Coupling a single electron on superfluid helium to a superconducting resonator

Gerwin Koolstra [1], Ge Yang[1] & David I. Schuster[1*]

1 The James Franck Institute and Department of Physics, University of Chicago, Chicago, IL 60637, USA.

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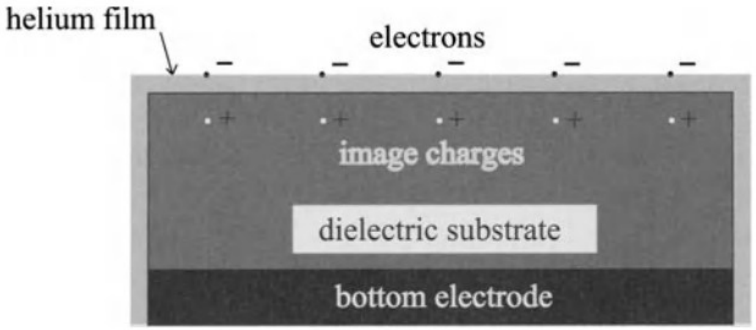
electron-on-helium quantum bit



Schematic view of SEs on a helium film and major image charges

Small electron-phonon coupling → low dissipation

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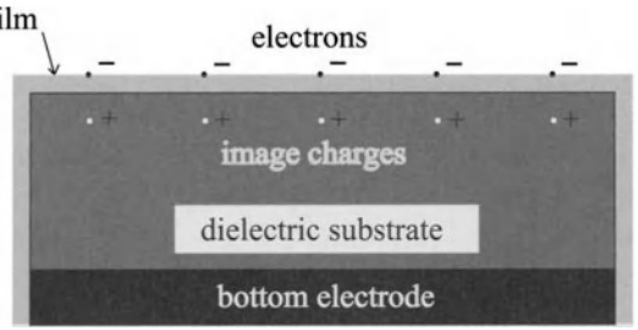

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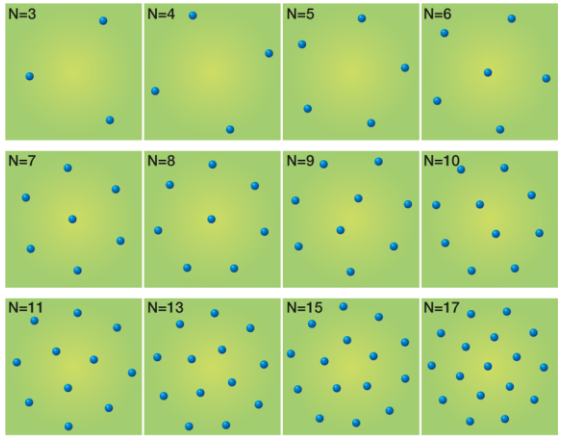
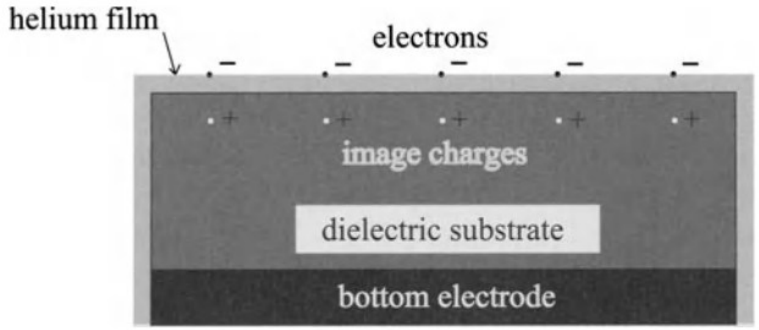


Electron crystallites floating on superfluid helium
François Peeters

Some ground state configurations

electron-on-helium quantum bit



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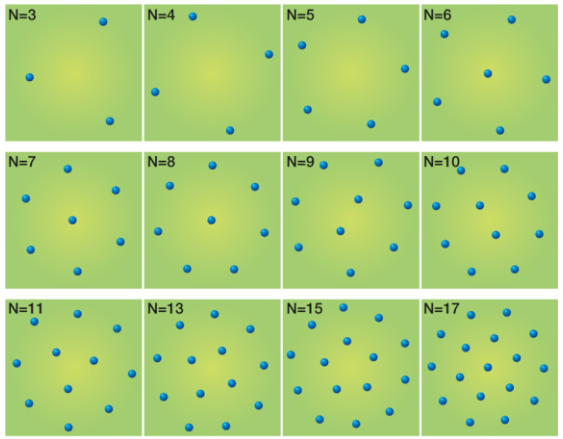

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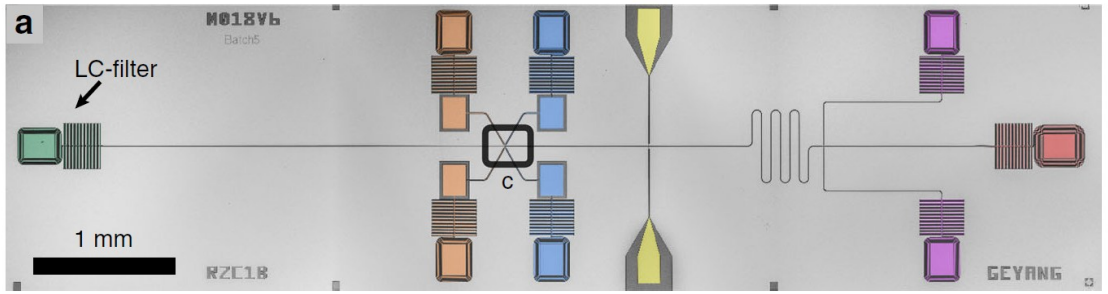

