Quantum State Engineering with Josephson Junctions

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Josephson junctions have been studied for decades because of their rich classical and quantum mechanical properties and their wide range of tunability, which allows entering otherwise inaccessible parameter regimes. In this talk I will shortly review some of their properties, selected according to my personal experiences. Starting in the 80s it became possible to fabricate sufficiently small, low-capacitance Josephson junctions such that quantum tunneling of the phase became observable. This raised the theoretically interesting question how dissipative effects influence the quantum dynamics. Later, in still smaller junctions the interplay of coherent Cooper pair tunneling and incoherent single-electron tunneling could be studied. This led in a natural way to Josephson qubits, based either on charge, flux, or phase degrees of freedom. Their quantum dynamics can be controlled by established electronics, and simple algorithms have been demonstrated by now. The control of dissipative effects, which limit the coherence time, remains one of the major challenges. By coupling Josephson qubits to superconducting resonators, concepts developed previously in cavity quantum electrodynamics could be demonstrated with, in part, unprecedented quality, and qualitatively new behavior, such as the properties of a single-atom laser could be observed.

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