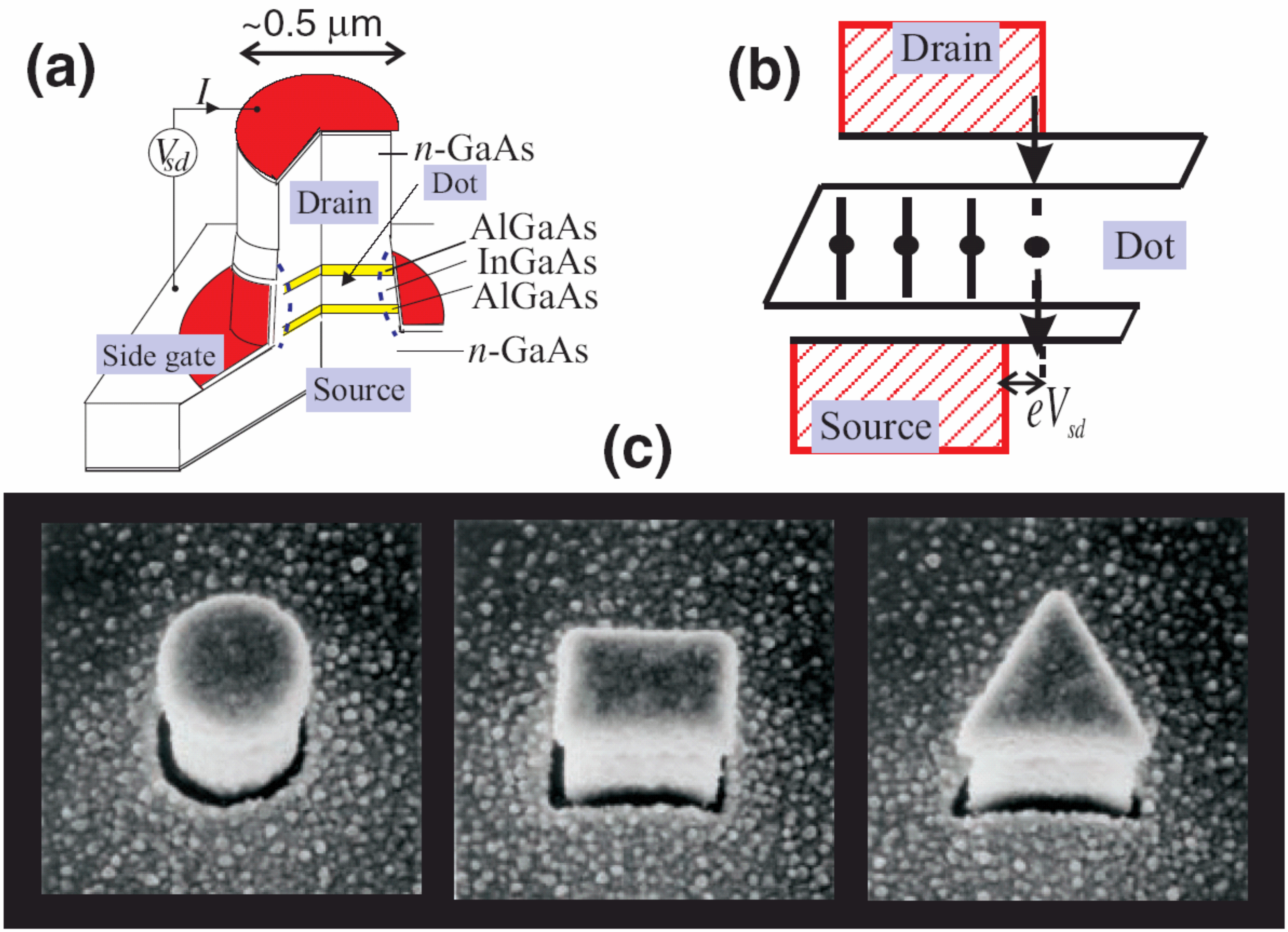
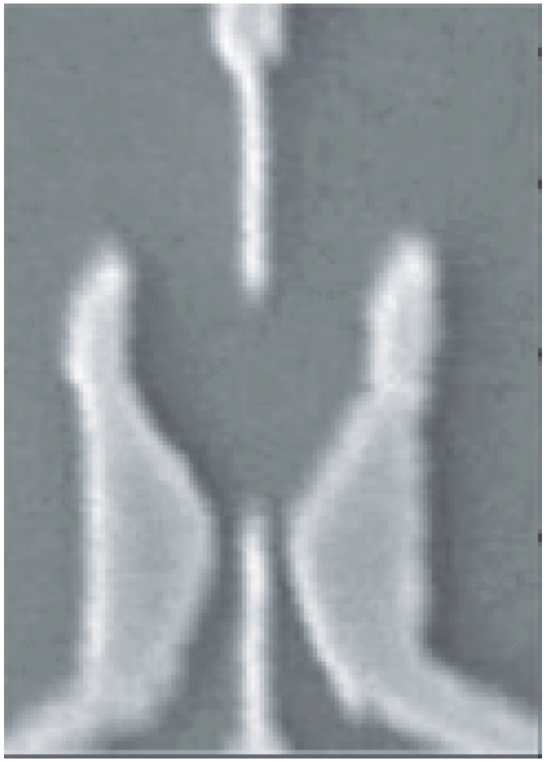
Kouwenhoven, Austing and Tarucha, RPP 64, 701 (2002)
Tarucha et al., PRL77, 3613 (1996)
Kouwenhoven et al., Science 278, 1788 (1997)