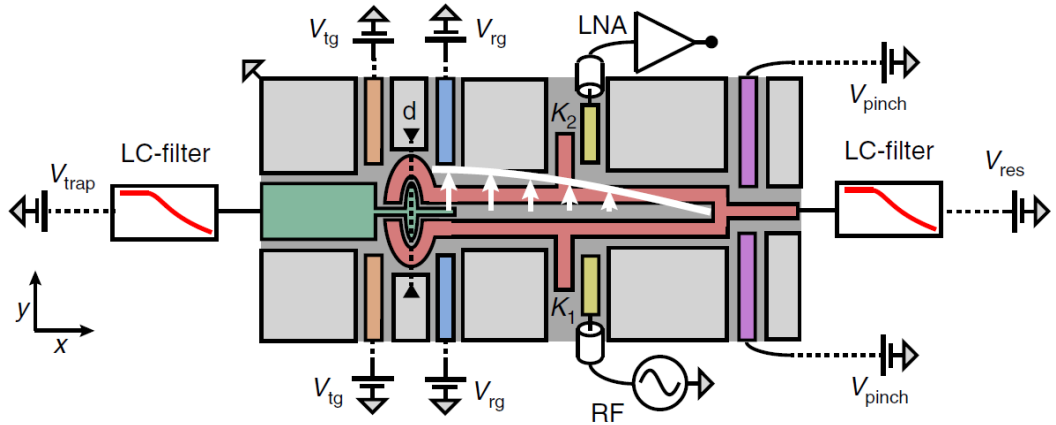

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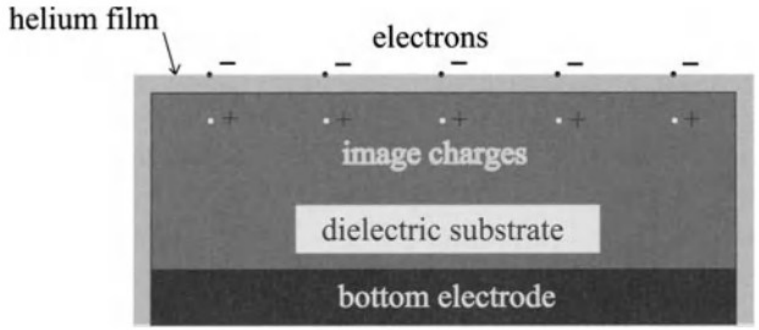

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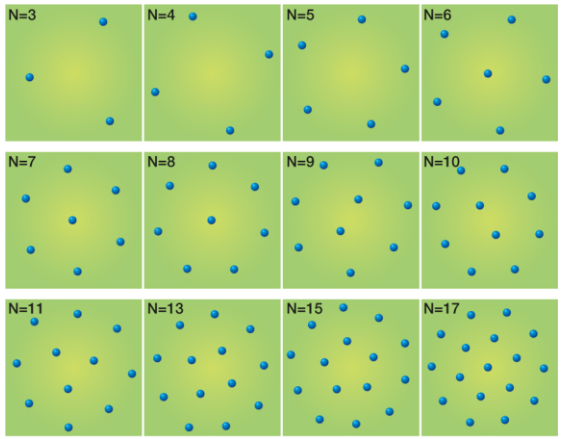

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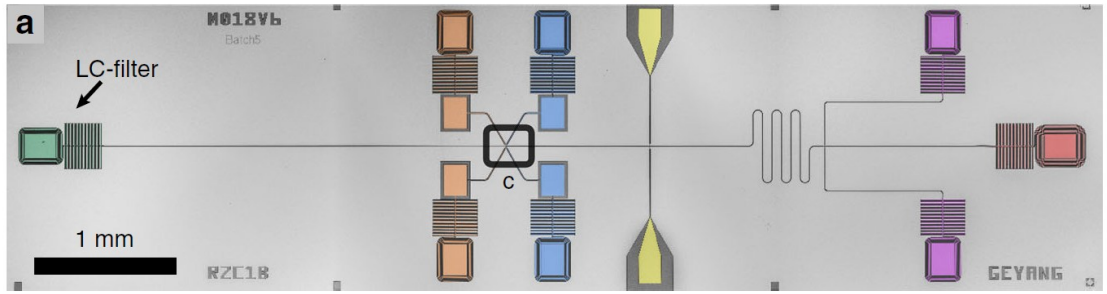
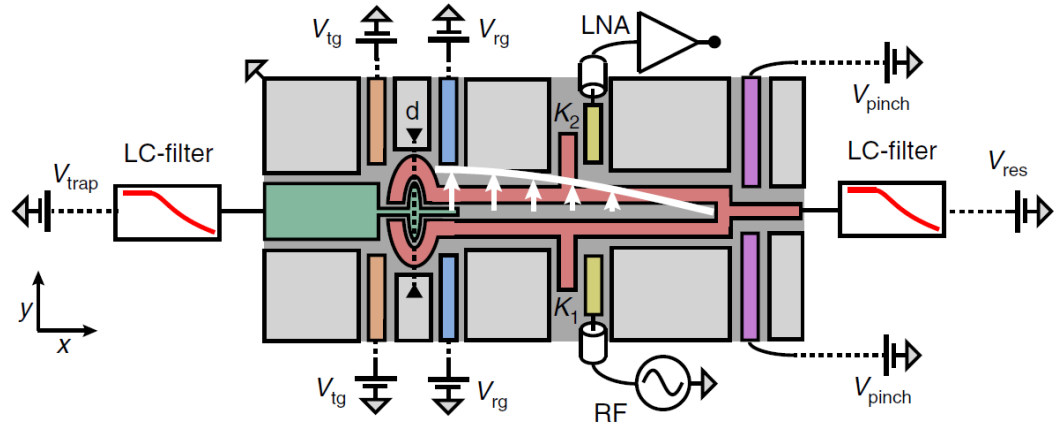
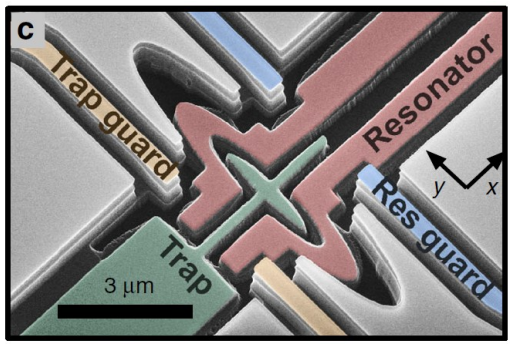
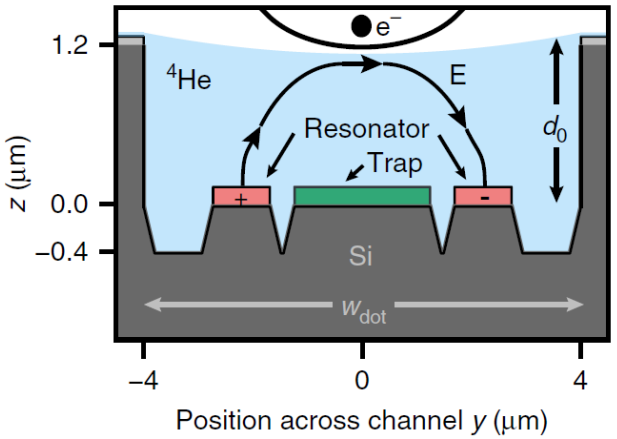




