

CLAIMS

What is claimed is:

1. A method of operating a quantum gate on a grouping of qubits, the method comprising:

selecting values for a set of parameters of at least a first and a second laser pulse, the parameters selected from a relative phase shift, a laser frequency, a laser intensity, and a pulse duration; and

applying the at least first and second laser pulses to all qubits within a grouping of N qubits, where N is equal to two or more, thereby coupling a non-interacting quantum state $|1\rangle$ to an interacting excited state $|r\rangle$, such that each qubit that begins in quantum state $|1\rangle$ returns to the state $|1\rangle$ upon completion of the at least first and second laser pulses, and such that qubits in the grouping are mutually blockaded.
2. The method of claim 1, wherein each qubit is an atomic qubit.
3. The method of claim 1, wherein each qubit is an ionic qubit.
4. The method of claim 1, wherein each qubit is a molecular qubit.
5. The method of any of claims 1-4, wherein the mutually blockaded qubits in the grouping are mutually dipole blockaded.
6. The method of any of claims 1-2, where the mutually blockaded qubits in the grouping are mutually Rydberg blockaded.
7. The method of any of claims 1-6, wherein all qubits in the grouping are mutually blockaded.
8. The method of claim 7, wherein the durations of the at least the first and the second pulses is selected so that if all qubits in the grouping begin in the quantum state $|1\rangle$, then all qubits in the grouping return to the quantum state $|1\rangle$ upon completion of each of the at least the first and the second laser pulses.

9. The method of claim 8, wherein the laser frequency of each pulse is detuned from the resonance transition between $|1\rangle$ to $|r\rangle$ by a detuning Δ and the pulse duration t is equal to $t = 2\pi/\sqrt{\Delta^2 + N\Omega^2}$, where Ω is the Rabi frequency of the laser pulses.
10. The method of any of claim 1-7, wherein one or more of the laser intensity, laser frequency, pulse duration, and laser phase is selected to achieve a desired fidelity of the quantum gate.
11. The method of any of claims 1-8, wherein the at least the first and the second pulses form a palindromic sequence of pulses.
12. The method of any of claims 1-10, wherein the gate is a controlled-phase gate $C^{N-1}Z(\theta)$, wherein θ is a conditional-phase angle.
13. The method of any of claims 1-10, wherein N is 2.
14. The method of claim 12, wherein the quantum gate is a controlled phase ($CZ(\theta)$) gate, and $N=2$.
15. The method of claim 14, wherein the laser frequency, the pulse duration, and the phase shift are selected based on the conditional-phase angle θ of the controlled phase gate.
16. The method of claim 15, wherein the laser frequency is detuned from the resonance transition between $|1\rangle$ to $|r\rangle$ by a detuning Δ and the laser intensity is selected such that the Rabi frequency of the laser pulses is Ω .
17. The method of claim 16, wherein the laser frequency, the laser intensity, the pulse duration, and the phase shift are selected such that the conditional-phase angle $\theta=\pi$.
18. The method of any of claims 1-10, wherein N is 3.
19. The method of claim 18, wherein the quantum gate is a controlled-controlled phase ($C^2Z(\theta)$) gate having a conditional-phase angle θ .

20. The method of claim 19, wherein the laser frequency, pulse duration, and phase shifts of each of the at least the first and second laser pulses are selected based on the conditional-phase angle θ .
21. The method of claim 18, the method comprising applying a sequence of six pulses.
22. The method of claim 21, wherein the sequence of six pulses is palindromic.
23. The method of any of claims 1-10, the method comprising applying a sequence of $4N-6$ pulses.
24. The method of claim 23, wherein the sequence of pulses is palindromic.
25. A method of operating a quantum gate on a grouping of qubits, the method comprising:
 - selecting time-dependent values for a set of parameters of a laser pulse, the parameters selected from a laser phase, a laser frequency, a laser intensity, and a pulse duration; and
 - applying the laser pulse to all qubits within a grouping of N qubits, where N is equal to three or more, thereby coupling a non-interacting quantum state $|1\rangle$ to an interacting excited state $|r\rangle$, such that each qubit that begins in quantum state $|1\rangle$ returns to the state $|1\rangle$ upon completion of the laser pulse, and such that qubits in the grouping are mutually blockaded.
26. The method of claim 25, wherein each qubit is an atomic qubit.
27. The method of claim 25, wherein each qubit is an ionic qubit.
28. The method of claim 25, wherein each qubit is a molecular qubit.
29. The method of any of claims 25-28, wherein the mutually blockaded qubits in the grouping are mutually dipole blockaded.
30. The method of any of claim 25-26, where the mutually blockaded qubits in the grouping are mutually Rydberg blockaded.

31. The method of any of claims 25-30, wherein all qubits in the grouping are mutually blockaded.
32. The method of any of claim 25-31, wherein the time-dependent values of the laser intensity, laser frequency, pulse duration, and laser phase are selected to achieve a desired fidelity of the quantum gate.
33. The method of any of claim 25-31, wherein the gate is a controlled-phase gate $C^N\text{-}^1Z(\theta)$, wherein θ is a conditional-phase angle.
34. The method of any of claims 25-31, wherein N is 3.
35. The method of claim 34, wherein the quantum gate is a controlled-controlled phase ($C^2Z(\theta)$) gate having a conditional-phase angle θ .
36. The method of claim 34, wherein the time-dependent values of the laser intensity, the laser frequency, laser phase, and pulse duration are selected based on the conditional-phase angle θ .
37. The method of claim 34, wherein the conditional-phase angle $\theta = \pi$.
38. A device comprising:

a grouping of N qubits, where N is equal to two or more; and

a coherent light source configured to, given selected values for a set of parameters of at least a first and a second laser pulse, the parameters selected from a relative phase shift, a laser frequency, a laser intensity, and a pulse duration:

apply at least the first and second laser pulses to all qubits within the grouping of N qubits, thereby coupling a non-interacting quantum state $|1\rangle$ to an interacting excited state $|r\rangle$, such that each qubit that begins in quantum state $|1\rangle$ returns to the state $|1\rangle$ upon completion of the at least first and second laser pulses, and such that qubits in the grouping are mutually blockaded.

39. A device comprising:

a grouping of N qubits, where N is equal to three or more; and

a coherent light source configured to, given selected time-dependent values for a set of parameters of a laser pulse, the parameters selected from a laser phase, a laser frequency, a laser intensity, and a pulse duration:

apply the laser pulse to all qubits within a grouping of N qubits, thereby coupling a non-interacting quantum state $|1\rangle$ to an interacting excited state $|r\rangle$, such that each qubit that begins in quantum state $|1\rangle$ returns to the state $|1\rangle$ upon completion of the laser pulse, and such that qubits in the grouping are mutually blockaded.