CLAIMS

1. A tunable resonator-resonator coupling circuit comprising:

   - a first resonator, the first resonator being linear or nonlinear and having a first frequency;

   - a second resonator, the second resonator being linear or nonlinear and having a second frequency, the first resonator and the second resonator having a direct coupling therebetween;

   - a tunable coupling element arranged to provide an indirect coupling between the first resonator and the second resonator, the tunable coupling element having an idling frequency that is below each of the first frequency and the second frequency;

   - a first readout resonator configured to readout the first resonator, the first readout resonator having a first operating frequency; and

   - a second readout resonator configured to readout the second resonator, the second readout resonator having a second operating frequency;

   wherein the tunable coupling element comprises a first superconducting island and a second superconducting island which are both ungrounded;

   wherein the indirect coupling comprises: (i) a first coupling between the first resonator and the first superconducting island, (ii) a Josephson coupling between the first superconducting island and the second superconducting island, and (iii) a second coupling between the second resonator and the second superconducting island; and

   wherein each of the first operating frequency and the second operating frequency is above each of the idling frequency of the tunable coupling element, the first frequency of the first resonator and the second frequency of the second resonator.

2. The circuit of claim 1, wherein each of the first resonator and the second resonator is implemented as one of a harmonic oscillator, a coplanar waveguide resonator and a lumped element resonator.

3. The circuit of claim 1, wherein each of the first resonator and the second resonator is implemented as a superconducting qubit.

4. The circuit of any one of claims 1 to 3, wherein the direct coupling is implemented as a non-galvanic coupling between the first resonator and the second resonator.

5. The circuit of any one of claims 1 to 4, wherein the first coupling is implemented as a capacitive coupling between the first resonator and the first superconducting island, and the second coupling is implemented as a capacitive coupling between the second resonator and the second superconducting island.

6. The circuit of any one of claims 1 to 5, wherein the tunable coupling element is implemented as a transmon qubit.

7. The circuit of any one of claims 1 to 6, wherein the indirect coupling further comprises a third coupling between the second resonator and the first superconducting island and a fourth coupling between the first resonator and the second superconducting island.

8. The circuit of claim 7, wherein the third coupling is implemented as a capacitive coupling between the second resonator and the first superconducting island, and the fourth coupling is implemented as a capacitive coupling between the first resonator and the second superconducting island.

9. The circuit of any one of claims 1 to 8, wherein at least one of the first superconducting island and the second superconducting island has a capacitive coupling to a ground.

10. A quantum computing apparatus comprising at least one tunable resonator-resonator coupling circuit according to any one of claims 1 to 9 and a control unit configured to perform quantum computing operations by using the at least one tunable resonator-resonator coupling circuit.