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Femtosecond electron-phonon lock-in in FeSe via ultrafast x-ray scattering and photoemission

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Identifying the degrees of freedom that lead to the emergence of superconductivity in iron-based materials remains the subject of active research. Amongst spin-driven scenarios, it has also been suggested that electron-electron correlations enhance the electron-phonon coupling in iron chalcogenides and related pnictides, but direct experimental verification has been lacking.

Measurements of ultrafast lattice dynamics benefit immensely from the advent of x-ray free-electron lasers, providing coherent femtosecond x-ray pulses with unprecedented brilliance. Using the Linac Coherent Light Source at the SLAC National Accelerator Laboratory, we have tracked the light-induced femtosecond coherent lattice motion in FeSe, which originates from a single optical phonon mode. At same time, photoemission spectroscopy allowed us to monitor the corresponding orbital-resolved, coherent change in the electronic band structure [Science **357**, 71 (2017)]. Combining these two time-domain experiments into a "coherent lock-in" measurement in the terahertz regime permits quantifying the electron-phonon coupling strength in FeSe purely from experiments and with high precision. Notably, comparison of the experimentally derived electron-phonon deformation potential with theory reveals a strong enhancement of the coupling strength in FeSe owing to correlation effects.

More generally, the coherent lock-in approach establishes an experimental paradigm for precision measurements of fundamental physical quantities by only relying on a linear, coherent response. Thereby, it provides a purely experimental and model-free technique for unbiased tests of emergent phenomena in correlated materials.

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