The Boundary for Quantum Advantage in Gaussian Boson Sampling

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Gaussian Boson Sampling (GBS), in which photons are measured from a highly entangled Gaussian state, is a leading approach in pursuing quantum advantage. State-of-the-art quantum photonics experiments that, once programmed, run in minutes, would require 600 million years to simulate using the best pre-existing classical algorithms. We find substantially faster classical GBS simulation methods, including speed and accuracy improvements to the calculation of loop hafnians, the matrix function at the heart of GBS. These results reduce the run-time of classically simulating state-of-the-art GBS experiments to several months—a nine orders of magnitude improvement over previous estimates [1].

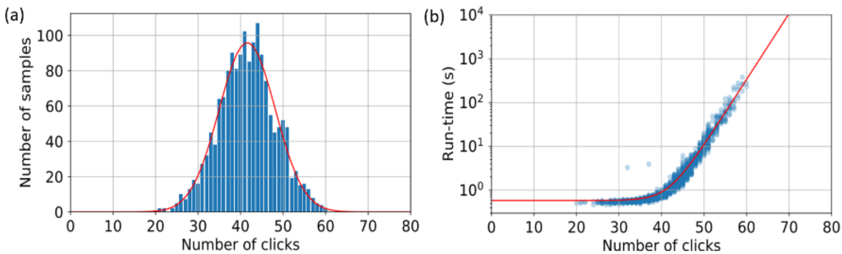

Fig. 1: Simulation results for an experiment comparable to ref. [1]. (a) shows click distribution of simulated samples, fit with a Gaussian (red line), (b) shows run-time, fit with a exponential plus a constant.

This run-time prediction is found using $\sim 100,000$ cores of an HPE Cray EX benchmarking system. Using the fits shown in Fig. 1, we find it takes 8.4 seconds on average to sample from the ideal GBS distributions, at a scale which claimed quantum advantage [1]. The improvement of our algorithm over reported estimates is even larger for updated versions of the experiment, due to a quadratic speedup of our algorithm compared to the methods considered in ref. [2].

References

[1] H.-S. Zhong et al., Science **370**, 1460 (2020).
[2] H.-S. Zhong et al., Phys. Rev. Lett. **127**, 180502 (2021).

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