ULTRAFAST MAGNETO-ACOUSTICS

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In magnetic metallic materials, the magnetization dynamics M(t) resulting from the interaction of ultrashort light pulses (femtosecond lasers) with the spins of the metal is due to several physical mechanisms. The spin-orbit interaction is efficient to modifiy the spin angular momentum in a time scale as short as the laser pulse itself (a few tens of femtoseconds). The Coulomb interaction (exchange and Pauli exclusion) is efficient when both the charges and the spins thermalize to a hot Fermi Dirac distribution, a process which occurs within a few hundreds of femtoseconds. The spin-phonon and magnon-phonon interactions are predominant when the magnetization comes back to its original value $M(t \ll 0)$, a process which occurs in two steps. First, during the equilibrium between the charges and the spins with the lattice dynamics (heating), M(t) re-increase within a few picoseconds. Second M(t) still increases and ultimately comes back to its initial value when the heat dissipates into the environment within a few hundreds of picoseconds. During this last process, the magnetization vector can precess around the effective field if the anisotropy of the metal has been sufficiently modified, due to the temperature change induced by the absorption of the laser photons. Therefore, one can take advantage of the changes of anisotropy to manipulate the magnetization. We propose here to study several effects related to the change of anisotropy induced by the laser interaction with the metal.

Of particular interest is the dynamical regime corresponding to the generation of longitidinal and transverse acoustic waves. We already know [1] that a longitudinal acoustic wave can propagate in a nickel film so that the corresponding lattice deformation modifies the anisotropy and therefore the effective field. It results in a precession of the magnetization that can be observed in time resolved magneto-optical measurements. In the present thesis, the conditions for inducing a switching with such magneto-acoustic coupling will be studied. Then the magnetization dynamics induced by transverse waves will be studied. These experiments will be carried out with a new laser system which wavelength can be tuned from the visible to the near IR. Second the magneto-acoustics waves will be studied with TeraHertz laser pulses that present the advantage to be on resonance with the magneto-acoustic waves.

The PhD student will perform experiments as well as perform numerical simulations of his/her results, using the Landau-Lifshitz formalism and acoustic deformation propagation in solids, taking into account the impedance between the various media (sample and substrate).

[1] Ji-Wan Kim, Mircea Vomir, and Jean-Yves Bigot, Phys. Rev. Lett. 109, 166601 (2012)