Coupling a single electron on superfluid helium to a superconducting resonator

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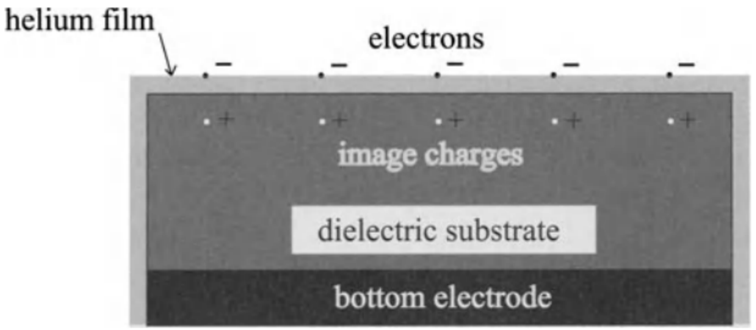
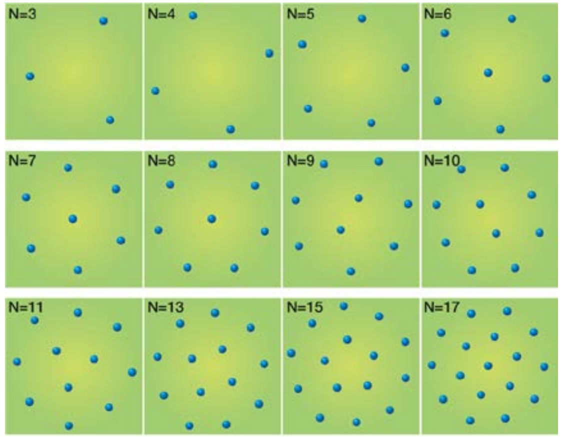
electron-on-helium quantum bit



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

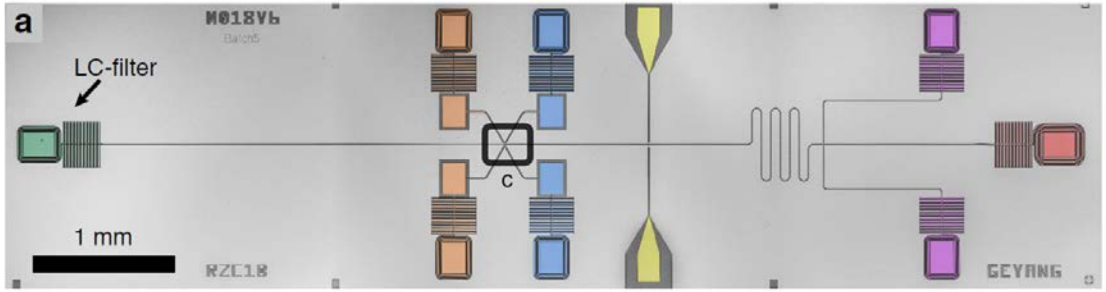
Small electron-phonon coupling → low dissipation

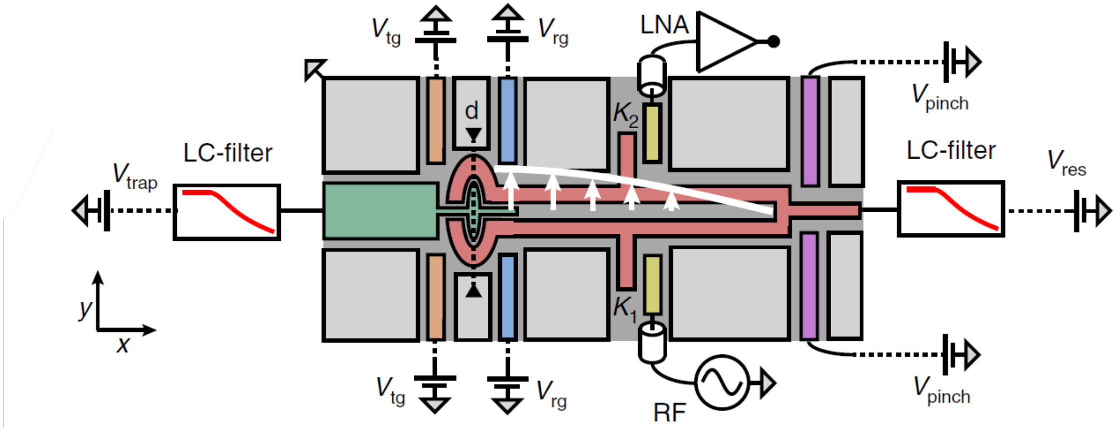
Monarkha, Y. & Kono, K. Two-Dimensional Coulomb Liquids and Solids (Springer-Verlag, Berlin, 2004).

