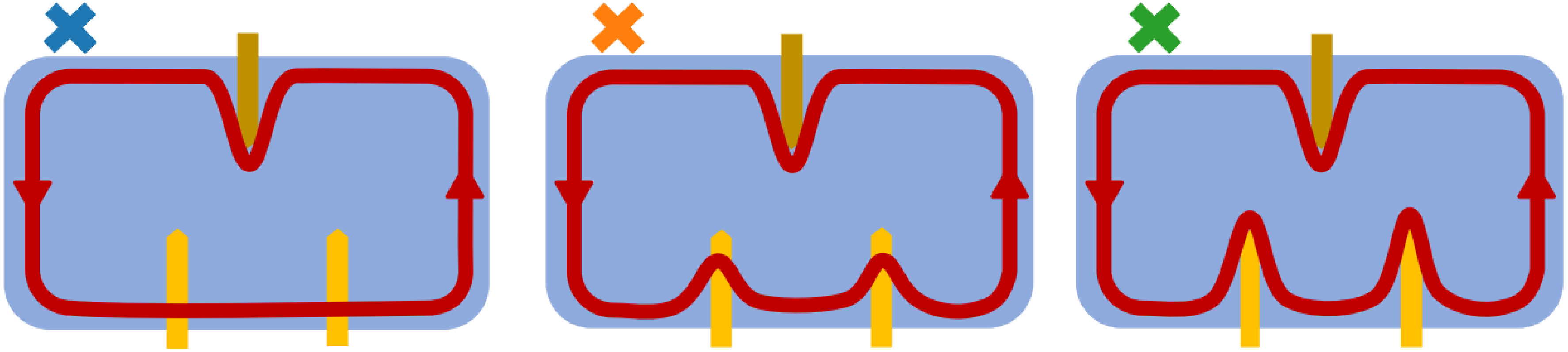
Gate tunable edge magnetoplasmon resonators

Elric Frigerio [1], Giacomo Rebora [2], Mélanie Ruelle [1], Hubert Souquet-Basiège [2], Yong Jin [3], Ulf Gennser [3], Antonella Cavanna [3], Bernard Plaçais [1], Emmanuel Baudin [1], Jean-Marc Berroir [1], Inès Safi [4], Pascal Degiovanni [2], Gwendal Fève [1] & Gerbold C. Ménard [1]

1 Laboratoire de Physique de l'École Normale Supérieure, ENS, Université PSL, CNRS, Sorbonne Université, Université Paris Cité, Paris, France.
2 Univ Lyon, ENS de Lyon, Université Claude Bernard Lyon 1, CNRS, Laboratoire de Physique, Lyon, France.
3 Centre de Nanosciences et de Nanotechnologies (C2N), CNRS, Université Paris-Saclay, Palaiseau, France.
4 Laboratoire de Physique des Solides-CNRS-UMR5802. University Paris-Saclay, Orsay, France



In today's talk

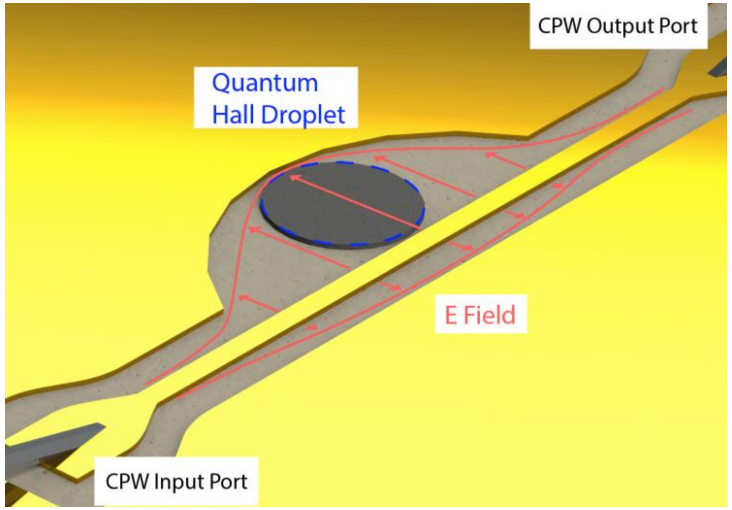
- What and why
- Previous literature
- Overview – device and experiments
- Theoretical model
- Experiment 1 - Discrete control
- Experiment 2 – Continuous control
- Takeaways
- How's going with the gyrator

What and why

- Edge states are described as free collective bosonic modes called edge magnetoplasmons (EMP) that propagate along the edge with given velocity)
- When two opposite edge states pass thru a QPC, you get a quasi electron (integer ν) or a non abelian anyon (ν=1/3,2/5,5/2).
- "One proposal to evidence these non-abelian properties is to study the absorption of microwave radiation by EMPs in an isolated Hall island[22]."

Previous literature

A classic problem in mathematical physics asks “can you hear the shape of a drum?” In this paper, we address the natural generalization: “can you hear an anyon in a drum?”

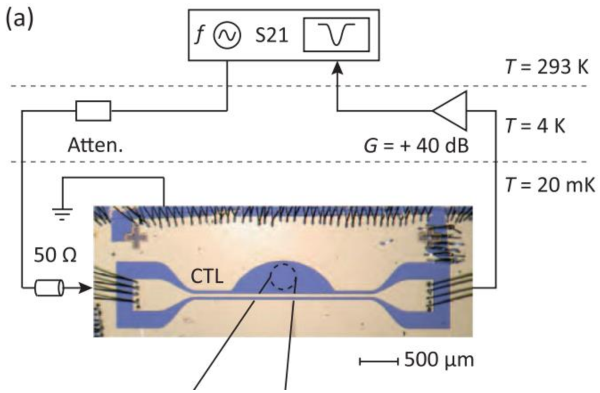


Microwave Absorption by a Mesoscopic Quantum Hall Droplet

Jennifer Cano,[1] Andrew C. Doherty,[2] Chetan Nayak,[3,1] and David J. Reilly[2]

