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

Quantum Foundries, Educational Initiatives, Sensing and Metrology

Moderators: Ekta Bhatia, NY CREATES, **Haozhi Wang**, University of Maryland College Park

11:00am **QS2-TuM-13 NIST on a Chip, Quantum-Based Sensors for Metrology in the Quantum Era***, **Jay Hendricks,*** National Institute of Standards and Technology (NIST) **INVITED**

The re-definition of the SI units enables new ways to realize fundamental units. Quantum-based metrology systems, however exciting, do raise new challenges and several important questions: Can these new realizations enable the size and scale of the realization to be miniaturized to the point where it can be imbedded into everyday products?What will be the role of metrology institutes in the is new ecosystem of metrology and measurement?This talk will begin to explore these important philosophical questions.The technical core of the talk will be a deeper dive into research on measurement methods for pressure, the Fixed Length Optical Cavity (FLOC) and for vacuum the Cold Atom Vacuum Standard (CAVS).What is exciting about many of these new measurement approaches is that they are both primary (relying on fundamental physics), are quantum-based and use photons for the measurement readout which is key for taking advantage of the fast-growing field of photonics.

11:30am **QS2-TuM-15 RF Imaging of Sub-Surface Defects in Si(100) with an STM Tip-Induced Quantum Dot***, **Jonathan Marbey,** Michael Dreyer, Matthew Brooks,* University of Maryland*; Omadillo Abdurazakov, Yun-Pil Shim,* University of Texas at El Paso*; Robert Butera,* Laboratory for Physical Sciences (LPS)

We present radio frequency (RF) reflectometry measurements that have been combined into a millikelvin scanning tunneling microscope (mK-STM). This technique is realized through a relatively straight forward integration of an LC tank circuit into the STM tip-plate. For semi-conductor samples, application of a voltage bias gives rise to tip-induced band bending which leads to the formation of an induced quantum dot that can be scanned across the sample surface. This measurement geometry provides a unique detection method, as variations in the energy of a state confined to the tip-induced quantum dot due to the local environment leads small changes in quantum capacitance. These capacitance variations can be effectively sensed via RF reflectometry of the tunnel junction provided the tank circuit has a sufficient quality factor Q. In particular, we find strong phase contrast in the presence of resonant tunnel coupling between the induced dot and sub-surface defect states. As a demonstration of this capability, we present experimental results on highly phosphorus doped ($10^{19}cm^{-3}$) Si(100). 1-D voltage dependent spectroscopy measurements in the vicinity of defects reveal ring-like structures in the reflected phase that can be effectively modeled by an asymmetric double-dot detuning picture. This technique ultimately aims to emulate read-out geometries relevant to modern quantum dot devices.

11:45am **QS2-TuM-16 Pushing the Boundaries of Coherence in Superconducting Quantum Systems at the SQMS Center for Computing, Sensing, and Metrology***, **Tanay Roy,*** Fermi Lab **INVITED**

This talk will highlight recent advances at the SQMS Center in understanding and mitigating decoherence in superconducting quantum systems, focusing on both transmon qubits and 3D superconducting cavities. I will present results from systematic studies of materials and devices, aimed at identifying key sources of loss: including two-level systems (TLS), quasiparticles, and other noise mechanisms. These studies span microwave loss characterization in materials such as niobium, tantalum, aluminum, and their native oxides, as well as substrate losses in silicon and sapphire. Using both qubits and cavities, we disentangle subsystem contributions to loss and develop a hierarchy of mitigation strategies. Through these efforts, we have achieved transmon coherence times exceeding one millisecond. I will also present investigations into quasiparticle dynamics, including bursts observed in qubits located above ground and in the Gran Sasso underground laboratory. Additional studies explore temperature dependence to distinguish between TLS and quasiparticle losses, and reveal that applying a magnetic field can reduce temporal T1 fluctuations in transmons.

Building on these results, we demonstrate a record-coherence two-cell cavity-qudit system with coherence times exceeding 20 milliseconds. By leveraging sideband interactions and error-resilient protocols—including measurement-based correction and post-selection, we achieve high-fidelity quantum state control. This includes preparation of Fock states up to N = 20 with fidelities over 95%, and two-mode entanglement with coherence-limited fidelities reaching 99.9% after post-selection. These achievements position the SQMS platform as a powerful foundation for scalable quantum information processing and high-dimensional qudit encodings. Finally, I will discuss how these ultra-coherent systems are being deployed in emerging quantum sensing applications, including dark matter searches and gravitational wave detection.

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