

Ultrafast pump-probe experiments: application to correlated electron systems

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Abstract. Among strongly correlated electron systems, superconductors and materials exhibiting metal-insulator transitions are usually characterized by strong electron-electron and electron-phonon couplings. Studying their electronic structure, atomic structure and phonon spectrum provides insight on the mechanisms of their phase transitions, which take place on quasi-adiabatic pathways. Correlated electrons systems also display fascinating out-of-equilibrium physics, in the form of ultra-fast symmetry changes known as photoinduced phase transitions, and occurrence of new, transient states. Out-of-equilibrium states are typically obtained by irradiation with ultra-short optical laser pulses. Those induce electronic transitions on a timescale for which the lattice is considered to be frozen, leading to a transient decoupling between electronic and lattice degrees of freedom. One then has the opportunity to study their mutual interaction during the relaxation process and, in certain cases, to modify their interaction in a controlled way. Ultrafast photo-induced dynamics of atomic and electronic structures are studied directly in the time domain, during so-called “pump-probe” experiments. The sample is excited (pumped) by a fs optical laser pulse, and probed after a delay Δt by a light pulse in the infrared, visible, UV or X-ray range of wavelengths. In the last decades, various experimental techniques were adapted to the pump-probe scheme, among which ARPES and X-ray diffraction that are especially relevant for studying correlated electron systems. The lecture will present various pump-probe setups used nowadays and examples of current research topics involving out-of equilibrium dynamics.

Suggested introductory readings (textbook, review or articles)

1. P. Beaud, A. Caviezel, ..., S.L. Johnson, U. Staub, *Nature Materials* **13**, 923 (2014)
2. S. Hellmann, T. Rohwer, ..., M. Bauer, K. Rossnagel, *Nature Comm.* **3**, 1069 (2012)
3. L. Guérin, J. Hébert, ..., H. Cailleau, E. Collet, *Phys. Rev. Lett.* **105**, 246101 (2010) //
C. Laulhé, T. Huber, ..., S.L. Johnson, S. Ravy, *Phys. Rev. Lett.* **118**, 247401 (2017)
4. R. Mankowsky, M. Först, A. Cavalleri, *Rep. Prog. Phys.* **79**, 064503 (2016)