Experiments with Superconducting Qubits: Multi-photon Dressing and Qubits with Magnetic Coupling

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Abstract — The experimental realization of quantum simulator and computers requires scalable and well-controllable qubits as building blocks. Superconducting quantum devices are a leading candidate for their implementation.
Superconducting resonant circuits behave as artificial quantum few-level systems. In contrast to natural atoms or molecules, such systems allow for very large couplings between the electromagnetic field and the effective dipole moment of the artificial atom that even remains frequency-tunable during operation. Ideally, these quantum circuits consist of arrays of two-level-systems. Due to the lack of such idealized quantum elements their basic building element is a few-level quantum circuit.

In this talk, we report on the investigation of such a superconducting anharmonic multilevel circuit that is coupled to a harmonic readout resonator [1]. We observe multiphoton transitions via virtual energy levels of our system up to the fifth excited state. The back-action of these higher-order excitations on our readout device is analyzed quantitatively and demonstrated to be in accordance with theoretical expectation. Multiphoton dressing within our anharmonic circuit yields emerging higher-order Rabi sidebands and associated Autler-Townes splittings

Furthermore, we present a planar qubit design based on a superconducting circuit that we call concentric transmon. While employing a straightforward fabrication process using Al evaporation and lift-off lithography, we observe qubit lifetimes and coherence times in the order of 10 us. We systematically characterize loss channels such as incoherent dielectric loss, Purcell decay and radiative losses [2].

Exploring spin wave dynamics in thin films by coupling to a superconducting qubit complements conventional measurement techniques based on photon, electron or neutron scattering methods, which require highly populated excitations. We discuss our measurement concept including coupling schemes of magnons to superconducting microwave resonators and qubits.

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Keywords (Index Terms) — Superconducting qubits, microwave resonant circuits, hybrid quantum systems.