Polaronic state across the photoinduced transition in a magnetoresistive manganite

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Creating non-ergodic 'hidden' phases beyond thermodynamic equilibrium is a key topic in condensed matter physics. Femtosecond laser pulses can induce long-lived, reversible transitions into such states, but their microscopic interactions remain elusive due to experimental limitations. Here, we combine femtosecond laser excitation with ultrahigh-resolution Resonant Inelastic X-Ray Scattering (RIXS) to probe elementary excitations in $La_{2/3}Ca_{1/3}MnO_3$ (LCMO). Ultrafast photoexcitation at 1.2 eV suppresses the Jahn-Teller distortion by renormalizing Mn^{3+} e_g electron occupancy, softening polaron energy, and stabilizing a metastable 'hidden' phase distinct from the bulk ferromagnetic metallic state. By correlating polaron energy with resistivity, together with the analysis of Jahn-Teller distortion, we reveal that polaronic states of the antiferromagnetic insulating (AFI), ferromagnetic metallic (FMM), paramagnetic insulating (PMI) and photoinduced phases in LCMO have distinct origins, highlighting the complexity of electron-lattice interactions in manganites. This laser-RIXS approach paves the way for exploring photoinduced 'hidden' phases in quantum materials with sensitivity to multiple electronic degrees of freedom.

Keywords [optional]: Polaron, RIXS, ultrafast laser, manganites, photoinduced `hidden' phase

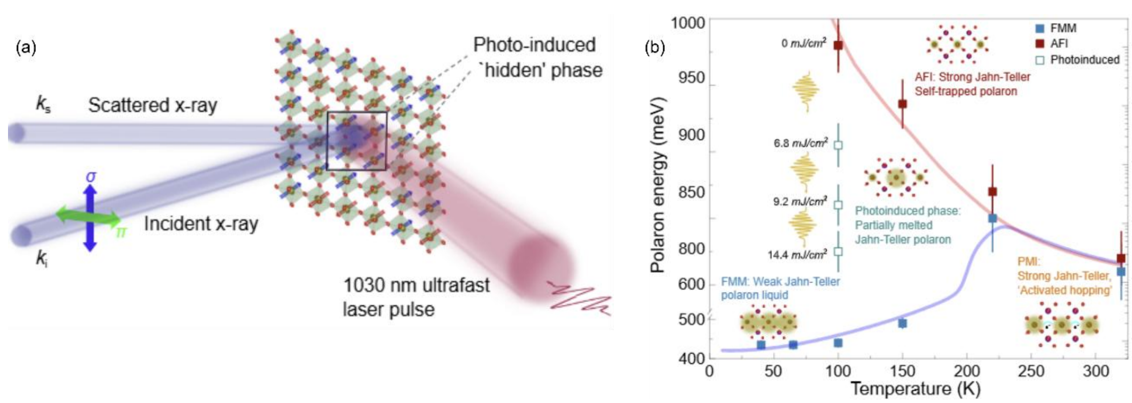

Figure 1: (a) Schematic view of the laser-RIXS experimental setup at the 2ID-SIX beamline in Brookhaven National Laboratory. (b) Polaron phase diagram of LCMO. Square data points are polaron energies measured by RIXS and the solid curves are electric resistivity. The cartoons illustrate the different Jahn-Teller polaronic states corresponding to the AFI, FMM, photoinduced, and PMI phases, respectively.