

Claims:

1. A method comprising:

receiving, by a controller of a quantum computer comprising qubit management
5 systems and a plurality of physical qubits, a quantum circuit that simulates dynamics of
evolution of quantum states defined on a lattice representing a physical domain, with
interactions between sections of the domain modeled via an operator, the operator is a local
operator that is a sum of operator terms where a k-th operator term corresponding to section k
of the domain acts on lattice sites of the lattice that are contained within a section of distance of
10 at most a positive integer p from section k, the quantum circuit comprising n circuit slices,
wherein a first-executed slice of the n circuit slices comprises a past causal cone of a first-
fully-evolved system qubit wire at a fully evolved level of the quantum circuit, and a
subsequently executed i-th slice of the plurality of circuit slices is defined to contain all gates
that are not within a past causal cone of any system qubit wire of the quantum circuit that
15 reaches the fully evolved level of the quantum circuit in slice i - j, where $0 \leq j < i$ is an
integer, but that can be executed after completion of slice i - 1 by initiating one or more
physical qubits that have reached the fully evolved level during execution of slice i - 1, have
optionally been measured, and reset onto the system qubit wires in a base level of slice i;

causing, by the controller, execution of the quantum circuit slice by slice starting with
20 the first-executed slice and continuing through each successive slice, wherein executing an i-
th slice of the quantum circuit causes at least a first physical qubit corresponding to a degree
of freedom of a first lattice site to reach the fully evolved level of the quantum circuit and at
least a second physical qubit corresponding to a degree of freedom of a second lattice site to
be evolved to an intermediate level of the quantum circuit, wherein executing the i-th slice of
25 the quantum circuit comprises:

causing, by the controller, interaction gates to be applied to physical qubits in
accordance with the i-th slice of the quantum circuit using the physical qubits of the quantum
computer, the interaction gates corresponding to interactions between neighboring lattice
sites of the lattice; and

30 when i is less than n, causing, by the controller, a physical qubit that was evolved as
the system qubit fully evolved via execution of the i-th slice to be optionally measured, and
reinitialized and reintroduced onto a system qubit wire at a base level of the i + m-th slice, m
a positive integer.

2. The method of claim 1, wherein executing the i-th slice of the quantum circuit comprises executing all gates for which incoming and outgoing wires lie within the i-th slice in order to propagate the system qubits forward in time.
- 5 3. The method of claim 2, wherein the quantum circuit comprises at least one ancilla wire and executing the i-th slice of the quantum circuit comprises interacting one or more system qubits at a bottom of the i-th slice with at least one ancilla qubit via unitary gates in order to introduce initial correlations between the one or more system qubits at the bottom of the i-th slice and system qubits at the bottom of one or more other slices.
- 10 4. The method of claim 1, wherein the quantum circuit encodes interactions governed by a Hamiltonian characterized by local interactions.
5. The method of claim 1, wherein each system qubit wire corresponds to a degree of freedom associated with a section of a physical domain being simulated.
- 15 6. The method of claim 5, wherein executing the i-th slice of the quantum circuit comprises evolving the degree of freedom in accordance with the operator.
- 20 7. The method of claim 6, wherein the operator is a Hamiltonian.
8. The method of claim 5, wherein the physical domain is one of a one dimensional, two dimensional, or three dimensional physical domain.
- 25 9. The method of claim 5, wherein the quantum circuit simulates the dynamics of the evolution of quantum states defined on a lattice representing the physical domain.
10. The method of claim 1, further comprising performing one or more measurements of at least one physical qubit of the plurality of qubits to determine a value corresponding to at least one degree of freedom within the physical domain.
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11. The method of claim 1, wherein at least one system qubit wire of the quantum circuit extends through multiple slices of quantum circuit.

12. A controller of a quantum computer comprising qubit management systems and a plurality of physical qubits, the controller is configured to control elements of the quantum computer to:

receive a quantum circuit that simulates dynamics of evolution of quantum states defined on a lattice representing a physical domain, with interactions between sections of the domain modeled via an operator, the operator is a local operator that is a sum of operator terms where a k-th operator term corresponding to section k of the domain acts on lattice sites of the lattice that are contained within a section of distance of at most a positive integer p from section k, the quantum circuit comprising n circuit slices, wherein a first-executed slice of the n circuit slices comprises a past causal cone of a first-fully-evolved system qubit wire at a fully evolved level of the quantum circuit, and a subsequently executed i-th slice of the n circuit slices is defined to contain all gates that are not within a past causal cone of any system qubit wires of the quantum circuit that reach the fully evolved level of the quantum circuit in slice i - j, where $0 \leq j < i$ is an integer, but that can be executed after completion of slice i - 1 by initiating one or more physical qubits that have reached the fully evolved level during execution of slice i - 1, have optionally been measured, and reset onto the system qubit wires in a base level of slice i ;

cause execution of the quantum circuit slice by slice starting with the first-fully-executed slice and continuing through each successive slice, wherein executing an i-th slice of the quantum circuit causes at least a first physical qubit corresponding to a degree of freedom of a first lattice site to reach the fully evolved level of the quantum circuit and at least a second physical qubit corresponding to a degree of freedom of a second lattice site to be evolved to an intermediate level of the quantum circuit, wherein executing the i-th slice of the quantum circuit comprises:

causing interaction gates to be applied to physical qubits in accordance with the i-th slice of the quantum circuit using the physical qubits of the quantum computer, the interaction gates corresponding to interactions between neighboring lattice sites of the lattice; and

when i is less than n, causing a physical qubit, that was evolved as the system qubit fully evolved via execution of the i-th slice to be optionally measured, and reinitialized and

reintroduced onto a system qubit wire at a base level of the $i + m$ -th slice of the quantum circuit, m a positive integer.

13. The controller of claim 12, wherein executing the i -th slice of the quantum circuit
5 comprises executing all gates for which incoming and outgoing wires lie within the i -th slice in order to propagate the system qubits forward in time.

14. The controller of claim 13, wherein the quantum circuit comprises at least one ancilla wire and executing the i -th slice of the quantum circuit comprises interacting one or more
10 system qubits at a bottom of the i -th slice with at least one ancilla qubit via unitary gates in order to introduce initial correlations between the one or more system qubits at the bottom of the i -th slice and system qubits at the bottom of one or more other slices.

15. The controller of claim 12, wherein (a) the quantum circuit encodes interactions
15 governed by a Hamiltonian characterized by local interactions and (b) each system qubit wire corresponds to a degree of freedom associated with a section of a physical domain being simulated.

16. The controller of claim 15, wherein the quantum circuit simulates the dynamics of the
20 evolution of quantum states defined on a lattice representing the physical domain.

17. The controller of claim 15, wherein executing the i -th slice of the quantum circuit comprises evolving the degree of freedom in accordance with the Hamiltonian.

25 18. The controller of claim 15, wherein the physical domain is one of a one dimensional, two dimensional, or three dimensional physical domain.

19. The controller of claim 12, wherein the controller is further configured to control elements of the quantum computer to perform one or more measurements of at least one
30 physical qubit of the plurality of qubits to determine a value of at least one degree of freedom within the physical domain.

20. The controller of claim 12, wherein at least one system qubit wire of the quantum circuit extends through multiple slices of quantum circuit.