SQUAT Design

Drew Gibson, Alain Fauquex

10/29/2025

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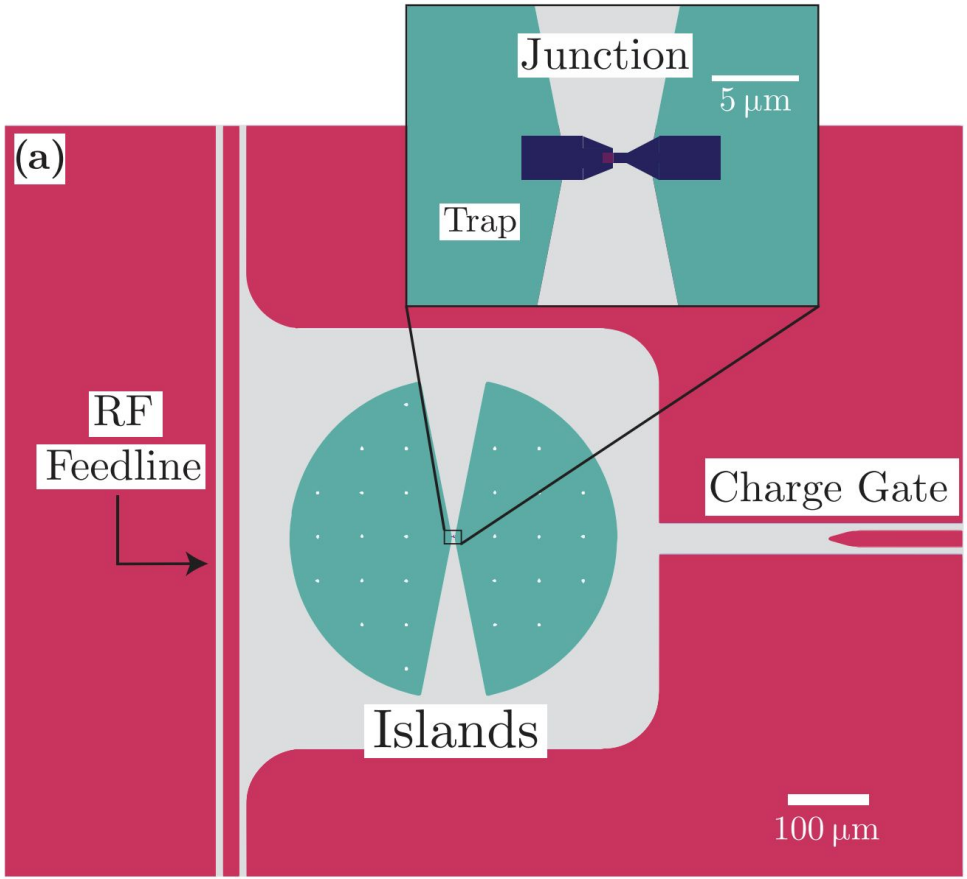
SQUAT



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Theory

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Hamiltonian of a Cooper-Pair-Box

$$\hat{H}_{\mathrm{CPB}} = 4E_C\left(\hat{n} - n_g + \frac{P-1}{4}\right)^2 - E_J \cos\hat{\varphi}.$$

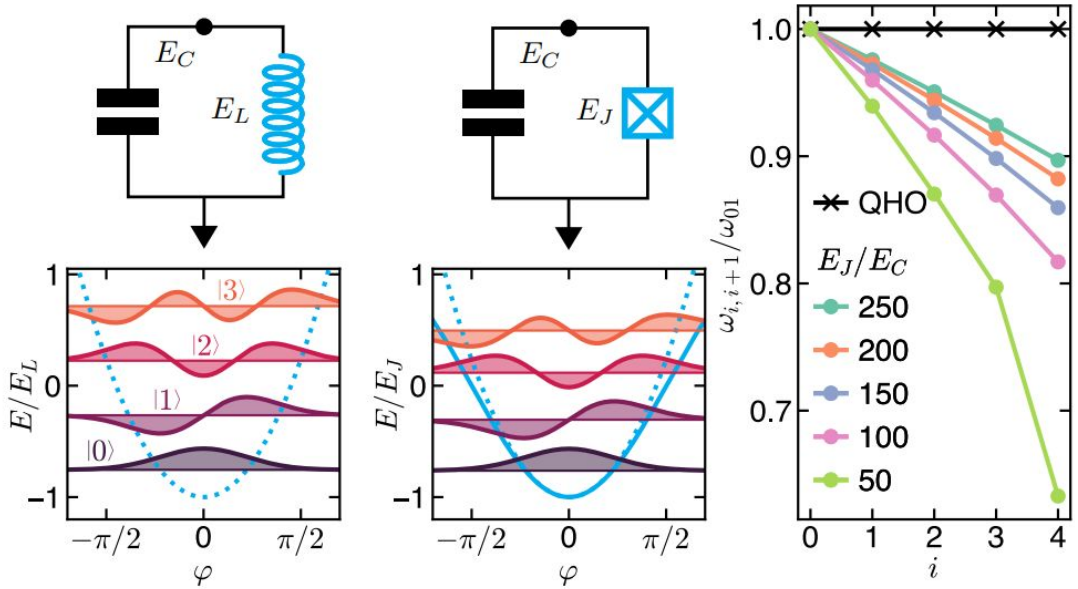
E_C = Single Electron Charging Energy
E_J = Josephson Coupling Energy

