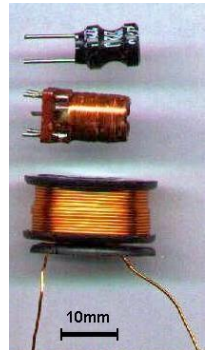
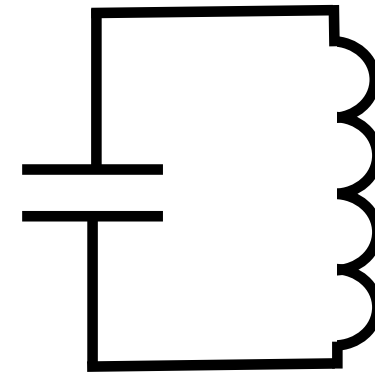
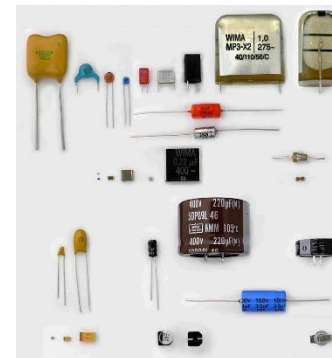
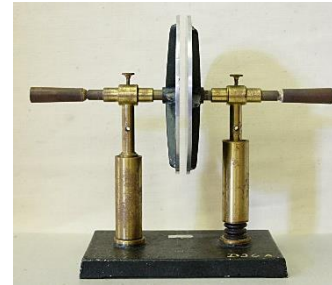
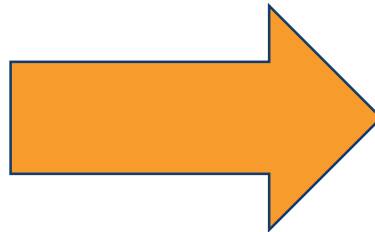
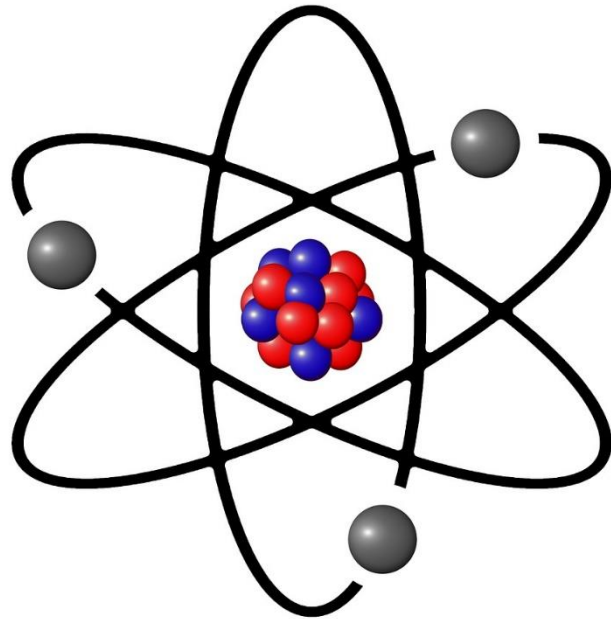


An Artificial Atom



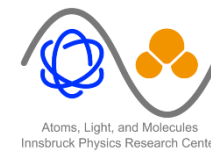
<https://pixabay.com/de/illustrations/atom-symbol-zeichen-abstrakt-68866/>

https://upload.wikimedia.org/wikipedia/commons/2/2c/Diverse_Spulen.JPG
[https://de.wikipedia.org/wiki/Kondensator_\(Elektrotechnik\)](https://de.wikipedia.org/wiki/Kondensator_(Elektrotechnik))



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Circuit QED with Superconducting Qubits

Maximilian Zanner
MIP Seminar 2019/11/29

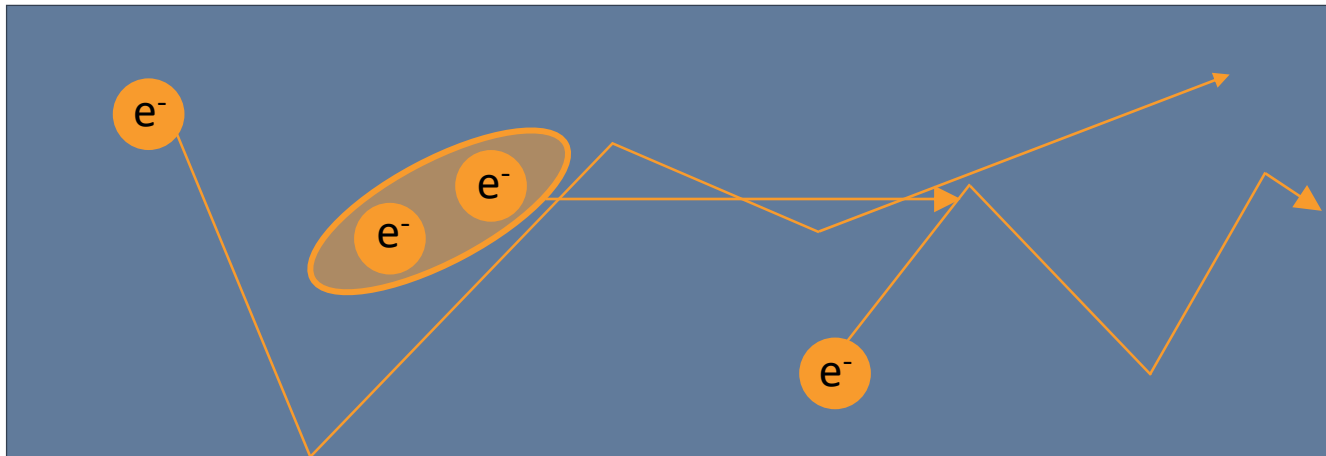
- Introduction
 - What is a Superconductor?
 - Electrical Circuits
- Circuit QED
 - Josephson Junctions
 - Quantum Information Processing
- Waveguide QED
 - Mirror-like Atom
 - Qubits in a Waveguide

What is a Superconductor?

