

CLAIMS

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 sequential laser pulse and a second sequential laser pulse, wherein the parameters are a relative phase shift between at least the first sequential laser pulse and the second sequential laser pulse, a laser frequency, a laser intensity, and a pulse duration; and
 - sequentially applying at least the first sequential laser pulse and the second sequential laser pulse each to all qubits within a gate, said gate consisting of 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 at least the first sequential laser pulse and the second sequential laser pulse, and wherein all qubits in the grouping are mutually blockaded.
2. The method of claim 1, wherein the durations of at least the first sequential laser pulse and the second sequential laser pulse are 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 at least the first sequential laser pulse and the second sequential laser pulse.
3. The method of claim 2,
 - wherein the laser frequency of each of at least the first sequential laser pulse and the second sequential laser pulse is detuned from the resonance transition between $|1\rangle$ and $|r\rangle$ by a detuning Δ ; and
 - wherein the pulse duration t is equal to $t = 2\pi\sqrt{\Delta^2 + N\Omega^2}$; and
 - wherein Ω is the Rabi frequency of each of at least the first sequential laser pulse and the second sequential laser pulse.

4. The method of claim 1 or claim 2, 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.
5. The method of any of claims 1-4, wherein the gate is a controlled-phase gate $C^N Z(\theta)$, wherein θ is a conditional-phase angle.
6. The method of any of claims 1-5, wherein N is 2.
7. The method of claim 6, wherein the quantum gate is a controlled phase ($CZ(\theta)$) gate.
8. The method of claim 7, 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.
9. The method of claim 8,
wherein the laser frequency is detuned from the resonance transition between $|1\rangle$ and $|r\rangle$ by a detuning Δ ; and
wherein the laser intensity is selected such that the Rabi frequency of each of at least the first sequential laser pulse and the second sequential laser pulse is Ω .
10. The method of claim 9, wherein the laser frequency, the laser intensity, the pulse duration, and the phase shift are selected such that the conditional-phase angle $\theta=\pi$.
11. The method of any of claims 1-4, wherein N is 3.
12. The method of claim 11, wherein the quantum gate is a controlled-controlled phase ($C^2Z(\theta)$) gate having a conditional-phase angle θ .
13. The method of claim 12, wherein the laser frequency, pulse duration, and phase shifts of each of at least the first sequential laser pulse and the second sequential laser pulse are selected based on the conditional-phase angle θ .

14. The method of any of claims 1-4, the method further comprising applying a sequence of $4N-6$ sequential laser pulses.
15. 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, wherein the parameters are a laser phase, a laser frequency, a laser intensity, and a pulse duration; and
 - applying the laser pulse to all qubits within a gate, said gate consisting of 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 $|r\rangle$, wherein 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.
16. The method of claim 15, 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, or wherein the gate is a controlled-phase gate $C^{N-1}Z(\theta)$, wherein θ is a conditional-phase angle, or wherein N is 3.
17. The method of claim 15, wherein N is 3, and wherein the quantum gate is a controlled-controlled phase ($C^2Z(\theta)$) gate having a conditional-phase angle θ .
18. The method of claim 15, wherein N is 3, and 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 .
19. The method of claim 15, wherein N is 3, and wherein the conditional-phase angle $\theta=\pi$.

20. The method of any preceding claim wherein each qubit is an atomic qubit, an ionic qubit, or a molecular qubit.
21. The method of any preceding claim wherein either:
 - (a) all qubits in the grouping are mutually blockaded; or
 - (b) each qubit is an atomic qubit, and wherein the mutually blockaded qubits in the grouping are mutually Rydberg blockaded.
22. A device comprising:

at least one gate consisting of 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 sequential laser pulse and a second sequential laser pulse, wherein the parameters are a relative phase shift between at least the first sequential laser pulse and the second sequential laser pulse, a laser frequency, a laser intensity, and a pulse duration:

sequentially apply at least the first sequential laser pulse and the second sequential laser pulse each to all qubits within the at least one gate, 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 at least the first sequential laser pulse and the second sequential laser pulse, and wherein all qubits in the grouping are mutually blockaded.
23. A device comprising:

at least one gate consisting of 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, wherein the parameters are a laser phase, a laser frequency, a laser intensity, and a pulse duration:

apply the laser pulse to all qubits within the at least one gate, 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 wherein all qubits in the grouping are mutually blockaded.