[1]Department of Physics, University of California, Santa Barbara, CA 93106
[2]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney, Sydney, NSW 2006, Australia
[3]Station Q, Microsoft Research, Santa Barbara, CA 93106-6105

Phys. Rev. B **88**, 165305 – Published 14 October 2013



On-Chip Microwave Quantum Hall Circulator

A. C. Mahoney,[1,2] J. I. Colless,[1,2,*] S. J. Pauka,[1,2] J. M. Hornibrook,[1,2] J. D. Watson,[3,4] G. C. Gardner,[4,5] M. J. Manfra,[3,4,5] A. C. Doherty,[1] and D. J. Reilly[1,2,†]

[1]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney, Sydney, New South Wales 2006, Australia
[2]Station Q Sydney, The University of Sydney, Sydney, New South Wales 2006, Australia
[3]Department of Physics and Astronomy, Purdue University, West Lafayette, Indiana 47907, USA
[4]Birck Nanotechnology Center, School of Materials Engineering and School of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana 47907, USA
[5]Station Q Purdue, Purdue University, West Lafayette, Indiana 47907, USA

Phys. Rev. X **7**, 011007 – Published 24 January 2017

Overview - The device

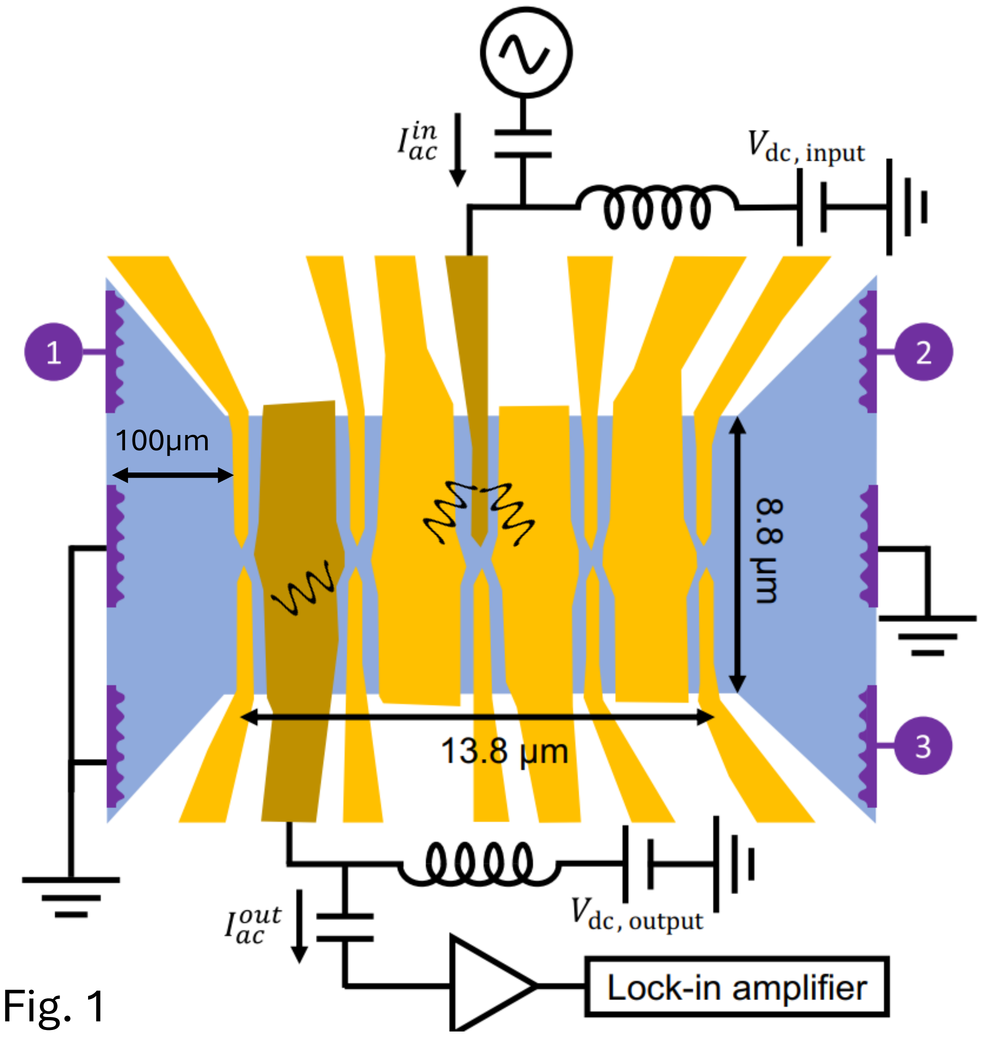
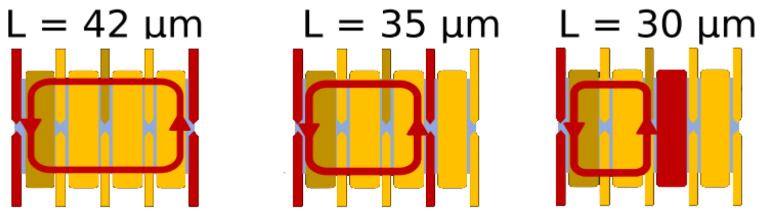