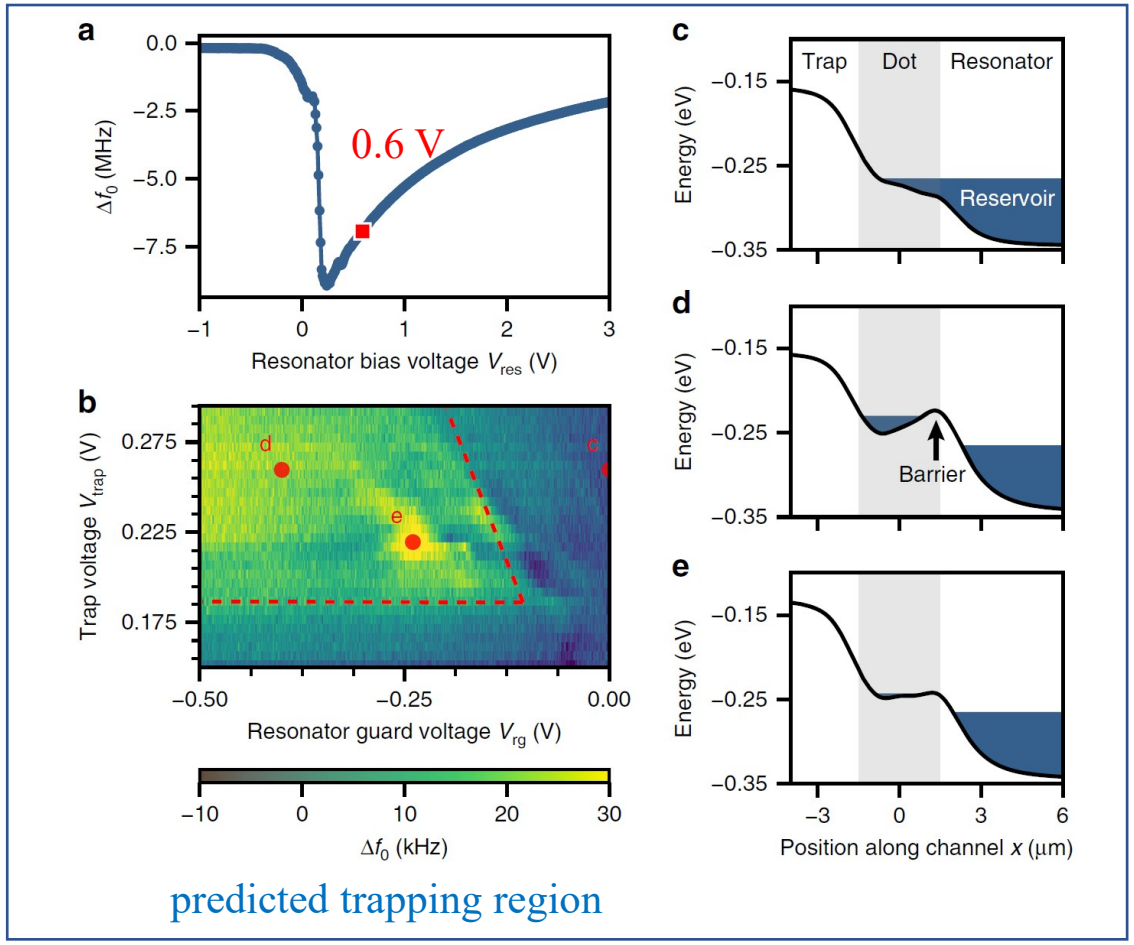




$$f_0 = 6.399\ \text{GHz}$$

$$\kappa_{\text{tot}}/2\pi = 0.4\ \text{MHz}$$

Detection of electrons



predicted trapping region

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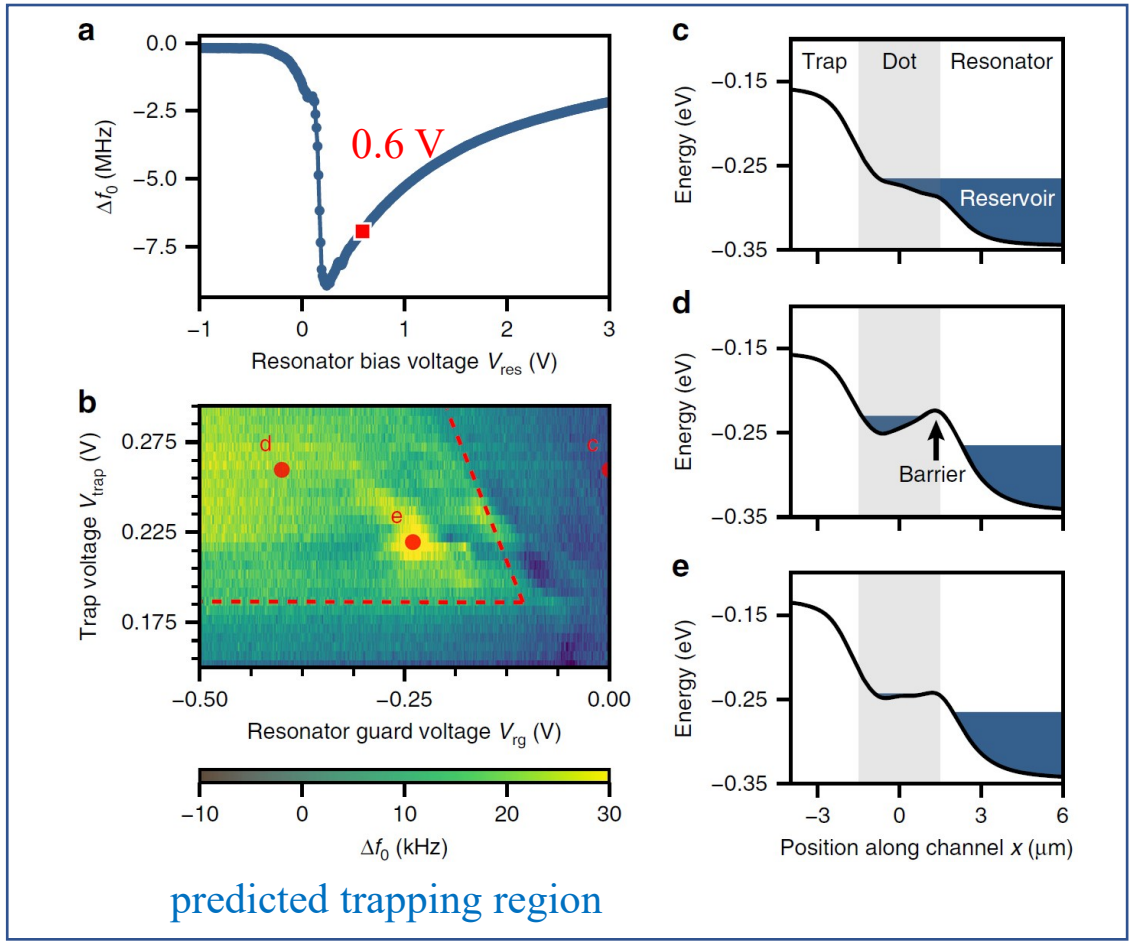