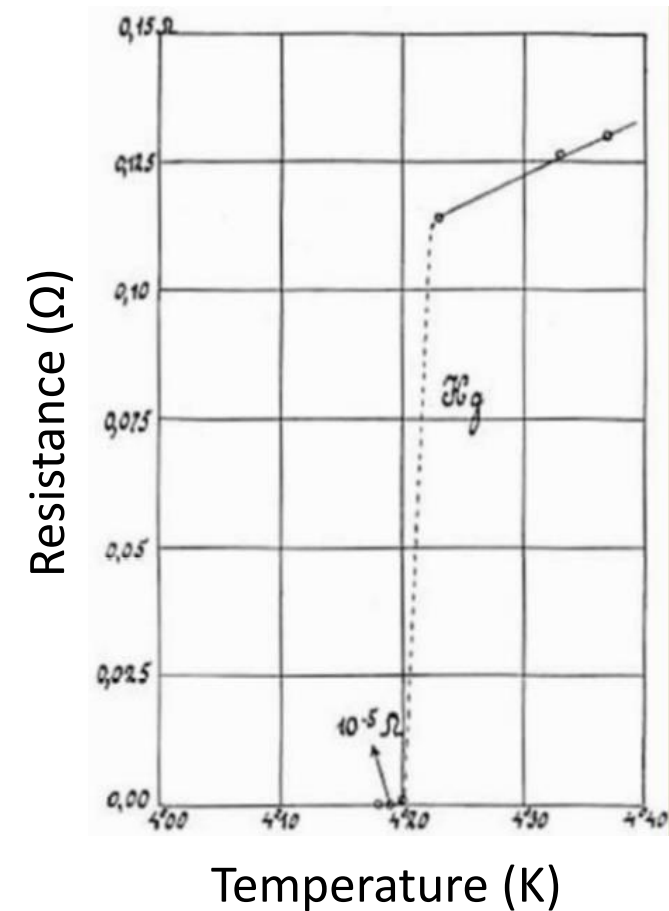


Superconductivity & Application

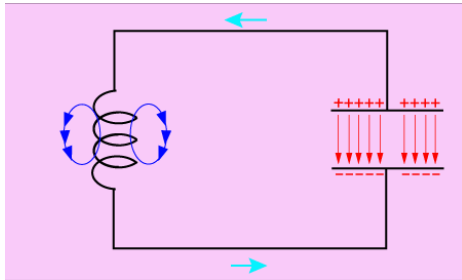
- No Resistance below T_c
- No Information Loss



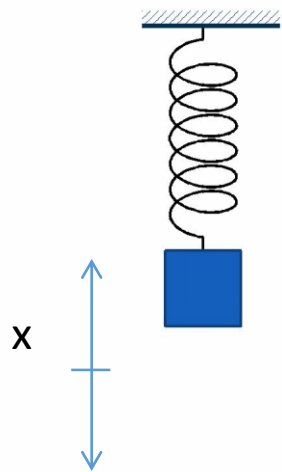
Heike Kammerlingh Onnes
October 26th, 1911



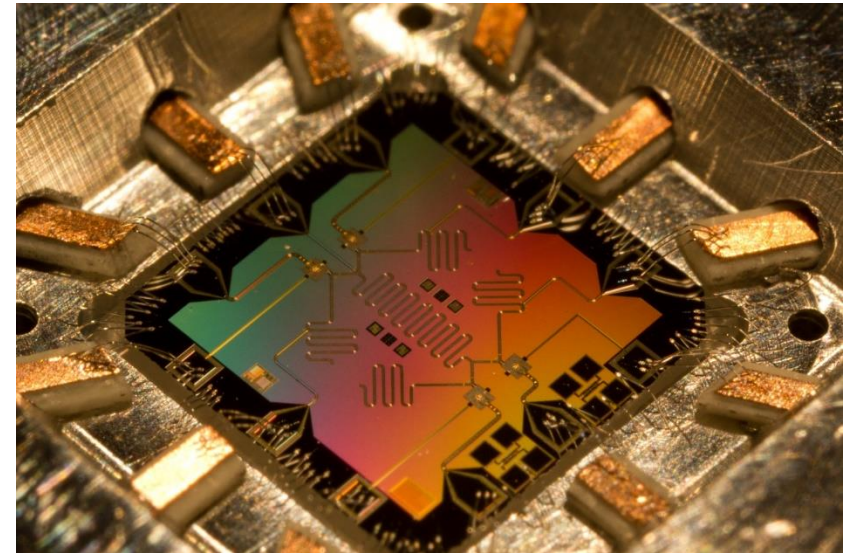
LC Oscillator & Circuits



$$f_r = \frac{2\pi}{\sqrt{LC}} \rightarrow 4 \dots 10 \text{ GHz}$$



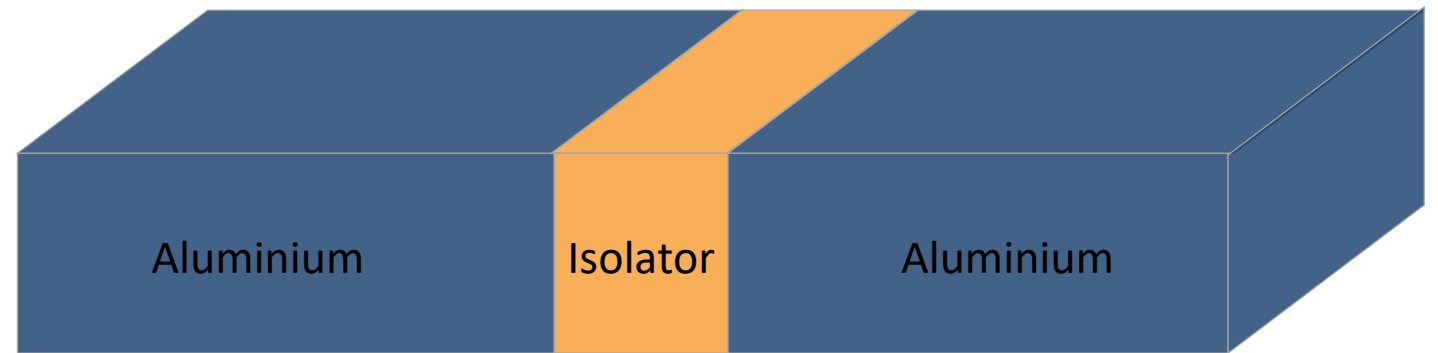
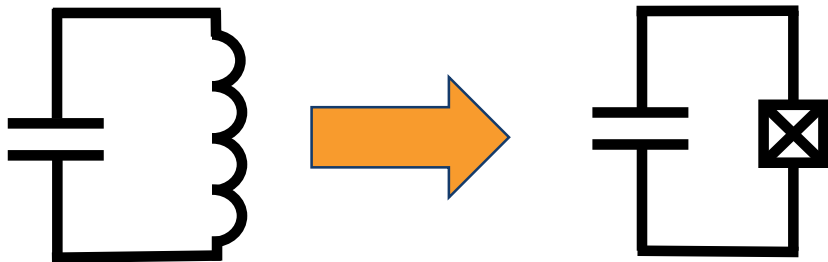
- Equidistant Energy Levels \rightarrow Cannot address only two of its states
- For QIP, need logical zero and one



