Title:
A blueprint for demonstrating quantum supremacy with superconducting qubits

Abstract:
Long coherence times and high fidelity control recently achieved in scalable superconducting circuits paved the way for the growing number of experimental studies of many-qubit quantum coherent phenomena in these devices. Albeit full implementation of quantum error correction and fault tolerant quantum computation remains a challenge the near term pre-error correction devices could allow new fundamental experiments despite inevitable accumulation of errors. One such open question foundational for quantum computing is achieving the so called quantum supremacy, an experimental demonstration of a computational task that takes polynomial time on the quantum computer whereas the best classical algorithm would require exponential time and/or resources. It is possible to formulate such a task for a quantum computer consisting of less than a 100 qubits. The computational task we consider is to provide approximate samples from a non-trivial quantum distribution. This is a generalization for the case of superconducting circuits of ideas behind boson sampling protocol for quantum optics introduced by Arkhipov and Aaronson. In this presentation we discuss a proof-of-principle demonstration of such a sampling task on a 9-qubit chain of superconducting gmon qubits developed by Google. We discuss theoretical analysis of the driven evolution of the device resulting in output approximating samples from a uniform distribution in the Hilbert space, a quantum chaotic state. We analyze quantum chaotic characteristics of the output of the circuit and the time required to generate a sufficiently complex quantum distribution. We demonstrate that the classical simulation of the sampling output requires exponential resources by connecting the task of calculating the output amplitudes to the sign problem of the Quantum Monte Carlo method. We also discuss the detailed theoretical modeling required to achieve high fidelity control and calibration of the multi-qubit unitary evolution in the device. We use a novel cross-entropy statistical metric as a figure of merit to verify the output and calibrate the device controls. Finally, we demonstrate the statistics of the wave function amplitudes generated on the 9-gmon chain and verify the quantum chaotic nature of the generated quantum distribution. This verifies the implementation of the quantum supremacy protocol.