Few Electron Quantum Dots: Vertical

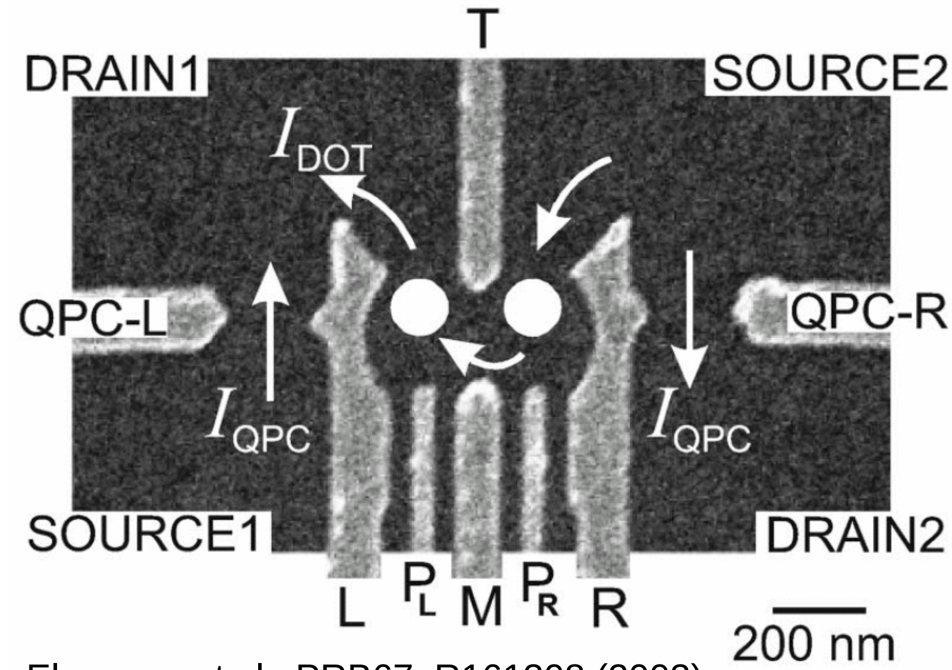


Kouwenhoven, Austing and Tarucha, RPP 64, 701 (2001)

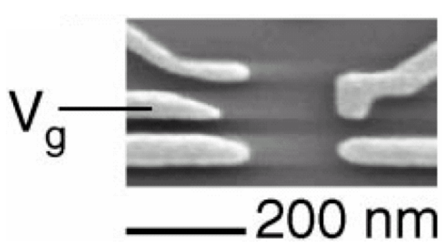
Few Electron Quantum Dots: Lateral



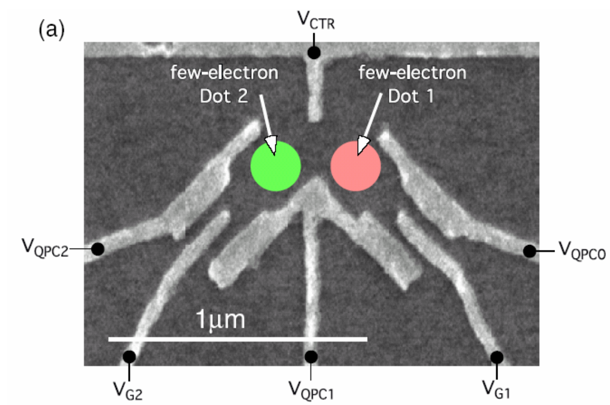
Ciorga et al., PRB61, R16315 (2000)



Elzerman et al., PRB67, R161308 (2003)
similar design: Marcuslab



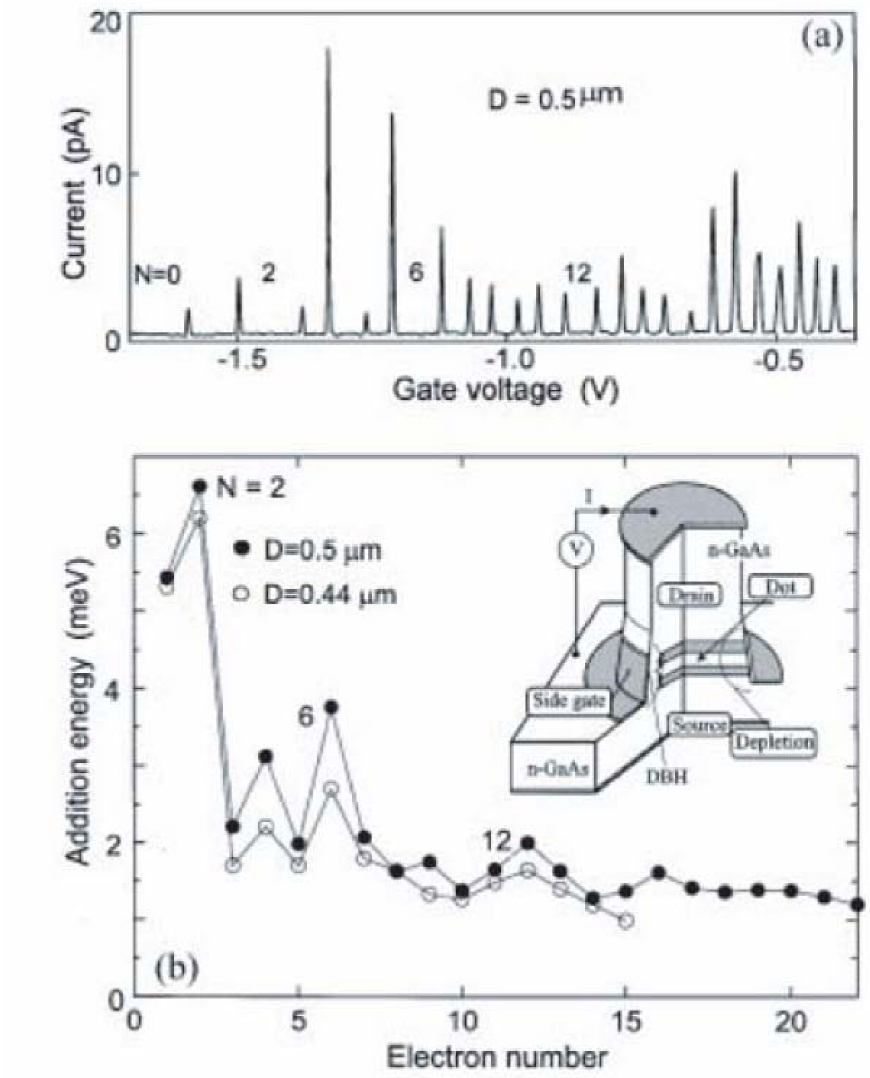
Zumbuhl et al., PRL93, 256801 (2004)



