The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1960-6

ICTP Conference Graphene Week 2008

25 - 29 August 2008

Graphene quantum dot with integrated charge detection

J. Guettinger
Nanophysics Group, Solid State Physics Laboratory
ETH, Zurich

C. Stampfer
Nanophysics Group, Solid State Physics Laboratory
ETH, Zurich

S. Hellmueller
Nanophysics Group, Solid State Physics Laboratory
ETH, Zurich

S. Schnez
Nanophysics Group, Solid State Physics Laboratory
ETH, Zurich

F. Molitor
Nanophysics Group, Solid State Physics Laboratory
ETH, Zurich

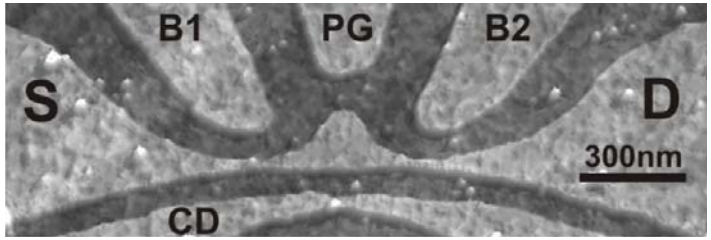
Strada Costiera 11, 34014 Trieste, Italy - Tel. +39 040 2240 111; Fax +39 040 224 163 - sci_info@ictp.it, www.ictp.it

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Graphene Week 2008 Triest,
25. August 2008

Graphene quantum dot with integrated charge detection

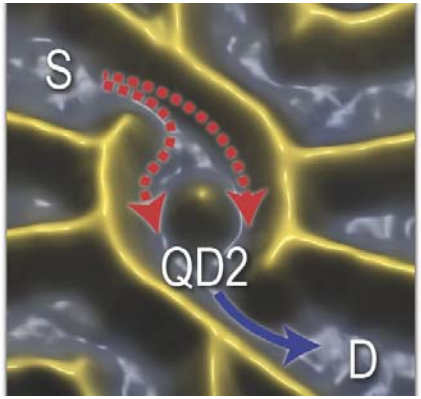
Johannes Güttinger
Nanophysics Group
Solid State Physics Laboratory
ETH Zurich, 2008

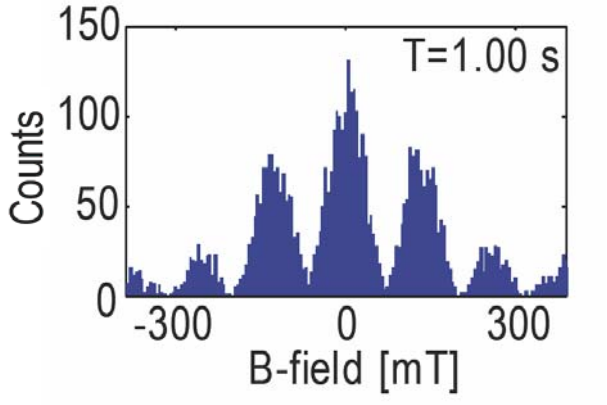


Christoph Stampfer, Sarah Hellmüller, Stephan Schnez, Françoise Molitor, Thomas Ihn, and Klaus Ensslin

Motivation

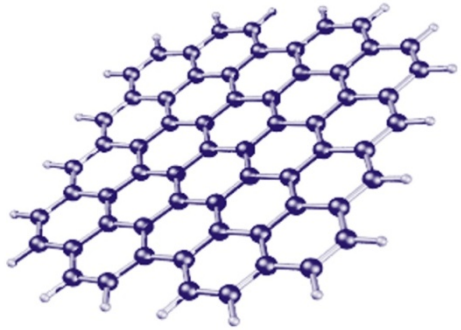
- Quantum Dots in GaAs heterostructures
  - Exquisit control of charges and spins
  - Control of q.m. degrees of freedom





S. Gustavsson et al., Nano Letters, 8 (8), 2547 (2008)

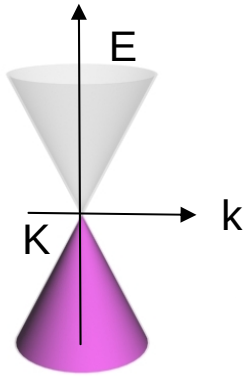
- Quantum Dots in Graphene
  - Solve technology problems
  - Sample preparation, sample stability
  - Experiment, ...