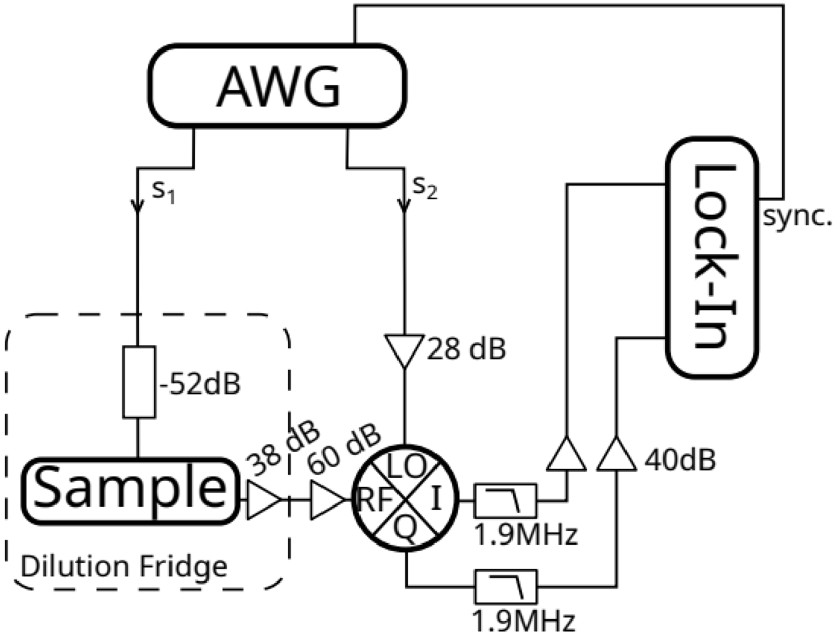
Fig. 1

- Many QPCs to control the size of the droplet
- Top gates to change density
- Far away ohmics (not used)
- QPC gate for injection, top gate for reception.

Overview - The experiments

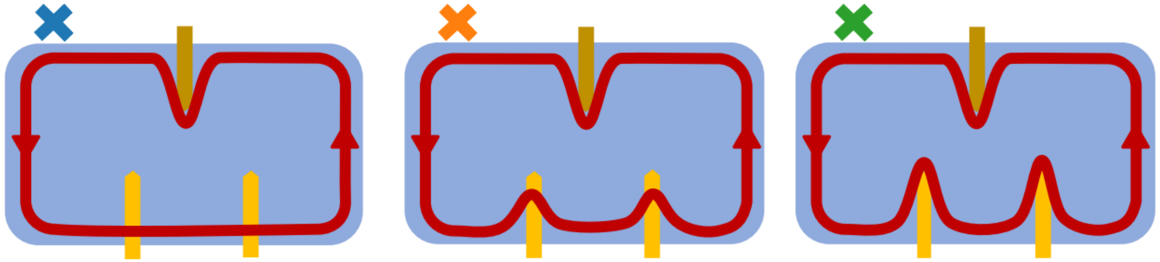
Discrete control of cavity (Fig. 2)

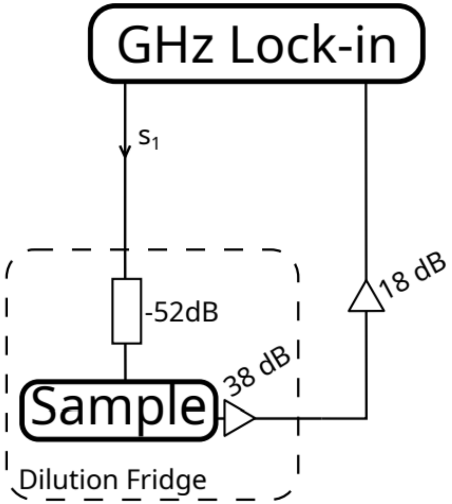




From supplementary S3

Continuous control of cavity (Fig. 4)





From supplementary S4

Theory - Estimating the EMP velocity

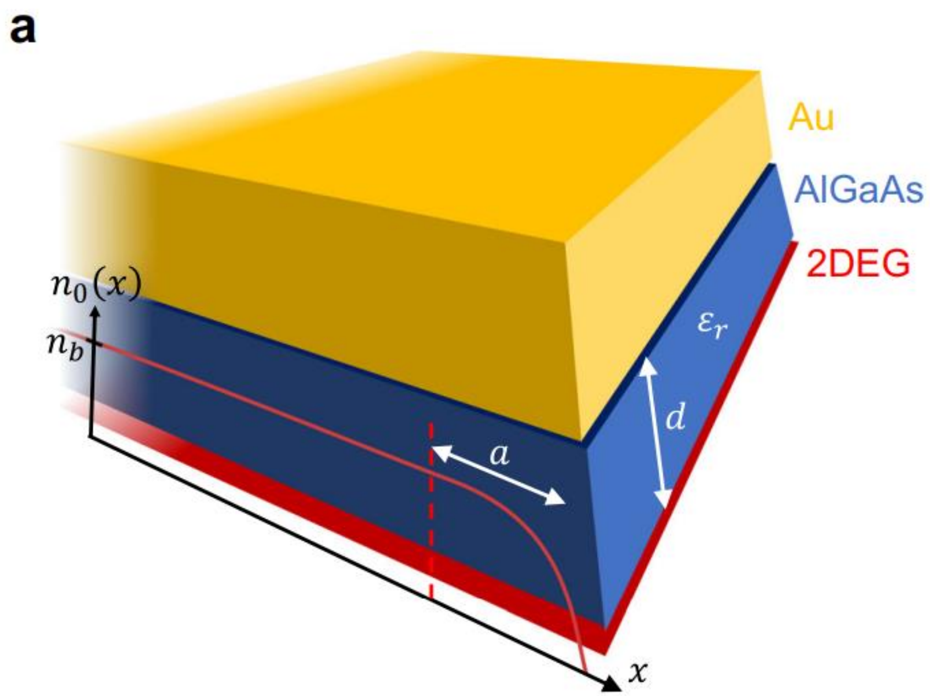


Fig.3

The trasmission over a cavity of lenght l is of the form exp(i k(ω) l)
Where:

$$k(\omega) = \frac{\omega}{v} + i\left(\frac{r^2}{4\omega_c \tau a} + \frac{\xi \omega^2}{v^2}\right)$$

Dissipation!

