SUPERCONDUCTING QUBITS: PATH INTERFERENCE

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Much interest has recently been focused on superconducting charge qubits, ([1],[2],[3]), which consist of small islands of superconductor connected by high-capacitance tunnel junctions to a reservoir. Gate voltages are applied to each island, so that the charging energy of each island is at a minimum when the charge is equal to the gate charge $n_{ig} = C_{ig}V_{ig}$. The high capacitance of the islands means that the eigenstates of charge are close to the eigenstates of the system, and that only the two states closest to the gate charge are occupied, with all others widely separated in energy.

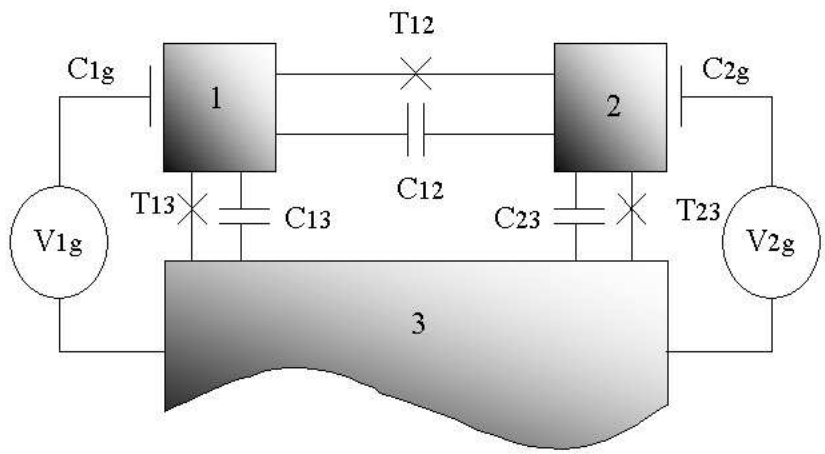

Fig. 1: Two Coupled Superconducting Charge Qubits

We discuss a simple and implementable extension to the recent experiment by Pashkin *et. al.* [3]. A tunnel junction is added between the two islands in addition to their capacitive coupling, and a magnetic flux passed through the loop formed by the three junctions (*Fig. 1*). The unitary evolution of the system is then calculated. The system oscillates between the charging states of the system, with the period of these oscillations dependent on the flux through the loop.

By making use of a perturbative expansion in tunnelling energy over charging energy, we show the flux-dependence of the period is due to cooper pairs tunnelling through different paths, for example, either hopping directly to qubit one, or hopping first to qubit two and then to qubit one. Each different path experiences a different vector potential, and therefore picks up a different phase. When the interaction charging energy is much larger than the tunnelling energy, only lowest order paths contribute and the flux just causes a change in the period of the oscillations.

If the charging energy is comparable to the tunnelling energy, the evolution should be regarded as a sum over all possible tunnelling paths, each picking up a phase due to the magnetic field and producing a more complex behaviour.

This 2-qubit interference can be observed in ensemble measurements on individual qubits, as performed in [3], and provides confirmation of the quantum coherence of this 2-qubit system.

We also discuss techniques for generation and storage of entangled states in such systems.

References

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