A femtosecond twist to magnetism

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RESEARCH HIGHLIGHT

A femtosecond twist to magnetism

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Imagine being able to write magnetic information efficiently at THz data rates, creating such content using only the helicity of light. A consortium of researchers from institutes in San Diego, Nancy, Tsukuba and Kaiserslautern recently showed the feasibility of this process, using femtosecond laser pulses. In a recent issue of Science, Lambert *et al.*[1] demonstrate all-optical helicity-dependent switching (AO-HDS) in ferromagnetic thin films with perpendicular magnetic anisotropy, $[Co/Pt]_n$ multilayers, as well as in granular recording media. Firing trains of femtosecond laser pulses while moving the laser spot across the specimen caused traces with up or down magnetization to be written when using left- or right-circularly polarized light, respectively, independently of the original magnetic state (see Figure 1).

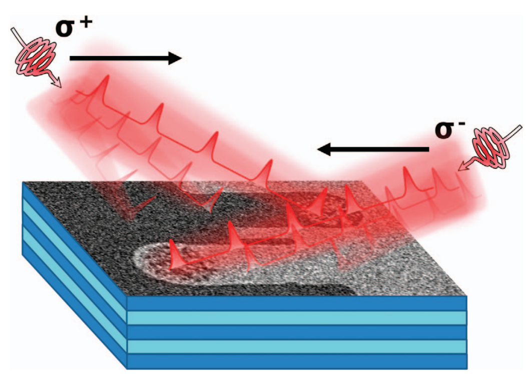

Figure 1 Kerr microscope image showing right- and left-circularly polarized laser pulses writing opposite magnetic domains while a train of laser pulses moves across a $[Co/Pt]_2$ thin film.

Similar AO-HDS results were reported 7 years ago for rare earth/transition metal alloys by Stanciu *et al.*[2] from the University of Nijmegen. However, the new data have completely altered what was previously understood about the switching process. Originally, Stanciu *et al.*[2] suggested that AO-HDS is governed by the so-called inverse Faraday effect (IFE), by which coherent magnetization is temporarily induced by circularly polarized light, acting as a seed for the magnetic state to be written. Later, the actual switch was demonstrated to be polarization independent; it was the result of a subtle balance between laser heating and exchange scattering between spins in two, oppositely polarized sublattices present in the investigated ferrimagnetic materials.[3] The resultant AO-HDS was a side effect of the dichroic nature of the materials, making laser heating dependent on helicity.[4]

From this perspective, the new data by Lambert *et al.*[1] are incredible, compelling the entire research field to reconsider these concepts. Using simple magnetic materials with similarly polarized sublattices, the presently accepted theory, valid for ferrimagnets only, does not apply. Could it be that, in this new class of materials, the IFE is at play? This is highly debatable because of the short coherence time in metallic films. Is there another, as yet unknown, mechanism that accomplishes storage of the angular momentum from the laser field, for an adequate amount of time to seed the growth of a reverse magnetic domain in the picoseconds after laser excitation? The authors have not yet resolved this mechanism. Meanwhile, the field has started a race for truly time-resolved data by employing pump-probe experiments. These experiments have not been reported in the first publication, but the data are essential for finding further fingerprints of the underlying mechanism. Once the overall understanding has improved, development of entirely new scenarios, as well as ultrafast storage, memory and logic devices, could be envisioned.

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