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Quantum State Engineering with Josephson Junctions: Superconducting Flux Qubits

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Quantum bits (qubits) have been designed in various physical systems, such as trapped ions, cavity QED, electron spins in quantum dots, nuclear spins, and so on. Essentially, any two-state quantum system that can be addressed, controlled, measured, coupled to its neighbors, and decoupled from the environment is potentially useful for quantum information process. Among those superconductor qubits based on Josephson junction devices are the most promising, for they are macroscopic in size, easy to control, easy to scale up in number, and noise strong. There are three types of superconductor qubits: charge-based qubits (Cooper-pair box), flux qubits, and phase qubits, all of which are made from thin superconductor films by existing technologies. In flux qubits, the two-state system is realized by applying a half flux quantum through the SQUID loop, at which two opposite current states are superposed and split into two levels: symmetric and antisymmetric combinations of the two current states. The flux qubit has been proposed in 1980 by T. Leggett, the 2003 Nobel Laureate, and realized in almost two decades. Basic phenomena in single qubits, such as Rabi oscillations, Ramsey interference, and spin echos have been observed, and qubit-coupling has been demonstrated by several groups. Recently, the c-NOT gate which is a universal gate in a quantum computer has been demonstrated by Delft group and architecture for a flux qubit quantum computer has been proposed by U. Waterloo group. In this presentation, basic concepts of superconductor qubits, operating principles of flux qubits and their requirements, and recent experimental developments will be reviewed.

Keywords : flux qubit, superconductor, SQUID