
Stefano Roddaro



Stark effect control of spin rectification in a nanowire multi-dot system

02.07.2014 - Institute of Solid State Physics - RAS

National Enterprise for nanoScience and nanoTechnology



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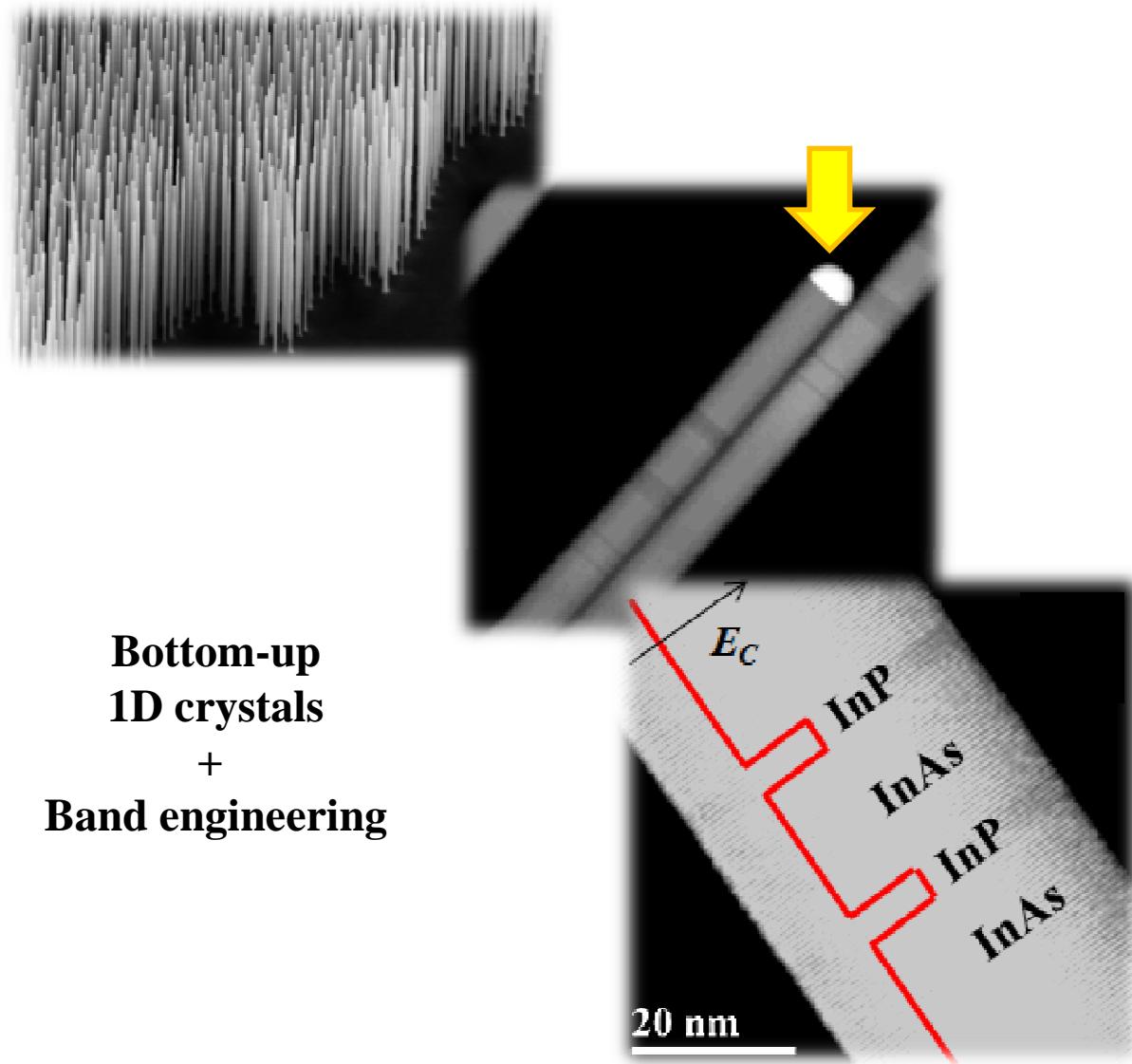


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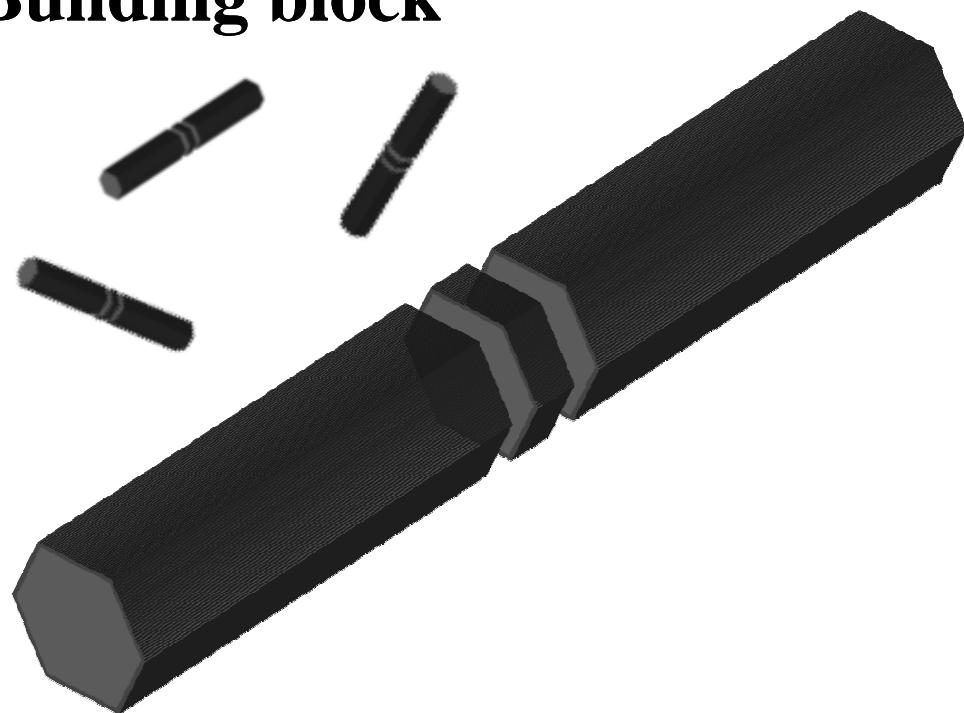
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- 2. Single-electron effects in NW-FET devices**
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- 4. Controlling two QDs at the same time without local gates**
- 5. Conclusions**

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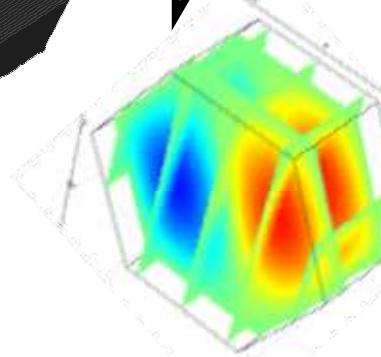
Building block



Building block



Fundamental research on
single-electron physics



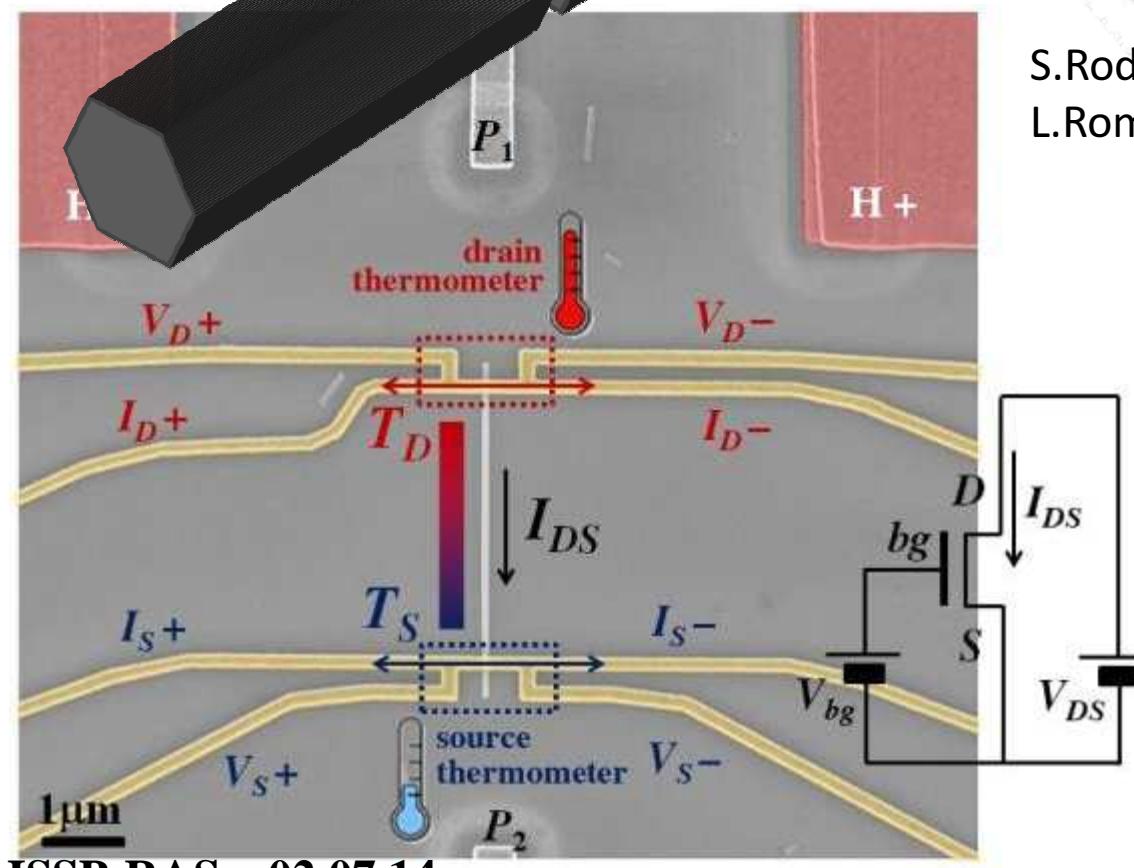
PERSPECTIVES

- Room temperature single-electron effects
- Single spin physics

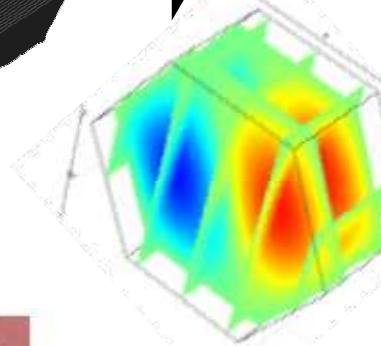
S.Roddaro *et al.* Nano Lett. **11**, 1695 (2011)

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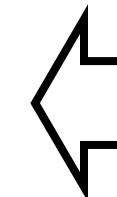
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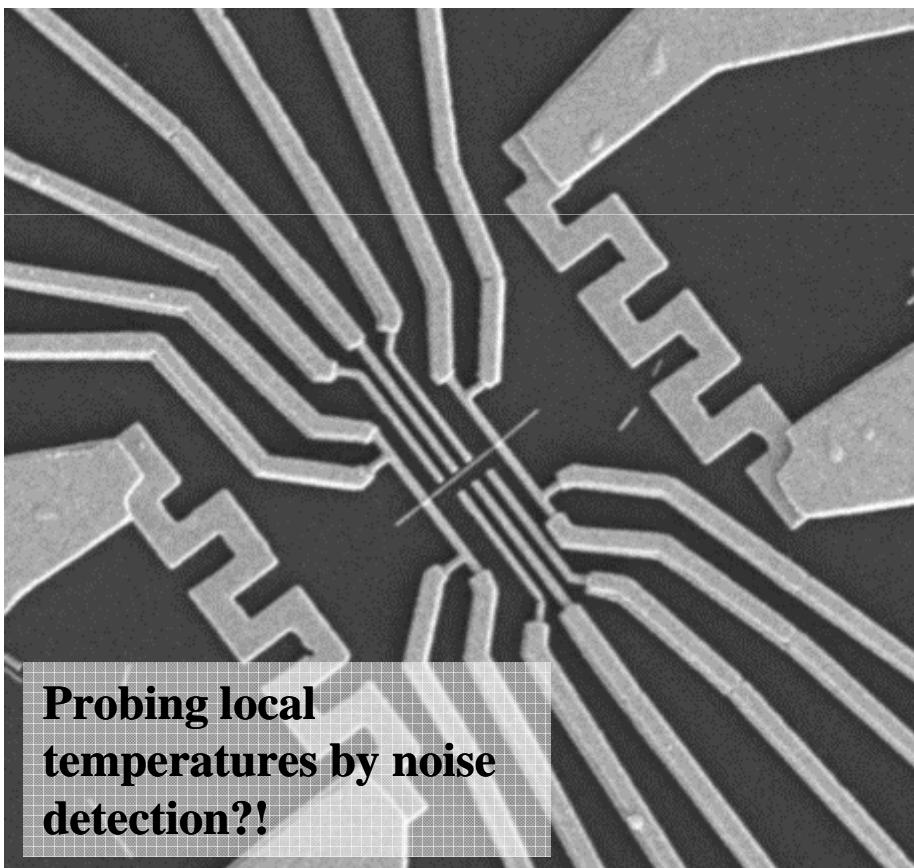
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Thermoelectric effects
on the nanometer scale

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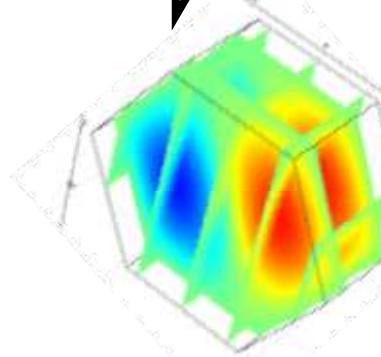
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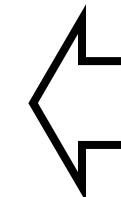
ISSP-RAS – 02.07.14



Fundamental research on
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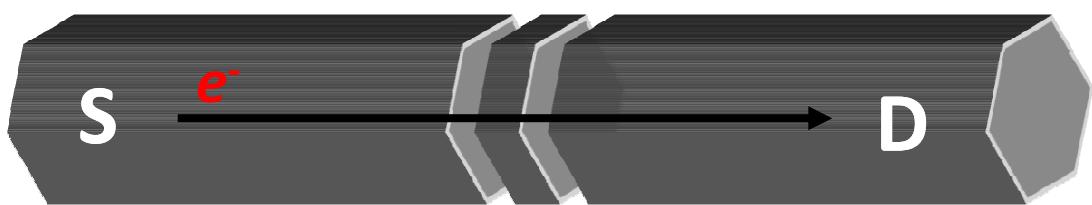


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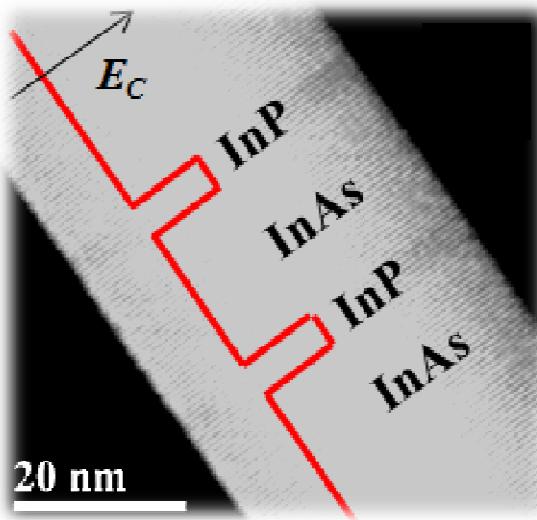
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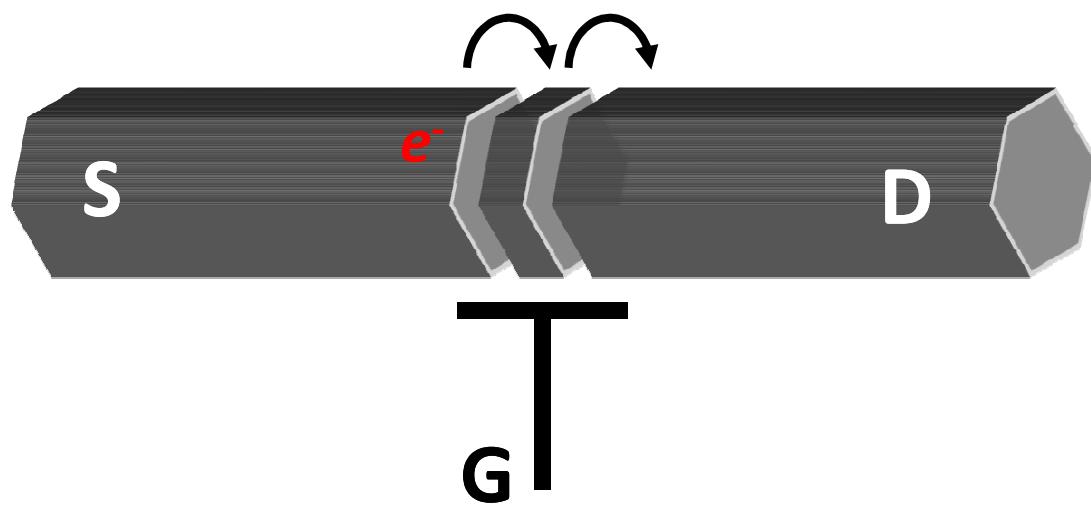


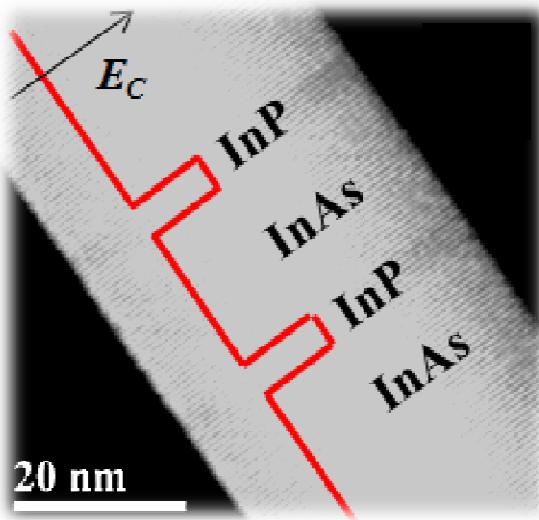


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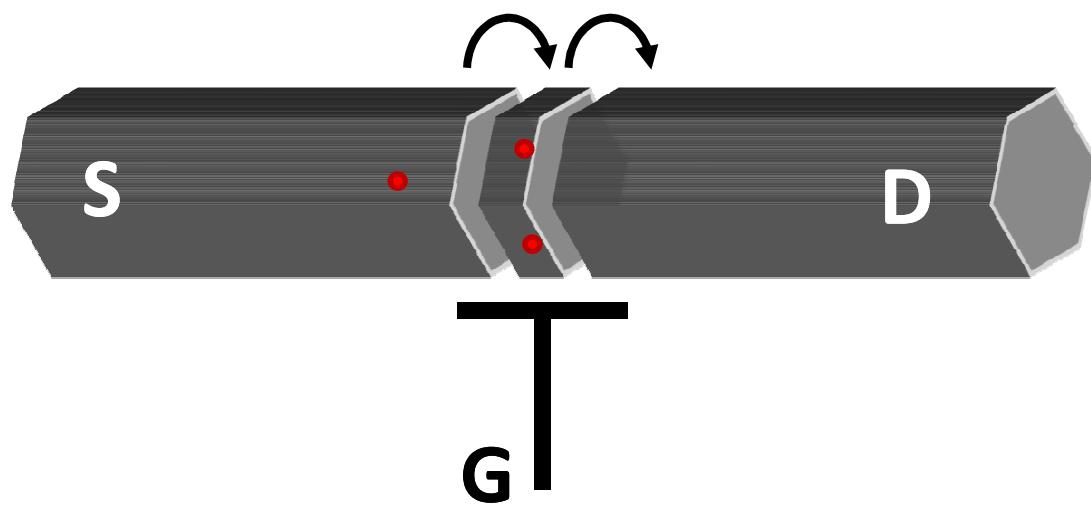


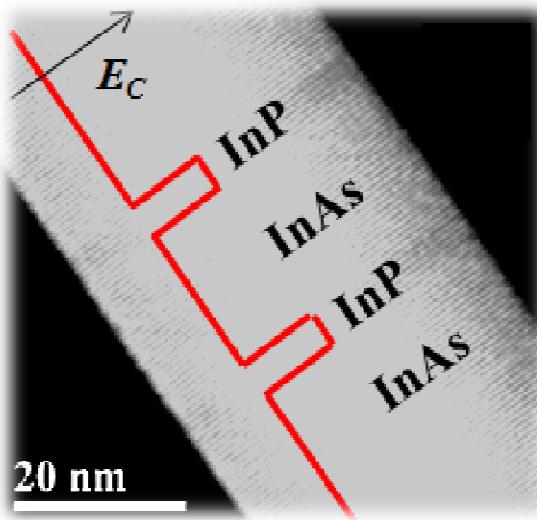
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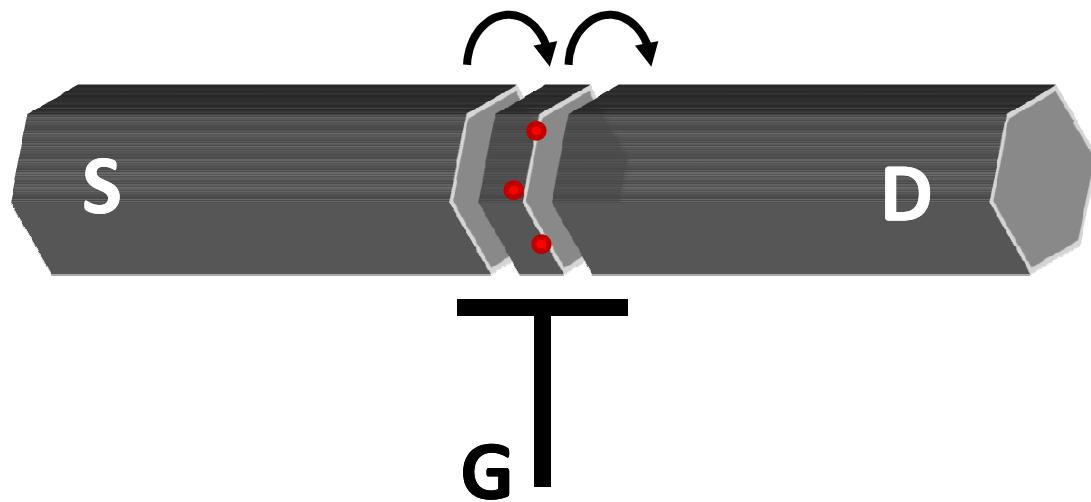


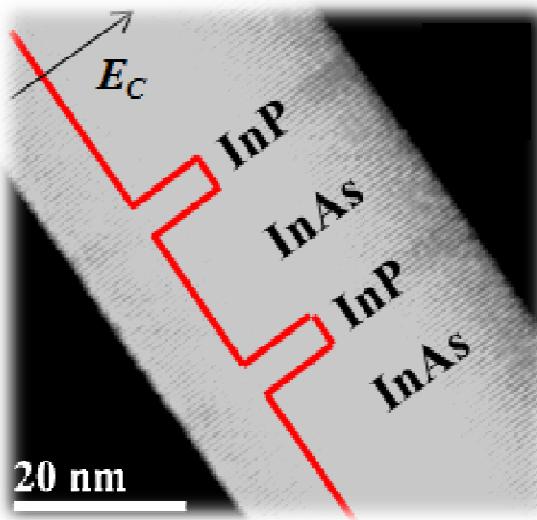
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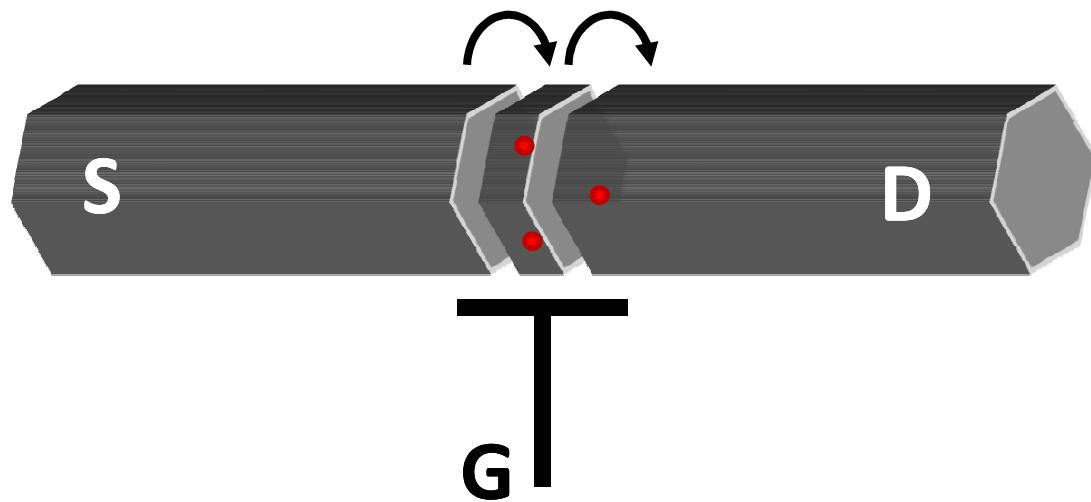


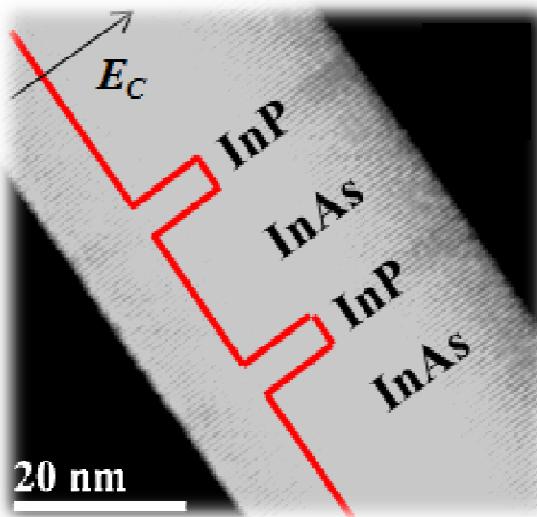
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- intermediate configuration
 \rightarrow charging cost e^2/C



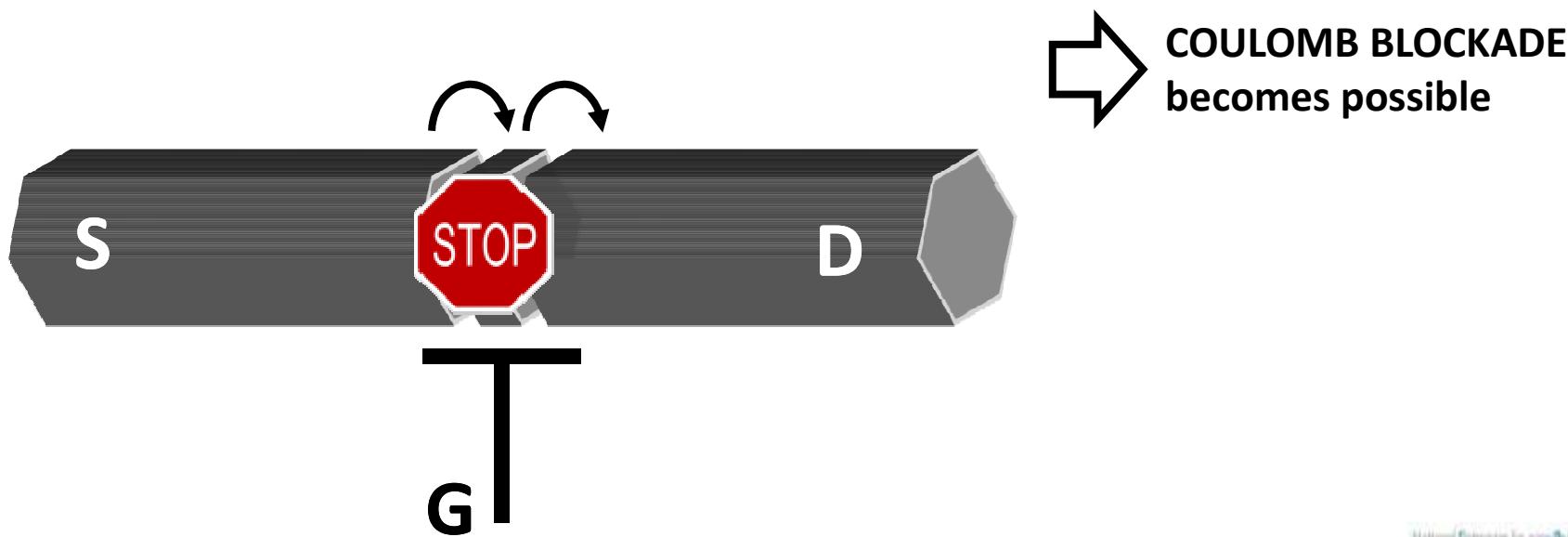


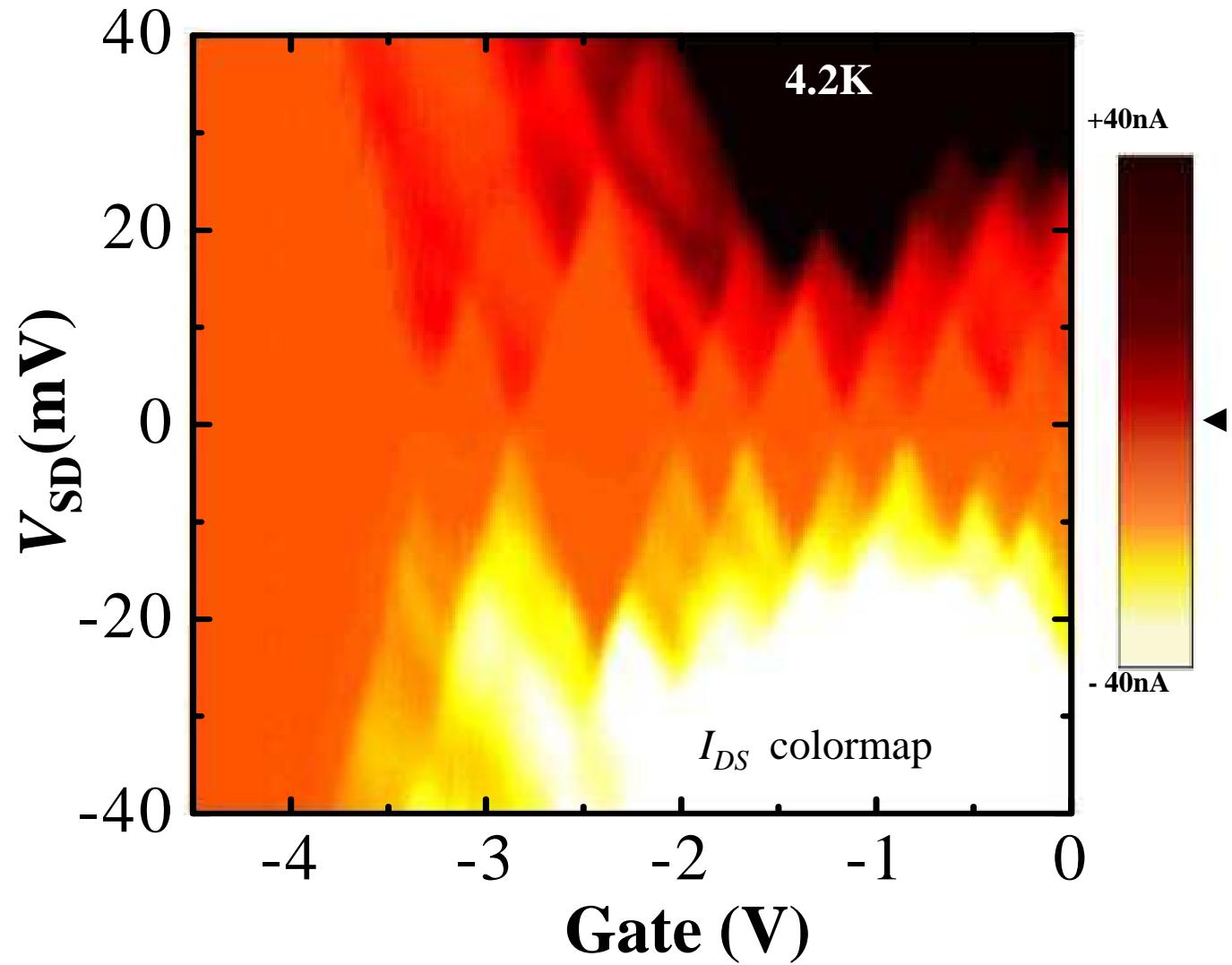
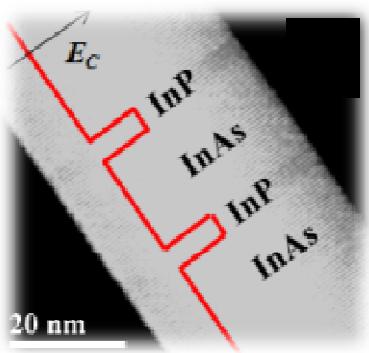
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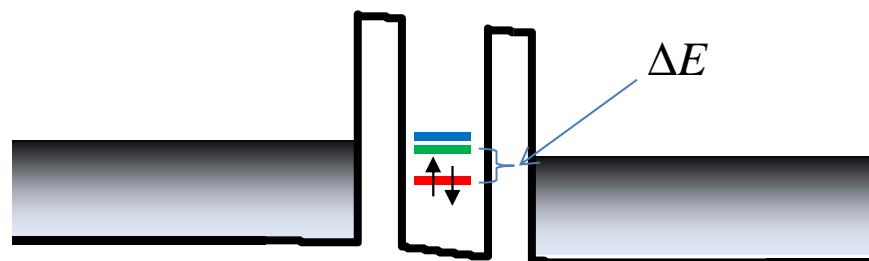
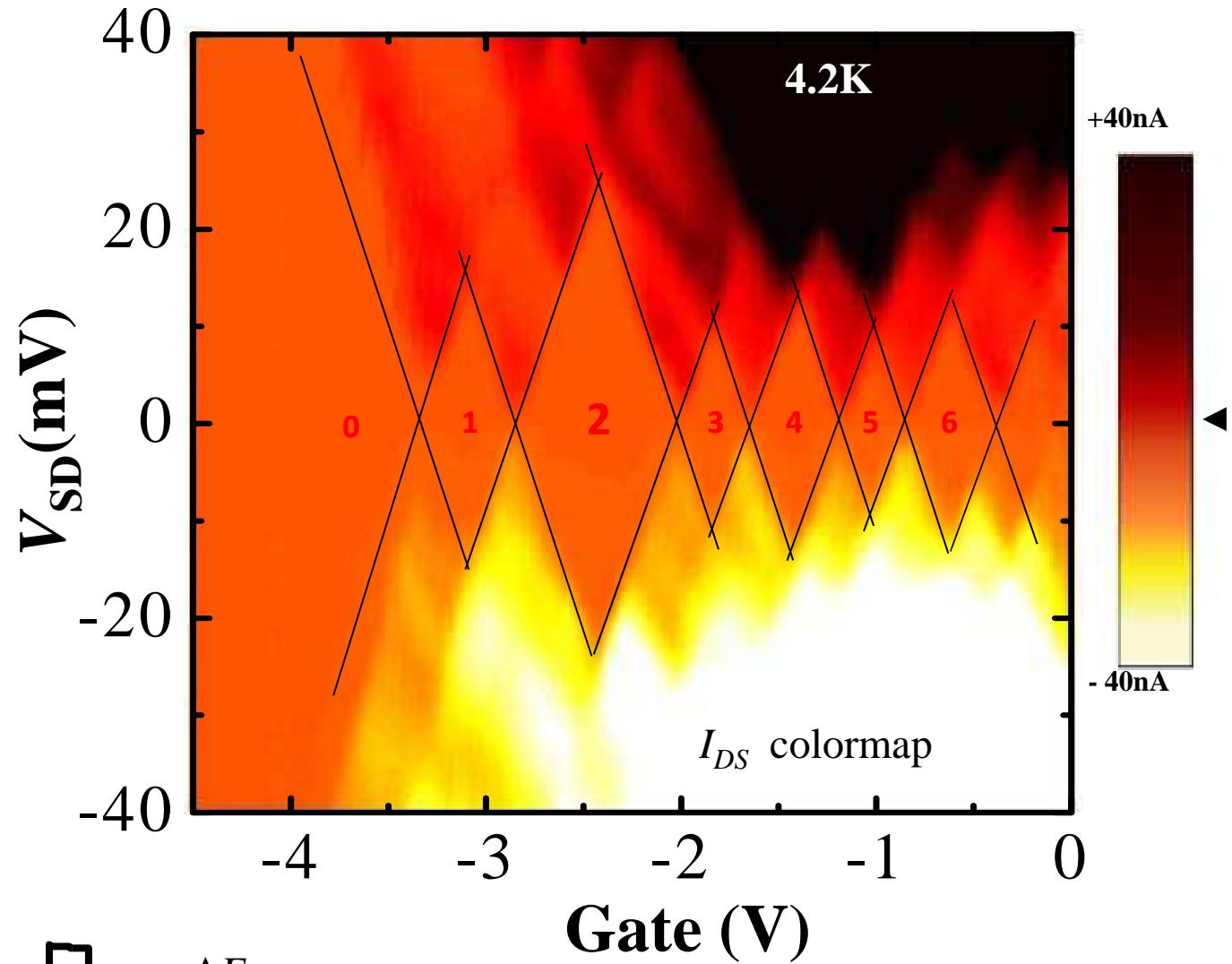
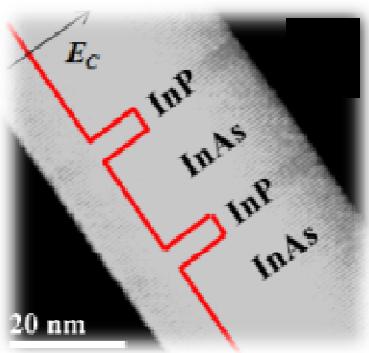


