Researchers flip a magnetic memory cell with a light pulse at record speed

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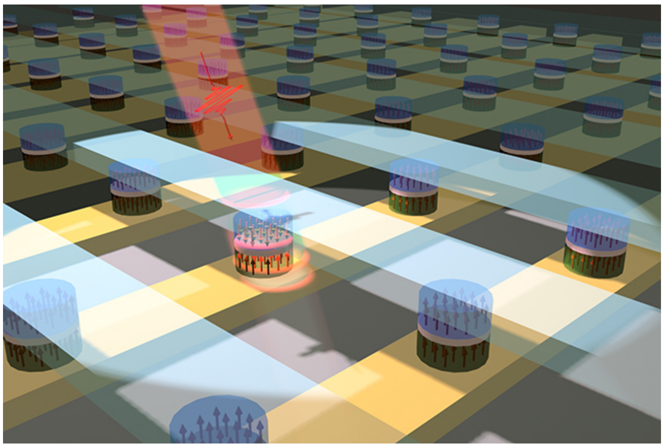

One modification researchers made to the device was to use a transparent electrical material called indium tin oxide for the electrode to allow light to pass through it. These layers are stacked into a pillar with a diameter of only 10 µm, which is only one-tenth the diameter of a typical human hair. Credit: Junyang Chen, University of Minnesota

University of Minnesota electrical and computer engineering researchers have created a magnetic tunnel junction that can be switched by a pulse of light lasting one trillionth of a second—a new record. The magnetic tunnel junction is critical to information technology advances with the termination of Moore's law, a principle that has ruled the microelectronics industry for five decades.

This advancement holds promise for the development of new, optically controlled, ultrafast magnetic devices collectively called spintronics (electronics that combine optical and magnetic nanotechnologies). These devices could lead to innovations in the storage, processing, and communication of information. An example of such innovation would be the development of a system that, like the human brain, can both store and analyze a large amount of data simultaneously.The details of the device and the tests conducted on it are reported in a paper published recently in *Physical Review Applied*, a journal of the American Physical Society.

Typically, the magnetic tunnel junction has a "sandwich-like" structure comprised of two layers of magnetic materials with an insulating layer, called barrier, in the middle. Information is written on the magnetic material by reversing the magnetization of one of the layers. This reversing process often involves spiral motion in the spinning electrons, called spin processing. However, there is a limitation on how fast the spin processing can be. The brakes are applied at roughly 1.6GHz, a current speed record that is much slower than silicon transistors. To enable faster writing speeds, the limitations on speed have to be overcome.

"With our invention of a new magnetic tunnel junction, there is now a way to speed things up," said Mo Li, an associate professor in the University of Minnesota Department of Electrical and Computer Engineering who led the research.

Inspired by the 2007 discovery by Dutch and Japanese scientists showing that the magnetization of an alloy of a rare earth element, called gadolinium (Gd), with iron (Fe), and cobalt (Co) could be switched using light pulses, University of Minnesota researchers used the alloy to replace the upper magnetic layer of a conventional magnetic tunnel junction. Another modification they made to the device was to use a transparent electrical material called indium tin oxide for the electrode to allow light to pass through it. These layers are stacked into a pillar with a diameter of 10 ?m, which is only one-tenth the diameter of a typical human hair.

To test their work, researchers sent laser pulses to the modified device using a low-cost laser based on optical fibers that emits ultrashort pulses of infrared light. The pulses are sent one in every microsecond (one millionth of a second), but each pulse is shorter than one trillionth of a second. Every time a pulse hit the magnetic tunnel junction pillar, the scientists observed a jump in the voltage on the device. The change in voltage confirms that the resistance of the magnetic tunnel junction "sandwich" changes each time the magnetization of the GdFeCo layer is switched. Because each laser pulse lasts less than 1 picosecond (a millionth of a microsecond), the device is capable of receiving data at an amazing rate of 1 terabit per second.

Li said the research holds exciting prospects. "Our result establishes a new means of communication between fiber optics and magnetic devices. While fiber optics afford ultra-high data rate, magnetic devices can store data in a non-volatile way with high density," he said.

Professor Jian-Ping Wang, director of the Center for Spintronic Materials, Interfaces, and Novel Structures (C-SPIN) based at the University of Minnesota and co-author of the study, also sees great promise. "The results offer a path toward a new category of optical spintronic devices that have the potential to address future challenges for developing future intelligent systems.

"These systems could use spin devices as neurons and synapses to perform computing and storage functions just like the brain, while using light to communicate the information," Wang said.

The ultimate goal for the research team is to shrink the size of the magnetic tunnel junction to less than 100 nanometers and reduce the required optical energy. To this end, the team is continuing its research, and is currently engaged in optimizing the material and structure of the device, and working on integrating it with nanophotonics.In addition to Li and Wang, postdoctoral associate Junyang Chen, and graduate student Li He are lead authors of the paper.

More information: Jun-Yang Chen et al, All-Optical Switching of Magnetic Tunnel Junctions with Single Subpicosecond Laser Pulses, *Physical Review Applied* (2017). DOI: 10.1103/PhysRevApplied.7.021001

Provided by University of Minnesota

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