Ultrafast optical manipulation of magnetic order: challenges and opportunities

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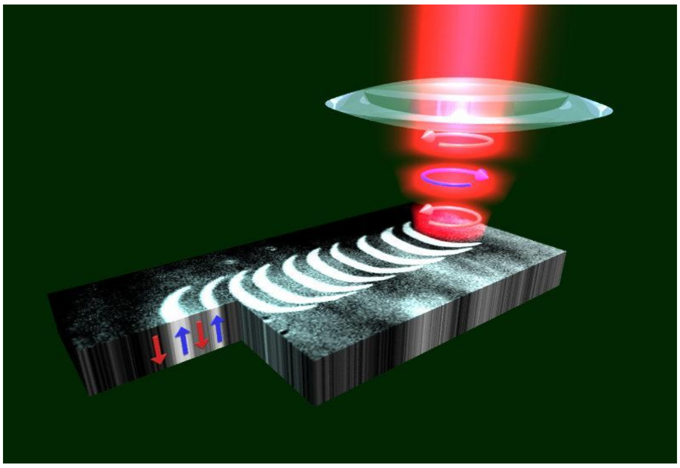
The interaction of sub-picosecond laser pulses with magnetically ordered materials has developed into an extremely exciting research topic in modern magnetism and spintronics. From the discovery of sub-picosecond demagnetization over a decade ago to the recent demonstration of magnetization reversal by a single 40 femtosecond laser pulse, the manipulation of spins by ultra short laser pulses has become a fundamentally challenging topic with a potentially high impact for future spintronics, data storage and manipulation and quantum computation.

Recent single-shot pump-probe magneto-optical imaging results show that circularly polarized subpicosecond laser pulses steer the magnetization reversal in a Transition Metal-Rare Earth alloy along a novel and ultrafast route, which does not involve precession but occurs via a strongly nonequilibrium state. However, the nature of this phase and the dynamics of the individual TM and RE moments remained elusive so far. Experiments indicate a possible difference in the dynamics of the TM and RE moments at time scales that are currently limited by the pulse widths of the optical excitations employed (~100fs). To investigate such highly nonequilibrium phases requires both excitation and probing at ultra short time scales and selectivity for the individual moments.

In addition, when the time-scale of the perturbation approaches the characteristic time of the exchange interaction (~10-100 fs), the magnetic dynamics may enter a novel coupling regime where the exchange interaction may even become time dependent. Using ultrashort excitations, we might be able to manipulate the exchange interaction itself. Such studies will require the excitation and probing of the spin and angular momentum contributions to the magnetic order at timescales of 10fs and below, a challenge that might be met by the future fs X-ray FEL's.



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. How and how fast does this work?

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