Probing the Nuclear Spin Environment in a Quantum Dot-Resonator System

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Circuit quantum electrodynamics (cQED) setups with superconducting qubits coupled to electromagnetic circuits, display many quantum optics effects and have attracted much attention. Recently different cQED setups have been proposed, where spin qubits realized by semiconductor double quantum dots are coupled to a transmission line. To achieve a sizeable coupling strength, charge degrees of freedom need to be involved, which reduces the coherence time of the spin qubit. We suggest that, by exploiting a sharp lasing resonance condition, this cQED setup allows for probing and resolving a small nuclear-spin induced Zeeman splitting difference between the two dots, which is interesting for manipulations of the spin qubits. Driving a current through the double dots can create a population inversion in the dot levels and, within a narrow resonance window, a lasing state in the resonator. The Zeeman splitting difference leads to two separate peaks in the photon number and the transport current as a function of detuning, which can be resolved due to the narrow resonance condition. This application imposes less stringent conditions on the coherence time. Remarkably, relaxation processes may even enhance the resolution of the resonances by releasing a trapped population in the off-resonant spin channel.