Quantum Science and Technology
Room 304 - Session QS-MoM

Qubit Modalities I — Hybrid Superconducting–Semiconducting Quantum Devices

Moderators: Dr. Aranya Goswami, Nokia Labs, **Dr. Dave Pappas**, Rigetti Computing

10:00am **QS-MoM-1 Quantum Devices based on Sn-InAs Nanowire Josephson Junctions***, **Sergey Frolov,*** University of Pittsburgh **INVITED**

I will discuss superconducting qubits and parametric amplifiers based on hybrid superconductor-semiconductor Josephson junctions. The basic physics of these platforms is fairly understood and non-controversial. The bigger circuits tend to use similar materials, such as aluminum. It is a great superconductor for device applications. But similar qubits can also be made out of different materials which come with larger gaps, stronger spin-orbit interaction, electrical and not magnetic tunability and other nominal advantages. We are working on unexplored materials for those, namely Sn-based InAs nanowire Josephson junctions. Of course new materials are less mature as device platforms, but trying to make them perform can offer valuable lessons and expand our understanding of what works and why. Our InAs-Sn transmonos have reached a T1 relaxation time of 27 microseconds, and T2 dephasing times of 18 microseconds. We also report reduced nonlinearity beyond the short junction limit due to higher-order Josephson harmonics. Our parametric amplifiers operate both in the four-wave mixing mode as well as in the three-wave mixing mode, driven by the unconventional Josephson relation. We also demonstrate Andreev qubits based on nanowires, including the spectroscopy of a perfectly transmitting Majorana-like Andreev bound state.

10:30am **QS-MoM-3 Transport Study of SQUID Devices on Ge Quantum Well for Protected Superconducting Qubit***, **Shukai Liu,** Adhilsha Parachikunnumal, Joshua Thompson, Kasra Sardashti,* University of Maryland College Park

Superconductor-semiconductor (super-semi) hybrid Josephson junctions (JJs)emerged as a promising platform for a protected superconducting qubit with a π-periodic potential in phase. The π-periodic potential is achieved by leveraging the non-sinusoidal current-phase relation (CPR) of the super-semi JJs and the phase interference between JJs in a SQUID loop. In this talk, we share our progress toward realizing a moderately-protected superconducting qubit based on super-semi JJs realized on a Ge quantum well(QW), which promises a high baseline coherence from not only the parity protection but also the high- purity Si substrate. We focus on the transport measurement of SQUID devices on Ge QW to extract the current-phase relation at half-integer flux quanta, aiming to optimize the device parameters for qubit protection against both depolarization and dephasing.

10:45am **QS-MoM-4 Characterizing single and double quantum dots with quenched charging energy in semiconductor PbTe nanowires***, **Seth Byard,** Maksim Gomanko,* University of Pittsburgh*; Tongxie Zhang, Shixiong Zhang,* Indiana University Bloomington*; Sergey Frolov,* University of Pittsburgh

PbTe is a IV-VI narrow-bandgap semiconductor with potential utility for novel topological or spin qubits. One of PbTe's most notable characteristics is its large static dielectric constant, which exceeds 1000 at cryogenic temperatures and thus results in quenched charging energy in hosted quantum dots (QDs). Here we present our findings from transport measurements of QD systems defined electrostatically in PbTe nanowire devices and examine the implications of these results for our ongoing development of PbTe spin qubits.Our samples display large and highly anisotropic spin-orbit interaction (SOI) strengths and effective Landé g-factors, both of which are generally desirable properties for spin qubits. We characterize these anisotropies through the use of an externally applied magnetic field with variable angle. We discuss our analysis and interpretation of these data, focusing on how they relate to PbTe's rocksalt crystal structure.We additionally report the definition and control of double quantum dots in such systems. We find charge stability diagrams distinguished by the spin degeneracy of all transport resonances at zero magnetic field. We show the fourfold splitting of high-bias triangles in an applied magnetic field to illustrate the lifting of spin degeneracy via the Zeeman effect. We also identify patterns of transport resonances within these high-bias triangles and discuss their possible physical origins.

11:00am **QS-MoM-5 Sn–Inas Nanowire Josephson Parametric Amplifiers as Probes of Hybrid Junction Nonlinearity***, **Amritesh Sharma,** Amrita Purkayastha,* University of Pittsburgh, USA*; Param Patel,* Yale University*; Subhayan Sinha, Shreyas Asodekar,* University of Pittsburgh, USA*; An-Hsi Chen,* Grenoble-INP/CNRS, France*; Connor Dempsey,* University of California Santa Barbara*; Kun Zuo,* University of Sydney, Australia*; Chris Palmstrom,* University of California at Santa Barbara*; Moira Hocevar,* Grenoble-INP/CNRS, France*; Michael Hatridge,* Yale University*; Sergey Frolov,* University of Pittsburgh, USA

Hybrid semiconducting Josephson junctions, where proximity-induced superconductivity in a spin–orbit-coupled nanowire can be tuned by gate voltage and magnetic field, offer a rich platform to explore nonlinear quantum dynamics beyond what conventional Josephson tunnel junctions provide. We embed single Sn-InAs nanowire Josephson junctions carrying supercurrents of order 0.5 μA into NbTiN coplanar waveguide resonators to realize Josephson parametric amplifiers (JPAs) and probe the junction's intrinsic nonlinearity in a controlled microwave environment. The intrinsic quartic (Kerr) nonlinearity drives a four-wave mixing process yielding up to 20 dB of parametric gain in reflection, building on our prior demonstration of nanowire-based transmon qubits[1,2] and further establishing Sn-InAs nanowire junctions as effective nonlinear circuit elements at microwave frequencies.

