Collective modes of layered superconductors in the mixed state

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Abstract

The Josephson-plasma and vortex modes in the mixed state of a layered superconductor have been analyzed for an arbitrary direction of the magnetic field. The continuum theory for an anisotropic superconductor has been used, but taking into account a peculiarity of layered superconductors: a vortex is formed by pancakes in superconducting layers connected by Josephson strings in interlayer spacings. The pinning force and the Magnus force act only on pancakes and therefore are lying in the plane ab. A special attention has been devoted to the role of strong pinning of pancakes on the Josephson-plasma mode and of the vortex mass on the vortex mode.

The theory was compared with the features of the magnetoabsorption resonances observed in Bi high-T_c superconductors. They usually interpret them as the Josephson-plasma resonances (JPR) in the presence of strong pinning of pancakes. Our analysis has demonstrated that (i) the JPR-interpretation, even assuming strong pancake pinning, is not able to explain observed dependence of the resonance frequency on the strong magnetic field, either normal or nearly parallel to layers; (ii) the vortex mode governed by the Magnus force also fails to explain some crucial features of the observed resonances; (iii) a qualitative agreement with the experiment has been found for the vortex mode governed by the pancake pinning and the vortex inertial mass.

Further experiments, which could resolve the controversy concerning the origin of the observed magnetoabsorption resonances, are discussed.

Nonlinear microwave properties of YBCO thin films

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Abstract

We report an experimental and theoretical study of the linear and nonlinear microwave impedance of thin $YBa_2Cu_3O_{7-\delta}$ films with and without a DC magnetic field parallel or perpendicular to the $\hat{c}$-axis. The measurements were done using the parallel-plate resonator technique at 5.66 GHz, 21 K$< T <$ 80 K, and for $H <$ 0.8 T. We demonstrate that the contributions to the microwave response from nonlinearity and from the DC magnetic field are almost additive for our films, i.e., the nonlinear effects do not affect the increase of the surface impedance produced by the DC field. The increase of microwave current is simply leads to a parallel shift of the DC magnetic field dependencies.

This result shows that widely discussed nonlinear mechanisms related to vortices produced by the DC field are not relevant for our experimental conditions. The theoretical analysis of other nonlinear mechanisms points out that the most probable source of nonlinearity is vortices produced by microwave currents in weak links. A *qualitative* description of the experimentally observed nonlinear microwave response is provided by the critical-state Bean model, which was modified for thin films.