Generating scalable graph states in an atom-nanophotonic interface

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Graph states, along with cluster states, represent a category of multipartite entangled states, serving as a valuable resource and laying the groundwork for one-way quantum computation. While sequentially-woven linear cluster states in time-bin photons require only a single setup of a single-photon source, this method is resource-efficient yet faces challenges in single-photon generation efficiency and state fidelity as the number of qubits increases. To address these challenges and enhance generation efficiency, one solution involves leveraging strong atom-photon coupling in a cavity. The photon-mediated interactions within such systems enable the engineering of four-mode square graph states or the preparation of W states via a state carving technique.

In this study [1], we propose a method to prepare high-fidelity and scalable graph states in one and two dimensions. These states can be crafted within an atom-nanophotonic cavity using a state carving technique. Our systematic protocol involves carving out unwanted state components, facilitating the generation of scalable graph states through the adiabatic transport of a specific number of atoms confined in optical tweezers. We present an analysis of state fidelity and demonstrate that the probability of state preparation can be optimized by employing multiqubit state carvings and sequential single-photon probes. The results underscore the capability to design scalable high-dimensional graph states with stationary qubits.

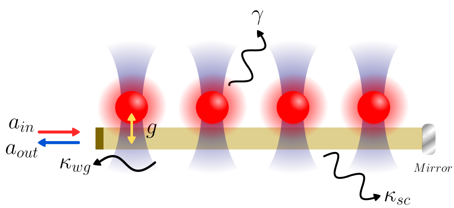

Fig. 1: Schematics of atoms coupled to nanophotonic cavity to grenerate graph states through state-carving procedure.

References

[1] C-H. Chien, , S. Goswami, C-C. Wu, W-S. Hiew, Y-C. Chen, and H. H. Jen, arXiv:2310.03990 (2023)

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Global quantum communication without quantum memory

I would like to humbly request to consider another submission (with the above title) along with the other work. This is a recently published work proposing a new technology for quantum communication - satellite relay. We claim to achieve global quantum communication with only reflection. This work was featured in APS Physics Magazine and Optica's Optics and Photonics News.

Abstract -

Photon loss is the fundamental issue toward the development of quantum networks. To circumvent loss quantum repeaters were proposed, which need high-performance quantum memories. We presented a new proposal. It showed that co-moving satellite chains can enable untrusted quantum communication between any two points on Earth, using only reflection as an optical relay. In this process, diffraction loss is eliminated by using the curved satellite telescope mirrors to converge light. The satellite as a whole will effectively behave like a lens and contain beam divergence. The satellite chain is co-moving and hence tracking error is also eliminated within the chain. Effectively the chain of satellites would behave like a set of lenses in an optical table containing beam divergence and hence photon loss indefinitely. No high-performance new quantum hardware (like quantum memory or QND detectors) needs to be invented which was the principal bottleneck of the existing approaches based on quantum repeaters.

I happy to present one of the works as a poster if the other one is selected for a small talk. I am attaching the longer one page description in next page.

Global quantum communication without quantum memory

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We showed that untrusted quantum communication to anywhere on Earth is possible with satellites [1]. All it needs is light reflection, through a satellite relay. Quantum memories or repeater protocols are not needed, which were previously thought essential to achieve similar results.

In satellite relay, global distances ($\sim$ 20,000 km) can be achieved, as photon loss is kept very low. Diffraction loss is nearly eliminated in the satellite-chain, by using the satellite telescope mirrors like lenses. So, the satellites focus light, effectively like lenses, and control diffraction.

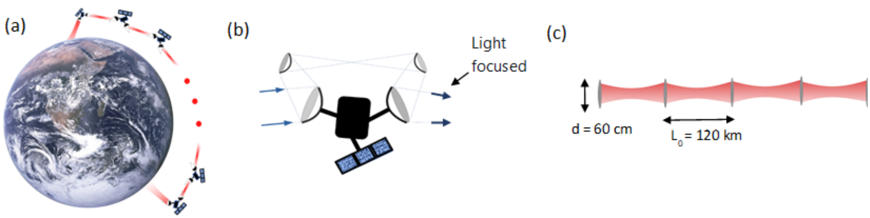

Fig. 1: Satellite relay - (a) Satellites sending single photons from one side of the earth to another through reflection. (b) Telescope setup in one satellite - focusing light. (c) Multiple satellites, modeled as lenses, control light diffraction indefinitely.

Tracking error is also eliminated within the satellite chain. Satellites inside the satellite chain are co-moving in the same orbit. Hence, the satellites would be 'relatively' stationary, making satellite tracking and point-ahead unnecessary within the satellite chain.

The only major loss left is the satellite absorption loss. Hence, our scheme ensures there are no other optical elements except reflecting telescopes in the light path, at each satellite. Reflection loss from good metal reflectors is low and can even be eliminated using ultra-high reflectivity Bragg mirrors. Overall, we did a detailed feasibility study of the proposal and didn't find any significant issues yet.

References

[1] S. Goswami and S. Dhara, Phys. Rev. Applied **20** 024048 (2023)

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