

Quantum Double Dot

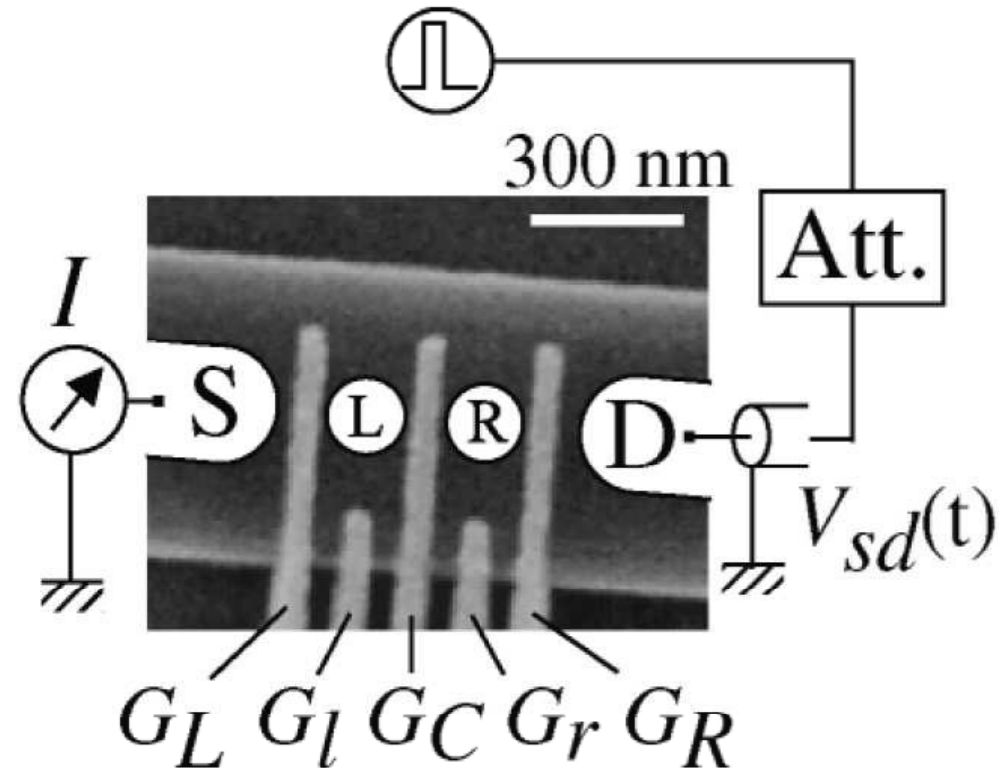
Markus Fleck, Florian Wodlei

Institut für Theoretische Physik

Juni 2007

Experimentelle Realisierung

(a) Pulse generator



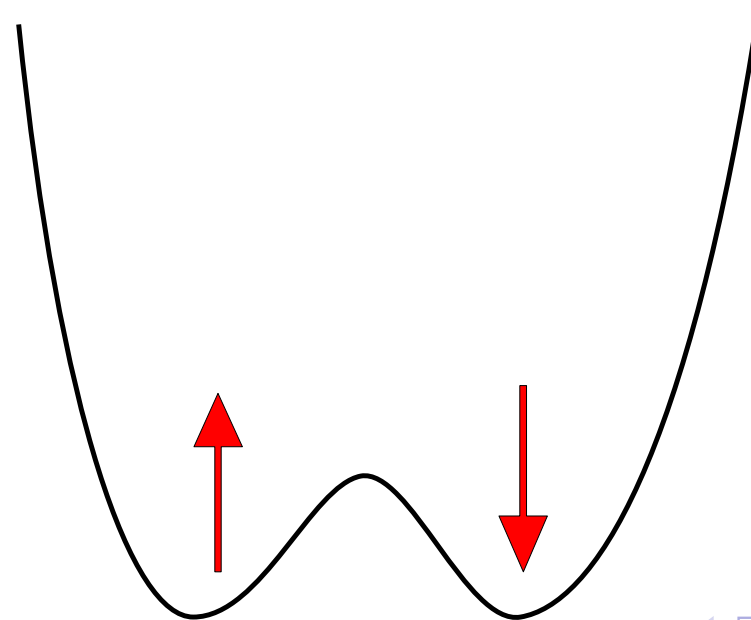
Experimentelle Fakten

Abmessung der Probe

- Abstand der Quantum Dots: 180 nm
- Durchmesser der Quantum Dots: ~ 30 nm

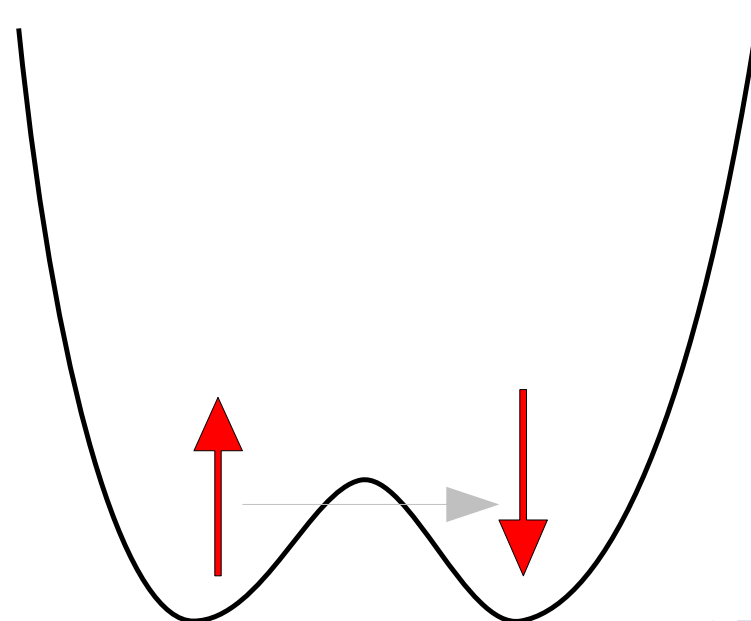
Hubbard Modell

$$H = U \underbrace{\sum_i c_{i,\uparrow}^\dagger c_{i,\uparrow} c_{i,\downarrow}^\dagger c_{i,\downarrow}}_{H_c} - t \underbrace{\sum_{i,\sigma} c_{i,\sigma}^\dagger c_{i+1,\sigma}}_T$$



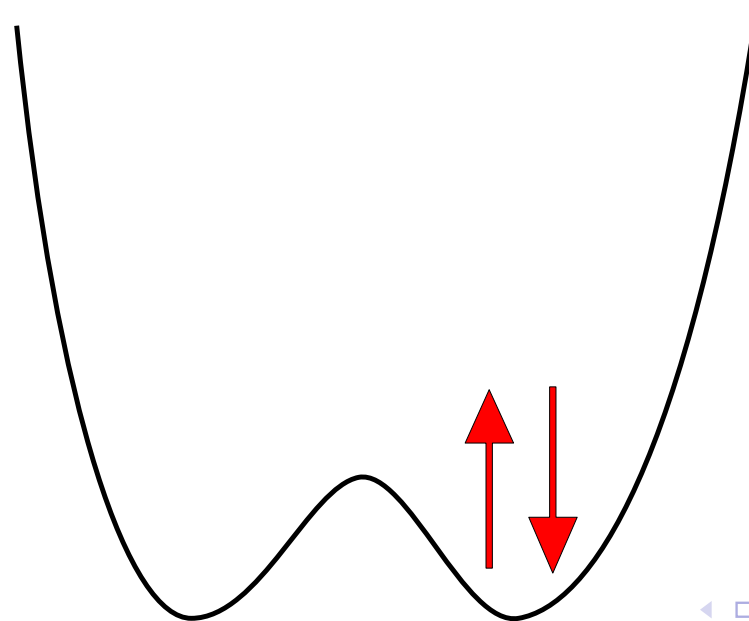
Tunneln der Elektronen

$$H = U \underbrace{\sum_i c_{i,\uparrow}^\dagger c_{i,\uparrow} c_{i,\downarrow}^\dagger c_{i,\downarrow}}_{H_c} - t \underbrace{\sum_{i,\sigma} c_{i,\sigma}^\dagger c_{i+1,\sigma}}_T$$



