Efficient State Estimation of Bosonic Modes with Quantum Machine Learning

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Bosonic superconducting devices are a promising platform for hardware-efficient and error-correctable quantum information processing. However, typical approaches to characterize bosonic modes, such as Wigner tomography, require a large number of measurements to densely map the phase space of these modes. Thus, Wigner tomography is a resource-intensive technique that becomes practically infeasible when scaling up to multimode systems. To overcome this challenge, we leverage on a quantum machine learning protocol to efficiently estimate arbitrary bosonic states with fewer measurements. More especially, our protocol is based on quantum reservoir processing (QRP). To measure an arbitrary state in the first cavity (Alice), we first scramble its information across a larger Hilbert space via ergodic evolutions, which can be achieved through a programmable beamsplitter interaction that couples Alice to a second cavity (Bob), as well as with displacement, and squeezing operations. We then measure the photon number distribution on Bob and use a previously-trained quantum map to transform the measurement results into a density matrix estimator. Assuming no measurement error, estimating an arbitrary state of dimension D with high fidelity only requires $D^2 - 1$ measurements. Hence, for the same number of measurements, QRP reconstructs the initial state with higher fidelity than Wigner tomography.

This project may contribute to establish a new technique for efficient state estimation of bosonic modes, which can become a useful tool to speed up measurements in day-to-day experiments.

References

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Figures

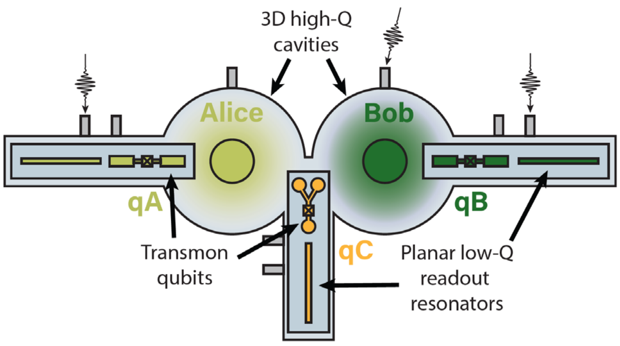

Figure 1: Schematic of the device used to perform the QRP protocol. Two 3D cavities (Alice and Bob) are coupled together through a transmon qubit (qC). Each cavity is also coupled to an individual transmon (qA and qB) for state preparation and cavity readout. Finally, each transmon qubit is coupled to its own readout resonator.