Researchers demonstrate electrical creation and control of antiferromagnetic vortices

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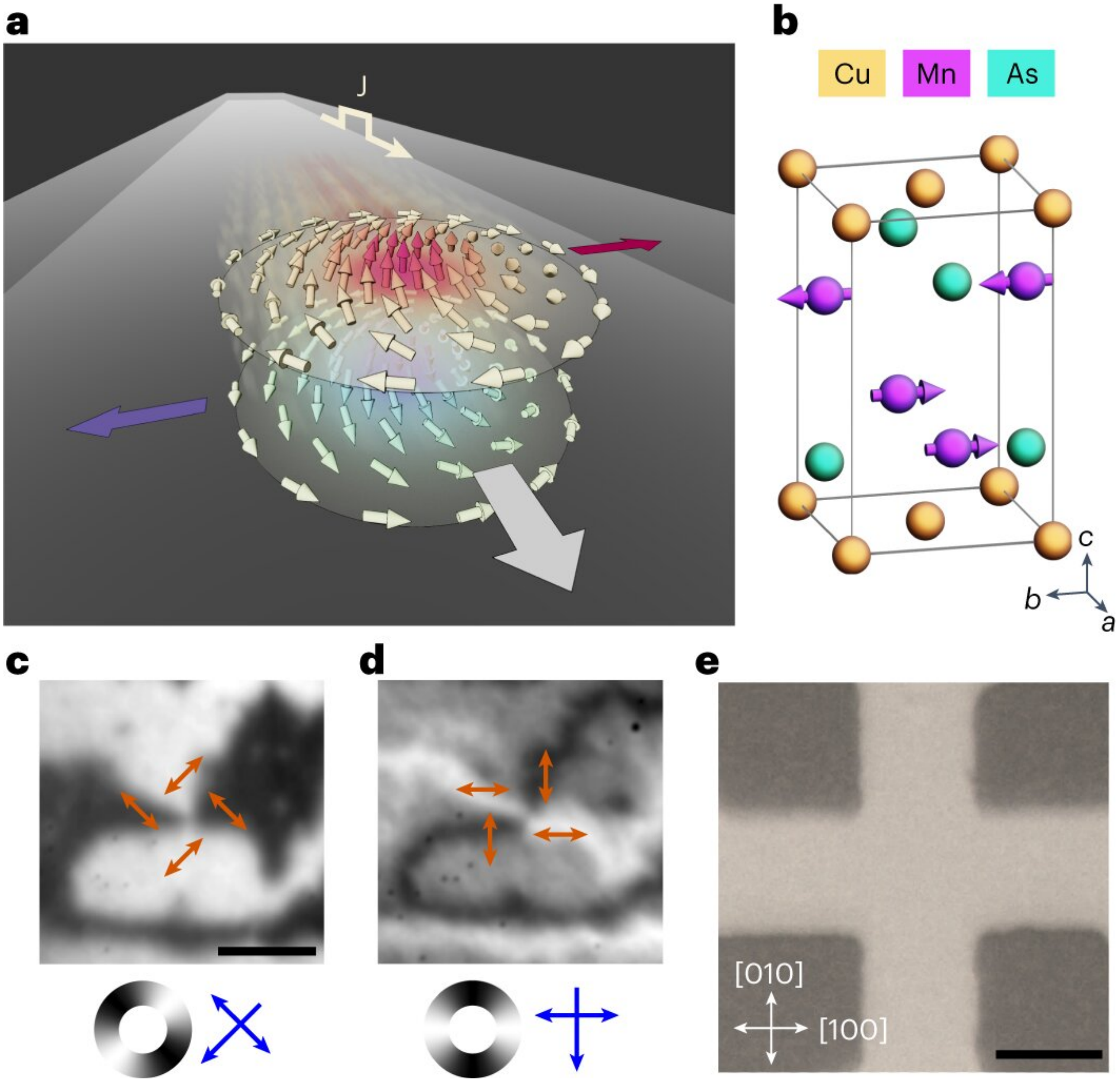

AF textures in CuMnAs. a, Spin structure and force acting on an AF Bloch-type meron under an applied current pulse J. b, Unit cell and magnetic structure of CuMnAs. c,d, XMLD–PEEM images of a vortex structure in CuMnAs. The blue single- and double-headed arrows indicate the X-ray incidence and polarization vectors, while the color wheels and red double-headed arrows indicate the spin axis orientation inferred from the XMLD contrast. The scale bar corresponds to 1 µm. e, Optical image of the device structure used for electrical pulsing. The spatial scale bar corresponds to 10 µm. Credit: *Nature Nanotechnology* (2023). DOI: 10.1038/s41565-023-01386-3

A new study has shown for the first time how electrical creation and control of magnetic vortices in an antiferromagnet can be achieved, a discovery that will increase the data storage capacity and speed of next generation devices.

Researchers from the University of Nottingham's School of Physics and Astronomy have used magnetic imaging techniques to map the structure of newly formed magnetic vortices and demonstrate their back-and-forth movement due to alternating electrical pulses. Their findings have been published in *Nature Nanotechnology*.

"This is an exciting moment for us, these magnetic vortices have been proposed as information carriers in next-generation memory devices, but evidence of their existence in antiferromagnets has so far been scarce. Now, we have not only generated them, but also moved them in a controllable way. It's another success for our material, CuMnAs, which has been at the center of several breakthroughs in antiferromagnetic spintronics over the last few years," says Oliver Amin.

CuMnAs has a specific crystal structure, grown in almost complete vacuum, atomic layer by atomic layer. It has been shown to behave like a switch when pulsed with electrical currents, and the research group in

Nottingham, led by Dr. Peter Wadley, alongside international collaborators, have "zoomed in" on the magnetic textures being controlled; first with the demonstration of moving domain walls, and now with the generation and control of magnetic vortices.

Key to this research is a magnetic imaging technique called photoemission electron microscopy, which was carried out at the U.K.'s synchrotron facility, Diamond Light Source. The synchrotron produces a collimated beam of polarized X-rays, which is shone onto the sample to probe to magnetic state. This allows for spatially resolution of micromagnetic textures as small as 20 nanometers in size.

Magnetic materials have been technologically important for centuries, from the compass to modern hard disks. However almost all of these materials have belonged to one type of magnetic order: ferromagnetism. This is the type of magnet we are all familiar with from fridge magnets to washing machine motors and computer hard disks. They produce an external magnetic field that we can "feel" because all of the tiny atomic magnetic moments that constitute them like to align in the same direction. It is this field that causes fridge magnets to stick and that we sometimes see mapped out with iron filings.

Because they lack an external magnetic field, antiferromagnets are hard to detect and, until recently, hard to control. For this reason they have found almost no applications. Antiferromagnets produce no external magnetic field because all of the neighboring constituent tiny atomic moments point in exactly opposite directions from each other. In doing so they cancel each other out and no external magnetic field is produced: they won't stick to fridges or deflect a compass needle.

But antiferromagnets are magnetically more robust and movement of their tiny atomic moments happens approximately 1,000 times faster than a ferromagnet. This could create computer memory which operates far faster than current memory technology.

"Antiferromagnets have the potential to out-compete other forms of memory which would lead to a redesign of computing architecture, huge speed increases and energy savings. The additional computing power could have large societal impact. These findings are really exciting as they bring us closer to realizing the potential of antiferromagnet materials to transform the digital landscape," says Dr. Peter Wadley.

More information: O. J. Amin et al, Antiferromagnetic half-skyrmions electrically generated and controlled at room temperature, *Nature Nanotechnology* (2023). DOI: 10.1038/s41565-023-01386-3

Provided by University of Nottingham

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