Chan et al., Nanotech. 15, 609 (2004)

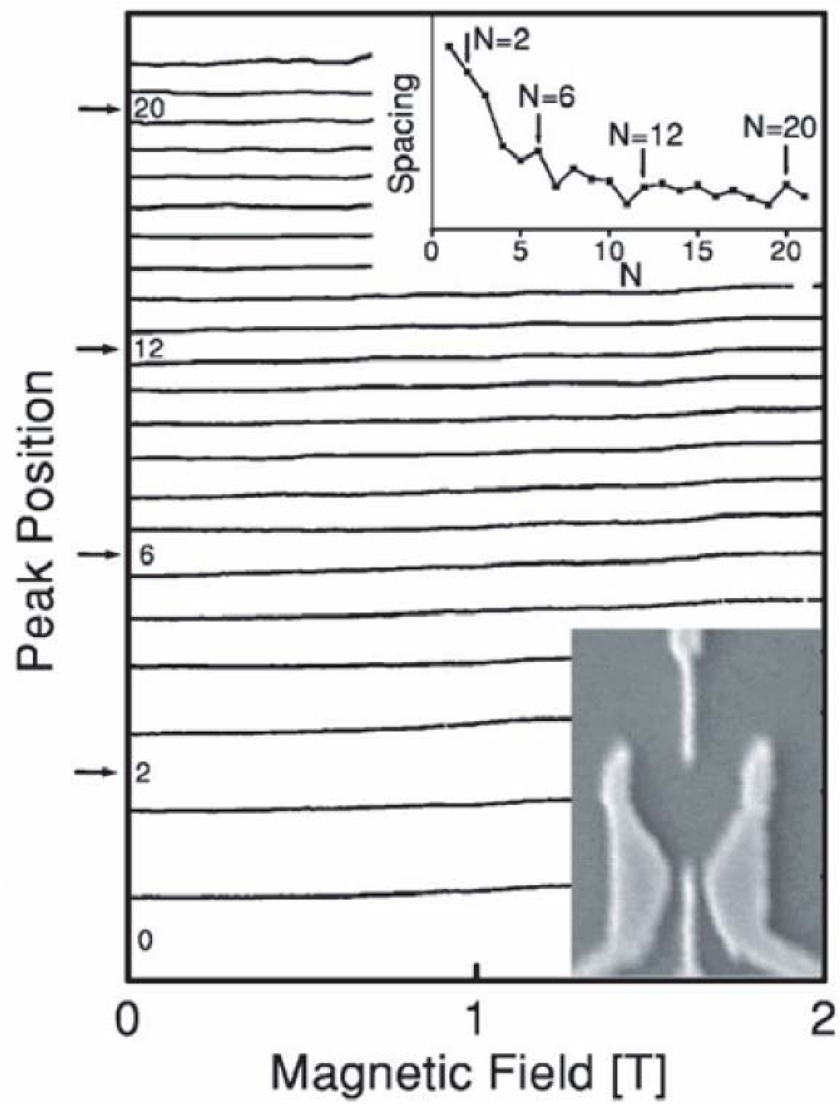
Rotation Symmetry and Angular Momentum

circular symmetry: 2D shell filling



Tarucha et al., PRL77, 3613 (1996)

circular symmetry broken



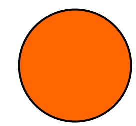
Ciorga et al., PRB61, R16315 (2000)

Quantum Harmonic Oscillator

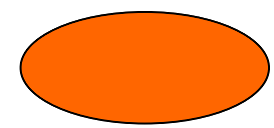
harmonic oscillator Hamiltonian

$$H = \frac{p_x^2}{2m^*} + \frac{1}{2}m^*\omega^2 x^2 + \frac{p_y^2}{2m^*} + \frac{1}{2}m^*\omega^2 y^2$$

isotropic, circular symmetry: $\omega_x = \omega_y$



anisotropic, no rotation symmetry: $\omega_x \neq \omega_y$



energy levels:

$$E_{p,q} = \left(p + \tfrac{1}{2}\right)\hbar\omega_x + \left(q + \tfrac{1}{2}\right)\hbar\omega_y$$

