Understanding complex materials using non-equilibrium spectroscopy: what can theory tell us?

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(Invited)

A powerful method to study the interactions between electrons and bosons in high-T_c superconductors is the measurement of the single-particle spectral function. The recent development of time-resolved ARPES (tr-ARPES) has allowed this measurement of be performed out of equilibrium, where the material is driven by an ultrafast laser pump pulse. We have developed a theoretical framework to complement to these experiments, and here we report on several aspects of electron-boson coupling out of equilibrium.

First, we will illustrate how time-resolved spectroscopy can be used to study the coupling between electrons and phonons observing the decay rate of the transient signals as a function of energy, momentum, and time. A sufficiently strongly coupled phonon will exhibit a signature in the tr-ARPES spectra as both a kink in the dispersion as well as a sharp change of the decay rates, and we will discuss how these effects appear out of equilibrium [1][2]. Second, we will focus on the return to equilibrium in systems with multiple interaction types, and show that there are two distinct types of scattering processes: those types of interactions that conserve the energy within a subsystem, and those that do not. While in equilibrium these two contribute equally to the linewidth, we will show that out of equilibrium they behave differently – the first type are mainly responsible for thermalization within the electronic subsystem, whereas the second type drain the energy out. As a result, the scattering rates out of equilibrium can be vastly different from the linewidth, and the features of the second type of interactions can be clearly observed [3][4].

In addition, I will present some aspects of non-equilibrium physics in BCS superconductors. We solve the Nambu-Gor'kov equations for superconductivity within the Migdal-Eliashberg approximation, obtaining a full dynamic description of non-equilibrium BCS superconductivity. The temporal behavior after a pump exhibits characteristic 2D oscillations, which we attribute to the Higgs, or amplitude mode [5]. Finally, motivated by recent experiments [6], I will illustrate how superconductivity can be enhanced or suppressed through non-linear phononics. By modifying the physical parameters, we can model the driving of a lattice distortion, leading to an enhanced T_c [7].

References:

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