} "Tunable" Parameters

$\hat{n} - n_g + \frac{P-1}{4}$ } Charge Environment

E_J/E_C

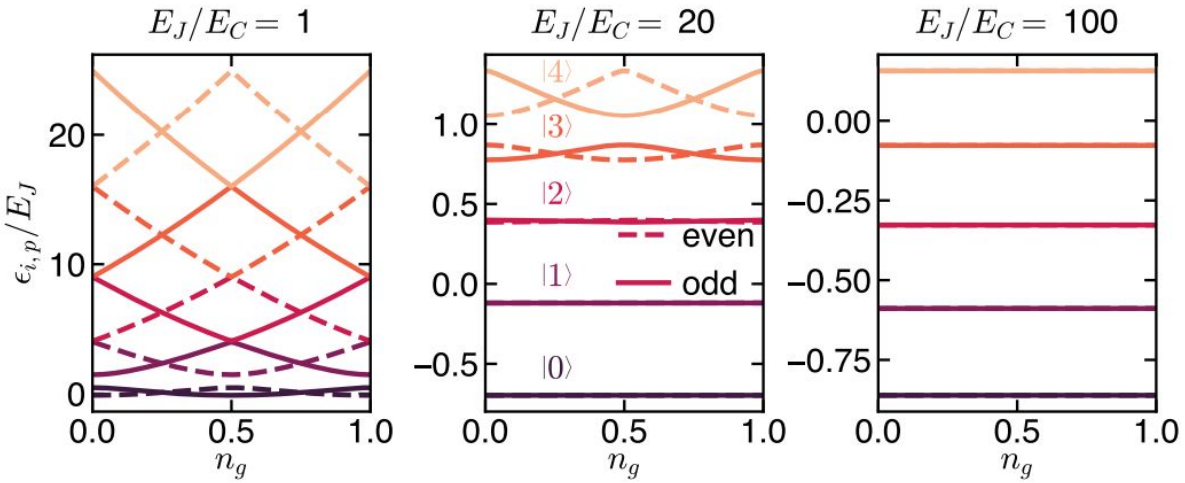
- The josephson junction has a nonlinear inductance.
- When E_J/E_C ≈ 1 the charge offset has a large effect on the energy eigenvalues.



Serniak (2019)

E_J/E_C

- We need to find a happy middle ground.
- Balancing the sensitivity with established energy eigenvalues.



Serniak (2019)

Simulating Ec

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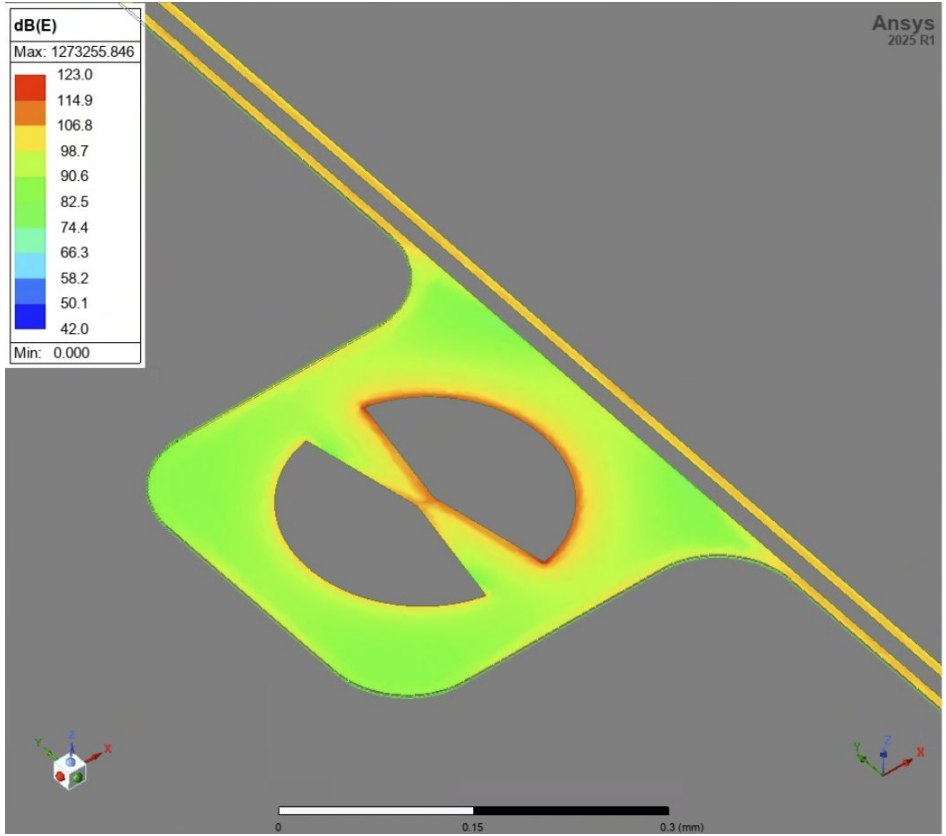
Simulating E_C

