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Breaking the Speed Limit of Magnetic Recording

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Spectroscopy of Solids and Interfaces

We have demonstrated controlled magnetization reversal induced by a single femtosecond circularly polarized laser pulse in the ferrimagnetic alloy GdFeCo. Today, magnetism is the base of most data storage. In magnetic memory devices, logical bits ("ones" and "zeros") are stored by setting the magnetization vector of individual magnetic domains either 'up' or 'down'. It is generally accepted that the fastest way to record a bit is to reverse the magnetization via magnetic field-induced precesional motion. However, it was recently concluded that this approach has an intrinsic speed limit of a few picoseconds. It was shown that using strong magnetic field pulses of about 2 picoseconds duration, the magnetization fractures and the switching behavior becomes chaotic[1].

Optical pulses could serve as an alternative stimulus to trigger magnetization reversal. In theory, circularly polarized light should have the ability to act upon a magnetic system in a way similar to a magnetic field directed parallel to the wave-vector of the light. Moreover, right- and left-handed circularly polarized waves should act as magnetic fields of opposite sign, as was only recently confirmed experimentally[2,3].

However, magnetization reversal induced by a sub-picosecond stimulus, i.e. a 180° switching of the magnetization into a stable and oppositely magnetized state, has remained an important fundamental and technological challenge. Further adding to this challenge is the common belief that the number of photons available in optical experiments is far from enough to contribute any significant amount of angular momentum to the magnetic system[4]. Despite the predicted speed limit and shortage of photons, we here demonstrate that a single 40 femtosecond circularly polarized laser pulse can cause well controlled permanent magnetization reversal in materials typically used for data storage. No external magnetic field is required for this opto-magnetic switching, and the stable final state of the magnetization is unambiguously determined by the helicity of the laser pulse. This finding demonstrates an efficient and straightforward way of recording as well as pushes the possible speed limit of magnetic writing by two orders of magnitude.

As a simple illustration of opto-magnetic recording it is shown in Figure 1 how optically written bits can be overlapped and made much smaller than the beam waist by modulating the polarization between right- and left-handed circularly polarized laser pulses as the laser beam is swept across the sample[5]. With the recent development of compact ultrafast laser systems and the successful incorporation of lasers in magnetic storage devices, the present demonstration of ultrafast all-optical magnetization reversal might spur the realization of a new generation of ultrafast magnetic recording devices.

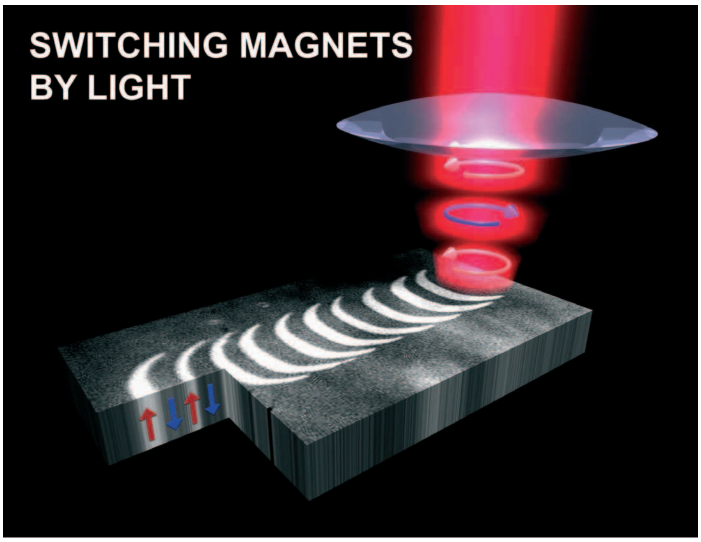

Figure 1. Demonstration of compact all-optical recording of magnetic bits by femtosecond laser pulses. This was achieved by scanning a circularly polarized laser beam across the sample and simultaneously modulating the polarization of the beam between left- and right circular. White and black areas correspond to 'up' and 'down' magnetic domains, respectively.

Literature

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