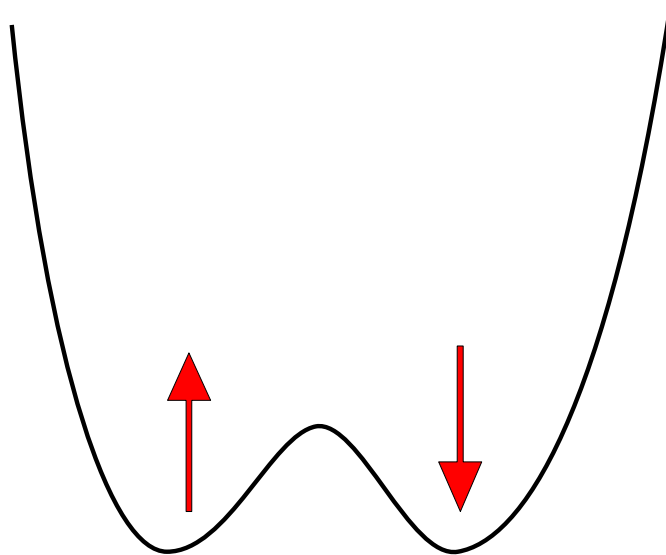
Coulomb Wechselwirkung

$$H = \underbrace{U \sum_i c_{i,\uparrow}^\dagger c_{i,\uparrow} c_{i,\downarrow}^\dagger c_{i,\downarrow}}_{H_c} - t \underbrace{\sum_{i,\sigma} c_{i,\sigma}^\dagger c_{i+1,\sigma}}_T$$



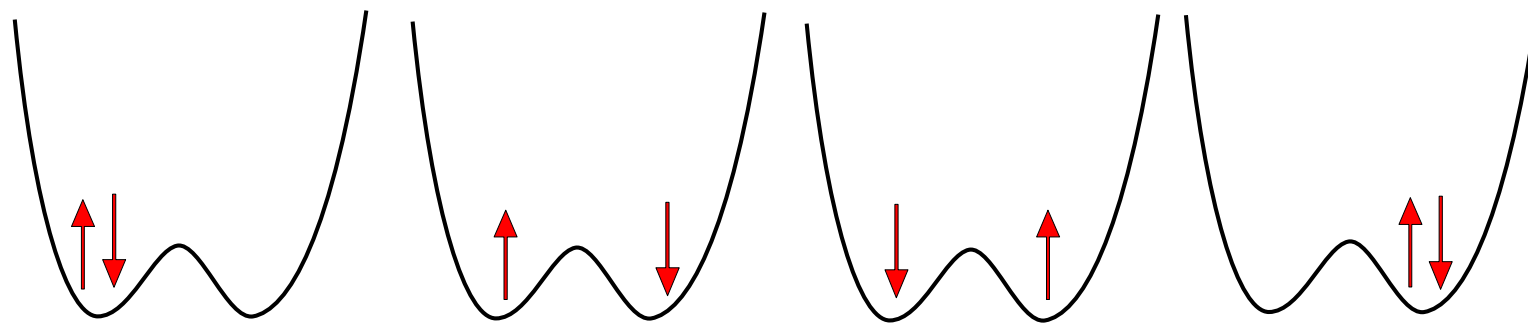
Parameter des Hubbard Modells

$$t = \int dr_1 \psi_L^*(r_1) H_0 \psi_R(r_1)$$
$$U = \frac{e^2}{\epsilon_B} \int dr_1 dr_2 \frac{|\psi_L(r_1)|^2 |\psi_L(r_2)|^2}{|r_1 - r_2|}$$



Basiszustände des Hubbard Hamiltonoperators

$$H = U \underbrace{\sum_i c_{i,\uparrow}^\dagger c_{i,\uparrow} c_{i,\downarrow}^\dagger c_{i,\downarrow}}_{H_c} - t \underbrace{\sum_{i,\sigma} c_{i,\sigma}^\dagger c_{i+1,\sigma}}_T$$


 $|L \uparrow, L \downarrow\rangle$
 $|L \uparrow, R \downarrow\rangle$
 $|R \uparrow, L \downarrow\rangle$
 $|R \uparrow, R \downarrow\rangle$

Hubbard Hamiltonoperators

$$H = \begin{pmatrix} U & -t & -t & 0 \\ -t & 0 & 0 & -t \\ -t & 0 & 0 & -t \\ 0 & -t & -t & U \end{pmatrix}$$

Eigenzustände und Energien

$$v_4 = \begin{pmatrix} 1 \\ -1 \\ -1 \\ 1 \end{pmatrix} \quad v_3 = \begin{pmatrix} -1 \\ 0 \\ 0 \\ 1 \end{pmatrix} \quad v_2 = \begin{pmatrix} 0 \\ -1 \\ 1 \\ 0 \end{pmatrix} \quad v_1 = \begin{pmatrix} 1 \\ 1 \\ 1 \\ 1 \end{pmatrix}$$

mit den Energien:

$$E_4 = \frac{1}{2}(U + \sqrt{16t^2 + U^2}) \quad E_3 = U \quad E_2 = 0 \quad E_1 = \frac{1}{2}(U - \sqrt{16t^2 + U^2})$$

Starke Coulomb Wechselwirkung ($U \gg t$)

Falls $U \gg t$ kann man T als Störung auffassen:

$$E_k = E_k^{(0)} + \langle k|T|k\rangle + \sum_{l \neq k} \frac{|\langle l|T|k\rangle|^2}{E_k^{(0)} - E_l^{(0)}}$$

D.h. für unseren Fall:

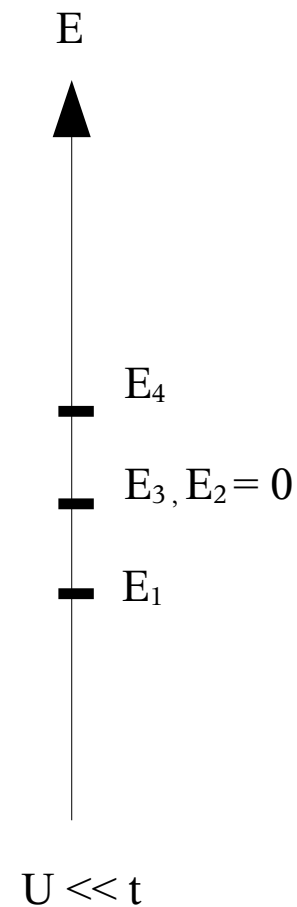
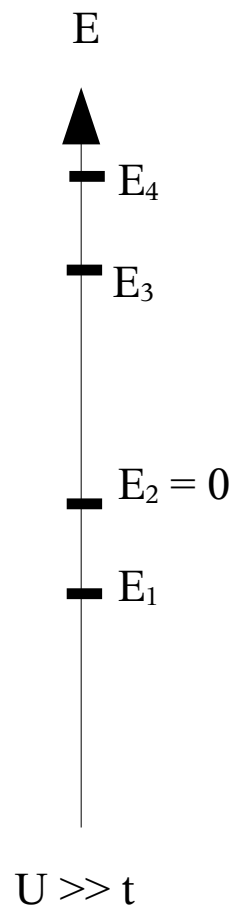
$$E_k = E_k^{(0)} - \frac{t^2}{U}$$

Schwache Coulomb Wechselwirkung ($U \ll t$)

