

Electric-field-induced X-ray Nonreciprocal Dichroism in α -Fe₂O₃

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Antiferromagnets with broken time-reversal symmetry have recently attracted significant attention from the perspectives of altermagnetism [1] and multipolar order [2]. Hematite (α -Fe₂O₃), despite being one of the most common iron oxides in nature, has long served as a prototype antiferromagnet and has recently been revisited as a platform for unconventional magnetic multipoles. In particular, theoretical studies have suggested the presence of higher-order multipoles such as magnetic octupoles, hexadecapoles, and even higher-rank multipoles [3]. However, direct experimental access to these hidden multipoles has remained extremely challenging. In this work, we reveal these hidden multipoles in hematite using X-ray absorption measurements under an applied electric field [4]. The electric field induces femtometer-scale shifts in the positions of iron ions relative to oxygen ions, breaking inversion symmetry. Combined with the broken time-reversal symmetry inherent to hematite, the applied electric field renders the hidden multipoles detectable in X-ray signals through their nonreciprocal nature. Our results demonstrate that hematite can host subtle and complex magnetic structures, providing a new pathway to uncover hidden multipoles in a wide range of quantum materials.

[1] L. Šmejkal, J. Sinova, and T. Jungwirth, Phys. Rev. X **12**, 040501 (2022).

[2] S. Bhowal and N. A. Spaldin, Phys. Rev. X **14**, 011019 (2024).

[3] X. H. Verbeek, D. Voderholzer, S. Schären, Y. Gachnang, N. A. Spaldin, and S. Bhowal, Phys. Rev. Res. **6**, 043157 (2024).

[4] T. Hayashida, K. Matsumoto, K. Arakawa, Y. Joly, S. Di Matteo, K. Tamasaku, Y. Tanaka, and T. Kimura, Phys. Rev. X **16**, 041015 (2026).