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Experimental observations of optical spin-transfer and spin-orbit torques in magnetic semiconductors[1]

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The spin transfer torque (STT) is a non-relativistic phenomenon where angular momentum of spin polarized carriers electrically injected into a ferromagnet from an external polarizer is transferred to the magnetization [1]. In the absence of an external polarizer a distinct phenomenon can occur in which carriers in a magnet under applied electric field develop a non-equilibrium spin polarization due to the relativistic spin-orbit coupling, resulting in a current induced spin-orbit torque (SOT) [1]. We show, using the experimental data observed in the ferromagnetic semiconductor (Ga,Mn)As, that there exists optical counterparts of STT (OSTT) [2] and SOT (OSOT) [3]. In OSTT a circularly polarized femtosecond pump laser pulse acts as the external polarizer and it induces a coherent magnetization precession due to the angular momentum transfer, in a direct analogy to the current induced STT [2]. The absence of an external polarizer in OSOT corresponds to photo-carrier excitations which are independent of the polarization of the pump laser pulses and the phenomenon relies on spin-orbit coupling of non-equilibrium carriers, as in the case of the current induced SOT [3]. Our work demonstrates the possibility to study the spin-transfer and spin-orbit torques on the sub-picosecond time-scales using the optical pump-and-probe experimental technique.

[1] A. Bratas et al., Nature Materials 11, 372 (2012).
[2] P. Nemec et al., Nature Physics 8, 411 (2012).
[3] N. Tesarova et al., submitted, arXiv: 1207.0307.

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