Plasmonic Response Of Superconducting Niobium In The Optical Spectral Range

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We present the first experimental evidence of a direct link between the optical properties of a material and onset of superconductivity.

By measuring the dielectric constants of an unpatterned niobium film as well as the reflectivity of a nanostructured niobium metamaterial, we demonstrate a critical dependence of niobium optical response on temperature near its superconducting transition at 9K. In non-superconducting metamaterials, the temperature-related variations in the optical response tend to saturate below 50K. In contrast, we show that both the position and the strength of niobium metamaterial resonances exhibit a pronounced dependence on temperature down to a few Kelvin, with a sharp change in the behavior around the superconducting transition temperature at 9K. In addition, we also observed dramatic changes in the dielectric constant of unstructured niobium film around the superconducting transition temperature, measured in a separate experiment.

Our studies point to a hitherto unknown connection between superconductivity and optical range plasmonics. We explain the experimentally observed critical dependence of the metamaterial resonance position on the transition temperature of niobium by means of a thermodynamics-based model that takes into account the change in the free energy of the metamaterial resonator between the normal and superconducting states. We argue that this is a signature of the transition to the superconducting state, which is detected by infrared photons.