Ultrafast optical-magnetic memory device

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Magnetic random-access memory (MRAM) technology offers substantial potential towards next-generation universal memory architecture. However, state-of-the-art MRAMs are still fundamentally constrained by a sub-nanosecond speed limitation, which has remained a long-lasting scientific challenge in the spintronics R&D. In this double doctorate project, Luding Wang experimentally demonstrated a fully-functional picosecond opto-MRAM building block device, by integrating ultrafast photonics with spintronics.

MRAM development bottlenecks

Have you ever experienced an unexpected shutdown of your computer, losing documents in the process that you have spent hours working on? Magnetic random-access memory (MRAM) technology focuses on manipulating electron spin to deal with such a technical glitch. Inside MRAM bits, data are written by switching the direction nanomagnets. Thus, MRAM allows data to be saved in an enduring manner when the power is off, computers to boot faster, and the devices consume less power.

Over the past 25 years, two major generations of MRAMs have been invented and released to the market. The earliest MRAMs employ a magnetic field to write the bits, whereas state-of-the-art MRAMs implement a spin-current based method. However, the data writing process of these MRAMs have been hindered by a long-lasting challenge: the speed is limited to the nanosecond regime and consumes a lot of power.

Ultrafast photonics integration

In this thesis, Luding Wang from the research group Physics of Nanostructures at the department of Applied Physics integrates a rapid development in the field of ultrafast photonics, the femtosecond (fs) laser: the fastest stimuli commercially available to humankind to break the nanosecond speed limitation, and in the process make it a thousand times more energy efficient.

In this double doctorate project, researchers from Eindhoven University of Technology (TU/e) led by prof. dr. Bert Koopmans, and the Fert Beijing Institute of Beihang University led by prof. dr. Weisheng Zhao, have shown the first proof of concept of this spintronic-photonic memory using an interdisciplinary mindset.

Hybrid optical-MRAM memory

Inspired by the femtosecond laser-induced all-optical switching (AOS) schemes in synthetic ferrimagnetic multilayers discovered by TU/e in 2017, integrating it with MRAM bit has emerged as a competitive route toward next-generation MRAM design. From his Ph.D. research, Wang reports on the design and characterization of such a "hybrid" opto-memory device, coined an opto-MRAM bit cell. He shows a world-record writing speed of 20 picoseconds (ps), which is 1–2 orders of magnitude beyond the current state-of-the-art MRAMs, with an enhanced energy efficiency (≈ 100 femtojoules to switch a 50×50 nm2 sized bit).

This first step toward the development of an "opto-MRAM" is a very promising start towards a unique non-volatile photonic memory. It enables a direct conversion of optical information to magnetic information, without energy-costly electronic conversion steps in between. Moreover, the experimental results represent an important advance to stimulate further fundamental scientific studies that combine the fields of spintronics and photonics.

More information: Integrating ultrafast all-optical switching with magnetic tunnel junctions. research.tue.nl/en/publication … ith-magnetic-tunnel-