Direct determination of mode-projected electron-phonon coupling in the time domain

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With its direct correspondence to the electronic structure, angle-resolved photoemission spectroscopy (ARPES) is a ubiquitous tool for the study of solids. When extended to the temporal domain, time-resolved ARPES offers the potential to move beyond equilibrium properties, exploring both the unoccupied electronic structure as well as its dynamical response under ultrafast perturbation [1]. Historically, ultrafast extreme ultraviolet sources have required compromises that make it challenging to achieve a high energy resolution, while producing sufficiently high photon energies and flux. In this talk I will discuss novel opportunities arising from the development of ultrafast laser-based sources generating ultraviolet photons in the 6-40 eV range, with 190 fs and 20 meV time and energy resolutions, respectively [2]. We have developed a novel approach for the direct determination of mode-projected electron-phonon coupling in the time-domain, and demonstrated its application to the case of graphite and its Dirac-like dispersion. Measuring the characteristic time scale for quantized energy-loss processes of photo-injected electrons at the K point allows for the direct, quantitative extraction of the electron-phonon matrix elements, for specific modes, and with unprecedented sensitivity [2]. The spectral features observed in this study arise from the non-thermal (i.e. non-Fermi-Dirac) occupation of electrons. We use Boltzmann simulations to map out various regimes in graphite where non-thermal features arise. These non-thermal signatures are not unique to graphite but are ubiquitous to pump-probe experiments and are intrinsically tied to the dominant scattering processes, their timescales, and corresponding bottlenecks [3].

[1] M. Zonno, F. Boschini, A. Damascelli, JESRP **251**, 147091 (2021).
[2] M.X. Na, A.K. Mills, et al., Science **366**, 1231 (2019).
[3] M.X. Na, et al., Phys Rev B **102**, 184307 (2020).