Spectroscopy and Coherent Control of Defects in Superconducting Films and Qubits

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***Abstract* – Parasitic Two-Level-Systems (TLS) which emerge from structural defects in amorphous materials are responsible for the major part of energy loss and decoherence in superconducting quantum devices. However, their microscopic origin is still unknown. Here, we use a superconducting quantum bit to characterize individual TLS residing in the AlOx tunnel barrier of a Josephson junction. By exploiting the strong coupling between the qubit and single TLS, we directly manipulate TLS quantum states by resonant microwave driving and read them out by coherent swap operations. In addition, we tune the TLS resonance frequencies by controlling the mechanical strain in the material. This allows us to perform a novel kind of defect spectroscopy which gives a detailed view onto the TLS distribution and provides direct evidence of their mutual interactions. Moreover, we reveal the interaction between TLS and BCS-quasiparticles by monitoring the decrease of TLS coherence times in dependence of the controlled quasiparticle density. We also present a method by which single TLS in thin films can be characterized using resonators instead of qubits. Our results show that superconducting quantum devices provide a unique and powerful access to the quantum properties of individual defects, and this greatly promotes clarification of their nature, emergence, and interactions.**

***Keywords (Index Terms)* – Superconducting quantum bits, two-level-systems, decoherence.**

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