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Designing quantum-information-processing superconducting qubit circuits that exhibit lasing and other atomic-physics-like phenomena on a chip[1]

FRANCO NORI, Frontier Research System, RIKEN, Saitama, Japan; and Physics Dept., Univ. of Michigan, Ann Arbor, USA.

Superconducting (SC) circuits can behave like atoms making transitions between a few energy levels. Such circuits can test quantum mechanics at macroscopic scales and be used to conduct atomic-physics experiments on a silicon chip. This talk overviews a few of our theoretical studies on SC circuits and quantum information processing (QIP) including: SC qubits for single photon generation and for lasing; controllable couplings among qubits; how to increase the coherence time of qubits using a capacitor in parallel to one of the qubit junctions; hybrid circuits involving both charge and flux qubits; testing Bell's inequality in SC circuits; generation of GHZ states; quantum tomography in SC circuits; preparation of macroscopic quantum superposition states of a cavity field via coupling to a SC qubit; generation of nonclassical photon states using a SC qubit in a microcavity; scalable quantum computing with SC qubits; and information processing with SC qubits in a microwave field. Controllable couplings between qubits can be achieved either directly or indirectly. This can be done with and without coupler circuits, and with and without data-buses like EM fields in cavities (e.g., we will describe both the variable-frequency magnetic flux approach and also a generalized double-resonance approach that we introduced). It is also possible to "turn a quantum bug into a feature" by using microscopic defects as qubits, and the macroscopic junction as a controller of it. We have also studied ways to implement radically different approaches to QIP by using "cluster states" in SC circuits. For a general overview of this field, see, J.Q. You and F. Nori, Phys. Today 58 (11), 42 (2005)

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