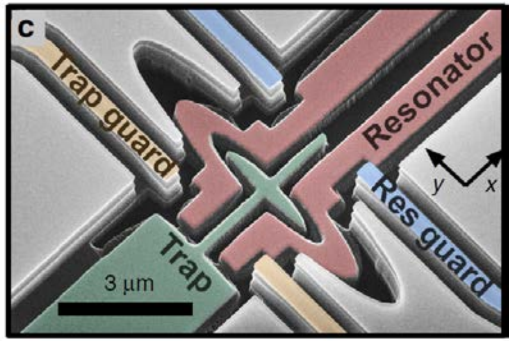


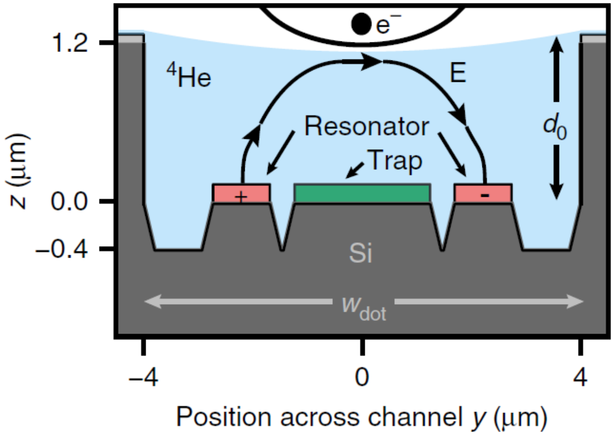
Electron crystallites floating on superfluid helium
François Peeters