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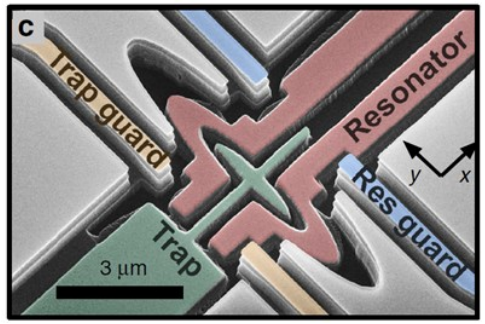

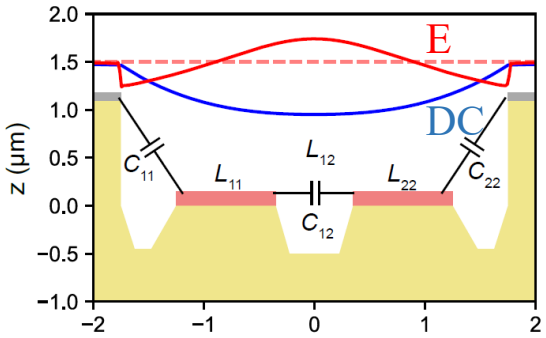

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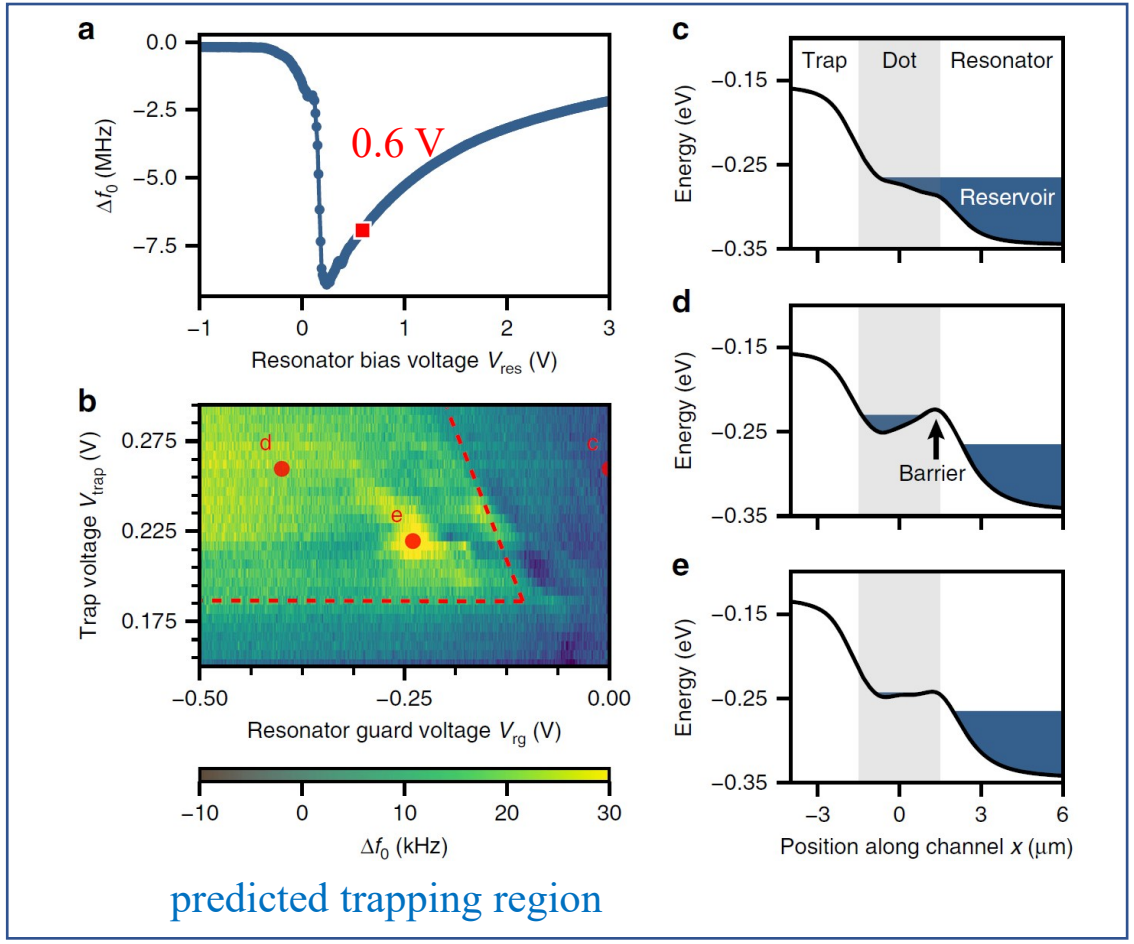

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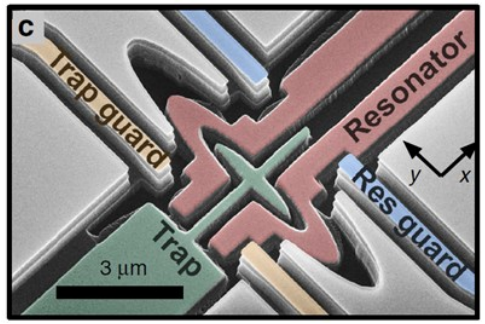
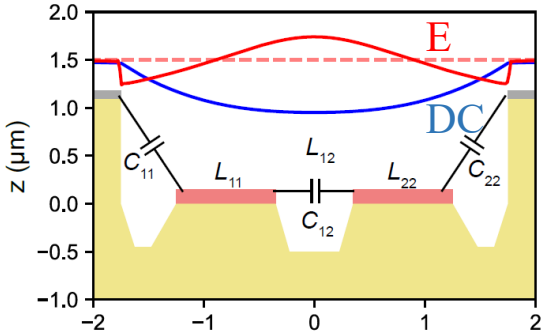
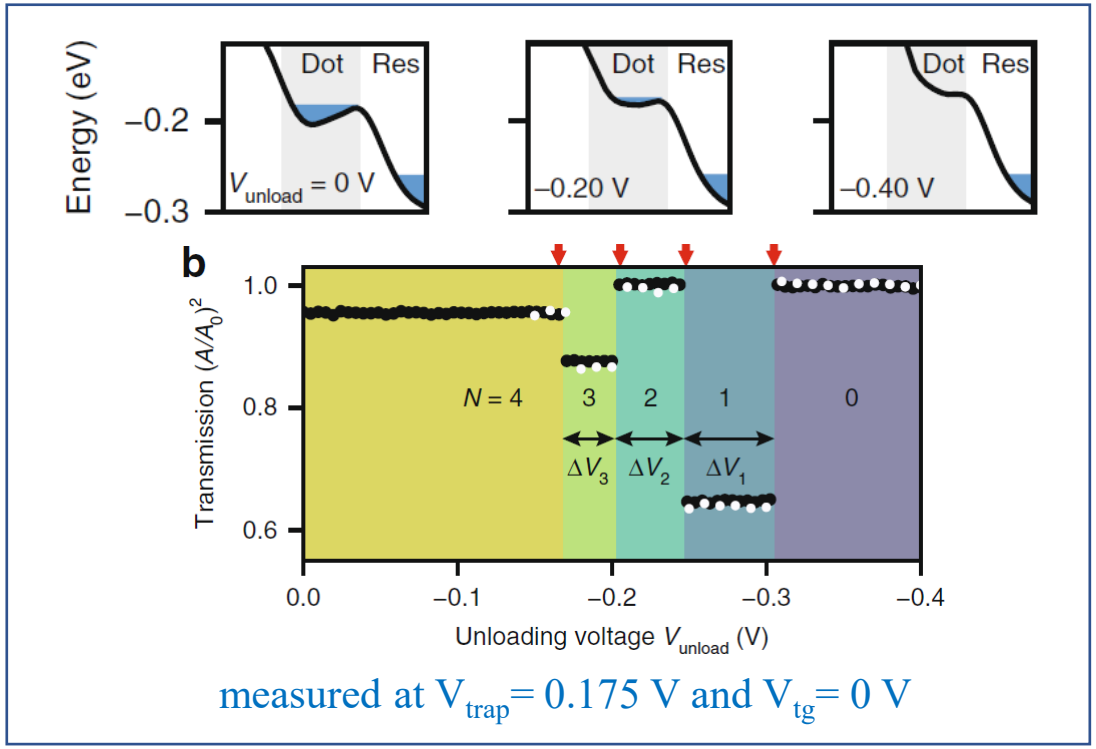