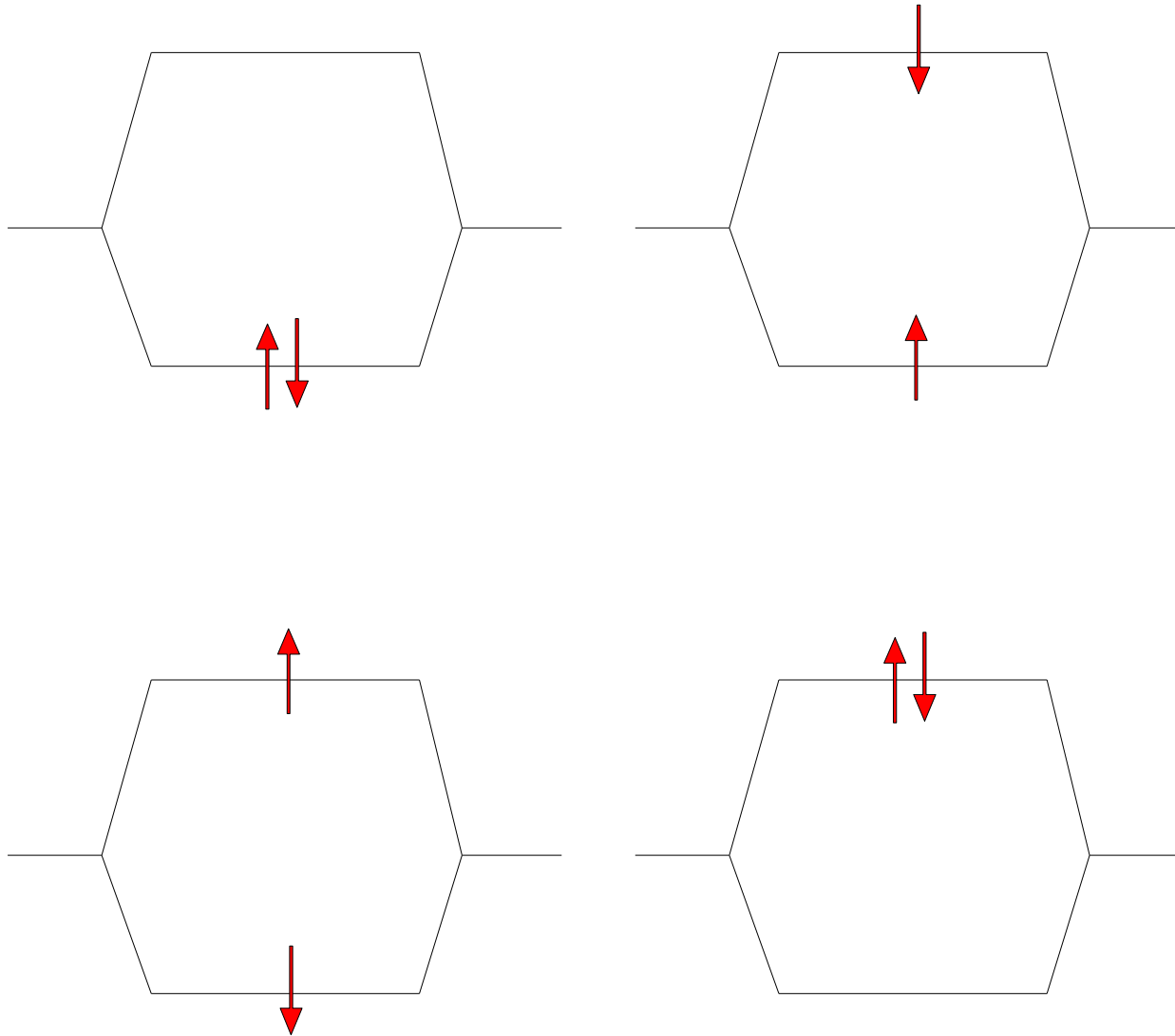
Falls $U \ll t$ folgt für die Energien:

$$E_4 = 2t \quad E_3 = 0 \quad E_2 = 0 \quad E_1 = -2t$$

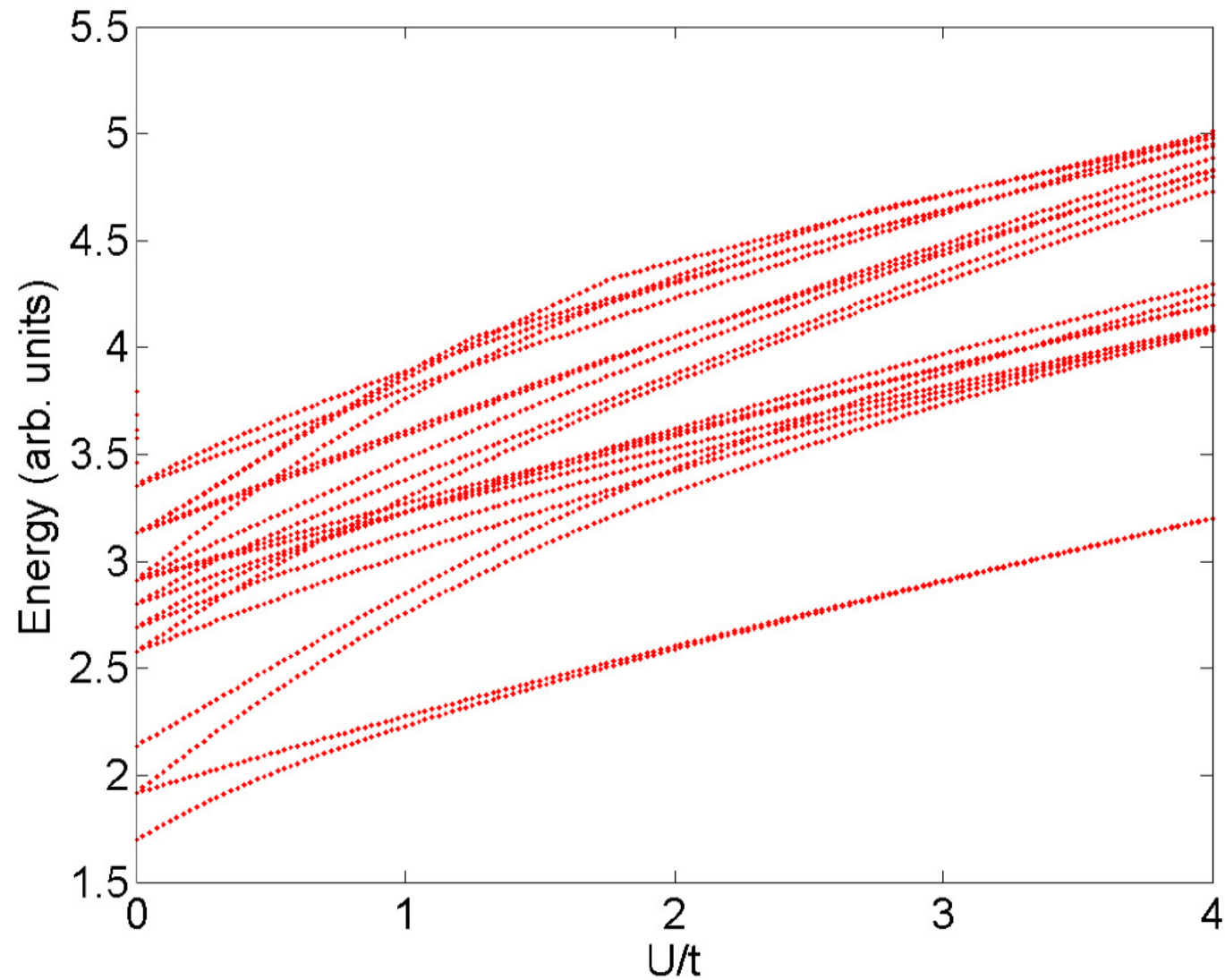
Energien für starke und schwache Coulomb Wechselwirkung



