Ultrafast photo manipulation of magnetization and non-local spin dynamics

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For further progress in applications on magnetic magnonic and spintronic technology, ultrafast control of magnetization (ordered spin system) is an issue of crucial importance. Controlling magnetism by light is one of the promising approaches as appealing scenario. For photo manipulation of magnetization, femtosecond laser pulses that are among the shortest stimuli in contemporary technologies could serve as an alternative stimulus to manipulate spin order and trigger magnetization reversal.

An ultrashort laser pulse allows excitation of magnetic systems at time scales much shorter than fundamental quantities such as spin precession or spin-lattice relaxation times. Deterministic magnetization reversal was demonstrated[1)2)] in ferrimagnetic GdFeCo driven by single shot irradiation of laser pulse without the presence of a magnetic field. This All Optical Switching (AOS) phenomena originated from transient non-equilibrium state and sub-lattice nature is fundamentally different from conventional magnetic field driven switching mechanism. Furthermore, from the compositional dependency of all-optical light helicity-dependent magnetic switching (AO-HDS) in ferrimagnetic GdFeCo alloy, it is found that AO-HDS is associated with the collinear sub-lattice magnetization and an explanation of the AO-HDS based on magnetic circular dichroism exactly matches the above features of experiments[3)].

Recently, it is revealed that further extraordinary spin dynamics in ultrashort time scale such as bellow ps region by ultrafast diffraction experiments with an X-ray probing[4)]. In particular, we observed Gd spin reversal in Gd-rich nano-regions within the first picosecond driven by the non-local transfer of angular momentum. These results suggest that a magnetic microstructure can be engineered to control transient laser-excited spins, potentially allowing faster spin reversal. Furthermore, AOS depends on the non-adiabatic energy dissipation of electron system in the GdFeCo layer from the incident surface in the depth direction during a few picoseconds[5)]. It will be also shown that employing plasmonic gold nano-antennas placed above TbFeCo magnetic layer it should be possible to confine photo-magnetic excitation in a spot well below diffraction limit as the order of 50 nm[6)]. Ultrashort non-local phenomena in magnetic material will be discussed.

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