$$v = \frac{\gamma \omega_c a}{1 + \gamma(r^2/4) + (1/\omega_c^2 \tau^2)}$$

$$l_0 = e^2 n_b / \varepsilon m \omega_c^2$$

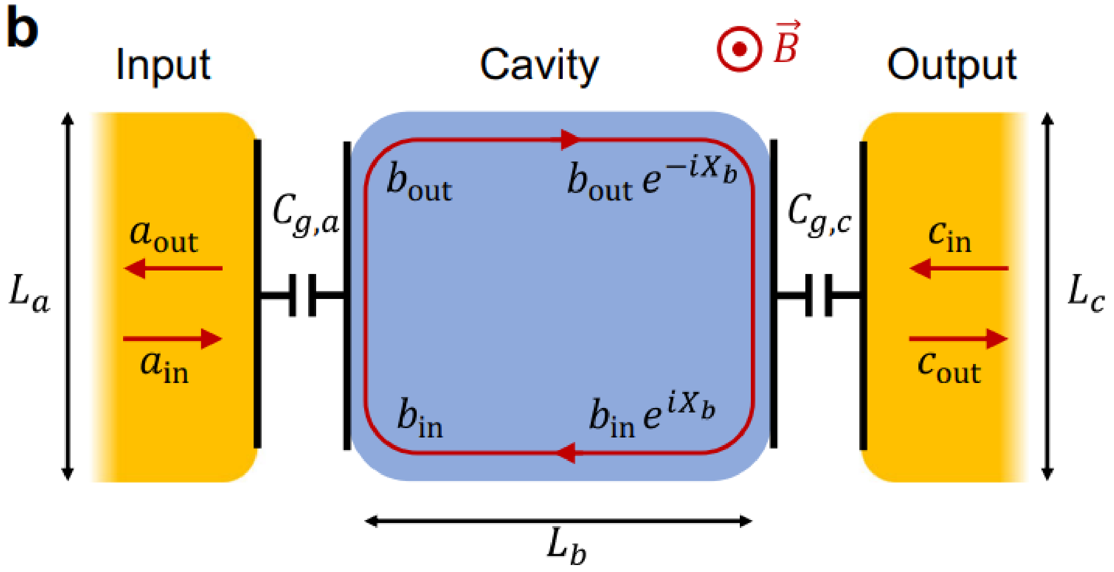
$$\gamma = l_0 d / a^2$$

a (fit)	2.8 µm
nb (n 2deg?)	1.9e-11 cm-2
d	105 nm
L0 @ 1T	1.1 µm

The extracted v is 1e5 m/s @ 1T and 2.1e4 m/s @5T

The model comes from M. D. Johnson and G. Vignale - Phys. Rev. B 67, 205332 (2003)

The scattering matrix



$$\begin{pmatrix} c_{out} \\ a_{out} \end{pmatrix} = \begin{pmatrix} S_{cc} & S_{ca} \\ S_{ac} & S_{aa} \end{pmatrix} \begin{pmatrix} c_{in} \\ a_{in} \end{pmatrix}$$

$$S_{ca} = \frac{t'_a t_c\, e^{iX_b}}{1 - r'_a r'_c\, e^{2iX_b}} . \qquad X_b = k(\omega) L_b$$

Things I didn't like about the paper

- There is no dc hall conductance plot
- There is no picture of the device, so no information regarding the part of RF, ground planes, CPW and so on
- The 2d plots have very low resolution

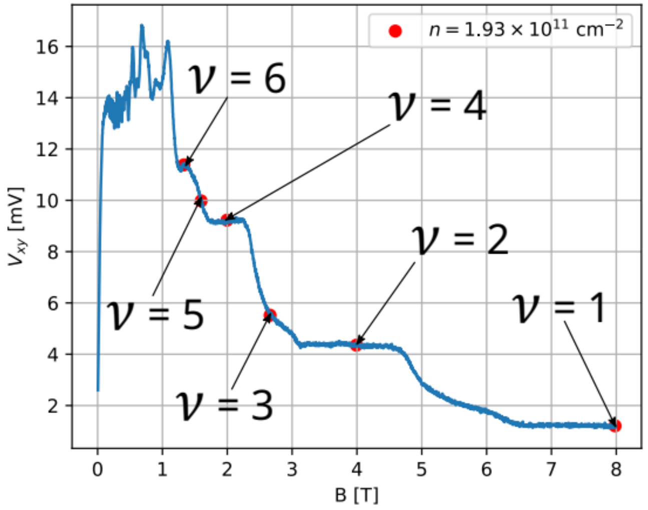


FIG. S2. 'Low frequency' measurement performed at 1.13kHz through Ohmic contacts. The data (blue lines) correspond to the transverse voltage drop of the 2DEG. The sample was measured in derivation with a 22 Ω resistor. The voltage is applied at contact 2, and the measurement is done at contact 1 (see figure 1 of the main text). The red dots represent the position of the Hall plateaus associated to an electronic density $n = 1.93 \times 10^{11} \mathrm{cm}^{-2}$.

Normalization – Taking the baby and the bathwater

- No cryogenic calibarion and varying gain/noise on frequency
- The features are "small" and depend on B, everything else no.

$$\overline{s_{\mathrm{raw}}}(f) = \langle s_{\mathrm{raw}}(f, B) \rangle_B$$

$$\sigma_{s_{\mathrm{raw}}}(f) = \sqrt{\langle | s_{\mathrm{raw}}(f, B) - \overline{s_{\mathrm{raw}}}(f) |^2 \rangle_B}$$

$$s(f, B) = \frac{s_{\mathrm{raw}}(f, B) - \overline{s_{\mathrm{raw}}}(f)}{\sigma_{s_{\mathrm{raw}}}(f)}$$