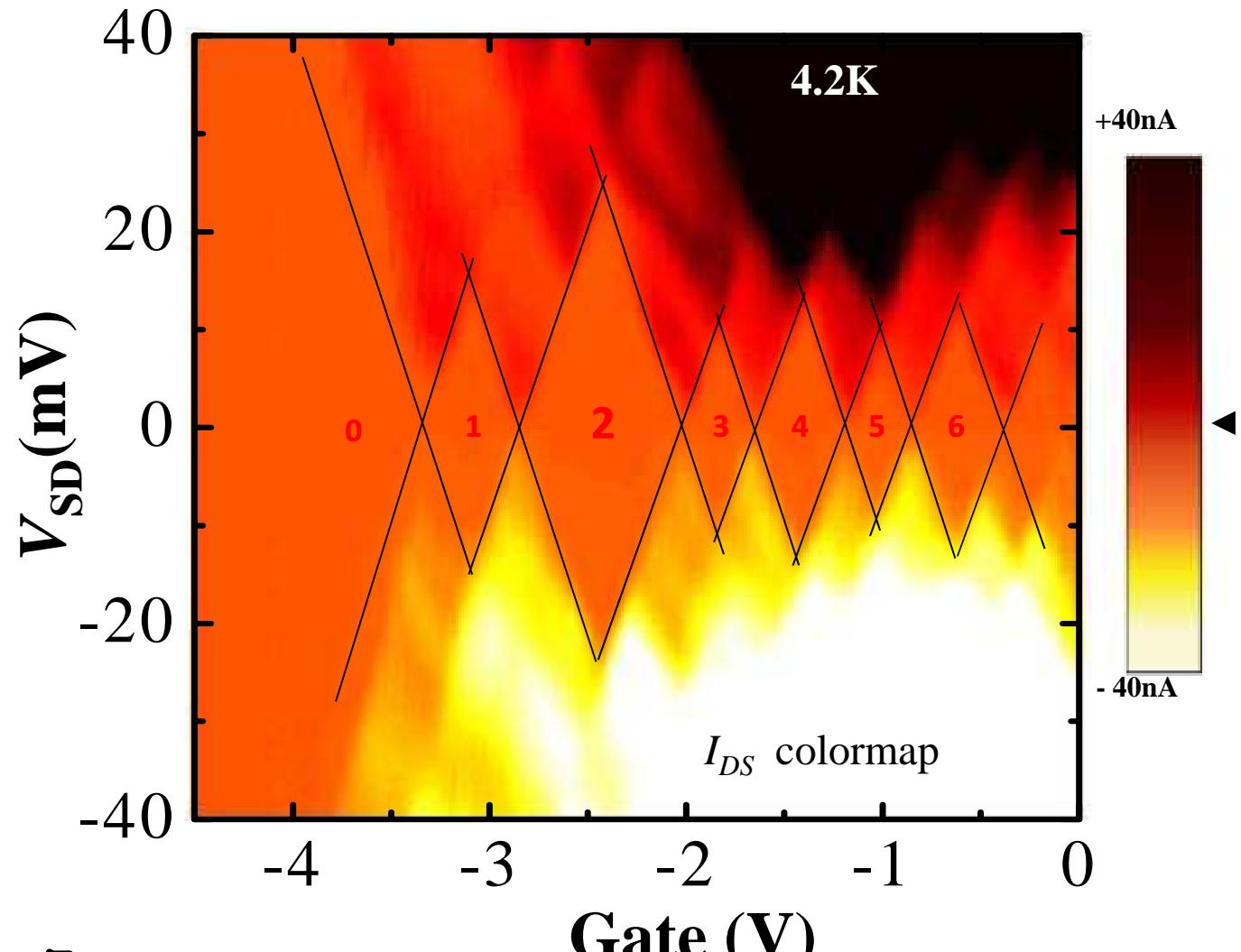
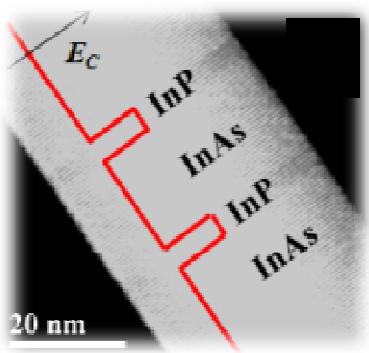


- small $\Gamma \rightarrow$ sequential tunneling dominates
- intermediate configuration
→ charging cost e^2/C
- not sufficient energy available ($|eV_{DS}| \ll e^2/C$
and $k_B T \ll e^2/C$) + small broadening ($R \gg h/e^2$)



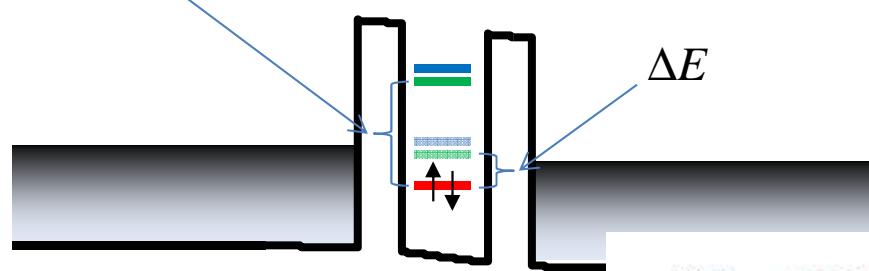






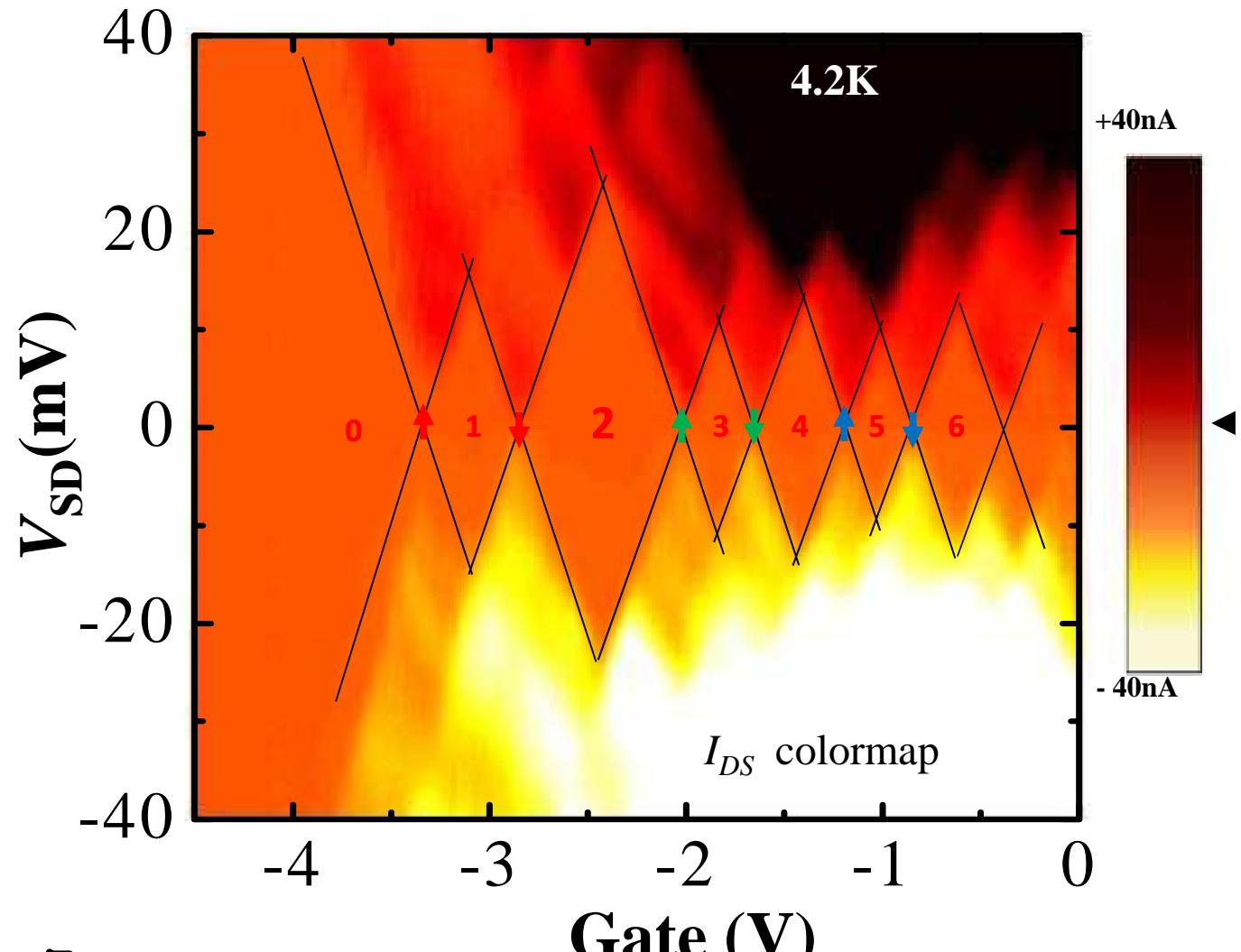
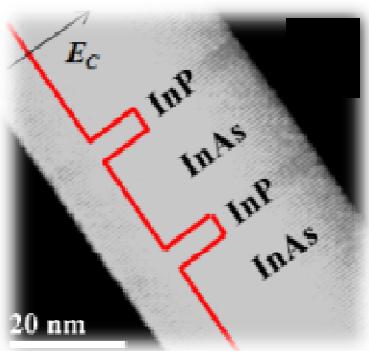
Coulomb gap

$\Delta E + e^2/C$



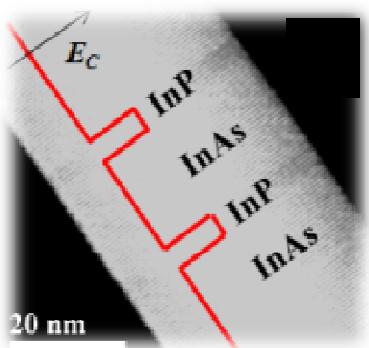
in constant interaction approx...

$$\mu_k(N) = U(N) - U(N-1) = \dots + \frac{e^2}{C_\Sigma} (N - 1/2) - e\alpha_G V_G + E_k$$



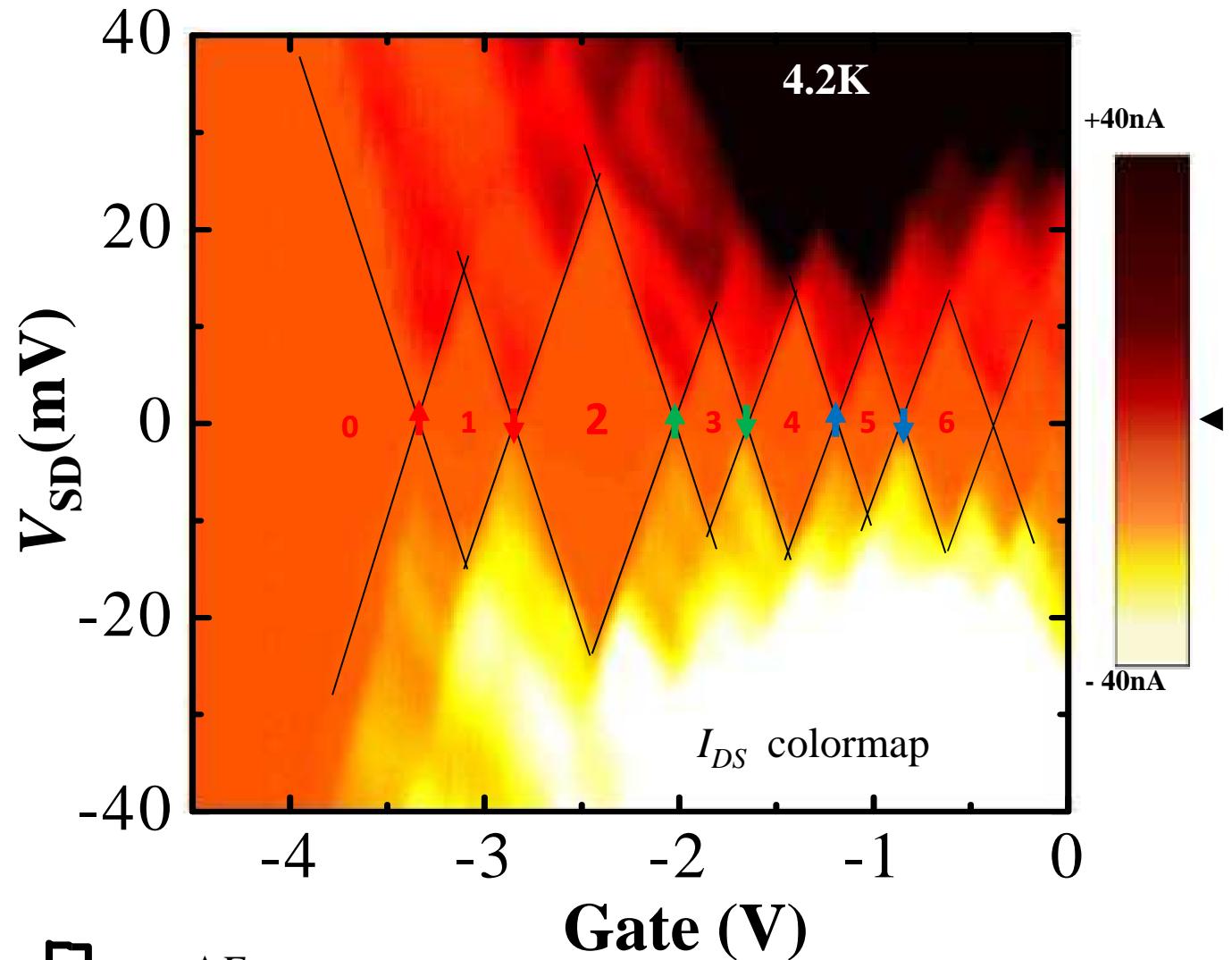
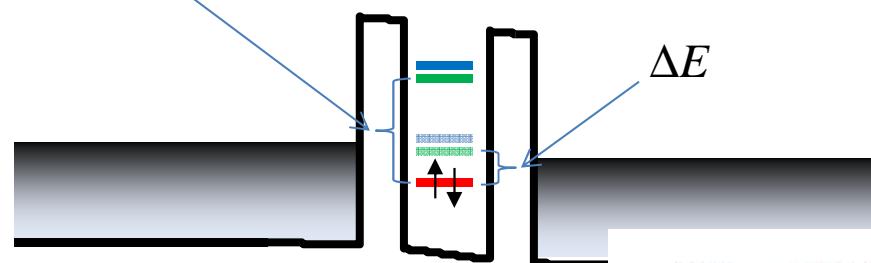
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Typical parameters
 $e^2/C \sim 10\text{meV}$
 $\Delta E = 0\text{-}10\text{meV}$
 Working $T \sim 10\text{-}15\text{K}$

Coulomb gap
 $\Delta E + e^2/C$



in constant interaction approx...

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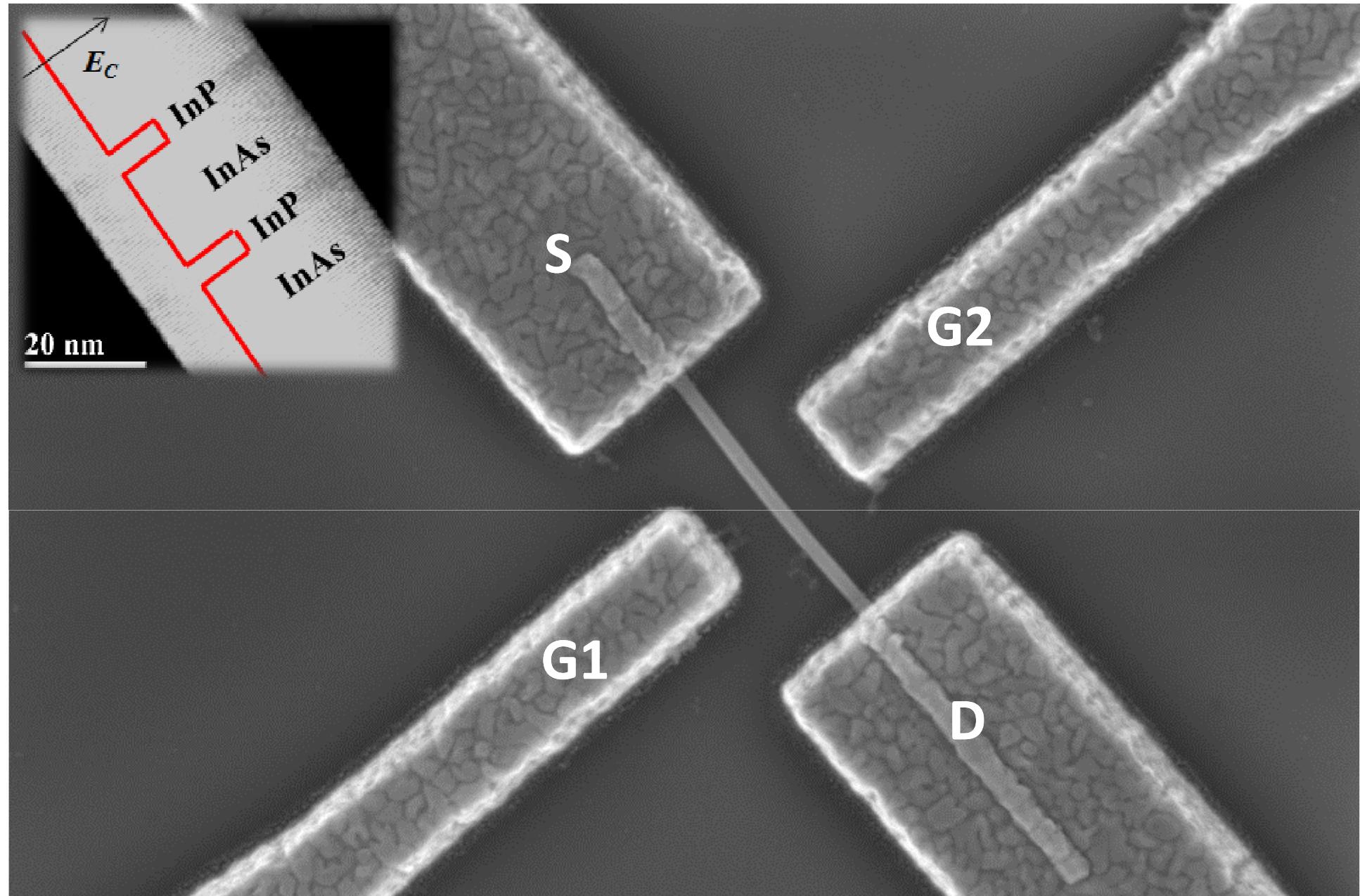


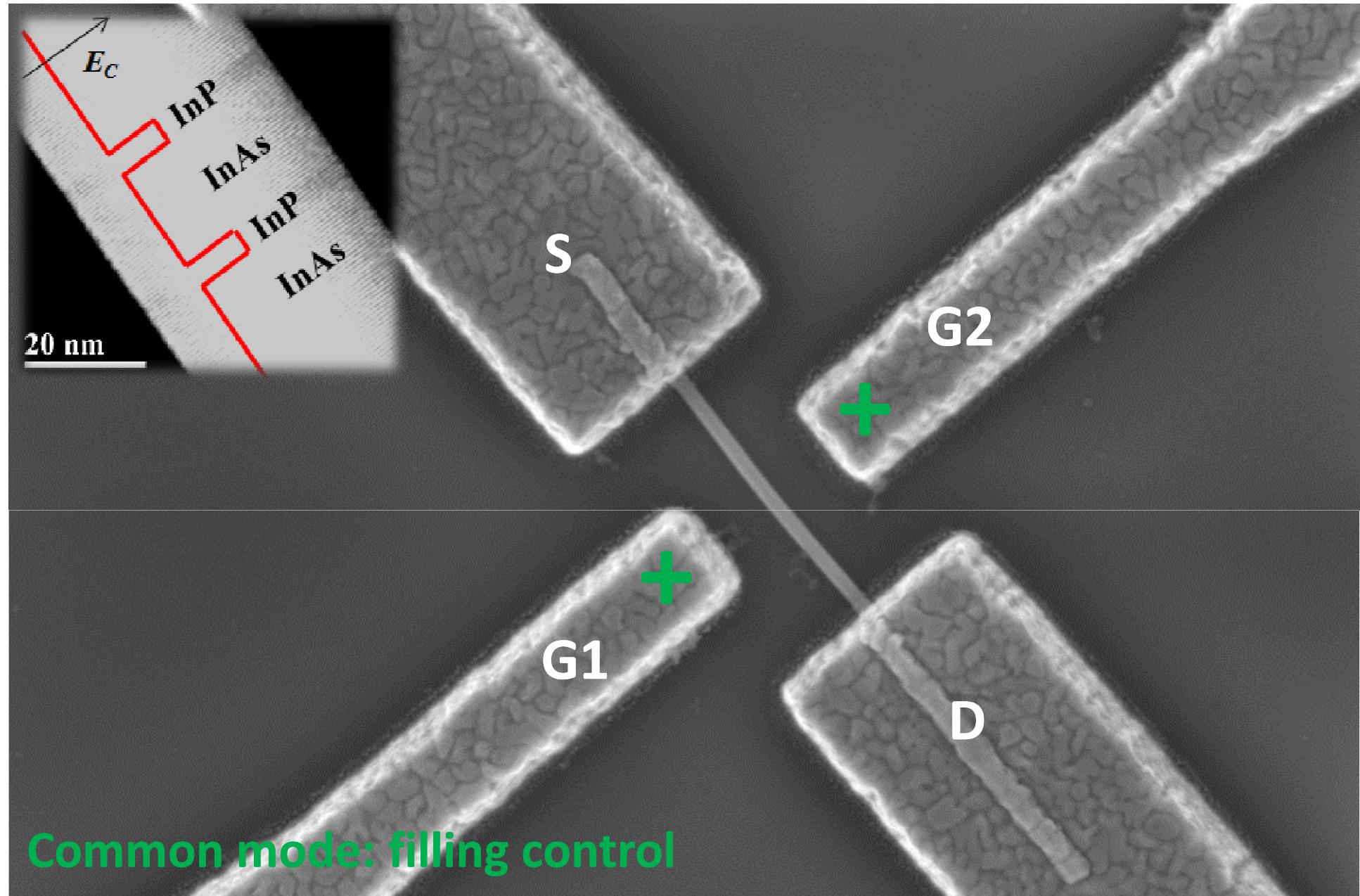
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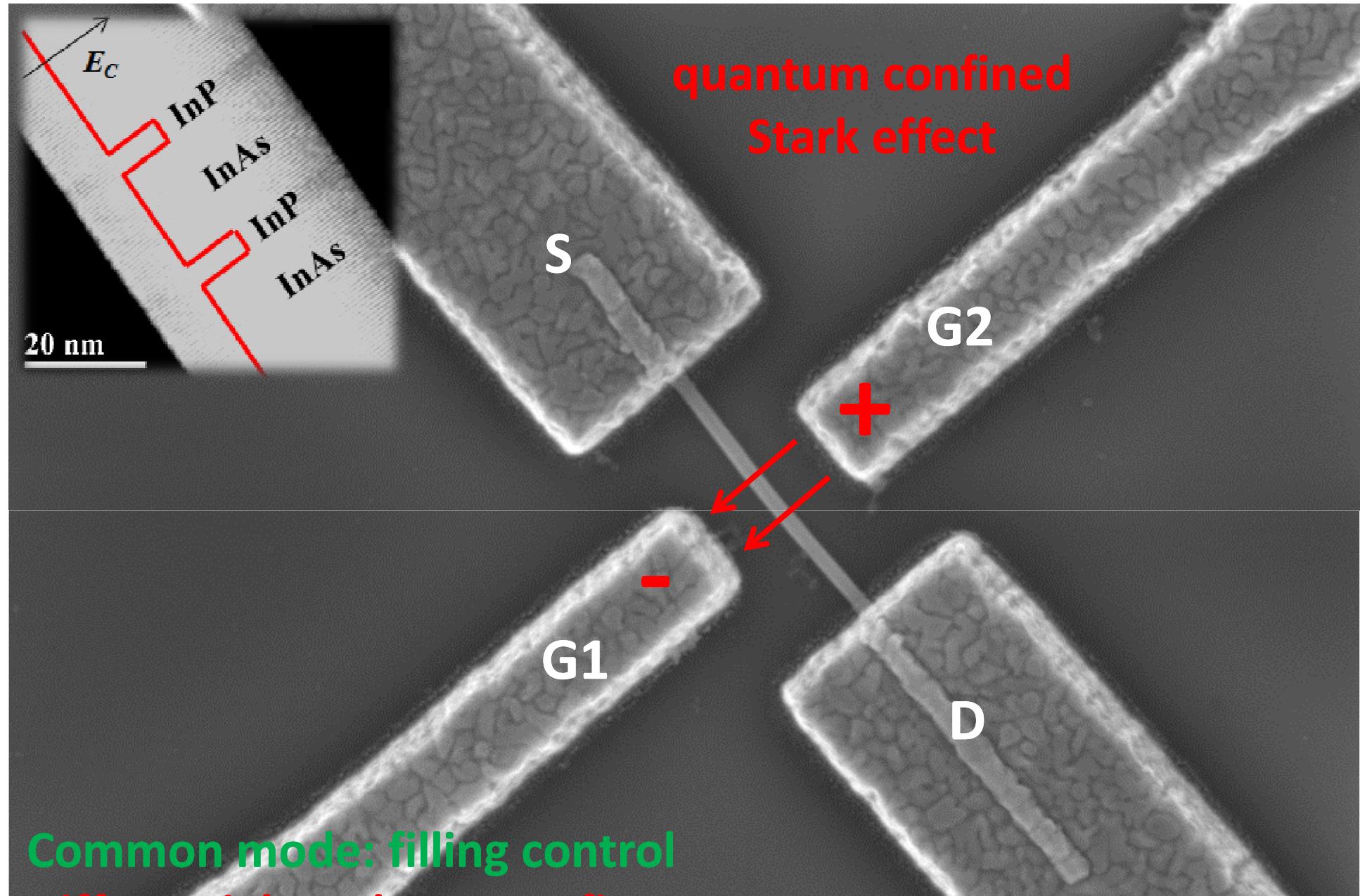
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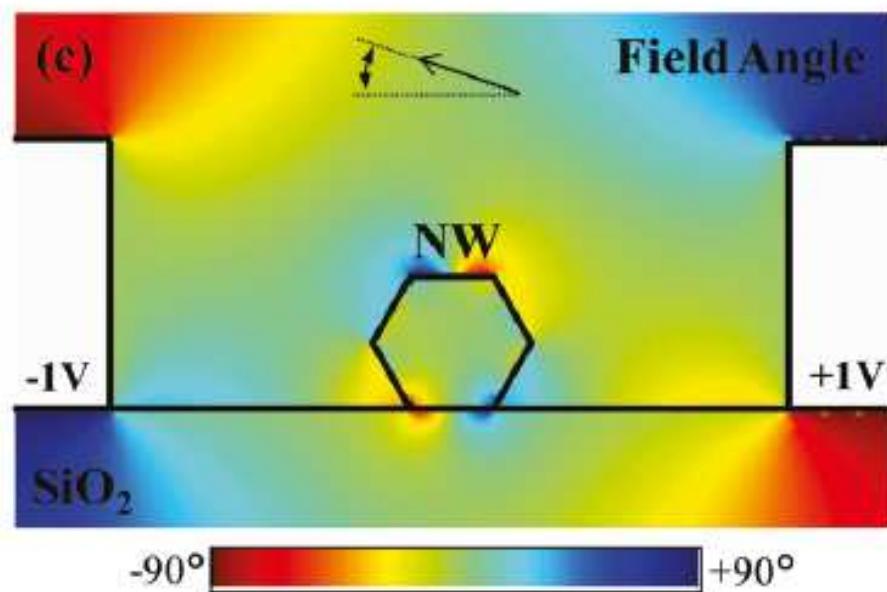
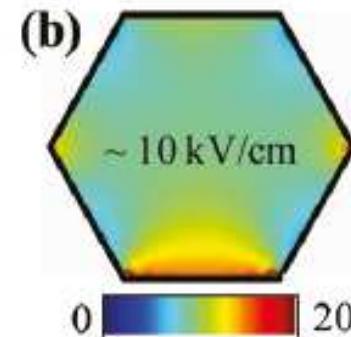
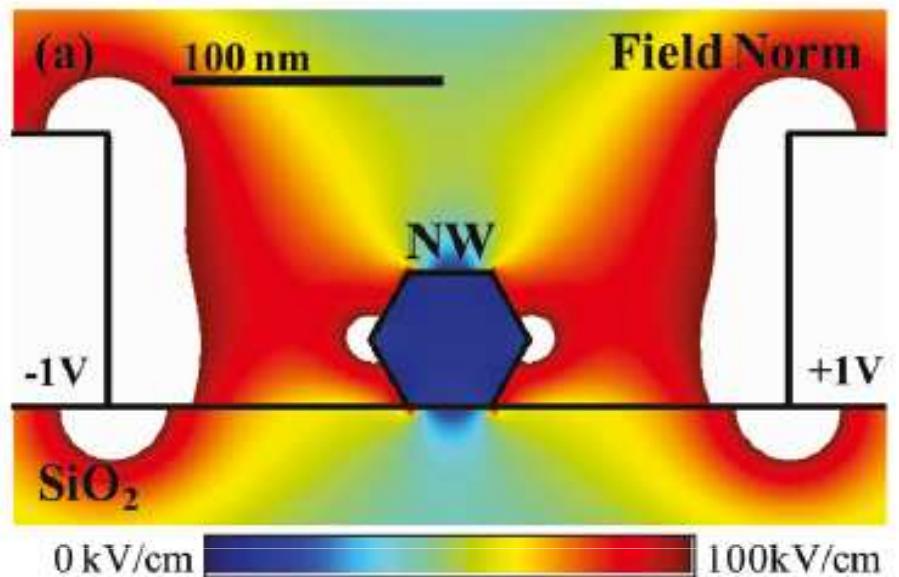


Common mode: filling control



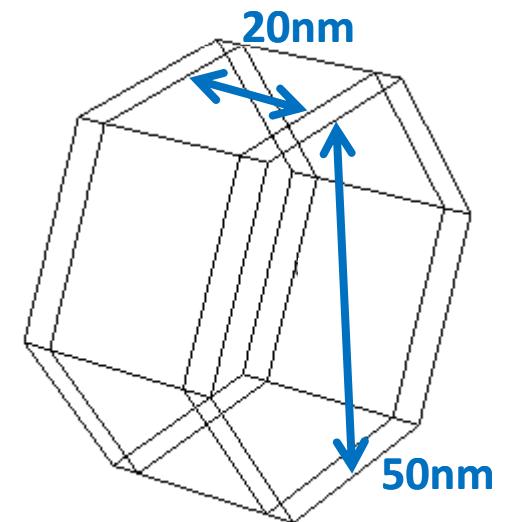
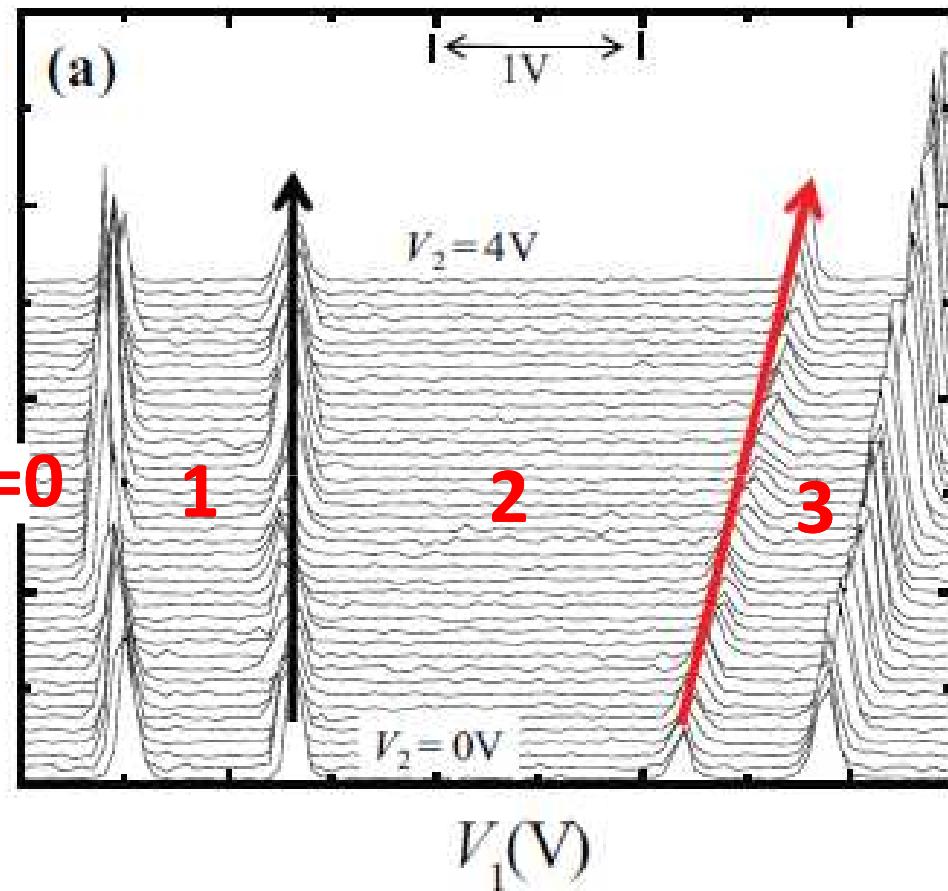
Common mode: filling control
Differential mode: FE confinement

Can this work?