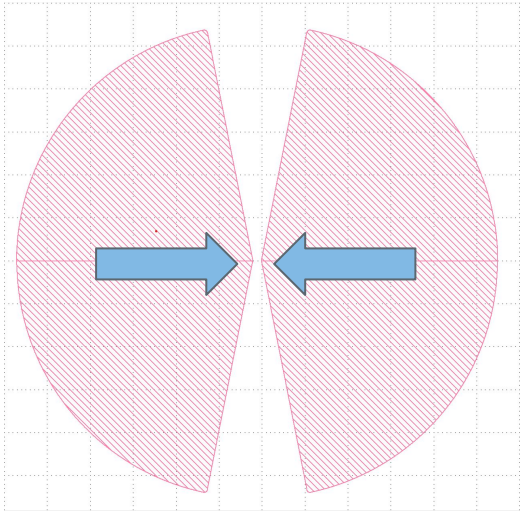
$$E_C = \frac{e^2}{2C_\Sigma}$$

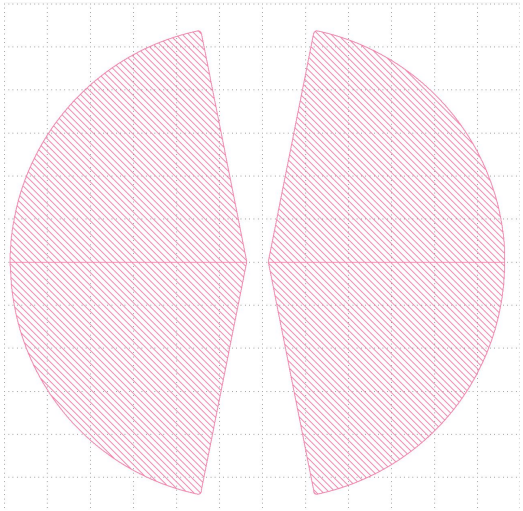
- Maxwell simulations can provide capacitances.
- Currently running verifications
- Switching to Sonnet

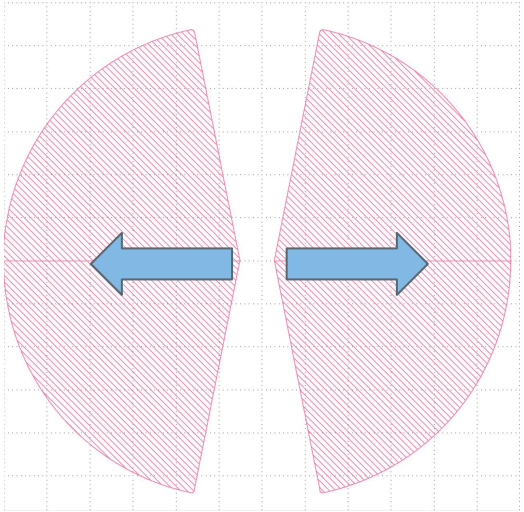


Future Work with E_C

Slight imprecisions with optical lithography can cause variations in the actual capacitances of the islands.







Determining Ej and Simulating Eigenmodes of SQUATs

Alain Fauquex

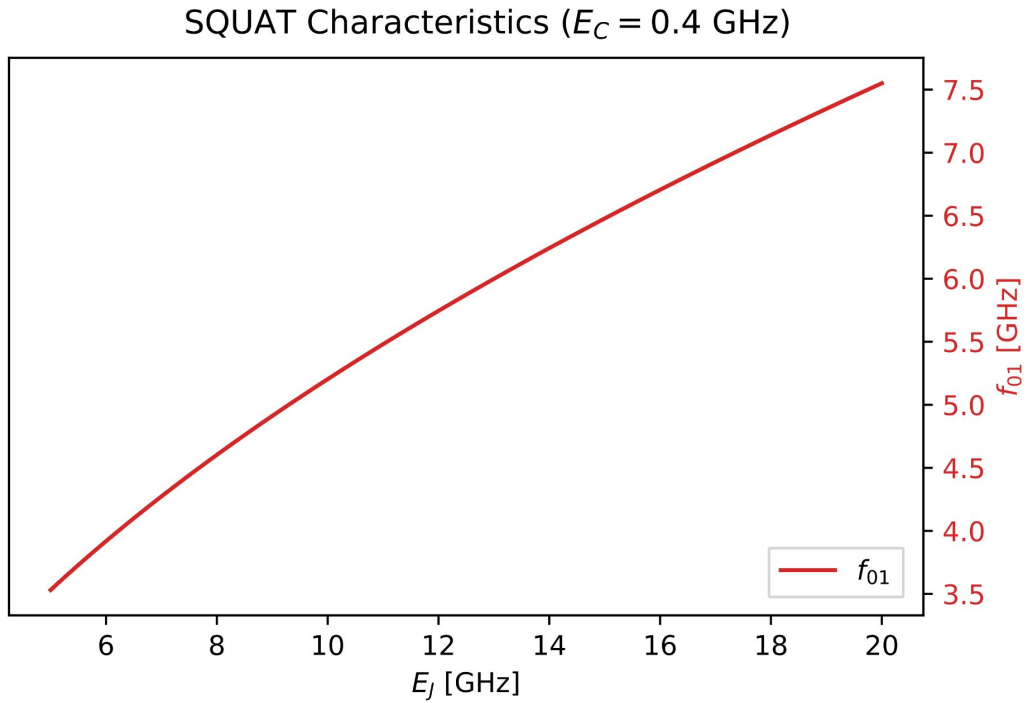
UC Berkeley

Determining a E_J of a SQUAT

Transition Frequency:

$$f_{01} \approx \frac{1}{h}\left(\sqrt{8E_C E_J} - E_C\right)$$

f_{01} : transition frequency,
E_J : Josephson energy,
E_C : charging energy



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Frequency dispersion:

$$\delta\epsilon_{01} \approx \chi_0 \cos(\pi n_g),$$
$$\text{where } \chi_0(E_J/E_C) := \chi_0$$

