

system, the problem-encoding configuration of the plurality of adjustable parameters. The single-body processing device is configured for evolving the quantum system according to a time evolution of the problem Hamiltonian. The apparatus includes a short-range coupling device connected to the classical computing system, the short-range coupling device being configured for evolving the quantum system according to a time evolution of one or more short-range Hamiltonians. The apparatus includes a measurement device connected to the classical computing system, the measurement device being configured to measure at least a portion of the plurality of qubits. The classical computing system is further configured for receiving one or more measurement outcomes from the measurement device. The classical computing system is further configured for instructing the single-body processing device and/or the short-range coupling device. The classical computing system is configured for receiving measurement outcomes from the measurement device; outputting a result of the quantum computation, wherein the apparatus is configured for performing N rounds of operations, wherein each round of operations comprises: determining, by the classical computing system, a sequence of unitary operators, wherein each unitary operator in the sequence is a unitary operator being a unitary time evolution of the problem Hamiltonian, wherein the plurality of adjustable parameters of the problem Hamiltonian are in the problem-encoding configuration, or a unitary operator being a product of two or more short-range unitary operators; evolving the quantum system by applying the sequence of unitary operators to the quantum system, wherein the single-body processing device is configured for performing each unitary operator of the sequence of unitary operators being a unitary time evolution of the problem Hamiltonian, and wherein the short-range coupling device is configured for performing each unitary operator of the sequence of unitary operators being a short-range operator; and performing, by the measurement device, a measurement of one or more qubits of the quantum system.

[0008] According to a further embodiment, an apparatus for gate-based quantum computing is provided. The apparatus includes a quantum system comprising a plurality of superconducting qubits. The apparatus includes a controller. The apparatus includes a flux bias assembly connected to the controller, the flux bias assembly comprising a plurality of flux bias units configured for generating a plurality of adjustable time-dependent magnetic fluxes, wherein each adjustable time-dependent magnetic flux acts on a single superconducting qubit in the plurality of superconducting qubits. The apparatus includes a coupling device connected to the controller, the coupling device comprising at least one

superconducting quantum interference device configured for coupling the plurality of superconducting qubits according to one or more short-range Hamiltonians. The apparatus includes a measurement device connected to the controller, the measurement device being configured to measure at least a portion of the plurality of qubits. The controller is configured for instructing the flux bias assembly and the coupling device to evolve the quantum system according to a sequence of operations. The controller is configured for instructing the flux bias assembly to evolve the quantum system by a time evolution of a problem Hamiltonian, wherein the problem Hamiltonian is a single-body Hamiltonian comprising a plurality of adjustable parameters, wherein the plurality of adjustable parameters encode a computational problem. The controller is configured for instructing the coupling device to evolve the quantum system according to a time evolution of a short-range Hamiltonian, wherein the apparatus is configured for performing N rounds of operations, wherein each round of operations comprises: determining, by the controller, a sequence of unitary operators, wherein each unitary operator in the sequence is a unitary operator being a unitary time evolution of the problem Hamiltonian, wherein the plurality of adjustable parameters of the problem Hamiltonian are in a problem-encoding configuration, or a unitary operator being a product of two or more short-range unitary operators; evolving the quantum system by applying the sequence of unitary operators to the quantum system, wherein the flux bias assembly is configured for performing each unitary operator of the sequence of unitary operators being a unitary time evolution of the problem Hamiltonian, and wherein the coupling device is configured for performing each unitary operator of the sequence of unitary operators being a short-range operator; and performing, by the measurement device, a measurement of one or more qubits of the quantum system.