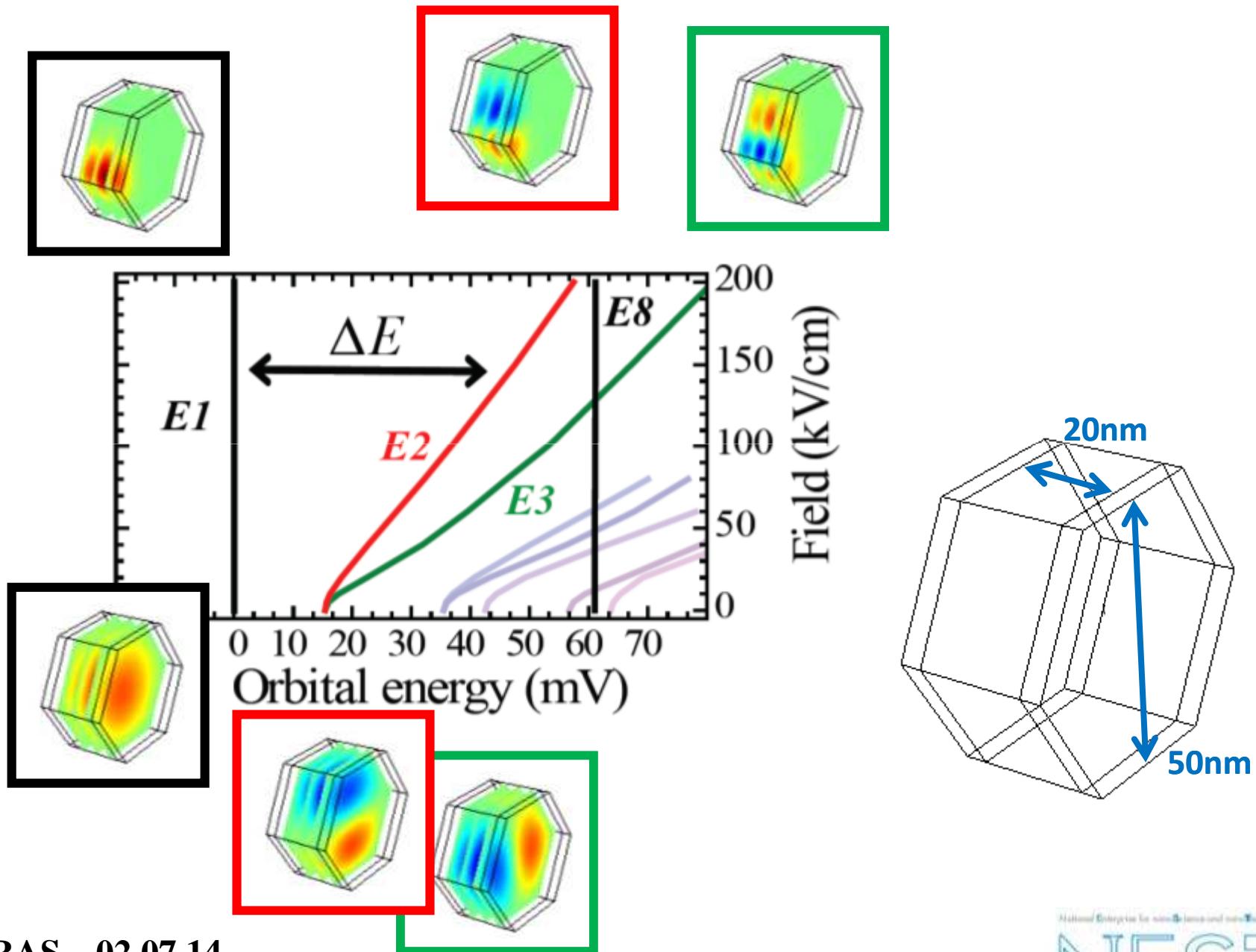


Changing the QD energy spectrum

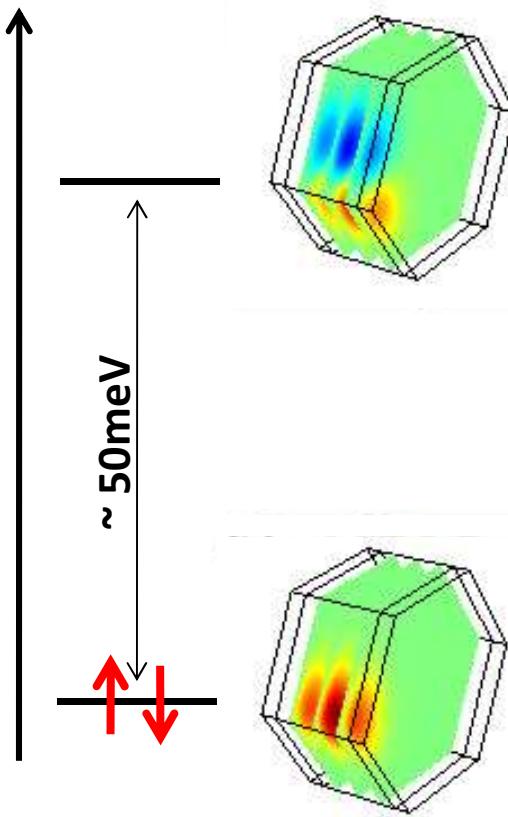
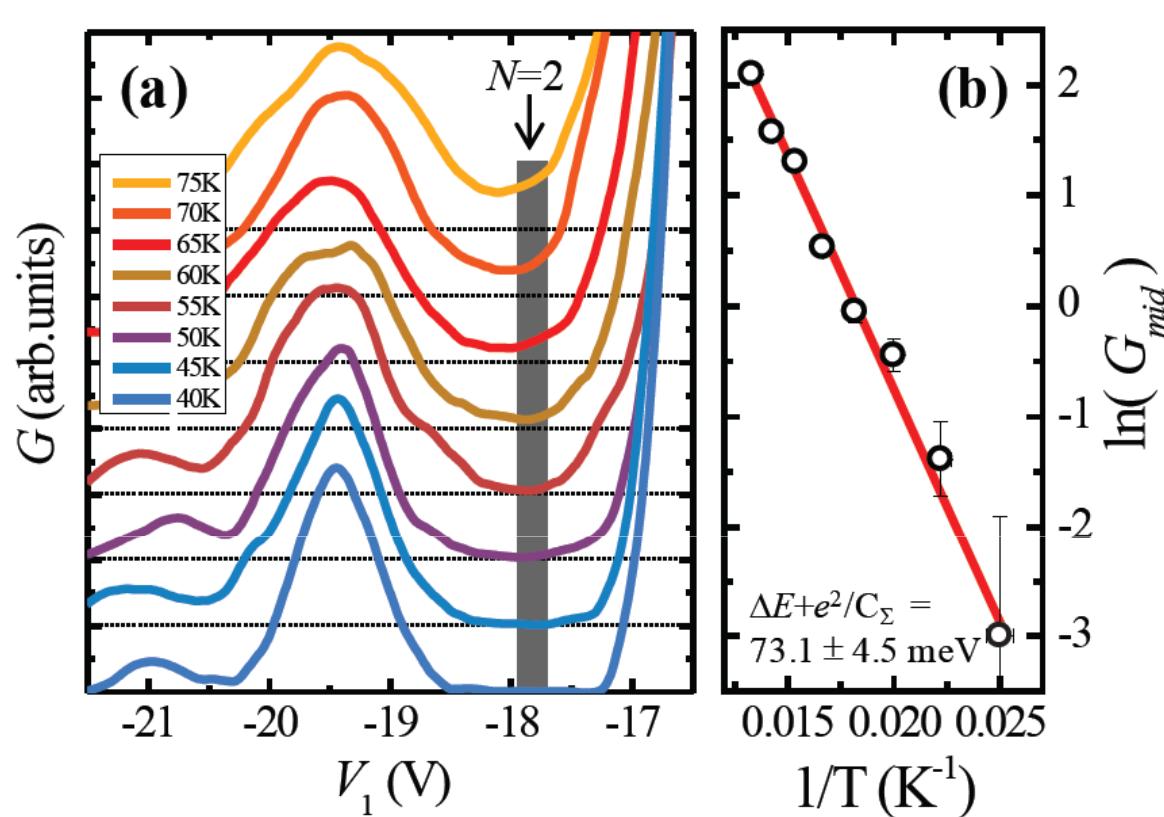
Conductance (arb.units)



Changing the QD energy spectrum



Changing the QD energy spectrum



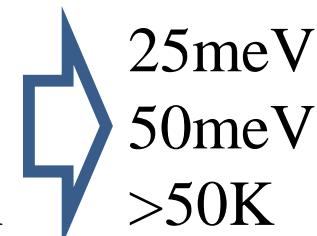
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$$\Delta E = 0-10 \text{ meV}$$

Working $T \sim 10$ K

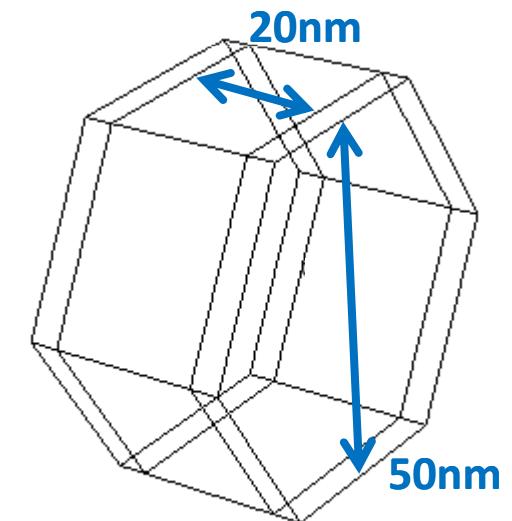
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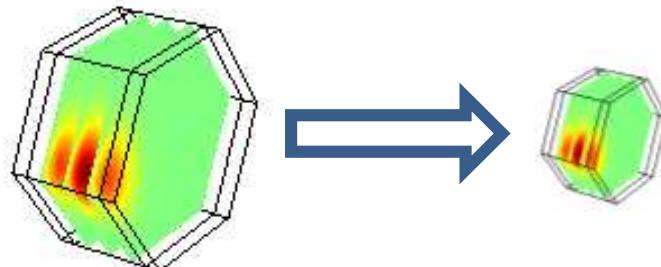
Room temperature SET with last-electron control?

Still a relatively
large QD!

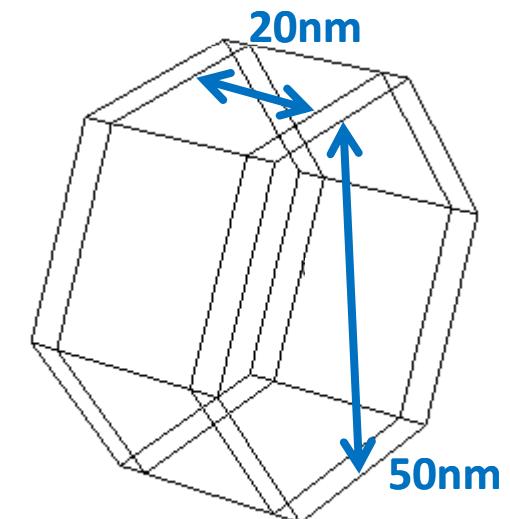


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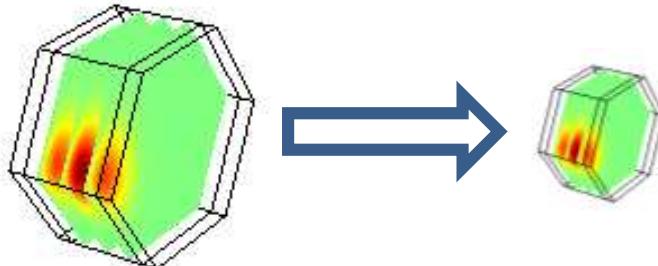


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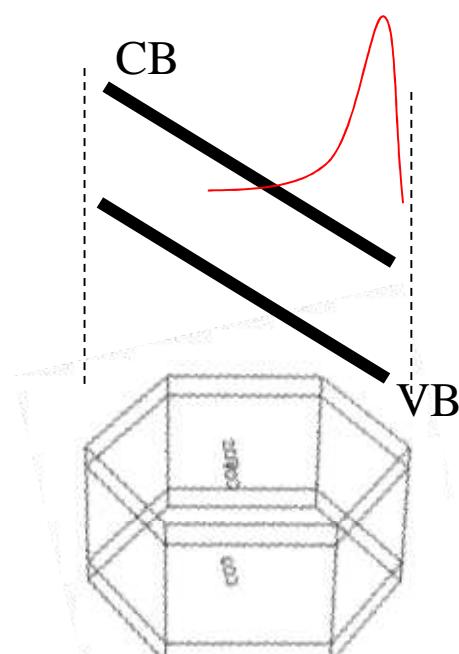


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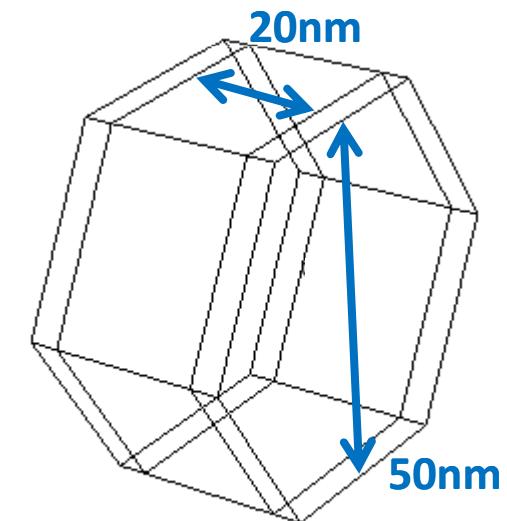


Still a relatively large QD!



2. Top lateral field

Check Zener and avalanche break-down!
150kV/cm @60nm
(already $>>40$ kV/cm break-down in bulk InAs)



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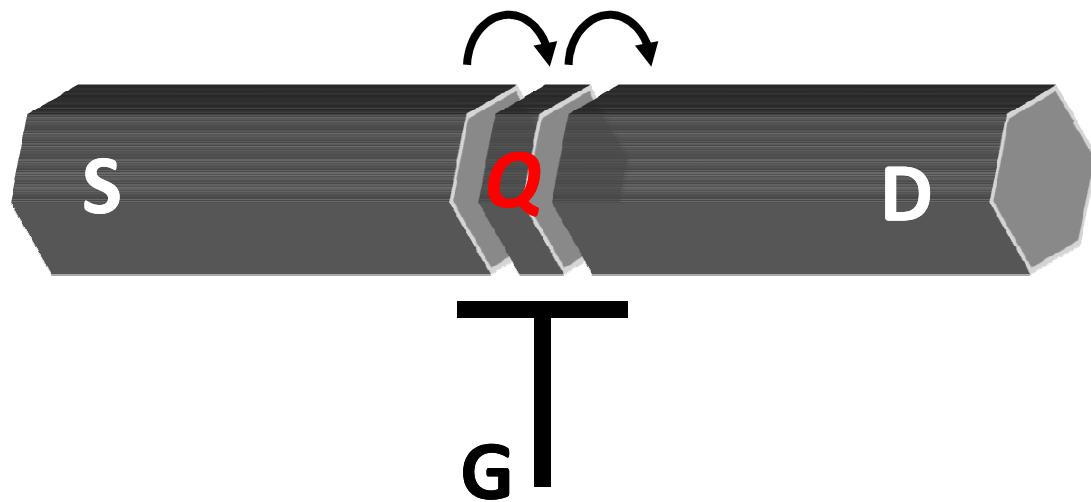
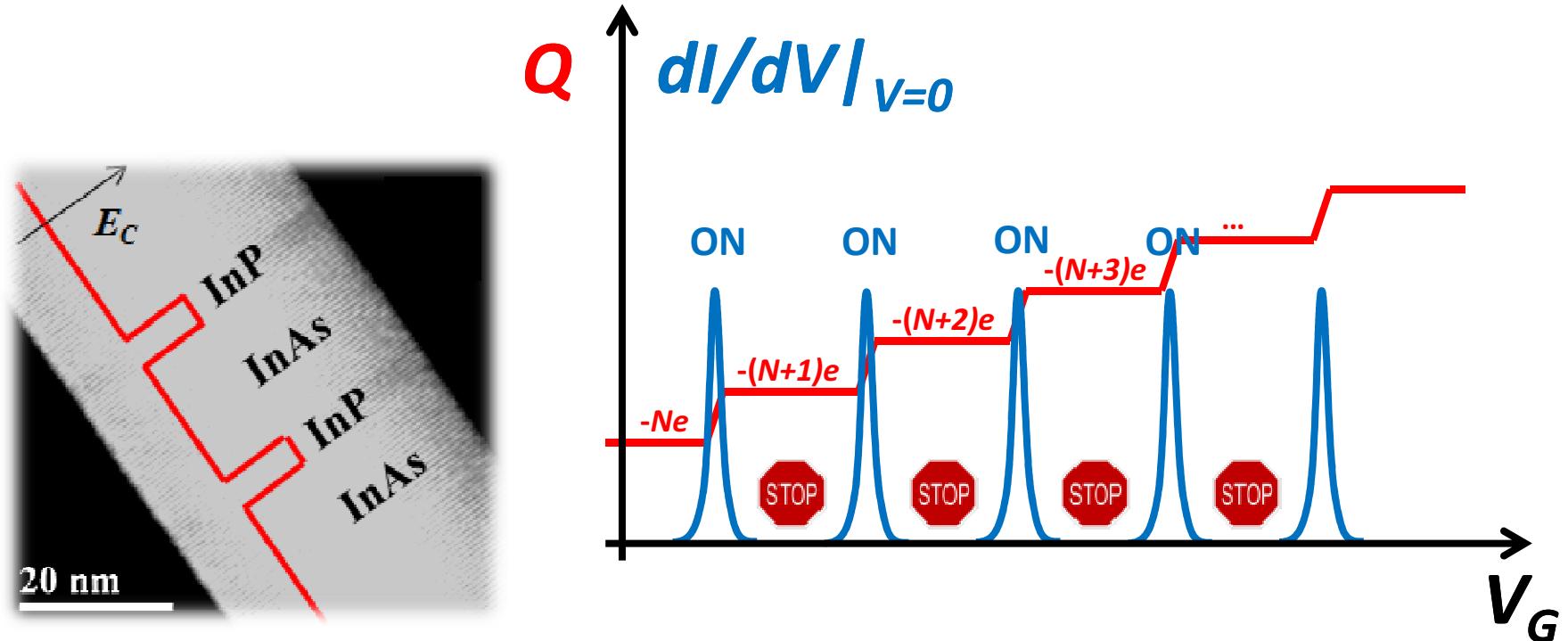


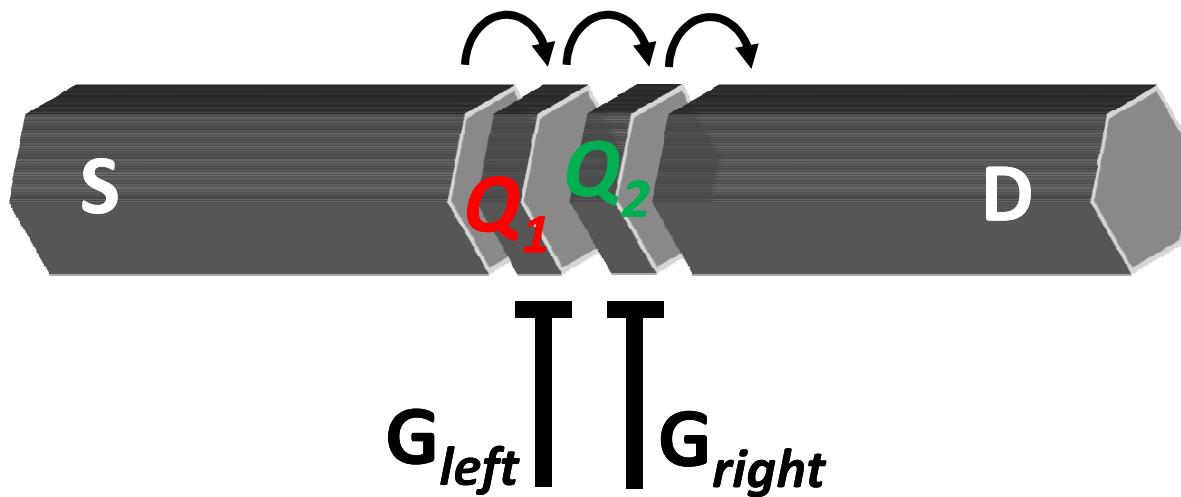
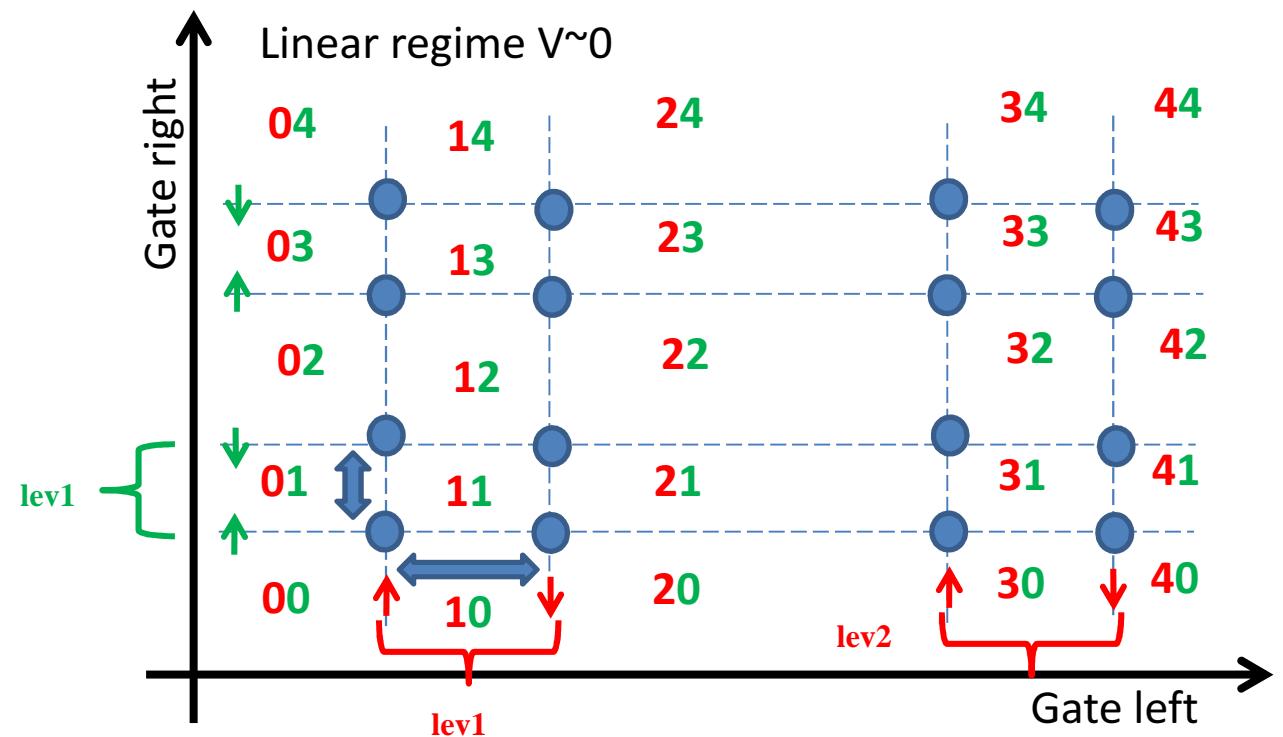
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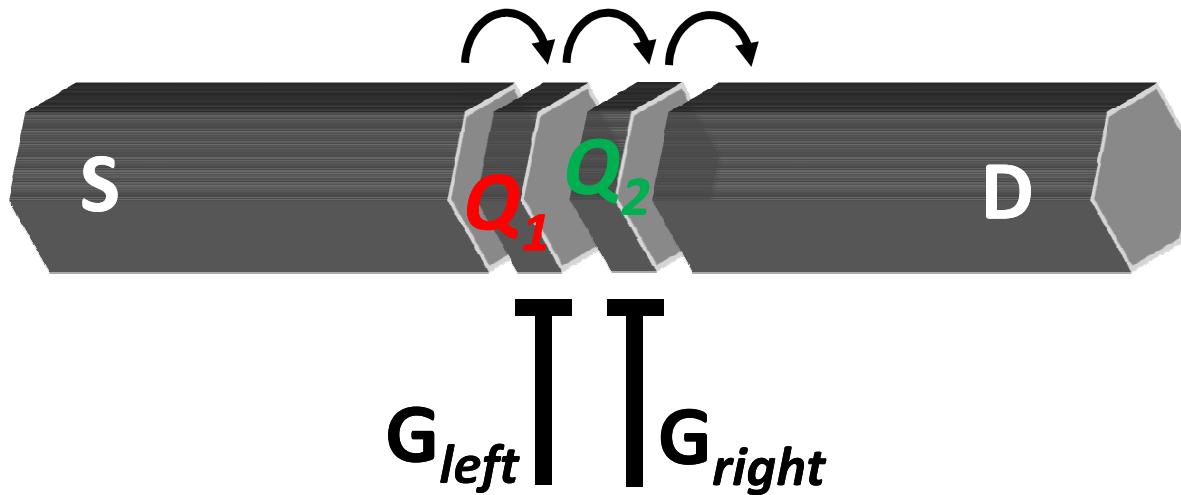
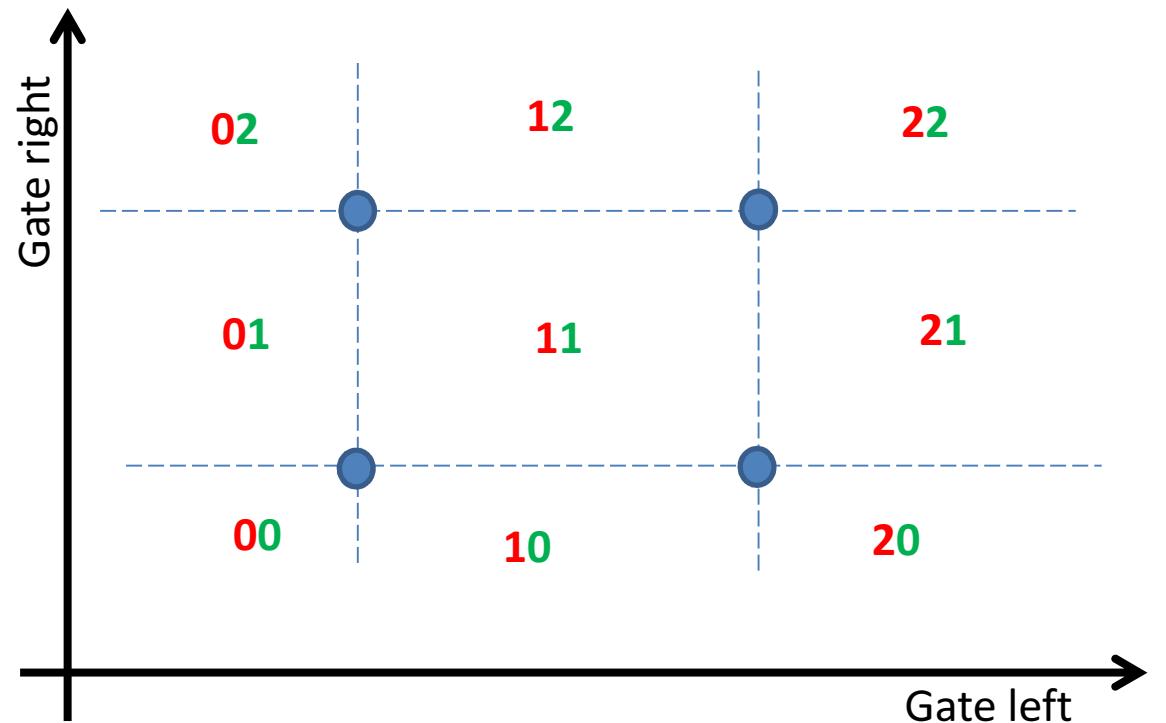
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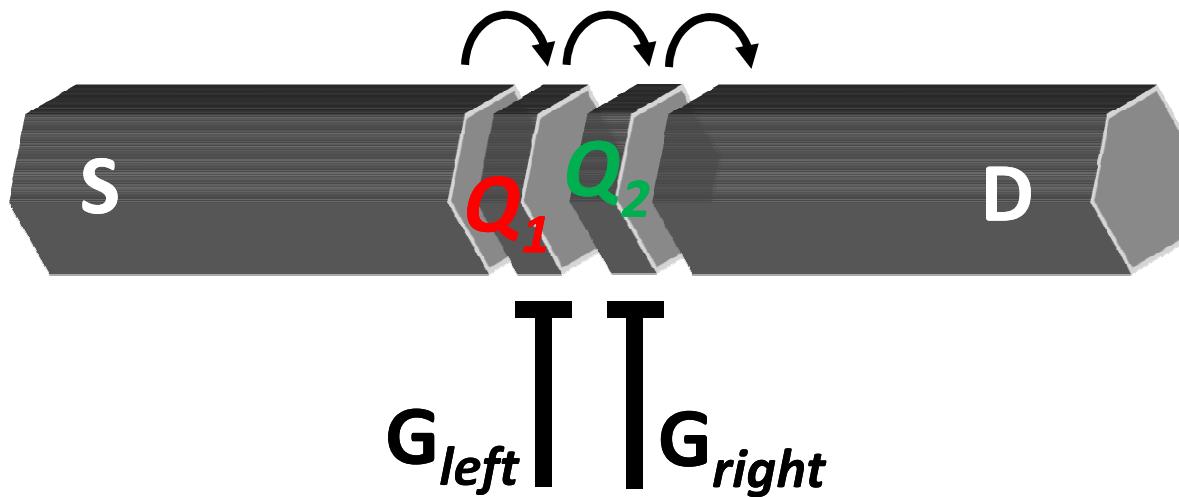
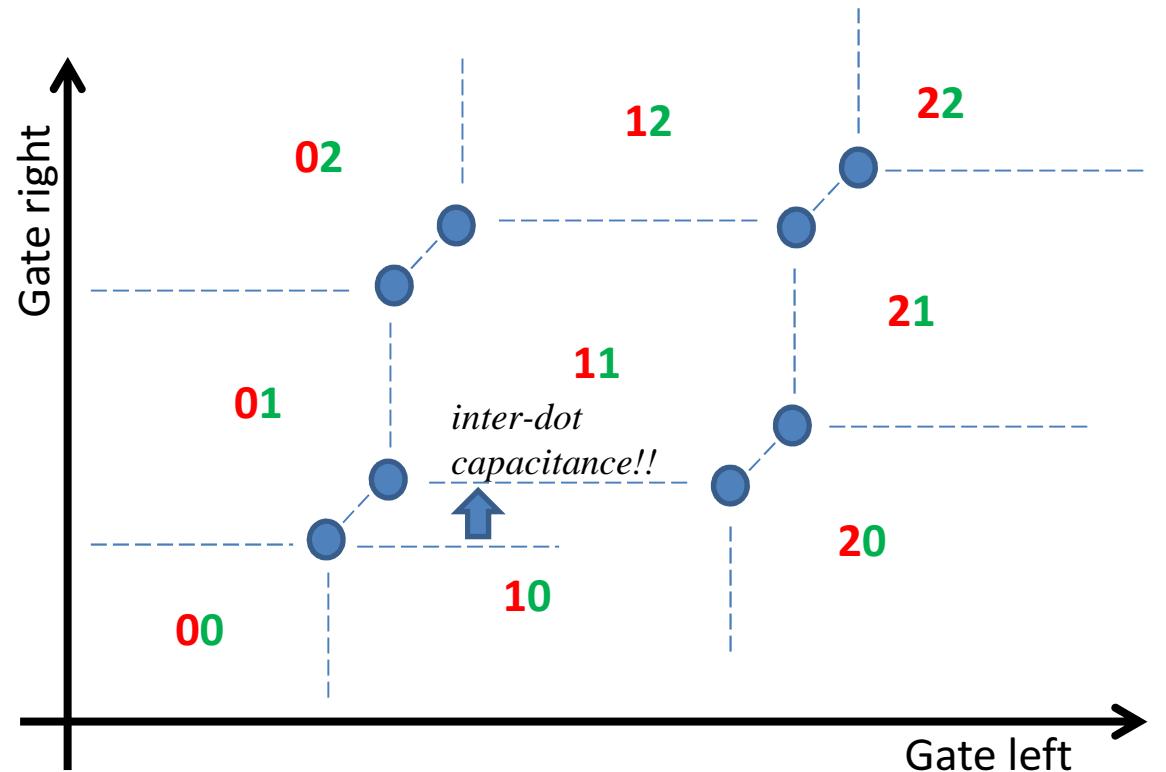
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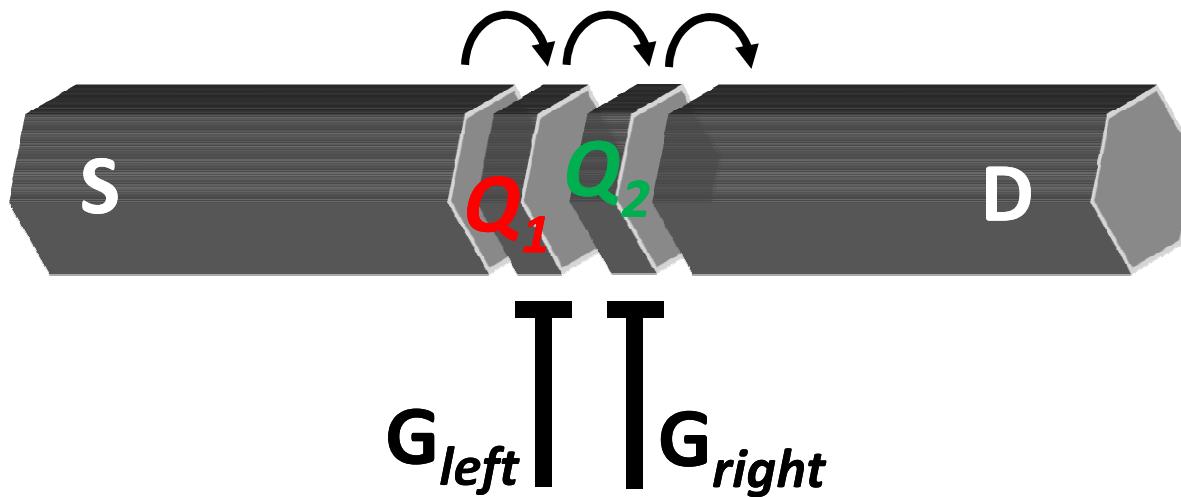
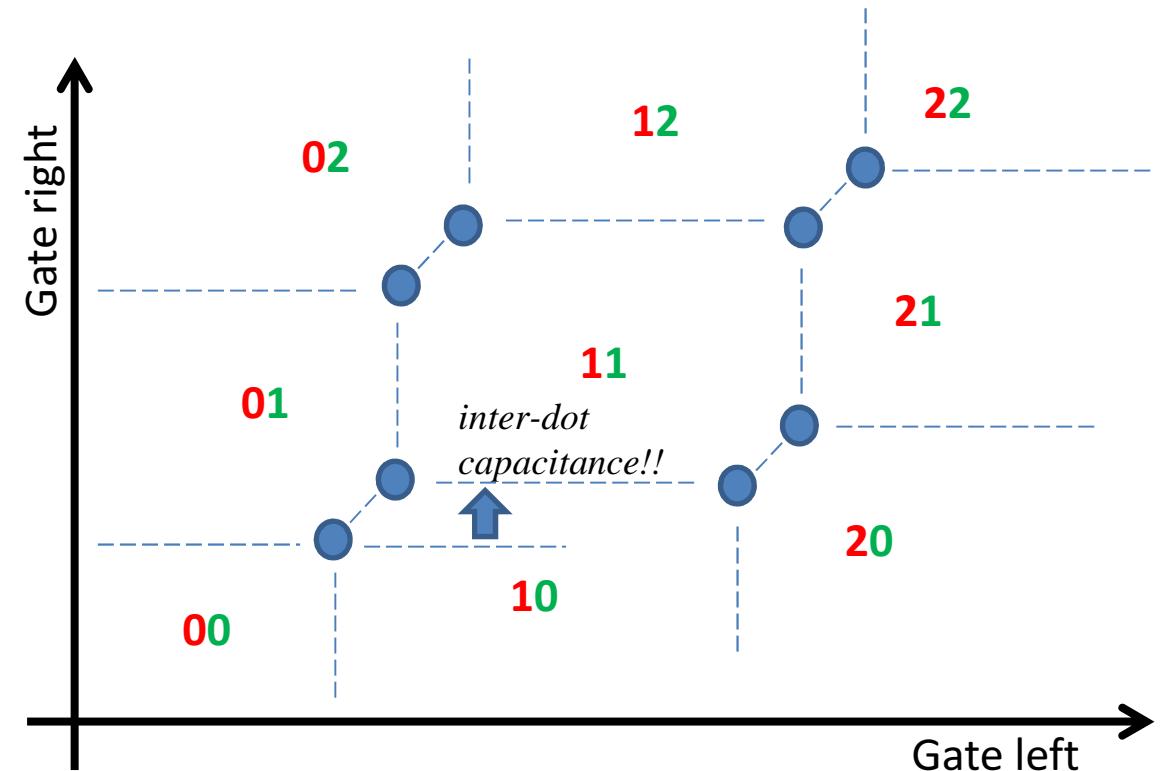
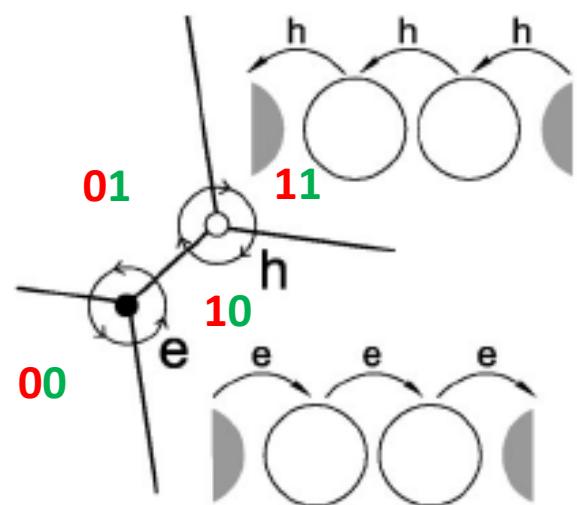