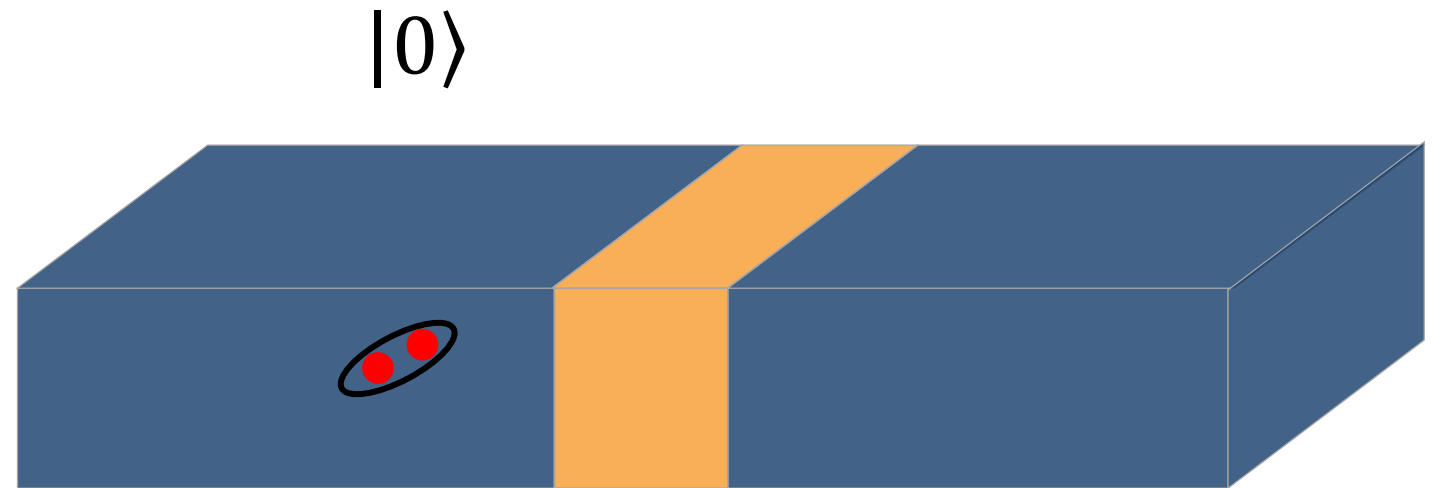
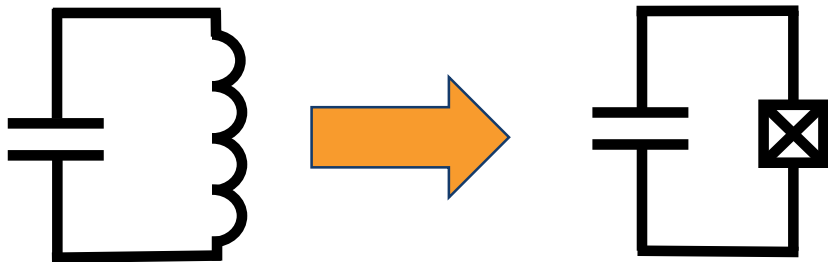
<https://web.physics.ucsb.edu/~martinisgroup/photos/BBCReZQu1103.jpg>

<https://media.giphy.com/media/EjxS2FRgJ4Hss/giphy.gif>

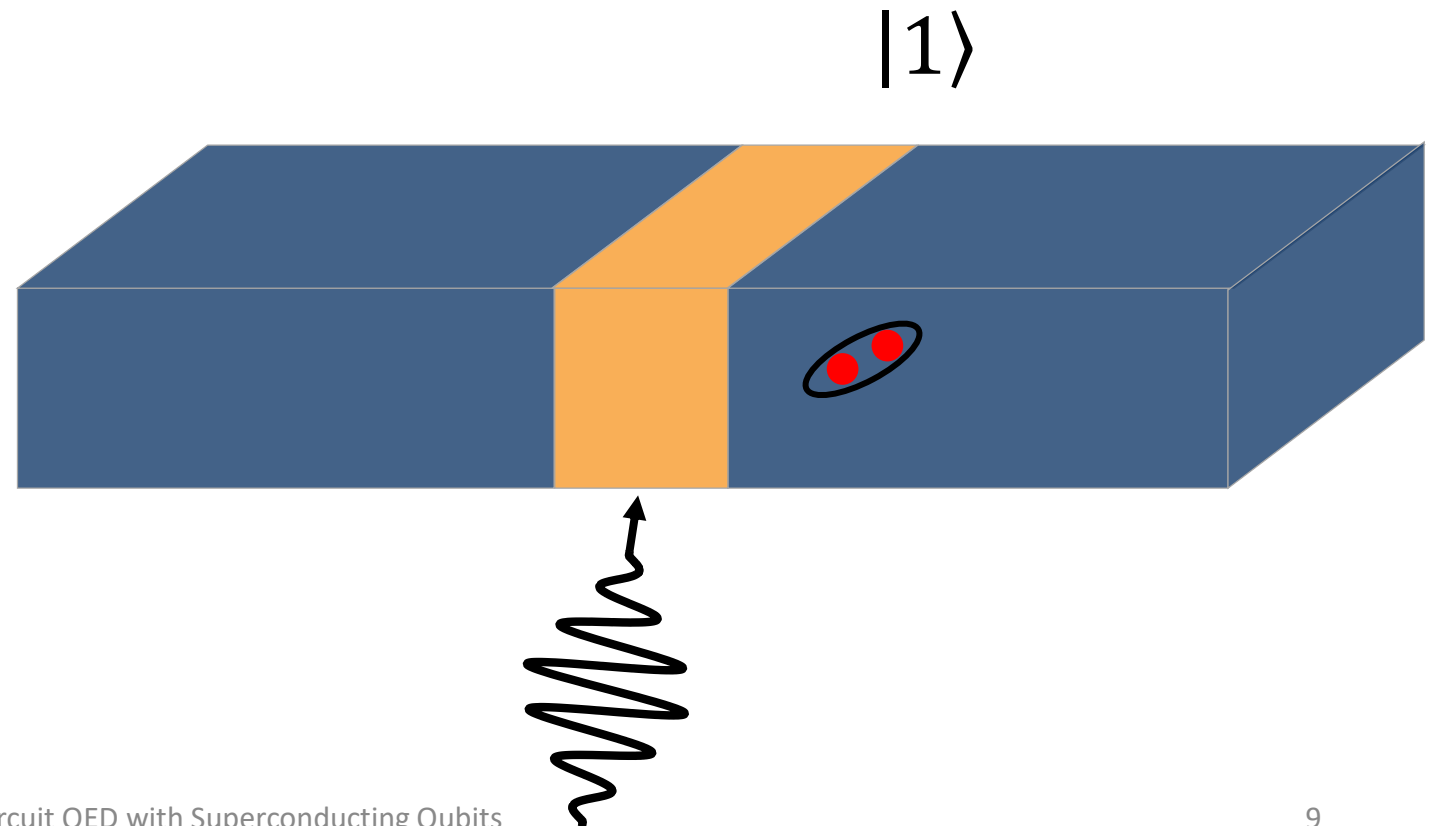
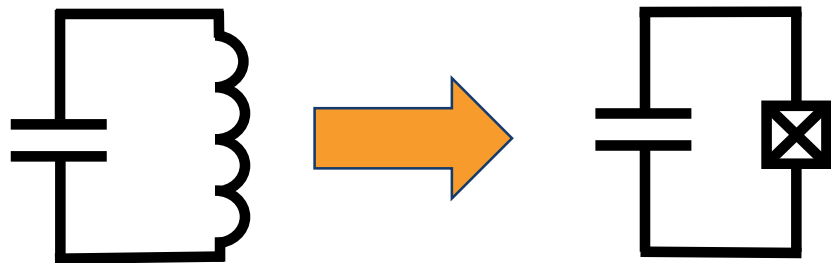
- Replacing the Inductor with a 'new' Element
- Qubit?



