Strong measurement of a superconducting qubit in superconducting circuit QED systems

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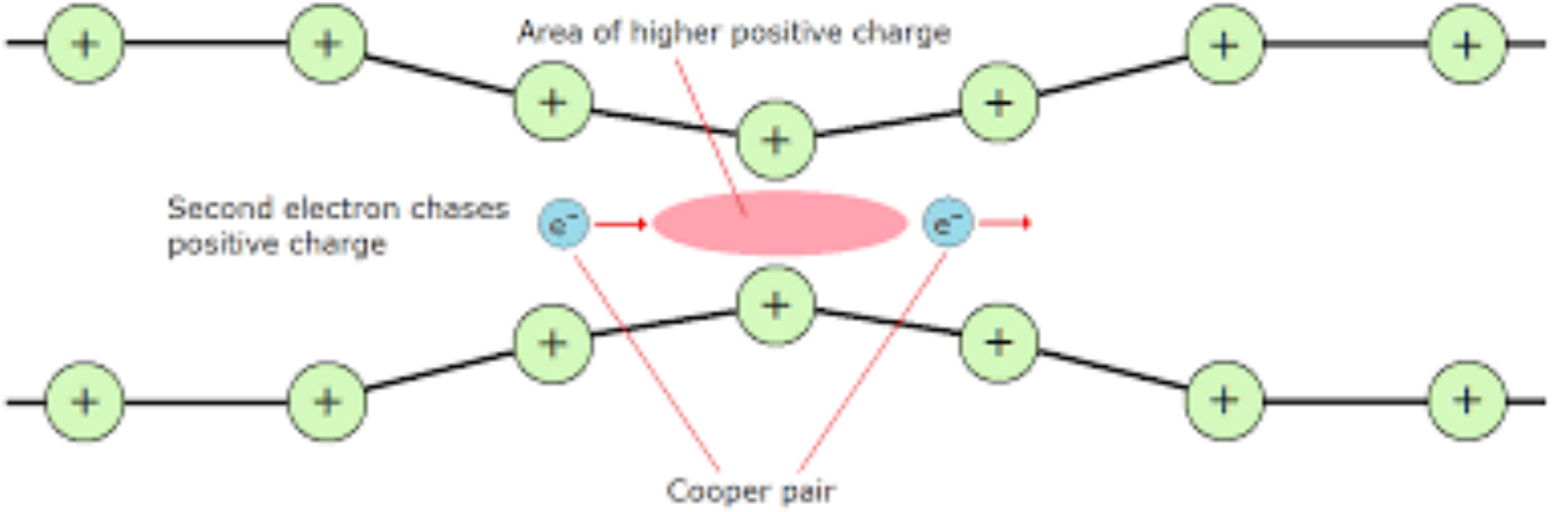
Summary

- Notions
- Charge Qubit
- Superconducting Qubit
- Hamiltonian of the circuit QED
- Qubit read-out

