Generation of Multiparty Entanglement in Superconducting Circuits

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Abstract

These proposed setup consists of artificial two-level atoms designed inside superconducting circuits which according to generalized circuit designs are labelled as charge qubits and phase qubits. Entanglement is achieved by building a connection among many charge qubits through phase qubits, which acts as the coupler. These qubits can be initialized in ground or excited state inside a circuit separately. Further, entanglement among two or higher party charge qubits can be observed and the action of coupler is traced out. These maximally entangled states are showing good fidelity and can further be utilized for quantum information processing tasks.

Keywords: Artificial Two-level atom, Entanglement, Fidelity

Artificial Atom in Circuit

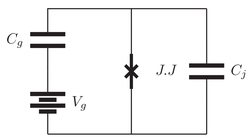


Figure 1:

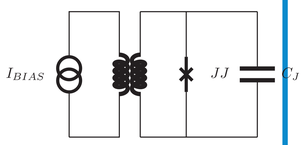


Figure 2:

$$\mathcal{H} = 4E_c(n-n_g)^2 - E_{Jo}(1+\cos\phi). \quad (1)$$

$$\mathcal{H} = 4E_c n^2 + E_{Jo}(1-\cos\phi+\frac{I_{bias}}{I_c}\phi). \quad (2)$$

$$E_n = \sqrt{\frac{E_c E_{Jo}}{2}}(n+\frac{1}{2}) - \frac{E_c}{2}(6n^2+6n+3). \quad (3)$$

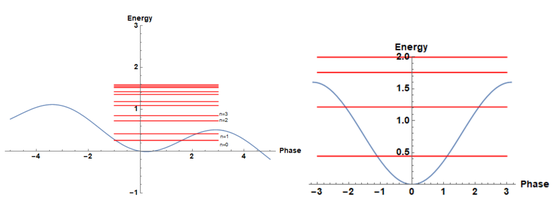
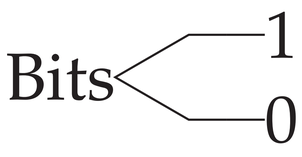


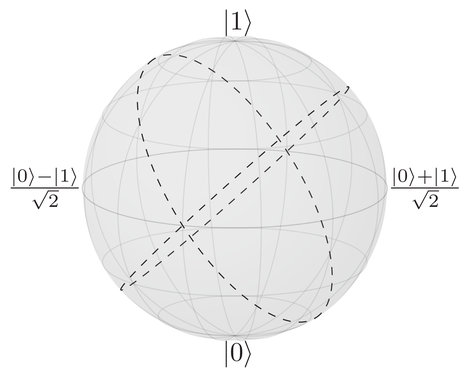
Figure 3:

Introduction

The classical representation of bits which is formed inside chips using transistors. The transistor turns on when certain amount current flows through it labelling the bit '1' and stays off if less currents flow through it hence labelling the bit '0'. Similarly, there are other systems using voltage fluctuations to represent binary bits that are utilized to operate computers.



The Bloch sphere represents all states of qubit. Since, the quantum system has superposition a qubit can be attained for every point on the Bloch sphere representing the interference between two qubits



References

[1] W. Cui et al. Non-markovian entanglement dynamics in coupled superconducting qubit systems. *Eur. Phys. J. D*, 2010.

[2] M. S. Zubairy et al. *Quantum Optics*. Cambridge University Press.

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Coupling of Two Artificial Atoms

$$\mathcal{H} = \sum_{m=1}^{2}\left(\frac{E_{Jm}(\Phi_m)}{2}\sigma_z^m - \frac{E_{cm}(n_{gm})}{2}\sigma_x^m\right) + \omega_c\sigma_z^c + \mu_{12}(\sigma_+^1\sigma_-^2 + \sigma_+^2\sigma_-^1), \quad (4)$$

$$\Psi(0) = |g\rangle_c |g\rangle_1 |e\rangle_2, \quad (5)$$

$$\Psi(t) = \cos(\mu_{12}t)|g\rangle_1|e\rangle_2 - i\sin(\mu_{12}t)|e\rangle_1|g\rangle_2. \quad (6)$$

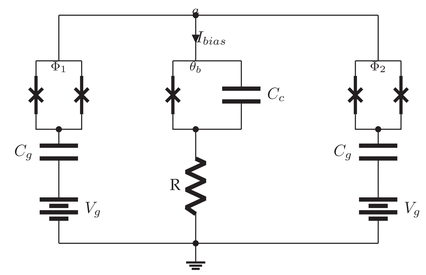

Figure 4:

$$U(t) = \exp\left(-i(\sum_{j=1}^{2}\omega_{cj}\sigma_z^{cj} + \frac{1}{2}\sum_{\substack{i,m=1\\ i\neq m}}^{3}\mu_{i,m}(\sigma_+^i\sigma_-^m + \sigma_+^m\sigma_-^i))t\right), \quad (7)$$

$$\hbar = 1$$

$$\Psi(t) = (\cos^2(\mu t) + \sin^3(\mu t))|g_1,e_2,e_3\rangle + (\sin^2(\mu t)\cos(\mu t) - i\cos(\mu t)\sin(\mu t))|e_1,g_2,e_3\rangle - i\sin(\mu t)\cos(\mu t)|e_1,e_2,g_3\rangle. \quad (8)$$

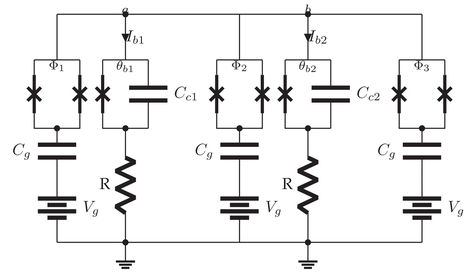

Figure 5:

Conclusion

Let us conclude by adding that the systems based on superconducting qubits are highly scalable and the generation of entanglement give quite satisfactory results. The bi-party entanglement is maximally entangled state with maximum fidelity while the higher party states are non-symmetrically entangled and the fidelity is relatively lower.

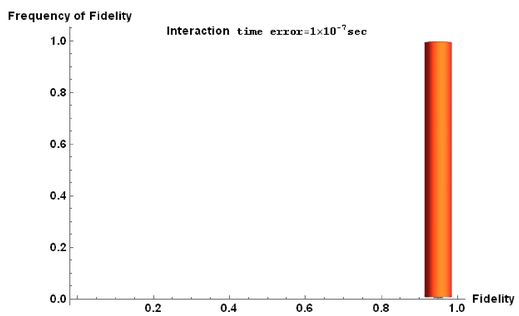

Figure 6:

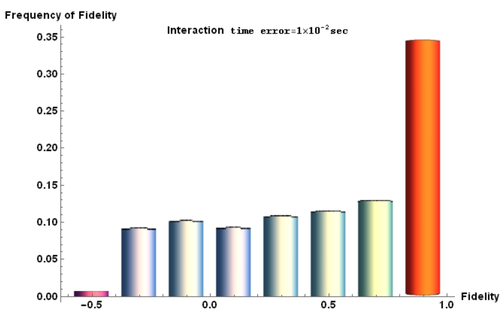

Figure 7: