CLAIMS

1. A method for implementing a quantum logic gate between a plurality of cavities comprising a first cavity and a second cavity, the method comprising:

performing a first beam splitter (BS) operation between the first cavity and the second cavity using a coupling transmon that is dispersively coupled to both the first cavity and the second cavity; and

performing a controlled phase shift (CPS) operation between the second cavity and an ancilla transmon that is dispersively coupled to the second cavity but not dispersively coupled to the first cavity.

2. The method of claim 1, further comprising performing a second BS operation between the first cavity and the second cavity using the coupling transmon, wherein the first BS operation is performed before the CPS operation and the second BS operation is performed after the CPS operation.

3. The method of claim 2, wherein the quantum logic gate comprises a controlled-SWAP (c-SWAP) operation.

4. The method of claim 3, wherein the quantum logic gate comprises an exponential-SWAP (e-SWAP) gate and the method comprises:

performing a first c-SWAP operation between the first cavity and the second cavity;

performing a second c-SWAP operation between the first cavity and the second cavity; and

performing a rotation operation on the ancilla transmon between the first c-SWAP operation and the second c-SWAP operation.

5. The method of claim 2, wherein the quantum logic gate comprises an exponential-SWAP (e-SWAP) gate, the CPS operation is a first CPS operation and the method comprises:

performing a second CPS operation between the second cavity and the ancilla transmon after the first CPS operation and before the second BS operation; and

performing a rotation operation on the ancilla transmon between the first CPS operation and the second CPS operation.

6. The method of claim 5, further comprising:

performing a first Hadamard operation before the first CPS operation and after the first BS operation; and

performing a second Hadamard operation after the second CPS operation and before the second BS operation.

7. The method of claim 6, further comprising measuring the ancilla transmon.

8. The method of claim 7, further comprising determining that a dephasing error a dephasing error occurred based on a result of measuring the ancilla transmon.

9. The method of claim 7, wherein:

at least four energy levels of the ancilla transmon are used;

a first energy level of the ancilla transmon is associated with a first decay error type;

a second energy level of the ancilla transmon is associated with a second decay error type; and

the method further comprises correcting for decay errors based on a result of measuring the ancilla transmon.

10. The method of claim 1, wherein at least one local quantum logic gate is performed on the ancilla transmon before and/or after the CPS operation.

11. The method of claim 10, wherein:

the at least one local quantum logic gate comprises a first Hadamard operation performed after the BS operation and before the CPS operation; and

the method further comprises measuring the state of the ancilla transmon to compare the a first quantum state of the first cavity to a second quantum state of the second cavity.

12. The method of claim 2, wherein:

the plurality of cavities further comprises a third cavity and a fourth cavity;

the coupling transmon is a first coupling transmon;

the ancilla transmon is dispersively coupled to the third cavity by not dispersively coupled to the fourth cavity;

the CPS operation is a first CPS operation; and

the method further comprises:

performing a third BS operation between the third cavity and the fourth cavity using a second coupling transmon that is dispersively coupled to both the third cavity and the fourth cavity; and

performing a second CPS operation between the third cavity and the ancilla transmon.

13. The method of claim 12, wherein the method further comprises:

performing a fourth BS operation between the third cavity and the fourth cavity using the second coupling transmon, wherein the fourth BS operation is performed before the second CPS operation and the second BS operation is performed after the second CPS operation;

performing a third CPS operation between the third cavity and the ancilla transmon after the second CPS operation and before the fourth BS operation;

performing a rotation operation on the ancilla transmon between the second CPS operation and the third CPS operation; and

performing a fourth CPS operation between the second cavity and the ancilla transmon after the third CPS operation and before the second BS operation.

14. The method of claim 13, wherein the method further comprises:

performing a first Hadamard operation before the first CPS operation and after the first and third BS operations; and

performing a second Hadamard operation after the fourth CPS operation and before the second and fourth BS operations.

15. A multi-cavity quantum information system comprising:

a first cavity configured to support microwave radiation;

a second cavity configured to support microwave radiation;

a first transmon dispersively coupled to the first cavity;

a second transmon dispersively coupled to the second cavity;

a third transmon dispersively coupled to both the first cavity and the second cavity; and

a microwave source configured to:

apply microwave radiation to the third transmon to implement beam splitter operations between the first cavity and the second cavity and transmon rotation operations, and

apply microwave radiation to the first transmon and the second transmon to implement controlled phase shift operations on the first cavity and the second cavity, respectively.

16. The multi-cavity quantum information system of claim 15, wherein the microwave source is further configured to apply microwave radiation to the first transmon and the second transmon to implement arbitrary rotation operation on the first transmon and the second transmon, respectively.

17. The multi-cavity quantum information system of claim 16, wherein the microwave source is further configured to apply microwave radiation to the first, second and third transmon to implement a set of universal quantum gates between the first cavity and the second cavity.

18. The multi-cavity quantum information system of claim 15, wherein the microwave source is further configured to apply microwave radiation to the first, second and third transmon to implement a controlled-SWAP gate between the first cavity and the second cavity.

19. The multi-cavity quantum information system of claim 15, wherein the microwave source is further configured to apply microwave radiation to the first, second and third transmon to implement an exponential-SWAP gate between the first cavity and the second cavity.

20. The multi-cavity quantum information system of claim 15, wherein the microwave source is further configured to:

apply microwave radiation to the first and/or second transmon to measure the first and/or second transmon; and

apply microwave radiation to the first, second, and/or third transmon to implement a quantum gate based on a result of measuring the first and/or second transmon.