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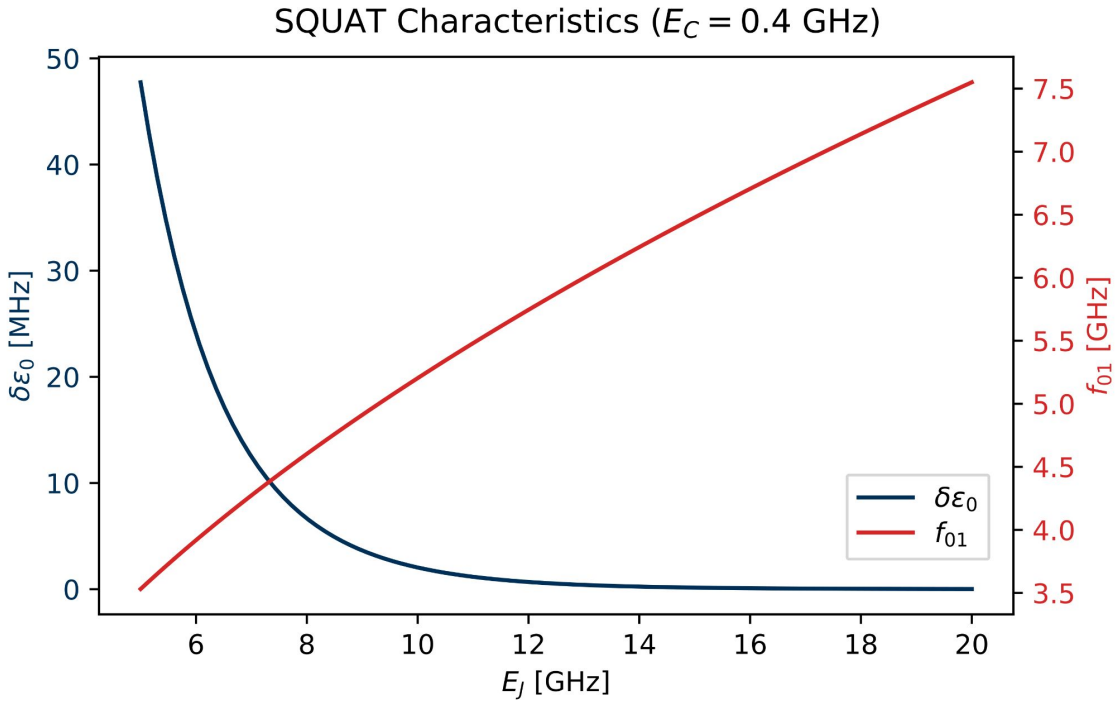

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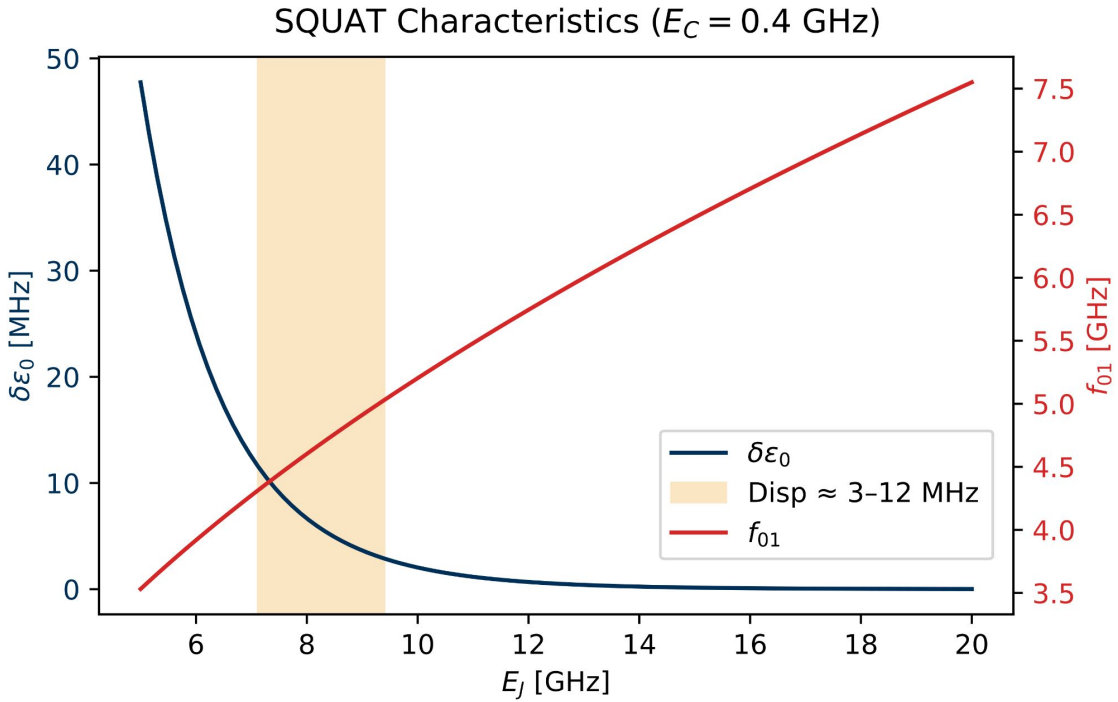