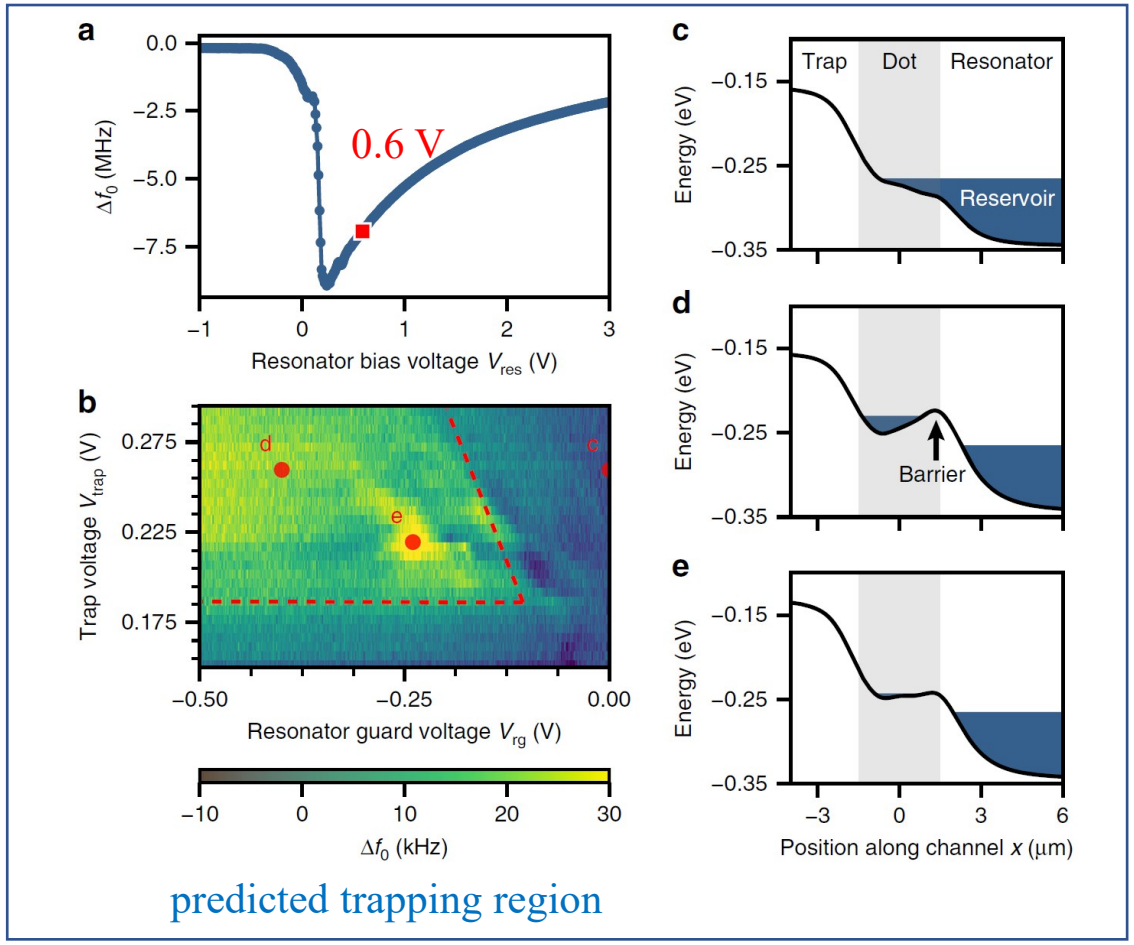




measured at V_{trap} = 0.175 V and V_{tg} = 0 V

Unloading & loading of the dot

Detection of electrons



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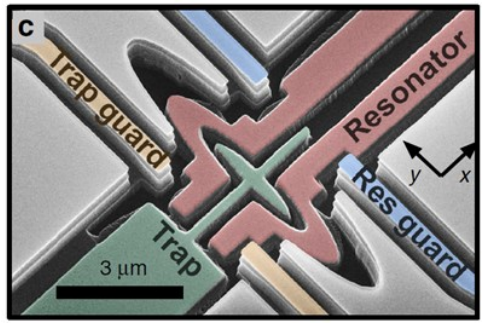

