Lasing and transport in a quantum dot-resonator circuit

Gerd Schön

Karlsruhe Institute of Technology, Institut für Theoretische Festkörperphysik, 76128 Karlsruhe, Germany

Circuit quantum electrodynamics (cQED) setups, where superconducting qubits are coupled to an electromagnetic circuit demonstrate many effects known from quantum optics, some of them with unprecedented quality. Moreover, the new parameter regime, i.e., strong coupling, low temperature, and single-qubit rather than many atoms, revealed qualitatively novel behavior. An example is lasing with a single superconducting qubit, where for strong coupling to the resonator, quantum noise influences the linewidth of the emission spectrum in a characteristic way [1].

We propose a different cQED setup, where a semiconductor double quantum dot is coupled to a high-Q (superconducting) resonator [2]. By driving a current through the dot system a population inversion in the dot levels can be created, which leads - within a narrow resonance window - to a lasing state in the resonator. In this semiconductor setup relaxation and decoherence processes are not weak. We analyze them in detail and show that the lasing state can be reached for realistic parameters.

In the proposed setup the lasing state correlates with the transport properties. On one hand, it allows probing the lasing state via a current measurement, which may be easier to perform in an experiment. On the other hand, the resulting narrow current peak opens perspective for applications of the setup for high resolution measurements. As an example we show that a small difference in the nuclear-spin induced Zeeman splitting between the two dots can be resolved with the help of the sharp lasing resonance condition. This allows for read-out and manipulations of spin qubits in doubly occupied double quantum dots.

[1] Single-qubit lasing in the strong-coupling regime, S. André, P. Q. Jin, V. Brosco, J. H. Cole, A. Shnirman, and G. Schön, Phys. Rev. A 82, 053802 (2010)

[2] Lasing and transport in a quantum dot-resonator circuit, P. Q. Jin, M. Marthaler, J. H. Cole, A. Shnirman, and G. Schön, arXiv:1103.5051 [cond-mat.mes-hall]