Physicists discover 'magnetotoroidic effect'

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(PhysOrg.com) -- For many years, scientists have known about the magnetoelectric effect, in which an electric field can induce and control a magnetic field, and vice versa. In this effect, the electric field has always been homogeneous. Now, scientists have found that a curled electric field can also be used to control magnetic fields, constituting a novel phenomenon that they call the "magnetotoroidic effect."

"A homogeneous electric field is one in which the electric field is a constant everywhere, as that produced by opposite static charges on two metallic capacitor plates," Wei Ren of the University of Arkansas told *PhysOrg.com*. "On the other hand, a time-varying magnetic field can also induce an electric field that possesses a curl according to the Maxwell-Faraday equation. However, such a curl is zero in the homogeneous electric field."

In their study, Ren and coauthor L. Bellaiche, also from the University of Arkansas, have performed atomistic simulations that have confirmed the existence of the new effect, which was previously predicted in theory. Their results are published in a recent issue of Physical Review Letters.

In their simulations, the researchers applied a curled electric field to nanodots made of bismuth iron oxide (BFO), which has magnetic properties. They found that, by playing with the magnitude and direction of a vector quantifying the curled electric field, they could control both the magnitude and direction of the nanodots' magnetization.

The simulations also revealed that the effect originates from an interplay among three different components: magnetic dipoles, electric vortices, and oxygen octahedral tilts (from the BFO). When using the curled electric field to control the nanodots' magnetization, the researchers discovered that the process involves some peculiar intermediate states. One such state, for instance, consists of pairs of electric vortices that coexist with a single antivortex.

"Some of our findings are quite surprising and unexpected," Ren said. "The coexistence of a vortex pair and an antivortex in ferroelectrics has never been reported before, although it is now known as an extremely interesting state in ferromagnetism research areas."

This understanding of the magnetotoroidic effect could enable scientists to use electric fields to better control magnetism, which could have a variety of useful applications. In their paper, the scientists mention the possibility of developing new memory devices with unprecedented storage density.

"The MT effect may find applications in the field-induced controlling of magnetic orders, switching of ferroelectric vortex, and modulation of oxygen octahedral tilts," Ren said. "More importantly, this effect can lead the burgeoning magnetoelectric research to some new arena thanks to the rapid development of nanoscience and engineering."

More information: Wei Ren and L. Bellaiche. "Prediction of the Magnetotoroidic Effect from Atomistic Simulations." *Physical Review Letters* 107, 127202 (2011).
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