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Exploring Ferrotoroidic Order in LiNi_0.8Fe_0.2PO_4

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Ferrotoroidicity is the fourth ferroic order characterized by the simultaneous breaking of both time and space-reversal symmetries [1]. The intrinsic magnetoelectric effect associated with this order makes it interesting for energy-efficient memory devices. The ability to pole and control ferrotoroidal domains could prove important for non-volatile and high-density data storage applications. [2]
Lithium orthophosphates, $LiMPO_4$ (M= Mn, Ni, Co, Fe) are a family of antiferromagnets that crystallize in the olivine crystal structure (orthorhombic space group Pnma) and exhibit a magnetoelectric effect below their ordering temperature [3]. The distinguishing factor among these compounds is the preferred orientation of magnetic moment. For instance, in $LiNiPO_4$ and $LiFePO_4$ the magnetic moments are aligned along the c and b axes respectively [4]. For the stoichiometric compounds, the form of the magnetoelectric tensor (α) which connects the electric polarisation to the applied magnetic field is determined by their magnetic point group [5]. Additionally, this family of compounds is notable due to their potential to support ferrotoroidal order. The non-zero off-diagonal elements in α in M=Fe, Co, and Ni suggest the possible existence of ferrotoroidic order [2] which was experimentally confirmed in $LiCoPO_4$ [6].
In this study, we focus on the ferrotoroidic order in the mixed compound $LiNi_{0.8}Fe_{0.2}PO_4$, where Ni sites are doped with Fe. Previous research on this compound identified a distinct low-temperature magnetic phase due to the combined effect of exchange interaction and mismatched anisotropy. Initially, the magnetic moments align along the b-axis below 25 K similar to $LiFePO_4$. However, below 21K they rotate towards the a-axis, a direction different from the easy axes of both parent compounds. In this phase, where we expect four domains, the strength of magnetoelectric coupling is increased by 100-fold [7].
Using spherical neutron polarimetry, we investigated the ferrotoroidic order in $LiNi_{0.8}Fe_{0.2}PO_4$ giving us direct insight into the magnetic domain distribution and poling behaviour under crossed magnetic and electric fields. Our results suggest mixed-anisotropy ferrotoroidal systems to be a promising route towards next-generation storage devices.

References
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