Superconducting Resonators:

The Canary in the Coherence Coalmine

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A quantum computer is believed to solve a certain set of problems much faster than any classical computer. Some interesting problems include integer factorization and simulation of quantum many-body systems. The realization of a useful quantum computer will require overcoming many technological obstacles. Currently one of the major obstacles is decoherence, or the loss of quantum information, before completing an algorithm and measuring the result. Decoherence arises from qubits interacting with their environment and can include sources such as control lines, external environment, and material defects.

Currently, qubits come in a variety of physical platforms including ion traps, quantum dots, and superconducting qubits as well as many others. Superconducting qubits are promising since their macroscopic size allows for relatively easy manipulation and coupling to other qubits, Figure 1a. Additionally, superconducting qubits are fabricated using standard integrated circuit technology providing a natural path for scaling up. On the other hand, these attributes allow unwanted coupling to numerous decoherence mechanisms, thereby limiting their performance. We have repeatedly and reliably improved the coherence of superconducting qubits by first improving simpler superconducting resonators, Figure 1b.

Superconducting resonators are affected by some of the same decoherence mechanisms as superconducting qubits and they also provide an ideal test bed due to their much simpler fabrication and measurement. After reducing extrinsic sources, decoherence is dominated by coupling to defects present in the materials used to fabricate these devices.[1] These material defects can also be introduced during various steps in a multi-layer fabrication process. Using resonators we individually isolate, characterize and then improve each step of the more complicated fabrication of superconducting qubits. These improvements to coherence have been directly used in more complex circuits including a nine qubit coupled linear array[2] as well as a fully connected three qubit system used for simulation of the molecular collision of Na and He.

1) A. Megrant*, et al.* Appl. Phys. Lett. **100**, 113510 (2012).
2) J. Kelly, et al. Nature **519,** 66-69 (2015).

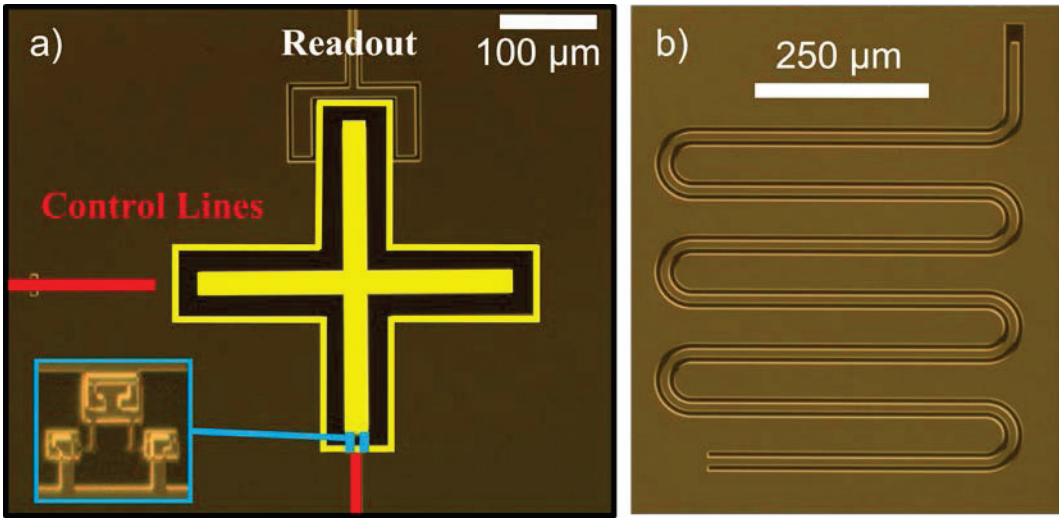

Figure 1: a) Micrograph of Xmon style superconducting qubit. Readout resonator shown at top and control lines come from left and bottom. Capacitor colored in yellow and Josephson Junction based SQUID loop shown in inset. **b)** Micrograph of coplanar waveguide superconducting resonator. Both the capacitor of the qubit and the resonator are fabricated out of 100nm of aluminum deposited on a c-plane sapphire substrate. They are then etched using inductively coupled plasma reactive ion etch with BCl3/Cl2 chemistry.