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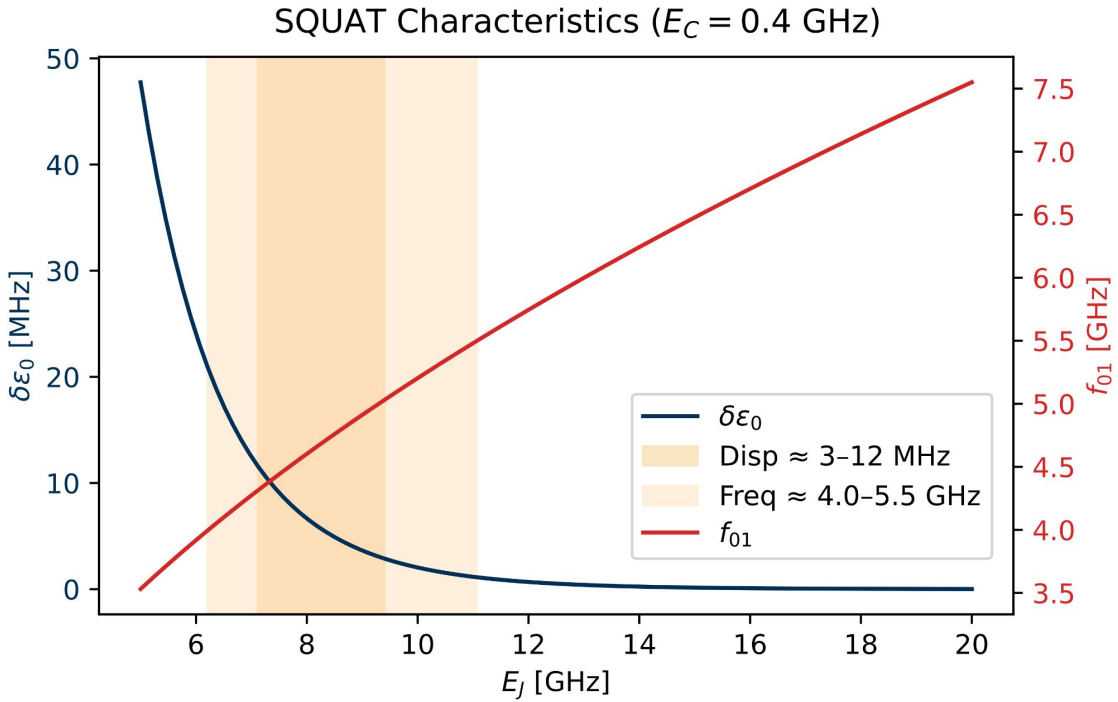

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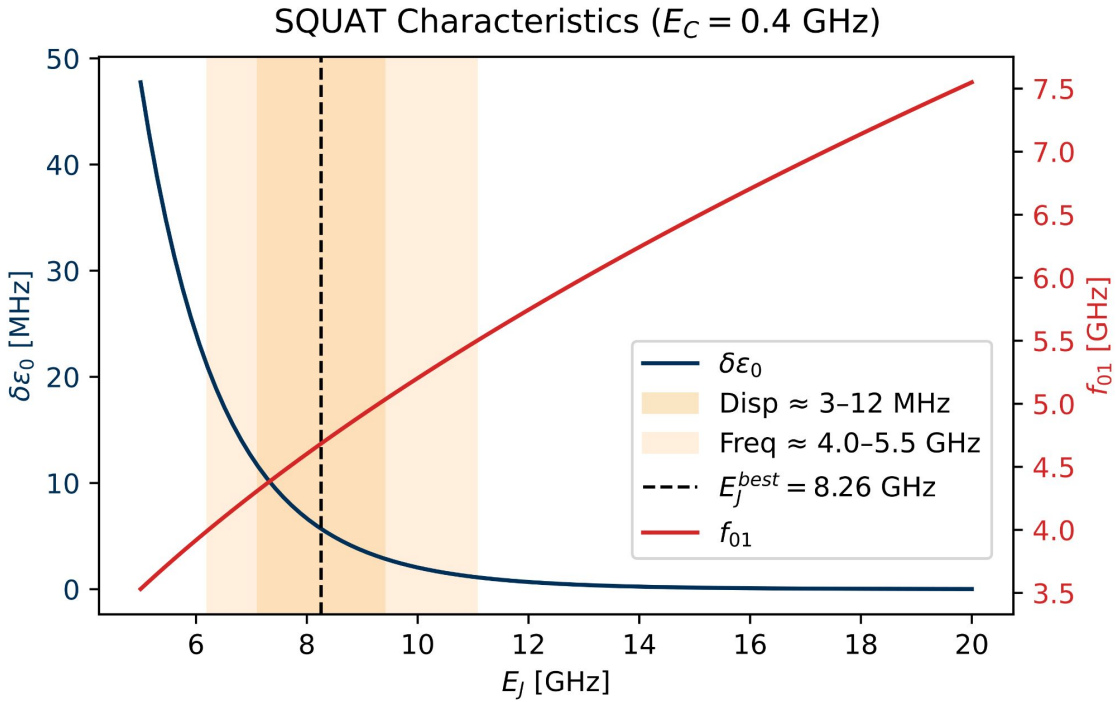