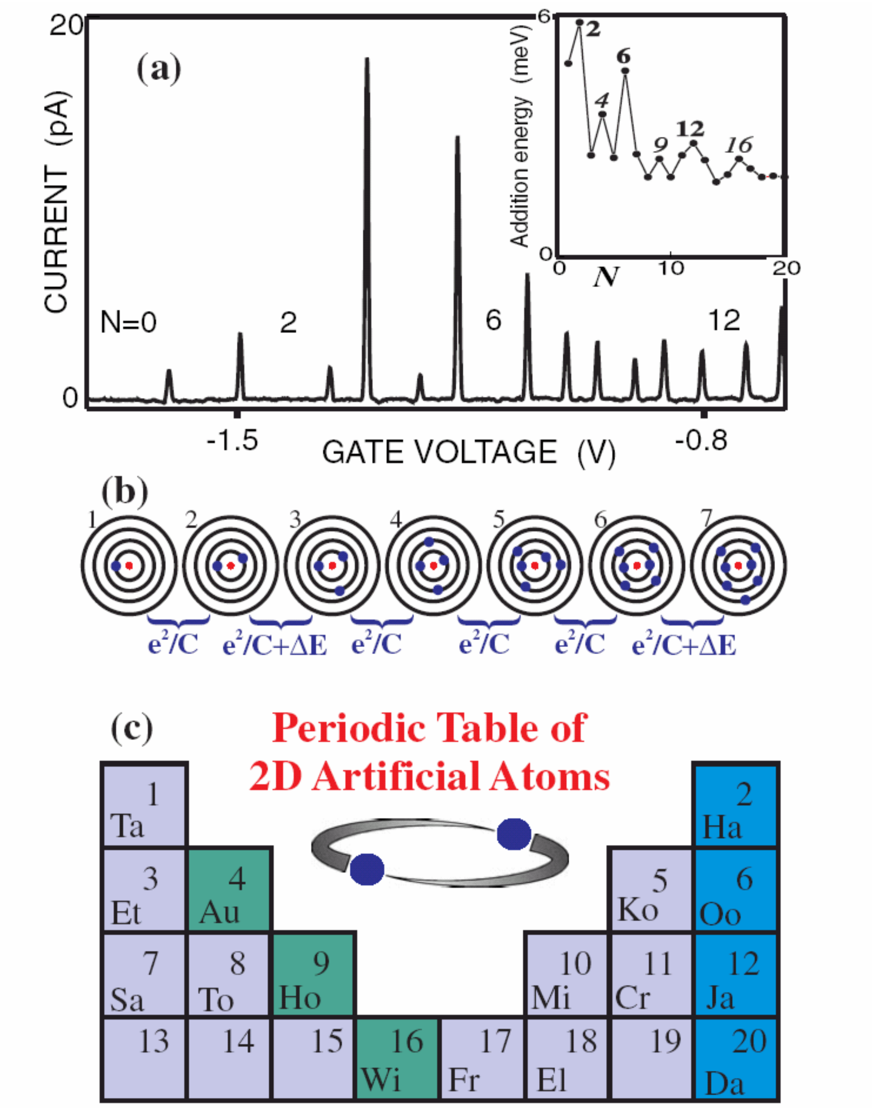
in magnetic field

$$\epsilon_{jk} = j\frac{\hbar}{2}\sqrt{\omega_c^2 + (\omega_a + \omega_b)^2} + k\frac{\hbar}{2}\sqrt{\omega_c^2 + (\omega_a - \omega_b)^2}$$