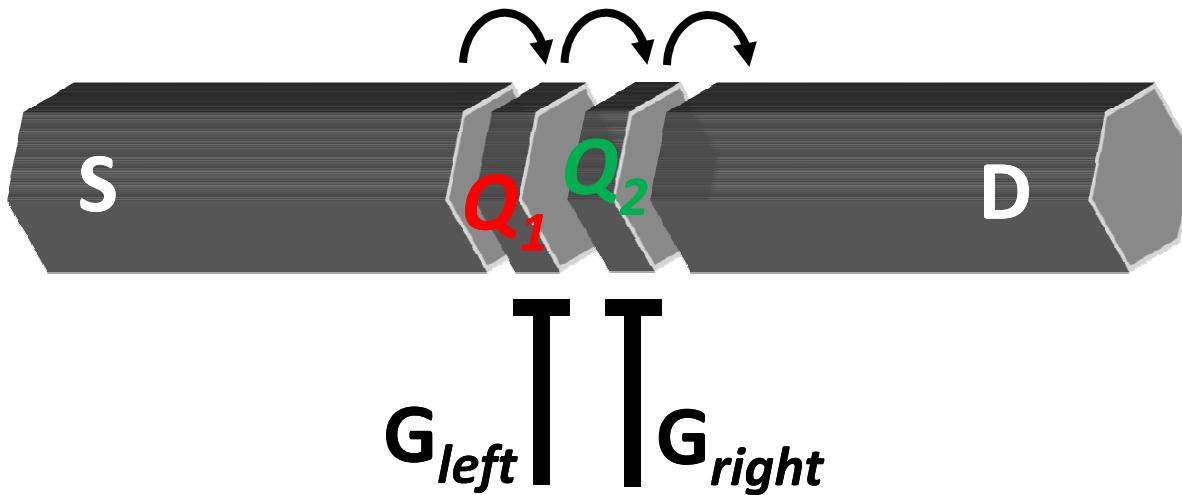
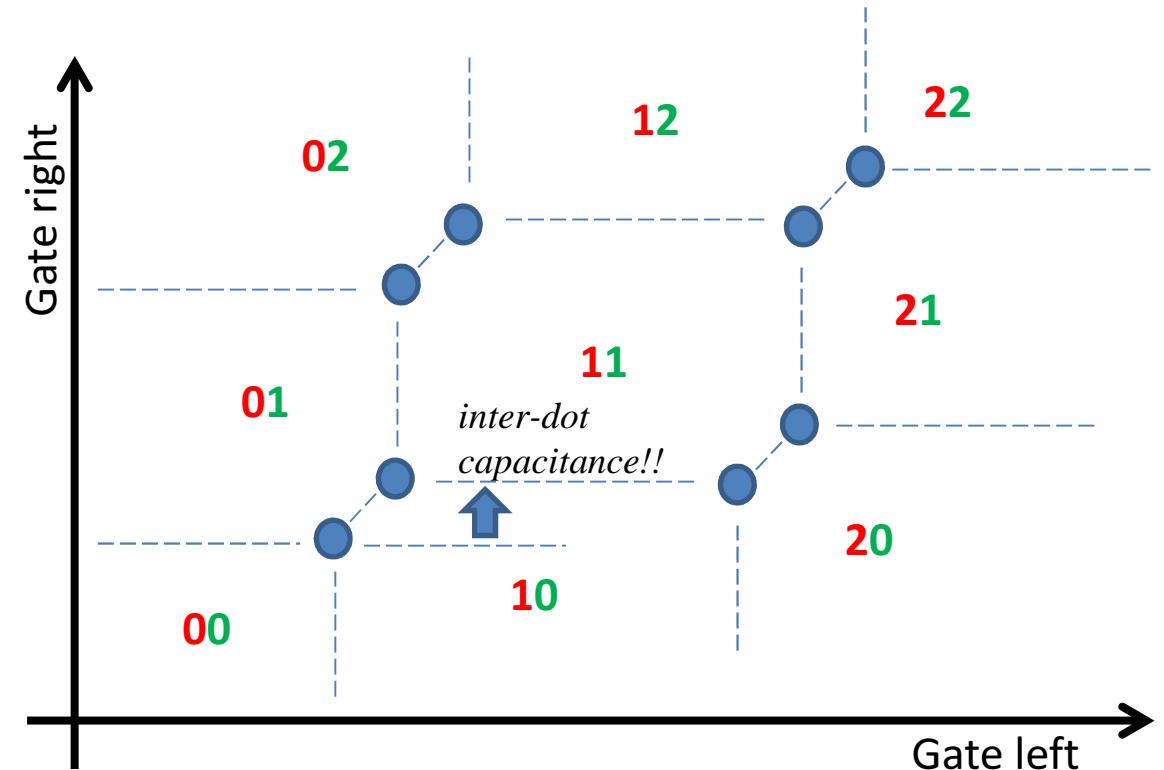
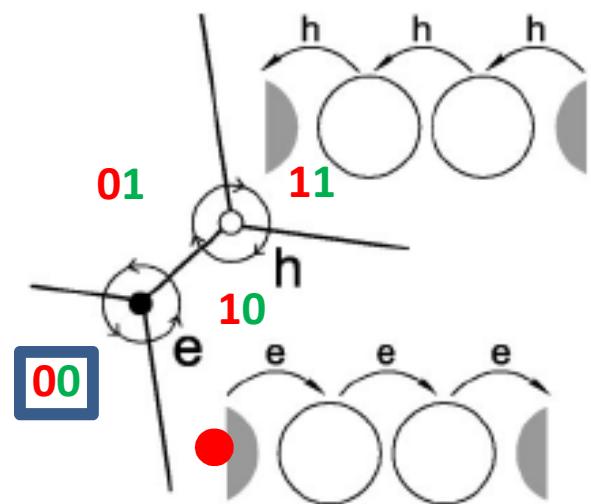


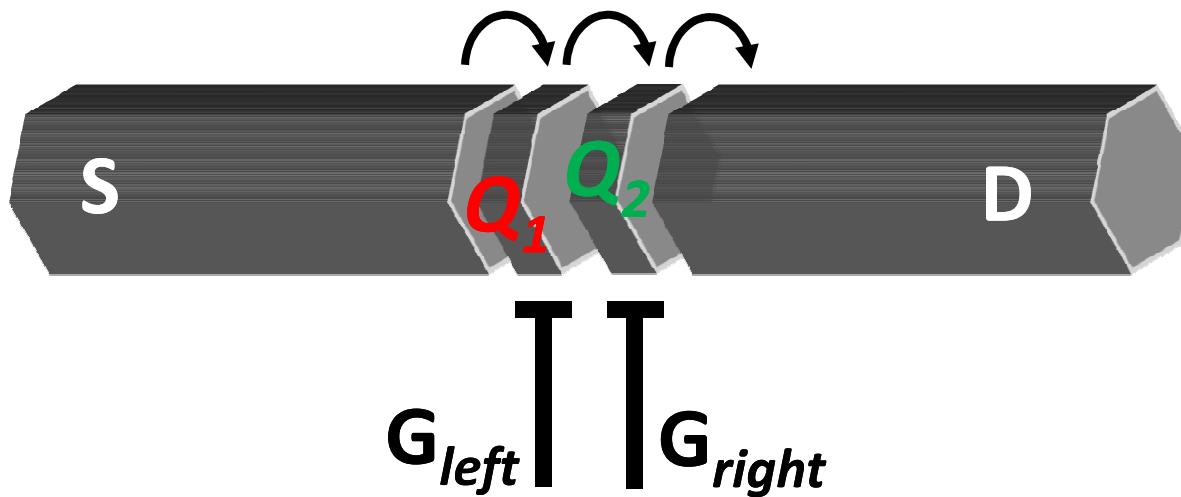
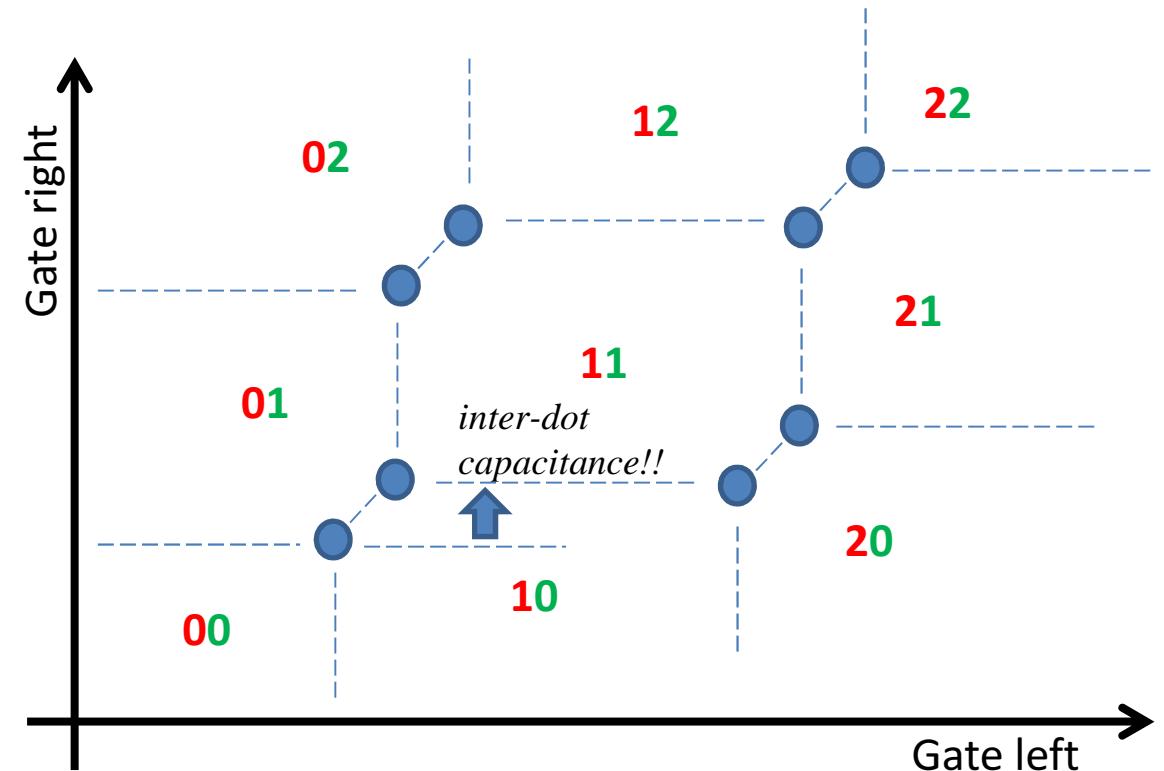
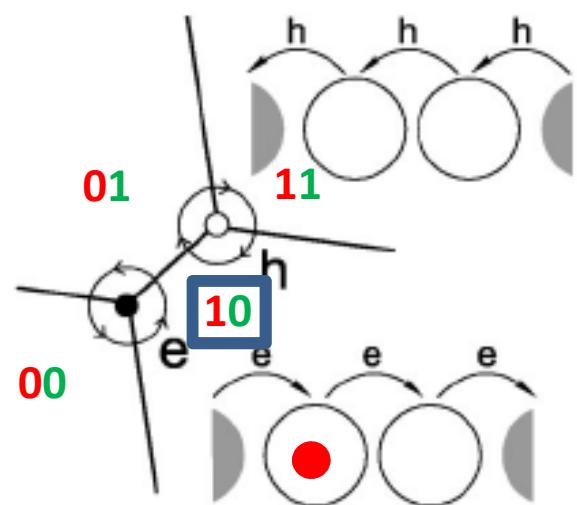


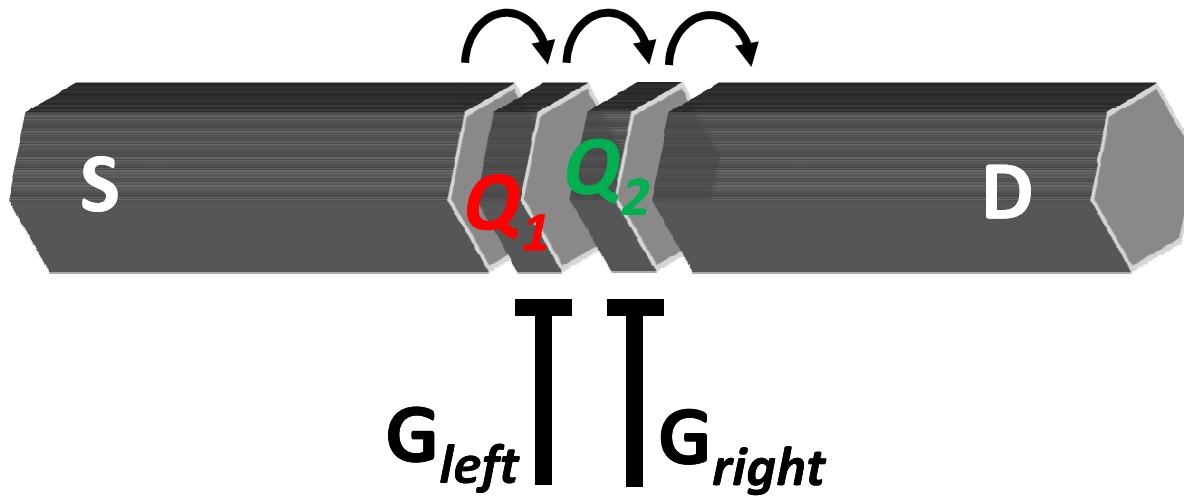
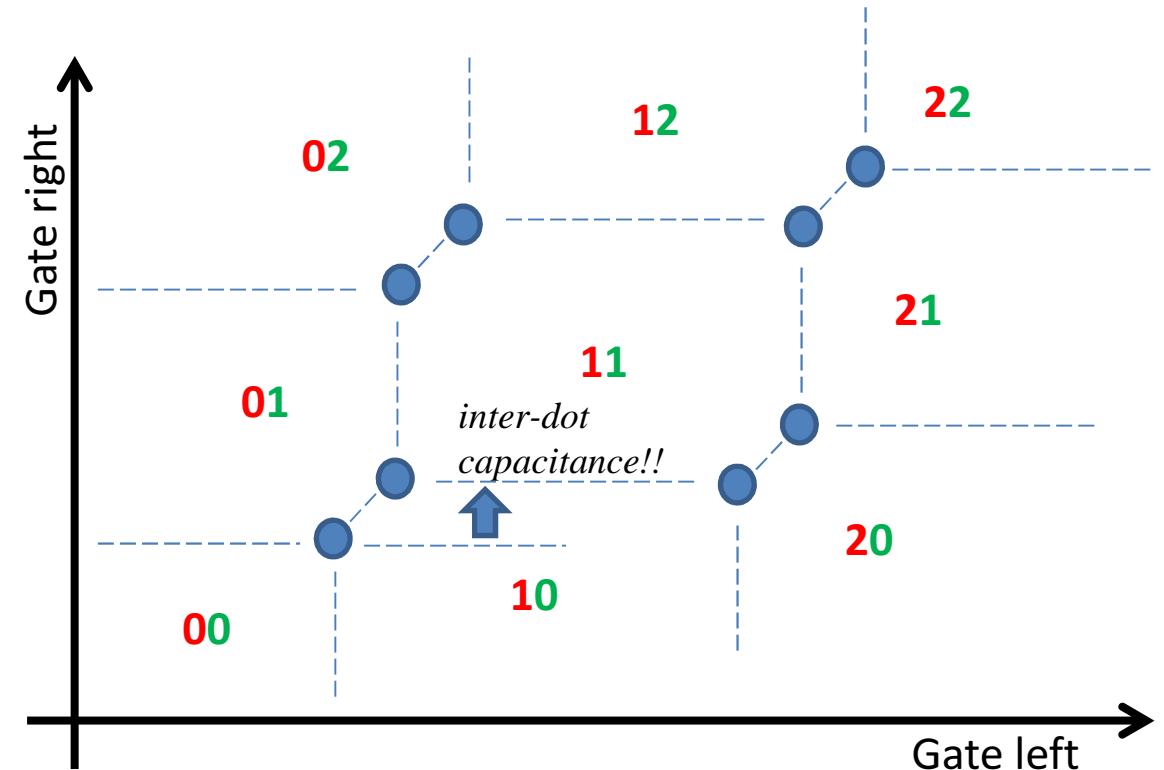
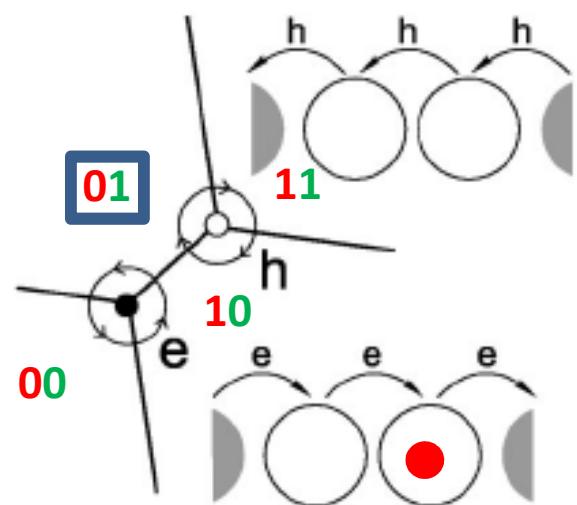


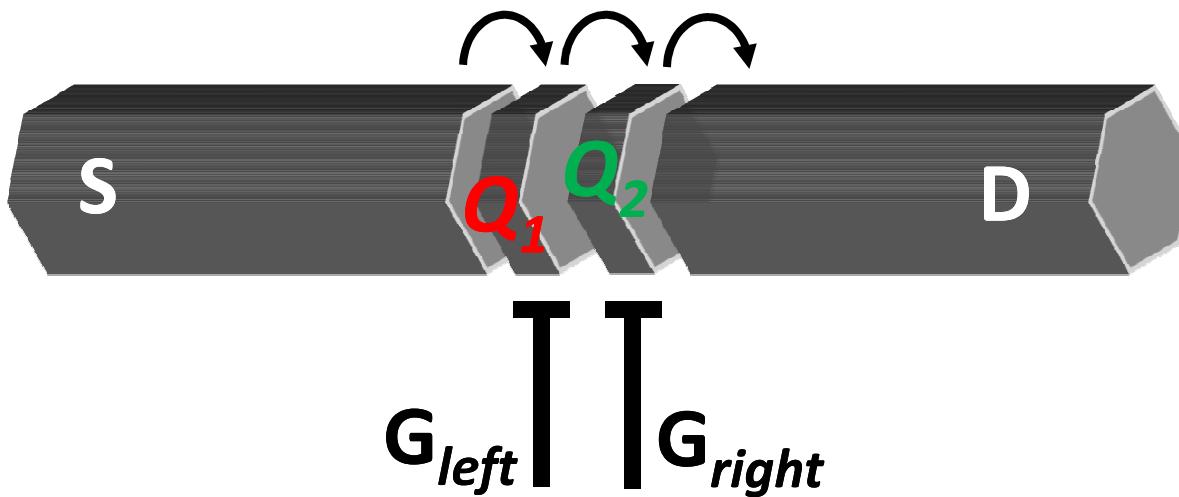
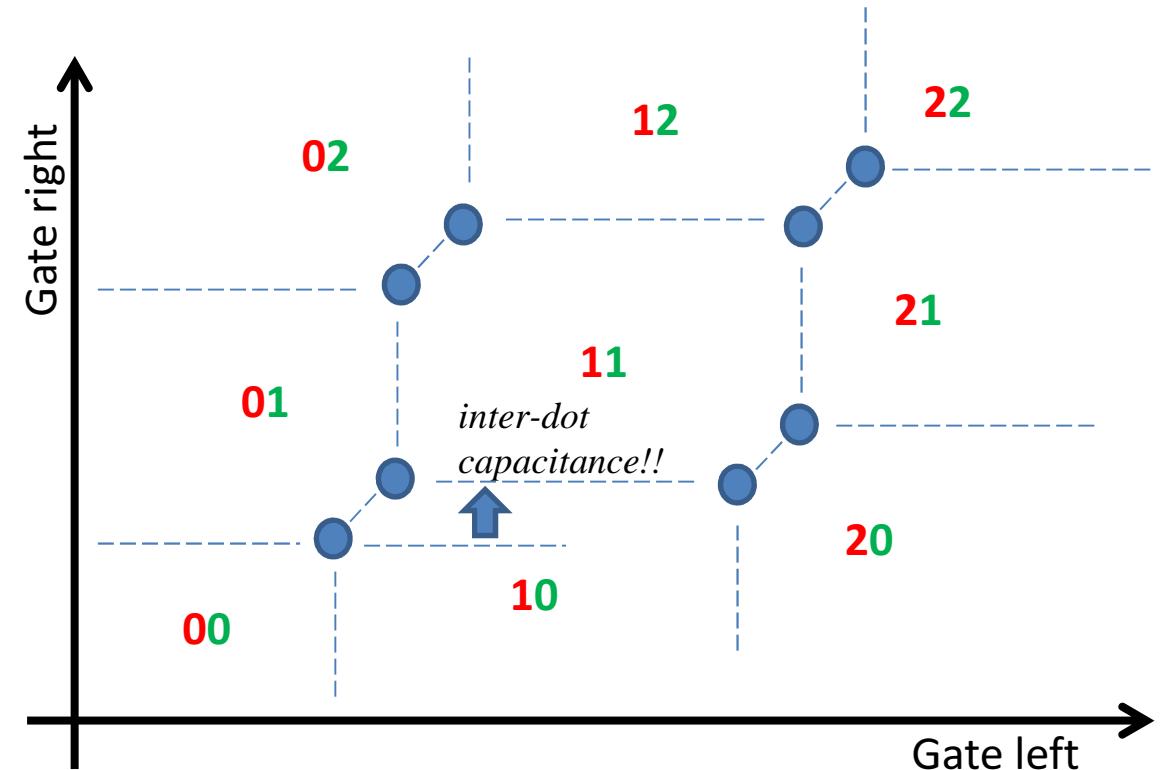
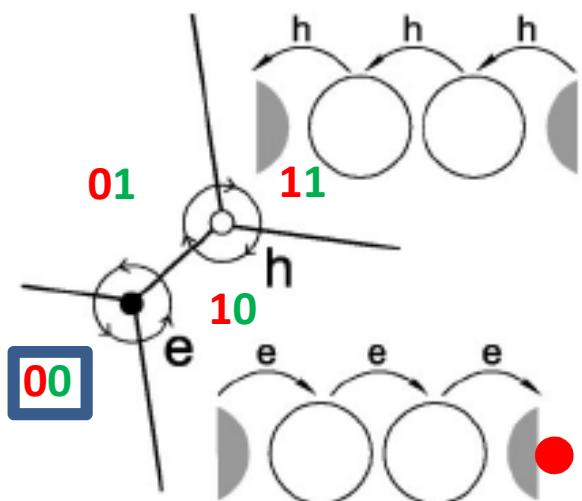


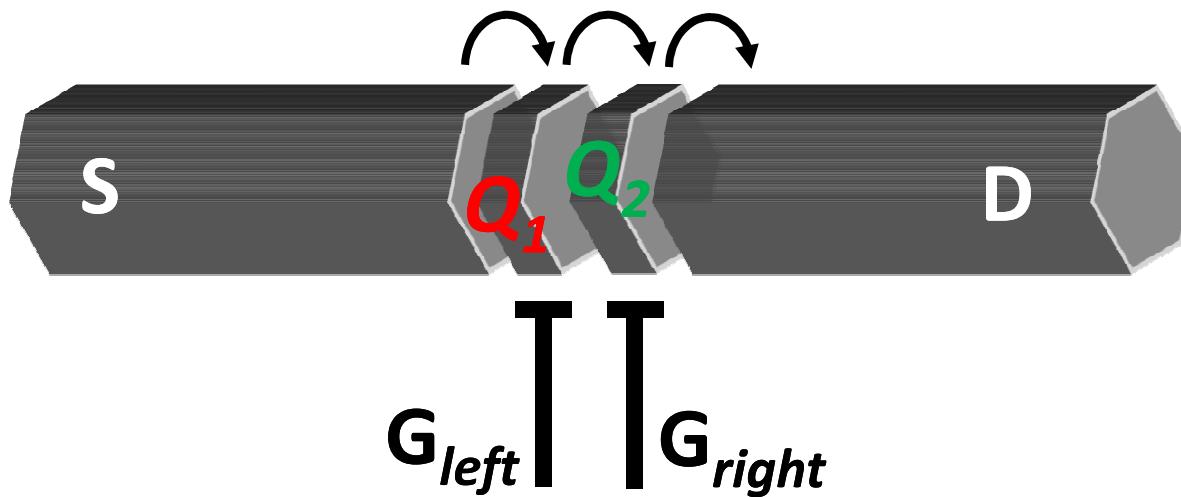
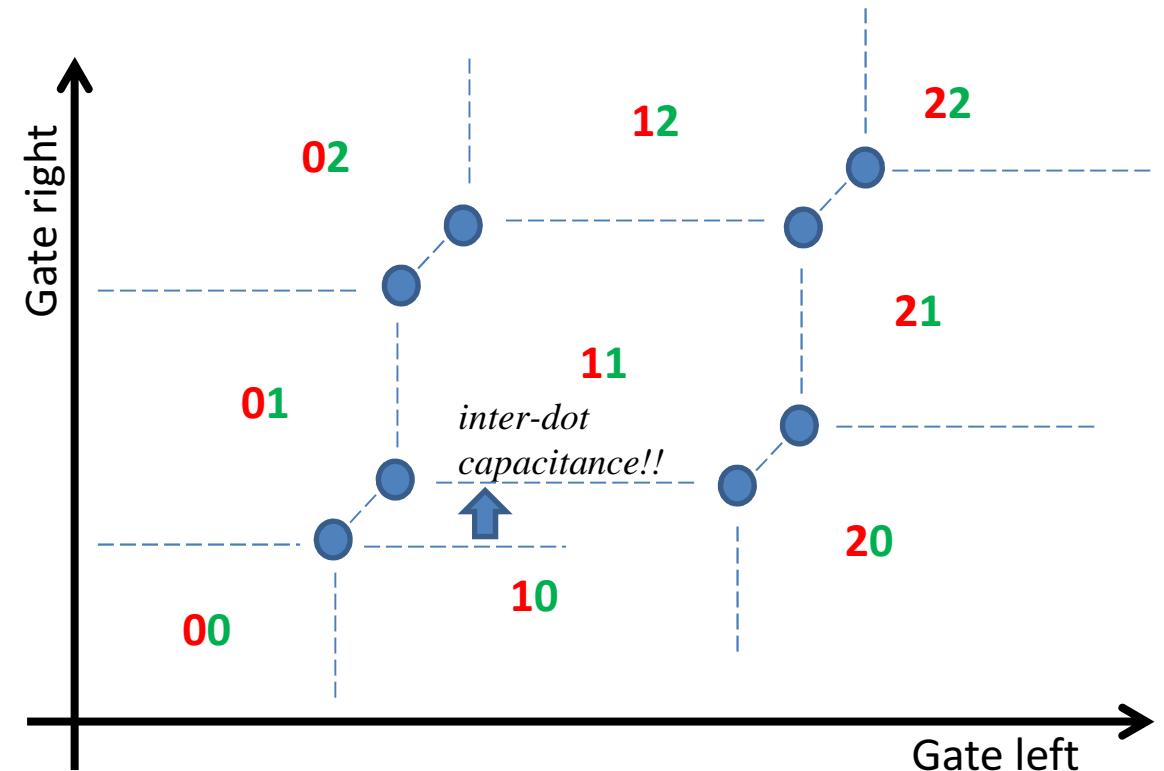
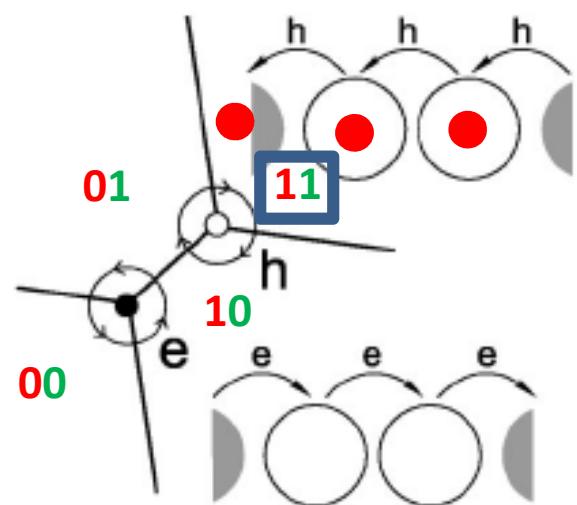


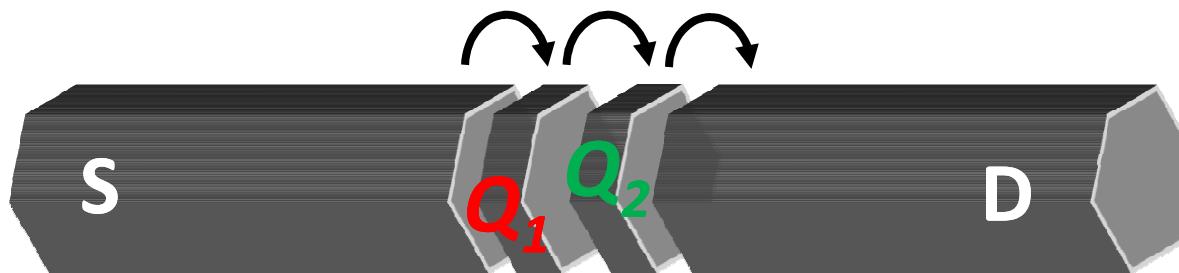
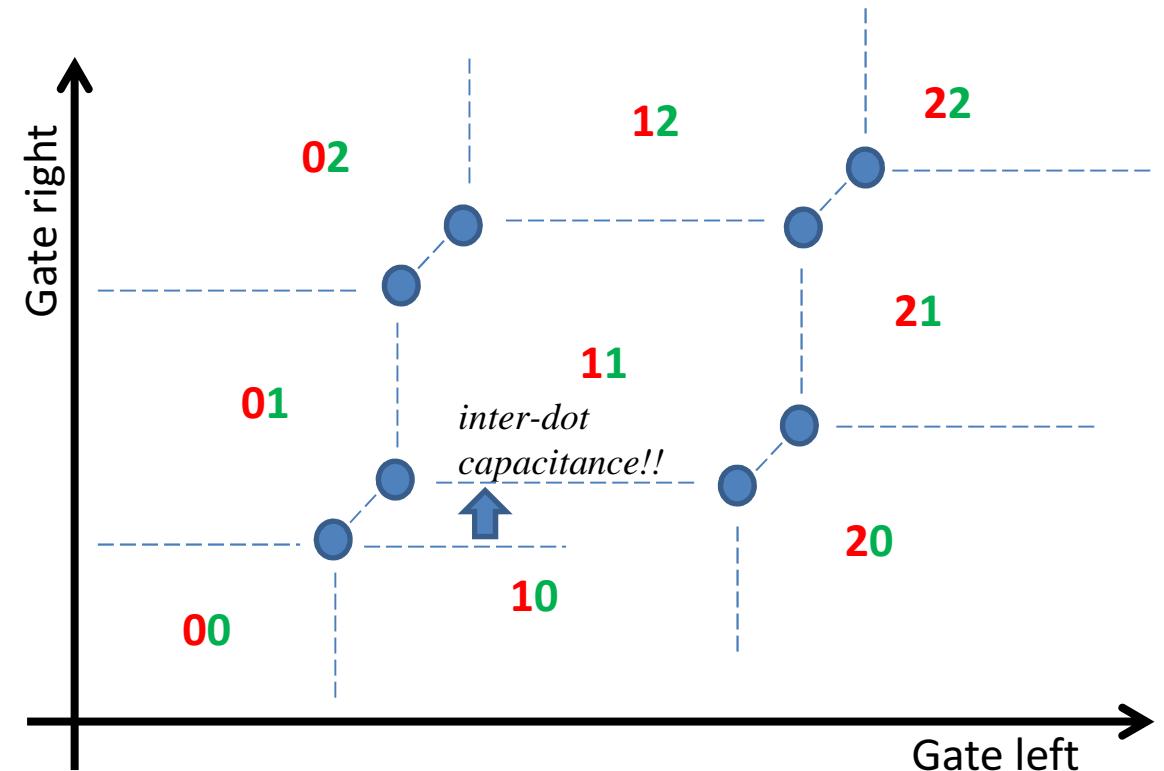
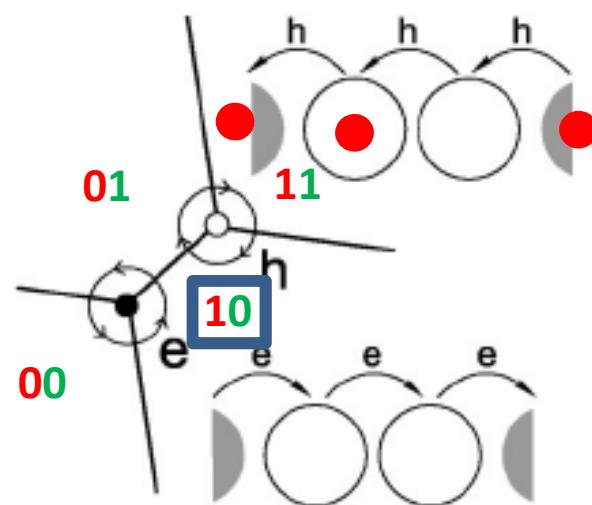


