Quantum Science and Technology
Room Ballroom A - Session QS-ThP
Quantum Science and Technology Poster Session

QS-ThP-1 from Quantum Device Output to Governed Compute Continuation: A Runtime Architecture for Heterogeneous Scientific Workflows, ***Thomas Porter,*** ACGEOS

The Issue:

Emerging quantum-enabled devices, including quantum computers, photonic devices, neuromorphic, superconducting, spin, and advanced microelectronic platforms, are increasingly presented as peer elements in heterogeneous computing scientific workflows. However, the boundary between experimental device output and runtime compute continuation remains creates isolation. Device configuration, execution conditions, telemetry, logs, uncertainty, AI/ML probability interpretation, and returned results are often handled through separate files, scripts, instruments, schedulers, or manual processes, limiting reproducibility and cross-platform comparison. Quantum computers are treated as stand-alone devices.

Presenting a solution:

This poster conceptually presents ACGEOS, a governed runtime orchestration architecture for integrating quantum-enabled devices into auditable heterogeneous workflows. The model treats each task, device, configuration, telemetry record, result, and continuation state as an identifiable object. A portable governed container, the .polyp , preserves the original request, device setup, execution context, telemetry, logs, error state, and returned data. A Binding Object Layer record links expected execution to actual returned state, allowing the workflow to continue without losing provenance.

Innovation:

A central feature is a triplet return model from the quantum-device integration:

1. un-edited quantum result preserved as a .polyp , the original evidence package,
2. a BOL-bound result returned to the compute runtime for deterministic workflow continuation, and
3. an AI/ML evaluation sidecar used for confidence scoring, anomaly detection, repeatability assessment, or interpretation of probabilistic device behavior. In this model, AI/ML does not replace the governed result of record; it becomes an attached evaluation layer.

The proposed architecture is intended for future testbeds where quantum, photonic, neuromorphic, GPU, CPU, and instrument-class devices must participate in reproducible scientific workflows. The goal is to provide a systems-level bridge between device performance, experimental evidence, and compute continuation, supporting scalability, reliability, and translation of emerging quantum technologies into practical research and engineering environments.

QS-ThP-2 Josephson Effect at the Atomic Scale with High Energy Resolution and Microwave Irradiation*, Soumyaranjan Jhankar,* *Christian Ast,* Max Planck Institute for Solid State Research, Germany

The Josephson effect is a fundamental phenomenon of a superconductor-insulator-superconductor (SIS) junction. The Josephson current encodes information about the Cooper pair condensate, and its spectral features can be exploited as a benchmark for the energy resolution of the system. Understanding the Josephson effect at the atomic level is directly relevant to superconducting devices such as SQUIDs and to emerging quantum technologies.

Using a low temperature scanning tunneling microscope (STM) with a superconducting tip and sample, it can be investigated at the atomic scale. In this work, we report high resolution STM measurements with a microwave source at the SIS junction. We have achieved an energy resolution of 9 μeV at 1.09 K, representing the lowest benchmark value reported at this temperature so far and on par with state-of-the-art mK systems.

Microwave irradiation allows the study of microscopic phenomena, including subgap bound states (e.g., Yu–Shiba–Rusinov states), tunneling processes such as Cooper pair and quasiparticle tunneling, and resonant processes such as electron paramagnetic resonance. This motivates us to study SIS junctions under microwave irradiation, where the energies of tunneling particles are varied non-adiabatically, giving rise to replica features in the differential conductance spectra and in the Josephson current–voltage characteristics. These features serve as a signature of quantum interference at the atomic scale.