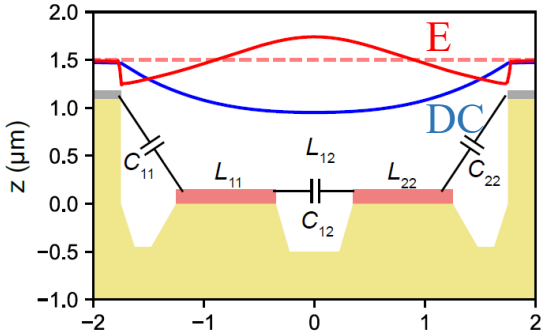

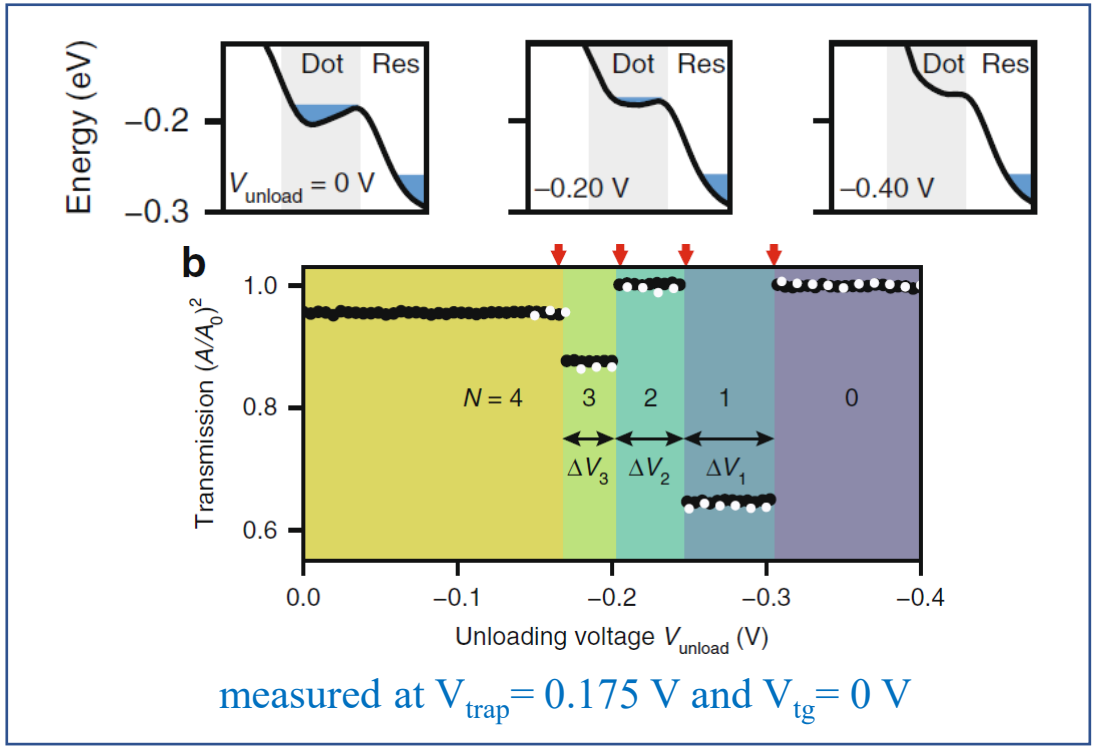

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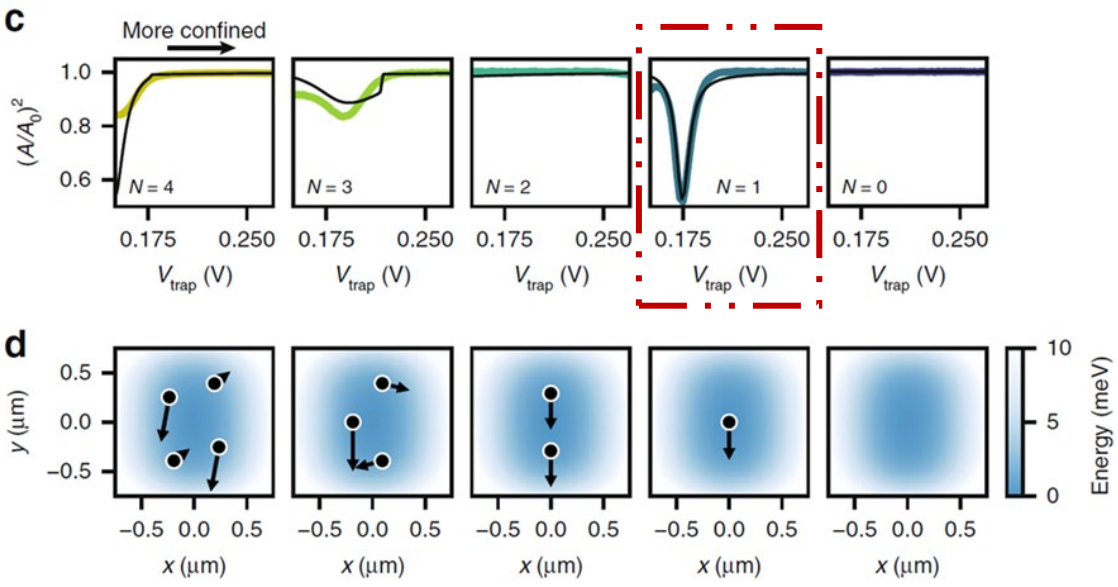
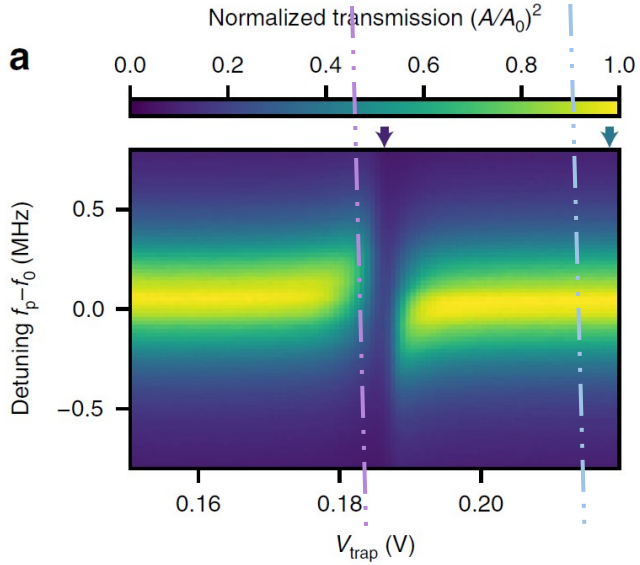
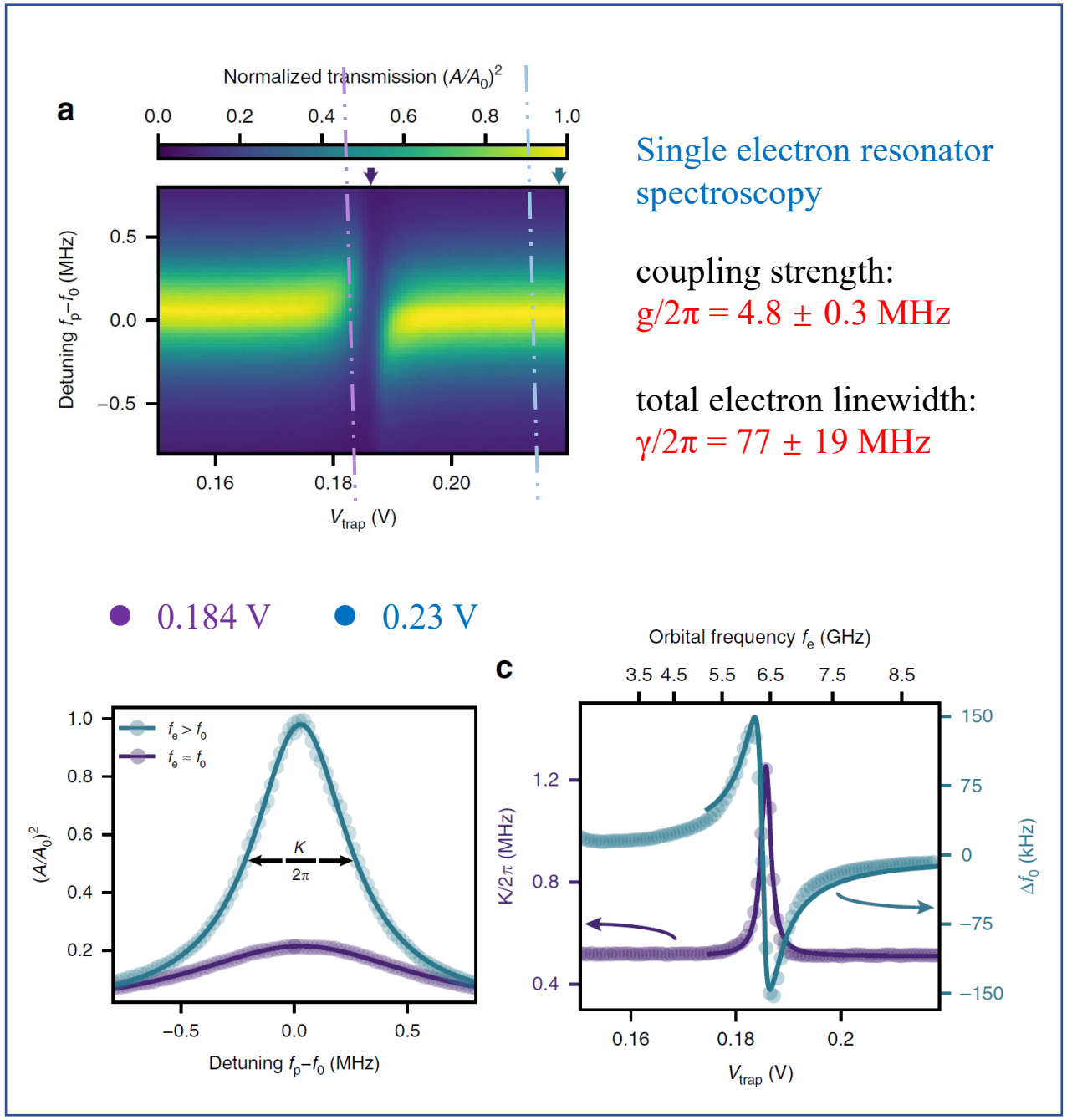


