Friday Morning, January 20, 2023

AVS Quantum Science Workshop
Room Redondo - Session AQS-FrM1

AVS Quantum Science Workshop: Superconducting Quantum Computing

Moderator: Hannes Kraus, Jet Propulsion Laboratory

8:45am **AQS-FrM1-1 Laser-Annealing Josephson Junctions to Achieve Scaled-Up High-Performance SuperconductingQuantum Processors***, Jared Hertzberg,* IBM Research **INVITED**

As we increase the scale of superconducting quantum-computing circuits, we face challenges in maintaining high-fidelity quantum gates across the device. Fixed-frequency tansmons offer excellent coherence, noise stability and simplicity of operation, making them an ideal qubit platform for large-scale circuits. However, established fabrication methods cannot set the frequencies of such qubits with precision better than about 2%. High two-qubit gate fidelities require precise control of the relative qubit frequencies. To quantify the precision needed, we define “frequency collisions” in a cross-resonance gate architecture, and show statistically that 2% frequency precision is insufficient to evade such collisions. To overcome this challenge, we introduce a ‘heavy hexagon’ lattice of qubits along with selective laser-anneal to tune the qubits into desired frequency patterns. This anneal procedure offers a nearly tenfold improvement in qubit frequency precision. In 28-qubit and 65-qubit processors, we demonstrate no measurable effect of this tuning on qubit coherence, and median two-qubit gate fidelity of 98.7%. We discuss the application of these techniques to the current generation of processors at 100-qubit scale, as well as prospects for further scaling. Precise control of qubit frequencies will be essential to increasing quantum volume and to achieving quantum advantage, at the 1000 qubit scale and beyond.

References:

[1] Zhang, E. J. et al. High-Performance Superconducting Quantum Processors via Laser Annealing of Transmon Qubits. *Science Advances* **2022**, *8* (19), eabi6690.

[2] Hertzberg, J. B. et al. Laser-Annealing Josephson Junctions for Yielding Scaled-up Superconducting Quantum Processors. *npj Quantum Inf* **2021**, *7* (1), 1–8.

[3] Chamberland, C. et al. Topological and Subsystem Codes on Low-Degree Graphs with Flag Qubits. *Phys. Rev. X* **2020**, *10* (1), 011022.

9:25am **AQS-FrM1-9 Progress Towards Merged-Element Transmons***, **David Pappas**, E. Lachman, J. Mutus,* Rigetti Computing*; C. Palmstrom,* University of California Santa Barbara **INVITED**

Transmons have become the dominant type of qubit used for superconducting quantum computing. This is primarily due to their relative charge insensitivity and well defined anharmonicity. However, significant technical challenges are presented in the areas of frequency allocation and loss. These challenges can be traced back to the use of amorphous, ultra-thin tunnel junctions used to generate the non-linear inductance. These challenges can be mitigated by actively trimming the junction normal resistance and using a quasi-lumped element approach, with very small junctions in parallel with a large shunt capacitor. However, it is clear that improvement of the frequency spreads will still likely be limited by fluctuations in the superconducting Josephson inductance and reductions of the size of the devices (typically on the order of 100’s of um^2) will be limited by the shunt capacitors. In addition, the appearance of spurious two-level systems in the amorphous material is still an issue. In this talk we will discuss the concept and implementations of the merged-element transmon (MET). The design goals and demonstrated optimization for low-loss will be presented, along with the new proposal for addressing the frequency allocation problem and achieving sub-um devices using single-crystal, fin-based tunneling technology.

Author Index

Bold page numbers indicate presenter