High-performance boson sampling using solid-state single photons

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Abstract: We develop single-photon sources that simultaneously combines high purity, efficiency, and indistinguishability. We demonstrate entanglement among ten single photons. We construct high-performance multi-photon boson sampling machines to race against classical computers.

Boson sampling is considered as a strong candidate to demonstrate the "quantum advantage / supremacy" over classical computers. However, previous proof-of-principle experiments suffered from small photon number and low sampling rates owing to the inefficiencies of the single-photon sources and multi-port optical interferometers. In this talk, I will report two routes towards building Boson Sampling machines with many photons.

In the first path, we developed SPDC two-photon source with simultaneously a collection efficiency of ~70% and an indistinguishability of ~91% between independent photons. With this, we demonstrate genuine entanglement of ten photons [1]. Very recently, we managed to observe 12-photon entanglement using a novel SPDC source. Such a platform will provide enabling technologies for teleportation of multiple properties of photons [2] and efficient scattershot boson sampling.

In the second path, using a QD-micropillar, we produced single photons with high purity (>99%), near-unity indistinguishability for >1000 photons [3], and high extraction efficiency [4]—all combined in a single device compatibly and simultaneously. We build 3-, 4-, and 5-bosonsampling machines which runs >24,000 times faster than all the previous experiments, and for the first time reaches a complexity about 100 times faster than the first electronic computer (ENIAC) and transistorized computer (TRADIC) [5,6]. We are currently increasing the rate by optimizing the single-photon system efficiency to near unity, background-free resonance fluorescence, and using improved schemes such as boson sampling with photon loss [7], with the hope of achieving 20-photon boson sampling in the near term.

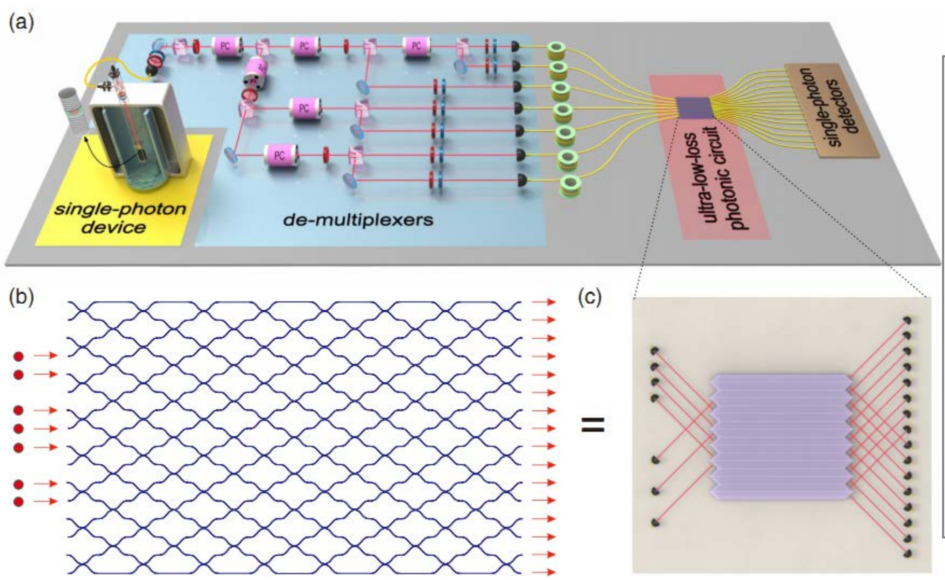

Figure 1: Experimental setup for boson sampling with 7 input single photons into an ultra-low-loss 16*16 interferometer. Quantum dot single photon extraction (system) efficiency is 82% (34%). Photon indistinguishability 94% (90%) at time separation of 13 ns (15μs). Three-photon count rate ~80 KHz.

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