Superconducting wires



Notions

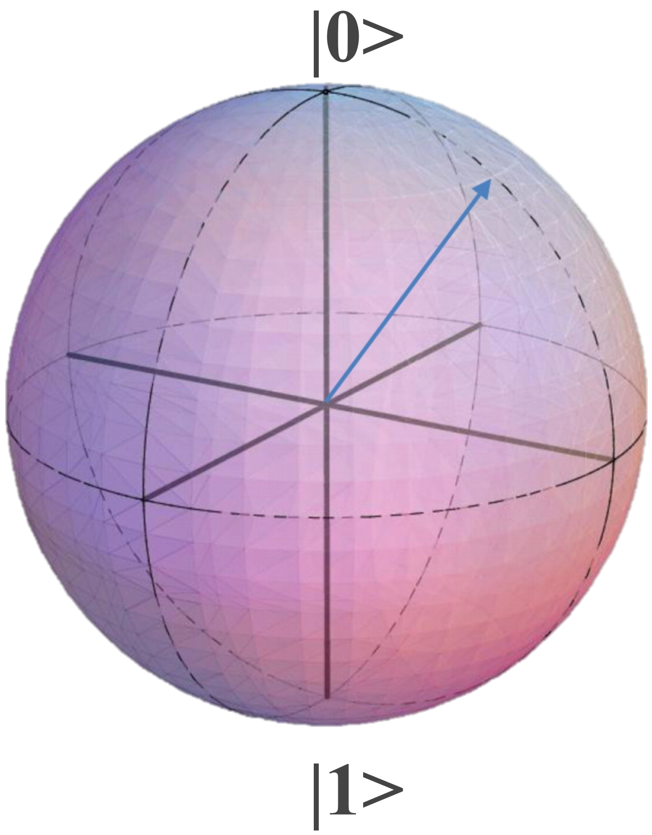
Charge Qubit

Superconducting Qubit

Hamiltonian of The circuit QED

Qubit read-out

Qubit



$$|\Psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle$$

Notions

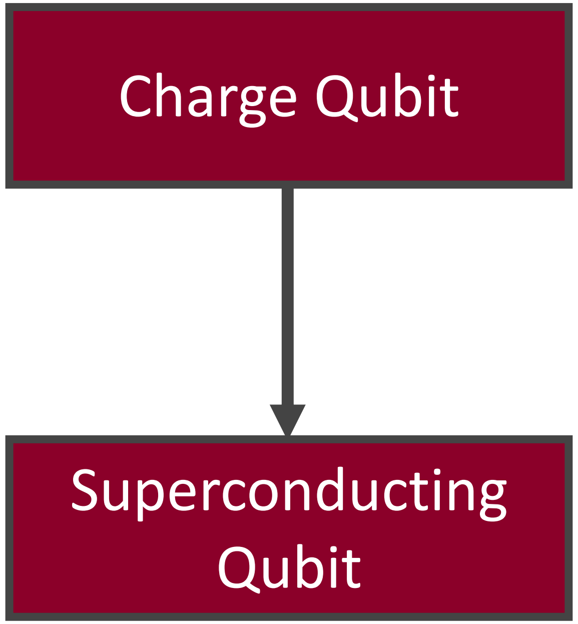
Charge Qubit

Superconducting Qubit

Hamiltonian of The circuit QED

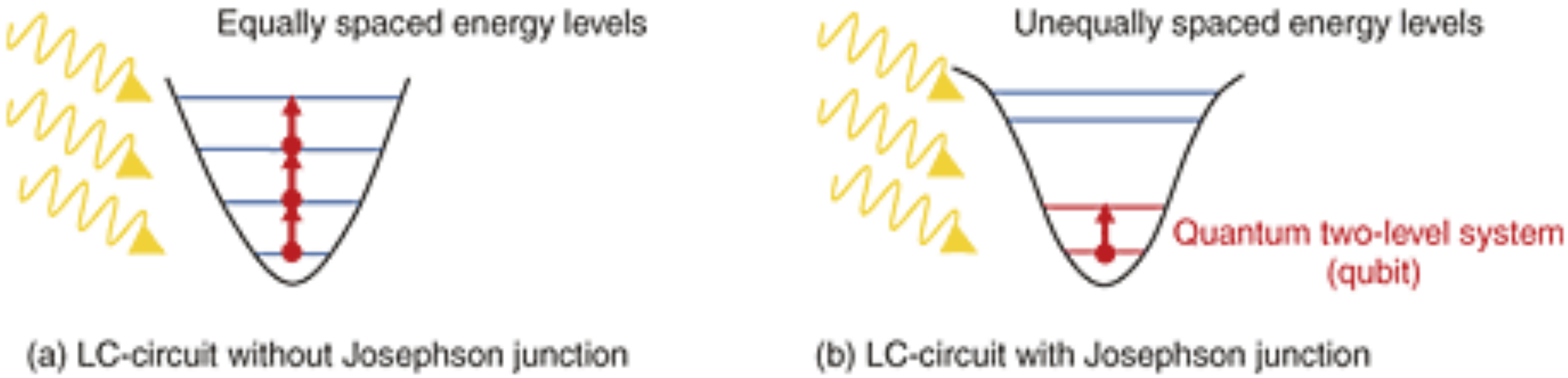
Qubit read-out

Qubit



Charge Qubit

Two-level system



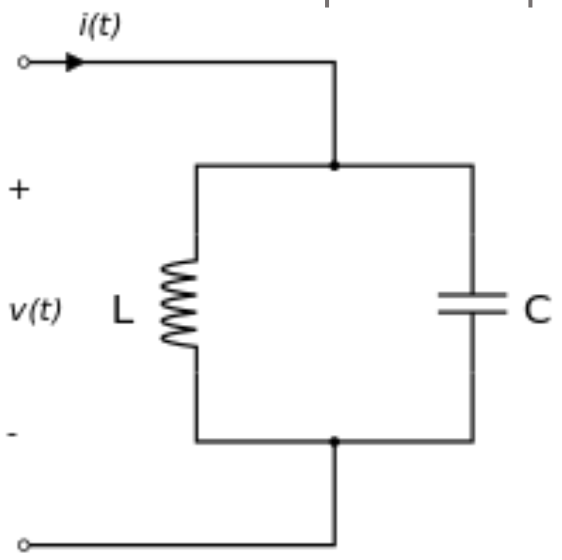
Harmonic oscillator → Resonator
Two-level system → Cooper-pair box

