Fabrication of Fluxonium-Like Qubits

CNF Project Number: 301022
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Primary CNF Tools Used: ASML DUV Stepper, JEOL 6300, PT770 Plasma Etcher, Oxford81 Etcher, Heidelberg DWL2000 Mask Writer

Abstract:

We fabricate fluxonium qubits to probe the behavior of broken cooper pairs (quasiparticles) in superconducting circuits and to study the effect of measurement-induced state transitions (MIST) [1]. To probe the quasiparticle population in our qubits, we fabricate Josephson junctions on the perimeter of the devices, which are biased beyond their superconducting gap, controllably generating a reproducible population of quasiparticles in the sample. Probing the qubit state with large numbers of photons can force the qubit outside of it's computational subspace, inducing the aforementioned MIST. The fluxonia for this project are fabricated using a previously reported recipe [2].

Summary of Research:

A fluxonium qubit (Fig. 1) is a superconducting circuit which is comprised of a 2-D capacitor shunted by a small Josephson junction and a 2-D inductor formed of a chain of larger Josephson junctions (Fig. 2). This device forms a loop through which a magnetic field is applied. At specific amounts of magnetic flux passing through this loop, various loss mechanisms which negatively impact qubit performance are suppressed. These qubits are capacitively coupled to a microwave resonator, whose fundamental mode shifts conditional on the state of the qubit. We measure microwave transmission near this frequency as a proxy for the measurement of the qubit state. Our devices are fabricated on Si wafers. All large features, capacitors, coplanar waveguides, and microwave resonators, are patterned into a ~ 70nm niobium base layer using the ASML DUV stepper and the PT770. After initial processing, the devices are cleaned in the CNF hot strip bath, the Glen1000, then in a bath of buffered oxide etch. To form Josephson junctions for both the inductive shunt and the small junction, electron beam lithography using the JEOL 6300 is required. The small junctions for our fluxonia are on the order of ~ 100nm × 100 nm, and ~ 1um × 1um for 1 each of the ~ 200 junctions in the chain. After electron beam patterning is complete, the junctions are formed by electron beam evaporation using the Dolan bridge technique at Syracuse University.

In the last year, we developed a new fluxonium design with the primary goal of increasing readout fidelity enormously. These design changes are also intended to enable improved characterization of measurement-induced state transitions (MISTs) in our qubits by enabling discrimination between states outside of the typical computational subspace. To achieve this, we increased the coupling between the microwave resonators used for readout and the transmission line used for S21 measurements. We also increased the qubit/resonator coupling from previous generations of samples fabricated at the CNF. Both of these changes, in addition to minor tweaks to various other circuit parameters, were implemented on our most recent generation of devices. Fabrication quality plays a direct role in our understanding of MIST, in that defects referred to as two-level systems contribute strongly to MIST effects, and give us a window to compare our fabrication quality to the state-ofthe-art. To fully leverage the new design, additional fine-tuning of the fabrication and preliminary characterization are required.

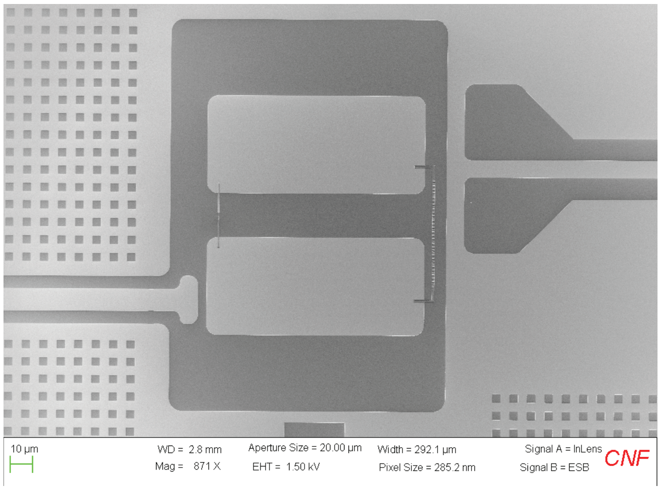

Figure 1: Scanning electron microscopy (SEM) image of one of the fluxonium qubits taken at CNF.

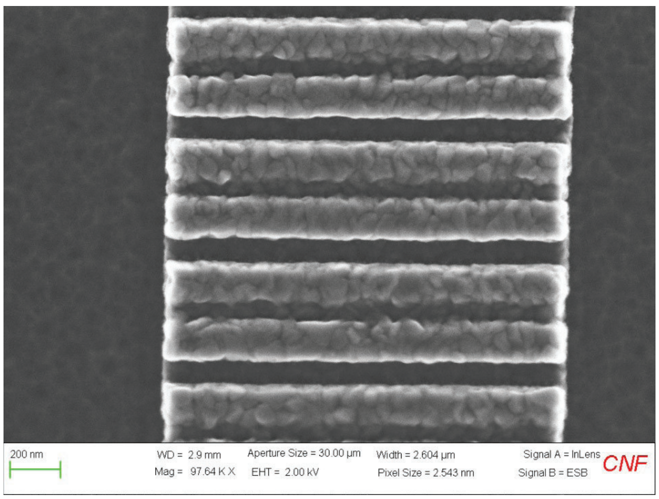

Figure 2: SEM image of a Josephson junction chain, taken at CNF.

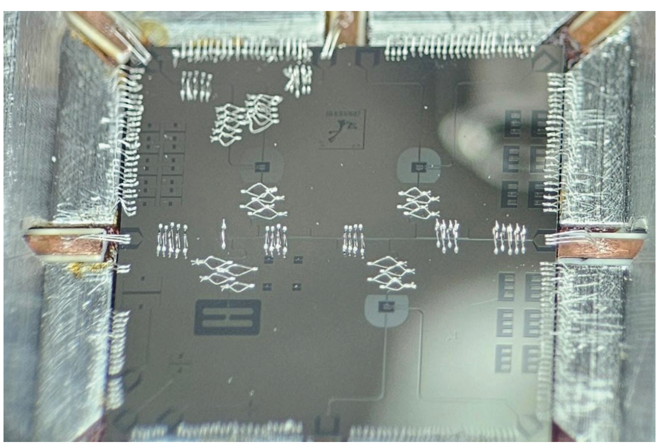

Figure 3: Photograph of a sample set into the holder wire-bonded for low-temperature measurements.

References:

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