Monday Morning, September 22, 2025

Quantum Science and Technology Mini-Symposium
Room 208 W - Session QS2-MoM

Systems, Devices, and Manufacturing Technologies for Quantum Technology

Moderators: Sisira Kanhirathingal, Rigetti Computing, **Aranya Goswami**, Massachusetts Institute of Technology

10:30am **QS2-MoM-10 Superconducting Qubits at MIT Lincoln Laboratory**, ***Mollie Schwartz***, MIT Lincoln Laboratory **INVITED**

Superconducting qubits are leading candidates in the race to build a quantum computer capable of realizing computations beyond the reach of modern supercomputers. Within this modality, the ability to robustly and reliably fabricate high-quality, quantum-compatible circuits is critical both for fundamental research efforts and for more complex and capable quantum processors.MIT Lincoln Laboratory has worked over the course of two decades to establish, and continually expand and improve, superconducting qubit fabrication capabilities.Recently, we have piloted a superconducting foundry model to enable the US quantum research and development community to leverage the most robust and reliable of these capabilities in order to accelerate research progress.This presentation will provide an overview of superconducting qubit fabrication at MIT Lincoln Laboratory, describe its transition from 50 mm prototyping tools to 200 mm fabrication to support an expanded user base, and provide perspectives on how to support and enable the broader quantum research community as the variety and complexity of questions at the research frontier continues to expand.

11:00am **QS2-MoM-12 Voltage Tunable MBE-grown Ge/SiGe Josephson Junctions for Gatemon Qubits**, ***Joshua Thompson***, *Jason Dong, Junior Langa,* Laboratory for Physical Sciences*; Brycelynn Bailey,* University of Arkansas*; Chomani Gaspe, Riis Card,* Laboratory for Physical Sciences*; Shiva Davari, Mariam Afrose,* University of Arkansas*; Thomas Hazard, Kyle Serniak,* MIT Lincoln Laboratory*; Kasra Sardashti,* Laboratory for Physical Sciences*; Hugh Churchill,* University of Arkansas*; Christopher Richardson,* Laboratory for Physical Sciences

Voltage tunable Josephson junctions (JJs) based on planar semiconductor quantum wells have potential to realize voltage tunable qubits fabricated at scale. Josephson junctions are fabricated from undoped Germanium quantum wells (Ge-QWs), grown by Molecular Beam Epitaxy (MBE), with carrier mobility greater than 40,000 cm^2/Vs and hole density less than $1x10^{12}$ cm^{-2}. These junctions use epitaxial aluminum to make transparent contact to the Ge-QW and a mesa structure that is 2.5-µm tall with only the JJ on top, minimizes microwave loss from epitaxial layers, which is critical for superconducting qubits. This presentation will demonstrate gate tunable critical currents and discuss the characterization of MBE-grown Ge JJs along with the path toward integrating these JJs into gatemon qubits.

11:15am **QS2-MoM-13 An Even-Odd Superconducting Diode Effect in Topological Insulator Josephson Junctions**, ***Jonathan Zauberman***, Harvard University*; Joon Young Park,* Sungkyunkwan University (SKKU), Republic of Korea*; Thomas Werkmeister,* Harvard University*; Omri Lesser,* Cornell University*; Laurel Anderson,* University of Washington*; Yuval Ronen,* Weizmann Institute of Science, Israel*; Satya Kushwaha,* Johns Hopkins University*; Robert Cava,* Princeton University*; Yuval Oreg,* Weizmann Institute of Science, Israel*; Amir Yacoby, Philip Kim,* Harvard University

The superconducting diode effect (SDE), in which supercurrent is asymmetric in applied current bias, can be observed when time reversal and inversion symmetries are broken in a Josephson junction. Recently, changes in the sign of the SDE have been correlated with possible topological phase transitions in certain regimes of linear Josephson junctions. Here we report an even-odd SDE in Corbino-geometry Josephson junctions, where even/odd flux parity states show a SDE alternating in sign. These junctions are fabricated on a single surface of a bulk-insulating three-dimensional topological insulator and can be used for probing signatures of Majorana states that are theoretically present within the junctions under a magnetic field. We fabricate high-quality niobium Josephson junctions on tellurium-capped Sn-doped $Bi_{1.1}Sb_{0.9}Te_2S$ (Sn-BSTS) single crystals, with junctions showing high transparency. Additionally, different Corbino-style geometries enable Josephson interferometry within a single junction, allowing us to explore the skewed current-phase relation. Our analysis attributes the flux-parity controlled SDE to a topological phase, with opposite diode polarity directly reflecting the sign change of the periodic boundary conditions for an even/odd number of Josephson vortices in the junction.

