Insights on condensed matter functions by FEL x-ray pulses

H.T. Lemke[1]*

[1]*Paul Scherrer Institute, 5232 Villigen, Switzerland*

*e-mail: henrik.lemke@psi.ch

Condensed matter and its functionality determine most processes in life and technology and therefore natural sciences. New insights into transition processes that happen on ultrashort timescale out of equilibrium can be gained using ultrashort and coherent x-ray pulses from Free Electron Laser (FEL) sources. With their femtosecond pulse length, it becomes possible to interrogate structural rearrangements during transitions on the timescale of atomic motions. With hard X-ray FEL pulses, structures on atomic length scale, as well as element specific spectroscopic signatures can be interrogated, which provides highly complementary information to ultrafast laser spectroscopy. Here, ultrafast spectroscopy signals remain often ambiguous in interpretation which can be resolved by the information of ultrafast X-ray probes.

Especially the interactions in condensed matter by vibrations, magnetic state, and electronic state or polarisation can create a complex interplay and deformations which may lead to e.g. macroscopic and stable quantum states, interesting for novel technical applications. Ordering or transition processes on different degrees of freedom may be targeted and measured by selective X-ray methods like resonant and non-resonant X-ray diffraction as well as spectroscopic techniques. The typically ultrafast processes can be triggered by excitation into electronic or vibrational states involved in their transformation by light. Selectivity can be accomplished by addressing states resonantly by choice of wavelength of an ultrafast exciting laser pulse. Those typically range from THz to Ir wavelengths for vibrations, phonons, magnons, polarons, to visible and UV wavelength for electronic excitations.

The main techniques and principles in ultrafast hard X-ray studies of condensed matter will be summarized with state-of-the-art examples of questions and results gained at SwissFEL and other FEL light sources.