Research team achieves controlled movement of skyrmions

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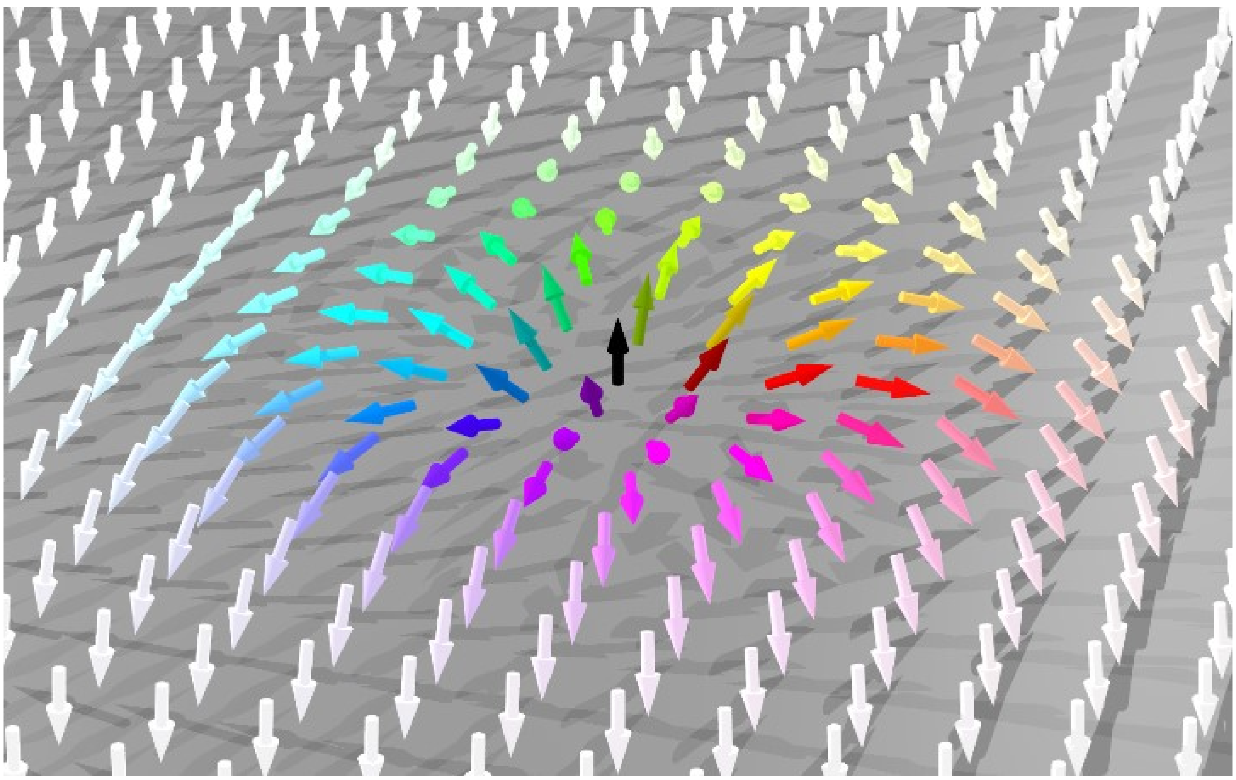

The magnetic structure of a skyrmion is symmetrical around its core; arrows indicate the direction of spin. Credit: ill./©: Benjamin Krüger, JGU

A joint research project being undertaken by Johannes Gutenberg University Mainz (JGU) and the Massachusetts Institute of Technology (MIT) has achieved a breakthrough in fundamental research in the field of potential future data storage technologies. The idea is that electronic storage units (bits) will not be stored on rotating hard disks as is currently standard practice but on a nanowire in the form of magnetic vortex structures, so-called skyrmions, using a process similar to that of a shift register. The magnetic skyrmion bits would be rapidly accessible, while storage density would be high and there would be improved energy efficiency. The project team managed, for the first time, to achieve targeted shifting of individual skyrmions at room temperature using electrical impulses. Their results have been published in the journal *Nature Materials*.

Magnetic skyrmions are special spin configurations that can occur in materials and particularly in thin layer structures when the inversion symmetry is broken. With regard to the systems that are of interest here, this means that a thin metal film with a non-symmetrical layer structure can be employed. In materials such as this, spin configurations that behave rather like a hair whorl can form. It can be just as difficult to eradicate a skyrmion as it can be to smooth out a hair whorl, a property that gives skyrmions enhanced stability.

An important characteristic of skyrmions is that they can exist in isolation in magnetic materials and generally do not tend to collide with the edge of a structure. This provides them with the unique ability to skirt any isolated defects or unevenness in the material with which other magnetic structures, such as domain walls, would collide. Skyrmions are therefore excellent candidates for use with magnetic shift registers, otherwise known as racetrack memory. Information could be encoded in the form of skyrmions and an electrical current could be employed to move them past fixed read/write heads. The process would be both rapid and completely independent of movable mechanical components and thus ideally suited for mobile applications.

During the project, it was demonstrated that individual skyrmions can indeed be moved in a controlled manner along a magnetic wire, i.e., the so-called racetrack, by exposing them to brief electrical impulses at room temperature. In addition, new methods to describe their dynamics were developed and confirmed by experimentation. This work can thus be regarded as laying down the cornerstone for the future use of skyrmions in application-related systems.

"It is always great to see when a joint project quickly leads to exciting results. This is particularly true in this case, as we have been able to produce this journal article within just a year of entering into our cooperation agreement. It would never have come about had it not been for the close collaboration between Mainz University and MIT and the lively exchange of ideas," said Kai Litzius, co-author of the article. Litzius is on a stipendiary scholarship awarded by the Graduate School of Excellence "Materials Science in Mainz" (MAINZ) and is a member of the team headed by Professor Mathias Kläui.

"I'm delighted by the way we were able to work efficiently and continuously with groups at MIT. After receiving start-up funding through a joint project financed by the German Federal Ministry of Education and Research, we have been able to produce six joint publications since 2014, partly as the result of several student visits to MIT," emphasized Kläui, a professor at the Institute of Physics and the director of the MAINZ Graduate School of Excellence.

More information: Seonghoon Woo et al. Observation of room-temperature magnetic skyrmions and their current-driven dynamics in ultrathin metallic ferromagnets, *Nature Materials* (2016). DOI: 10.1038/nmat4593

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