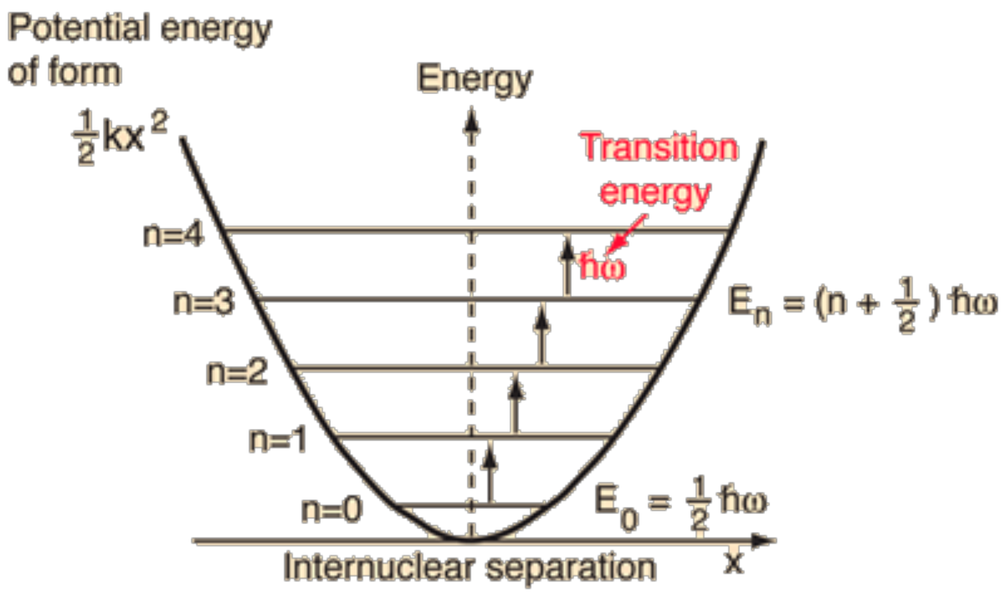
Charge Qubit

Resonator

$$\hbar\omega\left(a^{+}a+\frac{1}{2}\right)\psi(x)=E\psi(x)$$

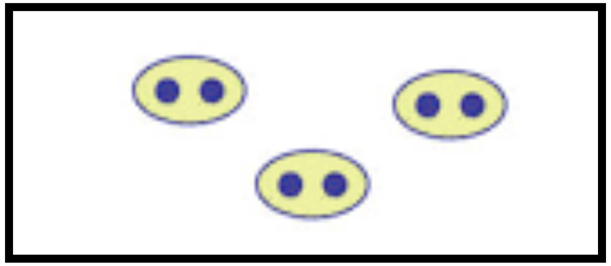
$$a^{+}a\,|n>=n\ \,|n>$$





Charge Qubit

Cooper pair box



|0>

$$E = Ec\,\mathrm{N}^2$$

|1>

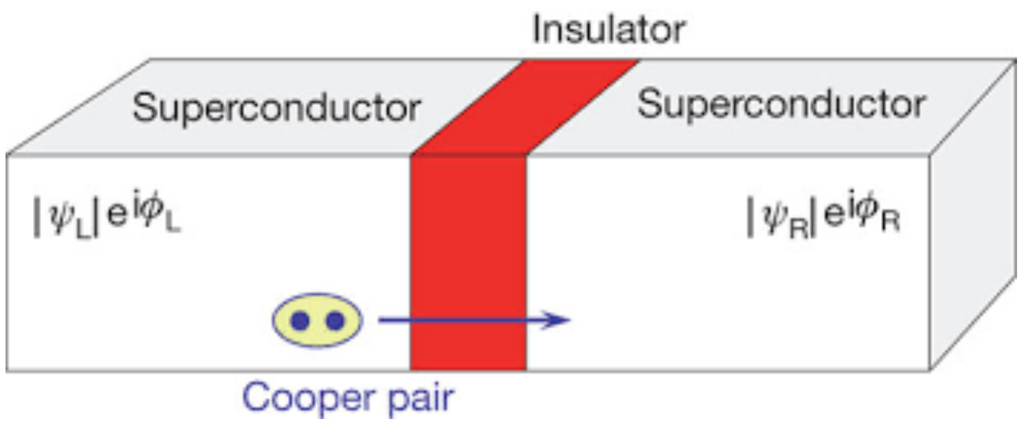
$$E = Ec\,(\mathrm{N}+1)^2$$

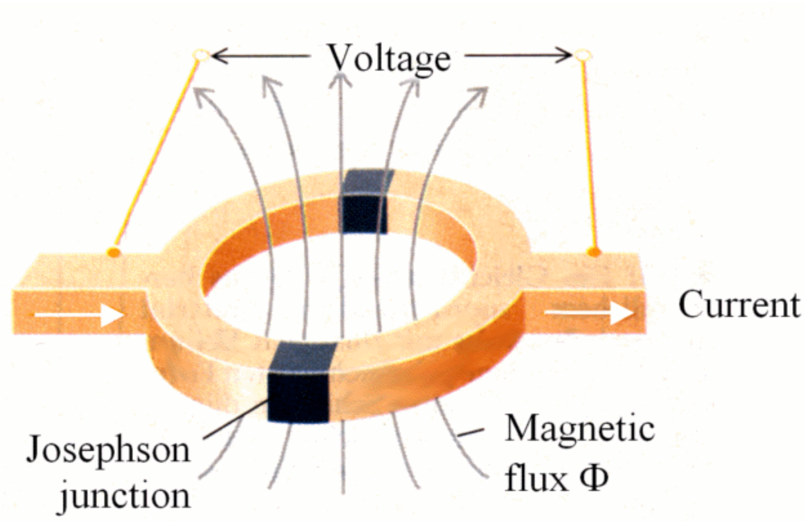
N Cooper pair in the Cooper pair box

=> Necessity of a Josephson Junction

Charge Qubit

