A single laser pulse to reverse magnetisation without any applied magnetic field

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The development of new strategies for changing the magnetic state of nanostructures on ultra-short time scales meets an ever-growing demand from the information storage industry using magnetic memory points (hard disk, MRAM magnetic random access memory). Historically, magnetic media were written by using a magnetic field. However, this method proved limiting when the size of the bits was reduced to a scale of less than a hundred nanometres and the writing speed was increased beyond GHz. Alternative solutions have emerged, using spin-polarised currents in nanometer-sized magnetic structures, such as spin-transfer torque switching or, more recently, spin-orbit torque switching. However, these technologies are limited by the sharp increase in current density required when the pulse duration is reduced, which rules out their use on time scales of less than 100 picoseconds.

In 1996, Beaurepaire and colleagues demonstrated that excitation of a thin Ni film by a femtosecond laser pulse led to its demagnetisation in a fraction of a picosecond [1]. This major discovery launched the field of femtomagnetism. Nearly fifteen years later, all-optical switching (AOS) of the magnetisation of ferrimagnetic GdFeCo alloys was demonstrated using a single laser pulse [2], with magnetisation reversal achieved in 1 picosecond. The effect is explained by an ultra-fast heating process linked to the distinct dynamics of rare-earth and transition metal elements and related to the high transient temperature of electrons in disequilibrium with the lattice. The observation of AOS has long been limited to materials containing Gd.

In this presentation, we will describe the evolution of this field of research over the last ten years. We will show that this reversal is not restricted to the use of materials containing Gd [3,4,5], that it is a fairly general phenomenon, that these materials can be integrated into commercial MRAM-type devices [6] and that it is even possible to do away with ferrimagnetic alloys by using exclusively ferromagnetic materials already used in commercial devices [7].

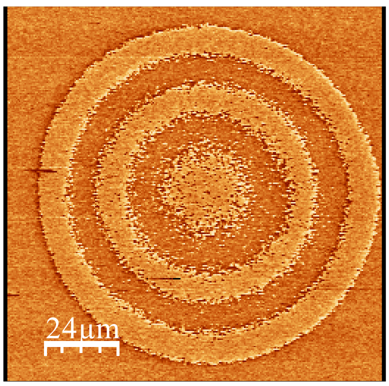

Figure: Domain structure stabilised after a single laser pulse of 5 ps. Image obtained by magnetic force microscopy. The orange (respectively brown) areas correspond to domains pointing upwards (respectively downwards) perpendicular to the plane of the sheet/screen.

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