Quantum Science and Technology Mini-Symposium
Room 208 W - Session QS1-MoM

Qubit Modalities for Quantum Computing

Moderators: Ekta Bhatia, NY CREATES, **Drew Rebar**, Pacific Northwest National Laboratory

8:15am **QS1-MoM-1 Strongly Anharmonic Gatemon Devices on Proximitized InAs 2DEG**, ***Shukai Liu,*** University of Maryland, College Park*; Arunav Bordoloi, Jacob Issokson, Ido Levy,* New York University*; Kasra Sardashti,* University of Maryland College Park*; Javad Shabani,* New York University*; Vladimir Manucharyan,* EPFL, Switzerland

Gatemon qubits represent an all-electric variant of the conventional transmon, where local electrically gated superconductor-semiconductor hybrid Josephson junctions (JJs) are employed for qubit operations. Gatemon qubits, made of transparent super-semi Josephson junctions, typically have even weaker anharmonicity than the opaque AlOx-junction transmons. However, flux-frustrated gatemons can acquire a much stronger anharmonicity, originating from the interference of the higher-order harmonics of the supercurrent. Here, we investigate this effect of enhanced anharmonicity in split-junction gatemon devices based on a proximitized InAs quantum well. We find that anharmonicity over 100% can be routinely achieved at the half-integer flux sweet-spot without any need for electrical gating or excessive sensitivity to the offset charge noise. We verified that such "gateless gatemon" qubits can be driven with Rabi frequencies more than 100 MHz, enabling gate operations much faster than what is possible with traditional gatemons and transmons. Furthermore, by analyzing a relatively high-resolution spectroscopy of the device transitions as a function of flux, we were able to extract fine details of the current-phase relation, to which transport measurements would hardly be sensitive. The strong anharmonicity of our gateless gatemons, along with their bare-bones design, can prove to be a precious resource that transparent super-semi junctions bring to quantum information processing.

8:30am **QS1-MoM-2 Quantum Keynote Lecture**, ***Jerry Chow*** [1], IBM Quantum **INVITED**

9:15am **QS1-MoM-5 Stable Cnot-Gate on Inductively-Coupled Fluxoniums with Over 99.9% Fidelity – Part 1**, *Wei-Ju Lin,* University of Maryland College Park, Taiwan*;* ***Hyunheung Cho,*** University of Maryland College Park, Republic of Korea*; Yinqi Chen,* Louisiana State University, China*; Kasra Sardashti,* Laboratory for Physical Sciences*; Maxim Vavilov,* University of Wisconsin - Madison*; Chen Wang,* University of Massachusetts - Amherst*; Vladimir Manucharyan,* EPFL, Switzerland

In this part of the talk, we report a detailed characterization of two inductively-coupled superconducting fluxonium qubits [1] for implementing high-fidelity cross-resonance gates [2]. Our circuit is notable because it behaves very closely to the case of two transversely coupled spin-$1/2$ systems. In particular, the generally unwanted static ZZ-term resulting from the non-computational transitions is nearly absent, even with a strong qubit-qubit hybridization. Spectroscopy of the non-computational transitions reveals a spurious LC-mode arising from the combination of the coupling inductance and the capacitive links between the terminals of the two-qubit circuit. Such a mode has a minor effect on the present device, but it must be carefully considered for optimizing future multi-qubit designs.

[1] Lin, Wei-Ju, et al. "Verifying the analogy between transversely coupled spin-1/2 systems and inductively-coupled fluxoniums." *New Journal of Physics* 27.3 (2025): 033012.

[2] Lin, Wei-Ju, et al. "24 Days-Stable CNOT Gate on Fluxonium Qubits with Over 99.9% Fidelity." *PRX Quantum* 6.1 (2025): 010349.

9:30am **QS1-MoM-6 Stable CNOT-gate on Inductively-coupled Fluxoniums with over 99.9% Fidelity – part 2**, ***Wei-Ju Lin***, *Hyunheung Cho,* University of Maryland, College Park*; Yinqi Chen,* University of Wisconsin - Madison*; Kasra Sardashti,* University of Maryland, College Park*; Maxim G. Vavilov,* University of Wisconsin - Madison*; Chen Wang,* University of Massachusetts, Amherst*; Vladimir E. Manucharyan,* EPFL, Switzerland

In this part of the talk, we discuss the realization of a 60 ns direct CNOT gate on two inductively-coupled fluxonium qubits over 99.9% fidelity [1]. Fluxonium qubit is a promising elementary building block for quantum information processing due to its long coherence time combined with a strong anharmonicity. In this paper, we realize a 60 ns direct CNOT-gate on two inductively-coupled fluxoniums, which behave almost exactly as a pair of transversely-coupled spin-$1/2$ systems [2]. The CNOT-gate fidelity, estimated using randomized benchmarking, was as high as 99.94\%. Furthermore, the fidelity remains above 99.9\% for 24 days without any recalibration between measurements. Compared with the 99.96\% fidelity of a 60 ns identity gate, our data brings the investigation of the non-decoherence-related errors during logical operations down to 2×10^{-4}. The present result adds a simple and robust two-qubit gate into the still relatively small family of the "beyond three nines" gates on superconducting qubits.

[1] Lin, Wei-Ju, et al. "24 days-stable CNOT-gate on fluxonium qubits with over 99.9% fidelity." *arXiv preprint arXiv:2407.15783* (2024).

[2] Lin, Wei-Ju, et al. "Verifying the analogy between transversely coupled spin-1/2 systems and inductively-coupled fluxoniums." *arXiv preprint arXiv:2407.15450* (2024).

9:45am **QS1-MoM-7 Silicon-Based Quantum Processors**, ***Jason Petta,*** University of California at Los Angeles **INVITED**

Of all of the qubit modalities being investigated, semiconductor spin qubits most closely resemble conventional transistors, which can be fabricated at scale with ~100 billion transistors on a chip. It is therefore important to pursue long-term approaches to fault-tolerant quantum computing with spin qubits. I will give an update on recent progress, including high-fidelity multi-qubit control [1,2], long-range spin-spin coupling [3,4], and two-dimensional spin qubit arrays [5,6].

References

[1] A Mills *et al*., Phys. Rev. Applied **18**, 064028 (2022).
[2] A. Mills *et al*., Sci. Adv. **8**, eabn5130 (2022).
[3] F. Borjans *et al*., Nature **577**, 195 (2020).
[4] X. Zhang *et al*., Phys. Rev. Applied **21**, 014019 (2024).
[5] W. Ha *et al*., Nano Lett. **22**, 1443 (2022).
[6] E. Acuna *et al*., Phys. Rev. Applied **22**, 044057 (2024).

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[1] **Quantum Keynote Lecture**

Author Index

Bold page numbers indicate presenter