Researchers design six-state magnetic memory

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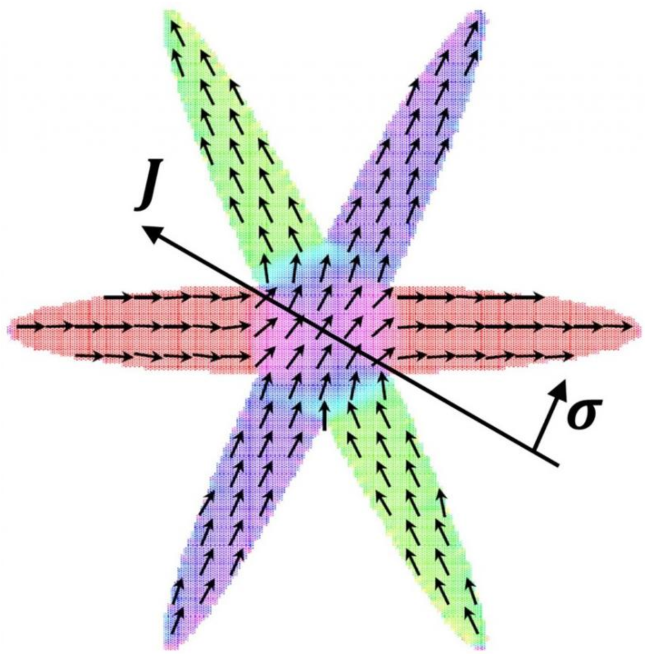


By arranging magnetic film into a pattern of three crossing ellipses, researchers demonstrated six magnetic configurations are possible in the overlapping region. Credit: Telepinsky et al. ©2016 AIP Publishing

(Phys.org)—Computers are often described with "ones and zeros," referring to their binary nature: each memory element stores data in two states. But there is no fundamental reason why there should be just two.

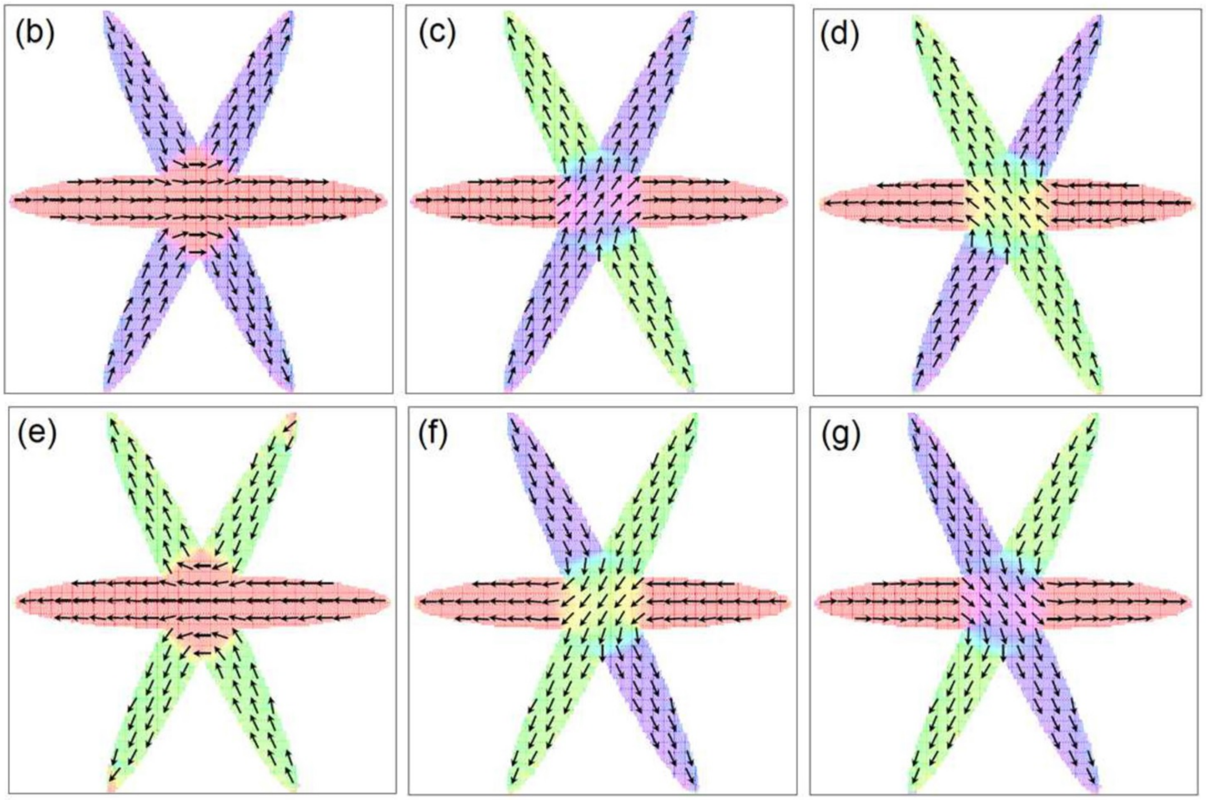
In a new study, researchers have designed a magnetic element that has six stable magnetic states, which paves the way toward realizing a six-state magnetic memory element.