Zustände für schwache Coulomb Wechselwirkung



Energie in Abhängigkeit von der Coulomb Wechselwirkung



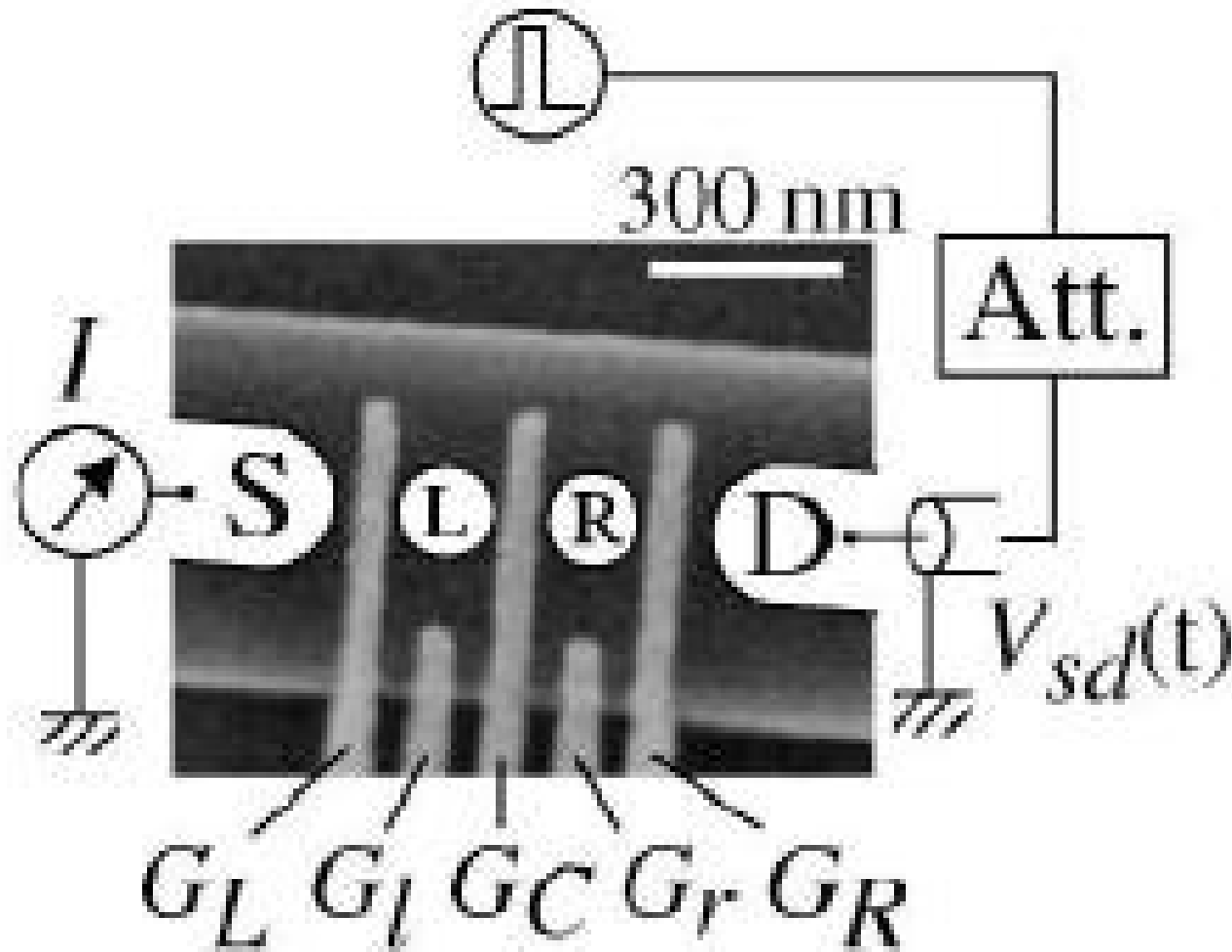
Double Quantum Dot

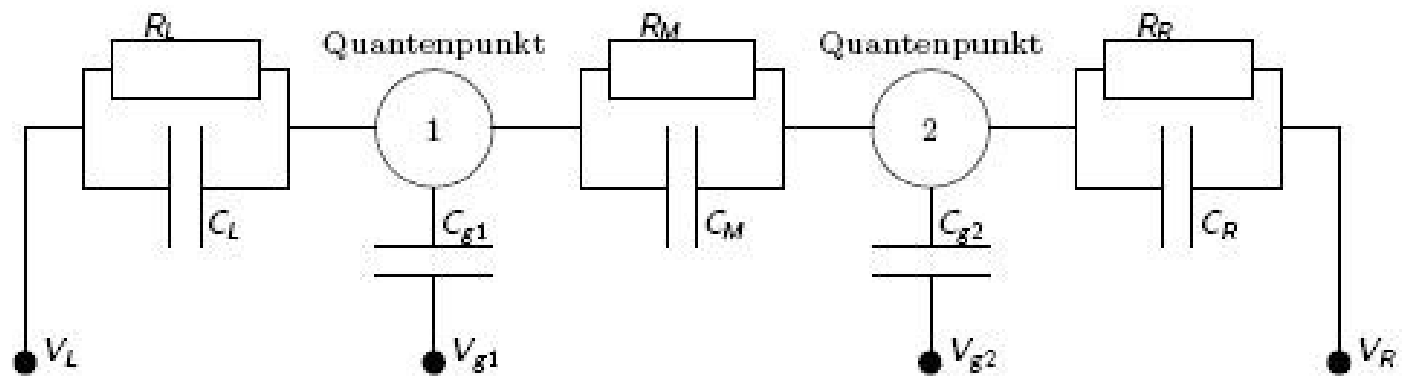
Fleck, Wodley