Some ground state configurations



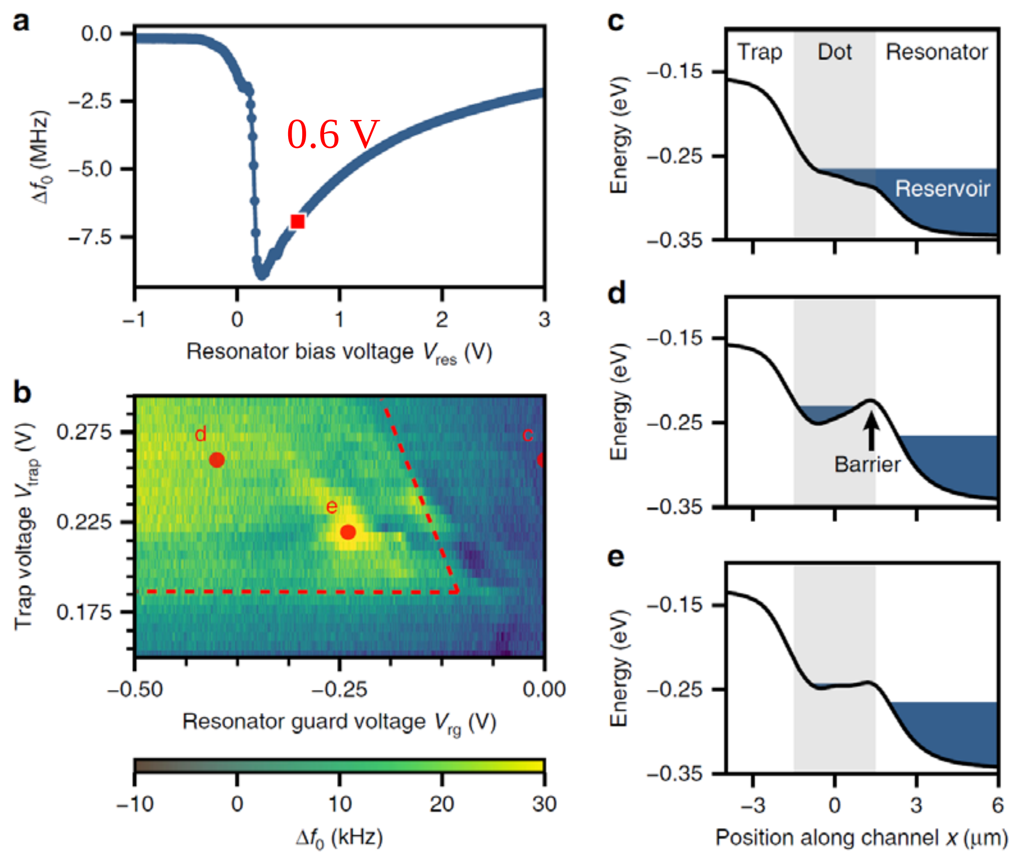




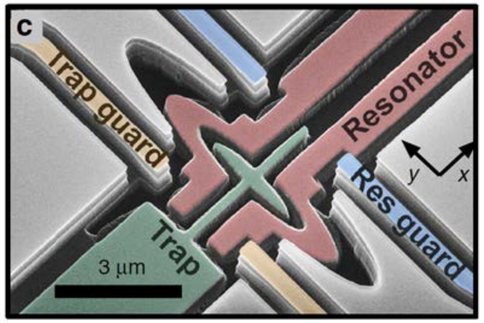


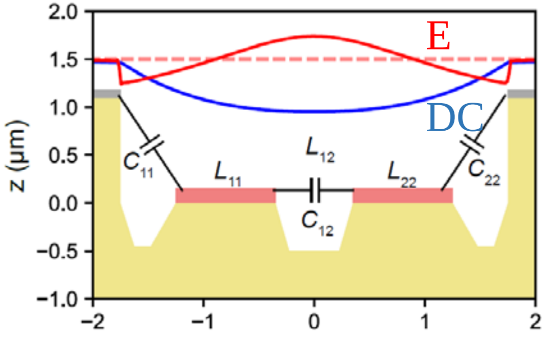
$$f_0 = 6.399\ \text{GHz}$$
$$\kappa_{tot}/2\pi = 0.4\ \text{MHz}$$