Simulating the Eigenmode of a SQUAT

Lumped element josephson inductance (Lj):

$$L_J = \frac{\hbar^2}{4e^2 E_J}$$

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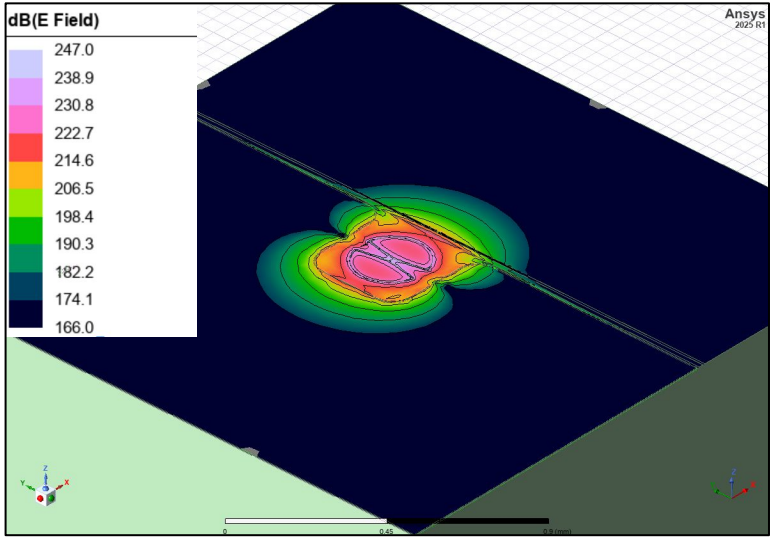
Spatial distribution of qubit resonant mode:



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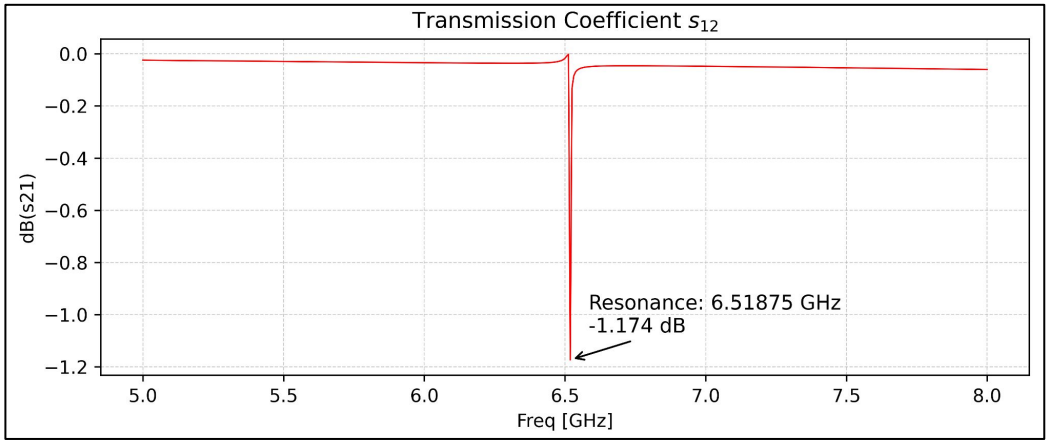
Transmission response from driven modal simulation:



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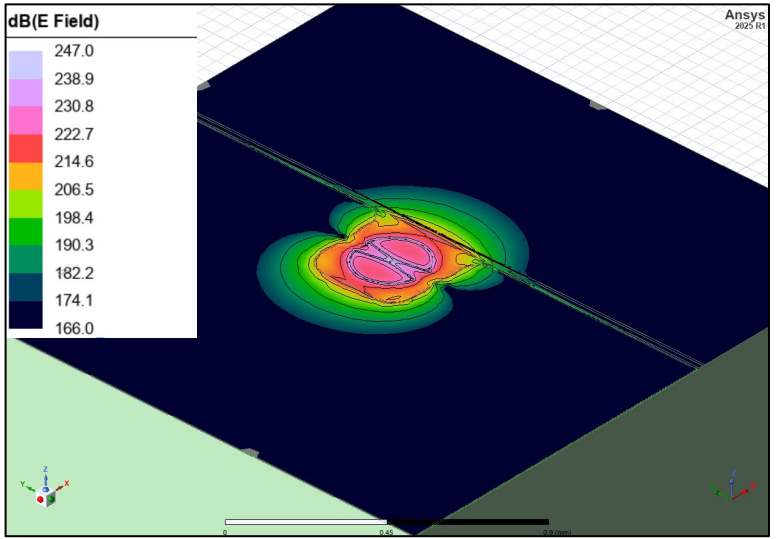


