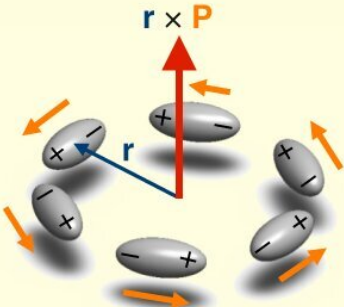
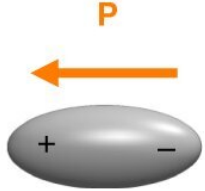




# Rotational form of spontaneous crystallographic ordering discovered in ferroic material

November 6 2019, by Bob Yirka

TR \ SI	+	-
	+	-
	<p>Rotational moment</p> <p><math>\mathbf{r} \times \mathbf{P}</math></p> 	<p>Electric dipole moment</p> <p><math>\mathbf{P}</math></p> 
	<p>Magnetic dipole moment</p> <p><math>\mathbf{M}</math></p> 	<p>Toroidal moment</p> <p><math>\mathbf{r} \times \mathbf{M}</math></p> 

a, A summary of the four vector order parameters classified by their parities under time-reversal (TR) and spatial-inversion (SI) operations, with illustrations of typical examples for realizing those order parameters. Here, + indicates even parity and – indicates odd parity. The yellow background highlights the ferro-rotational order parameter. b, The crystal structure of  $\text{RbFe}(\text{MoO}_4)_2$  as viewed along the c axis, both above and below the structural phase transition temperature  $T_c$ . Two domain states are expected below  $T_c$ , corresponding to counterclockwise and clockwise rotations of the  $\text{FeO}_6$  octahedra. Credit: *Nature*

*Physics* (2019). DOI: 10.1038/s41567-019-0695-1

A team of researchers from the University of Michigan and Rutgers University has discovered a rotational form of spontaneous crystallographic ordering in a ferroic material. In their paper published in the journal *Nature Physics*, the group describes their work with ferro-rotational orders under different conditions and what they learned about them. Manfred Fiebig with ETH Zurich has published a News & Views [piece](#) on the work done by the team in the same issue—he also gives a brief history of ferromagnetism and what has been learned about it over the past 2,000 years.

As Fiebig notes, all ferroic materials have some sort of switchable ordering that comes about spontaneously. He further notes that with ferromagnetism, [magnetic moments](#) line up in uniform ways and can be switched by exposing them to a [magnetic field](#). But, as he also notes, there are examples of ferro-rotational materials—another type of spontaneous ordering of atoms. Such materials have an order parameter that is an axial vector which is invariant under spatial inversion and time reversal operations. It also constitutes the final category of ferroics—after ferro-toroidal, ferroelectric and ferromagnetic. The researchers note that materials of this order have become increasingly popular for use in quantum applications. They further note that until now, such materials have not been given serious study.

The work by the team involved using a technique that involved doubling the frequency of light waves projected from a laser. The process, known as second-harmonic generation was useful for studying a ferro-rotational material  $\text{RbFe}(\text{MoO}_4)_2$  because of its extreme sensitivity to the symmetry involved with frequency doubling materials. And as Fiebig notes, all [ferroic materials](#) experience symmetry reduction when

ordering, making the technique particularly useful. The researchers used it to first identify and then characterize ferroic states. Removal of the mirror planes from the material, revealed the emergence of the uniform  $c^\pm$ -like rotation of the octahedra. The signal also allowed for identifying the  $c^+$  and  $c^-$  domains. In so doing, the researchers found that the areal ratio of the domains changed with temperature. They conclude by suggesting that their work showed that the conjugated field might be related to a 4<sup>th</sup> power combination of electric-field components.

**More information:** Wencan Jin et al. Observation of a ferro-rotational order coupled with second-order nonlinear optical fields, *Nature Physics* (2019). [DOI: 10.1038/s41567-019-0695-1](https://doi.org/10.1038/s41567-019-0695-1)

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Citation: Rotational form of spontaneous crystallographic ordering discovered in ferroic material (2019, November 6) retrieved 2 May 2024 from <https://phys.org/news/2019-11-rotational-spontaneous-crystallographic-ferroic-material.html>

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