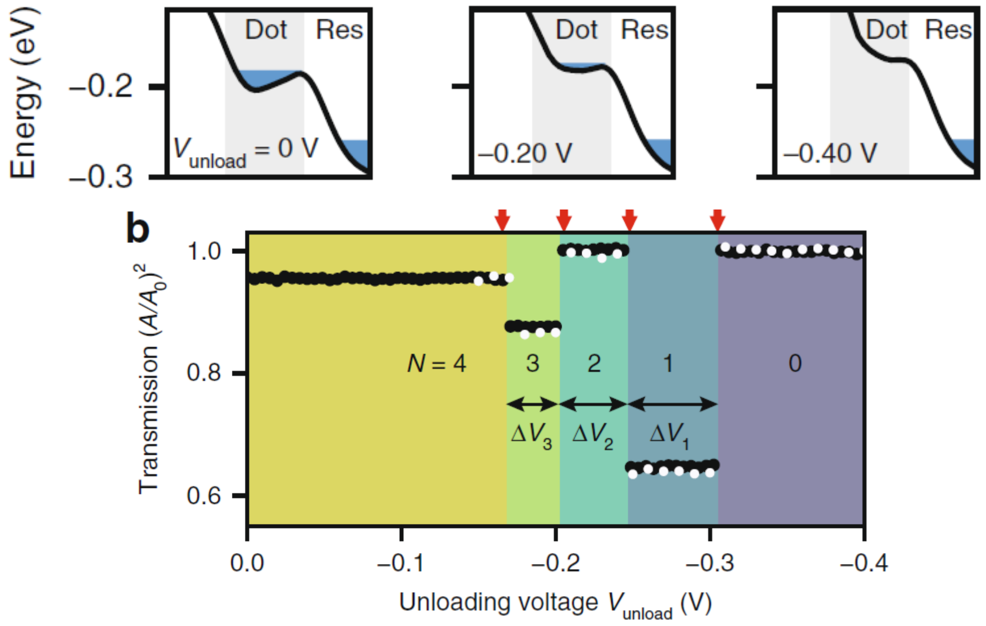
Detection of electrons



predicted trapping region

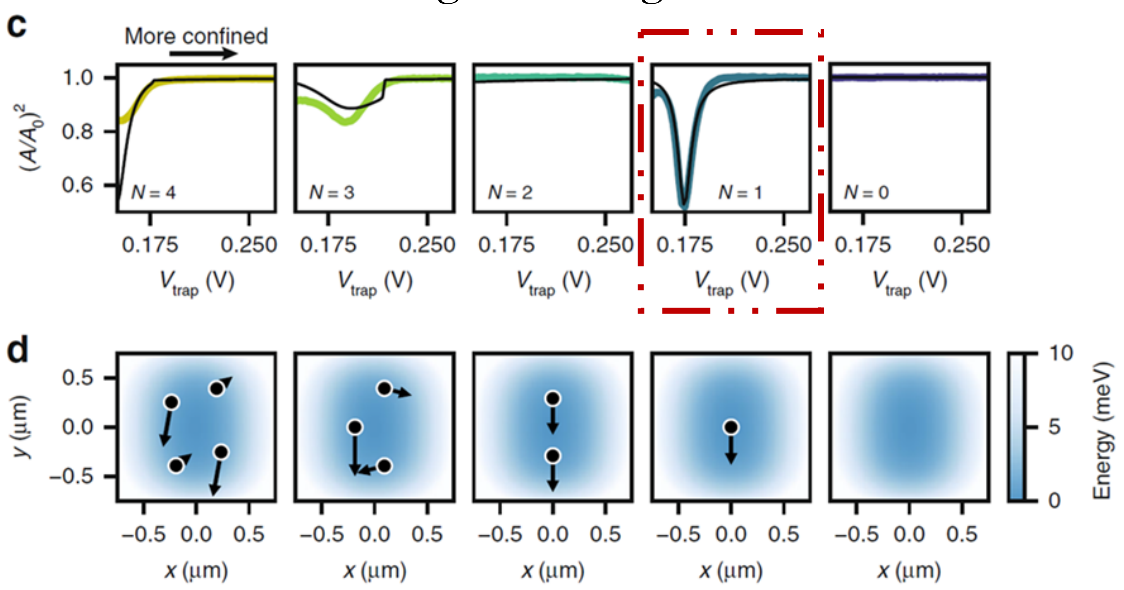






measured at V_{trap}= 0.175 V and V_{tg}= 0 V

Unloading & loading of the dot



Single electron properties

Electron-photon coupling

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

$$E_y \approx 2\times 10^5 \ \mathrm{V/m} \qquad Z = 90\ \Omega$$

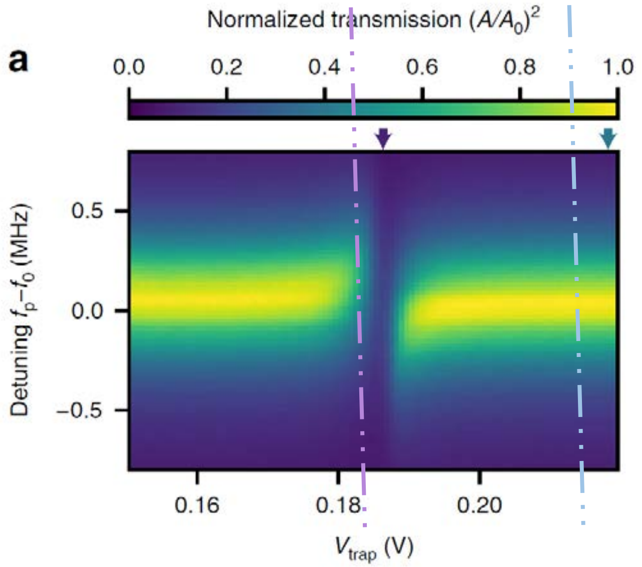
$$f_0 = \omega_0/2\pi = 6.45 \quad \mathrm{GHz}$$

