

In situ characterization of linear-optical networks in randomized boson sampling

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Abstract

We introduce a new method for characterization of linear-optical networks (LON) in randomized boson sampling (RBS) experiments. By exploiting the entanglement used in RBS, we show that a RBS experiment can be converted to a classically simulatable problem that enables us to characterize a lossy LON. Furthermore, we introduce a measure of distance for comparing ideal and lossy LONs. By using this measure, we obtain an upper bound on the total variation distance between the ideal probability distribution for the RBS problem and the actual probability distribution achieved by a lossy LON.

It is strongly believed that quantum computers can perform certain computational tasks much faster than classical computers. A universal fault-tolerant quantum computer, however, is still not available, so there is great interest in intermediate models of quantum computation, which can demonstrate quantum-computational speedups with much simpler physical systems and algorithms [1]. Randomized boson sampling (RBS) [2], which is a generalized version of boson sampling [3], is an example of such intermediate model has attracted much attention due to its simple physical implementations.

We formulate RBS as a distributed task between two parties, Alice and Bob, who share weakly two-mode squeezed vacuum states. Alice performs local measurements on her modes, either photon counting or heterodyne. Bob implements and applies to his modes the LON requested by Alice; at the output of the LON, Bob performs photon counting, the results of which he sends to Alice via classical channels. In the ideal situation, by using photon-counting measurements and having Bob's results, Alice obtains samples from the probability distribution of the RBS problem, a task that is believed to be classically hard to simulate. However, we show that, by using heterodyne measurements, Alice can convert the experiment to a problem that is not only classically efficiently simulable, but also enables her to characterize a lossy LON of Bob on the fly, without Bob's knowing. The characterization runs are interspersed with the RBS runs, and Bob cannot know which is which.

Furthermore, we introduce a measure of distance between the ideal LON, described by a unitary transfer matrix, and the lossy LON of Bob, described by a transfer matrix which is not unitary. This measure is, in fact, the fidelity between the joint states shared by Alice and Bob after the ideal and lossy LONs, which is interesting in its own right. By using this measure, we obtain an upper bound on the total variation distance between the ideal probability distribution for the RBS problem and the actual probability distribution achieved in the experiment. Thus our *in situ* characterization procedure can check that a RBS device samples from a probability distribution that is close to the ideal photocount distribution. We, however, emphasize that this does not address the problem of verification of RBS, i.e., distinguishing the samples generated by the experiment from ones generated by some classical algorithm.

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