Josephson Junction





=> Tunelling though the insulator due to Josephson effect

Charge Qubit

Cooper-pair box

Notions

Charge Qubit

Superconducting Qubit

Hamiltonian of The circuit QED

Qubit read-out

$$\hat{H} = Ec.\hat{N} - E_J.\cos(\hat{\phi})$$

Cooper pair box energy

Josephson junction energy

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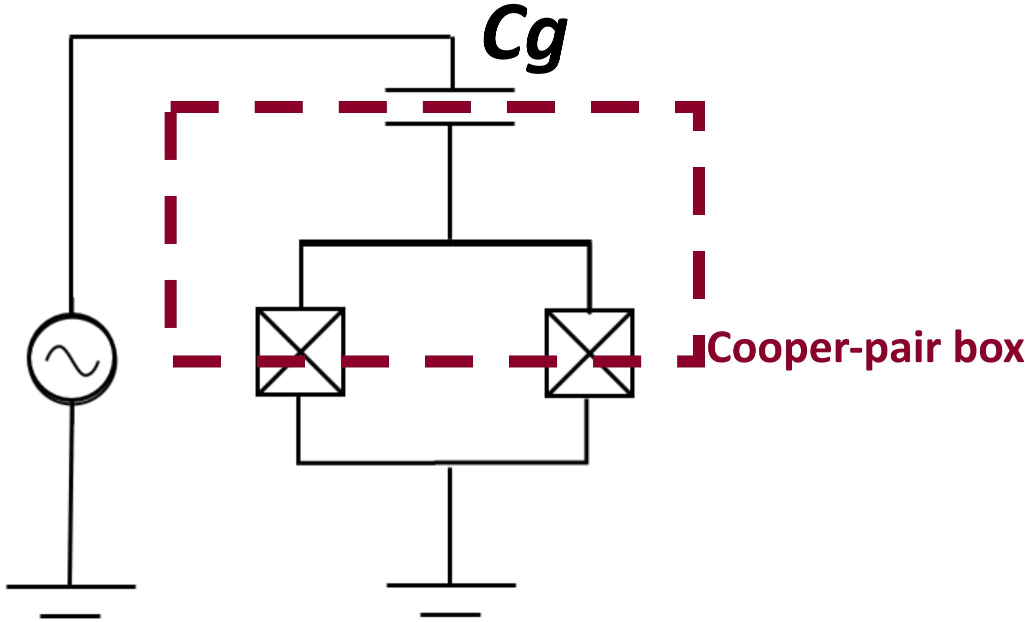
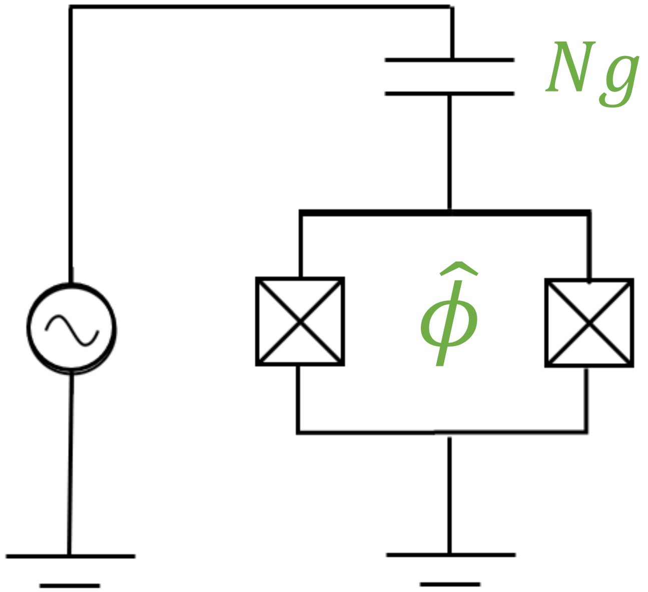
Cooper-pair box

