Ultrafast transfer of angular momentum in ferromagnets

Jean-Yves Bigot

Institut de Physique et Chimie des Matériaux de Strasbourg
UMR7504, CNRS, Université de Strasbourg
23 rue du Loess, 67034 Strasbourg Cedex, France

Studying the ultrafast magnetization dynamics of ferromagnetic materials using femtosecond laser pulses is an interesting approach both from a fundamental point of view and for potential applications in spin-photonics. It is now well known that several steps occur after the excitation of the ferromagnet with an intense optical pulse. First the electrons and spins thermalize to a hot Fermi distribution ($\sim$100 fs) due to the electron-electron scattering with the appropriate many body correlations. Then they cool down by relaxing their excess energy to the lattice ($\sim$1 ps) by interacting with the phonons. Subsequently the energy is dissipated into the environment (a few picoseconds up to nanoseconds) which may consist of the unexcited part of the studied sample or to the substrate. The dynamics of these different subsystems can be fairly well described phenomenologically by a three temperatures model where three coupled baths are considered with temperature T_e for the electrons (charges), T_{spin} for the spins (magnetization) and T_l for the phonons (lattice dynamics). The modeling can be further improved by taking into account the non-thermal regime of the charges and spins populations which prevail until they reach their equilibrium temperatures T_e and T_{spin}. This approach is satisfying from the point of view of the energy balance.

A complementary aspect to the magnetization dynamics concerns the total angular momentum which also must be conserved. More generally, the transfer of angular momentum in a correlated spin system perturbed by a laser pulse is important to take into account as it is related to the mechanisms which induce the spin flips associated to the demagnetizing process. This is the topic that we have investigated recently and that will be reported in our presentation [1,2]. Two main aspects will be raised. First the coherent interaction between the laser and the ferromagnetic system. We will describe the corresponding dynamics of the charges and spins of Ni and CoPt films excited by 50 fs pulses. Second the dynamics of the orbital and spin moments, observed by time resolved femtosecond Xrays magnetic circular dichroism, will be described in CoPd films.

[1] J.-Y. Bigot, M. Vomir, E. Beaurepaire, Nature Physics **5**, 515 (2009).

[2] C. Boeglin, E. Beaurepaire, V. Halté, V. López-Flores, C. Stamm, N. Pontius, H. A. Dürr and J.-Y. Bigot, Nature **465**, 458 (2010).