QS-ThP-3 TOF-SIMS Depth Profiling of Tantalum Deposited with Ar and Kr Sputter Gas*, Aleksandra Biedron,* *Vidya Kaushik,* NY Creates*; Maciej Olszewski, Lingda Kong, Simon Reinhardt, Daniel Tong, Xinyi Du,* Cornell University*; Gabriele Di Gianluca,* University of Florida*; Haoran Lu, Saswata Roy, Luojia Zhang, David Muller, Valla Fatemi,* Cornell University

Tantalum (Ta) is an attractive material for superconducting applications, and optimizing deposition conditions could improve compatibility with standard semiconductor processes. Ta is typically deposited on silicon at high temperature with argon (Ar) gas. This work examines how changing the sputter gas from Ar to krypton (Kr) promotes growth of high-quality Ta films at lower substrate temperatures. The Ta films were characterized with a variety of surface analysis techniques, including depth profiling with Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS). Changes in the morphology and structure of Kr sputtered films were observed, as compared to ones deposited using conventional Ar gas. The results from SIMS and other thin film analysis were in agreement and complemented by cryogenic microwave and qubit performance data. We therefore promote Kr as a superior process gas for scalable deposition of Ta films for superconducting qubit applications. [1]Reference: [1] arXiv:2601.20091 [quant-ph]; https://doi.org/10.48550/arXiv.2601.20091

QS-ThP-4 A High-Yield "Baseline" Fabrication Recipe for Superconducting Resonators and Qubits at Cornell Nanoscale Facility*, Xinyi Du,* *Maciej Olszewski, Simon Simon Reinhardt, Lingda Kong, Gabriele Gianluca, Ron Olson, Valla Fatemi,* Cornell University

The reliable scaling of superconducting quantum processors depends heavily on the reproducibility and yield of the underlying micro- and nanofabrication processes. As quantum computing research expands, open user facilities play a critical role in providing standardized, high-quality fabrication baselines that democratize hardware developmentand prototyping. In this work, we present a user-facility-compatible fabrication flow for coplanar waveguide (CPW) resonators and planar transmon qubits, developed using the equipment at the Cornell NanoScale Facility (CNF).

This baseline methodology focuses on process optimization to maximize device yield, establish a reliable foundation for quantum coherence, and improve overall fabrication efficiency. A primary challenge in planar qubit fabrication is mitigating Two-Level System (TLS) losses arising from interfacial defects and fabrication residues, a step that traditionally relies on labor-intensive processing. To address this, our process flow incorporates a streamlined wet chemical treatment protocol. This optimized approach significantly reduces hands-on effort while effectively minimizing polymer and oxide residues at critical material interfaces, providing an easier fabrication route that ensures no degradation of feature resolution or device quality.

We characterize the efficiency of this baseline flow through comprehensive room-temperature metrology, followed by cryogenic microwave measurements. The presentation details the step-by-step cleanroom recipe, emphasizing the correlation between our refined wet processing and the resulting quantum metrics. This baseline provides the broader materials for quantum information science community with a reliable approach to consistently achieve high-yield quantum hardware.

QS-ThP-5 Learning-Guided Variational Quantum Eigensolver with Circuit-Aware Parameterization and Post-Processing*, Yan Li,* Penn State University

Variational quantum eigensolver (VQE) methods provide a promising hybrid quantum-classical framework for estimating low-energy states of complex Hamiltonian systems on near-term quantum devices. However, practical VQE performance is often limited by the strong dependence of the optimization landscape on circuit structure, parameter initialization, measurement noise, and the quality of classical post-processing. This work develops a learning-guided VQE workflow that integrates circuit-aware characterization, machine-learning-assisted parameter prediction, and classical post-processing to improve convergence and solution quality. First, the variational circuit is analyzed to identify structural features that influence the energy landscape and parameter sensitivity, enabling a more informed design of the ansatz and search space. Second, machine learning models are trained to predict promising initial parameters or parameter-update directions from Hamiltonian features and prior optimization data, reducing the reliance on random initialization and repeated classical optimization. Third, post-processing techniques are applied to refine measured quantum outputs, mitigate sampling effects, and improve the physical interpretability of the resulting eigenstate estimates. The proposed framework is demonstrated through representative Hamiltonian problems relevant to quantum simulation and energy-system optimization. Results show that incorporating circuit-informed learning and post-processing can accelerate convergence, reduce optimization variability, and enhance the reliability of VQE under realistic measurement constraints. This study highlights the potential of combining quantum circuit analysis, data-driven parameter learning, and classical refinement to make variational quantum algorithms more scalable and robust for near-term quantum science and technology applications.

