Collective Modes in Josephson-coupled Layered Superconductors

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Abstract

We formulate a microscopic theory for the collective modes propagating in the direction perpendicular to the layeres (|| c-axis) in Josephson-coupled layered superconductors such as high-T_c superconductors. The longitudinal electric field parallel to the c-axis is quantized in terms of the phason gauge. This electric field is coupled with both the phase modes of the order parameter and the density oscillations of thermally excited quasi-electrons. The londitudinal Josephson plasma and the Carlson-Goldmann mode propagating along the c-axis appear as poles of the longitudinal photon propagator. It is shown that the Josephson plasma is well-defined even in the region near T_c and its frequency vanishes at T_c. The Carlson-Goldmann mode along the c-axis is unstable even at T_c. This result is sharply contrasted with that in the case propagating parallel to the layers. We also present a phenomenological theory based on the two-fluid model for the collective modes in a 1D Josephson junction array.