CLAIMS

1. A method for implementing a fault-tolerant quantum operation using a cavity and an ancilla transmon, the method comprising:

encoding a logical qubit using more than two energy levels of the cavity;

encoding information using more than two energy levels of the ancilla transmon; and

creating an interaction between the cavity and the ancilla transmon that decouples at least one error type in the ancilla transmon from the cavity.

2. The method of claim 1, wherein creating the interaction between the cavity and the ancilla comprises applying a sideband drive.

3. The method of claim 2, wherein the evolution of the logical qubit of the cavity is transparent to first-order ancilla errors when the sideband drive is applied.

4. The method of claim 2, wherein the sideband drive is configured to:

adjust a first frequency shift on the cavity by the ancilla transmon in a first excited state equal to a second frequency shift on the cavity by the ancilla transmon in a second excited state; and

adjust a third frequency shift on the cavity by the ancilla transmon in a ground state excited state is equal to a second frequency shift on the cavity by the ancilla transmon in a second excited state.

5. The method of claim 1, wherein the quantum operation comprises a quantum logic gate.

6. The method of claim 5, wherein the quantum logic gate comprises a selective number-dependent arbitrary phase (SNAP) gate.

7. The method of claim 5, wherein the quantum logic gate comprises a controlled-SWAP gate.

8. The method of claim 5, wherein the quantum logic gate comprises an exponential-SWAP gate.

9. The method of claim 5, wherein, when an error occurs in the transmon, the logical qubit of the cavity is unaffected.

10. The method of claim 1, wherein the quantum operation comprises a quantum measurement.

11. The method of claim 10, wherein the quantum measurement comprises a quantum parity measurement.

12. The method of claim 10, wherein the quantum measurement comprises a measurement of an error syndrome.

13. A quantum information system comprising:

a cavity configured to support microwave radiation;

an ancilla transmon dispersively coupled to the cavity;

a microwave source configured to:

apply microwave radiation to the cavity to encode a logical qubit using more than two energy levels of the cavity;

apply microwave radiation to the ancilla transmon to encode information using more than two energy levels of the ancilla transmon; and

apply microwave radiation to create an interaction between the cavity and the ancilla transmon that decouples at least one error type in the ancilla transmon from the cavity.

14. The quantum information system of claim 13, wherein applying microwave radiation to create an interaction between the cavity and the ancilla transmon comprises applying a sideband drive.

15. The quantum information system of claim 14, wherein the evolution of the logical qubit of the cavity is transparent to first-order ancilla errors when the sideband drive is applied.

16. The quantum information system of claim 14, wherein the sideband drive is configured to:

adjust a first frequency shift on the cavity by the ancilla transmon in a first excited state equal to a second frequency shift on the cavity by the ancilla transmon in a second excited state; and

adjust a third frequency shift on the cavity by the ancilla transmon in a ground state excited state is equal to a second frequency shift on the cavity by the ancilla transmon in a second excited state.

17. The quantum information system of claim 13, wherein the quantum operation comprises a quantum logic gate.

18. The quantum information system of claim 17, wherein the quantum logic gate comprises a selective number-dependent arbitrary phase (SNAP) gate, a controlled-SWAP gate, or an exponential-SWAP gate.

19. The quantum information system of claim 17, wherein, when an error occurs in the transmon, the logical qubit of the cavity is unaffected.

20. The method of claim 1, wherein the quantum operation comprises a quantum parity measurement and/or a measurement of an error syndrome.