After

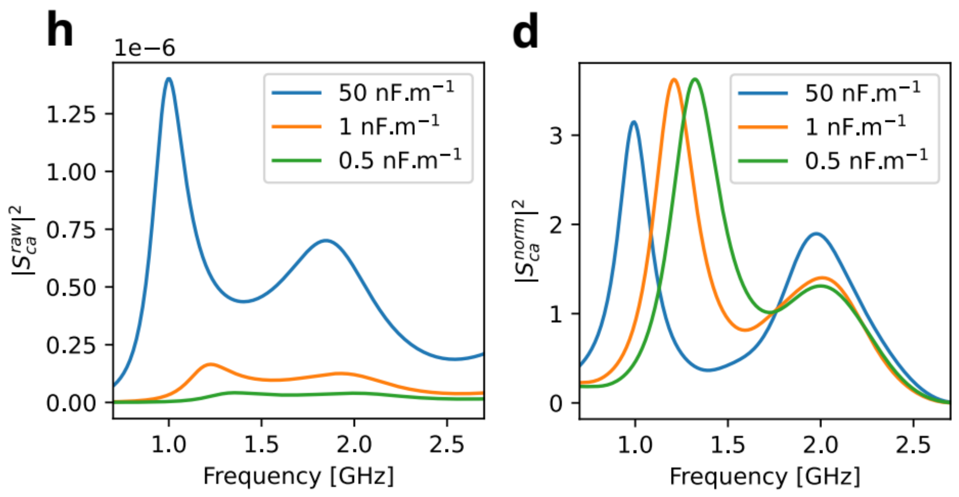
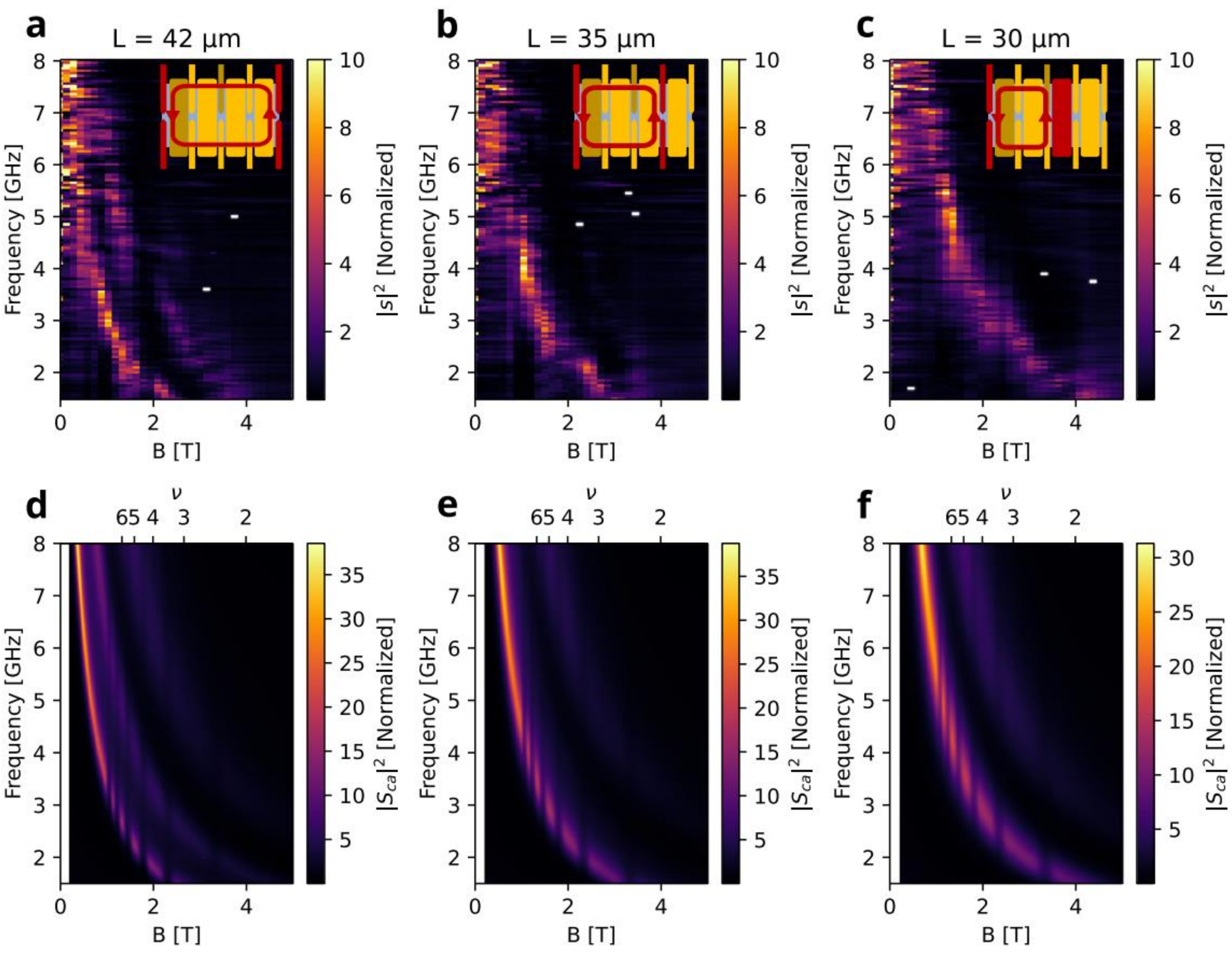


Fig S9

Discrete control (fig.2)