11:30am **QS2-MoM-14 Post-processing of Josephson Junctions for Precision Tuning of Qubit Frequencies** , ***David P. Pappas***, 775 Heinz Ave*; X Wang, Joel Howard, Greg Stiehl, Cameron Kopas, Stefano Poletto, Xian Wu, Mark Field, Nicholas Sharac, Christopher Eckberg, Hilal Cansizoglu, Raja Katta, Josh Mutus, Andrew Bestwick, Kameshwar Yadavalli,* Rigetti Computing*; Jinsu Oh,* Ames Laboatory*; Lin Zhou, Matthew Kramer,* Ames Laboratory **INVITED**

Thin layers of thermal aluminum oxide are the dominant material for making Josephson tunnel-junctions (JJs). These JJs are the key component for qubits in most superconducting implementations of quantum computing. It has become clear that it is necessary to address the issue of JJ homogeneity in order to more precisely tune the qubit frequencies. Work towards this using the newly developed alternating-bias assisted annealing (ABAA) technique will be discussed. ABAA illuminates a promising path towards precision tuning of qubit frequency post-processing while attaining higher coherence due to an apparent reduction in junction loss. Here, we demonstrate precision tuning of the qubits by performing ABAA at room temperature using commercially available test equipment and characterizing the impact of junction relaxation and aging on the resistance spread after tuning. A study of the structural properties of the material using transmission electron microscopy will be given with some thoughts of what the driving mechanism for ABAA is at the atomic scale.

12:00pm **QS2-MoM-16 Probing the Nonlinearities of Nb-Doped a-Si Josephson Junctions with Microwave Intermodulation Spectroscopy and Large-Signal Network Analysis**, ***Elyse McEntee Wei***, Colorado School of Mines; NIST*; Dylan Williams, Christian Long,* NIST-Boulder*; Serena Eley,* University of Washington

Niobium-doped amorphous silicon Josephson junctions are used in a variety of applications, such as the Josephson Programmable Voltage Standard and the Josephson Arbitrary Waveform Synthesizer. The operating parameters required of each application dictate the amount of niobium doping in the amorphous silicon barriers. By increasing the niobium doping concentration, the junction behavior can be tuned from superconductor-insulator-superconductor type junctions to superconductor-normal metal-superconductor or superconductor-weak superconductor-superconductor type junctions. Preliminary studies of these junctions suggest that the dependence of the supercurrent in the barrier on the phase difference of the superconducting order parameters (known as the current-phase relation) begins to deviate from a simple sinusoid with increasing concentrations of niobium. Although the skewing of the current-phase relation is suspected to influence the harmonic output of the device and significantly affect the device behavior, this correlation between the varying degrees of skewing and harmonic output is largely unexplored. Here we investigate two techniques to probe the nonlinear response of niobium-doped amorphous silicon Josephson junction arrays embedded in on-wafer niobium superconducting transmission lines. First, we perform on-wafer intermodulation spectroscopy by stimulating the Josephson junction arrays with two microwave tones and measuring the resulting intermodulation products to extract the current-phase relation. We then perform large-signal network analysis (involving a two-tier microwave calibration that includes absolute power and cross-frequency phase calibrations) to capture the harmonic spectral response of the junctions at the cryogenic device reference plane. Upon the successful combination and implementation of these two techniques, we will have developed a method to measure the current-phase relation and the resulting harmonic spectrum of a device in a single setup. By analyzing the current-phase relation's dependence on the niobium doping concentration and its effect on the harmonic output of a device, we can improve our device models to accurately predict a device's behavior in an application, leading to improved device design and performance.

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