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Ultrafast Optical Excitation in $YBa_2Cu_3O_{7-\delta}$: Tracing the Optical Phonons

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The time-resolved spectroscopy of nonequilibrium states proved to be a powerful tool for observation of the electron-phonon scattering dynamics and the recombination of photoexcited quasiparticles (QP), particularly in high-temperature cuprate superconductors. However, most of the reported experiments monitor only the electronic subsystem [1-5]. Thus, a detailed dynamics of the various phonon modes during an initial non-thermal regime has been beyond reach. Here we utilize the field-resolved ultrabroadband THz spectroscopy to resonantly trace ultrafast phonon and QP dynamics of optimally doped single crystals of $YBa_2Cu_3O_{7-\delta}$ [6]. The superconducting state is perturbed by 12-fs optical pump pulses, and the induced changes in the mid-infrared optical conductivity are probed by THz transients. Thus, we simultaneously observe the dynamics of nonequilibrium QPs and two specific phonon modes with a time resolution of 40 fs. A quantitative line shape analysis of the apex oxygen vibration allows us to separately follow its transient occupation and coupling to the Josephson plasma resonance. A strong phonon population and the maximum QP density are reached within the same time scale of 150 fs demonstrating that the lattice absorbs a major portion of the pump energy before the QPs are thermalized. Our results indicate substantial electron-phonon scattering in $YBa_2Cu_3O_{7-\delta}$ and introduce a powerful approach for characterizing transient phonon dynamics in a broad variety of solids.

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