Beyond amplification, we use the parametric response as a sensitive probe of how electrostatic gating, which tunes the resonant frequency by hundreds of MHz, and applied magnetic field modify the junction's nonlinear character. In select devices, we observe signatures of Kerr coefficient suppression and three-wave mixing, pointing to the activation of nonlinear terms beyond the standard quartic nonlinearity. These observations are consistent with higher-order or odd-order contributions expected when strong spin–orbit coupling and time-reversal symmetry breaking lift the constraints that ordinarily confine conventional Al/AlOx junctions to purely four-wave mixing processes [3]. These results establish the Sn-InAs nanowire JPA as both a functional quantum amplifier and a spectroscopic tool for studying field- and gate-tunable nonlinearity in hybrid Josephson systems.

References:

[1] A. Purkayastha et al., *Nano Lett.* 26, 2074 (2026).
[2] A. Purkayastha et al., arXiv:2603.26895 (2026).
[3] T. Reza et al., *SciPost Phys.* 20, 089 (2026).

11:15am **QS-MoM-6 Optimizing Ge/SiGe Quantum Well Interfaces for Low-Noise Spin Qubits via Surface Passivation***, **Iris Boateng,** Rebika Makaju, Giovanni Franco-Rivera, Kasra Sardashti,* Quantum Collaborative Research Corps & Department of Physics, University of Maryland, College Park MD, USA

Silicon-Germanium (SiGe) heterostructures are one of the leading platforms for semiconductor-based spin qubits. In silicon-based heterostructures, quantum dots (QDs) are defined electrostatically by lithographically patterned surface gates, allowing the confinement of a few electrons or holes and the manipulation of their spin degree of freedom for quantum information processing. However, a critical challenge in fabricating low-noise Ge/SiGe quantum dots is controlling the interface between the semiconductor and the high-κ gate dielectric, such as Al_2O_3. Imperfections at this boundary, primarily driven by the formation of unstable Ge-O bonds, lead to a high density of interface traps (D_{it}) [1]. These charge traps act as prominent sources of electrical noise, degrading device tune-up reliability and coherence [2]. In this work, we explore a systematic series of pre-deposition surface passivation methods designed to mitigate these interfacial defects and minimize D_{it}. We investigate a range of in-situ and ex-situ chemical treatments applied prior to atomic layer deposition (ALD). These protocols are specifically targeted at suppressing the formation of deleterious Germanium suboxides and promoting stable, stoichiometric bonding across the semiconductor-dielectric boundary. To evaluate the physical and chemical efficacy of these varying passivation techniques, X-ray photoelectron spectroscopy (XPS) is utilized to meticulously characterize the Silicon and Germanium chemical specie concentrations after each processing step. By correlating these chemical depth profiles with frequency dependent capacitance-voltage (C-V) measurements performed on Metal-Oxide-Semiconductor Capacitor (MOSCAP) devices, our aim is to establish a deterministic link between the targeted interface chemistry and the resulting electrical trap density. Ultimately, this comparative analysis aims to identify optimal interface engineering protocols, providing a clear pathway for the fabrication of highly stable, low-noise quantum dot devices for semiconducting based quantum computing architectures.

References:

[1] Duygu, K. et al. Microelectronic Engineering 88, 3428-3431 (2011).

[2] Leonardo, M. et al. Commun. Mater. 5, 151 (2024).

11:30am **QS-MoM-7 A Rapidly Iterable, Materials-Agnostic Platform for Correlating Loss in Superconducting Qubits**, ***Mihir Pendharkar**,* Stanford University **INVITED**

Most superconducting qubits use Josephson junctions made by angled evaporation, which ties the device to a narrow set of materials and processes. I will share our group's work on a junction approach that loosens these constraints. By decoupling junction synthesis from device geometry — the essence of a trilayer architecture — the junction becomes a designer element whose materials, barrier, and layering are chosen deliberately and iterated rapidly. The approach is, in a useful sense, materials-agnostic, since it accommodates many material systems; yet that same freedom makes it deeply materials-focused, turning the junction stack into a controlled experimental variable. It also extends naturally across qubit geometries, from transmons to mergemons and beyond, and supports industry-scalable practices such as lift-off-free junction fabrication.

I will delve into the novel junction materials this approach makes accessible and how they push qubit operation toward higher frequencies and temperatures than conventional devices reach. From there I will turn to what synchrotron x-ray techniques uncover about a working junction — the buried interfaces, disorder, and composition that define its true nature within the qubit and that electrical measurements leave hidden. Threading these together is a fast loop — design a junction, build it, measure it, resolve its structure — through which we aim to draw direct, microscopic correlations between materials and the sources of loss in superconducting qubits.

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