FM 80: Enabling Technologies: Cavity QED

Time: Thursday 14:00–16:00 Location: 2006

Invited Talk FM 80.1 Thu 14:00 2006
Photon-Qubit and Qubit-Qubit Interactions in Semiconductor Circuit Quantum Electrodynamics (QED) — •Andreas Wallraff — Department of Physics, ETH Zurich
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FM 80.2 Thu 14:30 2006
Quantum measurement of a single spin via energy-selective tunneling in a microwave resonator — •Florian Ginzel, Maximilian Russ, and Guido Burkard — University of Konstanz, D-78457 Konstanz, Germany

A modification of the Elzerman scheme for single-shot electron spin readout in a quantum dot embedded into a superconducting cavity is proposed and discussed. Depending on its spin state the electron can tunnel between two quantum dots or between the two dots and a lead. One of the dots is capacitively coupled to a microwave resonator whose output signal is monitored to recover the initial spin state. In this work a model to estimate expectation value and variance of the cavity response is presented. The feasibility of the proposed scheme is discussed by means of timescale, visibility and quantum mechanical back-action of the measurement. As a result, cavity-aided spin readout via spin-selective tunneling is expected to allow for fast, high fidelity measurements and, thus, fulfill a crucial requirement for usage in various quantum technologies ranging from information processing to sensing.

FM 80.3 Thu 14:45 2006
Optimal Dispersive Readout of a Spin Qubit with a Microwave Cavity — •Benjamin D'Anjou and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

Strong coupling of semiconductor spin qubits to superconducting microwave cavities was recently demonstrated. These breakthroughs pave the way for quantum information processing that combines the long coherence times of solid-state spin qubits with the long-distance connectivity, fast control, and fast high-fidelity quantum-non-demolition readout of existing superconducting qubit implementations. Here, we theoretically analyze and optimize the dispersive readout of a single spin in a semiconductor double quantum dot (DQD) coupled to a microwave cavity via its electric dipole moment. The strong spin-photon coupling arises from the motion of the electron spin in a local magnetic field gradient. We calculate the signal-to-noise ratio (SNR) of the readout accounting for both Purcell spin relaxation and spin relaxation arising from intrinsic electric noise within the semiconductor. We express the maximum achievable SNR in terms of the cooperativity associated with these two dissipation processes. We then optimize the SNR as a function of experimentally tunable DQD parameters. We estimate that with current technology, single-shot readout fidelities in the range 82%-95% can be achieved within a few μs of readout time without requiring the use of Purcell filters.
arXiv reference: https://arxiv.org/abs/1905.09702

FM 80.4 Thu 15:00 2006
Optimized cavity-mediated dispersive two-qubit gates between spin qubits — •Mónica Benito[1], Jason Petta[2], and Guido Burkard[1] — [1]University of Konstanz — [2]Princeton University

The recent realization of a coherent interface between a single electron in a silicon quantum dot and a single photon trapped in a superconducting cavity opens the way for implementing photon- mediated two-qubit entangling gates. In order to couple a spin to the cavity electric field some type of spin-charge hybridization is needed, which impacts spin control and coherence. In this work we propose a cavity-mediated two-qubit gate and calculate cavity-mediated entangling gate fidelities in the dispersive regime, accounting for errors due to the spin-charge hybridization, as well as photon- and phonon-induced decays. By optimizing the degree of spin-charge hybridization, we show that two-qubit gates mediated by cavity photons are capable of reaching fidelities exceeding 90% in present-day device architectures. High iSWAP gate fidelities are achievable even in the presence of charge noise at the level of 2 μeV.

[1] M. Benito, J. R. Petta, and G. Burkard, arXiv:1902.07649.
[2] M. Benito, X. Croot, C. Adelsberger, S. Putz, X. Mi, J. R. Petta, and G. Burkard, arXiv:1904.13117.

FM 80.5 Thu 15:15 2006
Scaling up superconducting qubits beyond the dispersive regime — •Mohammad Ansari — Forschungszentrum Jülich, Jülich Aachen Reseach Alliance (JARA), Jülich, Germany

Superconducting circuits consisting of a few transmons coupled to resonators can perform basic quantum computations; however such small scale circuits are unable to perform the power of quantum computation. Scaling up the number of qubits on the other hand will bring the circuit out of quantum control mainly because of noises. In order to come out of such dilemma, we need to look for other possibilities. This requires to further look into theory and improve it. For this aim we develop a new formalism that allows to consistently diagonalize superconducting circuit hamiltonian beyond perturbative regime. This will allow to study qubit-qubit interaction unperturbatively, therefore our formalism remains valid and accurate at any frequency detuning and interaction coupling. Moreover our formalism serves as a theoretical ground for designing qubit characteristics in scaling up.
Reference: M.H. Ansari, Superconducting qubits beyond the dispersive regime, arXiv:1807.00792 (To be published in Phys. Rev. B)

FM 80.6 Thu 15:30 2006
Storage and retrieval of short light pulses via fiber-based atom-cavity systems — •Tobias Macha, Lukas Ahlheit, Wolfgang Alt, Maximilian Ammenwerth, Pooja Malik, Deepak Pandey, Hannes Pfeifer, Eduardo Urunuela, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115, Bonn, Germany

We demonstrate the storage of 5 ns light pulses in a single rubidium atom coupled to a fiber-based optical resonator. Our storage protocol addresses a regime beyond the conventional adiabatic limit, for which the optimal control laser pulse properties are extracted from numerical simulations of the system via a Lindblad master equation approach. We investigate the dependence of the storage efficiency on various control pulse parameters, such as the peak amplitude or the delay with respect to the arrival of the light pulse [1]. For an optimized pulse, we measure storage efficiencies of (8.2 ± 0.9) %, in close agreement with the maximum expected efficiency for our atomic memory. In the adiabatic limit, we use optimized control pulses for single-photon generation by adapting the impedance-matching based storage scheme of Dilley et al. [2]. We achieve probabilities of 66 % for generating a single, arbitrarily-shaped photon into the cavity mode upon a trigger signal. Such well-controlled and high-bandwidth atom-photon interfaces are key components for future hybrid quantum networks.

[1] arXiv:1903.10922 (2019).
[2] PRA 85, 023834 (2012).

FM 80.7 Thu 15:45 2006
Coupling atoms to a superconducting coplanar microwave cavity — Manuel Kaiser[1], Conny Glaser[1], Lorinc Sárkány[1], Andreas Günther[1], Dieter Koelle[1], Reinhold Kleiner[1], David Petrosyan[1,2], and •József Fortágh[1] — [1]Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen — [2]Institute of Electronic Structure and Laser, FORTH, GR-71110 Heraklion, Crete, Greece

We report on experiments with ultra-cold rubidium atoms trapped on a superconducting atom chip. The focus is on the coupling of atomic Rydberg state pairs to the microwave field of a coplanar superconducting cavity. We discuss the feasibility of coherent long-range interaction between atoms mediated by a microwave cavity in a thermal state and the possibility of realizing Rydberg quantum gates under the given experimental conditions.