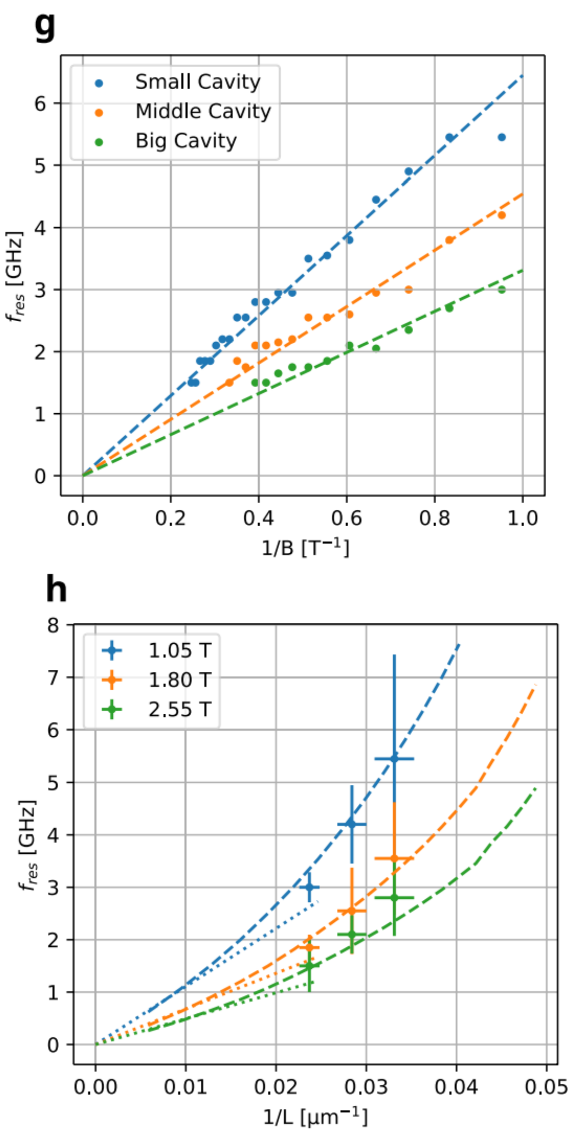
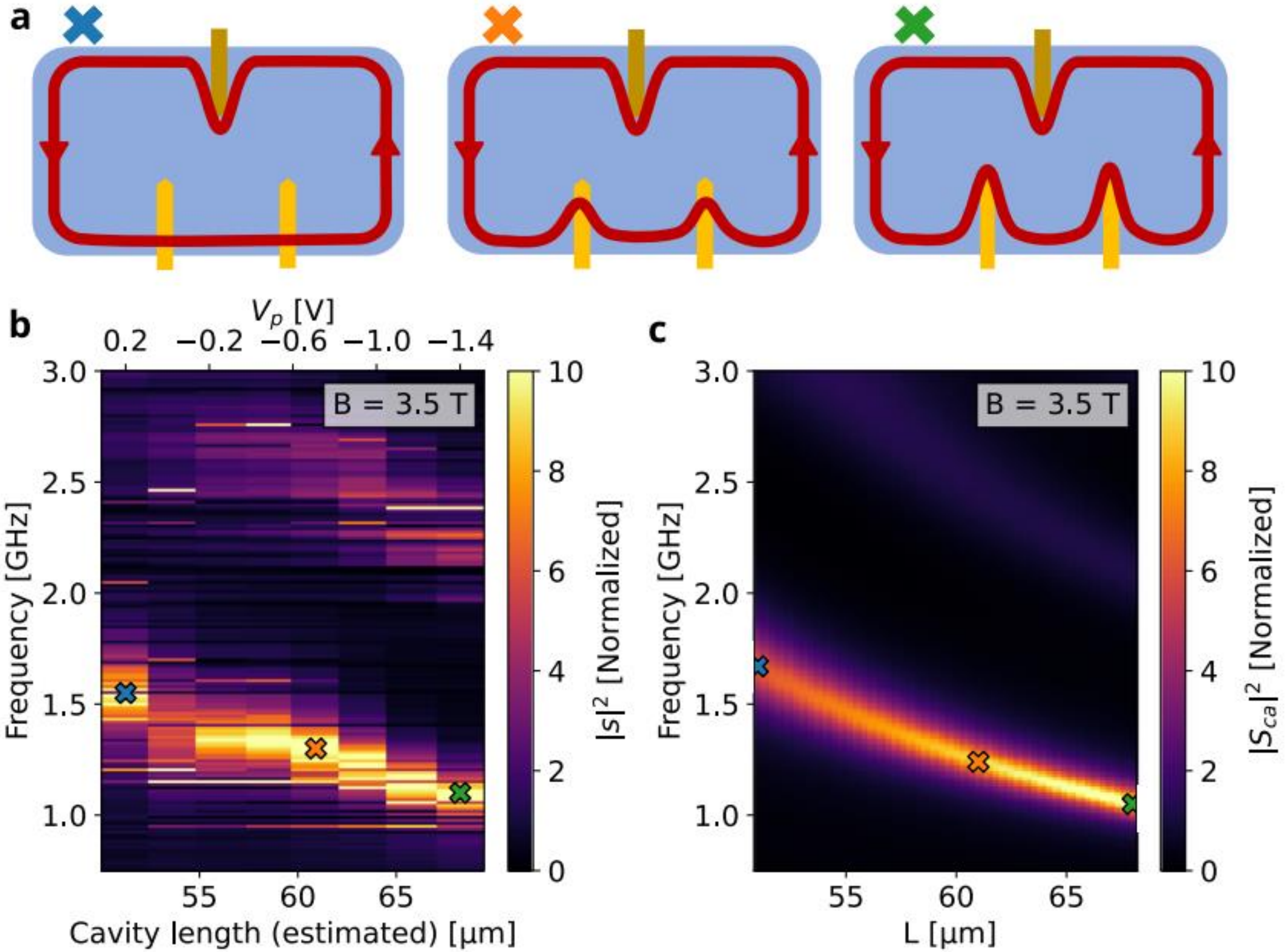


