Electrodynamic properties of superconductors: fundamentals and experimental approaches

B.Gorshunov
Moscow institute of physics and technology (national research university), Dolgoprudny, Russia

email: bpgorshunov@gmail.com

Abstract

The most prominent features of a superconductor compared to a regular conductor/metal are the infinitesimal direct current (dc, i.e., at zero frequency, ν=0) resistivity, ρ_{dc}=0, the presence of an energy gap in the density of states, and the Meissner effect. The first two lead to drastic transformations of the spectra of optical conductivity $\sigma_{opt}(\nu)$ and permittivity $\varepsilon'(\nu)$ of a material when the temperature is lowered below the superconducting transition temperature T_c. The dc resistivity is represented in the spectrum of optical conductivity by a delta function, $\sigma_{opt}(\nu)=1/\rho_{dc}=A\delta(0)$; here A is the spectral weight of the delta function, which can be expressed in terms of the plasma frequency of the Cooper pairs superconducting condensate, $\nu_{pl}^{SC}=\frac{ne^2}{\pi m}$ (n, e and m are concentration, charge and mass, respectively, of the electrons which are involved in the formation of Cooper pairs). The Kramers-Kronig relationships, which are based on the general causality principle, provide the "dielectric image" of this zero-frequency delta function, $\varepsilon'(\nu)=-\left(\frac{\nu_{pl}^{SC}}{\nu}\right)^2$. Measuring the temperature-dependent dielectric function $\varepsilon'(\nu,T)$ of a superconductor provides with a unique opportunity to determine its fundamental characteristics, and thus to gain insight into the microscopic mechanisms behind the phenomenon. Optical spectroscopy allows to determine another fundamental characteristic of a superconductor, the energy gap Δ in the density of state, which is detected in the optical conductivity spectrum in the form of a sharp feature indicating breaking of the Cooper pairs by the electromagnetic quantum with the energy h$\nu\geq2\Delta$ (h is the Planck's constant). A number of other specific electrodynamic properties of conventional low-temperature superconductors, and of high-temperature superconductors will be discussed, and some examples of spectroscopic studies performed at the MIPT Laboratory of terahertz spectroscopy on various superconducting compounds will be shown.