Many Body Operations Within Superconducting Circuits

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Abstract

We propose a Superconducting Circuit that can perform 3 body interactions by being driven with an external magnetic field. We provide a method for decomposing arbitrary unitary quantum gates into drives which can be applied to this circuit producing the correct dynamics. The system is Numerically simulated using Qutip [1] with a Toffoli Drive, the resulting gate is faster by a factor of 10,000 than current state of the art circuit and has a fidelity approaching 99% a significant improvement over current fidelities of 50%[2].

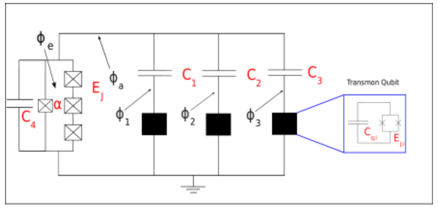

Figure.1. Circuit diagram for the System we are proposing. The Transmon qubits are capacitively coupled to a SNAIL. The SNAIL is threaded with an external magnetic flux to provide the drive for the system.

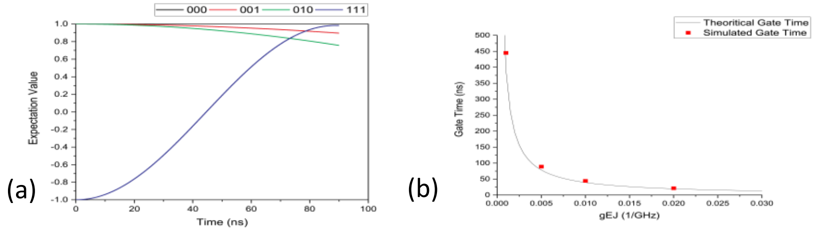

Figure. 2. Numerical results from Qutip simulation of the circuit in Figure 1. a.) Simulation of the Circuit Hamiltonian using a Dyson Series expansion. b.) Comparison of theoretical gate times with simulated gate times, they agree very well with each other showing that the system still exhibits the same properties as the theoretical Hamiltonian.

Project Description

We aim to describe and simulate a superconducting circuit capable of producing many body (>2) interactions which are controllable using an external magnetic field. These interactions are specifically designed using a decomposition technique developed in this project to decompose unitary quantum gates. This single shot technique improves both the gate time and the fidelity of these gates, which for higher order interactions are very low.

Here we theoretically predict the higher order interactions using a Dyson Series[3] expansion and then numerically simulate the resulting Hamiltonian using Qutip. We choose a Toffoli gate, this was an ideal candidate to show the benefits of our circuit due to it's low fidelity (50%) and high gate time 2μs.

Key Results and Conclusions

- We have theoretically proved that n-body interaction are present in the circuit
- We have Shown that it is possible to decompose general unitary matrices into series of Pauli operators which can be implemented in our circuit
- We showed numerically that the system will produce the predicted gate.
- Several possible applications for the circuit have been identified as future projects and/or experiments.

Refs & links

[1] - Johansson, J. R., Nation, P. D., & Nori, F. (2013). QuTiP 2: A Python framework for the dynamics of open quantum systems

[2] - Linke, N. M., Maslov, D., Roetteler, et al.(2017). *Experimental Comparison of Two Quantum Computing Architectures*.

[3] - James, D. F. V. (2000). Quantum Computation with hot and cold ions: An assessment of proposed schemes.