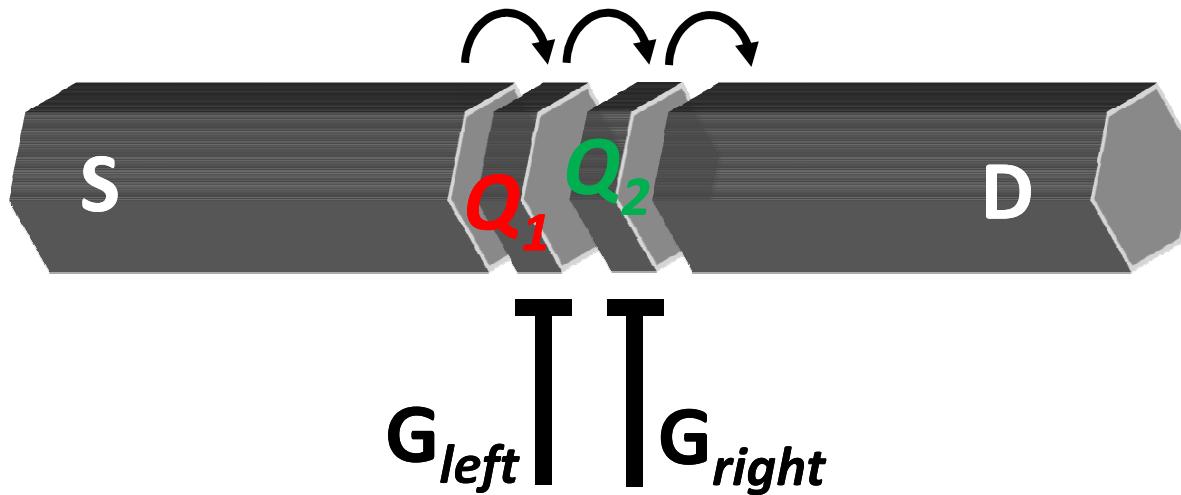
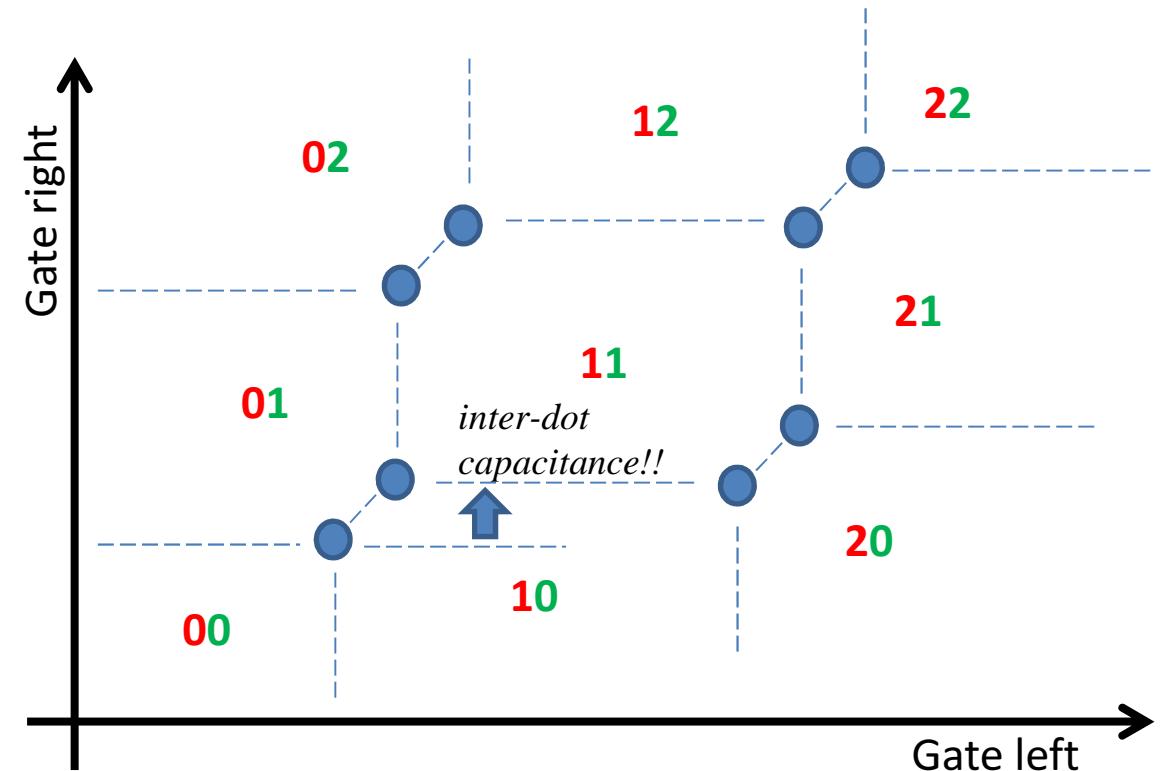
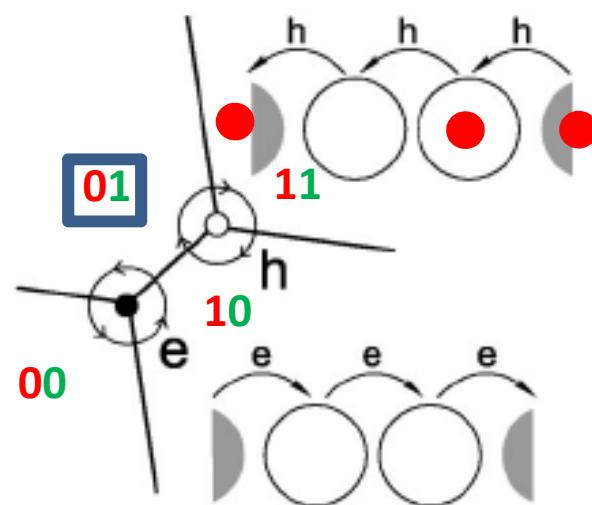


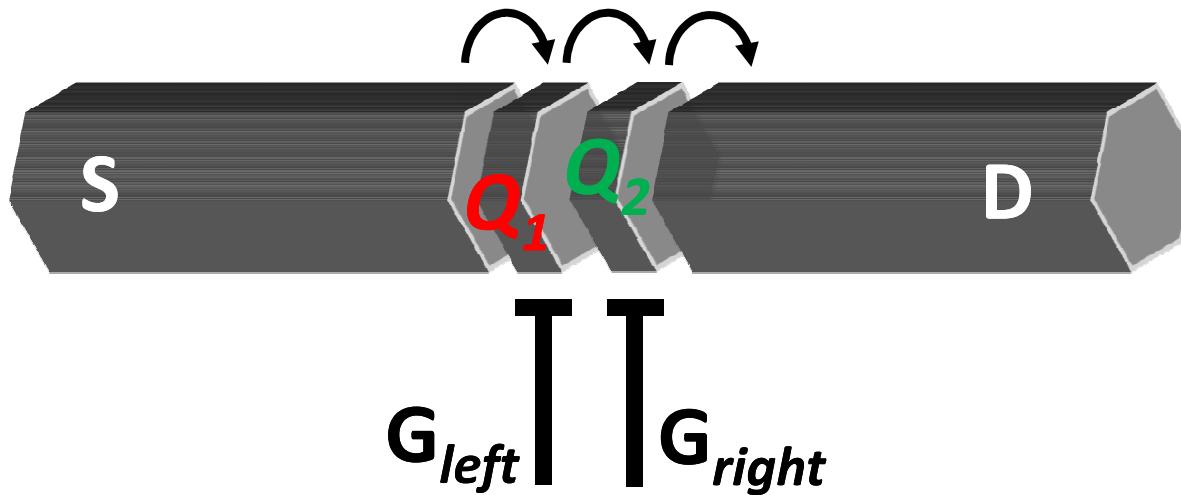
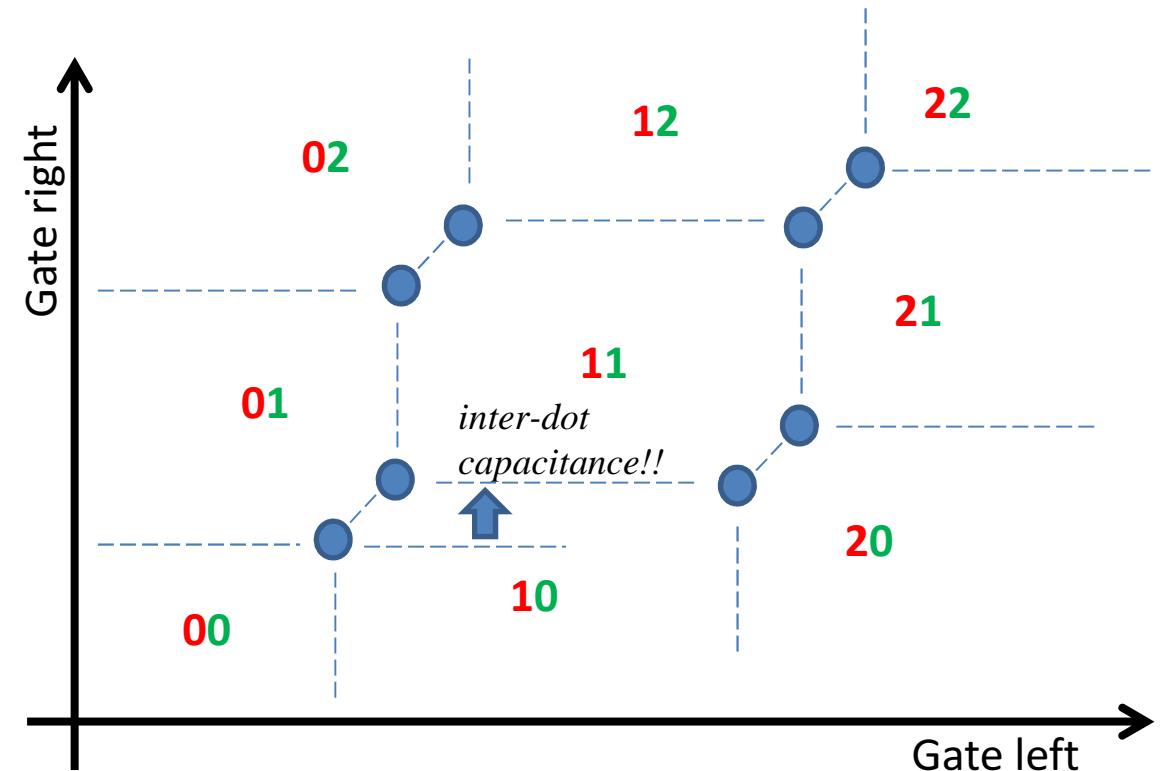
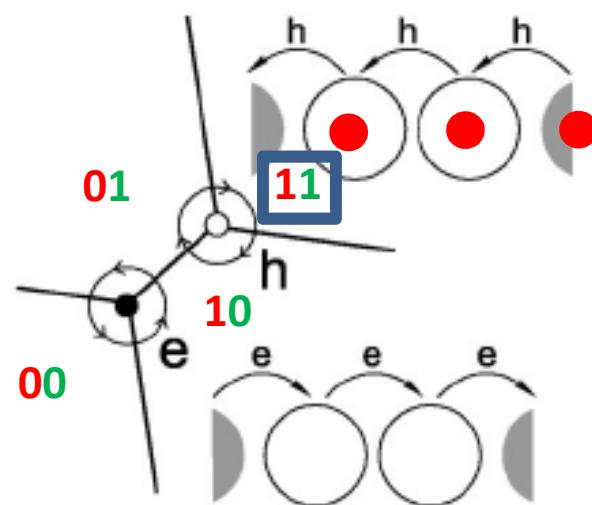




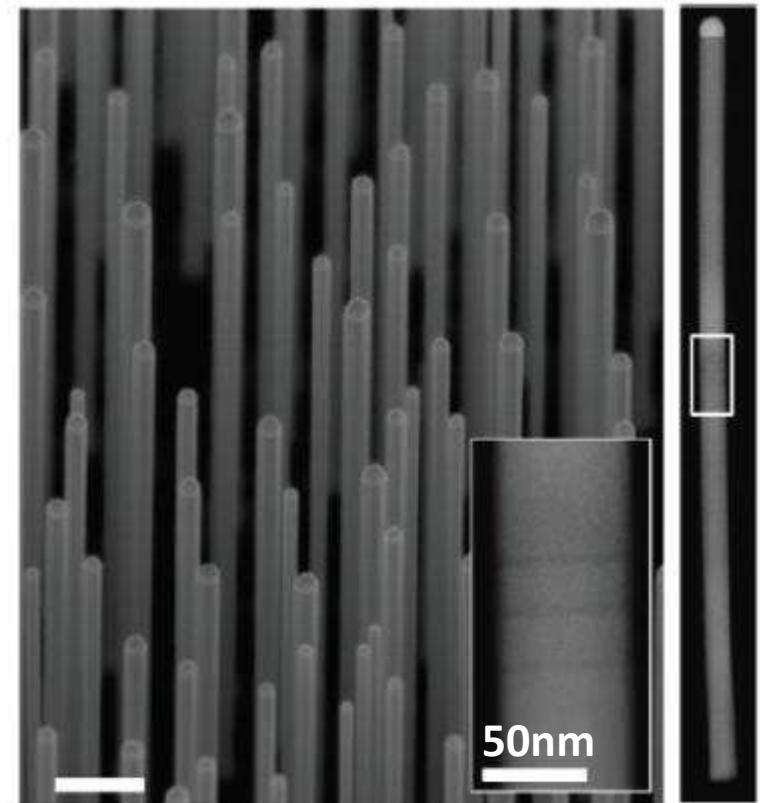
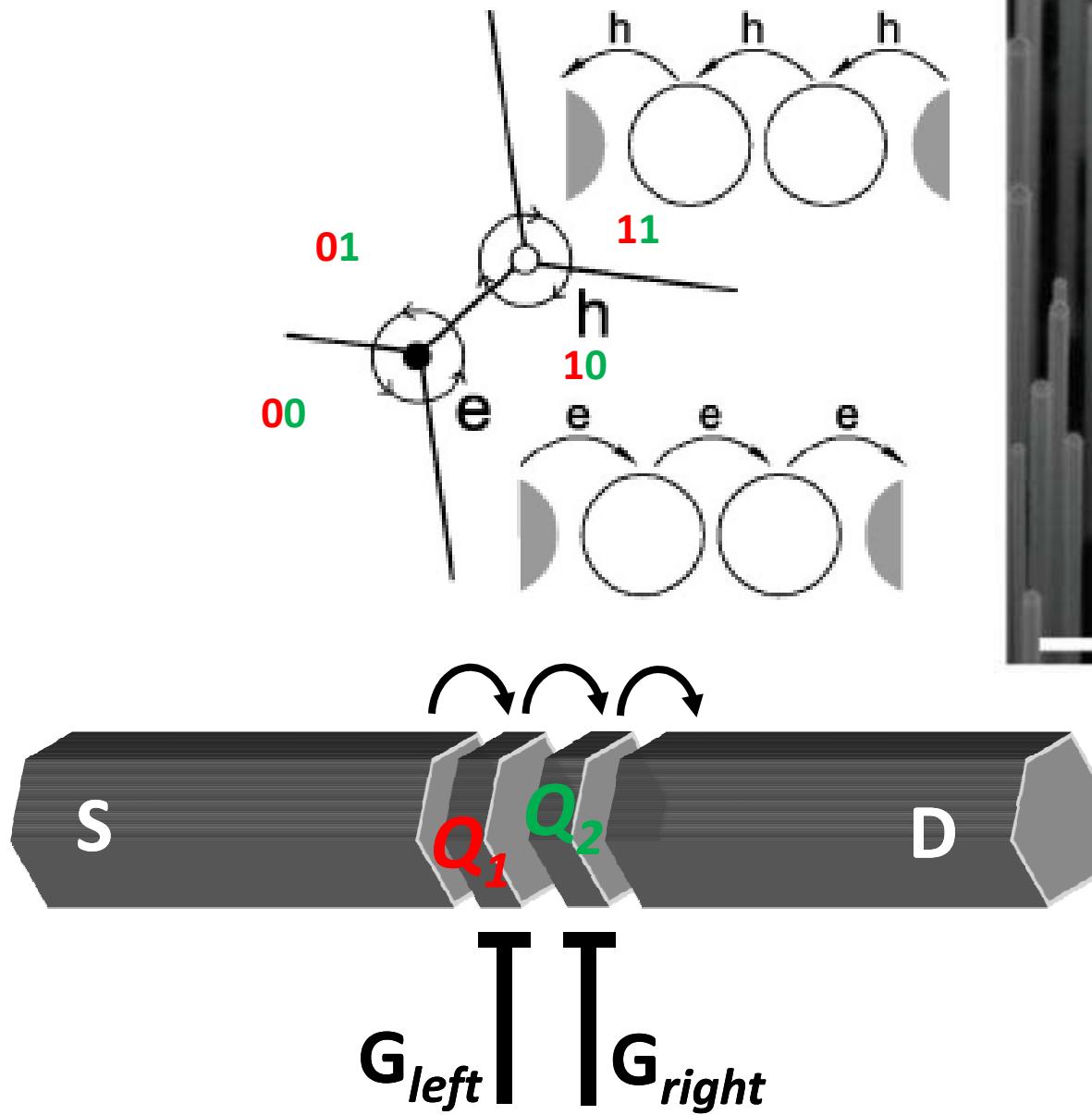




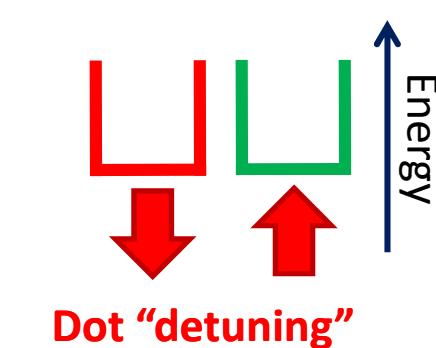
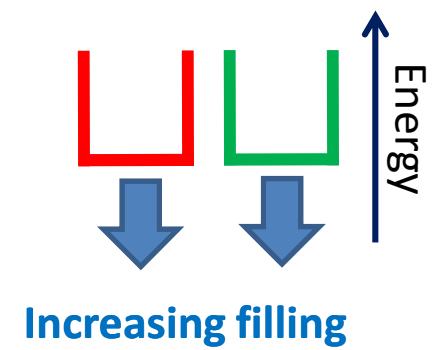
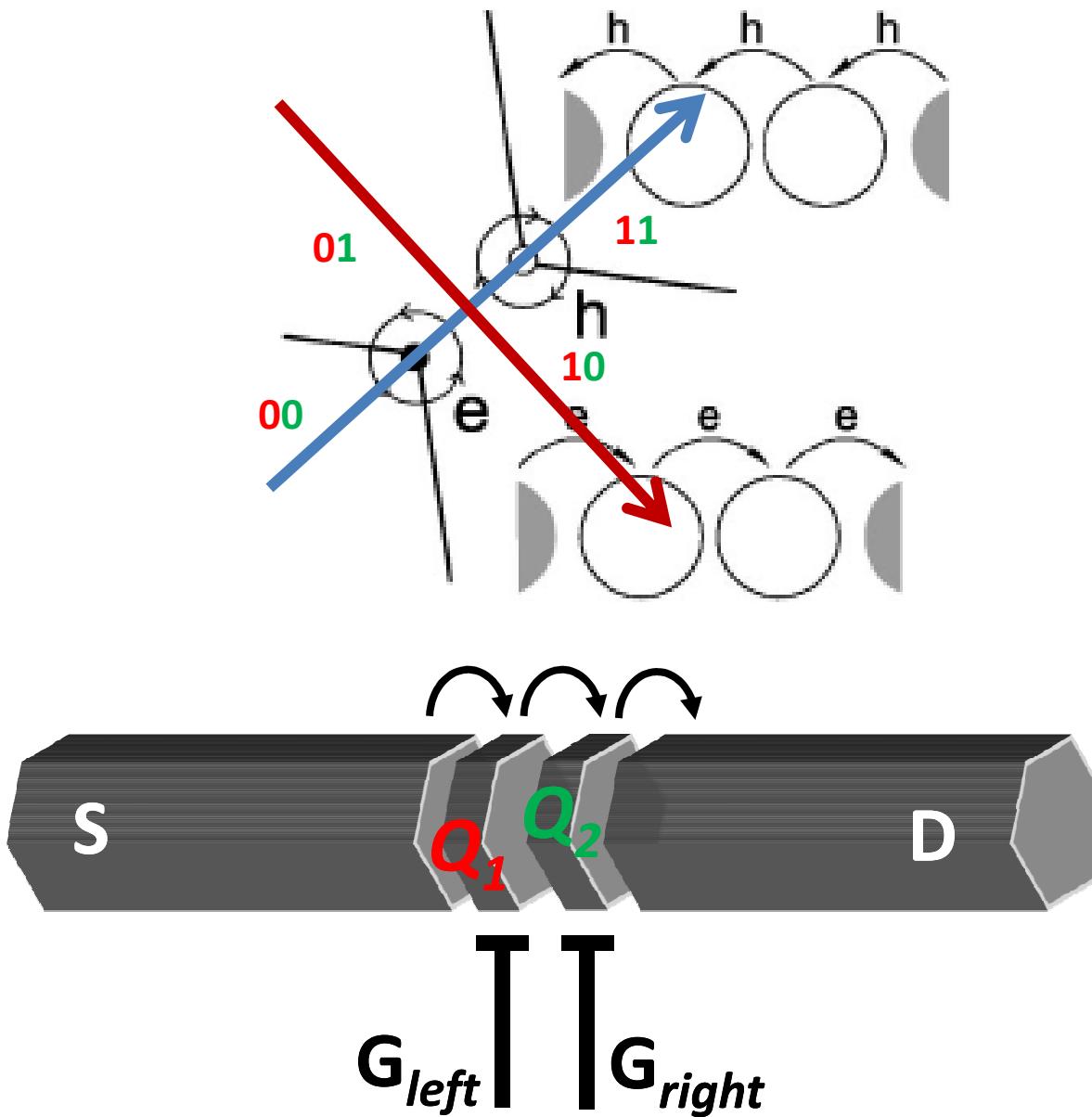




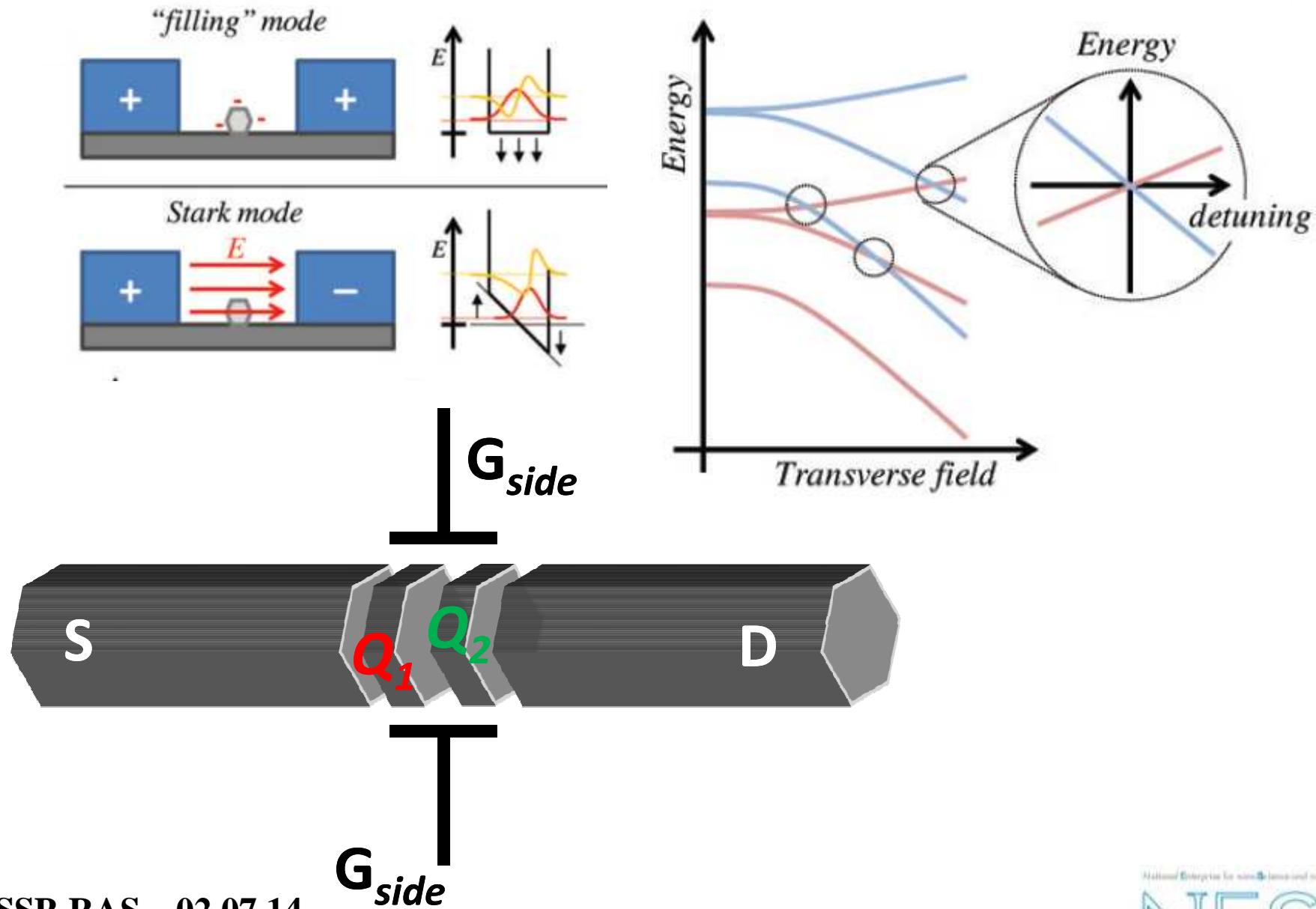
Controlling a double QD



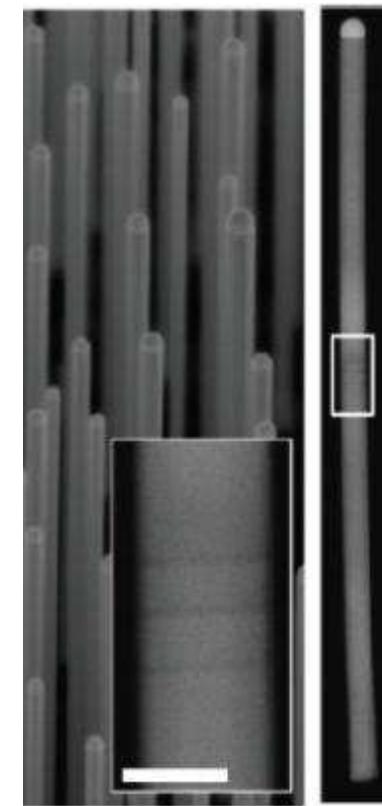
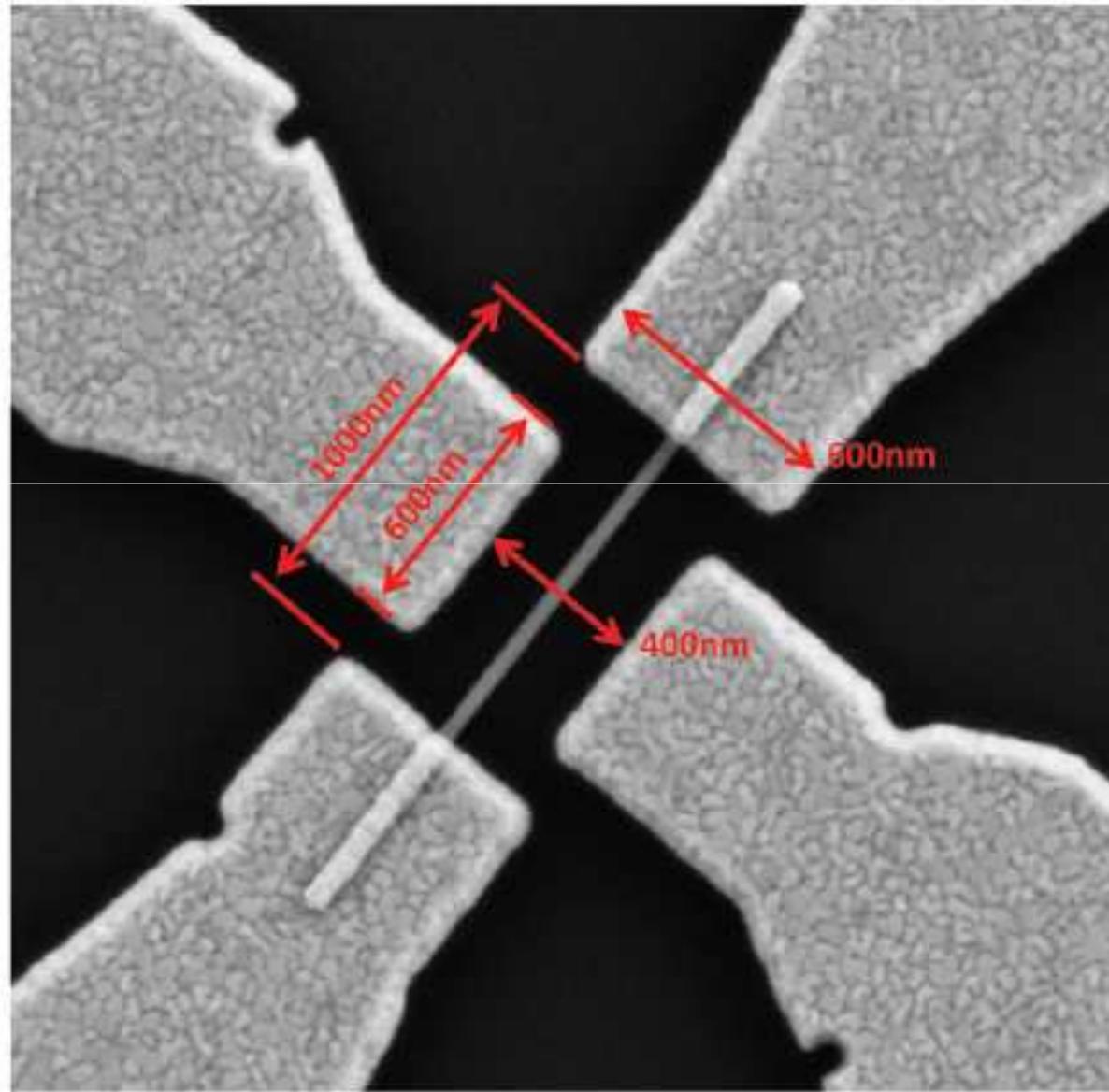
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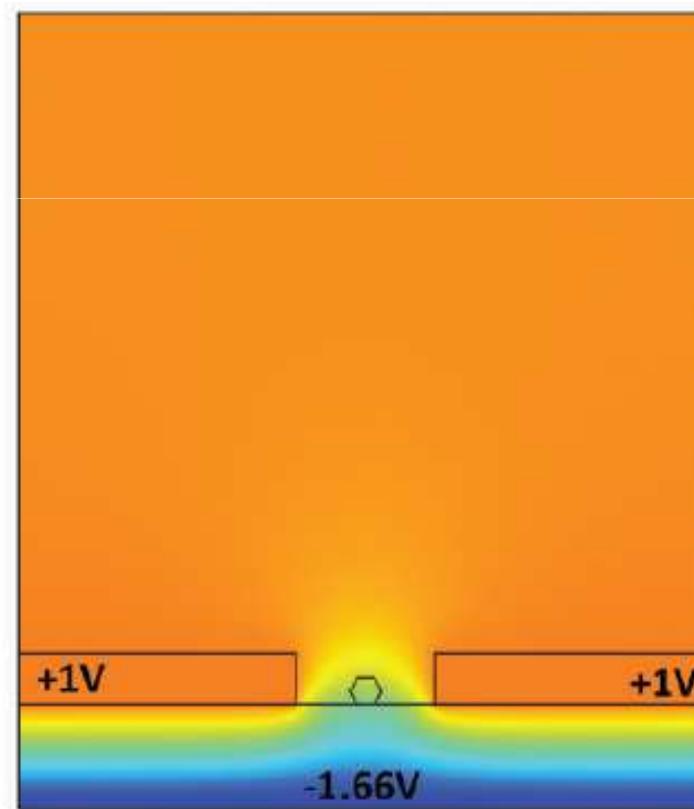
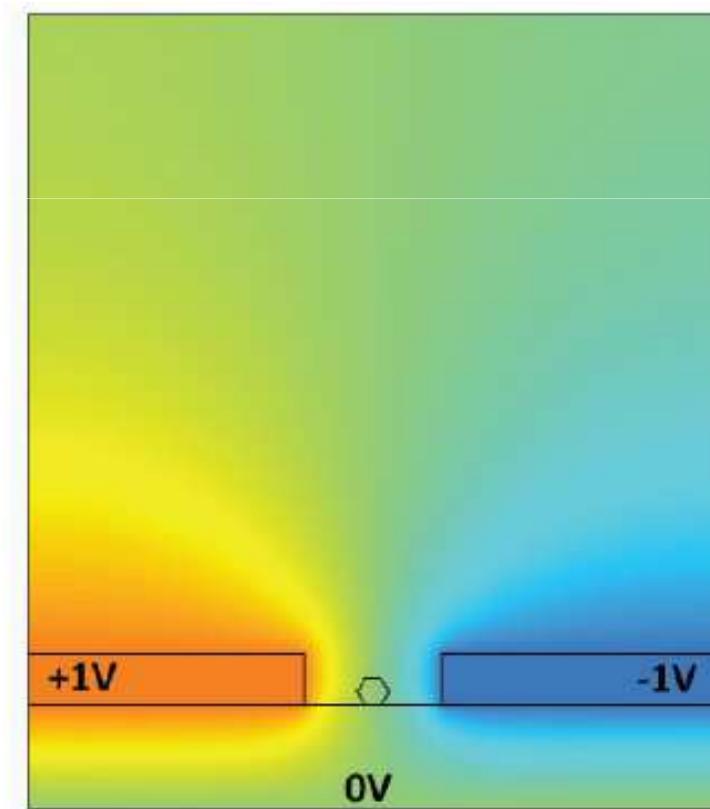
Controlling a double QD by Stark effect