QS-ThP-6 Scanning-Tunneling-Microscope-Defined Josephson Junctions as a Local Platform for Qubit-Relevant Phase Dynamics*, **Robertus Elbertse,** Dengyu Yang,* NIST-Gaithersburg*; Fabian Natterer,* ETH Zürich, Switzerland*; Joseph Stroscio,* NIST-Gaithersburg

Superconducting qubits rely on the controlled dynamics of the Josephson phase across weak links, yet the microscopic relationship between junction structure, dissipation, electromagnetic environment, and phase coherence remains difficult to access directly. Scanning tunneling microscopy provides an unusual route to this problem: the tunnel junction itself can act as a local, continuously tunable Josephson junction between superconducting electrodes. Unlike lithographically defined devices, an STM-defined junction allows the critical current, normal-state resistance, capacitance, and local atomic environment to be varied in situ while preserving cryogenic operation and microwave access.

Here we develop STM-defined Josephson junctions as a platform for exploring qubit-relevant superconducting phase dynamics. Using superconducting tips and samples, we characterize Josephson coupling as a function of junction conductance, material parameters, and engineered microwave environment. We examine signatures associated with phase fluctuations, junction switching, and the crossover toward regimes where the junction potential becomes sufficiently nonlinear and isolated to support phase-qubit-like dynamics. Even when operated below the threshold for a fully realized qubit, this approach provides direct access to the ingredients that govern superconducting weak-link behavior: local structure, dissipation, impedance, and noise. The resulting platform bridges atomic-scale superconducting spectroscopy and circuit-level Josephson physics, offering a flexible route toward local studies of superconducting quantum devices.

QS-ThP-7 Structure-Transport Relationships of Epitaxial Superconducting Nitride Films*, Evangeline Beeching, Sabin Regmi, Amey Khanolkar, Ahmed Wasif Mustakim, Volodymyr Buturlim, Zach Cresswell, Kevin Vallejo,* Idaho National Laboratory*; Robert Makin,* Western Michigan University*; Krzysztof Gofryk,* Idaho National Laboratory*; **Brelon May,*** Montana State University

The high tunability of semiconductor platforms has enabled them to be leveraged for various technologies and applications. The aspects of superconductivity can also be engineered to have specific targets. Recent efforts surrounding superconducting films for quantum systems have largely focused on achieving higher critical temperatures. However, as consensus is reached surrounding the importance of defects in quantum systems there is increasing interest in elucidating and controlling other mechanisms and resulting parameters. Understanding how synthesis parameters influence structural disorder at various length scales and their impact on the physical properties is a complex problem. This work will look into aspects of disorder ranging from the atomic scale to longer range inhomogeneities in the crystalline lattice and the relationships with electrical transport.

We will discuss the deposition of epitaxial superconducting ZrN by molecular beam epitaxy, the separate roles of atomic and crystalline disorder, and relationships between synthesis parameters and resulting structural and physical properties. The use of various substrates and orientations allows for insight into the effects of lattice mismatch and the preferential growth directions. Under the conditions investigated, rocksalt ZrN appears to prefer formation along the (001) direction but (111) oriented inclusions are observed when the temperature is too low. There is a complex relationship between synthesis parameters and resulting short range (atomic scale) and long range (crystalline lattice) order, as measured by detailed X-ray diffraction. The resulting structure shows tunability of electrical transport and optical properties, which can both range from metallic to dielectric. A broad generalization shows that samples deposited at elevated temperatures were more metallic and have higher superconducting transitions. However, other properties change in unintuitive ways, which can be explained by the non-monotonic changes in the atomic scale disorder. This work integrating superconducting films with known semiconductor platforms provides an avenue for the pursuit of (001) oriented heterostructures for superconducting or optical quantum applications.

