# Understanding and overcoming limitations of linear-optical quantum computation

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## Abstract

Passive linear optics corresponds to photonic linear transformations that map input creation operators into output creation operators. These transformations preserve the number of photons, and can be physically implemented with passive linear-optical elements[1]. These are among the simplest transformations to implement in a quantum optics laboratory[2]. In a landmark 2001 paper, Knill, Laflamme and Milburn [3] showed that single photons and linear optics suffices to implement scalable, universal quantum computation. Even without adaptivity bosonic linear optics is known to be hard to simulate on classical computers[4].

We study the use of linear interferometers photonic bunching and routing and the induction of optical nonlinearity via measurement. The canonical example of bosonic bunching is Hong-Ou-Mandel effect where two identical photons enter an even beam-splitter one in each input port and both always come out in the same output port[5]. We explore the importance of bosonic statistics for more complex routing tasks and find interferometers which optimize success probabilities for these tasks.

There is among physicists the intuition that bosonic statistics tends to cluster particles together in a smaller number if states relative to indistinguishable particles. In quantum linear optics this intuition can be wrong. As an example, the three-mode Fourier interferometer exhibits the reverse behaviour in that photon collisions are less likely between bosons than between distinguishable particles. We extend this analysis to partially distinguishable photons and find greater discrepancy between intuition and theoretical predictions.

The probability of full bunching in a linear optical device in strongly dependent on the degree of distinguishability between the photons[6]. In particular, for many photon experiments, it depends on multi-particle relations that cannot be observed in a simple Hong-Ou-Mandel experiment. In particular, this probability is directly proportional to the permanent of the Gram matrix describing the relations between internal photon states including three photon relations. We propose some hypothetical experimental three-photon set-ups which could measure the dependence of full-bunching on three-photon relations.

# References

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