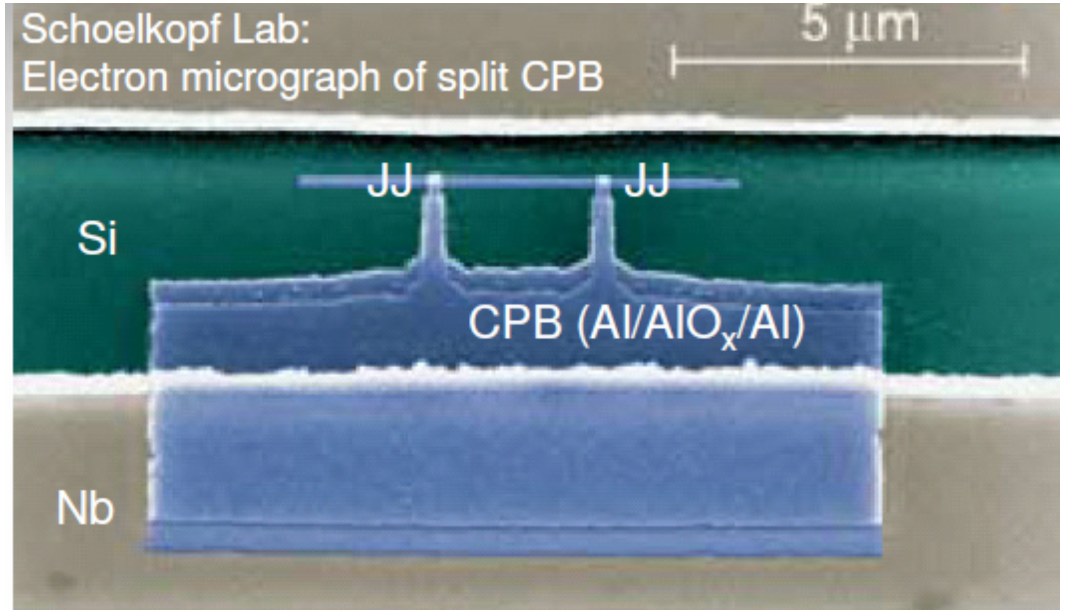


$$Cg = \frac{Ng.2e}{Vg}$$

$$\hat{H} = Ec.(\hat{N} - Ng) - E_J.\cos(\hat{\phi})$$

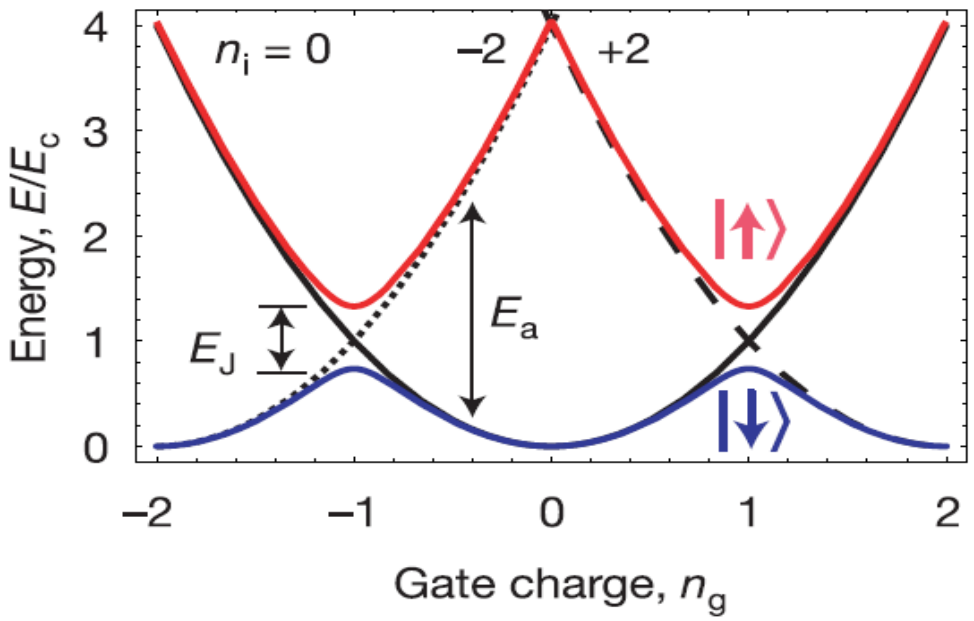
Charge Qubit





Charge Qubit
Energy levels of the system

$$\hat{H} = Ec.(\hat{N} - Ng) - E_J.\cos(\hat{\phi})$$



Affected by random charges in the system

Notions

Charge Qubit

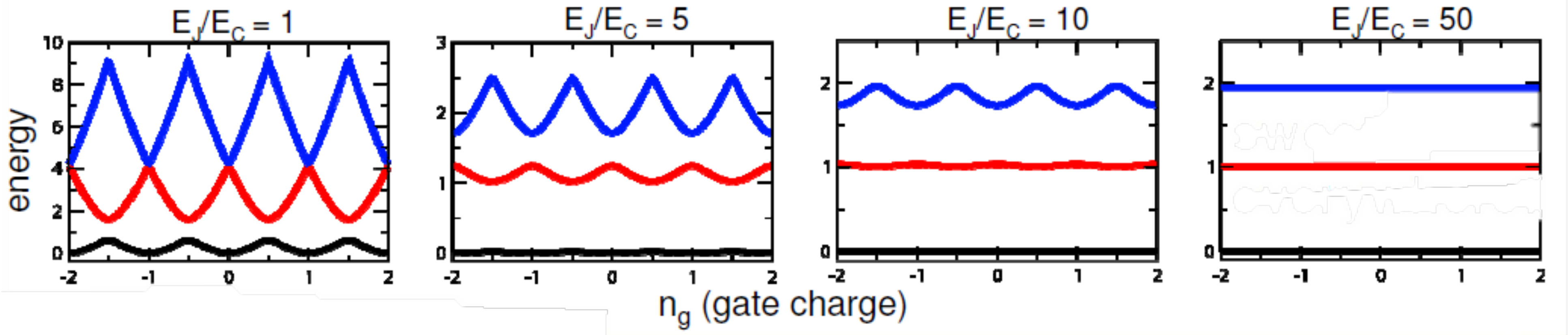
Super-conducting Qubit

Hamiltonian of The circuit QED

