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Quantum phase transitions and vortex dynamics in superconducting networks

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Abstract

Josephson-junction arrays are ideal model systems to study a variety of phenomena such as phase transitions, frustration effects, vortex dynamics and chaos. In this review, we focus on the quantum dynamical properties of low-capacitance Josephson-junction arrays. The two characteristic energy scales in these systems are the Josephson energy, associated with the tunneling of Cooper pairs between neighboring islands, and the charging energy, which is the energy needed to add an extra electron charge to a neutral island. The phenomena described in this review stem from the competition between single-electron effects with the Josephson effect. They give rise to (quantum) superconductorâ€“insulator phase transitions that occur when the ratio between the coupling constants is varied or when the external fields are varied. We describe the dependence of the various control parameters on the phase diagram and the transport properties close to the quantum critical points. On the superconducting side of the transition, vortices are the topological excitations. In low-capacitance junction arrays these vortices behave as massive particles that exhibit quantum behavior. We review the various quantumâ€“vortex experiments and theoretical treatments of their quantum dynamics.

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