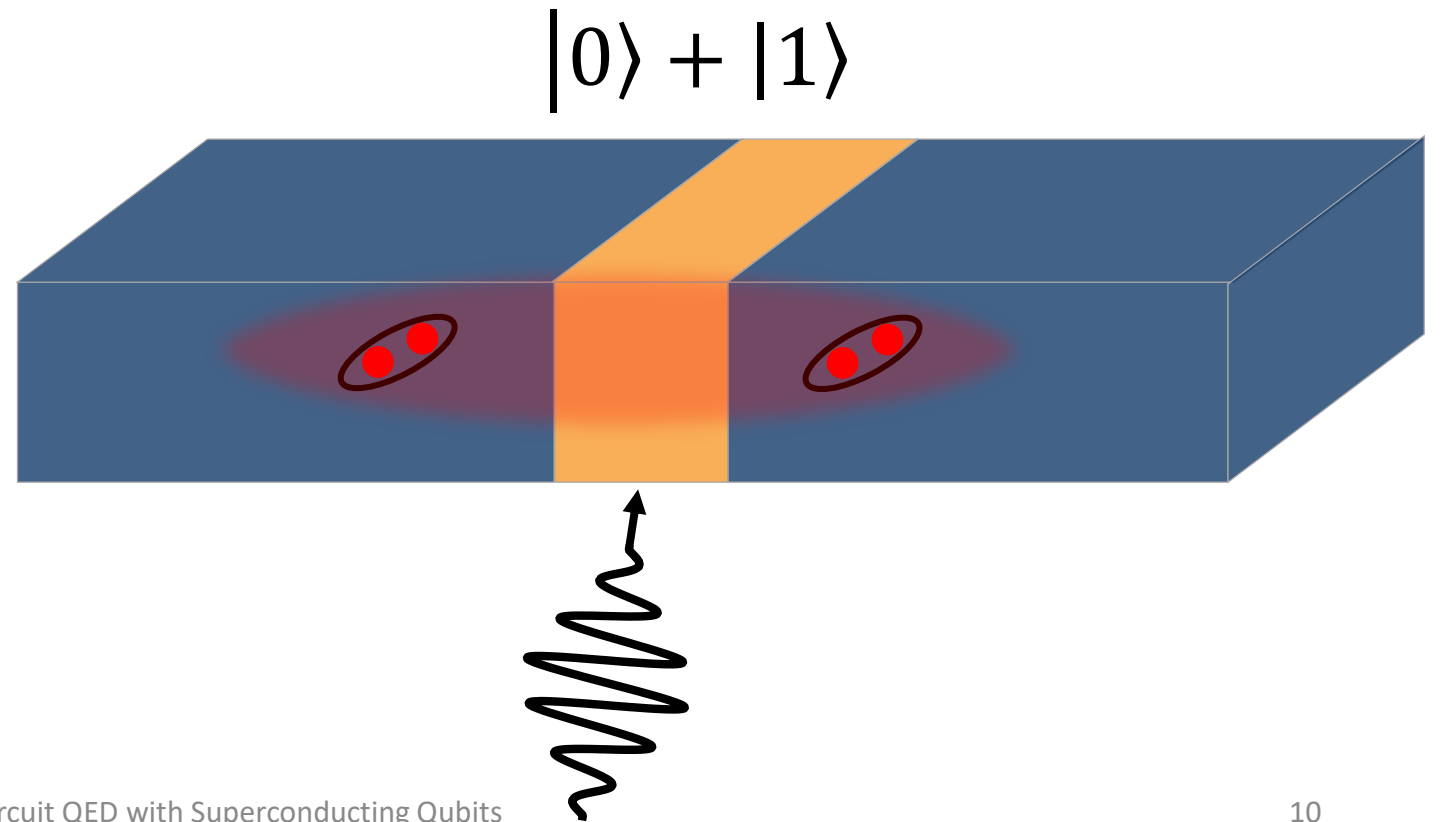
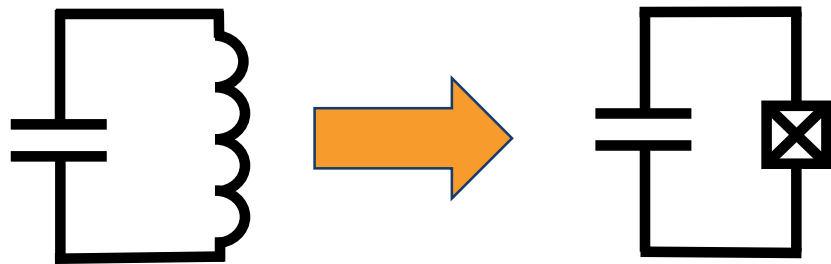
- Replacing the Inductor with a 'new' Element
- Qubit?



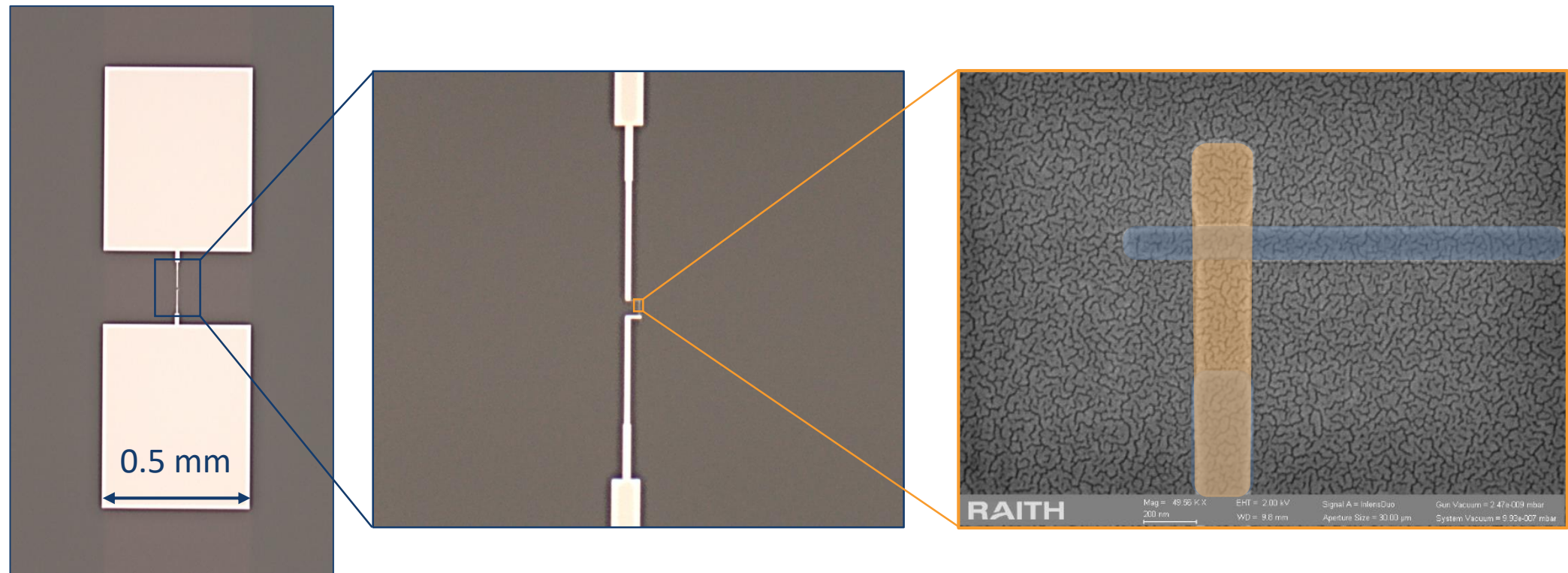
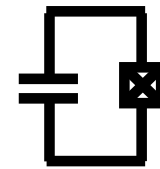
- Replacing the Inductor with a 'new' Element
- Qubit?



