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Quantum Electrodynamics

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Editorial

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EDITORIAL NOTE

Quantum-mechanical effects at the macroscopic level were first explored in Josephson-junction-based superconducting circuits within the 1980s. In recent decades, the emergence of quantum informatics has intensified research toward using these circuits as qubits in quantum information processors. the belief that superconducting qubits are often made to strongly and controllably interact with microwave photons, the quantized electromagnetic fields stored in superconducting circuits, led to the creation of the sector of circuit QED (Quantum Electrodynamics), the subject of this review. While atomic cavity QED inspired many of the first developments of circuit QED, the latter has now become an independent and thriving field of research in its title. Circuit QED allows the study and control of light-matter interaction at the quantum level in unprecedented detail. It also plays an important role altogether current approach to gate-based digital quantum information science with superconducting circuits. Additionally, circuit QED provides a framework for the study of hybrid quantum systems, like quantum dots, magnons, Rydberg atoms, surface acoustic waves, and mechanical systems interacting with microwave photons. Here the coherent couplings of superconducting qubits to microwave photons in high-quality oscillators that specialize in the physics of the Jaynes-Cummings model, its dispersive limit, and therefore the different regimes of light-matter interaction during this system are reviewed. Also discussed is coupling of superconducting circuits to their environment, which is important for coherent control and measurements in circuit QED, but which also invariably results in decoherence. Dispersive qubit readout, a central ingredient in most circuit QED experiments, is additionally described. Following an introduction to those fundamental concepts that are at the guts of circuit QED, important use cases of those ideas in quantum information science and in quantum optics are discussed. Circuit QED realizes a broad set of concepts that open up new possibilities for the study of physics at the macro scale with superconducting circuits and applications to quantum informatics within the widest sense.

Circuit QED focuses on the interaction of small superconducting circuits, tailored to behave as two-level quantum systems, with one mode of the electromagnetic field sustained by a superconducting resonator. It’s thus concerned with the investigation of phenomena that arise from the coupling between the only non-trivial quantum system-a spin-1/2 or qubit-and a harmonic oscillator. As such, circuit QED belongs to the more general field of cavity QED, which deals with natural or artificial spins within the optical, microwave or radio-frequency domains interacting with all quite resonators