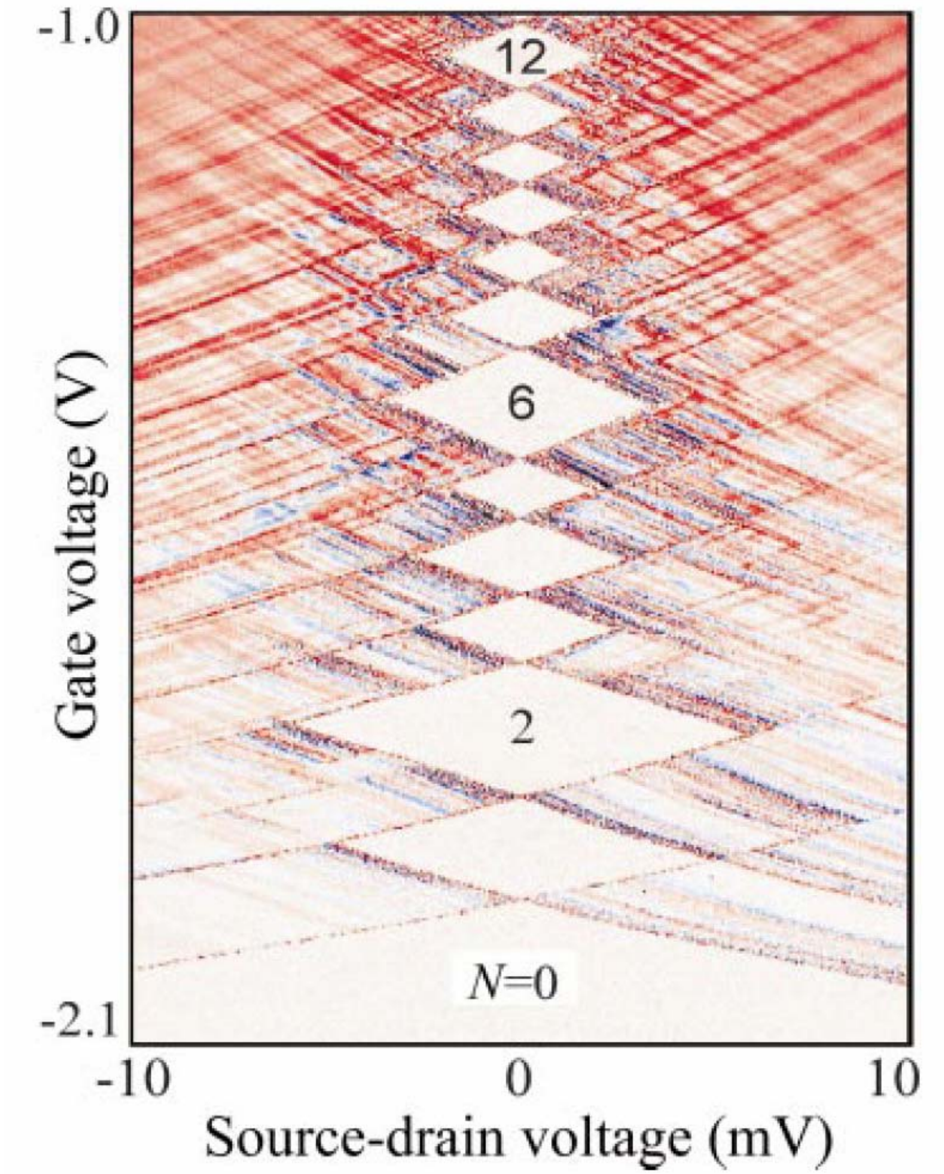
$$j \in \{1, 2, ...\} \text{ and } k \in \{j-1, j-3, ..., -j+1\}$$

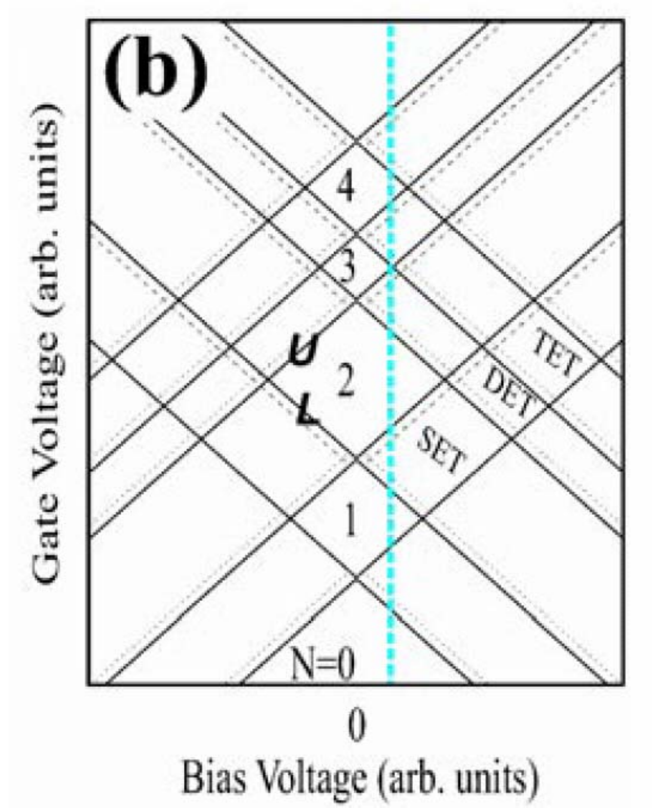
B. Schuh, J. Phys A: Math. Gen. 18, 803 (1985)