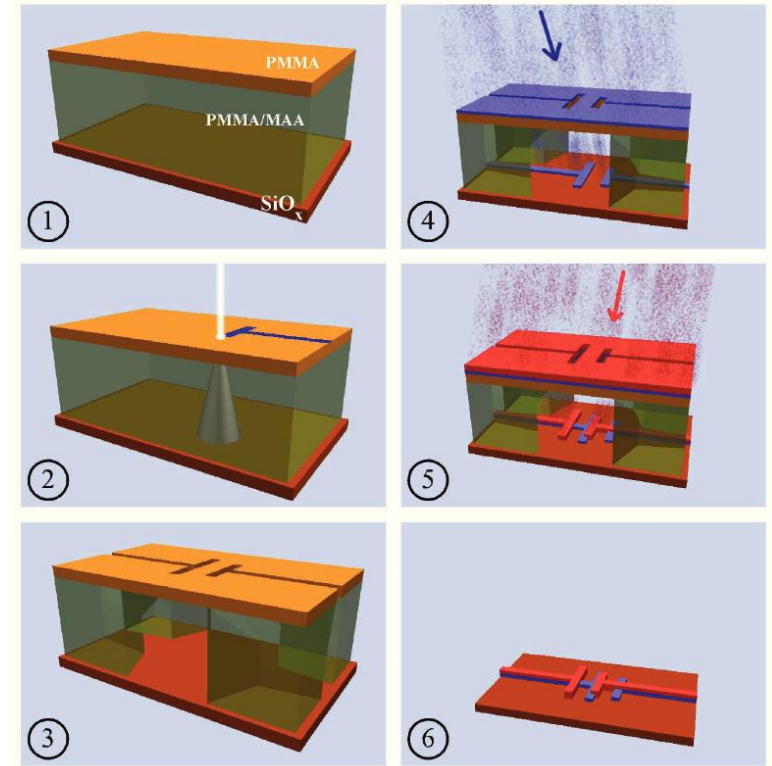
- Replacing the Inductor with a 'new' Element
- Qubit?



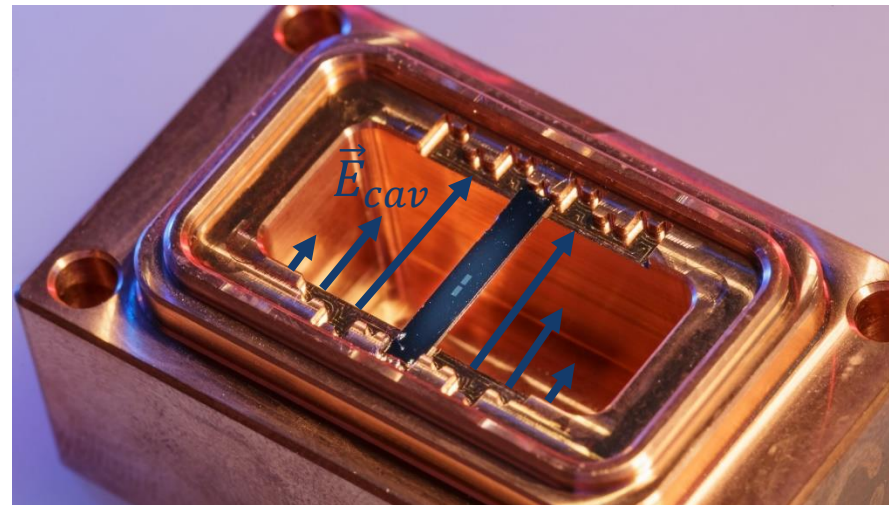
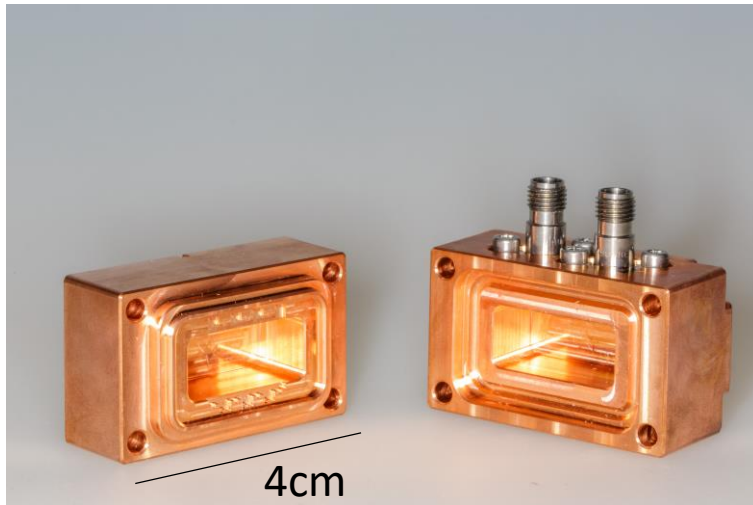
Macroscopic Atom: The Transmon Qubit