Single electron properties



Single electron resonator spectroscopy

Single electron properties



Single electron properties

Electron-photon coupling

$$g/2\pi = \boldsymbol{d}\cdot\mathbf{E} = \frac{1}{2}eE_y f_0\sqrt{\frac{Z}{m_e\omega_e}}$$

$$E_y \approx 2\times10^5\ \mathrm{V/m} \qquad Z = 90\ \Omega$$

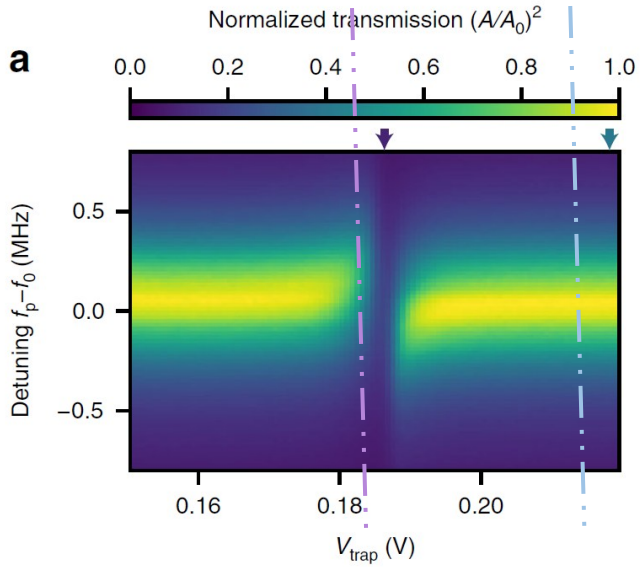
$$f_0 = \omega_0/2\pi = 6.45\ \ \mathrm{GHz}$$

Contributions to single electron linewidth

$$\gamma = \frac{\gamma_1}{2} + \gamma_\varphi$$

transverse decay γ_1 dephasing rate γ_φ

Type	Mechanism	Magnitude
Dephasing	Voltage noise from the gates	0.5 MHz
Dephasing	Helium vibrations in the dot	110 MHz
Dephasing	Reservoir electrons on the resonator	20 MHz
Transverse	Microwave leakage through gates	< 1 MHz