Qubit read-out

Superconducting Qubit

Larger capacitor



→Reduced sensitivity to charge noise

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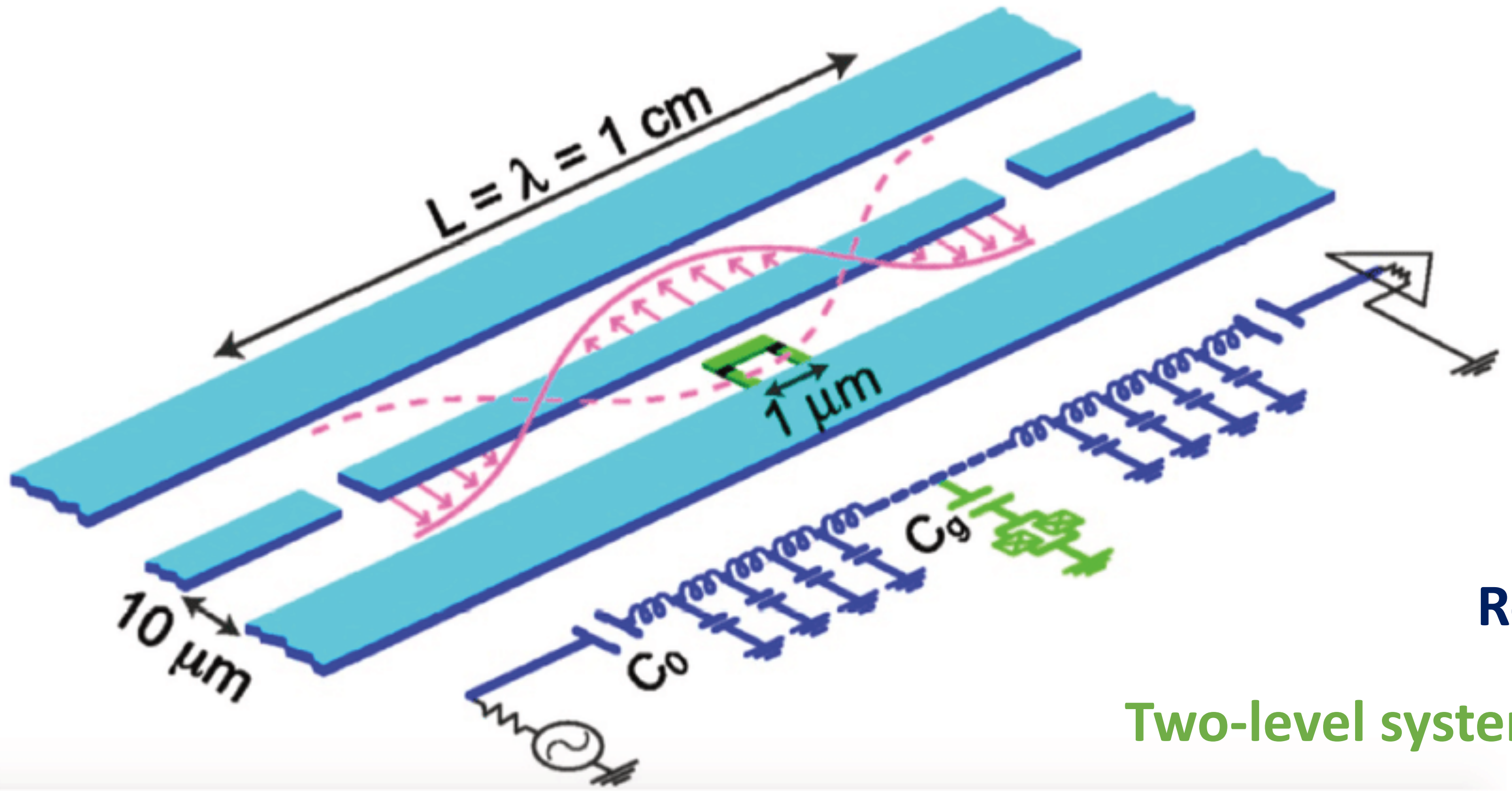
Superconducting circuit QED



Resonator

Two-level system (Qubit)

Hamiltonian

Hamiltonian equation

$$H_{Rabi} = \omega(a^{+}a) + \frac{1}{2}\Omega\sigma^{Z} + g(a^{+} + a)(\sigma^{+} + \sigma^{-}) + H_{\kappa} + H_{\gamma}$$