Table 1 | Experimental gate configuration used in fig. 2 of the main text

V_G^{in}	V_G^{out}	Top gates	Density
0 V	0 V	20 mV	1.93×10^{11} cm^{-2}

Continuous control



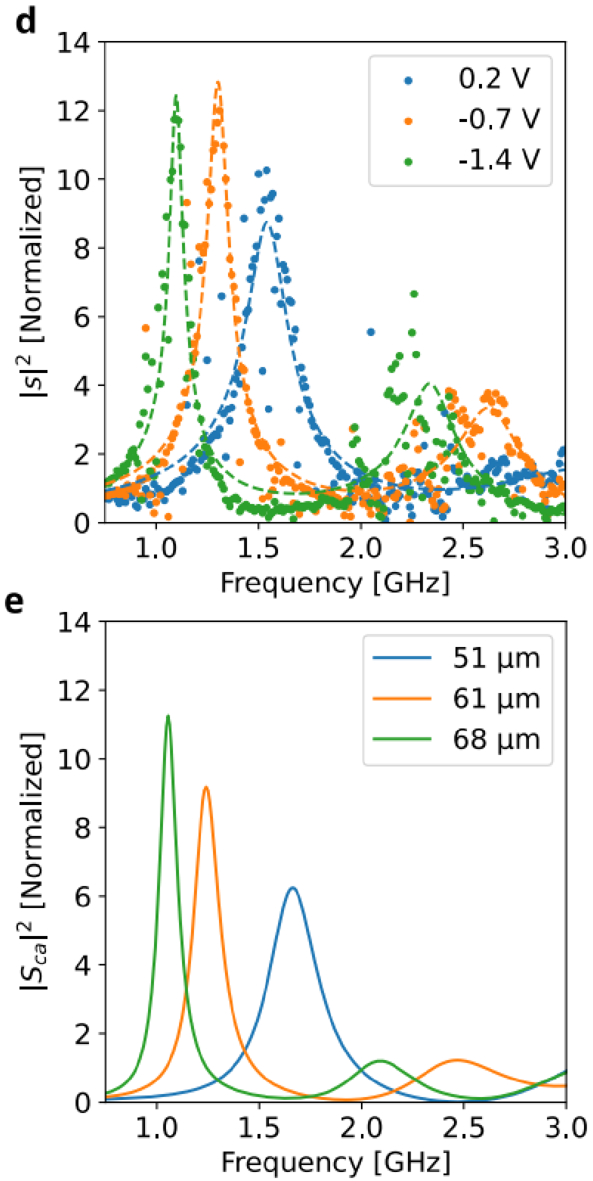
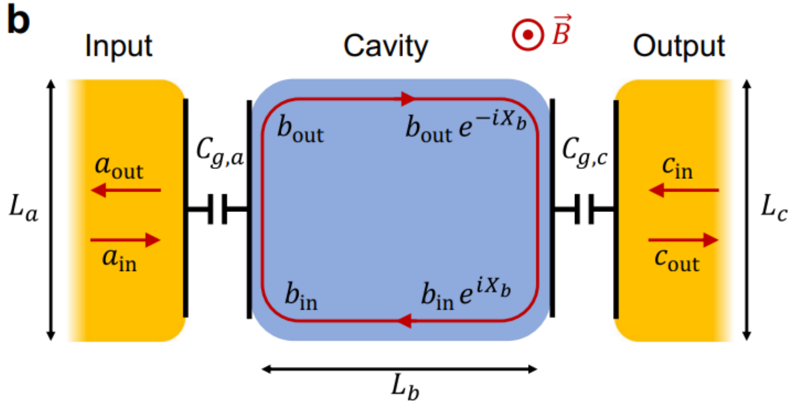


Table 2 | Experimental gate configuration used in fig. 4 of the main text

V_G^{in}	V_G^{out}	Top gates	Density
−1.1 V	50 mV	50 mV	2×10^{11} cm^{-2}

Gate copuling capacitance



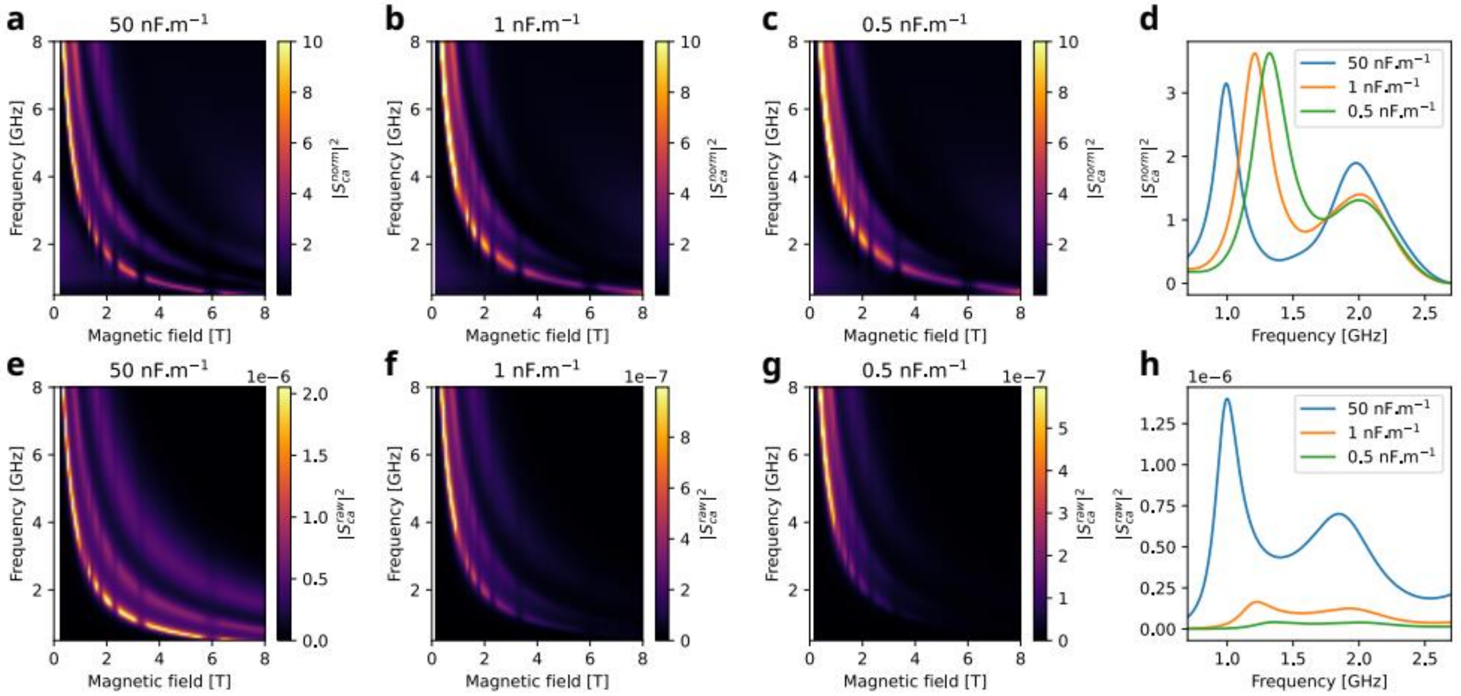
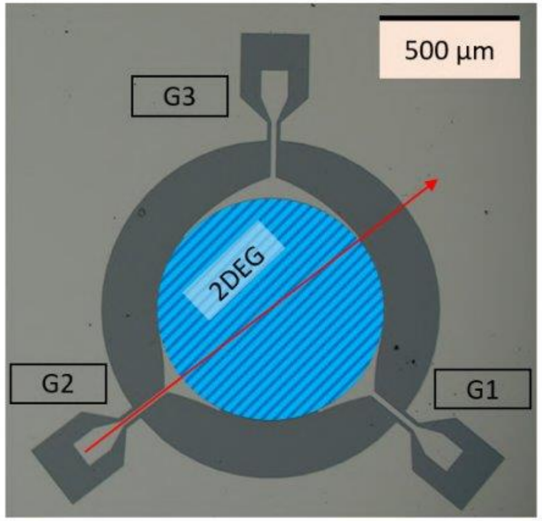


