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Improving the coherence of superconducting resonant quantum circuits

Superconducting quantum devices are a leading candidate for quantum information processing. A wide range of quantum experiments, such as violation of Bell's inequality, two qubit algorithms, or implementation of error correction codes have been demonstrated using these circuits. However, the materials used for their linear and non-linear circuit elements set a limit on the best achievable coherence times and are increasingly researched.
I will discuss our material research for microwave resonators and qubits. For the linear elements such as capacitors and inductors, titanium nitride resonators showing single photon quality factors up to 1 million were developed. The quality factor is related to the surface contributions of film and substrate, and can be optimized by aspect ratio and surface treatment [1]. Mixed-material, lumped element resonators allow to systematically locate and extract residual resonator losses and to distinguish between dielectric and inductive losses. The method was applied to hybrid titanium nitride/ aluminum resonators at high and low photon numbers and temperatures [2].
Josephson junctions, acting as non-linear elements and providing the qubit's anharmonicity, are known to suffer from detrimental interaction with two-level-systems in the amorphous tunnel oxide. These residual states can absorb energy and interfere with the qubit state, resulting in shorter coherence times. Epitaxial tunnel barriers –having fewer defect states than conventional amorphous barriers –were developed and implemented in qubits [3]. Their lifetime, around 1 usec, exceeds the best reported values in other multileveled qubits. Very recently, a superconducting qubit design of increased coherence was developed [4]. It is fabricated in a 2D geometry over a superconducting ground plane with the qubit being coupled to a microstrip readout resonator. The circuit is fabricated on a silicon substrate using low loss titanium nitride for capacitor pads and small, shadow-evaporated aluminum/aluminum-oxide junctions. A significant increase in lifetime is projected for a reduced qubit-to-superconducting plane separation.

[1] Sandberg et al., Appl. Phys. Lett. **100**, 262605 (2012)
[2] Vissers et al., Appl. Phys. Lett. **101**, 022601 (2012)
[3] Weides et al., Appl. Phys. Lett. **99**, 262502 (2011)
[4] Sandberg et al., arXiv:1211.2017 (2012)

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