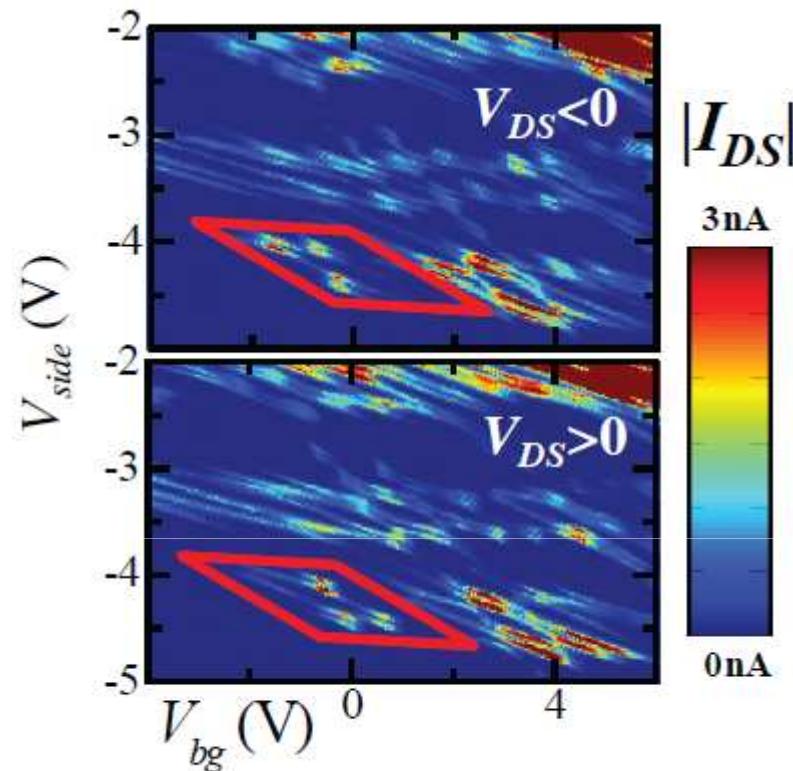
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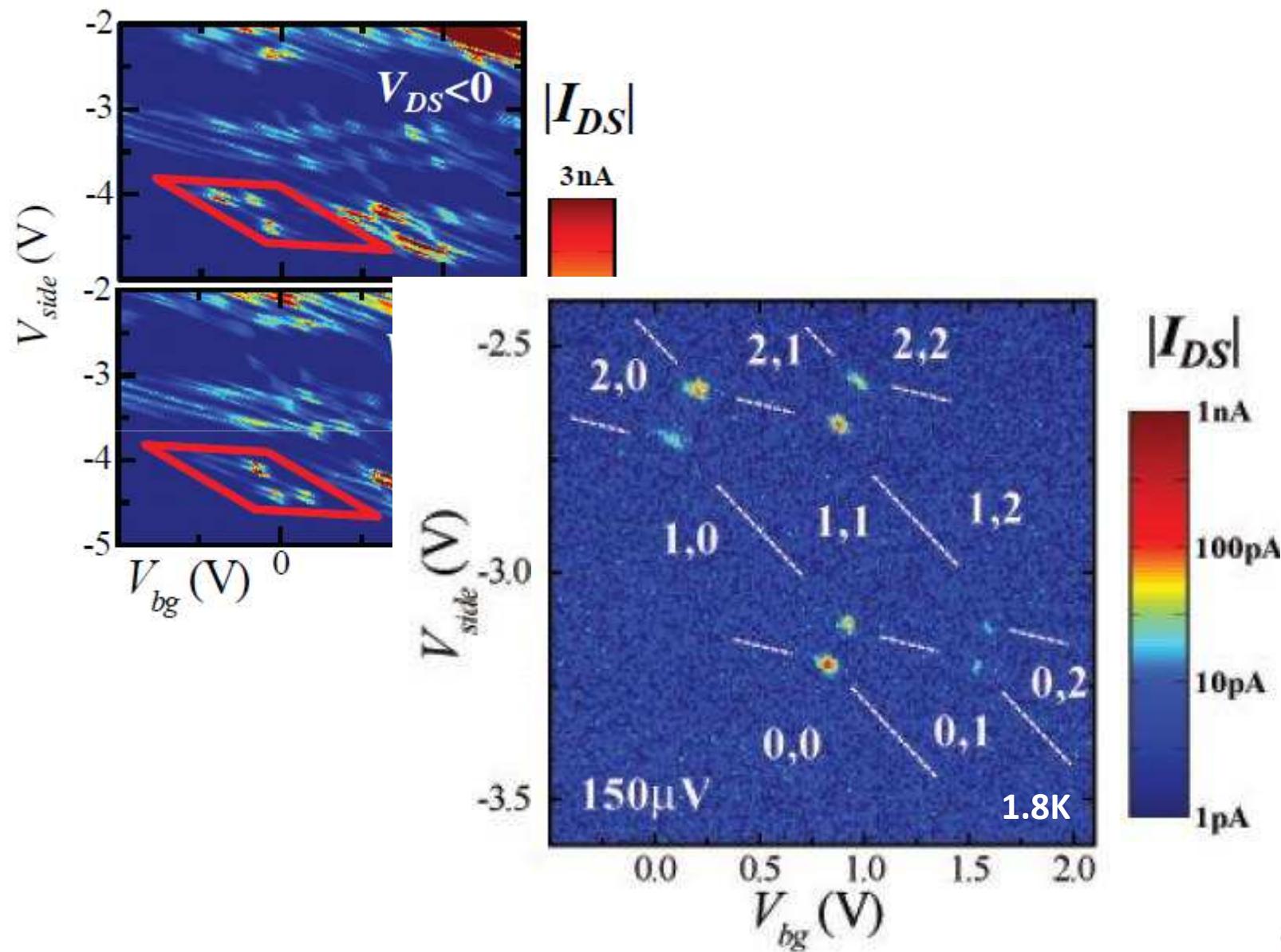
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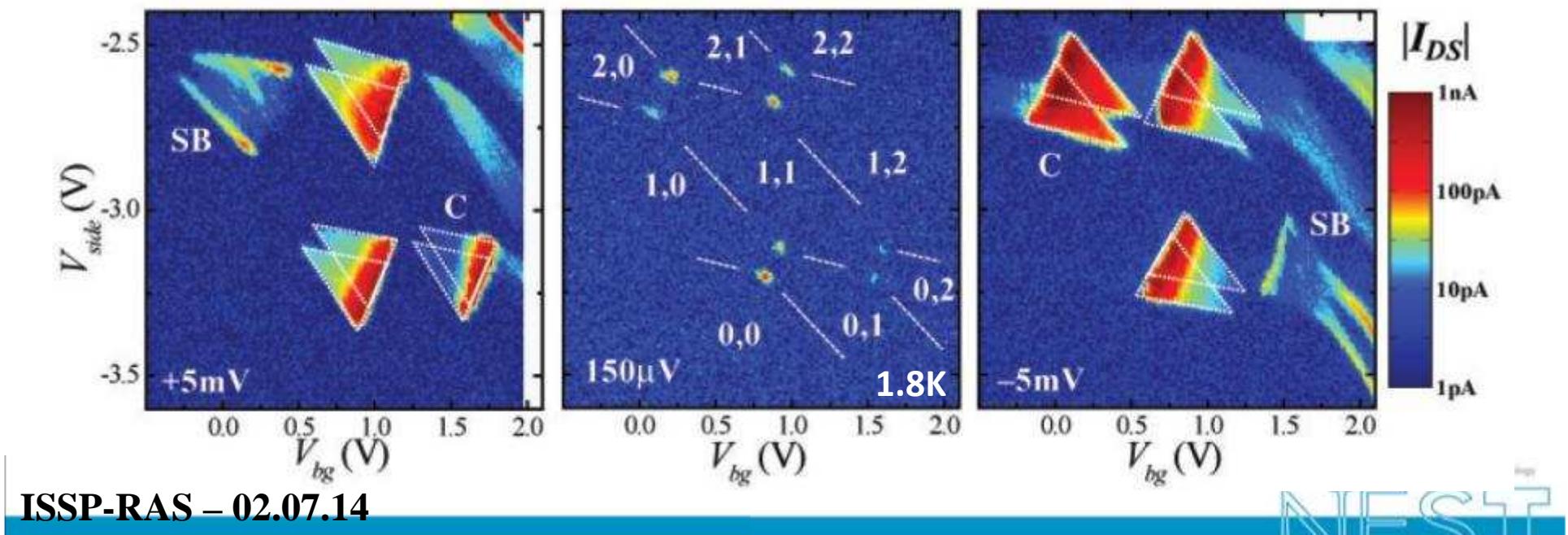
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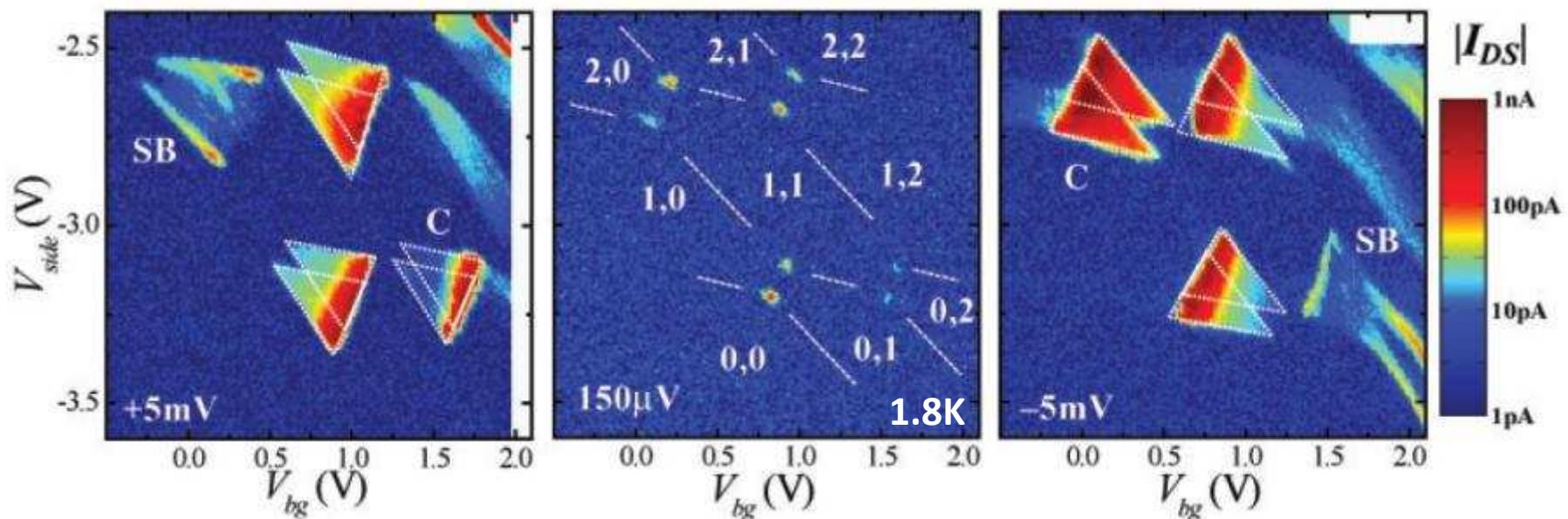
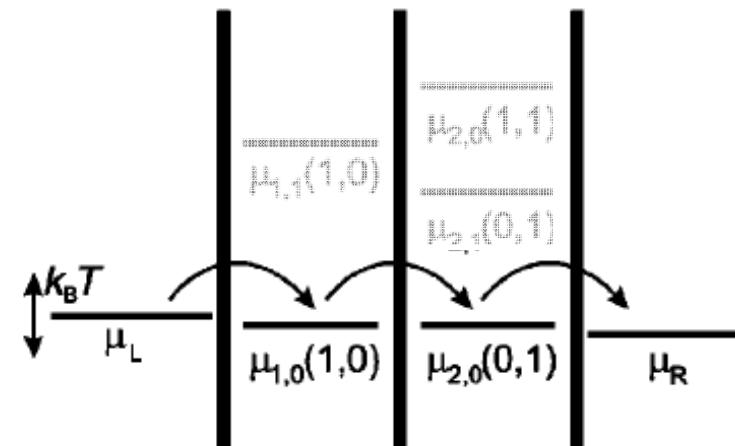
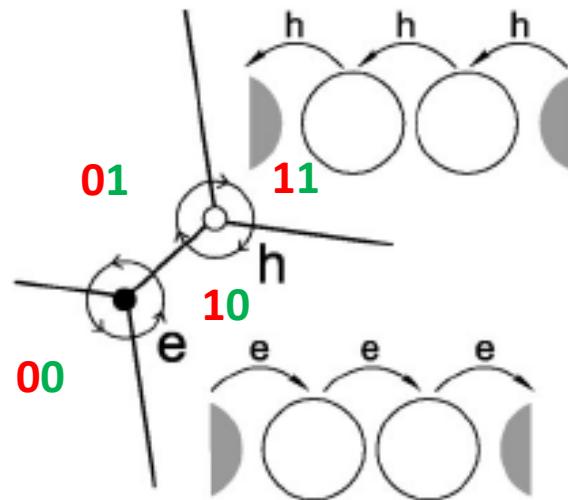
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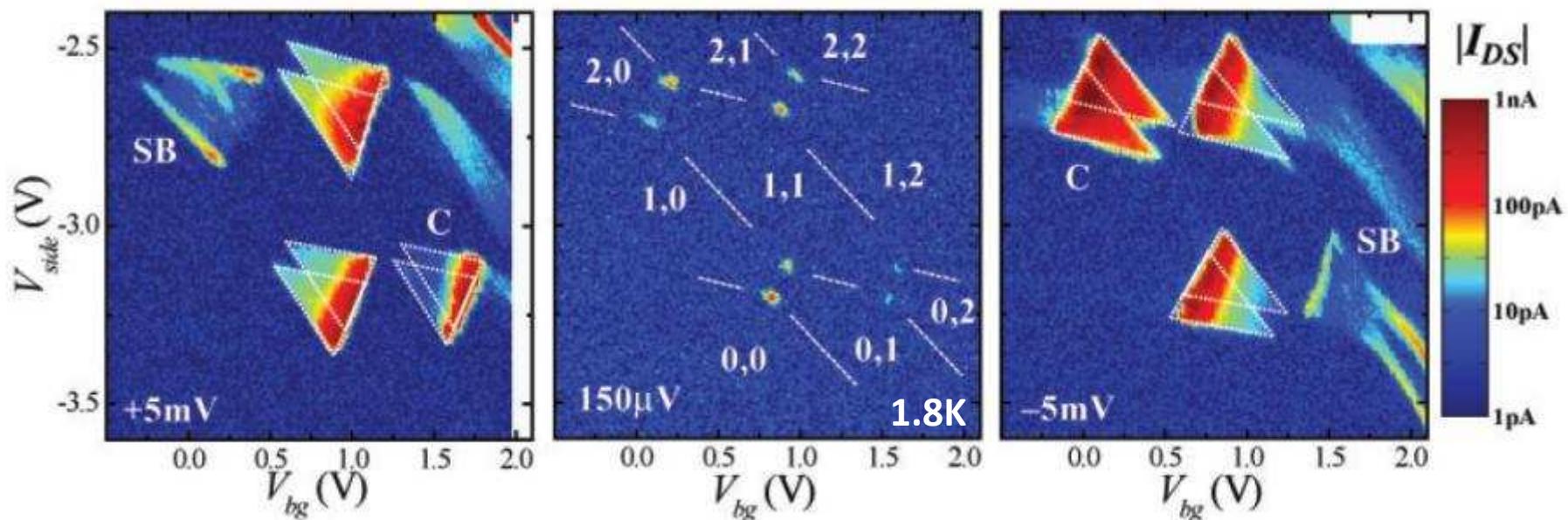
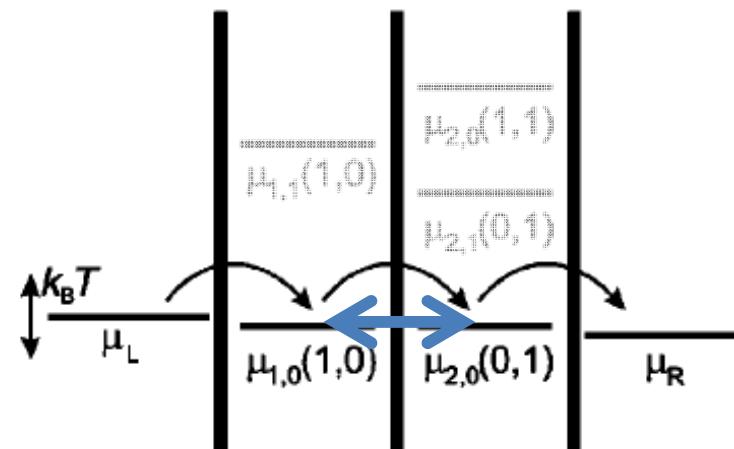
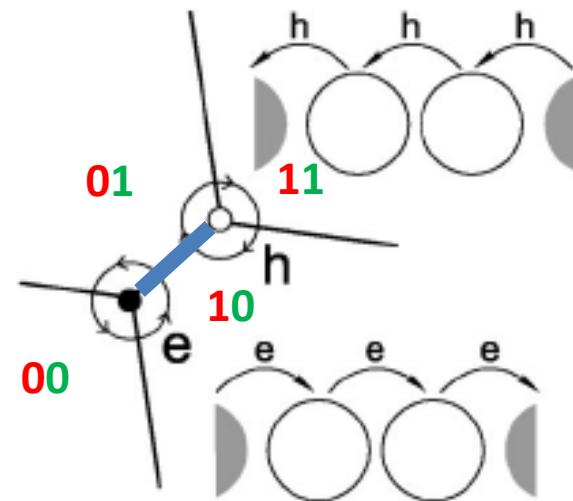
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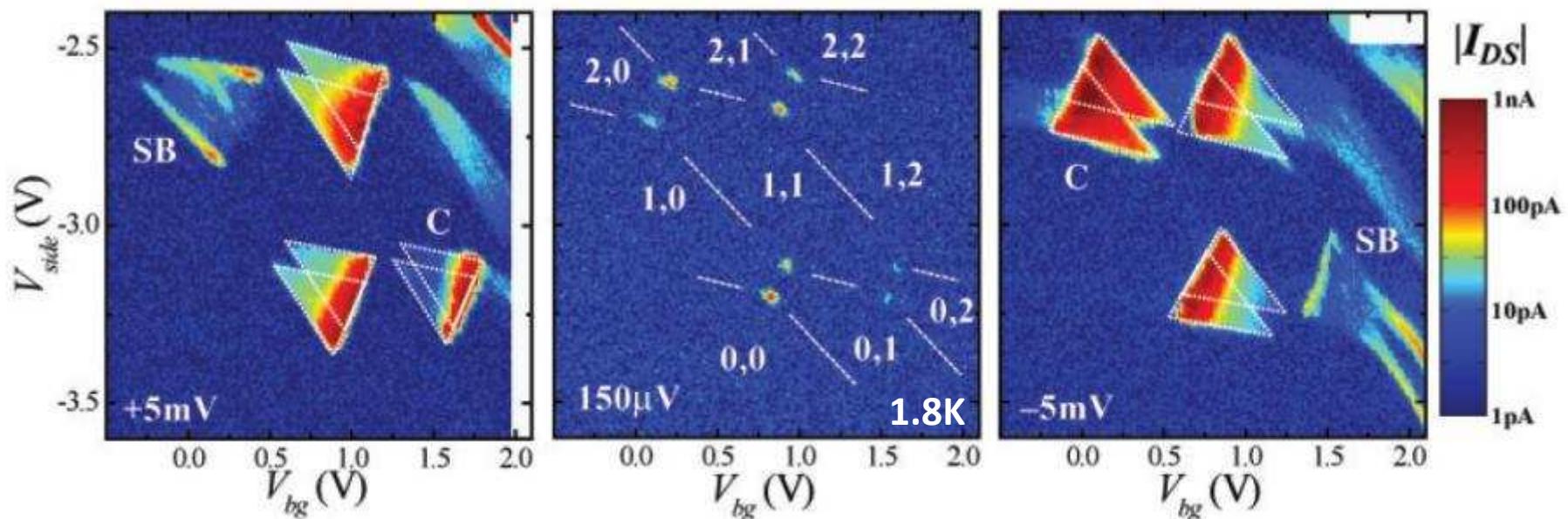
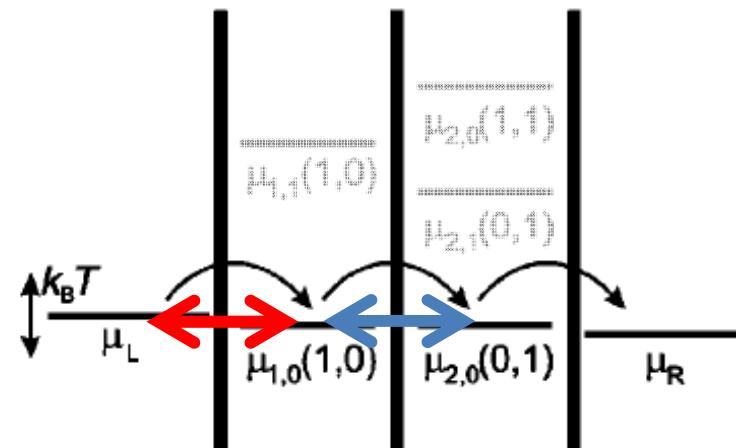
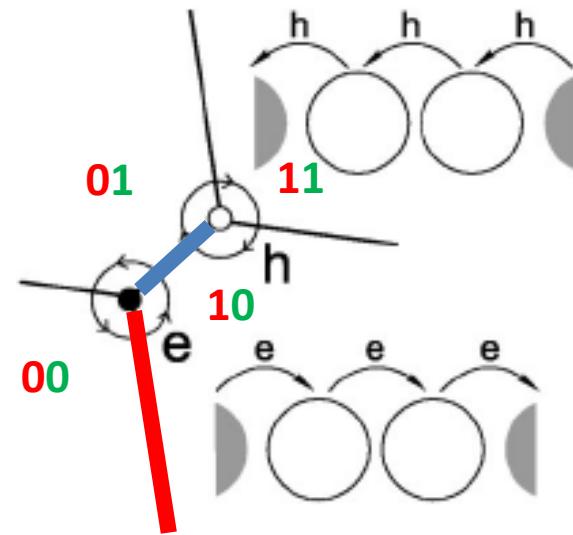
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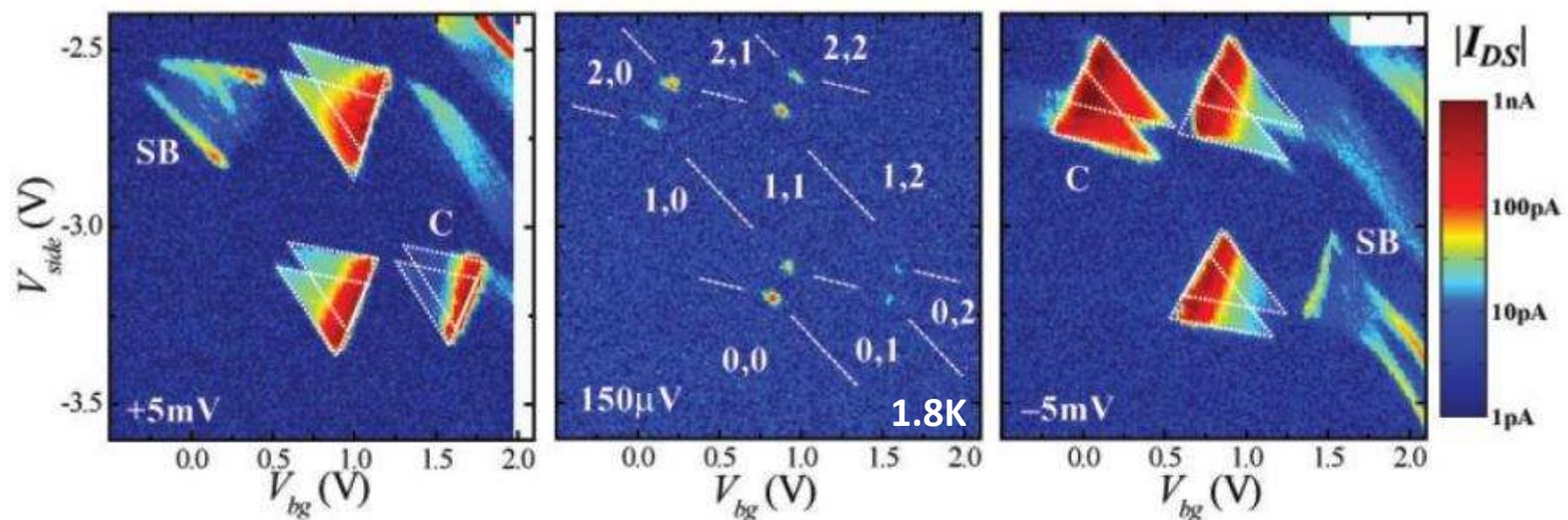
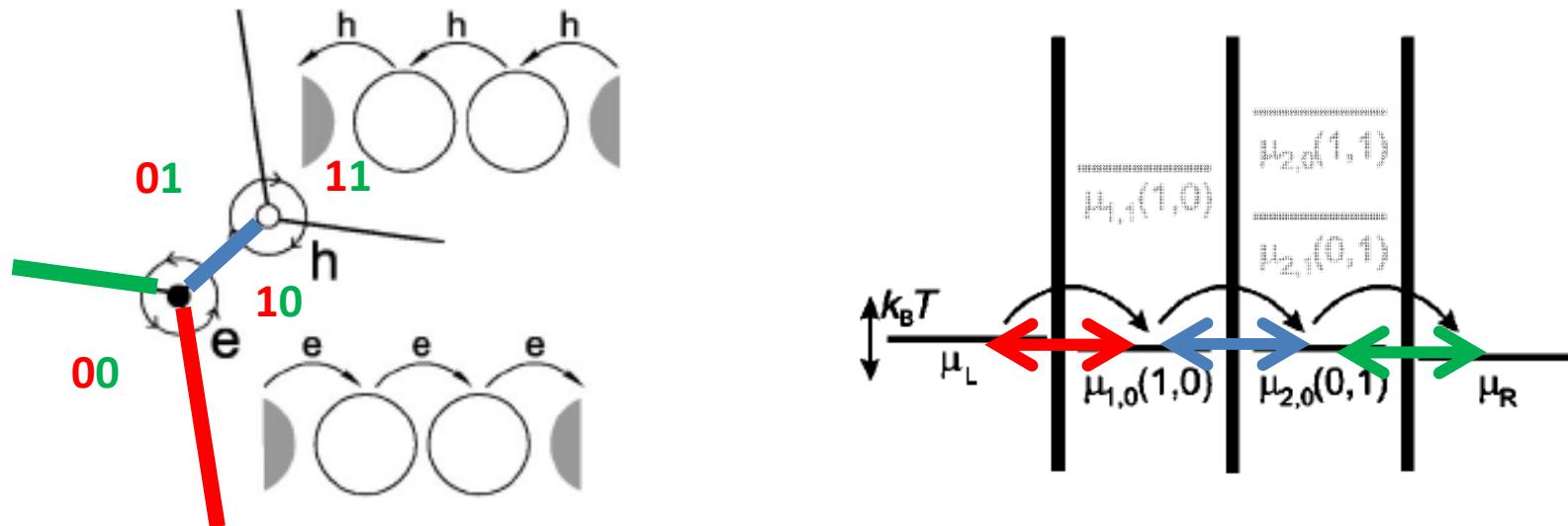
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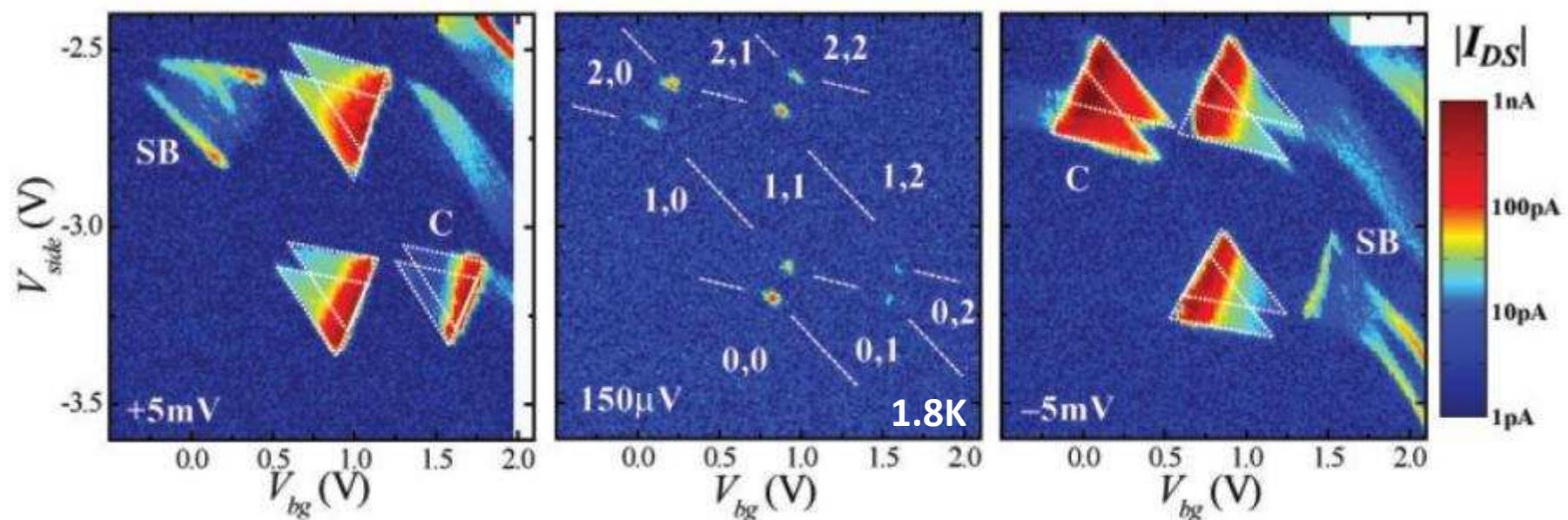
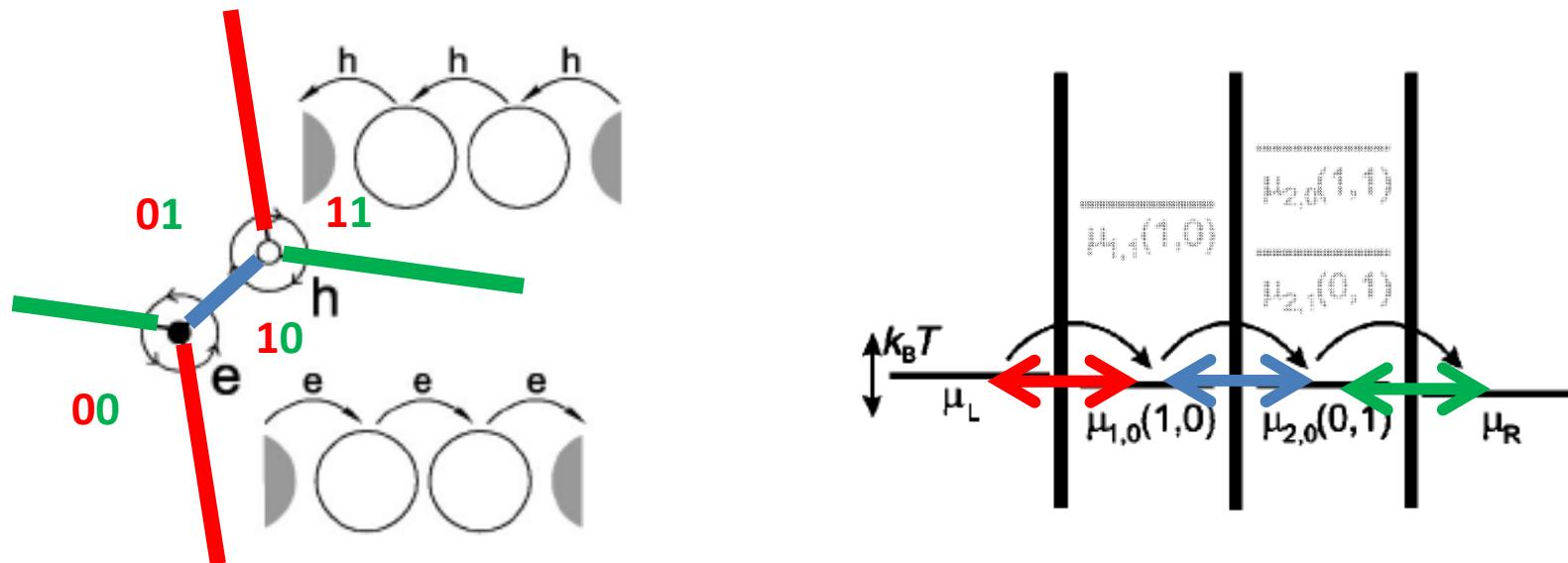
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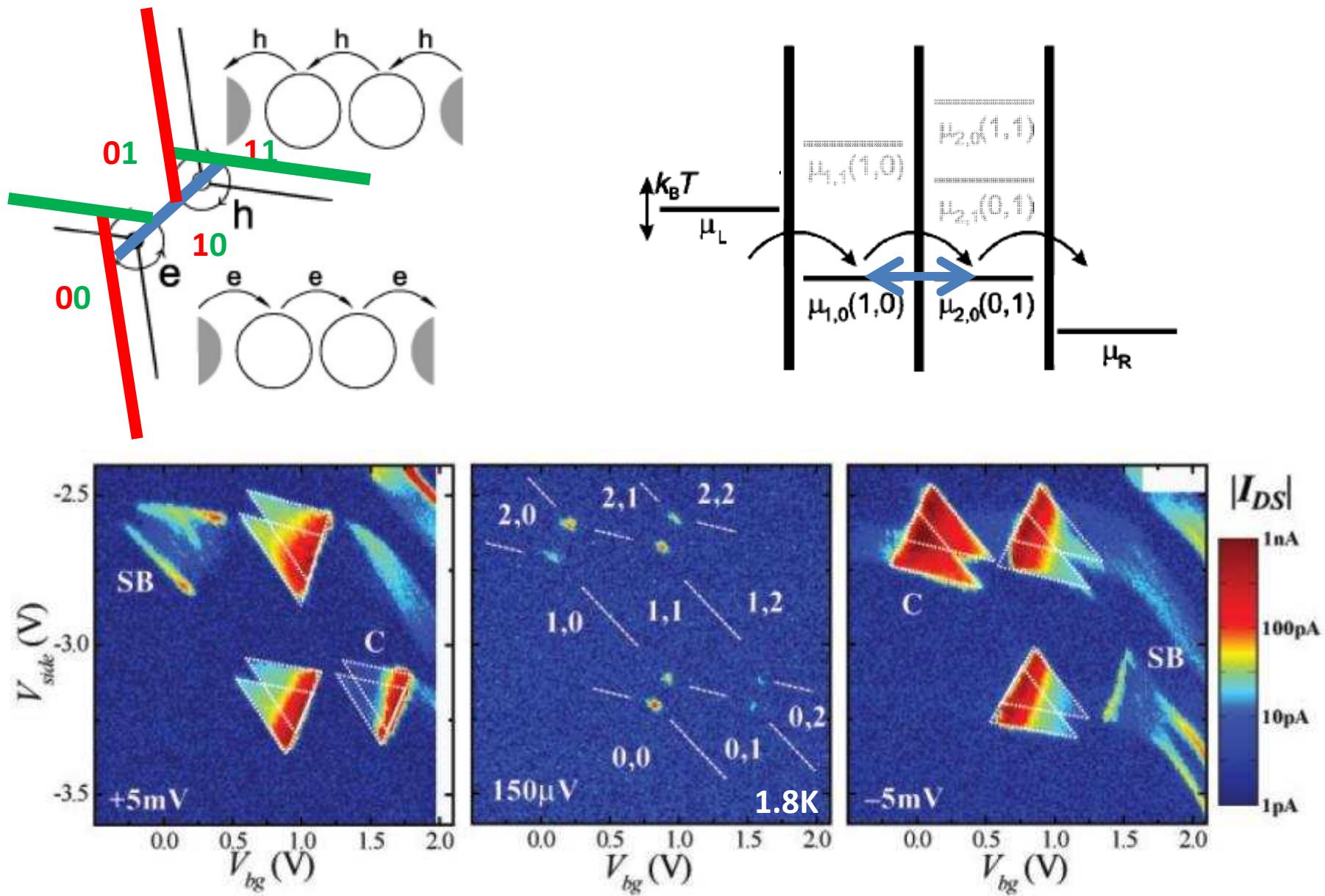
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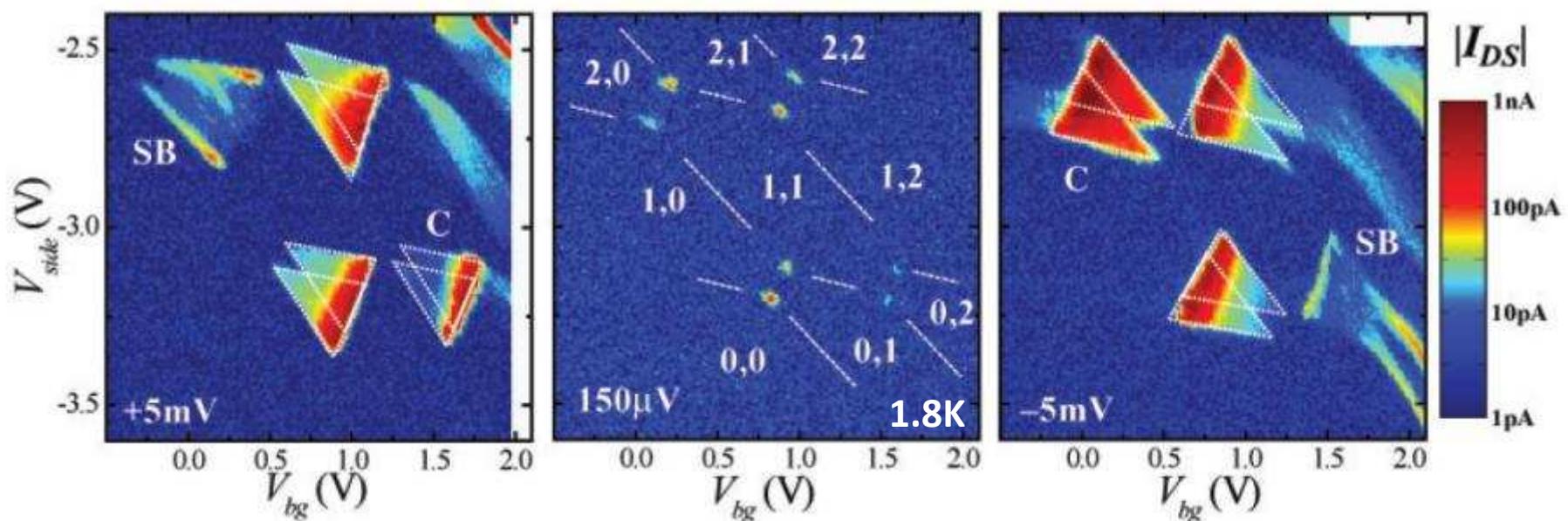
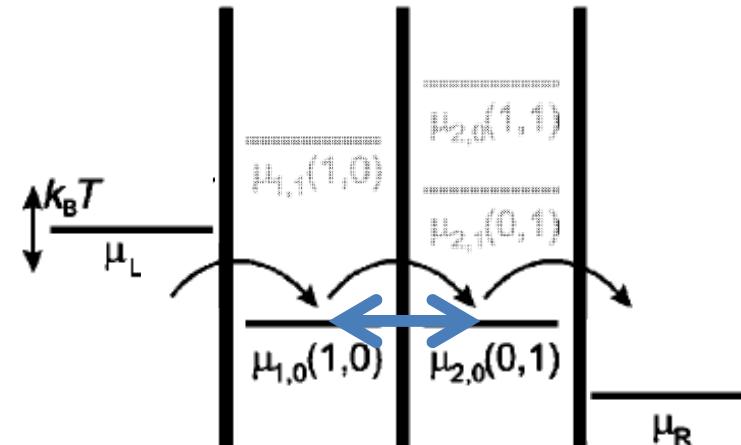
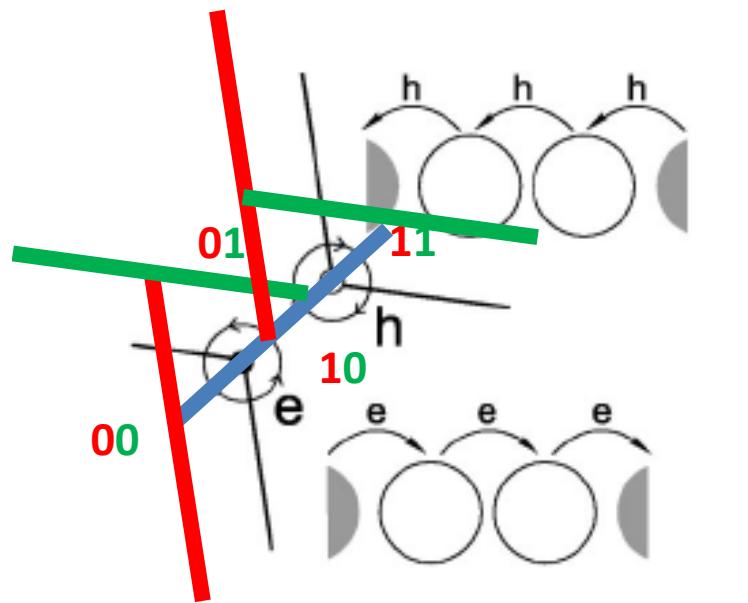
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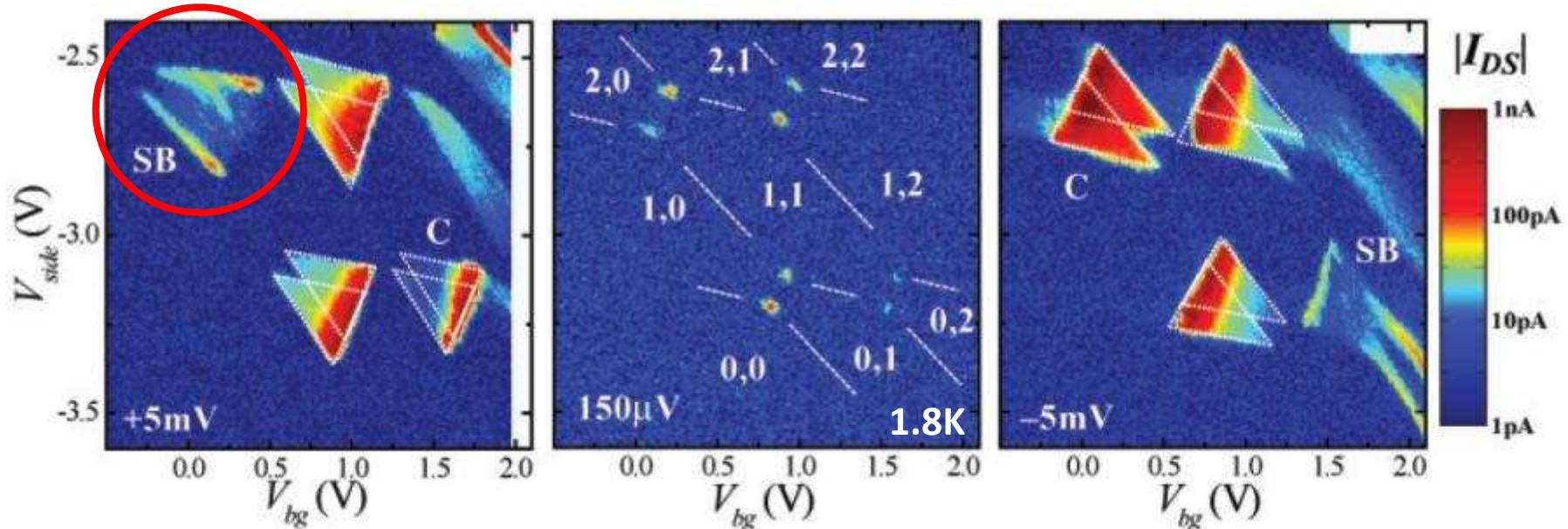
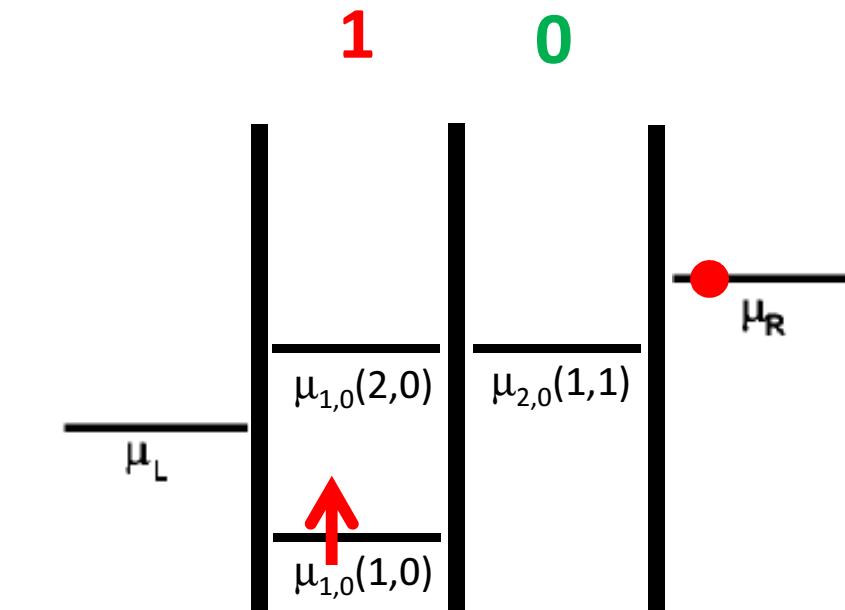
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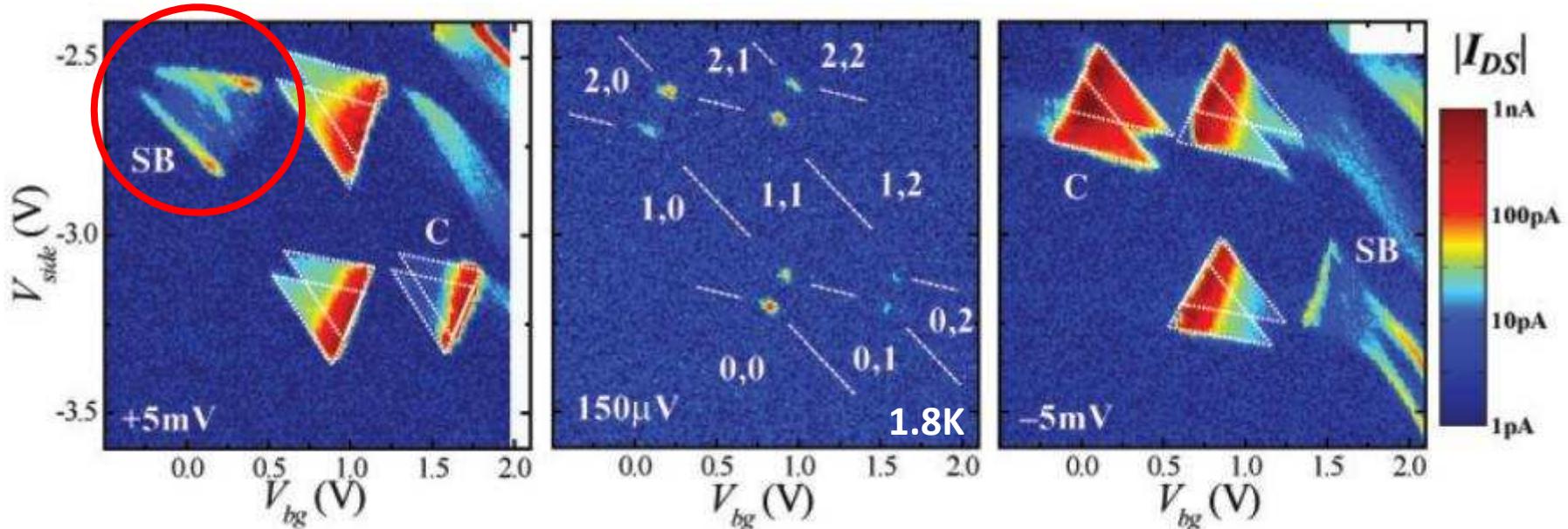
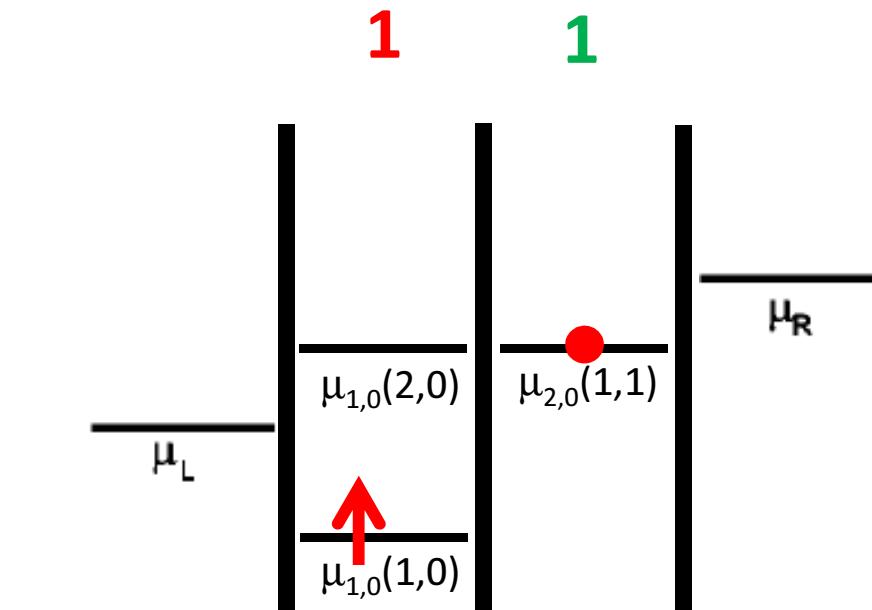
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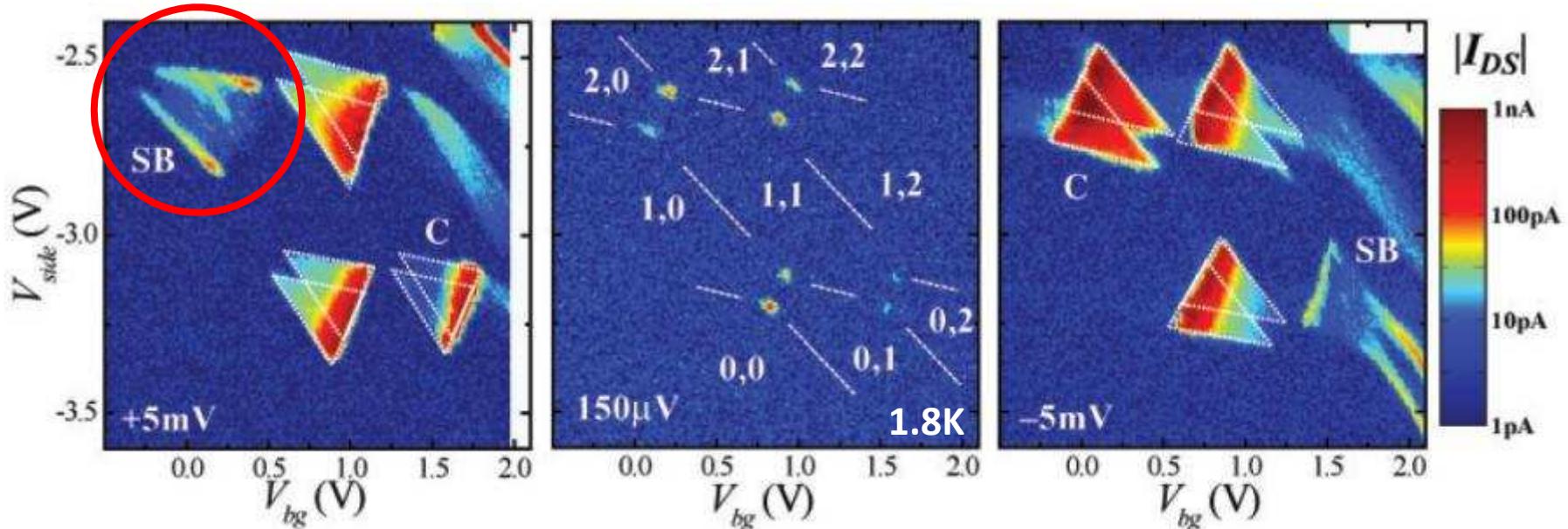
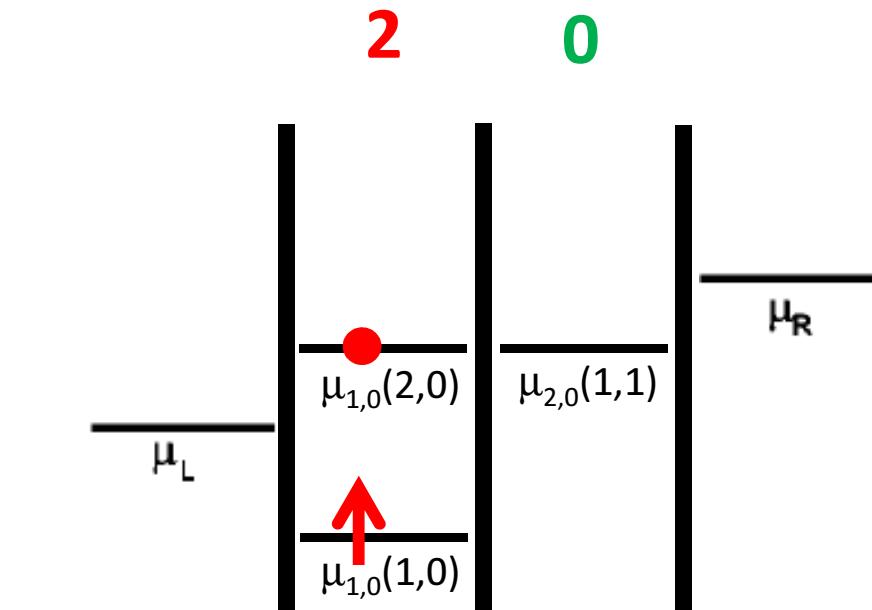
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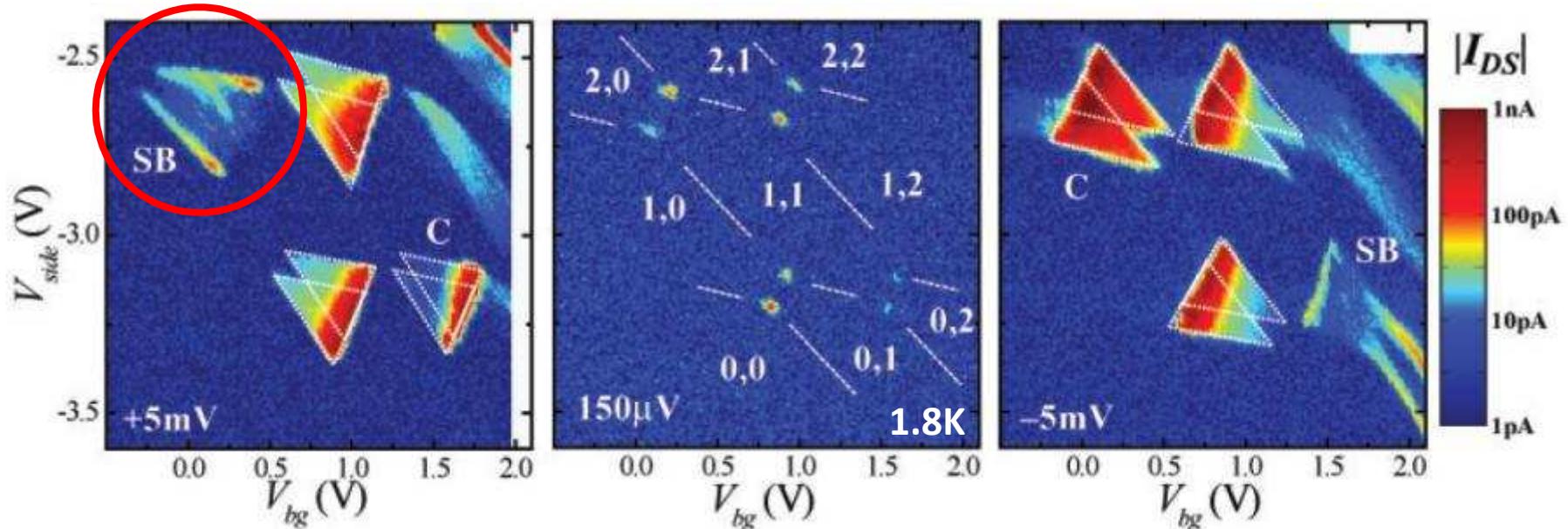
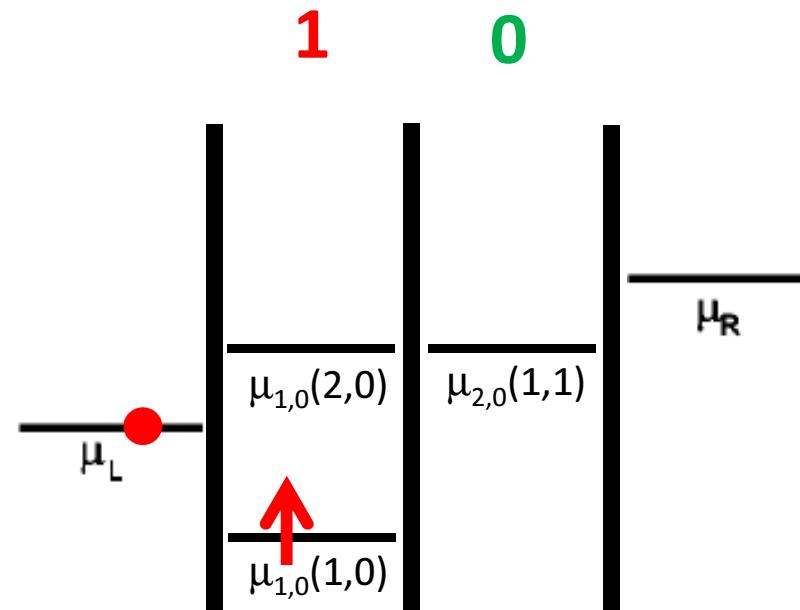
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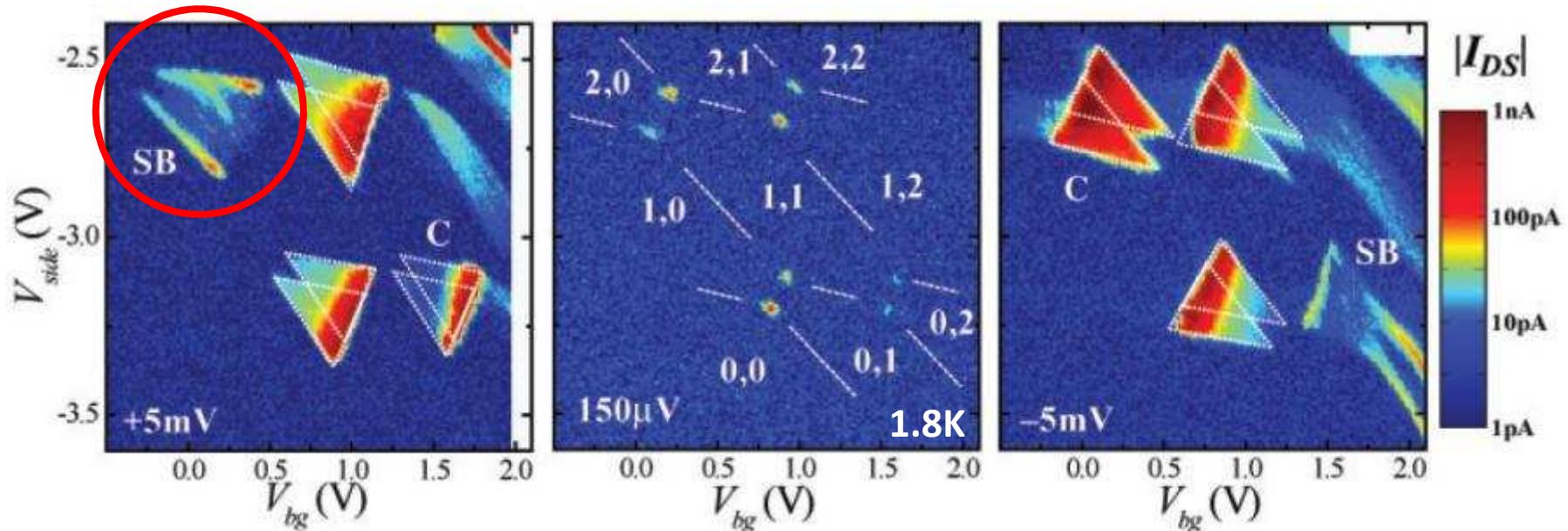
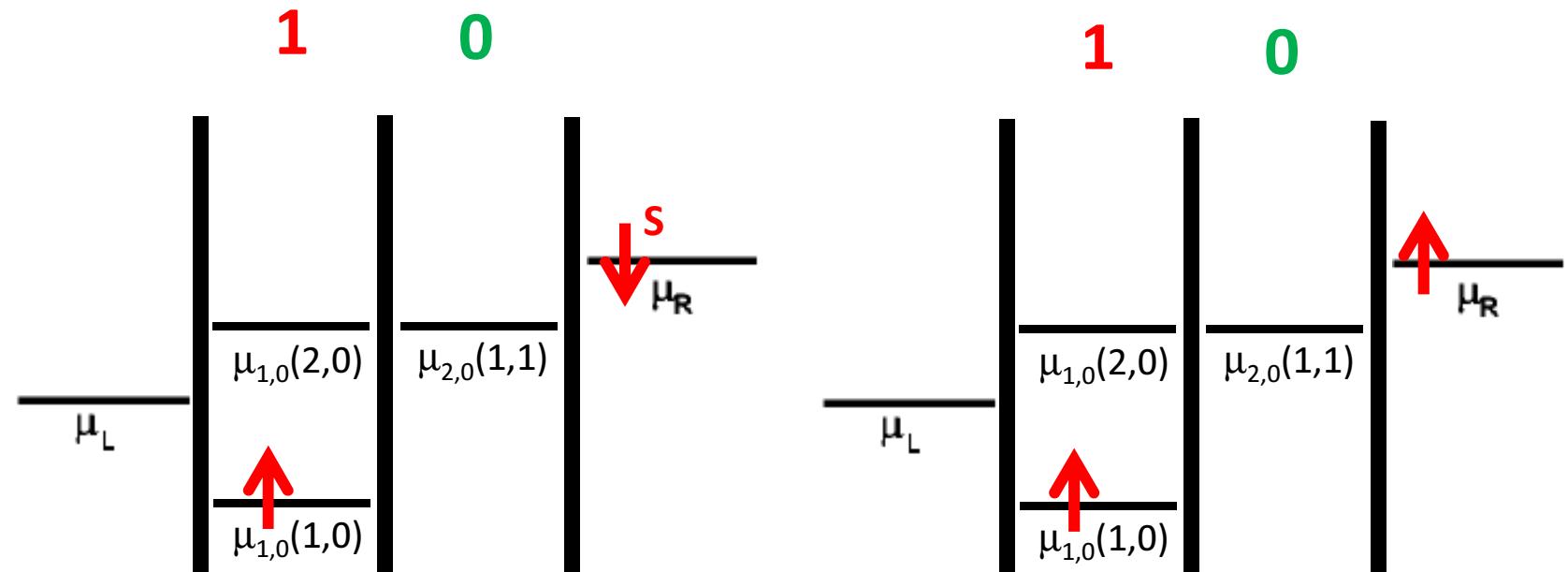
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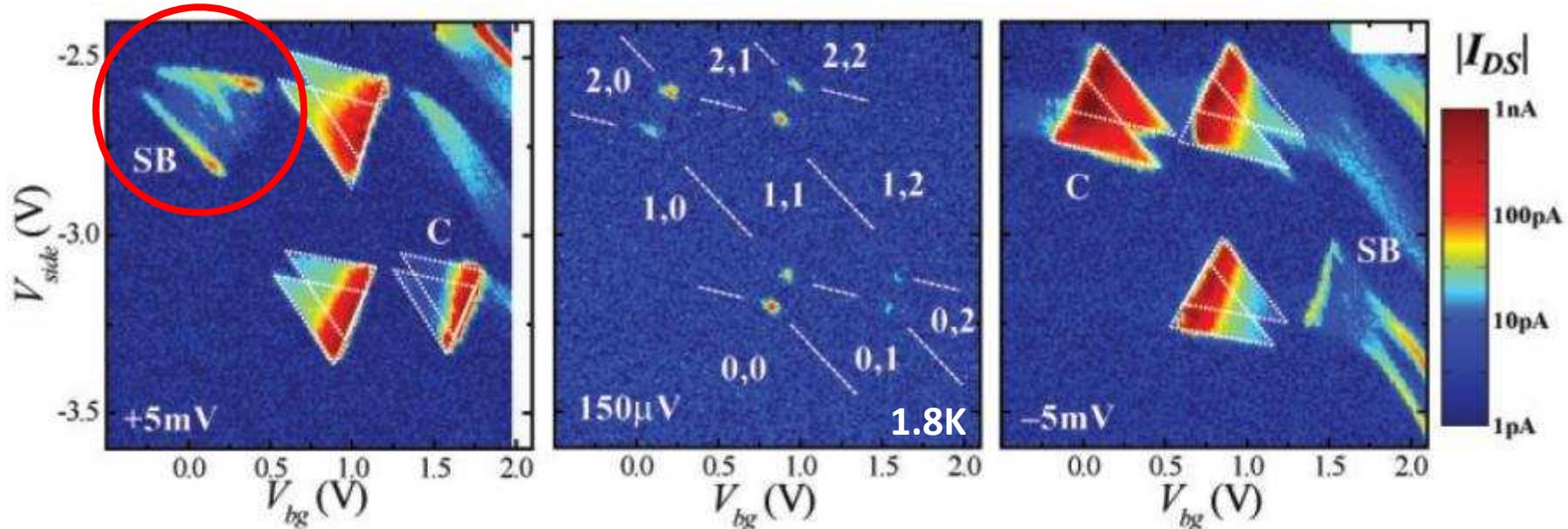
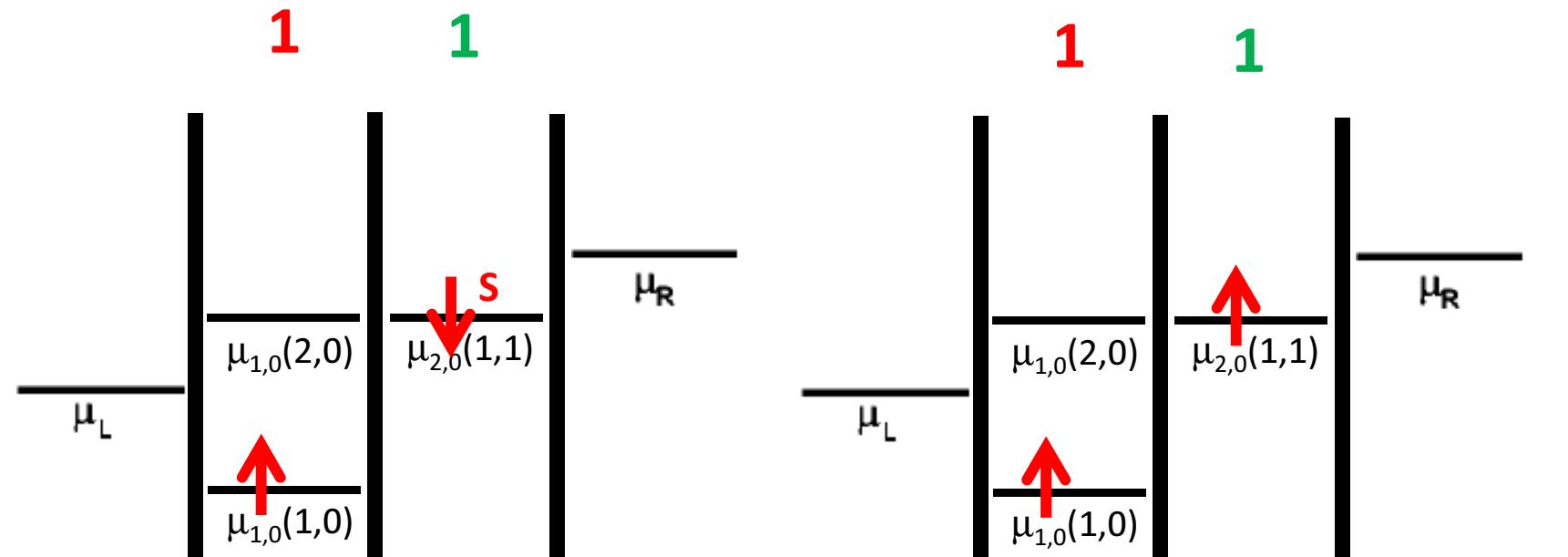
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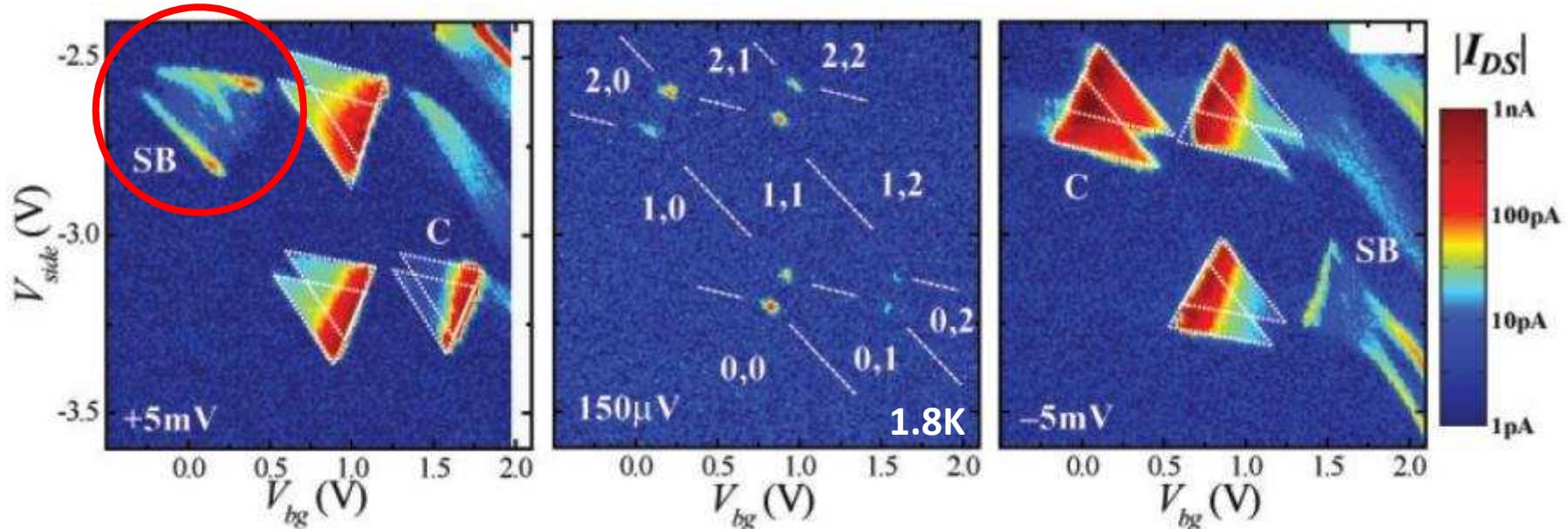
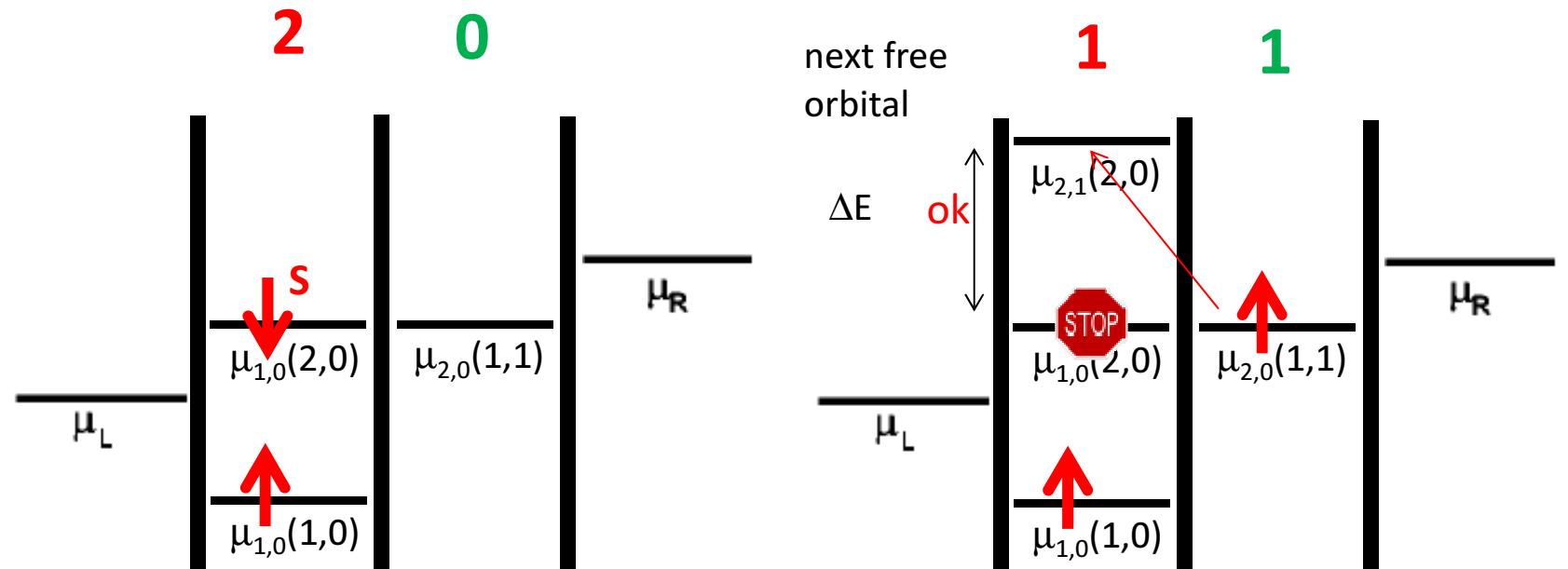
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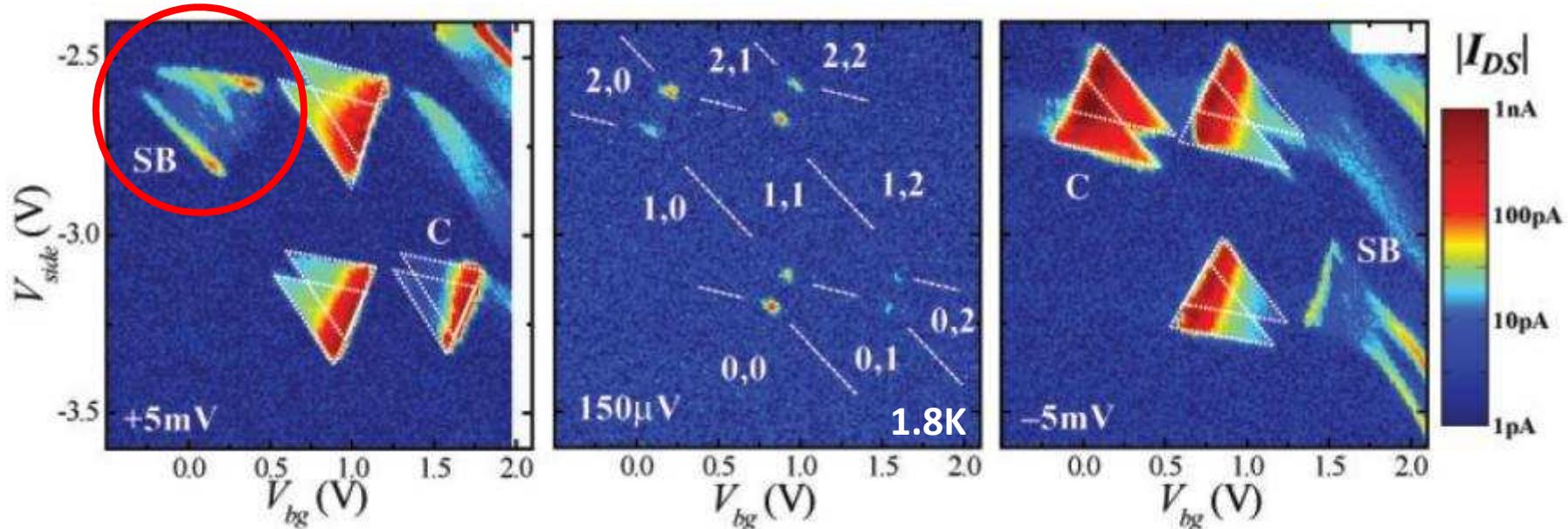
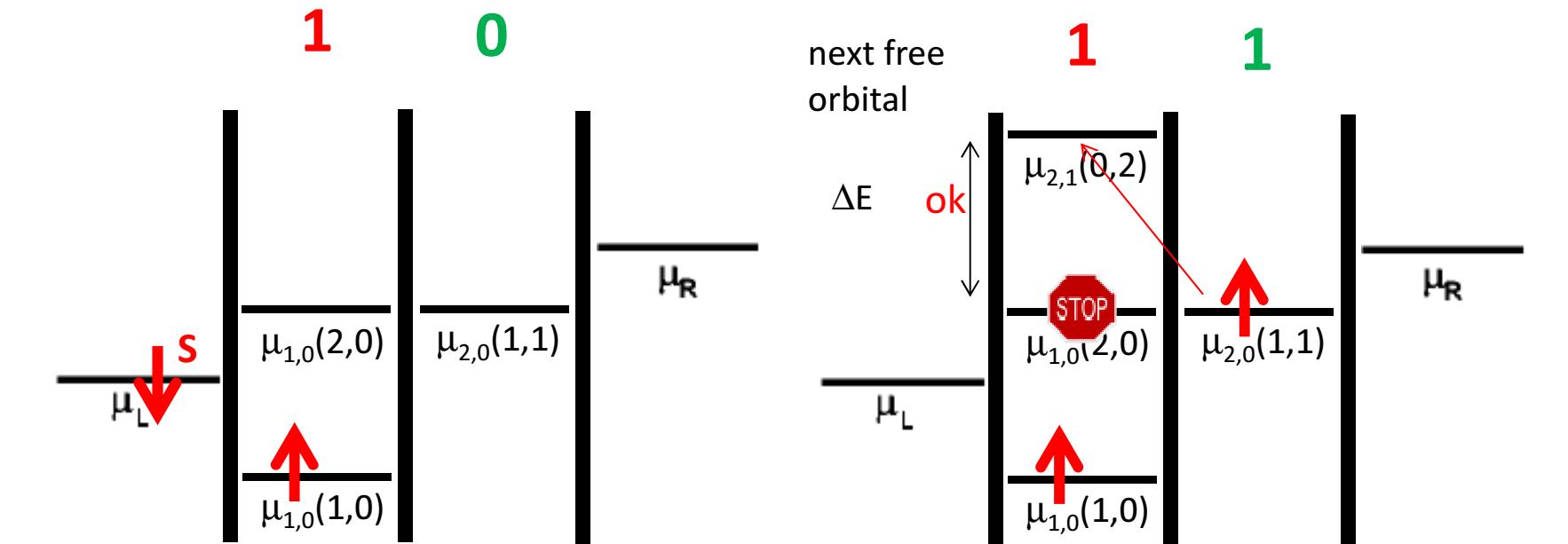
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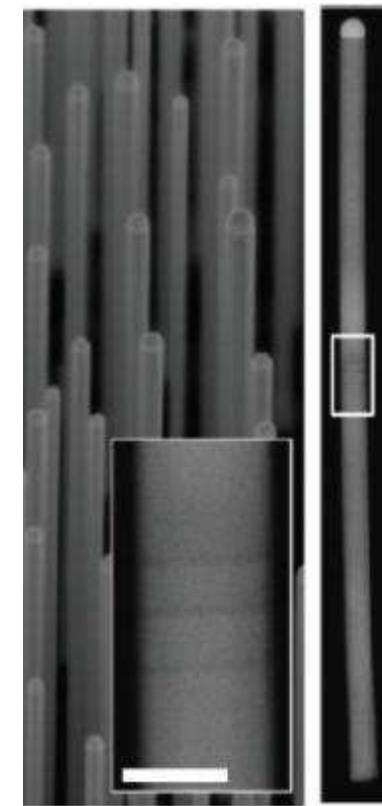
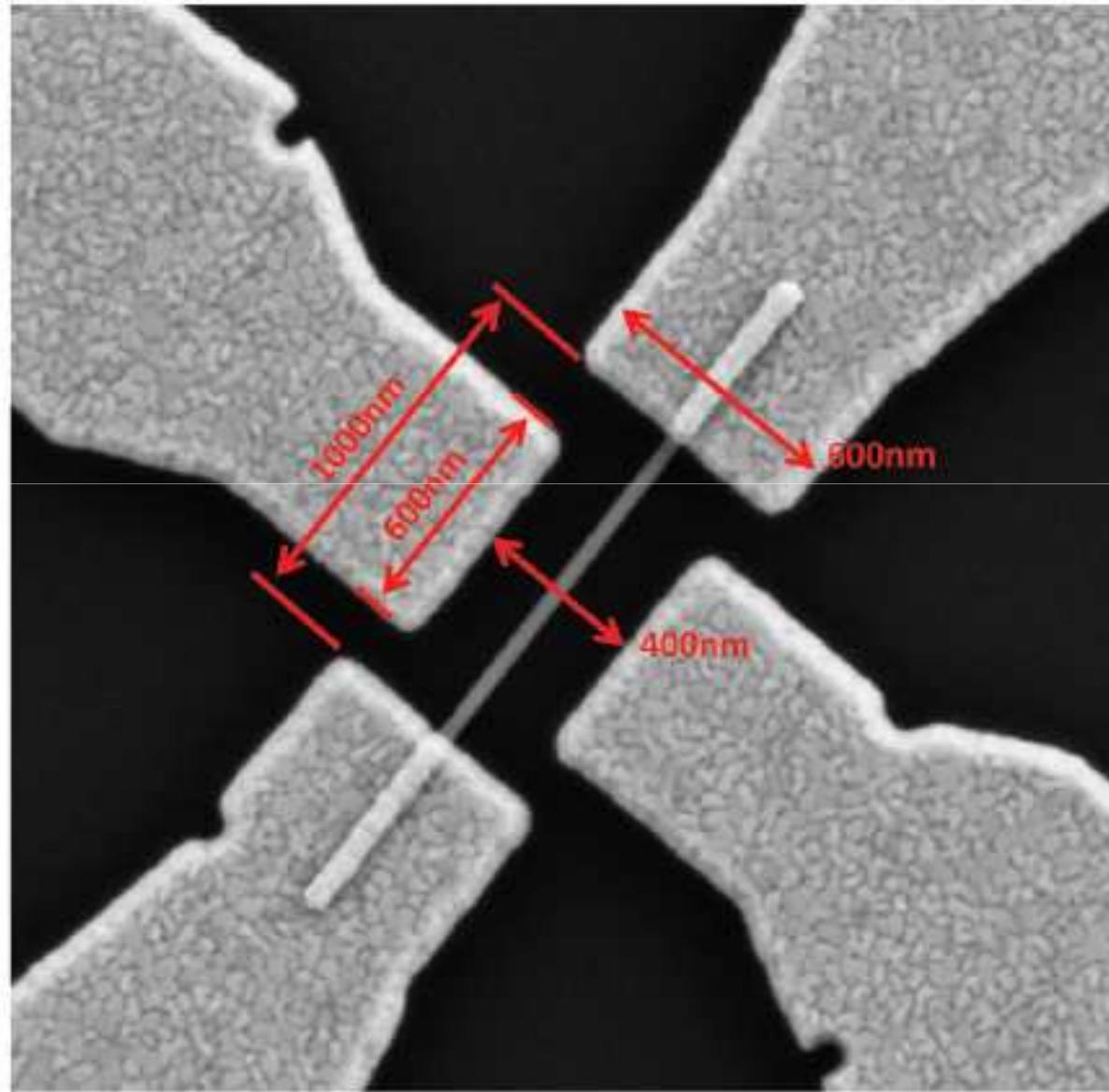
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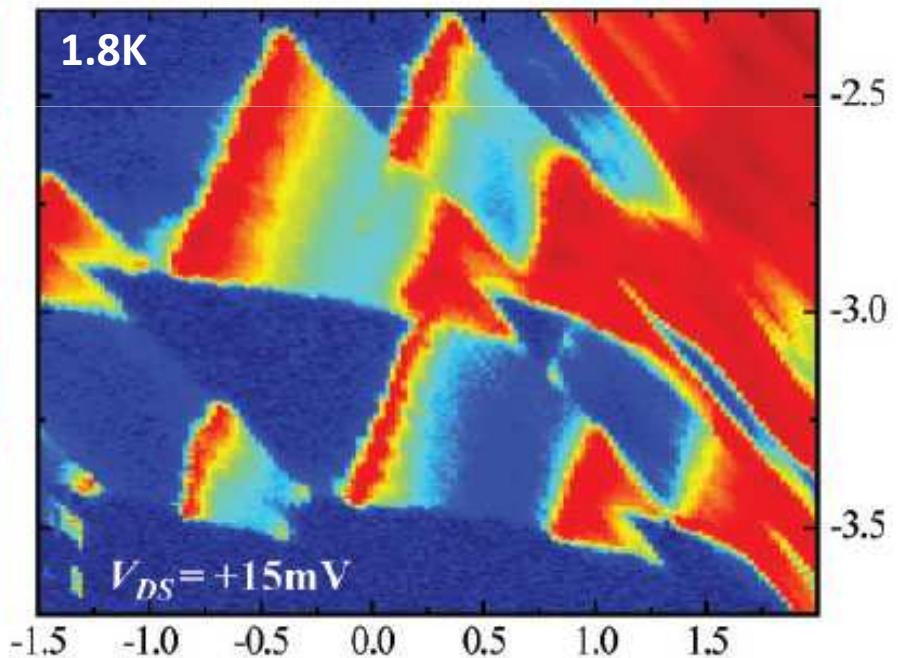
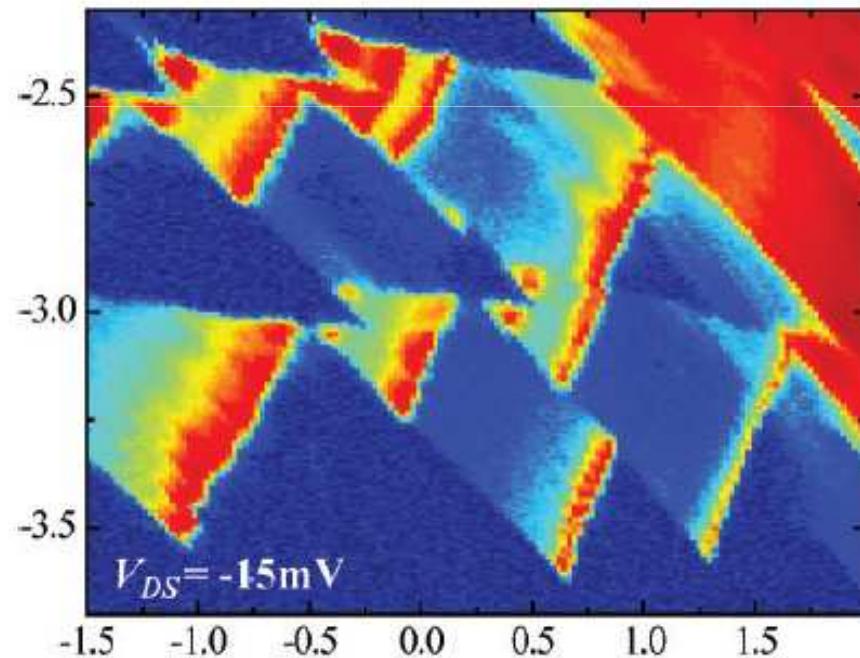