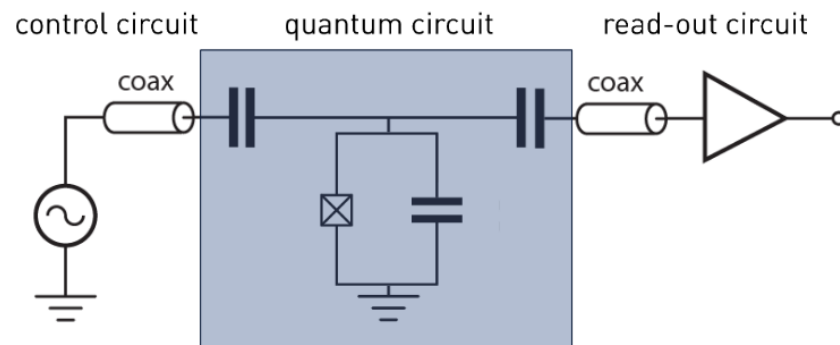
Fabrication of a Qubit



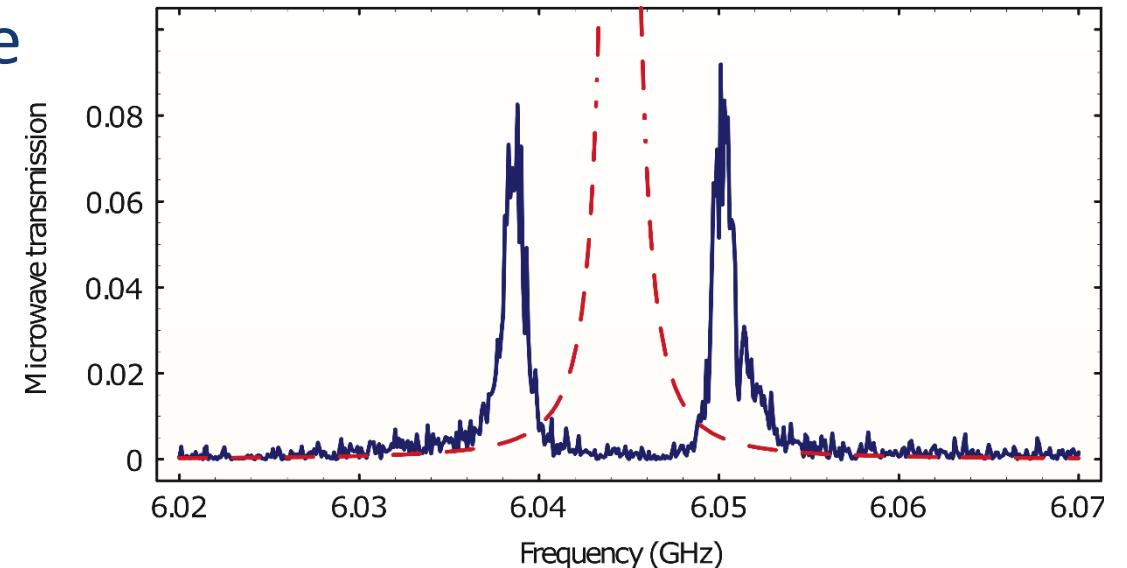
- Qubit looks like Antenna
- Need: Box to protect the Qubit



- Isolation from Environment: $f_{Qubit} \ll f_{Box}$
- Dispersive Readout
- Excitation with High Amplitude Pulse

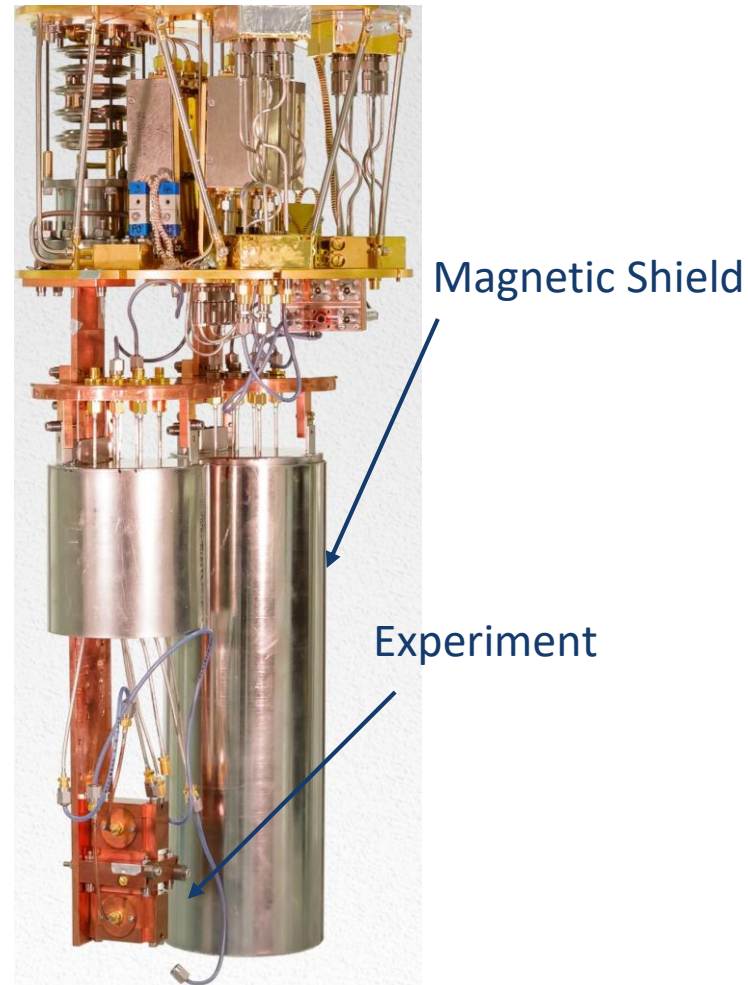
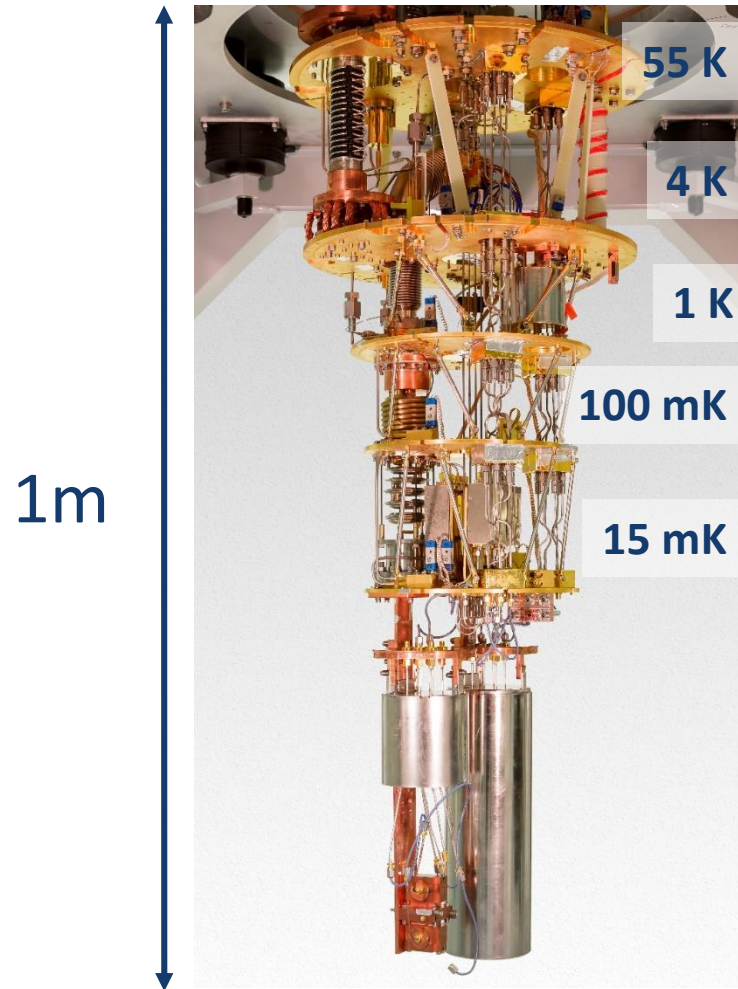


