CFEL SCIENCE

Colloquium

24th January 2014 - 14:00

CFEL Seminar rooms I-III (DESY Bldg. 99)

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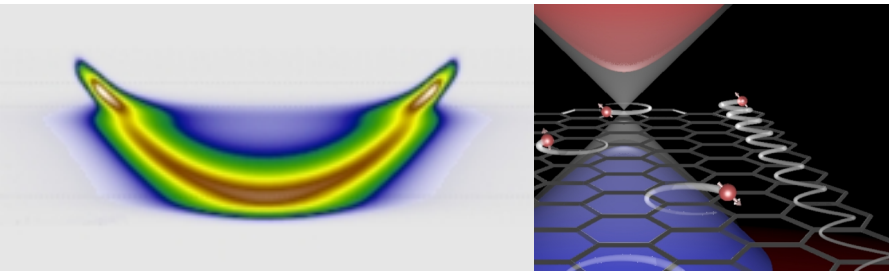
Theoretical understanding of ultrafast electron dynamics in model systems



Pump-probe laser spectroscopy, so far largely limited to the field of atomic and molecular physics, is gaining a surging interest in condensed matter physics. In this talk I will discuss two important achievements in a theoretical understanding of non-equilibrium dynamics that does not rest on any equilibrium assumptions.

One of its potentials is as a method for probing the so-called electron-phonon coupling—the dynamics of interaction between electrons and quantum modes of collective vibrations of the atomic nuclei in a solid-state material, crucial to the understanding of, for example, superconductivity among many phenomena. But, how to make sense of the “movies” obtained in this way remains a fundamental challenge. In this talk, I will discuss a significant step in the development of a concrete and general understanding of pump-probe spectroscopy studies of electron-phonon coupling. By analyzing the energy-dependent electronic relaxation time, we can directly determine the strength of electron-phonon coupling—without the need to resort to any assumptions for electronic distribution in terms of electronic temperature and underlying bare-band structure, which is required by the existing methods for determining electron-phonon coupling.

While equilibrium band gap engineering has become a major theme since the first synthesis of monolayer graphene, it was only recently proposed that circularly polarized laser light could turn trivial equilibrium bands into topological non-equilibrium bands. I will discuss simulations that observe ultrafast band gap openings and paradoxical gap closings at a critical field strength. Importantly, the gap openings are accompanied by nontrivial changes of the band topology, realizing a photo-induced Haldane multilayer system. We show that pump-probe photoemission spectroscopy can track these transitions in real time via energy gaps exceeding 100 meV. We thus predict a nonequilibrium realization of a tunable Haldane multilayer model with a Berry curvature that can be tipped optically by small changes in external fields on femtosecond time scales. Since we are focused on the physics of chiral Dirac fermions, these results apply equally to all systems possessing Dirac points, such as surface states of topological insulators.

Host: Andrea Cavalleri / Stefan Kaiser, MPSD-CFEL