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Abstract for an Invited Paper
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Frank Isakson Prize for Optical Effects in Solids: Optical spectroscopy and mechanisms of superconductivity.

DIRK VAN DER MAREL[1], University of Geneva

By its very nature the phenomenon of superconductivity is intimately connected to the electrodynamics properties of a material, both in the normal and in the superconducting state. Optical spectroscopy and electrical transport -corresponding to the zero-frequency limit of the optical response- provide for this reason sensitive tools probing the collective response of a superconducting material. Optical spectroscopy can provide the real and imaginary parts of the optical conductivity of an electron liquid for all frequencies from radiowaves through infrared and visible up to the ultraviolet and even X-ray frequencies. Theory of the optical response is particularly well developed, leading among others to a number of sumrules, providing powerful tools for confronting experiment and theoretical models of superconducting pairing. In this talk examples of sumrules will be discussed relating to the kinetic energy and the Coulomb energy of the paired electrons, and experimental data of addressing these two energies will be presented. The basic understanding of pair formation in the conventional (i.e. BCS) model of superconductivity is, that electrons form pairs as a result of an attractive interaction. On general grounds one than expects the interaction energy to become reduced when the electrons form pairs, while at the same their kinetic energy increases. Superconductivity is a stable state of matter provided that all contributions together result in a lowering of the total (interaction, kinetic plus other terms if relevant) lowering of energy. In this talk I will demonstrate that these two effects can be observed in the cuprate superconductors, that behave according to aforementioned trends for strongly overdoped cuprates, but that the observed effects have the opposite sign for underdoped and optimally doped cuprates. These observations compare favorably with published numerical calculations based on models of strong electron-electron correlation, not involving the vibrations of the lattice, and where the electron-electron interaction is purely repulsive.

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