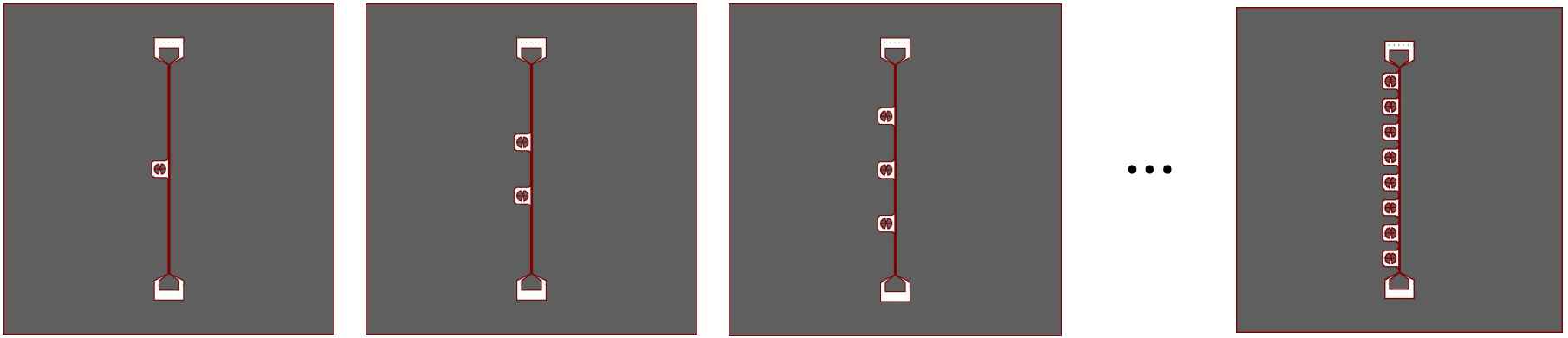
Future SQUAT Design Work

Alain Fauquex

UC Berkeley

Future Design Work at Berkeley

- “Densifying” the SQUATs (theory, simulation, experiment)



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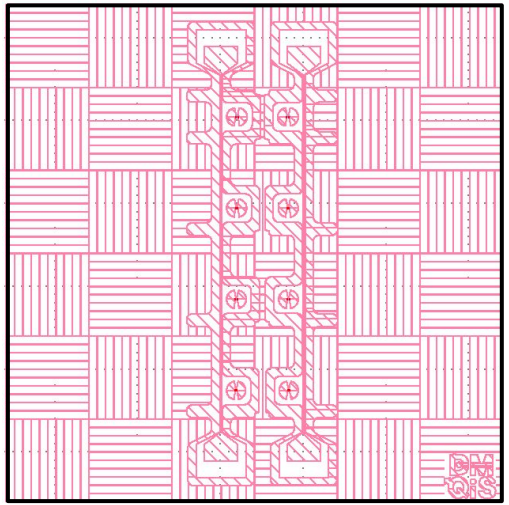
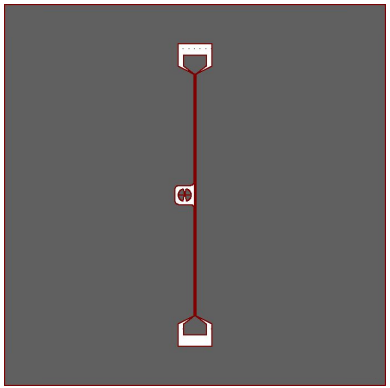
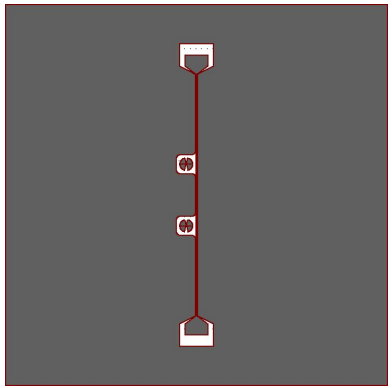
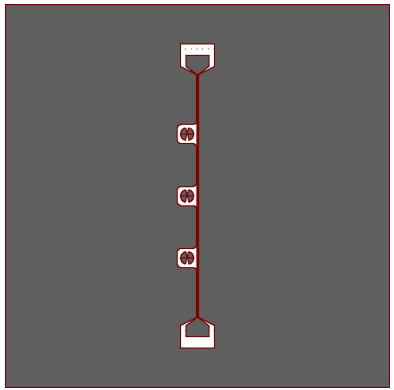
Future Design Work at Berkeley

- “Densifying” the SQUATs (theory, simulation, experiment)
- Less ground plane









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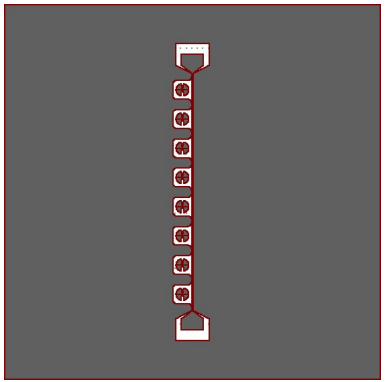
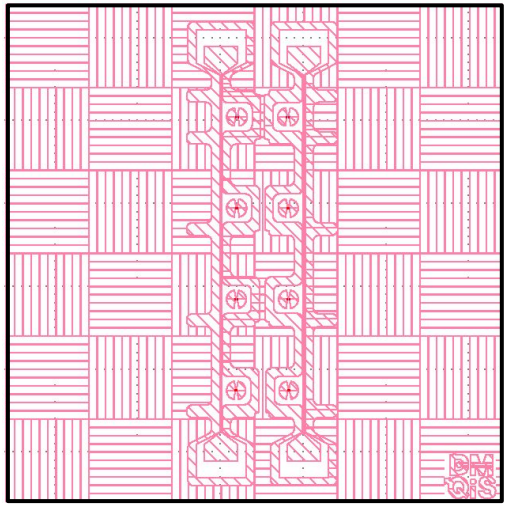
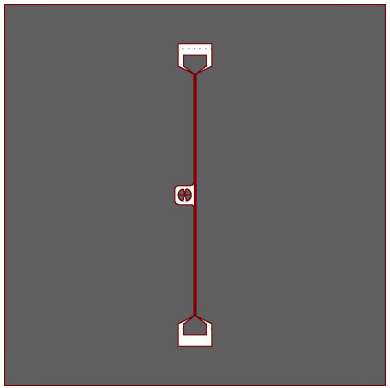
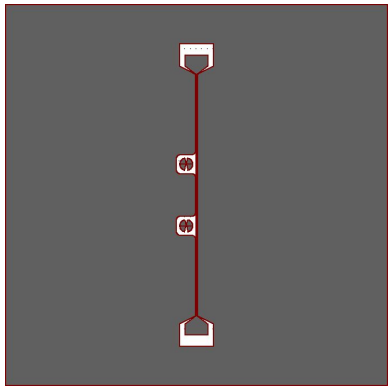