<https://arxiv.org/pdf/cond-mat/0411174.pdf>

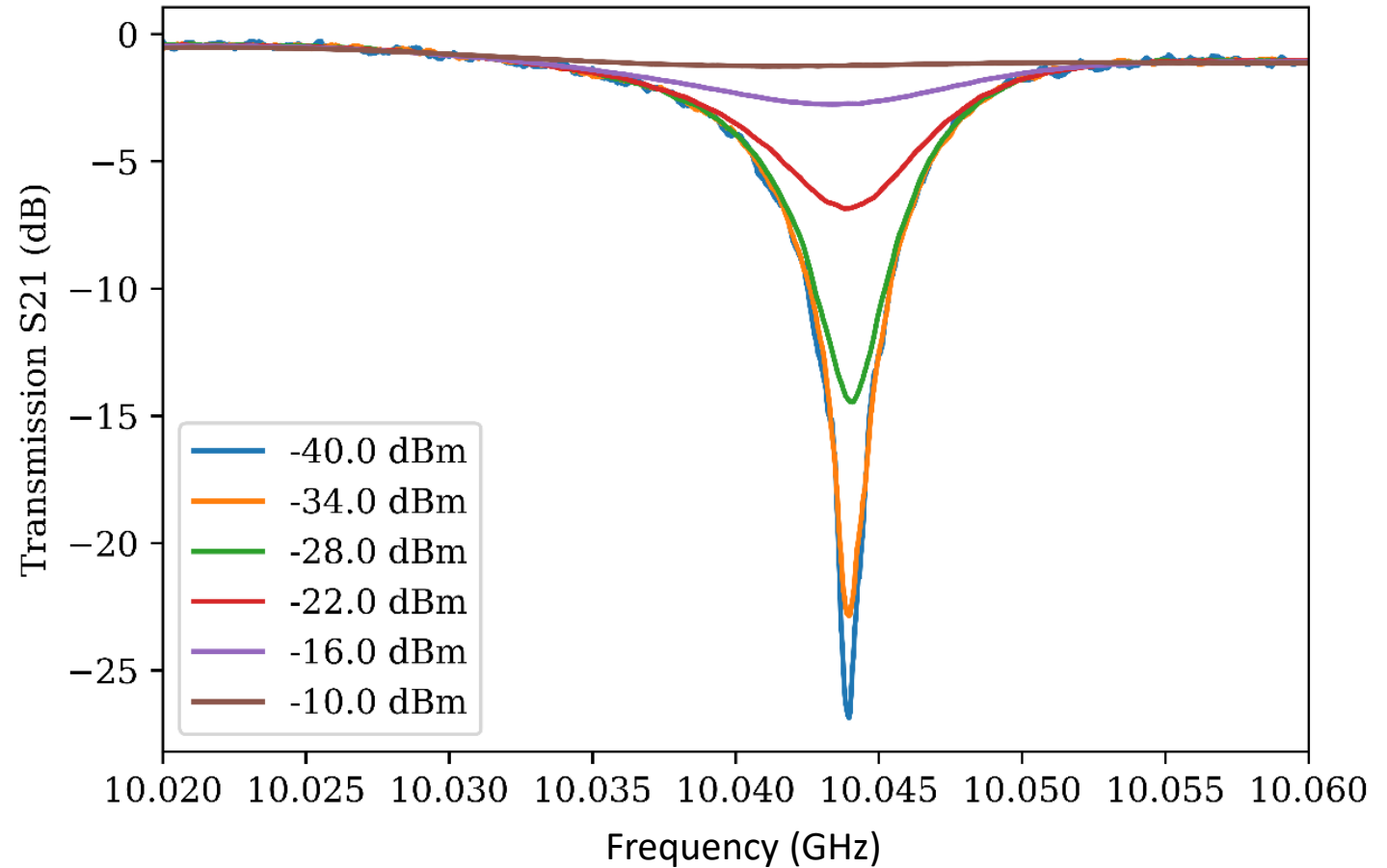
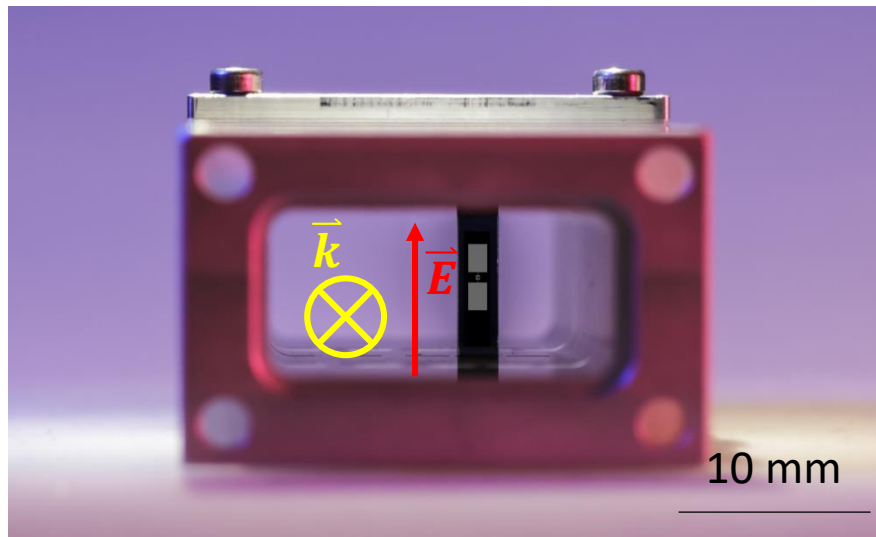


Nature **451**, 664 (2008)

