Ultrafast Quasiparticle Dynamics of Strongly Correlated Electron Systems
by
Dr. Chia Ee Min, Elbert

Abstract:

In recent years, femtosecond real-time spectroscopy has been shown to present an excellent experimental alternative for studying temperature-dependent changes of the low-lying electronic structure of superconductors and other strongly correlated electron systems like charge density waves, manganites, or heavy fermions. In these experiments, a femtosecond laser pump pulse excites electron-hole pairs. These high-energy quasiparticles rapidly, within 100s of femtoseconds, thermalize via electron-electron and electron-phonon collisions, reaching states near the Fermi energy. Further relaxation dynamics are strongly affected by the low-energy electronic structure in these materials. The dynamics are extracted either by time-resolved measurements of the photoinduced changes in reflectivity or transmission at optical frequencies, or by directly measuring conductivity dynamics, with the probe wavelength in the terahertz (far-infrared) range.

In my work in Los Alamos I have extended the utility of ultrafast spectroscopy to another class of correlated electron materials, namely spin-density-wave (SDW) compounds, whether in its pure state or when it coexists with another order such as superconductivity. My talk will present time-resolved photoinduced reflectivity data of itinerant antiferromagnets UMGa₅ (M=Ni, Pt), and their parent compound UGa₃ down to 10K. For UNiGa₅ (Tₙ = 85 K) the relaxation time τ shows a sharp increase at Tₙ consistent with the opening of a SDW gap, which is the charge gap that opens up along the nested regions of the Fermi surface. In addition, the temperature dependence of τ below Tₙ is consistent with the opening of a SDW gap leading to a quasiparticle recombination bottleneck as revealed by the Rothwarf-Taylor model. For UPtGa₅ (Tₙ = 26 K) however, no change in τ was observed across Tₙ, suggesting that no SDW gap opens up in the antiferromagnetic phase. We attribute this to UPtGa₅ having a different type of magnetic order compared to UNiGa₅, leading to a gapless quasiparticle spectrum. Our results thus challenge the conventional wisdom that a SDW phase necessarily implies a SDW gap at the Fermi level.

Finally, I will present data on the high-temperature superconductor Tl₂Ba₂Ca₂Cu₃O₇ (Tl-2223). Without applying any external magnetic field, we see a qualitative change in the relaxation dynamics below ~40 K, which is suggestive of an entry into the coexistence phase where superconductivity and antiferromagnetism coexist. To quantitatively explain our data, we combined a coupled model describing the time-evolution of quasiparticles and high-frequency phonons in the presence of a gap in the density of states, and a mean field model that gives rise to a decrease in the superconducting gap as one enters the coexistence state. Our study once again points to a magnetic origin in the mechanism of high-temperature superconductivity.

Date: Thursday, 14 Dec 2006
Time: 10.30am to 11.30am
Venue: PAP Meeting Room (SBS B3n-19)