Generation of large photonic cluster states with Linear optics

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Multi-partite entanglement is a key resource for quantum technologies. In particular, photonic cluster states, where photons are entangled in a graph-like structure, is necessary for photonic one-way quantum computing [1]. However, the generation of these photonic cluster states is a challenging task and scaling up in the number of entangled photons relies on heavy integration [2].

We present a resource-efficient way to generate large photonic linear cluster states based on linear optics manipulation of a single photon stream. We follow the entanglement scheme proposed by [3]. We use an InGaAs quantum dot embedded in a micropillar cavity [4] to produce single photons. The single photons are sequentially sent into a polarizing beamsplitter and a fibered delay-loop that entangle the photons with a 50% success probability. By postselecting instances where one photon goes into the loop while the other exits, we eliminate the which-path information between them, thereby entangling the photon leaving the setup with the one staying in the loop. This technique can be repeatedly used to entangle chains of photons, requiring a constant amount of resources to form an arbitrarily large linear cluster state [3].

To characterize the generated state, we vary the phase in the delay loop of our sequential entangler. From the visibility of this signal, we compute a lower bound on the fidelity of the generated state. We demonstrate the generation of two, three and four photons cluster states with respective fidelities of $F_2 \geq 86.5 \pm 0.1\%$, $F_3 \geq 77.6 \pm 0.9\%$, and $F_4 \geq 63.8 \pm 1.0\%$. We can push this entangling scheme to produce six-photon linear cluster states for the first time using a solid-state quantum emitter, with a mHz rate [5].

We develop a residual visibility measurement method to monitor and optimize the long-cluster state generation [5]. This method consists of measuring the visibility of a subset of size $p \in [2, N-1]$ of entangled photons in a N-photon experiment (Fig.1). The measurement requires a significantly shorter acquisition time which enables the detection and correction of experimental drifts during a long N-photon experiment e.g the week-long acquisition of the six-photon cluster states.

Figures

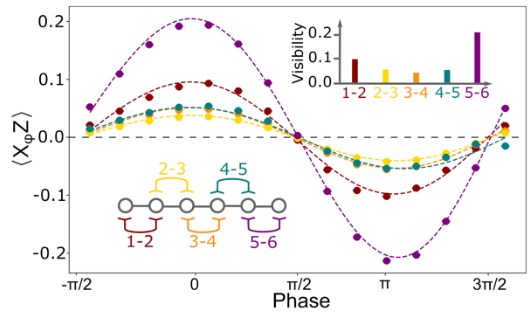

Figure 1: Residual visibilities of the subsets of size p=2 in a six-photon experiment.

References

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