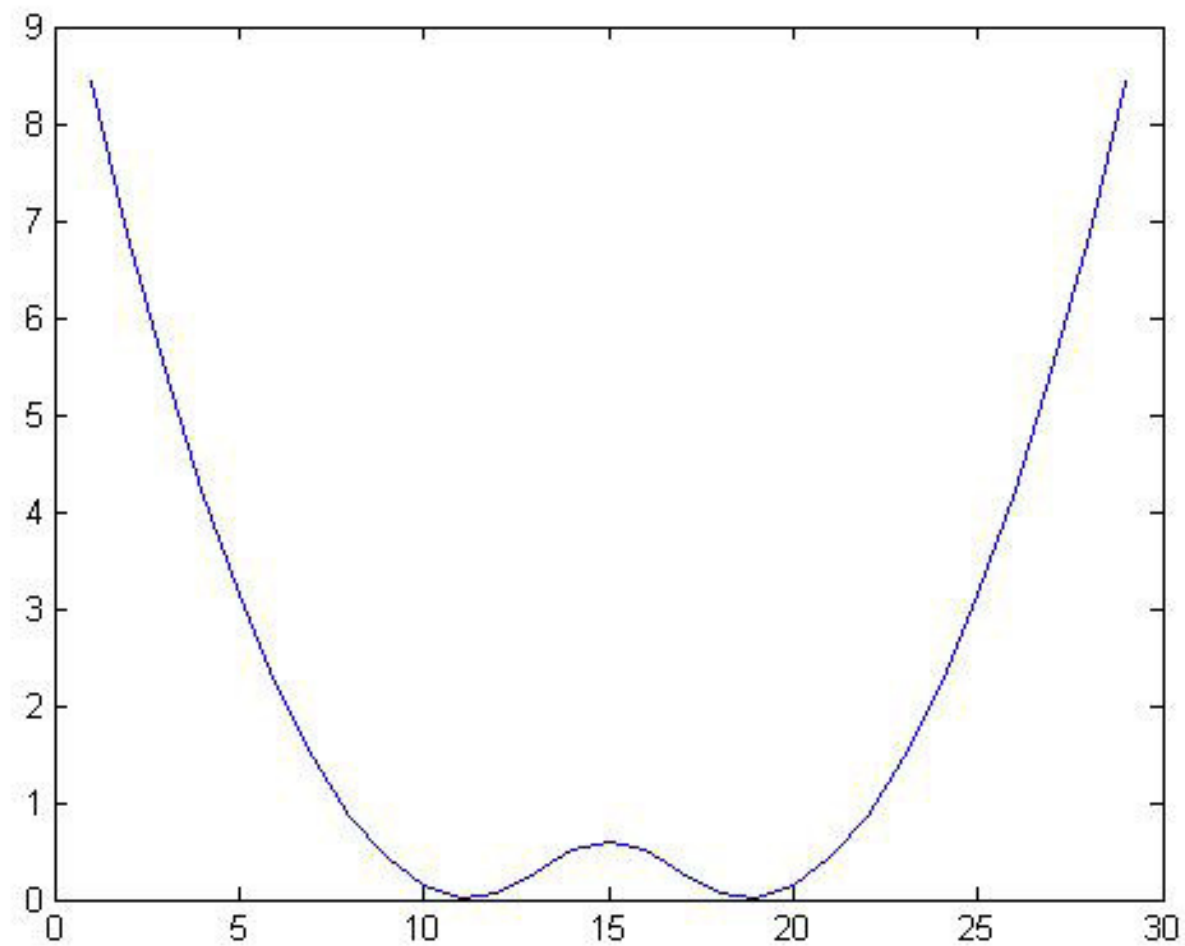
Theoretische Physik KF-Uni Graz

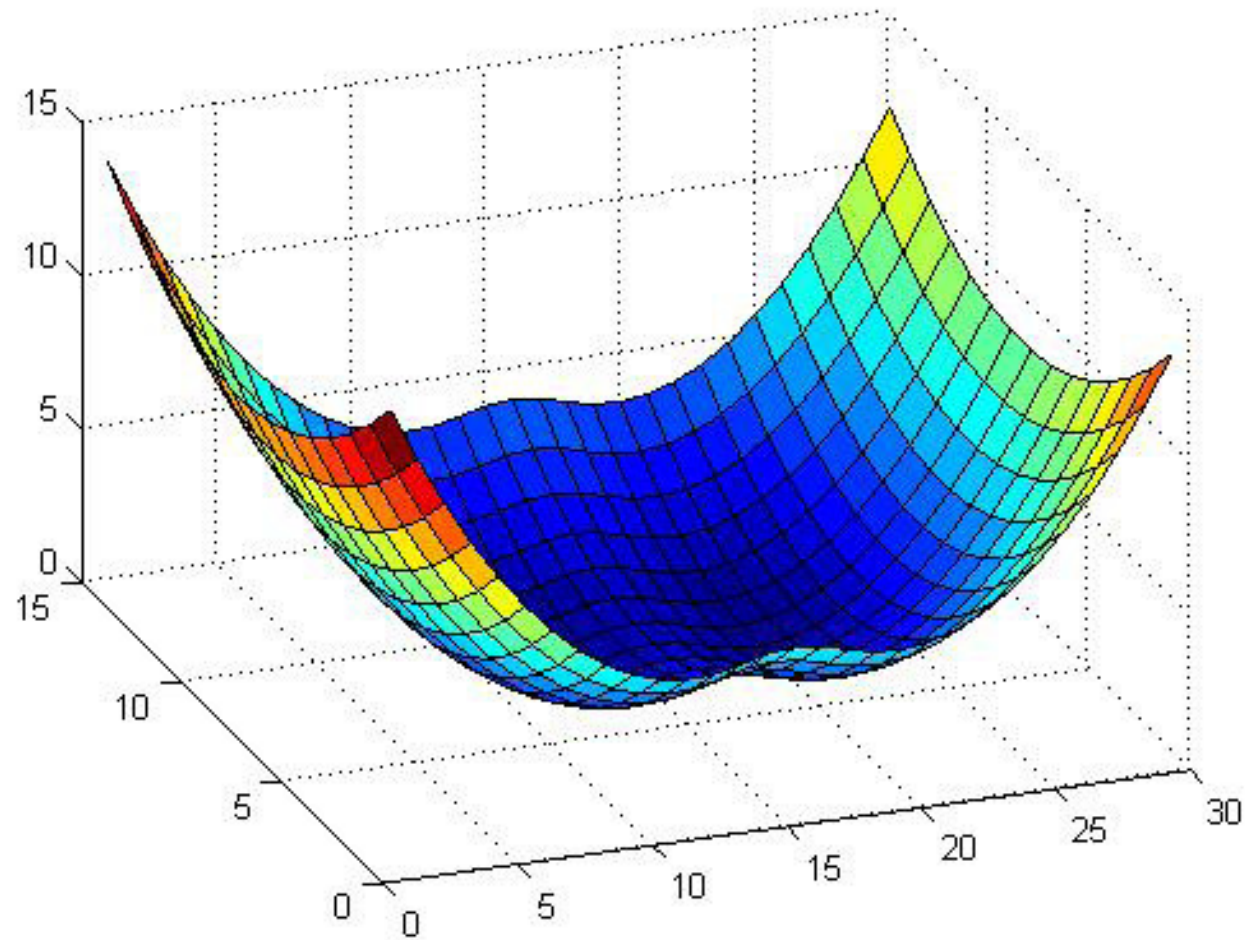
May 29, 2007

Pulse generator



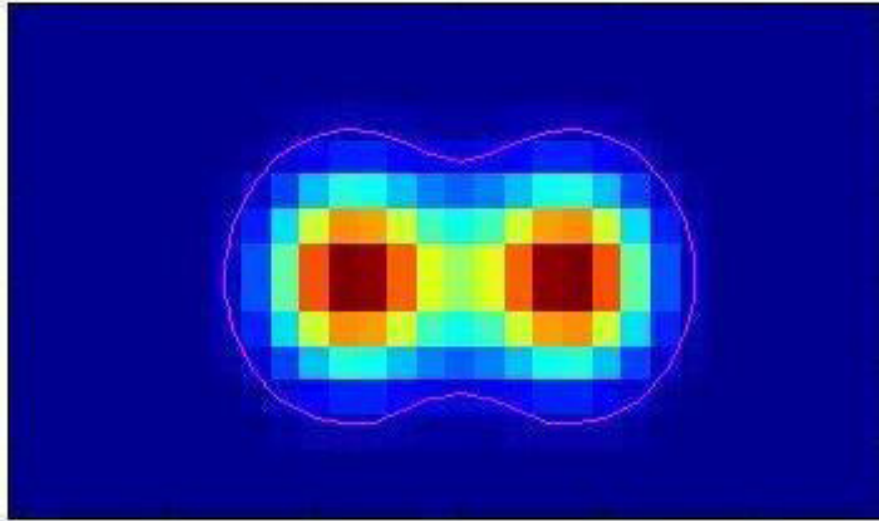




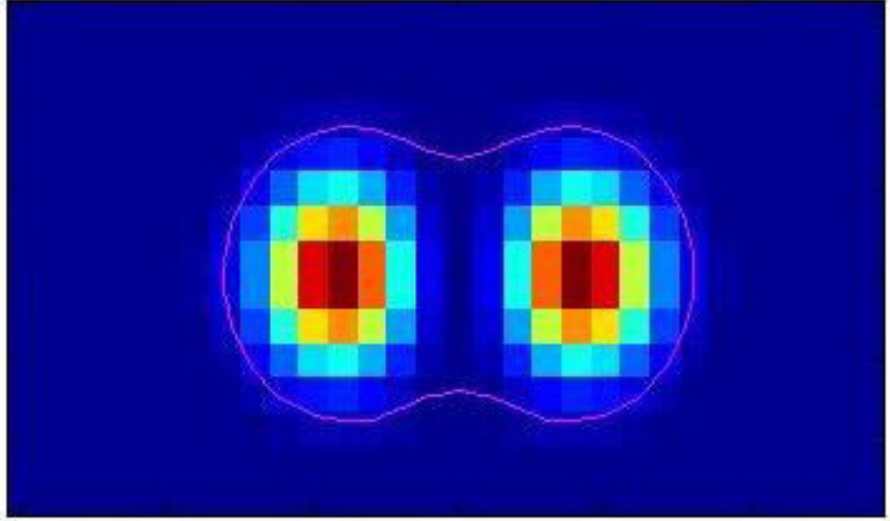


Low coulomb:

state 1

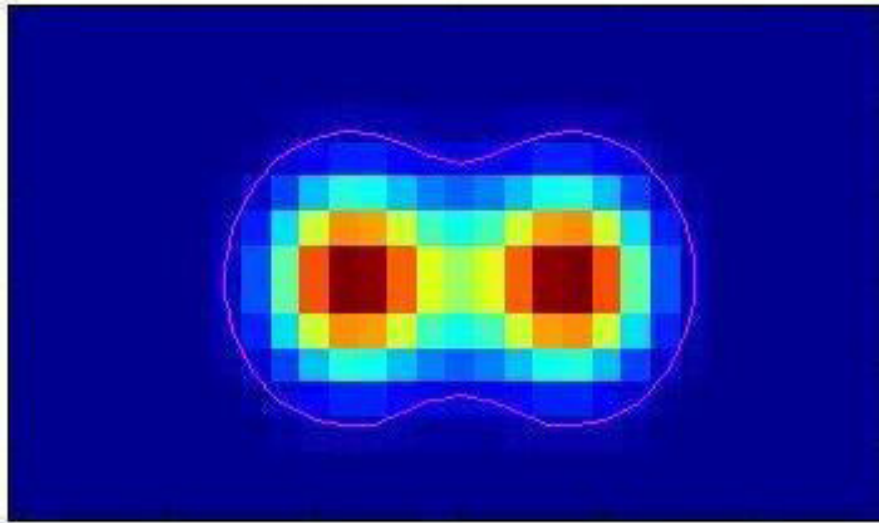


state 2

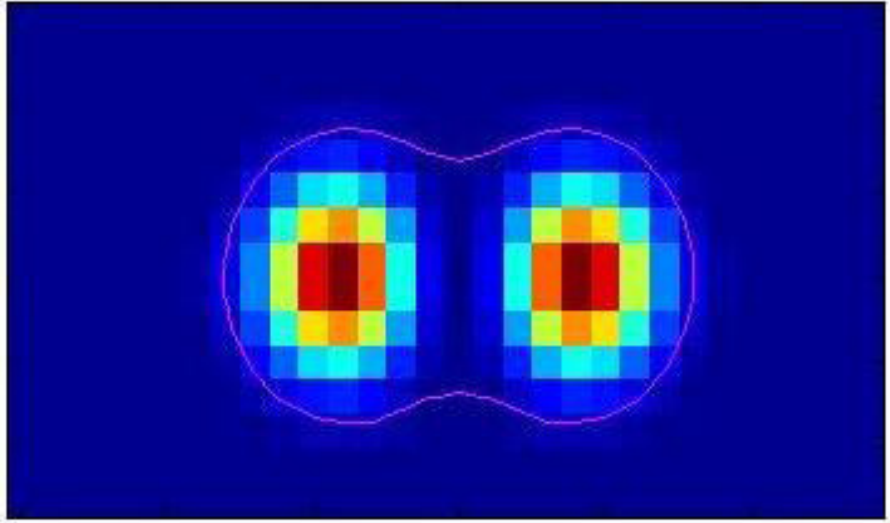


Low coulomb:

state 1

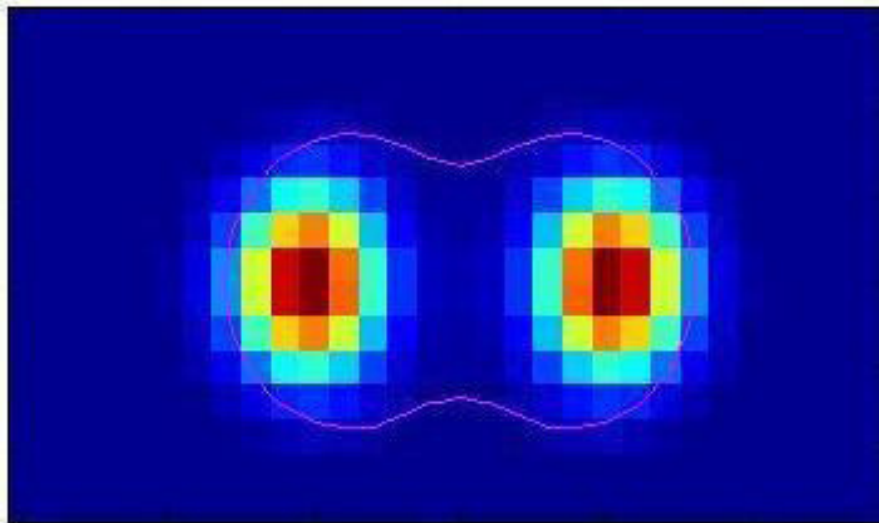


state 2

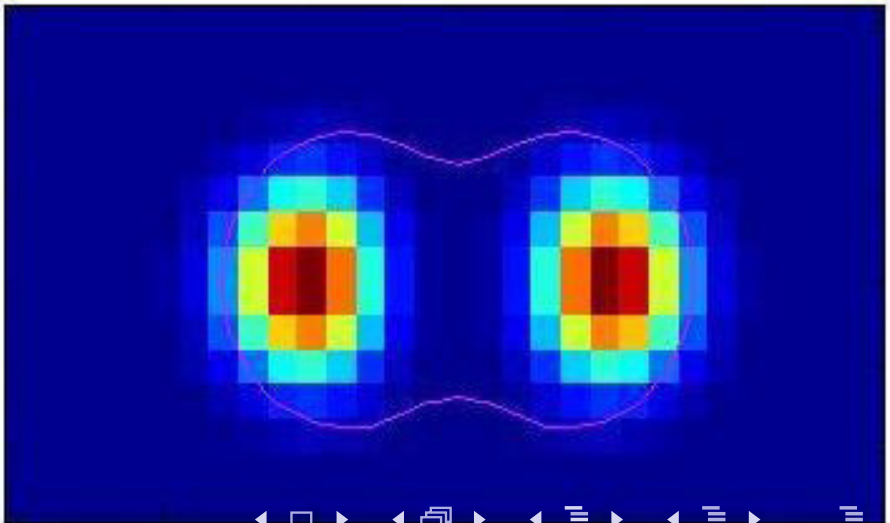


High coulomb:

state 1

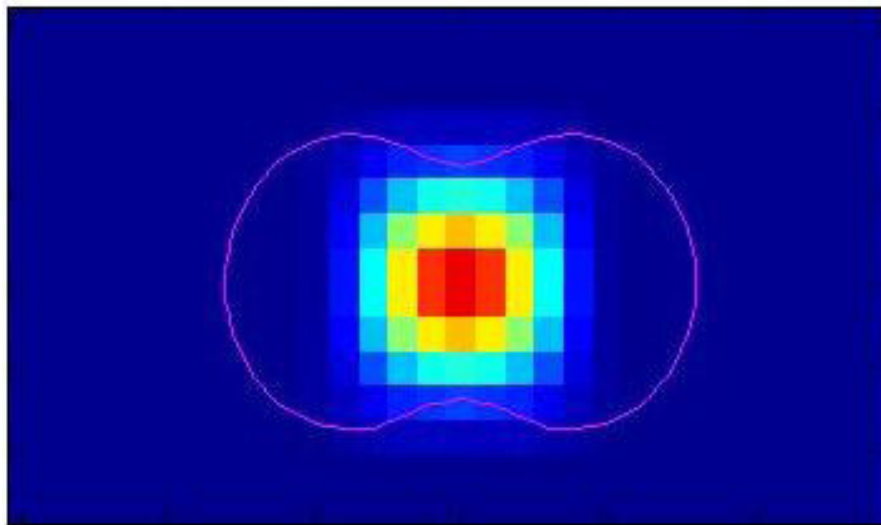


state 2

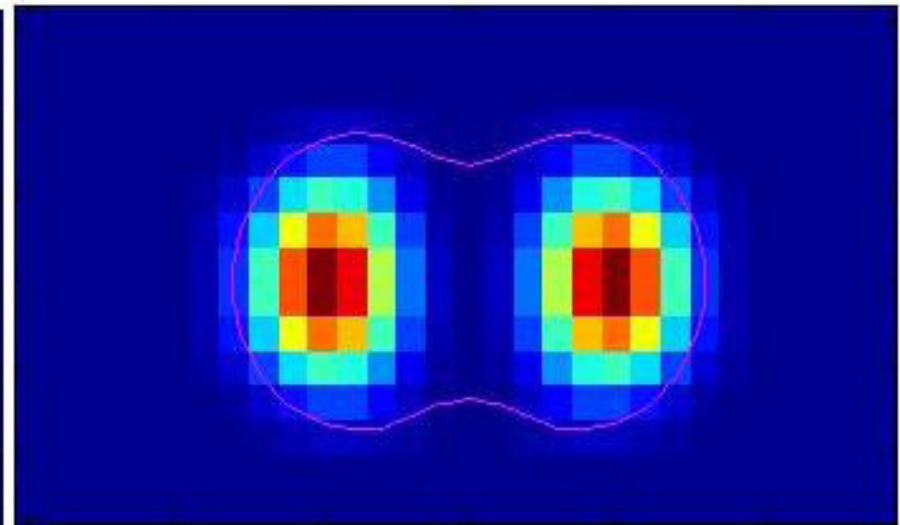


Low coulomb:

state 3

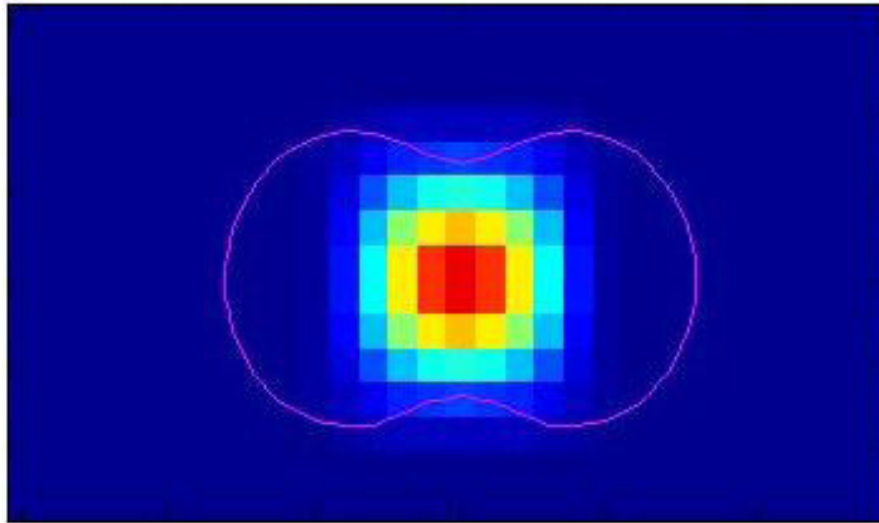


state 4

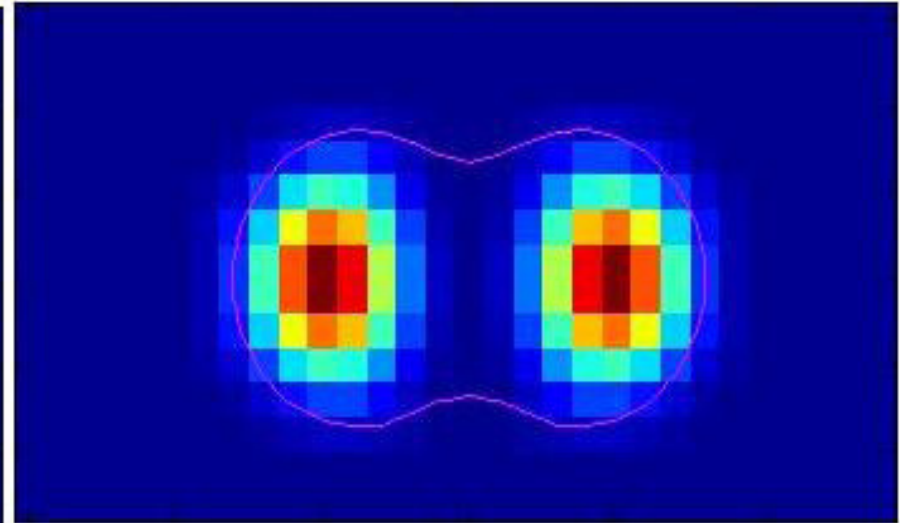


Low coulomb:

state 3

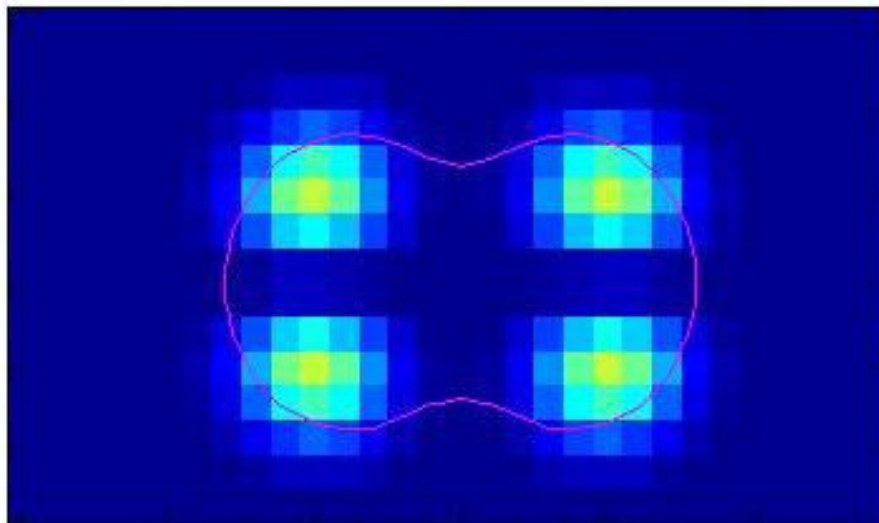


state 4

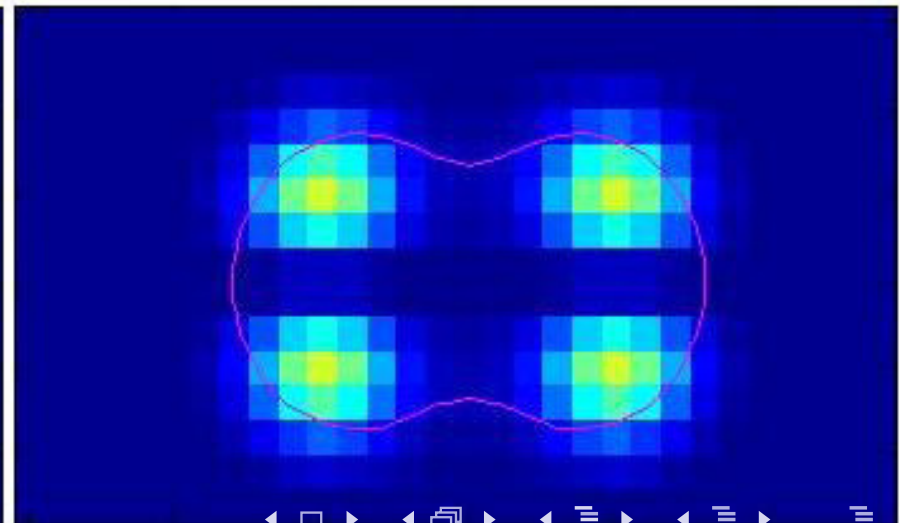


High coulomb:

state 3

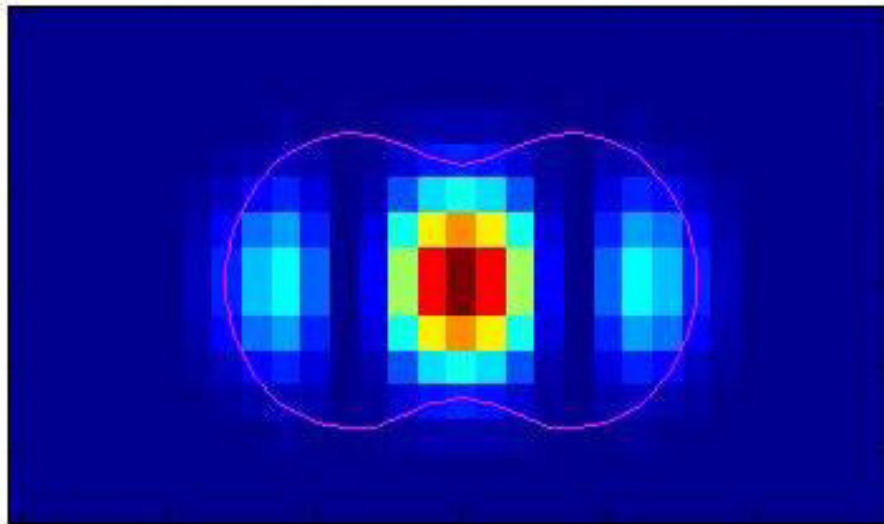


state 4

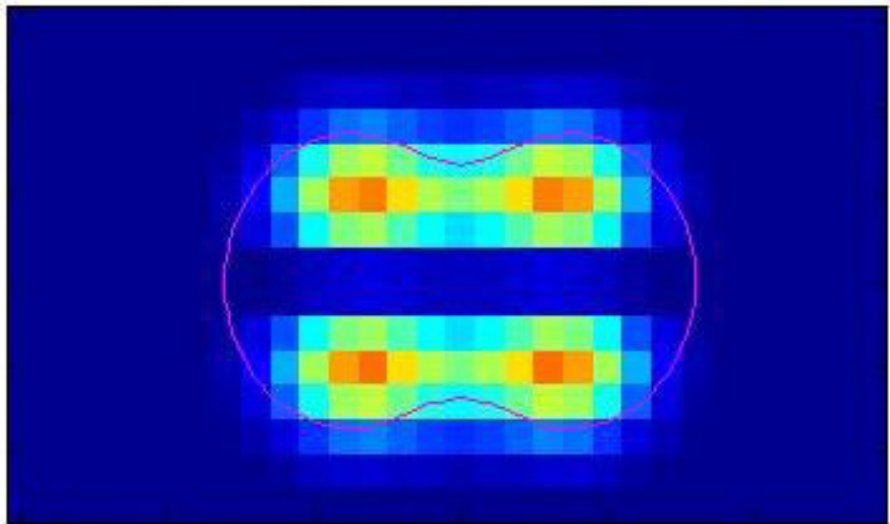


Low coulomb:

state 5

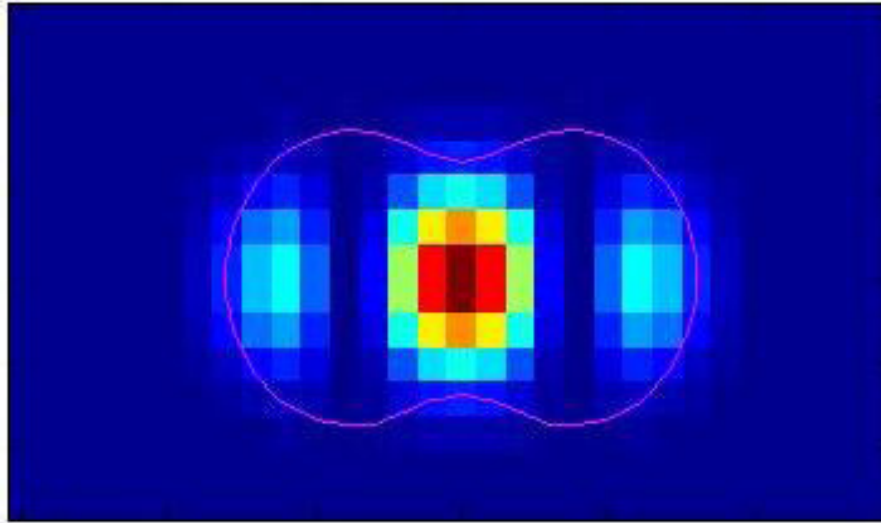


state 6

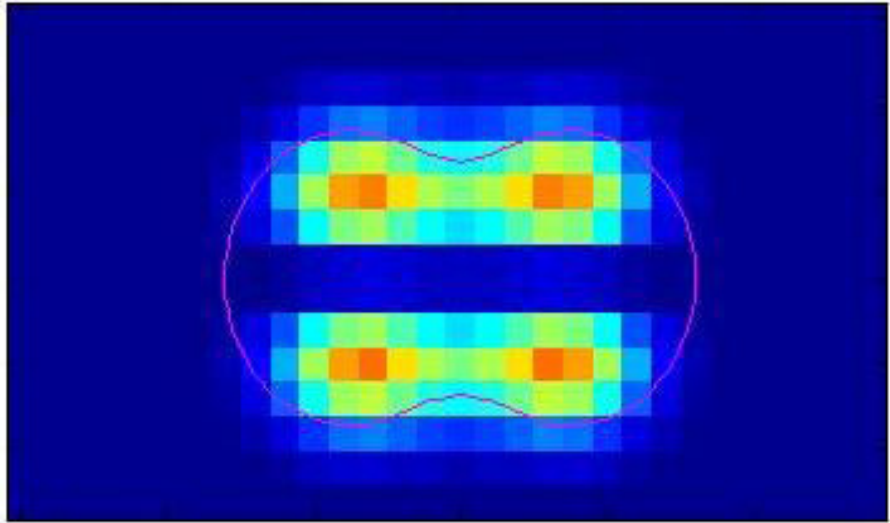


Low coulomb:

state 5

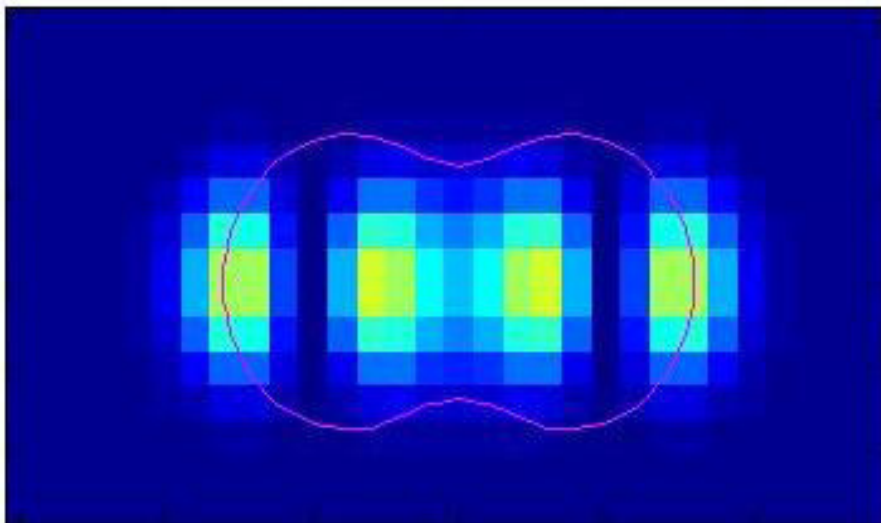


state 6



High coulomb:

state 5



state 6

