Optical spin transfer torque in two dimensional ferromagnets

The cornerstone of spintronics is manipulation of spins in magnetic materials. The magnetic domains store data (0's and 1's). Finding efficient ways for writing (switching the direction of magnetization) and read-out (detecting the magnetization direction) of data are important for data storage and data processing. So far, several methods have been proposed and successfully realized for manipulation of magnetization direction such as external magnetic fields, spin-currents, spin-orbit torques and spin waves. Realization of the magnetization switching via femtoseconds circularly polarized laser pulses in ferrimagnets, antiferromagnets and very recently in ferromagnetic materials promises a new way to ultrafast spintronics. So far, most of theoretical and experimental works on the ultrafast light-induced magnetization dynamics have been focused on a parallel configuration, in which light propagates along the initial magnetization direction. In this configuration, light induces two effective magnetic fields $\mathbf{B}_{\mathrm{eff}}$, along the light propagation direction and magnetization. One of them is helicity dependent called inverse Faraday effect (IFE), and other is helicity independent called inverse Cotton-Motton effect (ICME). Both of these fields cannot exert a torque **T,** on the local initial magnetization $\mathbf{M}$, *i.e.* $\mathbf{T} \propto \mathbf{M} \times \mathbf{B}_{\mathrm{eff}} = \mathbf{0}$.

On the other hand, it was shown that in the case of perpendicular configuration, i.e. the magnetization vector perpendicular to the light propagation direction, two effective helicity dependent magnetic fields perpendicular to the initial magnetization direction exert torques on the local magnetization. One of them is the usual IFE along the light propagation direction, but in this configuration; this field can exert an in-plane torque on the local magnetization. Another effective magnetic field is perpendicular to the both light and magnetization directions. The later exerts an out-of-plane torque on the local magnetization called optical spin transfer torque (OSTT).

In this project, first, we model a two-dimensional metallic (anti)ferromagnetic system with a simple Hamiltonian called (anti)ferromagnetic Rashba Hamiltonian. Then within the second-order perturbation theory, we will calculate different torques (or equivalently magnetic fields) arising from the light: OSTT, IFE and ICME. This project is mostly analytical with some numerical calculations. The aim of this project is to offer a taste of research in one of the hot topics in condensed matter physics and show how simple mathematical models, are able to describe the real and complex world.

Pre-knowledge requirements: Basic courses in solid-state physics, quantum mechanics and mathematics. Programming ability is an advantage.

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