QS-ThP-8 High Purity CaO thin films for quantum information science*, **Jake DeChiara,*** Pennsylvania State University*; Bonnie Lin,* MIT*; Amirehsan Alizadeh, Edo Waks,* University of Maryland College Park*; James LeBeau,* MIT*; Saeed Almishal, Jon-Paul Maria,* Pennsylvania State University

Computational studies predict CaO as a promising host crystal suitable to sustain optically addressable QuBits with long coherence times due to low natural abundance of calcium isotopes with nuclei with net spin and low spin orbit coupling, allowing defect states to be well isolated from magnetic noise. In this work we experimentally engineer bismuth and rare earth lanthanide dopants in varying concentration levels in an ultra-high purity, low defect CaO thin film to experimentally verify defect structure and coherence times. Reactive RF Sputtering is selected as a desirable physical vapor deposition method allowing tunable deposition rates through changes in magnetron power and cathode working distance to the substrate. Relaxed (001) oriented CaO films are grown on r-plane sapphire single crystal substrates achieving film heteroepitaxy. Host crystal purity is paramount to achieving long spin coherence times, as any magnetic impurities may interact with defect states. To minimize chemical impurity, we develop an ultra-high purity calcium sputtering source by hydrothermal sintering. 1- and 2-inch calcium hydroxide (99.999% pure) to above 95 % theoretical density. Sintering temperatures below 150°C inhibit solid state diffusion of contaminants into the source target, maintaining exceptionally high target purity throughout all processing stages. Calcium oxide thin films and dopants are co-sputtered via an off-axis geometry to mitigate anion bombardment, allowing for increased deposition rates, smooth film morphology, high density, and low film mosaicity as quantified via XRD and XRR. High deposition temperatures (875°) allow for film deposition with high crystallinity. Dopant concentration down to the single part-per-million level is quantified by induction coupled plasma optical emission spectroscopy via film dissolution in aqueous solution. Dopant concentration is coupled with deposition rate from the calcium and dopant source magnetrons and is experimentally tuned by changing dopant magnetron working distance and power, in turn modifying calcium and dopant source flux to the substrate. Oxygen vacancy defects that scale with Er are identified in the CaO lattice via deep UV photoluminescence measurements performed with a 248 nm laser excitation at room temperature – these provide an interesting pathway to infer dopant concentrations. Finally STEM analysis, including electron ptychography, that shows film microstructure, lattice strains, and defects will be presented.

QS-ThP-9 Physical Vapor Deposition of Highly Crystalline Cerium Oxide (CeO_2) Thin Films for Quantum Information Technology*, **Andrey Shults,** Saeed Almishal,* The Pennsylvania State University*; Sooyoon Hwang,* MIT*; Amirehsan Alizadehherfati,* University of Maryland*; James LeBeau,* MIT*; Edo Waks,* University of Maryland*; Jon-Paul Maria,* The Pennsylvania State University

CeO_2 is a well-known host for defect-generated qubits that offers high relaxation and coherence times desirable in quantum computing applications. Scalable and reproducible qubit performance with large spin coherence lifetimes requires materials with high crystallinity, low point defect concentrations, and excellent surface quality. In this work, we investigate structural and electronic properties of erbium doped CeO_2 to better understand how the crystalline quality and the defect chemistry affect its performance in quantum information technology. Utilizing RF magnetron sputtering from CeO_2 ceramics, we can tune the crystalline quality by methodically adjusting the deposition parameters such as substrate temperature, total pressure, gas ratio, and stage bias. We find that high deposition temperatures and low oxygen flows yield films with smooth surfaces (<1nm RMS), outstanding crystallinity, and low mosaicity (<0.2° FWHM rocking curve) but also create oxygen vacancies. We demonstrate that a subsequent thermal anneal in oxygen atmosphere heals the films and improves electrical properties. By dilute-doping CeO_2 with optically-active erbium, we can introduce defect qubits without altering the overall crystalline quality. During the erbium co-sputtering, we can modulate dopant levels from tens to hundreds parts per million throughout the CeO_2 thickness, as confirmed by inductively coupled plasma atomic emission spectroscopy. Photoluminescence spectroscopy results show a strong erbium emission at ~1510 nm with a 3.7 ms lifetime in agreement with theoretical calculations. Transmission electron microscopy confirms homogenous erbium doping within the film, coherent film-substrate interface, dense and continuous growth, and a smooth surface. Ultimately, we use a rich combination of characterization probes to better understand the connection between thin film structure and electronic properties that give rise to high-performing defect qubits.

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