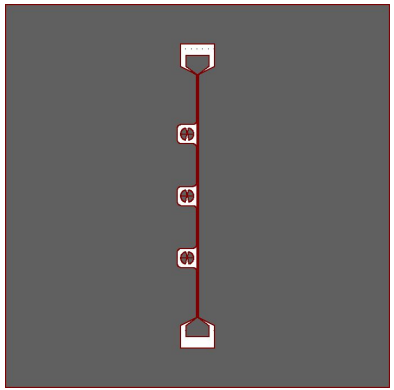
Future Design Work at Berkeley

- “Densifying” the SQUATs (theory, simulation, experiment)
- Less ground plane
- New materials (circuit elements & substrate)









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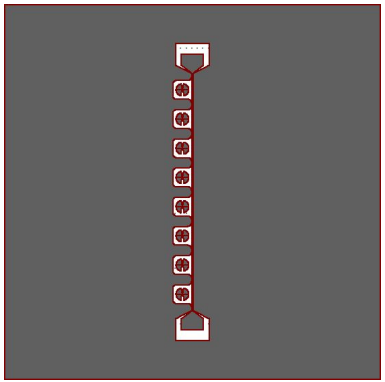

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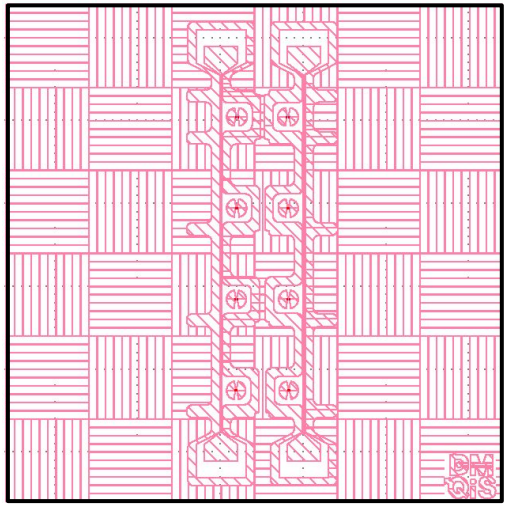
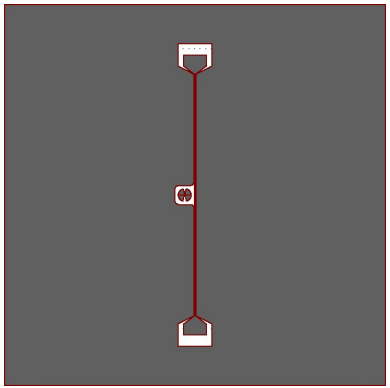
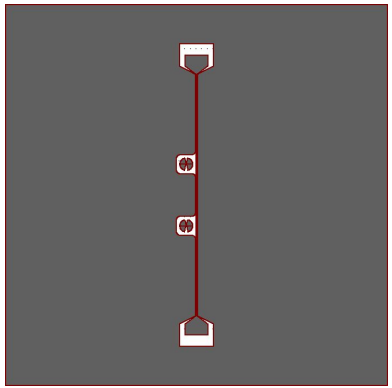
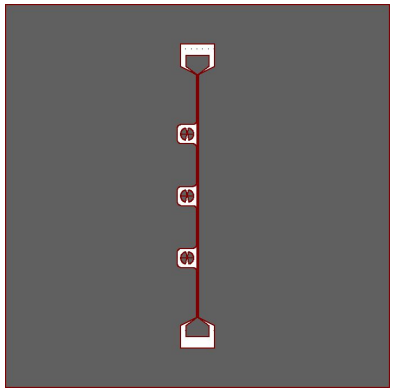
Future Design Work at Berkeley

- “Densifying” the SQUATs (theory, simulation, experiment)
- Less ground plane
- New materials (circuit elements & substrate)
- Fast-cycle design test fridge









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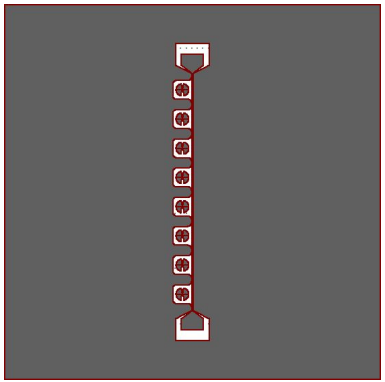

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