CLAIMS

1. A method of performing a quantum computation, comprising:

providing a quantum system comprising a plurality of qubits:

encoding a computational problem into a problem Hamiltonian of the quantum system, wherein the problem Hamiltonian is a single-body Hamiltonian comprising a plurality of adjustable parameters, wherein the encoding comprises determining, from the computational problem, a problem-encoding configuration for the plurality of adjustable parameters;

performing N rounds of operations, wherein $N \geq 2$, wherein each round of operations comprises:

determining a sequence of unitary operators, wherein each unitary operator in the sequence is

a unitary operator being a unitary time evolution of the problem Hamiltonian, wherein the plurality of adjustable parameters of the problem Hamiltonian are in the problem-encoding configuration, or

a unitary operator being a product of two or more short-range unitary operators;

evolving the quantum system by applying the sequence of unitary operators to the quantum system; and

performing a measurement of one or more qubits of the quantum system; and

outputting a result of the quantum computation.

2. The method of claim 1, wherein the N rounds of operations include one or more adaptive rounds of operations, wherein, for each adaptive round of operations, the unitary operators of the sequence of unitary operators of the adaptive round are determined based on at least one measurement outcome of a measurement performed in a previous round of the N rounds of operations.

3. The method of any of the preceding claims, wherein each product of two or more short-range unitary operators comprised in the N rounds of operations is parallelizable to a constant depth.

4. The method of any of the preceding claims, wherein the sequence of unitary operators of each of the N rounds of operations is a sequence of alternations of the form $A_1 B_1 A_2 B_2 \dots$,

wherein each A_i is a unitary time evolution of the problem Hamiltonian, wherein the plurality of adjustable parameters of the problem Hamiltonian are in the problem-encoding configuration, and

wherein each B_i is a product of two or more short-range unitary operators.

5. The method of any of the preceding claims, wherein the N rounds of operations include a first round of operations, wherein applying the sequence of unitary operators of the first round of operations results in a first quantum state of the quantum system, wherein the method comprises:

measuring an energy of the first quantum state.

6. The method of claim 5, wherein the N rounds of operations include a second round of operations performed after the first round of operations, wherein applying the sequence of unitary operators of the second round of operations results in a second quantum state of the quantum system, wherein the method comprises:

measuring an energy of the second quantum state;

comparing the energy of the first quantum state with the energy of the second quantum state; and

determining the sequence of unitary operators to be applied in a third round of the N rounds of operations, wherein the third round is to be performed after the second round, wherein the sequence of unitary operators to be applied in the third round is determined based

at least on the comparison of the energy of the first quantum state with the energy of the second quantum state.

7. The method of any of the preceding claims, wherein the plurality of adjustable parameters of the problem Hamiltonian comprises a plurality of field strengths and/or a plurality of field directions of single-body fields acting on the plurality of qubits.

8. The method of any of the preceding claims, wherein the problem Hamiltonian has the form $\sum_k J_k \sigma_z^{(k)}$, wherein $\sigma_z^{(k)}$ is a Pauli operator of a k-th qubit of the plurality of qubits, wherein each J_k is a coefficient, and wherein the coefficients J_k form the plurality of adjustable parameters of the problem Hamiltonian.

9. The method of any of the preceding claims, wherein the plurality of qubits are arranged according to a 2-dimensional lattice.

10. The method of any of the preceding claims, wherein the plurality of qubits are arranged according to a 2-dimensional lattice and wherein each short-range unitary operator of each of the N rounds of operations is either a 2-body unitary operator acting on adjacent qubits of the 2-dimensional lattice or a single-body unitary operator.

11. The method of any of the preceding claims, wherein each short-range operator of each of the N rounds is either a controlled-not operator or a single-body unitary operator.

12. The method of any of the preceding claims, wherein the computational problem is an NP-hard problem, particularly an Ising spin model problem, and wherein the outputted result of the quantum computation is a solution to the NP-hard problem.

13. The method of any of the preceding claims, wherein the quantum system comprises a plurality of ancillary particles including a first ancillary particle, the method further comprising:

coupling a first qubit of the plurality of qubits with the first ancillary particle;

moving the first ancillary particle from the first qubit to a second qubit of the plurality of qubit; and

coupling the second qubit with the first ancillary particle.

