भारतीय विज्ञान शिक्षा एवं अनुसंधान संस्थान पुणे
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MS Project Proposal

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Tentative title of the Project:

Phonon-Electron Equilibriation: A Keldysh Field Theoretic Study

Brief description of the proposed work: (200–400 words)

The equilibration of hot electrons , excited to a high energy state either by external electromagnetic waves or by collision with high energy particles, is relevant to a large class of problems, from pump-probe spectroscopy to stability of solid state transistors to response of photodetectors to operation of thermoelectric devices. One of the main dissipation mechanism for hot electrons is to transfer the energy to phonons through electron phonon interactions . In this project, we will study the equilibration process of a coupled electron phonon system where some electrons are initially excited to high energy states.

While the "hot electron" problem has been studied in quite some detail, most calculations treat the phonons as a thermal bath whose density matrix (or distribution functions) remain invariant with time [1]. In this project, we will consider the self-consistent time evolution of the coupled system using Schwinger-Keldysh field theory [2, 3]. In fact, one of our key motivation is to study the time evolution of the phonons and their equilibration properties. The equilibration of optical phonons in Iron based superconductors have been studied recently using pump-probe and time resolved X-Ray techniques[4]. Instead of a single massive mode, here we are interested in the many body dynamics of the longitudinal phonons.

The equilibration of phonons is of great importance in constructing low temperature efficient bolometric particle detectors. Here the high energy particle creates the hot electrons, which subsequently transfer their energy to the phonons. The rise in specific heat of the phonons (assumed to be $\tilde{}T^3$) is used to measure the energy of the particle. In this context, some key questions are: (a) How much energy is transferred to the phonons for a given excitation energy? (determines calibration) (b) How long does it take for the phonons to equilibriate (determines off-time of detectors)? (c) Do the long wavelength modes (which give rise to the T^3 law) equilibriate as a Markovian process with a scale, or does the equilibriation follow a quintessentially non-Markovian power law behaviour[5]?

In this thesis, we will try to answer these questions using a non-equilibrium field theory based approach.

References

1. Saavedra, J., Asenjo-Garcia, A. & García de Abajo, F. J. Hot-electron dynamics and thermalization in small metallic nanoparticles. *ACS Photonics* **3,** 1637–1646 (2016).
2. Keldysh, L. V. *et al.* Diagram technique for nonequilibrium processes. *Sov. Phys. JETP* **20,** 1018–1026 (1965).
3. Kamenev, A. *Field theory of non-equilibrium systems* (Cambridge University Press, 2011).
4. Mansart, B. *et al.* Ultrafast transient response and electron-phonon coupling in the iron-pnictide superconductor Ba (Fe 1- x Co x) 2 As 2. *Physical Review B* **82,** 024513 (2010).
5. Chakraborty, A. & Sensarma, R. Power-law tails and non-Markovian dynamics in open quantum systems: An exact solution from Keldysh field theory. *Physical Review B* **97,** 104306 (2018).

Signature of

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