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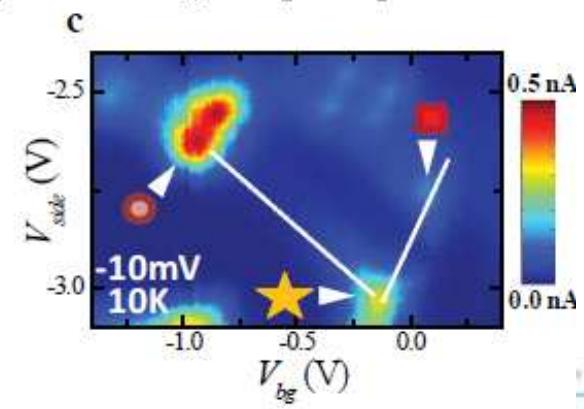
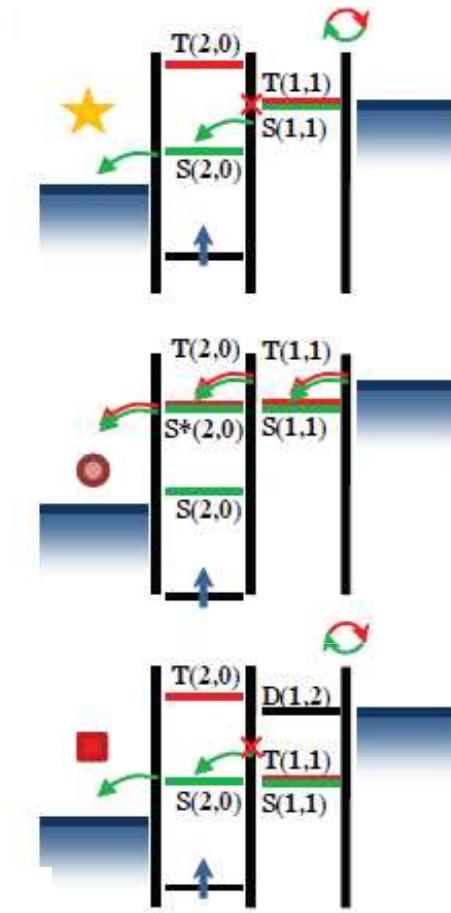
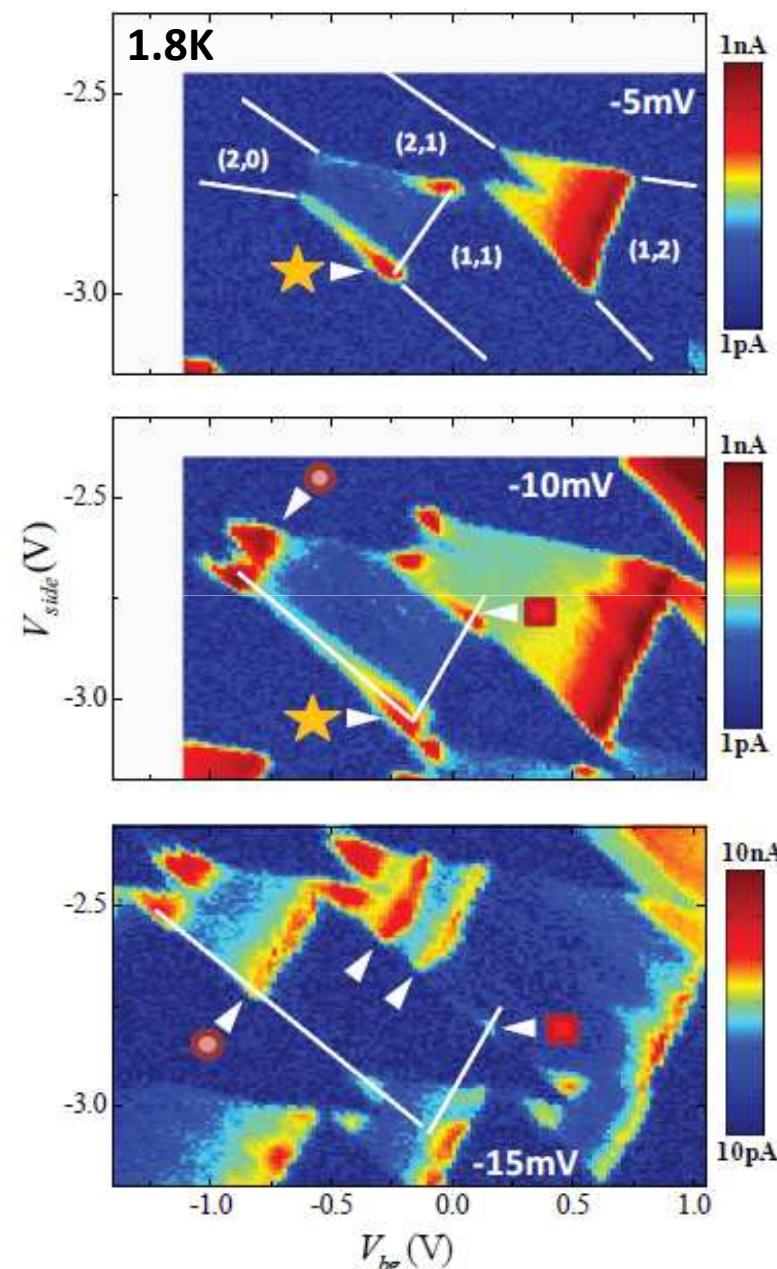


