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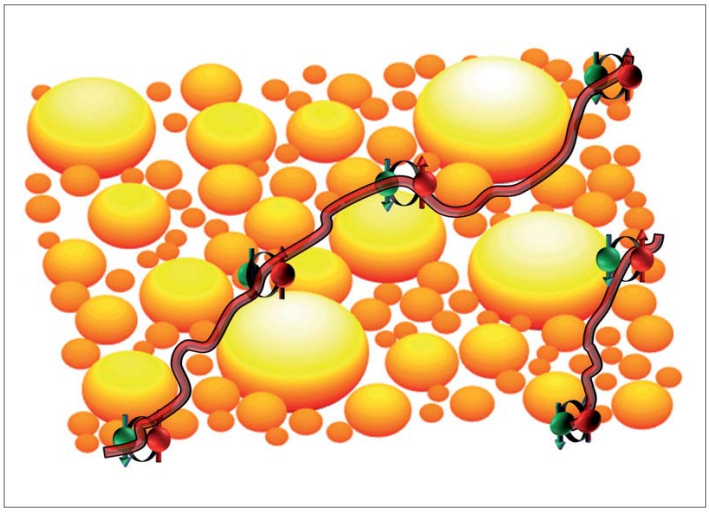

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16.3

Infrared measurements of the superfluid and normal-fluid densities in the cuprate superconductors

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Keywords: high Tc, infrared, cuprate

Measurements for a number of cuprate families of optical reflectance over a wide spectral range (far-infrared to ultraviolet) have been analyzed using Kramers-Kronig analysis to obtain the optical conductivity, $\sigma(\omega)$,and (by integration of the real part of the conductivity) the spectral weight of low- and mid-energy excitations. For the Kramers-Kronig analysis to give reliable results, accurate high-frequency extrapolations, based on x-ray atomic scattering functions, were used. When the optical conductivities of the normal and superconducting states are compared, a transfer of spectral weight from finite frequencies to the zero-frequency delta-function conductivity of the superconductor is seen. The strength of this delta function gives the superfluid density, ρ_s. There are two ways to measure ρ_s, using either the partial sum rule for the conductivity or by examination of $\sigma_2(\omega)$; both estimates show that 98% of the *ab*-plane superfluid density comes from energies below 0.15 eV.

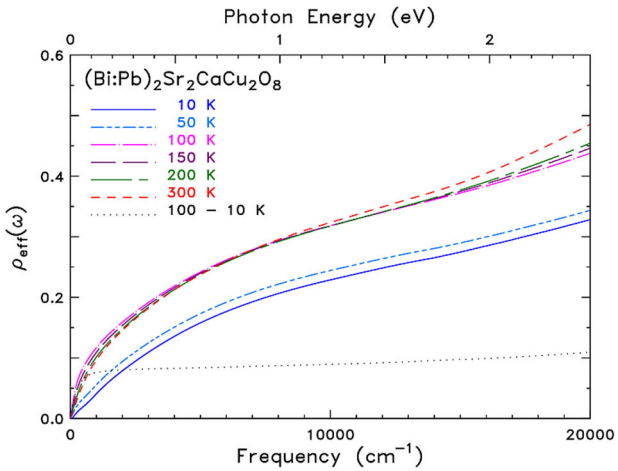

Figure 1: Integrated spectral weight in a $(Bi:Pb)_2Sr_2CaCu_2O_8$ crystal as a function of the upper limit of integration. The low energy spectral weight is exhausted by about 12,000 cm^{-1} (1.5 eV). Below Tc about 20% of the total, spectral weight is removed to the zero-frequency delta function. Note that the difference (dotted line) saturates at around 1000 cm^{-1}.

Moreover, there is a notable difference between a clean metallic superconductor and the cuprates. In the former, the superfluid density is essentially equal to the conduction electron density. The cuprates, in contrast, have only about 20% of the *ab*-plane low-energy spectral weight in the superfluid. The rest remains in finite-frequency, midinfrared absorption. In underdoped materials the superfluid fraction is even smaller.