Strong Coupling Between Single-Electron Tunneling and Nanomechanical Motion

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- coupling quantum dot transport to nanomech. Motion (bidir.)
- shift in resonance freq. by addition of single electron
- damping of mech. resonator by electron tunneling
- strong coupling, nonlinear regime, instabilities / several stable modes
- self-driving by large dc bias

- all done in suspended, ultraclean CNT with Q ~ 150’000 (driven by coax)
Device

- SiO2 trench dry etch
- W/Pt contacts S-D
- (wet etch)
- CNT growth
- Q-dot, confined by contacts
- $T = 80\text{ mK}$ (fridge @ 20 mK)

device 1
- 800 nm trench
- 300 mV bandgap
- $\sim$3 nm diameter
- 4-fold shell filling
- coax unterm. 2 cm away

device 2
- 430 nm trench
- 100 mV bandgap
- $\sim$3 nm diameter
- 4-fold shell filling

total of 12 devices confirming effects
ultraclean device: 4 fold symmetry
Nanotube Resonator

- actuated by nearby coax
- detected by dc-current through tube

- Q two orders of magnitude larger than previous works
- narrow line width: unprecedented sensitive probe for studying nanomechanics

- tunable res. frequency: gate pulls tube, tightening “string”, tuning freq.
Detection of mechanical Motion

- displaced CNT: changed gate capacitance
- shifting dot potential
- non-linearity of Coulomb blockade:
  rectified signal, detectable dc current
- decreasing Vg increases tension, frequency: linear
- addition of one electron: 0.1 MHz offset (0.5 MHz)
- on peaks: fluctuating charge (by one e-) I = e Γ
many electrons tunnel per mech. osc.: time fluctuating, dynamical force causes softening, dips in res. freq., depending on V_{sd}
Res. frequency dips: source-drain bias dependence
Charge fluctuations (CB peaks): dissipation, Strong driving regime (non-linear)

Replacing $k$ with $(k + \alpha^2)$

The sign of $\alpha$ follows the curvature of $f_0(V_g)$

Switching between several different metastable modes
Spontaneous Driving by single electron tunneling (NO rf driving)
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similar experiments: (but Qs orders of magnitude smaller, tubes disordered)
Lassagne, Tarakanov, Kinaret, Garcia-Sancez, Bachtold, Science ibid