Experimentelle Physik 2

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Studying electron-phonon coupling in the time domain

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The electron-phonon interaction is ubiquitous in crystalline materials, leaving fingerprints on both physical and electronic properties. In the study of materials, angle-resolved photoemission spectroscopy (ARPES) can uniquely access the momentum-resolved electronic structure in which electronic interactions are encoded. However, disentangling the contributions from different degrees of freedom -- such as electron-electron and electron-phonon – can be prohibitively difficult. Extension of ARPES into the time domain via pump-probe spectroscopy allows one to access the electronic structure on an ultrafast timescale: this is advantageous as the intertwined interactions in equilibrium become naturally separated in the time domain.

We show that time-resolved (TR)-ARPES can be used to study the mode-projected electron-phonon interaction in graphite. Specifically, we observe spectral features arising from the photoexcitation of electrons from the valence band to the conduction band, followed by quantized energy-loss processes corresponding to the emission of strongly-coupled optical phonons. The transfer of spectral weight from an identifiable initial and final state is the direct manifestation of a microscopic two-body scattering process from which we can extract the mode-projected electron-phonon matrix element.

These results – the first of their kind – were made possible by a custom-built state-of-the-art laser source featuring cavity-enhanced high-harmonic generation. In addition to high photon energies, the source features a high repetition rate that minimizes the space-charge effect and a balanced time and energy resolution capable of studying subtle spectral features. With these results, we demonstrate that the maturation of high-harmonic sources as a tunable table-top source with unprecedented intensity, repetition rate and resolution.