFeO_3$ are of first-order and second-order type, respectively.

The incommensurate magnetic order of Tb^{3+} in $TbFeO_3$ is reported as the solitonic lattice [4], while for Dy^{3+} magnetic ordering in $DyFeO_3$, three models are proposed in the literature: (i) spin density wave [1], (ii) elliptical-based helical ordering [1], and (iii) spin density wave on the top of commensurate ordering [2]. Our half polarization analysis on $DyFeO_3$ [3] shows no magnetic chirality term and our spherical neutron polarimetry analysis supports the spin density wave ordering model over the helical ordering model (both measured on TASP, PSI). Surprisingly, we observed a high value of the Pxz component of the polarization matrix measured on magnetic satellite peaks, in contradiction with all models proposed in the literature [1,2]. According to the Blume-Maleev equations, the Pxz component arises from nuclear-magnetic interference, however, high values of the Pxz term were observed for (001)±q and (003)±q satellite peaks, which are pure magnetic as (001) and (003) commensurate peaks are nuclear-forbidden. Spherical neutron polarimetry data were collected very recently and we are working on the model of the Dy^{3+} magnetic ordering in $DyFeO_3$.

[1] C. Ritter, et al.; *J. Phys.: Condens. Matter* **34** (2022) 265801; [2] B. Biswas, et al.; *Phys. Rev. Mater.* **6** (2022), 074401; [3] Under preparation; [4] S. Artyukhin, et al.; *Nat. Mater.* **11** (2012) 694

Primary author: FABRYKIEWICZ, Piotr (IfK, RWTH Aachen and JCNS at MLZ, FZ-Jülich)

Co-authors: XU, Jianhui (IfK, RWTH Aachen and JCNS at MLZ, FZ-Jülich); BHOSALE, Dnyaneshwar Raghunath (JCNS at MLZ, FZ-Jülich); STEKIEL, Michal (JCNS at MLZ, FZ-Jülich); ROESSLI, Bertrand (PSI); SCHMALZL, Karin (JCNS at ILL, FZ-Jülich); SCHNEIDEWIND, Astrid (JCNS at MLZ, FZ-Jülich); MEVEN, Martin (JCNS at MLZ, FZ-Jülich)

Presenter: FABRYKIEWICZ, Piotr (IfK, RWTH Aachen and JCNS at MLZ, FZ-Jülich)

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