Superconducting circuits for detecting and manipulating spins in solids

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The detection of spins in solids or biological materials by electron-spin resonance (ESR) spectroscopy has numerous applications in material science and biology. Besides, dilute spins in solids have long quantum coherence time, which makes them promising candidates for storing quantum information. In our laboratory, we use superconducting circuits to try to store and retrieve quantum information in spin ensembles, as well as to increase the ESR sensitivity and detect as few spins as possible. In this presentation, we will first show how a superconducting resonator can be strongly coupled to a spin ensemble [1], and how quantum information can be stored in and retrieve from the ensemble [2] [3] using circuits combining superconducting resonators and a Josephson quantum bit (see Fig. 1). In a second part, we will show how using the tools offered by circuit Quantum Electrodynamics (QED), namely high quality factor superconducting resonators and Josephson parametric amplifiers that operate at the quantum limit, we increase the sensitivity of ESR by four orders of magnitude over the state-of-the-art [4]. Finally, we will show how the energy relaxation time of the spins can be limited by spontaneous emission of microwave photons through the resonator, which opens the way to on-demand spin initialization via Purcell effect [5].

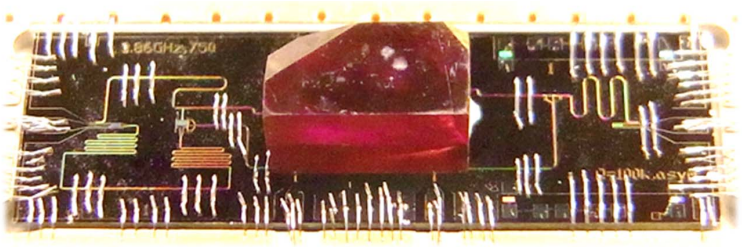

Fig. 1: Hybrid circuit with superconducting resonators and qubits coupled to an ensemble of NV centers in diamond.

References

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