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

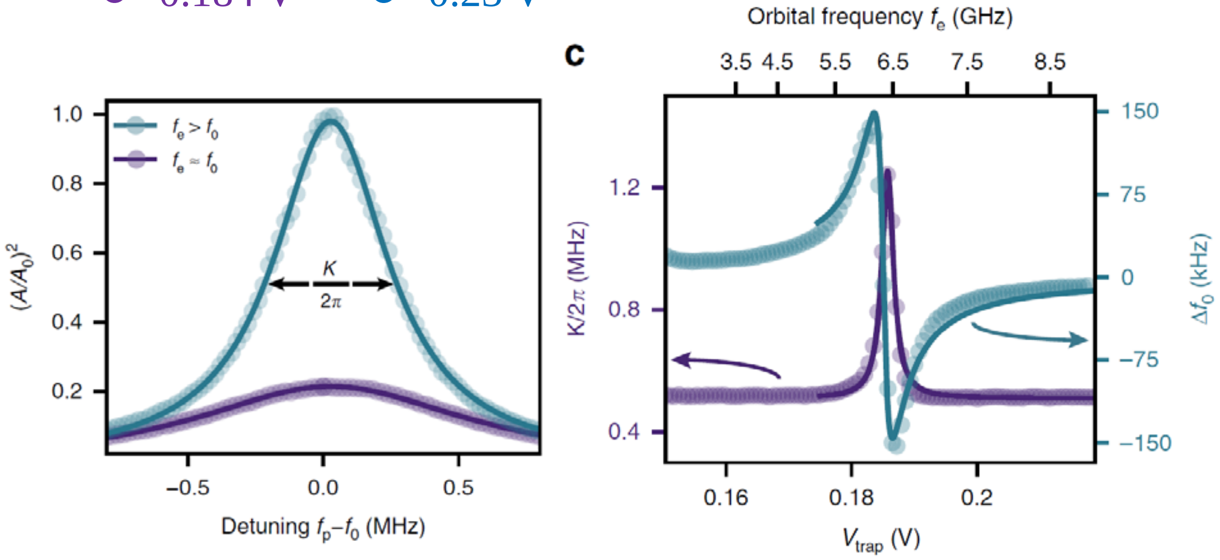


Single electron resonator spectroscopy

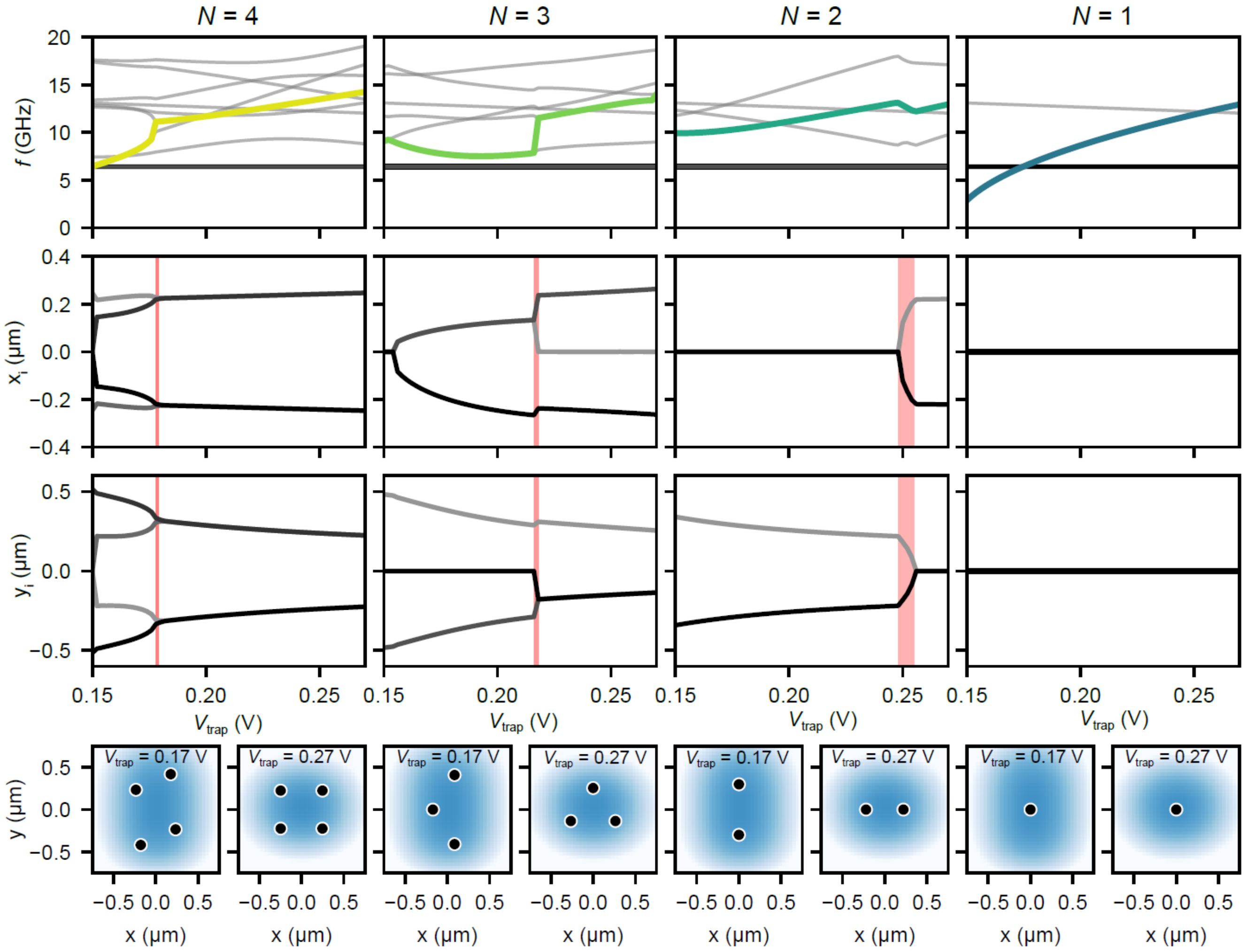
coupling strength:
$g/2\pi = 4.8 \pm 0.3$ MHz

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