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Frank Isakson Prize Talk: Superfluid and normal-fluid densities in the cuprate superconductors from infrared spectroscopy¹

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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 . In a clean metallic superconductor 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. There are two ways to measure ρ_s , using either the partial sum rule for the conductivity or by examination of $\sigma_2(\omega)$. Comparison of these two estimates of the superfluid density shows that 98% of the *ab*-plane superfluid density comes from energies below 0.15 eV.

¹Many students, postdocs, and materials preparers have contributed to this work; to all I am very grateful.