Search on Superconducting Qubits

International Young Quantum Meet 2024

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Introduction to the talk

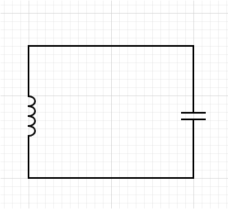
Qubits can be realised in a lot of ways, examples include

1. Ion trap quantum computing
2. NMR quantum computing
3. Optical photon quantum computing to name a few.

My talk will be focused more on Superconducting qubits and applying it to model a theoretical problem.

How do you build Superconducting Qubits

By using so called "Artificial atoms". You cool a LC circuit to the material's critical temperature, into it's superconducting phase.

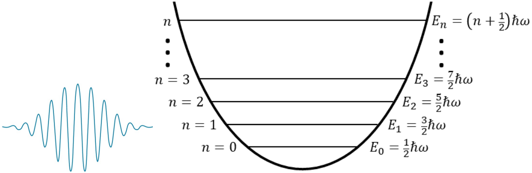


Where, means Inductor and means Capacitor. The Hamiltonian of this circuit is given by

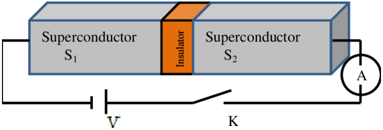
$$H = \frac{\hat{Q}}{2C} + \frac{\hat{\Phi}}{2L} = \hbar\omega(aa^{\dagger} + \frac{1}{2})$$

Issues with simple superconducting qubits

Energy levels of the circuit mimic a linear Harmonic oscillator



This can't be an ideal two qubit system as all energy levels are equally spaced. But how do we modify the energy levels?
Enter **Josephson Junctions** !!



How can you modify Superconducting Qubits (Josephson Junctions and dc-SQUIDs)

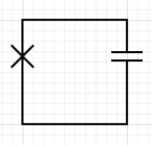
Josephson Junctions are represented by  . I am not focusing more on the derivation of V, I and L of Josephson Junctions, I just mention it here. Interested can refer to Feynman lectures volume 3 last chapter.

$$V_J = \frac{\Phi_0}{2\pi}\frac{d\varphi_J}{dt}$$

$$I_J = I_c sin\varphi_J$$

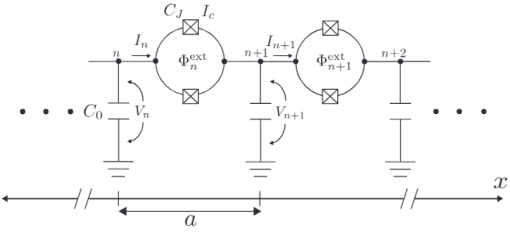
$$L_J = \frac{\phi_J}{I_c sin(2\pi\phi_J/\phi_0)} = \frac{\phi_0\varphi_J}{2\pi I_c sin\varphi_J}$$

The circuit can be drawn like



Analog gravity using superconducting qubits

We construct an infinite circuit like



Now, we apply Kirchoff law and Faraday's law as

$$I_n - I_{n+1} = \frac{dQ_{n+1}}{dt}$$

$$V_n - V_{n+1} = \frac{\Phi_0}{2\pi} \frac{d\varphi_{Jn}}{dt}$$

Obtaining the Lagrangian and Hamiltonian

Plugging in the formulas obtained for Josephson junctions, we can obtain the current entering the nth unit cell as

$$I_n = 2C_J \frac{\Phi_0}{2\pi} \frac{d^2\varphi_{Jn}}{dt^2} + 2I_c cos\left(\frac{\pi\Phi^e xt_n}{\Phi_0}\right) sin\varphi_{Jn}$$

Conclusions

So in this talk, we have discussed about

1. A brief introduction to Superconducting qubits
2. Construction of superconducting qubits
3. A brief application of superconducting qubits in Analogue Gravity and Hawking radiation.

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Thank You !!