2D Periodic Table of Elements

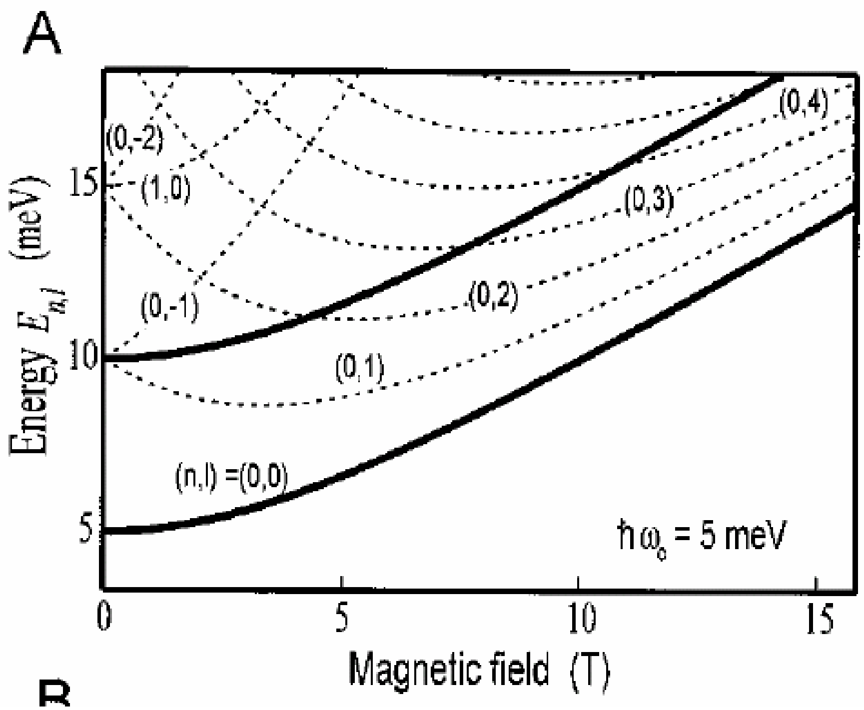


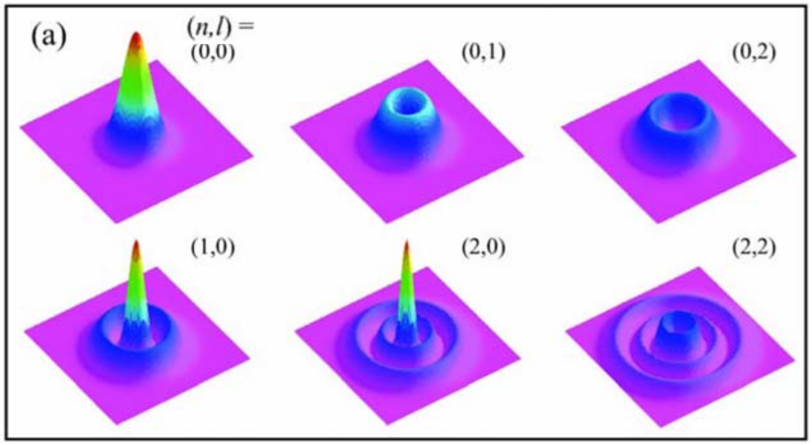
Excitation Spectra of Circular, Few Electron Dots





Fock-Darwin States: Single Particle Levels





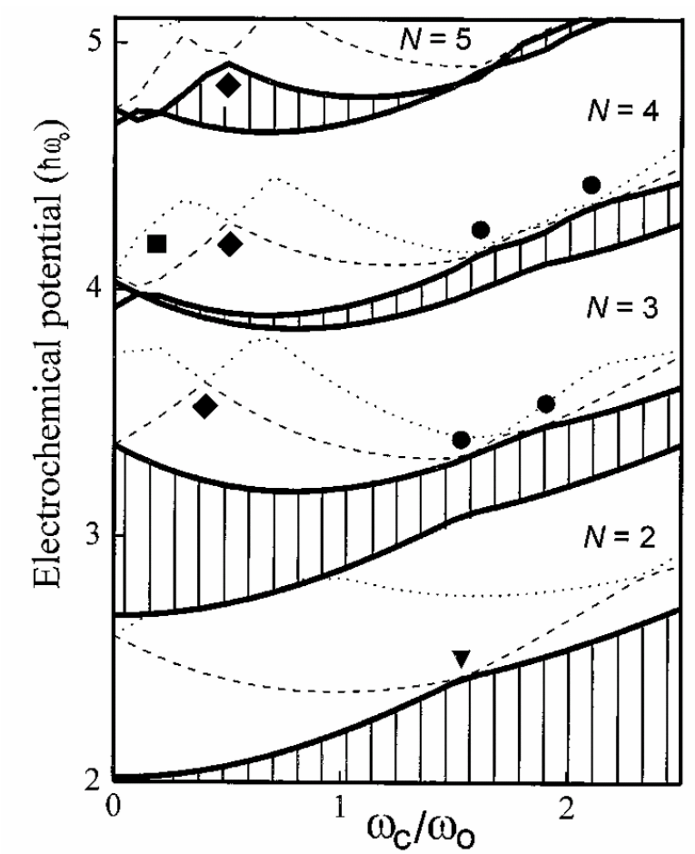
Fock-Darwin Energies

$$E_{n,\ell} = (2n + |\ell| + 1)\hbar\sqrt{\left(\frac{1}{4}\omega_c^2 + \omega_o^2\right)} - \frac{1}{2}\ell\hbar\omega_c$$