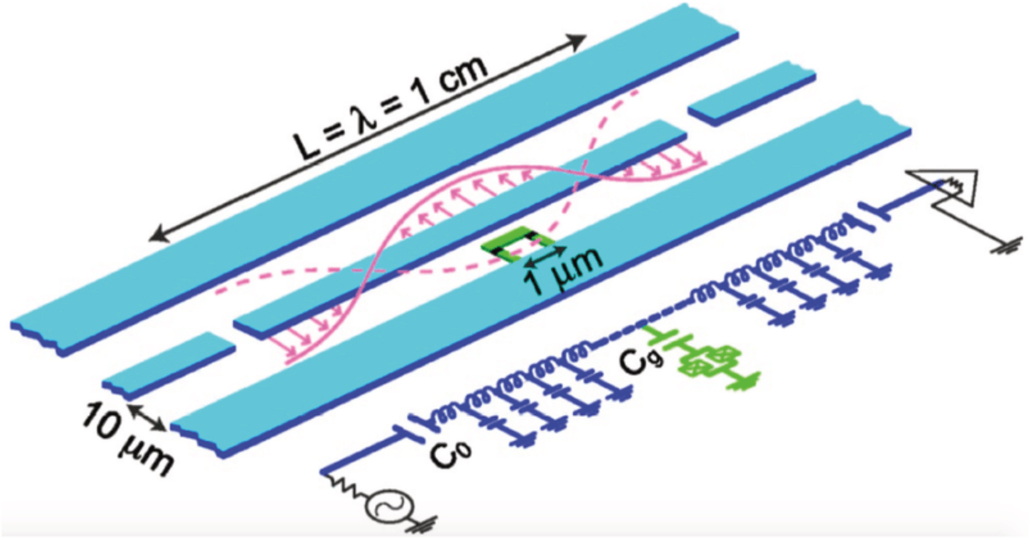
Energy loss

Resonator

Two-level system (Qubit)

Resonator-Qubit coupling

ω : resonator frequency
Ω : two-level system frequency
g : resonator-qubit coupling strengh



Dispersive Hamiltonian

<u>Dispersive limit :</u>

g<<|Ω-ω|

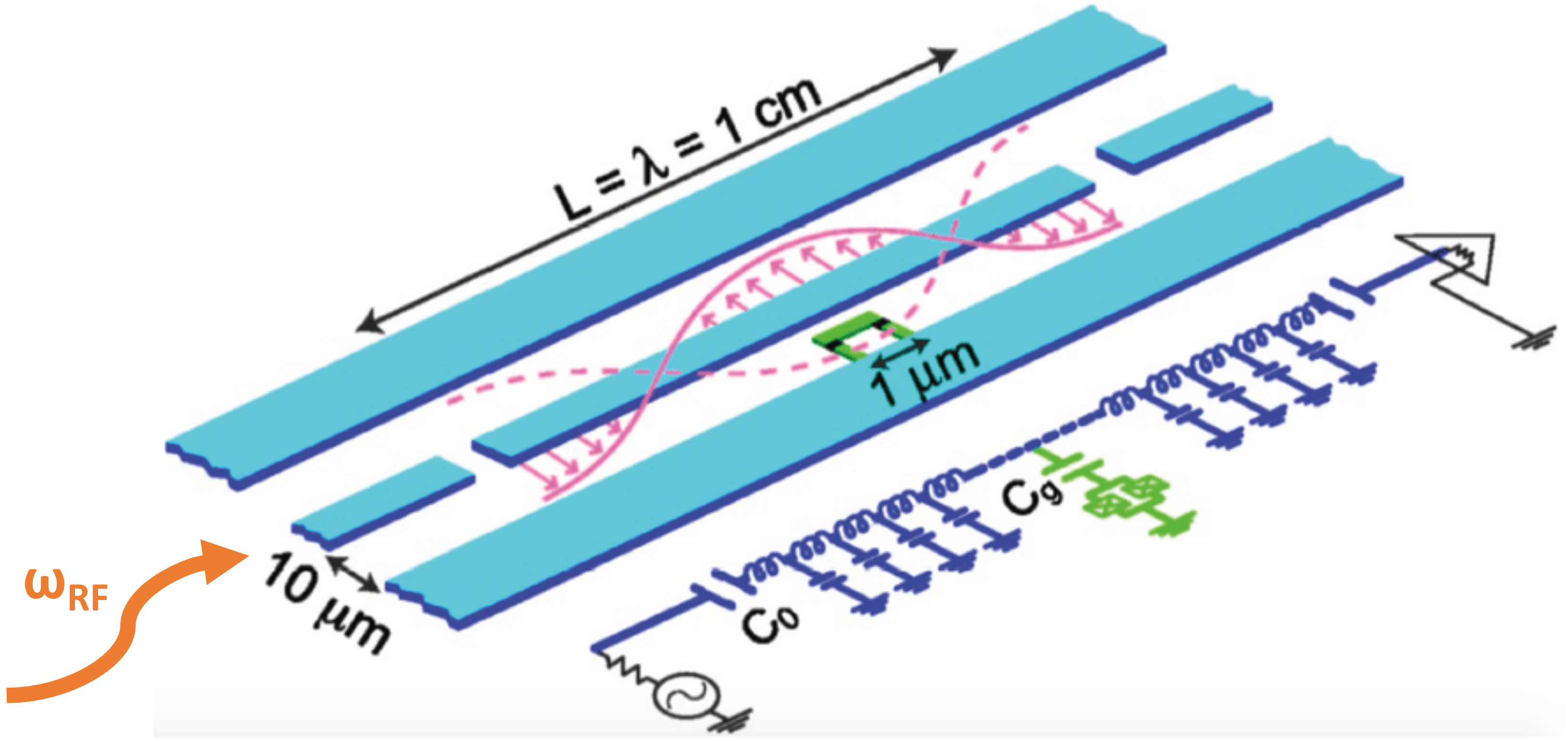
+ : Lifetime enhancement

<u>Strong measurement :</u>

g>>κ

$$H_{Disp} = \frac{1}{2}\Omega\sigma^Z + \frac{g^2}{2\Delta}\sigma^Z + \left(\omega + \frac{g^2}{\Delta}\sigma^Z\right)a^+a$$

