Superconducting Microwave Resonators for Probing Dissipation from Vortices

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Abstract:
We are fabricating superconducting microwave resonators for probing the response of vortices at high frequencies. Vortices are quantized bundles of magnetic flux that thread many different superconductors over a particular range of applied magnetic field. These measurements are useful for probing fundamental physical properties of vortices. In addition, trapped vortices are an important loss mechanism that can limit the performance of superconducting microwave detectors and quantum coherent circuits. We have recently implemented a technique to pattern and etch nanoscale surface features on the resonators to reduce the microwave loss contributed by vortices.

Summary of Research:
Vortices in superconductors can respond quite differently in the microwave range compared to dc driving [1]. High-quality factor superconducting microwave resonators are useful tools for investigating this response and for exploring fundamental physical properties of vortices at microwave frequencies. Vortices trapped in superconducting traces can result in substantial reductions in the quality factor of such resonators. Thus, understanding and controlling this dissipation mechanism can be important in the design of superconducting systems that use microwave resonators, including sensitive photon detectors and quantum computing applications.

We fabricate our resonators from various superconducting films, including aluminum deposited onto sapphire or silicon wafers in our electron-beam evaporator at Syracuse University. We define the patterns on the Autostep 200 and transfer them into the films with reactive ion etching. We measure these circuits in a 3He refrigerator in our lab at Syracuse University at a temperature of ~ 300 mK.

References:
Figure 1: Optical micrograph of coplanar waveguide Al resonator on sapphire substrate with partially etched slot in center conductor.

Figure 2: Atomic force microscope (AFM) image of center conductor of Al resonator with partially etched slot.

Figure 3: Transmission through microwave feedline for resonator with no slot with no vortices present (open blue circles) and with trapped vortices from cooling in $B = 86$ micro tesla (closed black circles).

Figure 4: Measurement of resonator containing a partially etched slot with no vortices present (open blue circles) and with trapped vortices from cooling in $B = 86$ micro tesla (closed black circles).