Complete device QND measurement tomography and applications to IBM-Q

Luciano Pereira
Juan José García-Ripoll
Tomás Ramos

Instituto de Física Fundamental IFF-CSIC, Calle Serrano 113b, Madrid 28006, Spain

Luciano.ivan@iff.csic.es

Quantum non-demolition (QND) measurements are a fundamental element for quantum computing. However, they are currently a limiting factor in the performance of quantum devices based on superconducting circuits. Dispersive readout, which is the standard strategy for measuring these systems, is unavoidably affected by noise such as non-dispersive errors, higher-level leakage, decoherence, and crosstalk, which reduce the quality of the readout and the QND nature of the measurement. In order to improve QND detectors, we require efficient characterization technics to identify and mitigate the source of errors. In this work, we present an efficient scaling strategy to characterize all the measurements of a device by quantum tomography. The protocol reconstructs the Choi matrices that describe the measurements of every single qubit and all the pairs of physically connected qubits. The protocol requires a bounded number of circuits for any number of qubits thanks to an efficient parallelization of the tomography. This allows us to avoid the exponential scaling of a standard QND measurement tomography. Besides, postprocessing can be also solved efficiently by parallelizing it on a classical processor. We perform an experimental implementation of the protocol to fully characterize all the detectors of a 7-qubits IBM-Q quantum device. We use the tomographic estimates to study properties of the measurement such as readout fidelity, qndness, destructiveness, and crosstalk. After that, we apply the method to characterize a custom detector composed by a standard measurement, a reset, and a conditional state preparation.

References

[1] L. Pereira, J.J. García-Ripoll, and T. Ramos, arXiv:2109.06616 (2021).