SCALABLE PHOTONIC QUANTUM COMPUTING WITH HYBRID RESOURCE STATES

Cross-Reference to Related Applications

[0001] This application claims priority to and benefit of U.S. Provisional Patent Application No. 63/084,994, filed September 29, 2020 and titled "Scalable Photonic Quantum Computing with Hybrid Resource States," the entire content of which is incorporated herein by reference in its entirety.

Field

[0002] The present disclosure relates generally to the field of photonic quantum computing, and more specifically, to the generation of three-dimensional resource states such as bosonic qubits and squeezed states.

Background

[0003] The ability to store and coherently manipulate quantum optical pulses is desirable for the development of long-distance quantum communications and quantum computing. Integrating these functions into a photonic chip with other quantum technologies, such as sources of entangled photons, is an important practical step towards implementing such applications.

Summary

[0004] One or more embodiments described herein relate to the generation of three-dimensional resource states including bosonic qubits and squeezed states. In some embodiments, a system for scalable, fault-tolerant photonic quantum computing includes multiple optical circuits, multiple photon number resolving detectors (PNRs), a multiplexer, and an integrated circuit (IC). During operation, the optical circuits generate output states via Gaussian Boson sampling (GBS), and the PNRs generate qubit clusters based on the output states. The multiplexer multiplexes the qubit clusters and replaces empty modes with squeezed vacuum states, to generate multiple hybrid resource states. The IC transforms the hybrid resource states (e.g., by stitching together the hybrid resource states) into a higher-dimensional cluster state that includes states appropriate for fault-tolerant quantum computation.

[0004a] According to a first aspect of the present invention, there is provided an apparatus, comprising: an integrated circuit including: a plurality of sources including qubit sources and cluster sources; and a plurality of controlled-Z gates, each controlled-Z gate from the plurality of controlled-Z gates connecting at least two sources from the plurality of sources, the integrated circuit configured, during operation, to sequentially energize subsets of sources from the plurality of sources and to generate a Raussendorf lattice based on interactions between sources from the plurality of sources.

[0004b] According to a second aspect of the present invention, there is provided a system, comprising: a plurality of optical circuits configured to generate light having a plurality of output states via Gaussian Boson sampling (GBS); a plurality of photon number resolving detectors (PNRs) operatively coupled to the plurality of optical circuits, the plurality of PNRs configured to generate qubit clusters based on the plurality of output states; a multiplexer operatively coupled to the plurality of PNRs, the multiplexer configured to perform multiplexing of the qubit clusters and to replace empty modes with squeezed vacuum states, thereby configured to generate light having a plurality of hybrid resource states; and an integrated circuit operatively coupled to the multiplexer, the integrated circuit configured to entangle hybrid resource states from the plurality of hybrid resource states into a higher-dimensional cluster state that includes states for fault-tolerant quantum computation.

[0004c] According to a third aspect of the present invention, there is provided an apparatus, comprising: an integrated circuit including: a plurality of multi-mode sources; and a plurality of beamsplitters operatively coupled to the plurality of multi-mode sources, each beamsplitter from the plurality of beamsplitters connecting at least two multi-mode sources from the plurality of multi-mode sources, the integrated circuit configured, during operation, to sequentially energize subsets of multi-mode sources from the plurality of multi-mode sources and to generate a Raussendorf lattice based on interactions between multi-mode sources from the plurality of multi-mode sources and at least one homodyne measurement.

[0004d] According to a fourth aspect of the present invention, there is provided a method, comprising: receiving an input vector of homodyne measurements and a noise model; identifying, based on the input vector of homodyne measurements and the noise model, at least one direction having a noise level above a predetermined threshold; performing a change-of-

basis on the input vector of homodyne measurements, based on the identified at least one direction, to generate a first modified vector; applying a transformation to the first modified vector, the transformation including a binning operation and a rounding operation, to generate a second modified vector; undoing the change-of-basis based on the second modified vector, to return a candidate lattice point; and generating a binary string based on the candidate lattice point, the binary string representing an interpreted qubit measurement outcome.