14. An apparatus for quantum computing, comprising:

a quantum system comprising a plurality of qubits;

a classical computing system configured for:

receiving, as an input, a computational problem; and

encoding the computational problem into a problem Hamiltonian of the quantum system, the problem Hamiltonian being a single-body Hamiltonian comprising a plurality of adjustable parameters, wherein the encoding comprises determining, from the computational problem, a problem-encoding configuration for the plurality of adjustable parameters;

a single-body processing device connected to the classical computing system, the single-body processing device being configured for:

receiving, from the classical computing system, the problem-encoding configuration of the plurality of adjustable parameters; and

evolving the quantum system according to a time evolution of the problem Hamiltonian;

a short-range coupling device connected to the classical computing system, the short-range coupling device being configured for evolving the quantum system according to a time evolution of one or more short-range Hamiltonians; and

a measurement device connected to the classical computing system, the measurement device being configured to measure at least a portion of the plurality of qubits,

wherein the classical computing system is further configured for:

instructing the single-body processing device and/or the short-range coupling device;

receiving measurement outcomes from the measurement device;

outputting a result of the quantum computation,

wherein the apparatus is configured for performing N rounds of operations, wherein each round of operations comprises:

determining, by the classical computing system, a sequence of unitary operators, wherein each unitary operator in the sequence is

a unitary operator being a unitary time evolution of the problem Hamiltonian, wherein the plurality of adjustable parameters of the problem Hamiltonian are in the problem-encoding configuration, or

a unitary operator being a product of two or more short-range unitary operators;

evolving the quantum system by applying the sequence of unitary operators to the quantum system, wherein the single-body processing device is configured for performing each unitary operator of the sequence of unitary operators being a unitary time evolution of the problem Hamiltonian, and wherein the short-range coupling device is configured for performing each unitary operator of the sequence of unitary operators being a short-range operator; and

performing, by the measurement device, a measurement of one or more qubits of the quantum system.

15. An apparatus for gate-based quantum computing, comprising:

a quantum system comprising a plurality of superconducting qubits;

a controller;

a flux bias assembly connected to the controller, the flux bias assembly comprising a plurality of flux bias units configured for generating a plurality of adjustable time-dependent magnetic fluxes, wherein each adjustable time-dependent magnetic flux acts on a single superconducting qubit of the plurality of superconducting qubits;

a coupling device connected to the controller, the coupling device comprising at least one superconducting quantum interference device configured for coupling the plurality of superconducting qubits according to one or more short-range Hamiltonians; and

a measurement device connected to the controller, the measurement device being configured to measure at least a portion of the plurality of qubits,

wherein the controller is configured for instructing the flux bias assembly and the coupling device to evolve the quantum system according to a sequence of operations,

wherein the controller is configured for instructing the flux bias assembly to evolve the quantum system by a time evolution of a problem Hamiltonian, wherein the problem Hamiltonian is a single-body Hamiltonian comprising a plurality of adjustable parameters, wherein the plurality of adjustable parameters encode a computational problem,

wherein the controller is configured for instructing the coupling device to evolve the quantum system according to a time evolution of a short-range Hamiltonian,

wherein the apparatus is configured for performing N rounds of operations, wherein each round of operations comprises:

determining, by the controller, a sequence of unitary operators, wherein each unitary operator in the sequence is

a unitary operator being a unitary time evolution of the problem Hamiltonian, wherein the plurality of adjustable parameters of the problem Hamiltonian are in a problem-encoding configuration, or

a unitary operator being a product of two or more short-range unitary operators;

evolving the quantum system by applying the sequence of unitary operators to the quantum system, wherein the flux bias assembly is configured for performing each unitary operator of the sequence of unitary operators being a unitary time evolution of the problem

Hamiltonian, and wherein the coupling device is configured for performing each unitary operator of the sequence of unitary operators being a short-range operator; and

performing, by the measurement device, a measurement of one or more qubits of the quantum system.