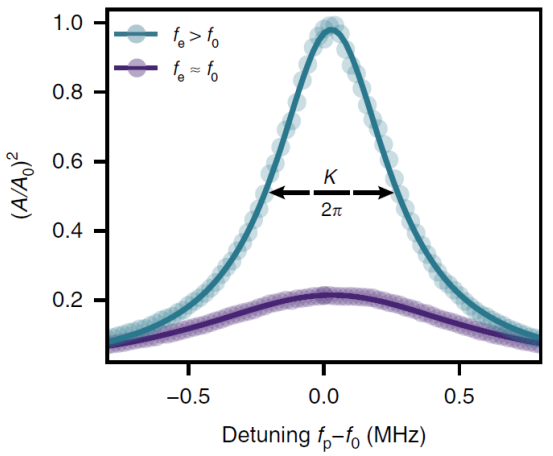


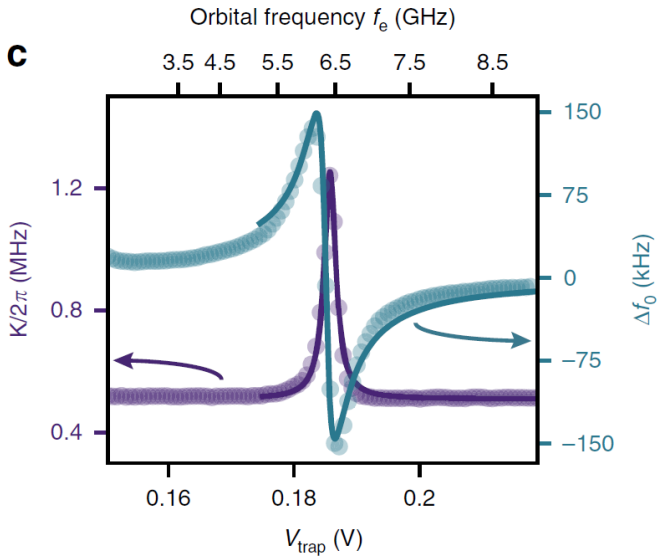
Single electron resonator spectroscopy

coupling strength:
$g/2\pi = 4.8 \pm 0.3$ MHz

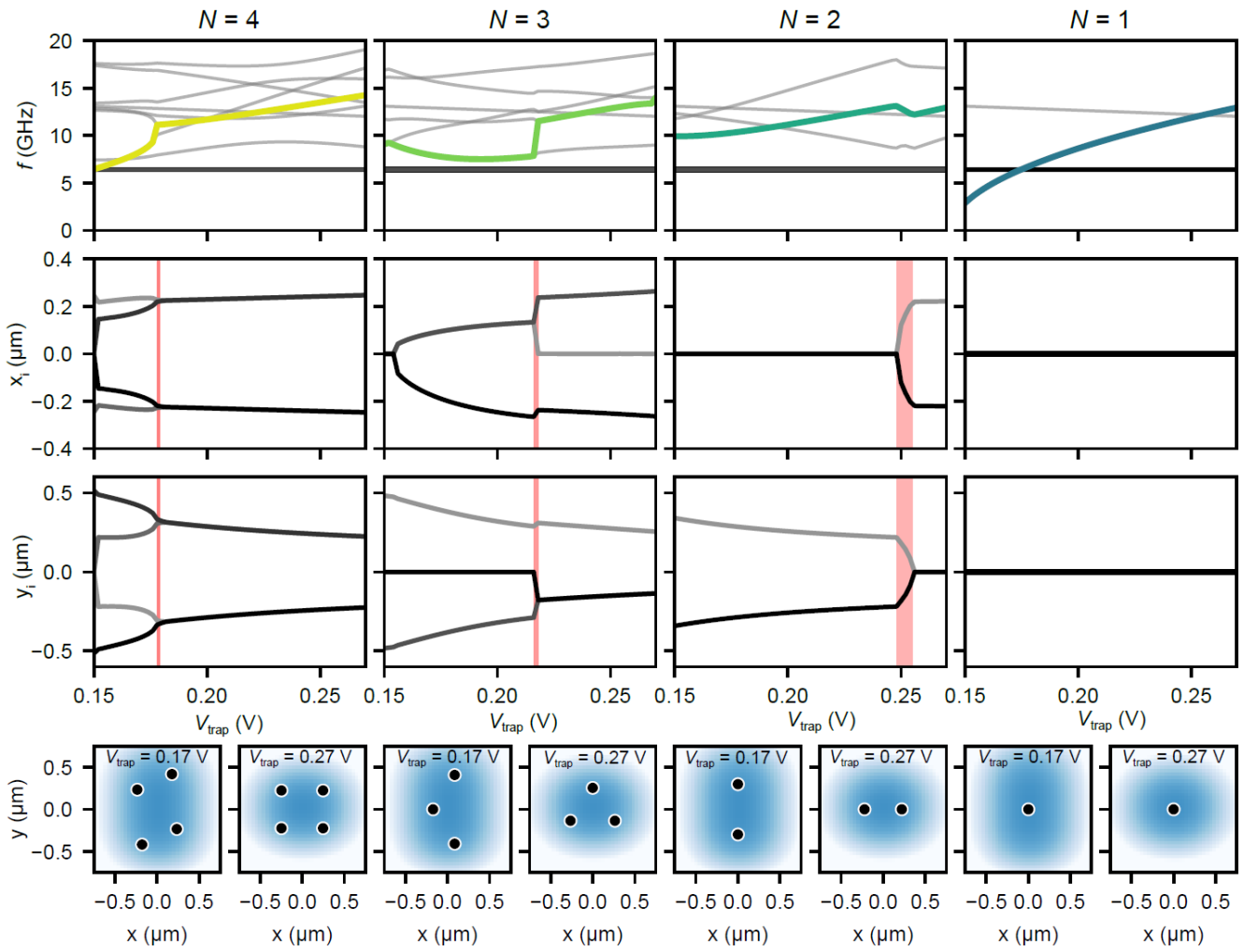
total electron linewidth:
$\gamma/2\pi = 77 \pm 19$ MHz

● 0.184 V ● 0.23 V





Orbital frequencies of small electron clusters



Cavity transmission

$$\frac{A}{A_0} = \left| \frac{\sqrt{\kappa_1 \kappa_2}}{i(\kappa_1 + \kappa_2 + \kappa_{\text{int}})/2 - \chi(\omega_0)} \right|$$

susceptibility $$\chi(\omega_0) = \frac{g^2}{(\omega_0 - \omega_e) + i\gamma}$$

strongest-coupled orbital frequency

Research plans for single spin project

- Do simulations to look into methods of engineering cooperativity

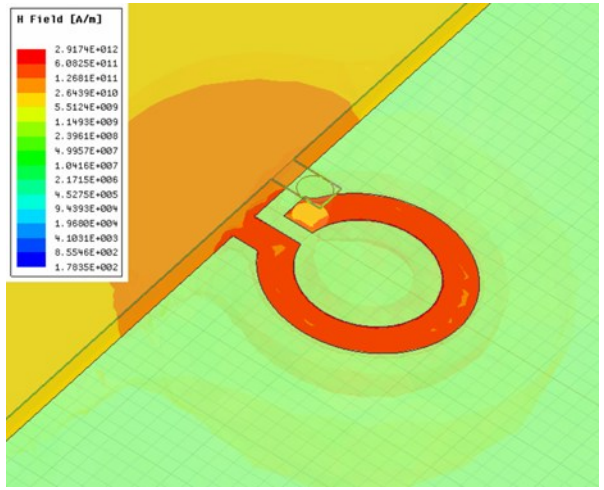
  (e.g. Purcell effect)

- Coherent readout

  Try to engineer spin linewidth to enhance single spin cooperativity

- Fabrication

  Look into nano-fabrication methods for the device



Research plans for nuclear spin project

- Do simulations to look into nuclear spin splitting levels of ^{167}Er

- Experiment setup

  Pure optical/optical & RF/ all MW approach

- Cavity with two resonance

  Detuned MW drives, double resonance, detect nuclear spin