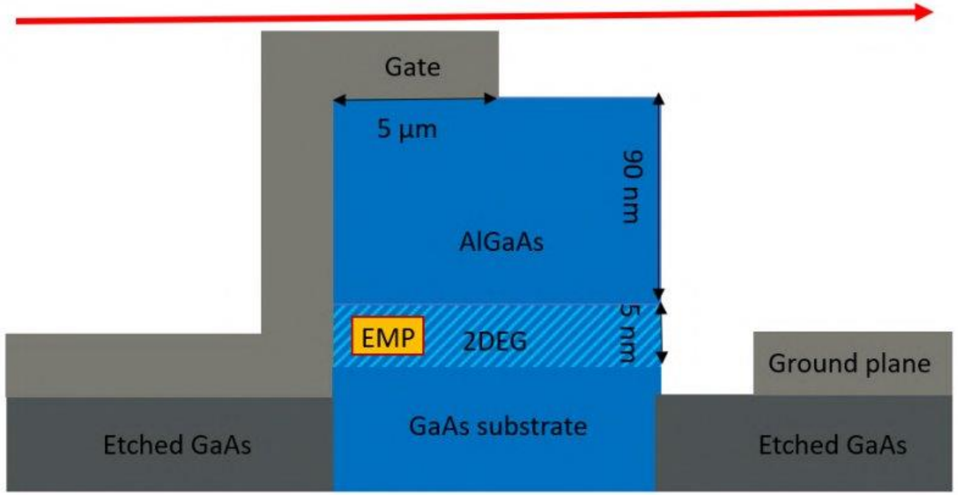
Fig S9

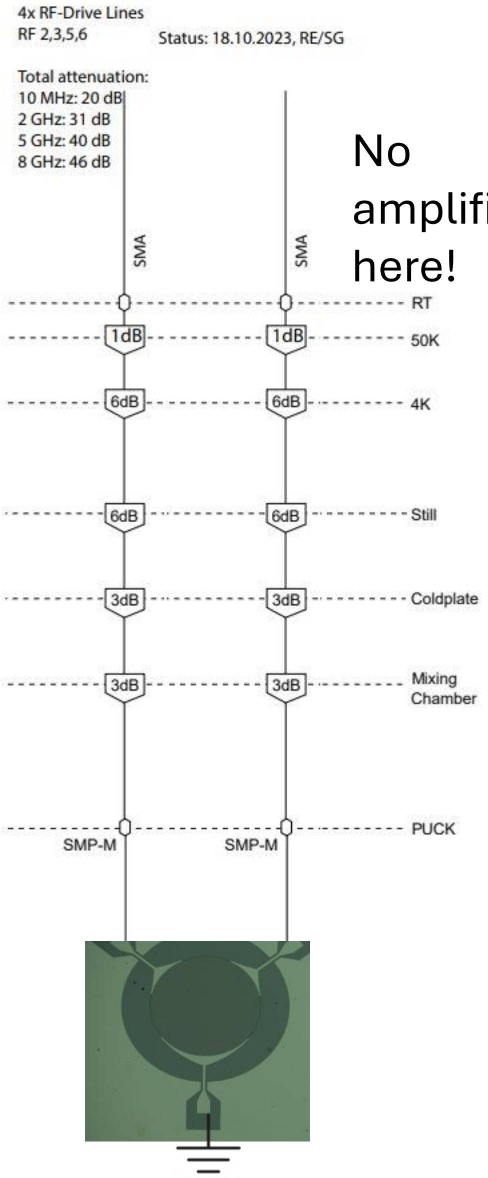
In conclusion

- Created a compact, tunable resonator with electrostatic and magnetic control.
- Achieved good match between theory and experiment, with finite size effects noted.
- Enabled adjustable cavity size for broad resonance studies.
- Proposed future studies on quasiparticle statistics and nonlinear effects.

Our device







No amplification here!

If G1:G2:G3 = 1:1:2 , then you are impedance matched!

	G1 µm	L*7 (circ) µm	R µm
L	550	3850	612.7646
M	350	2450	389.9411
S	200	1400	222.8235

Much longer than the paper!

CD1 id:248   f_step: 1.0Mhz   b_step: 0.005T