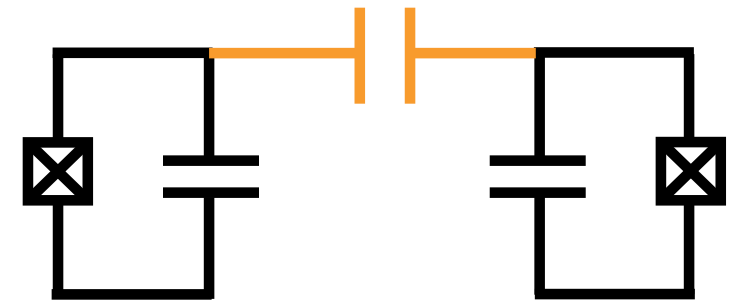
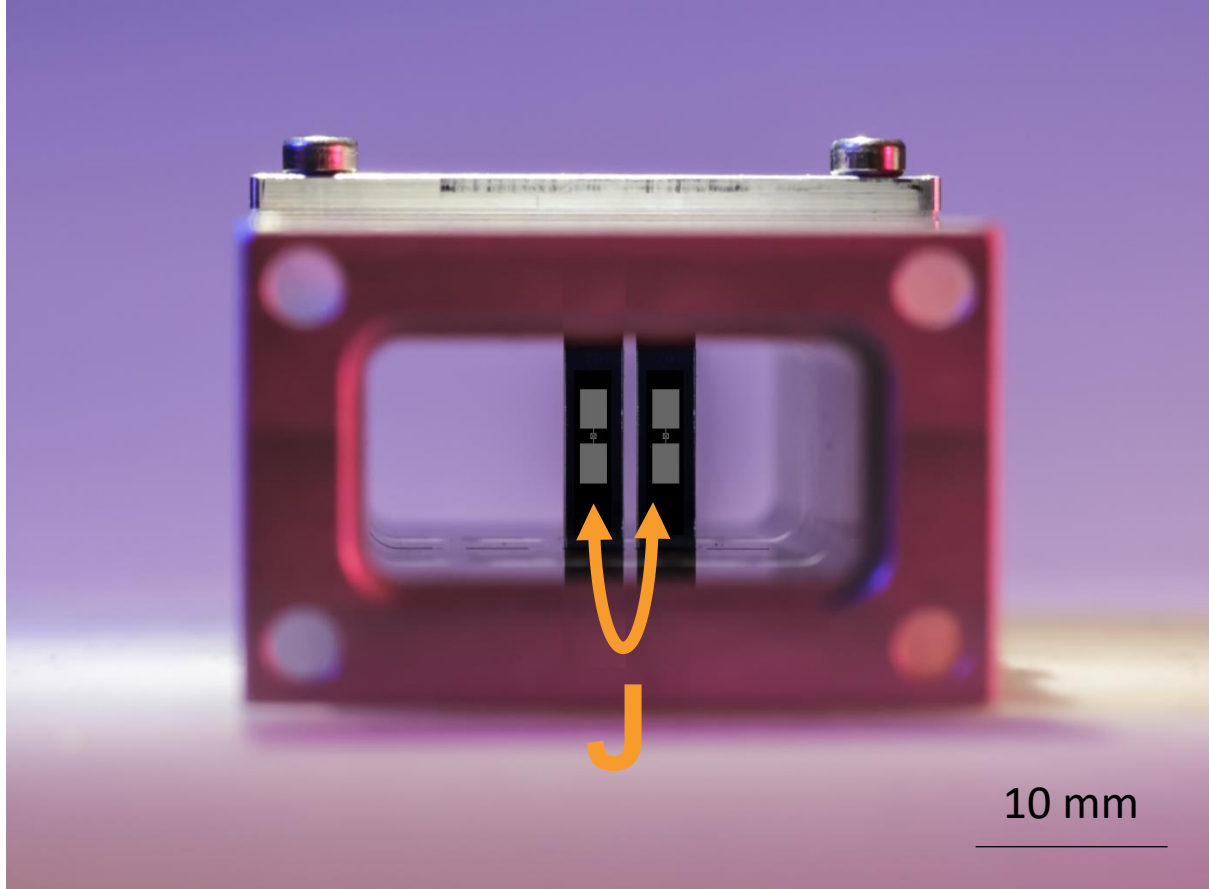
The Cryostat



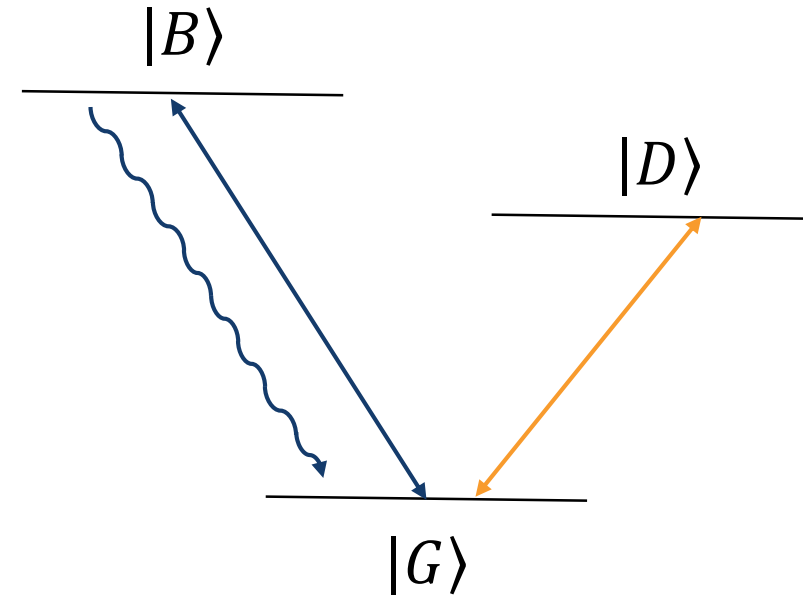
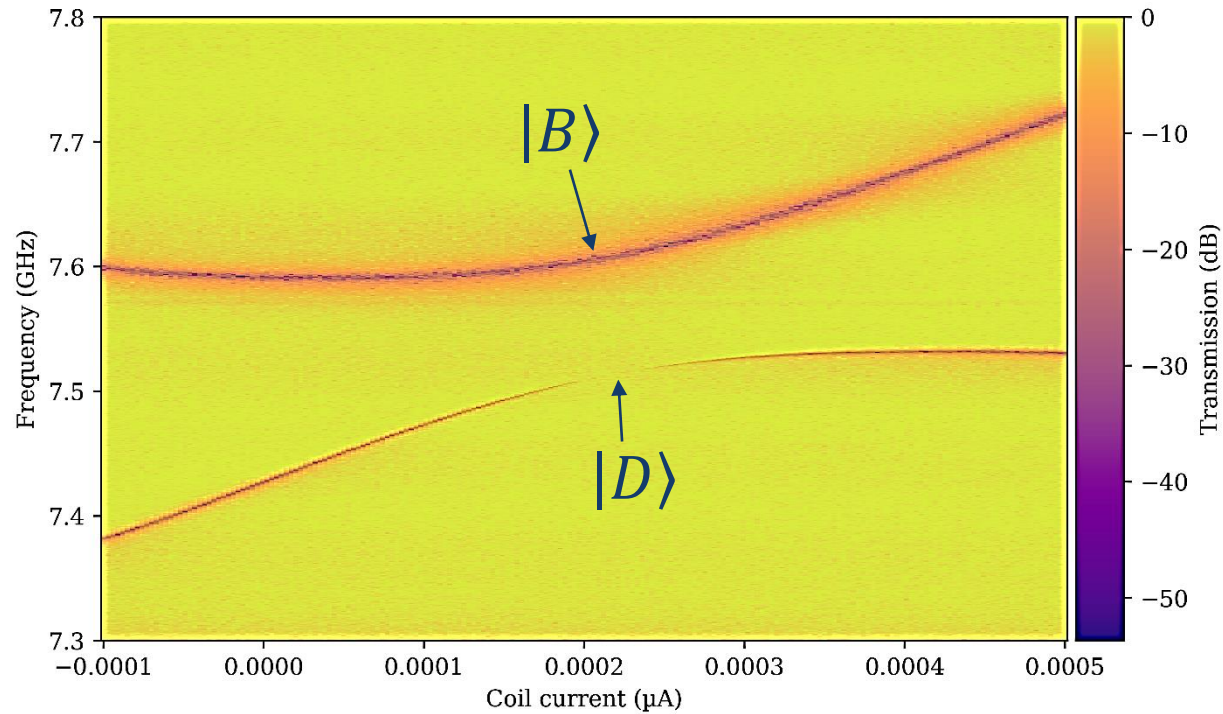
Single Qubit – Saturable Mirror



Direct Coupling



Dark State Qubit



Superconducting Circuits Group