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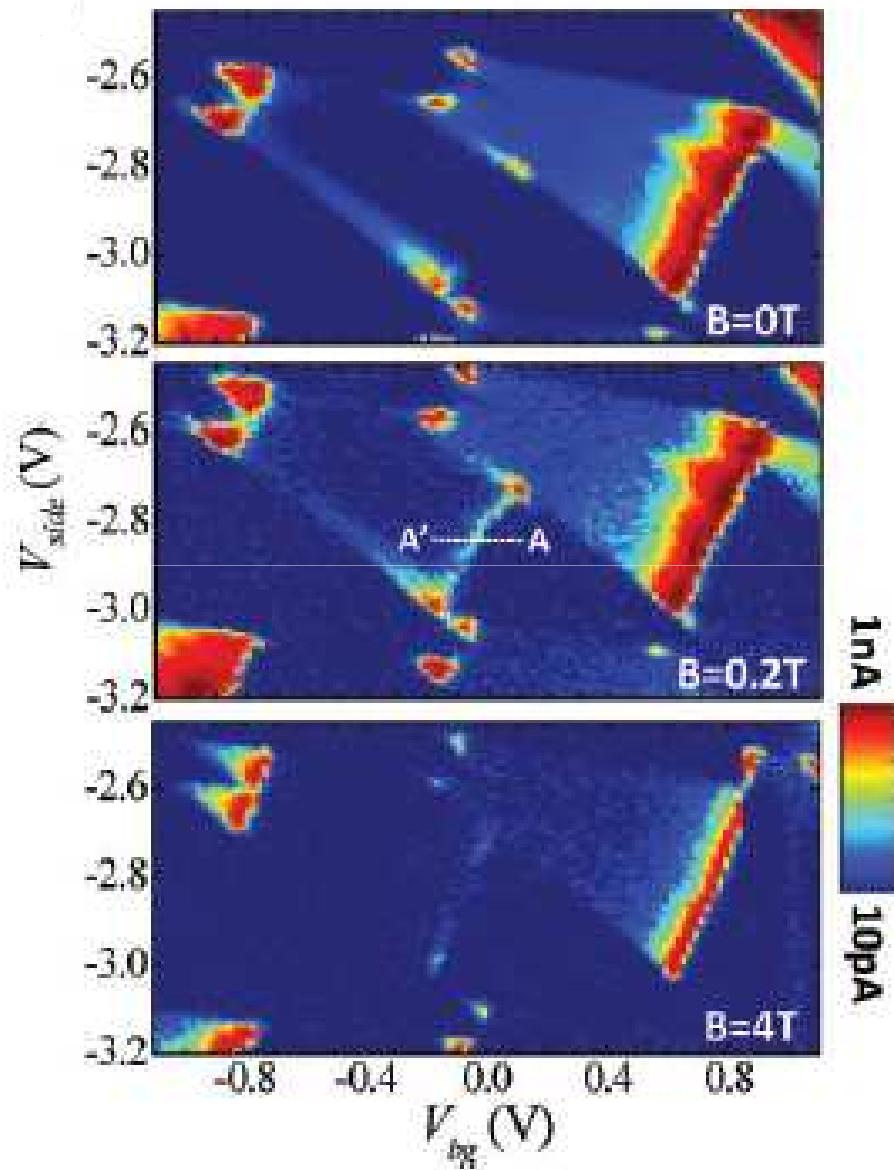
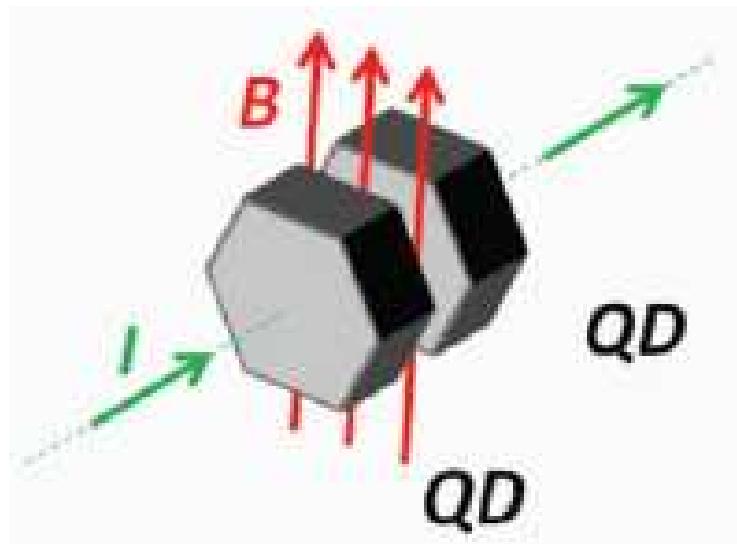
Bias	Tunnel configurations & resonance energies			
+15 mV {	$(0, 1) \rightarrow (1, 0)$ 10.1 meV	$(0, 2) \rightarrow (1, 1)$ 10.7 meV	$(1, 1) \rightarrow (2, 0)$ 9.1 meV	$(1, 2) \rightarrow (2, 1)$ 9.9, 11.9 meV
-15 mV {	$(0, 1) \leftarrow (1, 0)$ 10.1 meV	$(0, 2) \leftarrow (1, 1)$ ≈ 10 meV	$(1, 1) \leftarrow (2, 0)$ 10.3 meV	$(1, 2) \leftarrow (2, 1)$ ≈ 10 meV



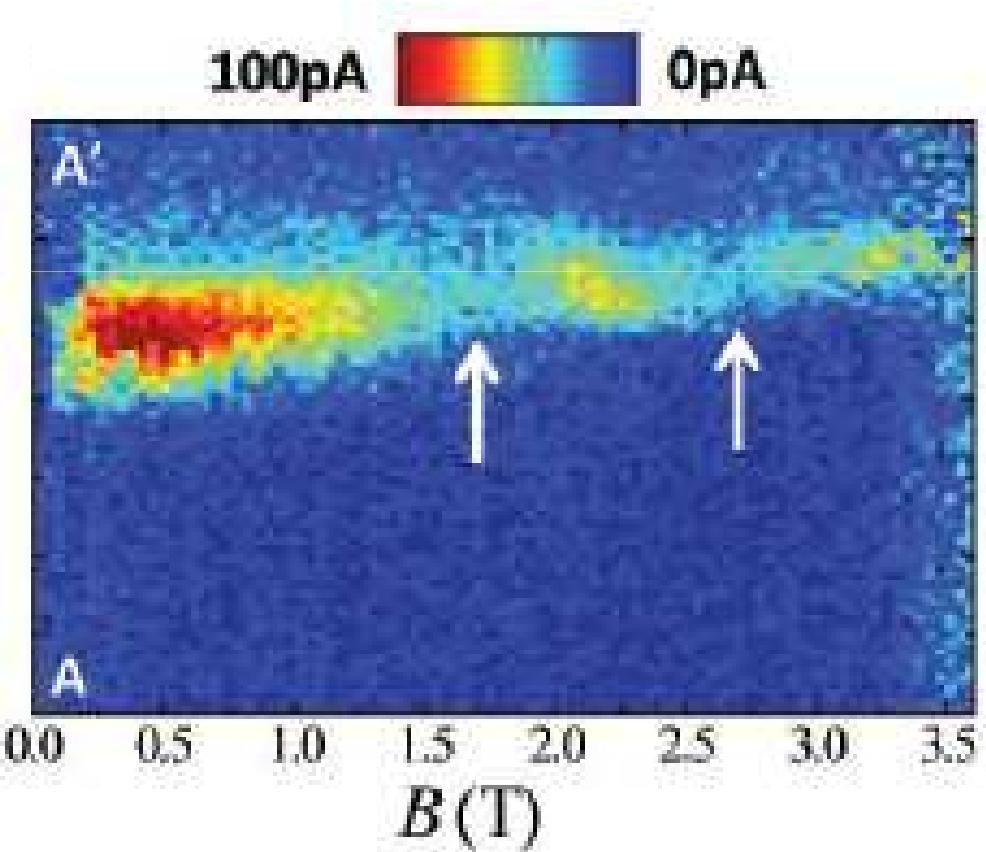
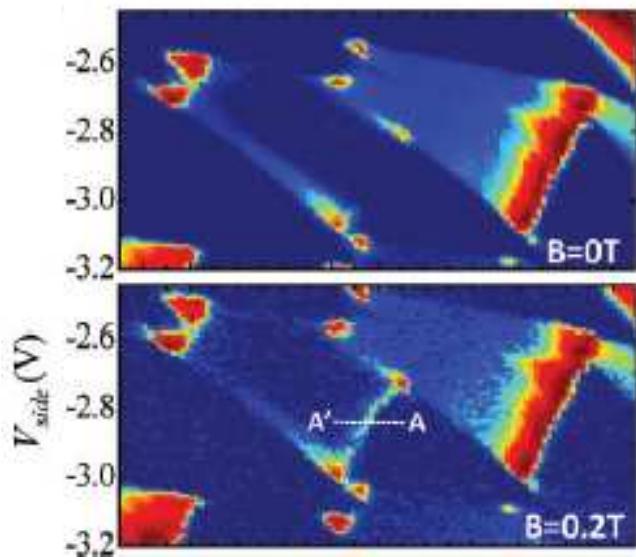
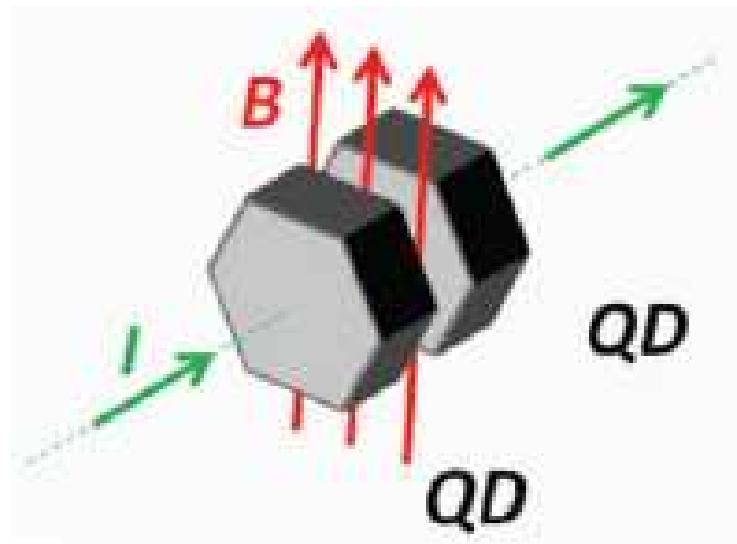
Spin blockade lifting



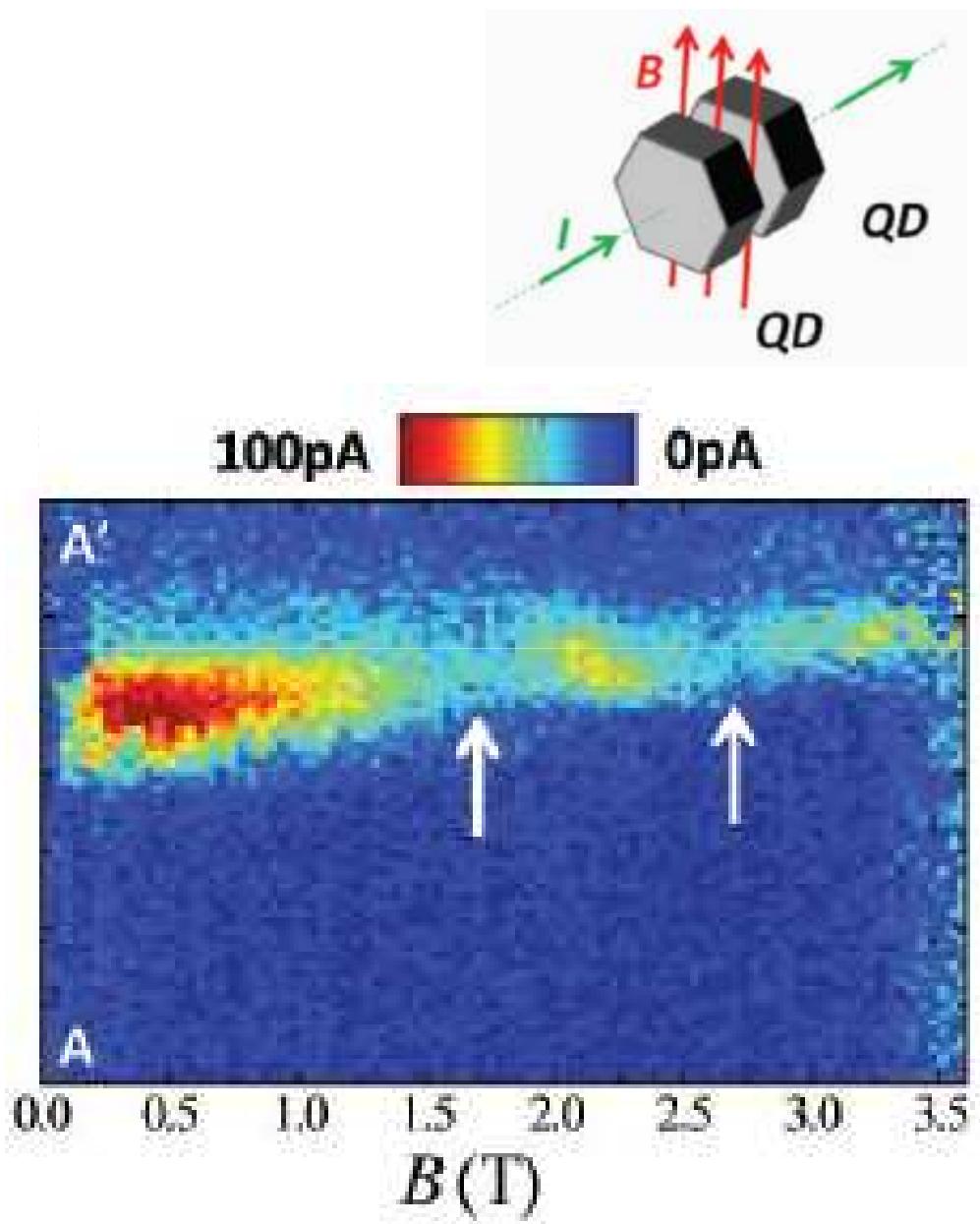
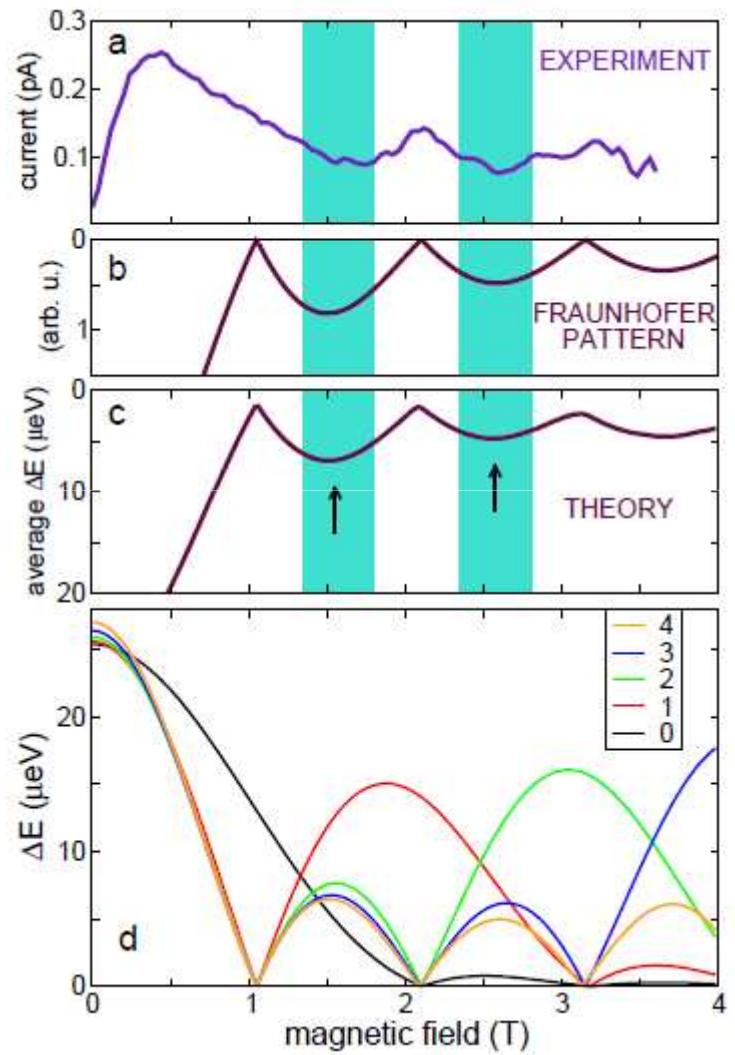
Spin blockade lifting



Spin blockade lifting



Spin blockade lifting



Stefano Roddaro



Stark effect control of spin rectification in a nanowire multi-dot system

- 1. Nanowire heterostructures: motivation**
- 2. Single-electron effects in NW-FET devices**
- 3. Stark shift in single InAs/InP dots**
- 4. Controlling two QDs at the same time without local gates**
- 5. Conclusions**

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Conclusions

- **Stark effect** allows to strongly modify hard-wall confined QDs in InAs/InP nanowires → partial tunability in heterostructured QD; gate-tunable spin transitions driven by exchange interaction (not shown)... room temperature operation?!

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Thank you

Past/present collaborators:

Fabio Beltram, head of NEST

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Alessandro Pitanti, postdoc (QD)

Francesco Rossella, postdoc (DQD)

Daniele Ercolani, growth staff (QD)

Andrea Pescaglini, undergrad (QD)

Lorenzo Romeo, undergrad (QD)

Lucia Sorba, head of the epitaxy group