The researchers, Yevgeniy Telepinsky *et al.*, from Bar-Ilan University in Israel and New York University in the US, have published a paper on the new magnetic structure in a recent issue of *Applied Physics Letters*.

This isn't the first time that researchers have designed memory cells with more than two states, or bits. The best-known example is multi-level flash memory cells, which can store up to four bits per cell. While multi-level flash cells have advantages such as a higher density and lower cost, they also suffer intrinsic drawbacks such as lower writing speeds and higher power consumption.

The new six-state memory element presented here is different because it is magnetic, whereas flash memory is electronic. Although electronic memories are currently the most commonly used type of memory, various types of magnetic random access memory (MRAM) are being actively researched due to advantages in low power consumption, fast operation, and long lifetime.

"Our proposal paves the way for enjoying the benefits of multi-level cells in MRAM, making it even more attractive for applications," Lior Klein, a physics professor at Bar-Ilan University and one of the study's lead authors, told *Phys.org*. "Furthermore, since MRAM is different in its nature from flash, there is no reason that it should suffer from the drawbacks of multi-level-cell flash memory."



Six magnetic configurations generated by simulations. Credit: Telepinsky et al. ©2016 AIP Publishing

Realizing the six-state magnetic element does not require any significant increase in complexity, such as adding layers, but rather involves simply structuring one of the magnetic layers differently—specifically, arranging the magnetic film into a pattern of three crossing ellipses. In the middle region where all three ellipses overlap, the researchers found that there are six different stable magnetic orientations. The orientations are parallel to the long axis of each ellipse, and can run in two opposite directions.

If such a pattern with six magnetic orientations can be controlled and incorporated in a magnetic memory element, then the number of memory states can be increased from two to six. The researchers showed that such control is possible by using a technique called spin-orbit torque switching, which uses spin-polarized electric current to switch between magnetic states. This demonstration shows that the spin-orbit torques can write data onto the magnetic structure, showing the potential for using the structure as a memory element.

The main advantage of having six states is that it would increase the memory density while avoiding the problems inherent in miniaturization. Currently the primary strategy for increasing memory density is to miniaturize each memory element so that more of them can fit on a chip. However, at these small scales, the memory elements are so close together that they begin to interfere with each other's states. The new design can avoid this problem, and also offers other advantages.

"Going from two to six states would triple the density under certain conditions (for example, maintaining the lateral scale of the bit)," Klein said. "In addition, other advantages are also expected. The cost of the memory would probably decrease significantly, and when such bits are incorporated in a magnetic memory array, we may witness other benefits such as increased reading speeds."

The researchers expect that it may be possible to design patterns with even more magnetic states. For example, their simulations show that a pattern of four crossing ellipses would yield a memory element with eight magnetic memory states.

"We intend to further increase the number of magnetic states and explore the limits of such an extrapolation," Klein said. "In addition, we would like to progress towards fabricating a prototype that will help us convince the magnetic memory industry to make a shift towards multi-level magnetic memory."

More information: Yevgeniy Telepinsky *et al.* "Towards a six-state magnetic memory element." *Applied Physics Letters*. DOI: 10.1063/1.4948455