Quantum vortices, quantum phase slip and quantum bits

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Modern nanofabrication techniques allow access to new physical phenomena. Superconducting thin film structures at very low temperatures exhibit quantum effects that can be explored for their fundamental interest and for possible applications. Three examples will be discussed.
- In two-dimensional arrays of small Josephson tunnel junctions, vortices can be created that distinctly behave as quantum particles. Localization in artificial potentials and interference of vortices moving around a charge are manifestations of this quantum nature.
- In long, extremely thin and narrow nanowires the phase differences along the wire can locally jump by 2pi in a quantum process. When the strength of this quantum phase slip process is large enough, a quantum phase transition from superconducting to superinsulating occurs. The dynamics should be similar (dual) to the dynamics of Josephson junctions, but observation is difficult.
- Circuits of small junctions can be used to create quantum bits. The flux qubit, with quantum superpositions of macroscopic currents, is one of several practical realizations.