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Building a **QUANTUM COMPUTING ARCHITECTURE** using 3D superconducting cavities

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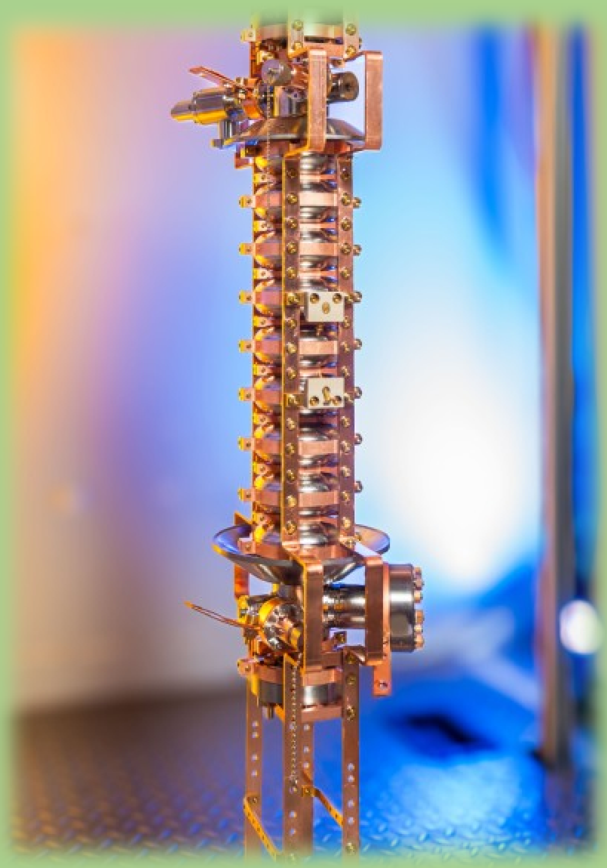
Quantum computers promise advantages over classical machines for solving certain complex problems, but building processors that truly deliver this advantage remains a central challenge, particularly due to limited coherence times. Three-dimensional superconducting radio-frequency (SRF) cavities offer an attractive platform due to their exceptionally long lifetimes. However, since these harmonic systems require nonlinear elements, such as transmons, for control, additional losses are often introduced.

The speaker will present a multimode quantum system built on an elliptical SRF cavity that hosts two cavity modes weakly coupled to an ancillary transmon circuit. The architecture is engineered to maintain coherence while allowing efficient control. By mitigating transmon-induced decoherence, the system achieves single-photon lifetimes of 20.6 ms and 15.6 ms in the two modes, with pure dephasing times surpassing 40 ms. Through sideband interactions and error-resilient protocols—such as measurement-based correction and post-selection—the work demonstrates high-fidelity state control, including preparation of Fock states up to N=20 with fidelities above 95% (the highest reported to date), as well as high-fidelity two-mode entanglement. These results establish 3D SRF cavities as a strong platform for qudit-based quantum information processing, leveraging the large Hilbert space of cavity modes. The presentation will conclude with strategies for further enhancing coherence in both cavities and ancilla qubits, along with pathways toward scaling this architecture for larger quantum computing systems.



Dr. Tanay Roy is an Associate Scientist at the Superconducting Materials and Systems (SQMS) Center at Fermilab, where he serves as Deputy Head of the “3D Quantum Systems” department. He leads efforts to develop next-generation 3D quantum computing architectures based on superconducting radio-frequency cavities, with the goal of building prototype quantum processors that achieve dramatically improved coherence times and enhanced controllability. His research focuses on harnessing these bosonic systems for high-dimensional quantum information processing using qudits, which offer potential advantages over traditional qubit-based approaches. Prior to joining Fermilab, Dr. Roy was a postdoctoral researcher at the University of Chicago, where he worked on autonomous quantum error correction, quantum search algorithms, and demonstrated a qutrit-based quantum processor. He received his Ph.D. from the Tata Institute of Fundamental Research (India), where he co-developed broadband superconducting parametric amplifiers and India’s first three-qubit superconducting processor.

Oct 10, 2025 at 4 p.m.

Lecture Theatre AG66, TIFR

YouTube Live: https://tinyurl.com/TanayRoy

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