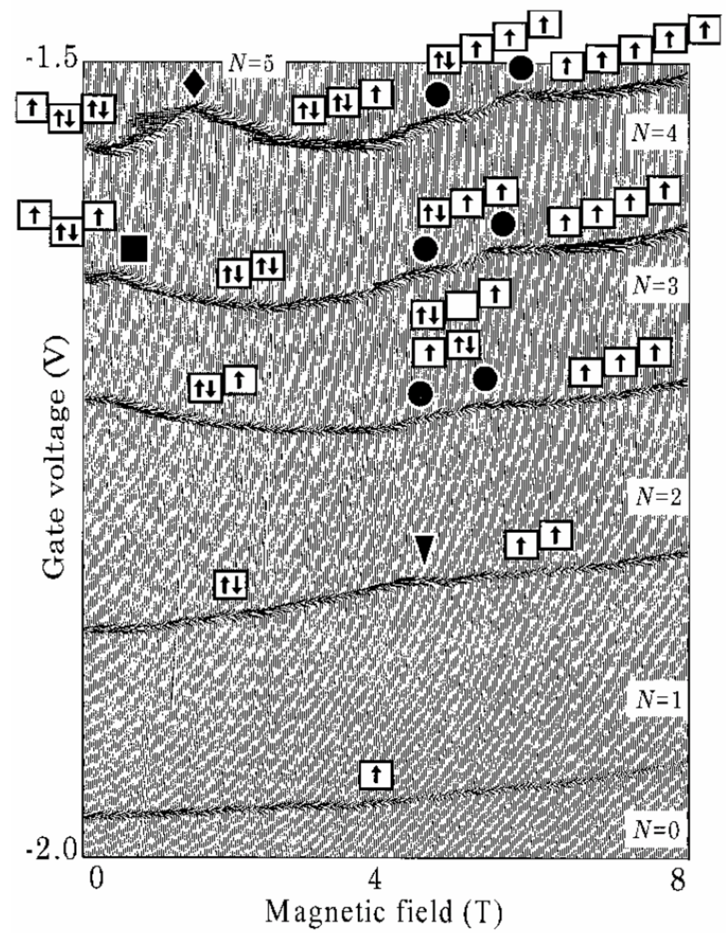
$n = 0, 1, 2, \ldots$ radial

$l = 0, \pm 1, \pm 2, \ldots$ angular momentum

Magnetic Field Transitions



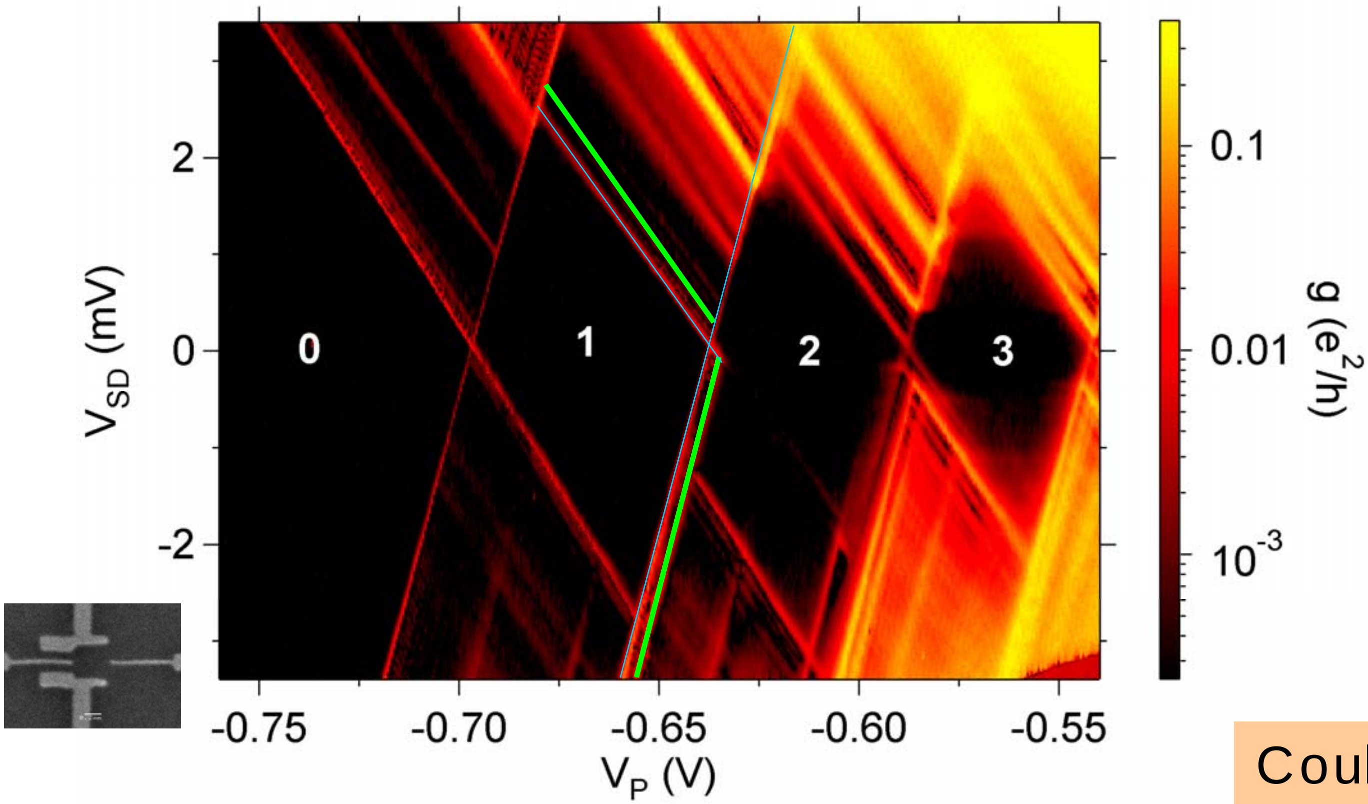
exact calculation

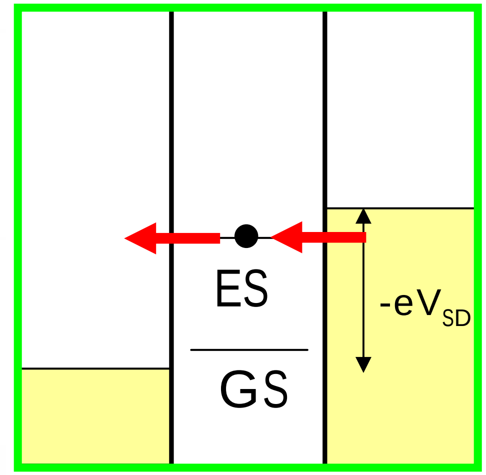


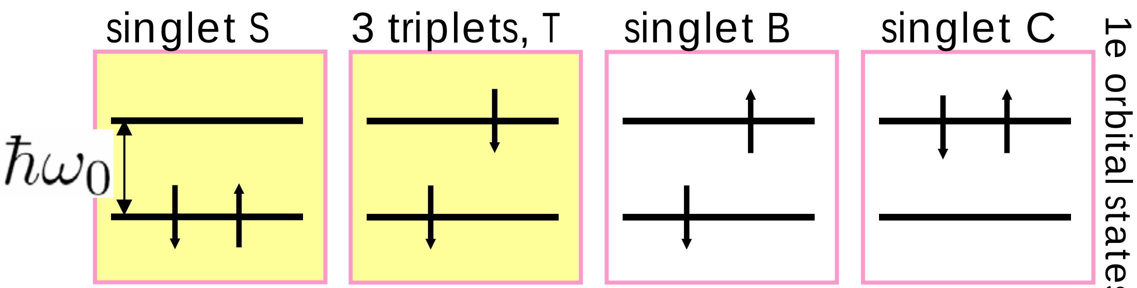
experiment

"atomic physics" like experiments not accessible in real atoms!!

Two Electron States







