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 examples 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] In an aspect, the present disclosure refers to a method of quantum error decoding, the 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 phase-space direction having a noise level above a predetermined threshold indicative of an error occurring;

performing a change-of-basis on the input vector of homodyne measurements, based on the identified at least one phase-space 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, the interpreted qubit measurement outcome at least in part representing at least one error-corrected homodyne measurement.

[0004b] In an aspect, the present disclosure refers to a method of quantum error decoding, the 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 phase-space direction having a noise level above a predetermined threshold indicative of an error occurring;

performing a change-of-basis on the input vector of homodyne measurements, based on the identified at least one phase-space 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 third modified vector;

modifying half-integer valued components of the third modified vector to yield a fourth modified vector n; and

taking n mod 2 = s to produce a string of bit values s, representing error-corrected homodyne measurements.

[0004c] In an aspect, the present disclosure refers to a quantum error decoder, comprising:

a processor; and

a memory, storing instructions to cause the processor to:

receive an input vector of homodyne measurements and a noise model;

identify, based on the input vector of homodyne measurements and the noise model, at least one phase-space direction having a noise level above a predetermined threshold indicative of an error occurring;

perform a change-of-basis on the input vector of homodyne measurements, based on the identified at least one phase-space direction, to generate a first modified vector;

apply a transformation to the first modified vector, the transformation including a binning operation and a rounding operation, to generate a second modified vector;

undo the change-of-basis based on the second modified vector, to return a candidate lattice point; and

generate a binary string based on the candidate lattice point, the binary string representing an interpreted qubit measurement outcome, the interpreted qubit measurement outcome at least in part representing at least one error-corrected homodyne measurement.

[0004d] In an aspect, the present disclosure refers to a quantum error decoder, comprising:

a processor; and

a memory, storing instructions to cause the processor to:

receive an input vector of homodyne measurements and a noise model;

identify, based on the input vector of homodyne measurements and the noise model, at least one phase-space direction having a noise level above a predetermined threshold indicative of an error occurring;

perform a change-of-basis on the input vector of homodyne measurements, based on the identified at least one phase-space direction, to generate a first modified vector;

apply a transformation to the first modified vector, the transformation including a binning operation and a rounding operation, to generate a second modified vector;

undo the change-of-basis based on the second modified vector, to return a third modified vector;

modify half-integer valued components of the third modified vector to yield a fourth modified vector n; and

take $n \bmod 2 = s$ to produce a string of bit values s, representing error-corrected homodyne measurements.