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EINLADUNG zum IFP-SEMINAR

Ultrafast magnetization dynamics beyond the three temperature model

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Host:	Marco Battiato
Termin:	Donnerstag, 24. November 2016, 12:00 Uhr
Ort:	Institut für Festkörperphysik, TU Wien Wiedner Hauptstraße 8-10, 1040 Wien Seminarraum DB gelb 09 (gelber Bereich, 9. OG)
Förderer:	FWF M1925-N28 FeMDy

Femtosecond lasers allow to observe magnetization dynamics on unprecedently short timescale. It has been commonly described employing the three temperature model, without information about its validity. We examine by means of ab initio calculations when this model fails to describe correctly the specific subsystems (electrons, spins and lattice).

In order to study the lattice subsystem we calculate the electron-phonon scattering rates for systems with high electronic temperature [1], and phonon lifetimes due to phonon-phonon scattering. From this we obtain phonon population that differs sharply from the thermal one within picoseconds after the pump. This allows to understand recent experimental observations and disproves the applicability of the model based on one lattice temperature here [2].

Equilibration between magnetizations of 4f and 5d electrons represents an interesting problem that can be studied in Gd metal pumped by a fs laser, employing first principles exchange interaction between atomic moments, as well as the intra-atomic exchange between 4f and 5d orbitals. Spin dynamics solution of the corresponding effective orbital-resolved Heisenberg Hamiltonian has shown disparate magnetization dynamics of the 4f and 5d moments, in a good agreement with the experiment [3].

An ultrashort laser pulse excites electrons occupying the d band into the s band, which is characterized by higher electron mobility. As a result of the nonequilibrium situation due to laser heating, hot charge carriers move away and remarkably reduce the local magnetic moment [4].
This mechanism results in ultrafast generation of spin currents which emerge in an adjacent nonmagnetic layer. Consequently, the spin current of hot electrons can exert spin transfer torque (STT) on another magnetic layer in a multilayer structure, as recently observed in experiments [5]. We again examine the question whether this mechanism is thermal or not, which is related to its similarity to the spin-dependent Seebeck effect.

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[5] K. Carva, Nat. Phys. **10**, 552 (2014); A.J. Schellekens, K.C. Kuiper, R.R.J.C. de Wit, B. Koopmans, Nature Comm. **5**, 4333 (2014); G.-M. Choi, B.-Ch. Min, K.-J. Lee, D.G. Cahill, Nature Comm. **5**, 4334 (2014)