GS | $\hbar\omega_0$ | $\hbar\omega_0$ | $2\hbar\omega_0$

noninteracting

Coulomb interactions

$E_{singlet\ B,\ C} >> E_{S,\ T}$

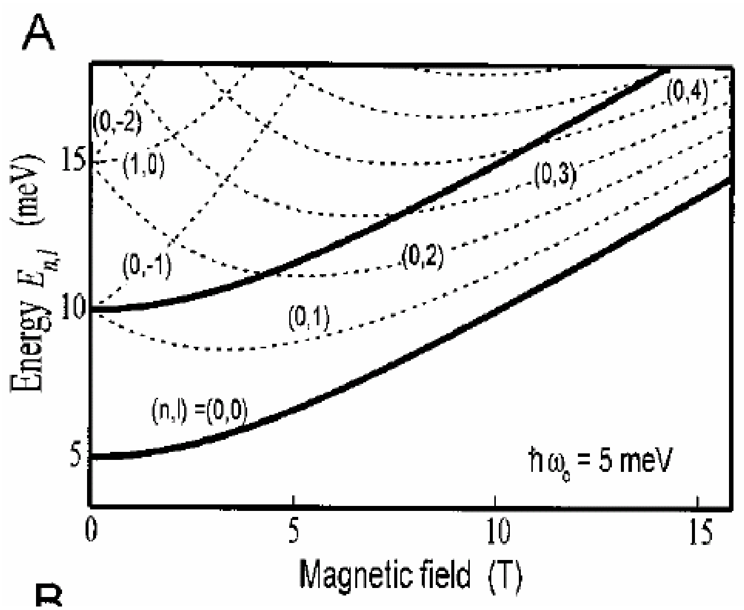
$J = E_T - E_S \sim 0.15$meV

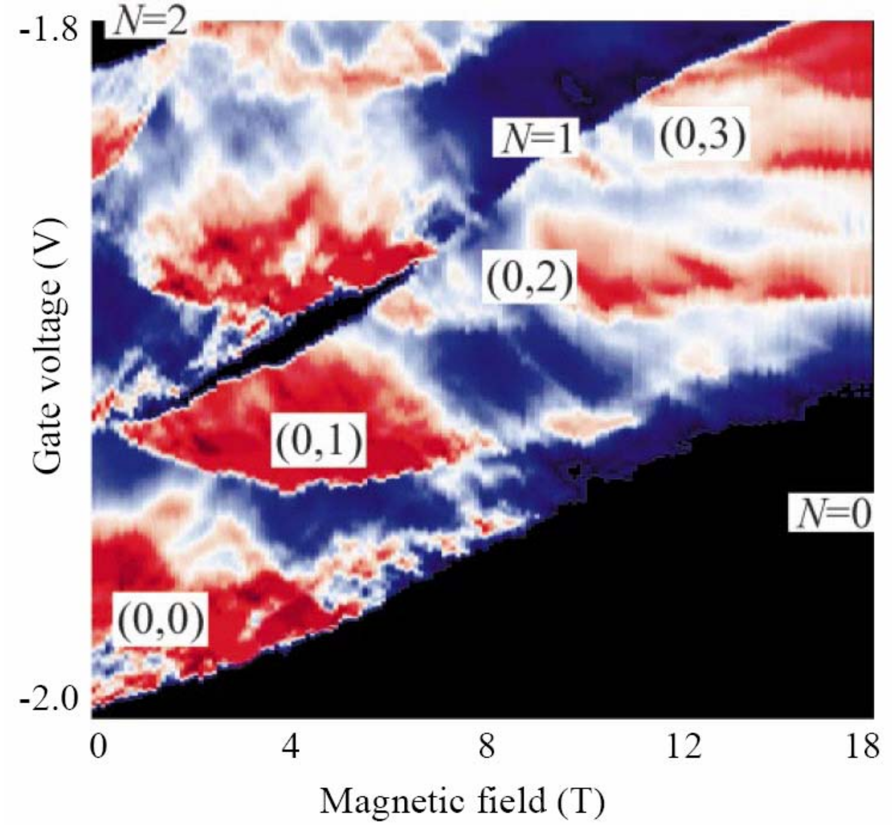
note:

$J << \hbar\omega_0 = 1\,\mathrm{meV}$

$E_T > E_S$ for N=2, B=0

Zero to One Electron Transition





Higher Transitions