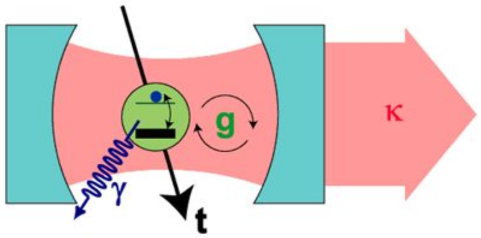
Qubit read-out

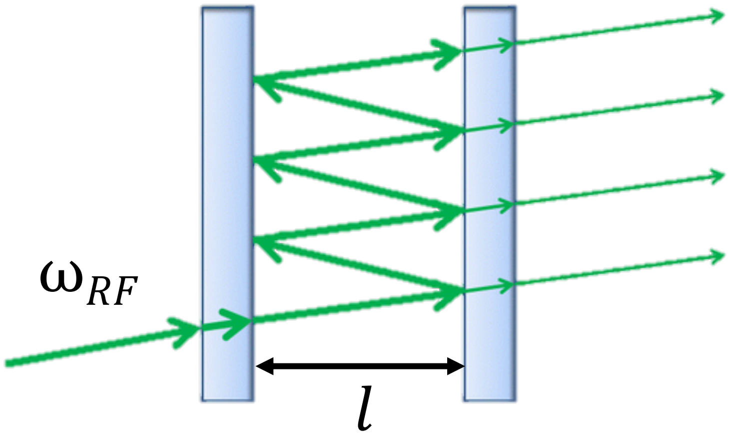


Qubit-Readout

Form of the transmission

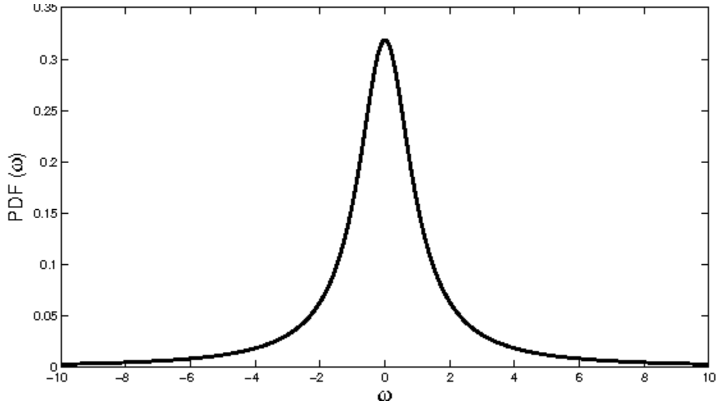
Fabry Perot Interferometer





$$Transmission \propto \frac{1}{1 - r^2 (e^{ikl})^2}$$

=> Lorentzian



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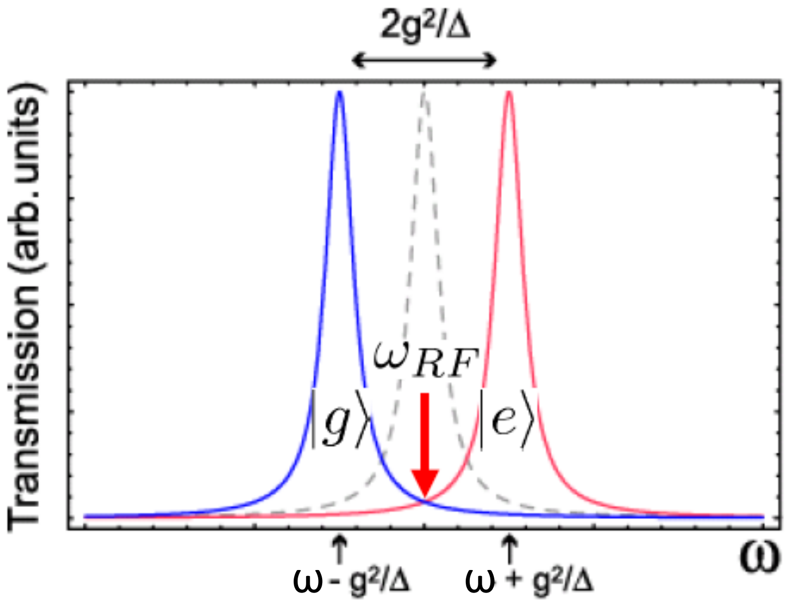
$$H_{Disp} = \frac{1}{2}\Omega\sigma^Z + \frac{g^2}{2\Delta}\sigma^Z + \left(\omega + \frac{g^2}{\Delta}\sigma^Z\right) a^+ a$$

Cavity frequency shift

| ↑> | ↓>

$$\sigma^Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$



=> state readout by measurement of transmission

Conclusions and Perspectives

What has been achieved :

- **Understanding QED Systems**
- **Searching the Hamiltonian and use it to understand the qubit read-out**

Possibility to continue this internship on :

- **Multiple Qubit in the QED System**
- **Weak measurement**

Thank you for listening

Do you have any questions ?