

CLAIMS

What is claimed is:

1. A method of operating a system that includes a multi-level quantum system dispersively coupled to a first quantum mechanical oscillator and dispersively coupled to a second quantum mechanical oscillator, the method comprising:
 - applying a first drive waveform to the multi-level quantum system;
 - applying one or more second drive waveforms to the first quantum mechanical oscillator; and
 - applying one or more third drive waveforms to the second quantum mechanical oscillator.
2. The method of claim 1, wherein:
 - the first quantum mechanical oscillator implements a first logical qubit,
 - the second quantum mechanical oscillator implements a second logical qubit, and
 - the first drive waveform, one or more second drive waveforms and one or more third drive waveforms are together configured to perform a quantum logic gate between the first logical qubit and the second logical qubit.
3. The method of claim 1, wherein the multi-level quantum system is a nonlinear quantum system.
4. The method of claim 1, wherein:
 - the first drive waveform is configured to produce a superposition of states of the multi-level quantum system,
 - the one or more second drive waveforms are configured to coherently add or remove energy to or from the first quantum mechanical oscillator conditional on a state of the multi-level quantum system, and
 - the one or more third drive waveforms are configured to coherently add or remove energy to or from the second quantum mechanical oscillator conditional on the state of the multi-level quantum system.

5. The method of claim 4, wherein the state of the multi-level quantum system is a superposition of a ground state and a first excited state.
6. The method of claim 5, wherein the one or more second drive waveforms and one or more third drive waveforms are configured to coherently add or remove energy conditional on whether the multi-level quantum system is in the ground state or in the first excited state.
7. The method of claim 5, wherein the one or more second drive waveforms consist of a single drive waveform with a bandwidth smaller than a dispersive frequency shift of the first quantum mechanical oscillator associated with a transition between the ground state and the first excited state of the multi-level quantum system.
8. The method of claim 1, wherein applying the one or more second drive waveforms comprises:
 - applying an initial drive waveform to the first quantum mechanical oscillator that coherently adds or removes energy to or from the first quantum mechanical oscillator;
 - waiting for a predetermined time subsequent to application of the initial drive waveform; and
 - applying a subsequent drive waveform to the first quantum mechanical oscillator that coherently adds or removes energy to or from the first quantum mechanical oscillator.
9. The method of claim 1, wherein prior to application of the first drive waveform, the multi-level quantum system, the first quantum mechanical oscillator, and the second quantum mechanical oscillator are in respective ground states.
10. The method of claim 4, further comprising:
 - applying a fourth drive waveform to the multi-level quantum system, the fourth drive waveform configured to change the state of the multi-level system conditional on a state of the first quantum mechanical oscillator and a state of the second quantum mechanical oscillator.

11. The method of claim 1, further comprising measuring joint parity of the first quantum mechanical oscillator and second quantum mechanical oscillator.
12. The method of claim 11, wherein measuring joint parity of the first quantum mechanical oscillator and the second quantum mechanical oscillator comprises:
 - applying a fifth drive waveform to the multi-level quantum system;
 - waiting for a first predetermined time subsequent to application of the fifth drive waveform;
 - applying a sixth drive waveform to the multi-level quantum system;
 - waiting for a second predetermined time subsequent to application of the sixth drive waveform; and
 - applying a seventh drive waveform to the multi-level quantum system.
13. The method of claim 1, further comprising measuring a state of the multi-level quantum system via a readout resonator coupled to the multi-level quantum system.
14. The method of claim 13, wherein the readout resonator is capacitively coupled to the multi-level quantum system and wherein the readout resonator is further coupled to a transmission line.
15. The method of claim 13, wherein measuring the state of the multi-level quantum system via the readout resonator comprises measuring an amplitude and a phase of a signal output from the readout resonator.
16. The method of claim 1, wherein $\chi_B^{ge} > \chi_A^{ge}$,
 - where χ_A^{ge} is a dispersive frequency shift of the first quantum mechanical oscillator associated with a transition between a ground state of the multi-level quantum system and a first excited state of the multi-level quantum system, and

where χ_B^{ge} is a dispersive frequency shift of the second quantum mechanical oscillator associated with the transition between the ground state of the multi-level quantum system and the first excited state of the multi-level quantum system.

17. The method of claim 1, wherein the multi-level quantum system is a superconducting transmon.
18. The method of claim 1, wherein the first quantum mechanical oscillator and the second quantum mechanical oscillator are resonator cavities.
19. A circuit quantum electrodynamics system, comprising:
 - a multi-level quantum system;
 - a first quantum mechanical oscillator dispersively coupled to the multi-level quantum system;
 - a second quantum mechanical oscillator dispersively coupled to the multi-level quantum system; and
 - at least one electromagnetic radiation source configured to apply independent electromagnetic pulses to the multi-level quantum system, to the first quantum mechanical oscillator, and to the second quantum mechanical oscillator.
20. The system of claim 19, wherein the at least one electromagnetic radiation source is configured to:
 - apply a first drive waveform to the multi-level quantum system, the first drive waveform configured to produce a superposition of states of the multi-level quantum system;
 - apply one or more second drive waveforms to the first quantum mechanical oscillator, the one or more second drive waveforms configured to coherently add or remove energy to or from the first quantum mechanical oscillator conditional on a state of the multi-level quantum system; and
 - apply one or more third drive waveforms to the second quantum mechanical oscillator, the one or more third drive waveforms configured to coherently add or remove

energy to or from the second quantum mechanical oscillator conditional on the state of the multi-level quantum system.

21. The system of claim 19, wherein the multi-level quantum system is a nonlinear quantum system.

22. The system of claim 21, wherein the nonlinear quantum system comprises:
a Josephson junction comprising a first superconducting portion, a second superconducting portion, and an insulating portion, wherein the first superconducting portion and the second superconducting portion are physically separated by the insulating portion;
a first antenna electrically connected to the first superconducting portion;
a second antenna electrically connected to the first superconducting portion; and
a third antenna electrically connected to the second superconducting portion.

23. The system of claim 22, wherein the first quantum mechanical oscillator is dispersively coupled to the nonlinear quantum system via the first antenna, and wherein the second quantum mechanical oscillator is dispersively coupled to the nonlinear quantum system via the second antenna.

24. The system of claim 19, wherein the multi-level quantum system is a superconducting transmon.

25. The system of claim 19, wherein the first quantum mechanical oscillator and the second quantum mechanical oscillator are resonator cavities.

26. The system of claim 19, further comprising a stripline readout resonator capacitively coupled to the multi-level quantum system.

27. The system of claim 20, wherein at least one of the first drive waveform, the one or more second drive waveforms, and the one or more third drive waveforms are produced by a field programmable gate array (FPGA).

28. A nonlinear quantum device comprising:
- a Josephson junction comprising a first superconducting portion, a second superconducting portion, and an insulating portion, wherein the first superconducting portion and the second superconducting portion are physically separated by the insulating portion;
 - a first antenna electrically connected to the first superconducting portion;
 - a second antenna electrically connected to the first superconducting portion; and
 - a third antenna electrically connected to the second superconducting portion.
29. The nonlinear quantum device of claim 28, wherein the first antenna, the second antenna and the first superconducting portion intersect at a single location.
30. The nonlinear quantum device of claim 28, further comprising a metallic strip capacitively coupled to the third antenna.