

Ultrafast dynamics of highly correlated materials

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The electronic properties of highly correlated materials are often governed by strong electron-phonon coupling and correlation effects leading to phenomena like formation of charge density waves (CDW), metal insulator transitions and superconductivity. When an ultrashort laser pulse drives the system out of equilibrium the response of the correlated electronic system and the relaxation of lattice degrees of freedom occur typically on different timescales. Time- and angle-resolved photoelectron spectroscopy (trARPES) provides direct access to the dynamics of the electronic structure of such photoexcited materials. In particular both single particle excitations and collective modes (e.g. coherently excited phonons) can be analyzed via the temporal evolution of the spectral function.

In this talk I will present several applications of femtosecond trARPES to optically excite and probe the dynamics of correlated electron systems, namely the Mott insulator TaS₂ and the CDW compound TbTe₃, as well as high T_c superconductors (iron pnictides). In TaS₂ photoexcitation by an intense laser pulse leads to an ultrafast (<50fs) insulator-to-metal transition towards a gapless phase which is accompanied by periodic oscillations of the electronic states. This is in clear contrast with the retarded (>100fs) response which we observe for the transient melting of the CDW phase in TbTe₃. Applying trARPES to iron pnictides superconductors we are able to demonstrate momentum dependent electron relaxation dynamics as well as collective excitations in real time.

Finally, we discuss recent experiments employing intense phase-locked electromagnetic transients in the terahertz (THz) spectral domain to coherently control collective spin oscillations (magnons) in the prototypic antiferromagnet NiO. Remarkably, the spins in NiO are excited by the magnetic rather than the electric field of the intense THz transient. In contrast to optical excitation, the THz field addresses the spins resonantly via direct Zeeman interaction leaving other degrees of freedom unchanged. A sequence of two pulses in this contact-free THz electron spin resonance technique (THz-ESR) is used to coherently switch on and off the cooperative spin precession at a frequency as high as 1 THz.

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