Dr Robert Amsüß

Strong coupling of an NV- spin ensemble to a superconducting resonator

Supervisor: Prof. Jörg Schmiedmayer

Abstract:

This thesis is motivated by the idea of hybrid quantum systems, one promising approach to exploit quantum mechanics for information processing. The main challenge in this field is to counteract decoherence - an inevitable companion of every quantum system. Indeed some quantum systems are intrinsically better isolated from their environment and are therefore less prone to the loss of coherence. But it's the ambivalent nature of decoherence that these highly isolated systems are usually very difficult to interact with and coherently control. To overcome these obstacles ideas were born to combine or “hybridize” different quantum systems with mutually opposing properties - fast control and long coherence times - and take advantage of the prospective better behavior of the combined system.

In this thesis, defects in single crystal diamond – negatively-charged nitrogen-vacancy centers (NV-centers) - are chosen as the quantum memory medium. Because an NV- center constitutes a defect in a solid, its combination with other solid-state quantum systems, as electrical circuits based on Josephson junctions, appears natural. In our work we aimed at the integration of a large number of NV- centers in a circuit quantum electrodynamics (cQED) set-up. These circuits, operating at microwave frequencies, are extremely fast and versatile quantum processors but suffer from short coherence times. Usually single microwave photons stored in a resonant circuit act as information carrier between different parts of the chip.

As a main result we observe the coherent energy exchange between the NV- color centers and the electromagnetic field of a microwave resonator. We study in detail a number of important aspects of collective magnetic spin-field coupling as the characteristic scaling with the square root of the number of emitters. Additionally we measure weak coupling to 13C nuclear spins mediated by the hyperfine coupling to the NV- electron spins. The quantum memory capabilities of ensembles of NV- centers are shown in experiments with flux qubits. Generally the main challenge is to find counter measures against inhomogeneous broadening due to paramagnetic impurities in diamond which at the moment is the limiting source of decoherence in this system.