TIME-RESOLVED ELECTRON-PHONON INTERACTION IN CUPRATE SUPERCONDUCTORS

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We report on femtosecond pump-probe measurements of the optical reflectivity of La2-xSrxCuO4 thin films, La2CuO4+y thin films, Bi2Sr2CuO6+x single crystal (doped with La, Tc = 18K and 21K) and Bi2Sr2CaCu2O8+y single crystal samples (underdoped, Tc = 84K; optimally doped, Tc = 92K; overdoped, Tc = 74K). We used a pump-probe technique in four independent laboratories. The method is based on Ti:sapphire femtosecond lasers (hν= 1.56 eV, repetition rate 80 MHz, pulse widths ranging from 30 fs to 240 fs. At sufficiently low pump fluence (energy per pulse as low as 3 x 10⁻¹² joule/pulse illuminating an area of ~ 5 x 10⁻⁵ cm²) we measure a quasi-divergence in the relaxation time (τR) versus temperature (T): (τR) ~ T⁻².5 ± 0.5; a similar divergence was reported for YBa2Cu3O6.5.1 The onset of the quasi-divergence, at 100 ± 30K, is in the normal state of the samples. At higher, but still perturbative, pump fluencies, the relaxation time exhibits a marked change across the superconducting phase transition temperature but no divergence at low temperatures, similar to earlier reports.2

The electron-electron interaction time increases across the superconducting phase transition and is significantly longer in the superconducting state. We discuss this in terms of the opening of the superconducting gap.

For the Bi2Sr2CuO6+x and Bi2Sr2CaCu2O8+y samples, there is a sign change in the photoinduced reflectivity response from positive (increased reflectivity) to negative that depends on both temperature and doping. The reflectivity response is positive in the superconducting state for underdoped and optimally doped samples, but negative for overdoped Bi2Sr2CaCu2O8+y samples. The reflectivity response changes from positive to negative near Tc for the overdoped and optimally doped Bi2Sr2CaCu2O8+y samples, and from negative to positive for overdoped Bi2Sr2CuO6+x sample. For the Bi2Sr2CuO6+x samples the sign change occurs in the normal state. For the La2-xSrxCuO4 and La2CuO4+y samples, there is no such sign change with temperature or doping. We discuss the changes with doping and temperature in terms of the electronic structure.