See also **L. A. Ponomarenko et al.,** Science 320, 356 (2008)
and work by Delft and Columbia

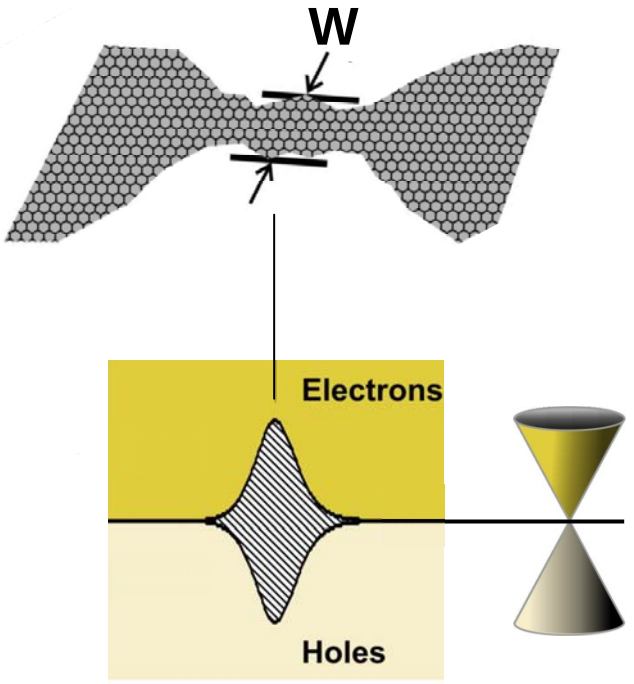
Electron confinement in graphene

- Difficulties to confine carriers electrostatically
  - Absence of an energy gap
  - Klein tunneling through p-n barriers



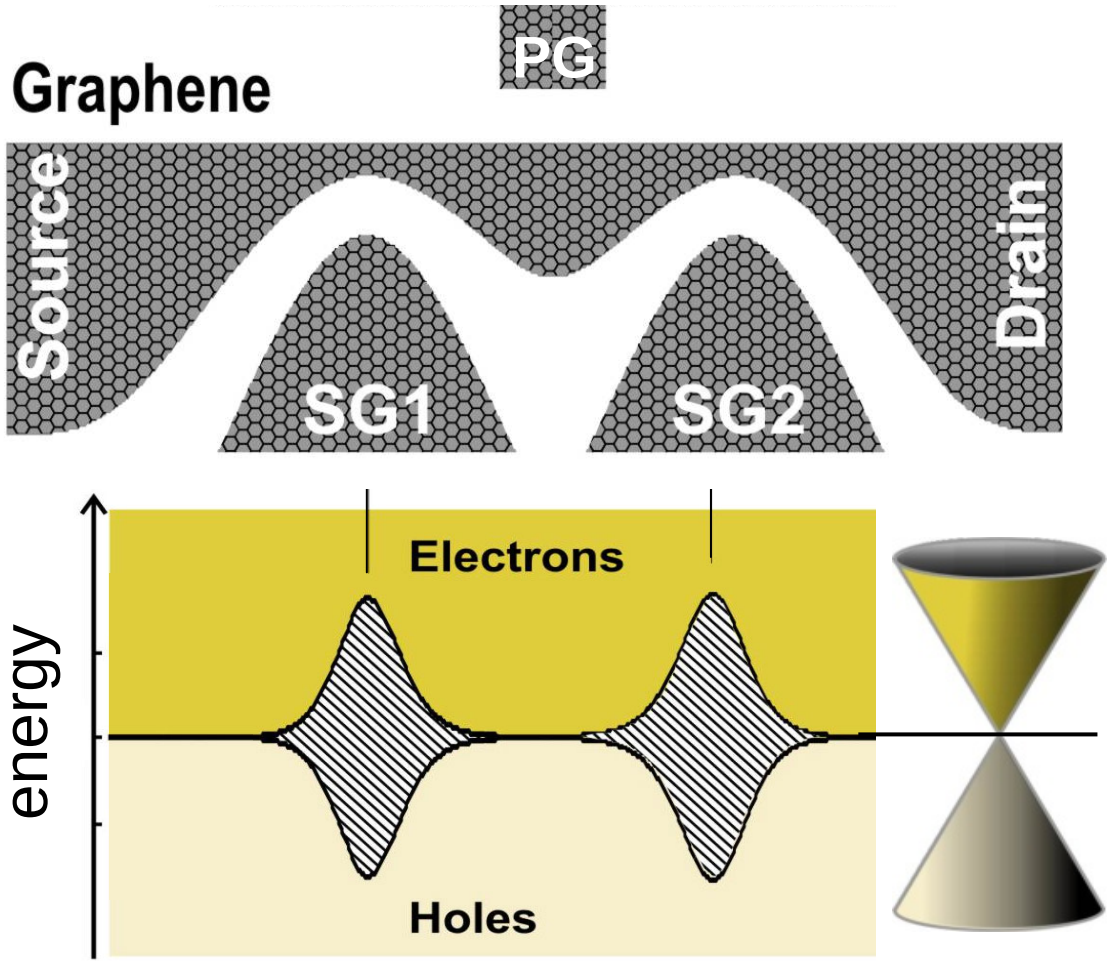
- Structural confinement of electrons

Graphene nanoribbons:
Han et al., PRL 98, 206805 (2007)
Özyilmaz et al., APL 91, 192107 (2007)
Chen at al., cond-mat/0701599 (2007)



- Opening of a transport gap

Electron confinement in graphene



Model including interactions

$$E_g(W) = \frac{a}{W} e^{-bW}$$

$$a = 1\ eV \times nm$$

$$b = 0.023\, nm^{-1}$$

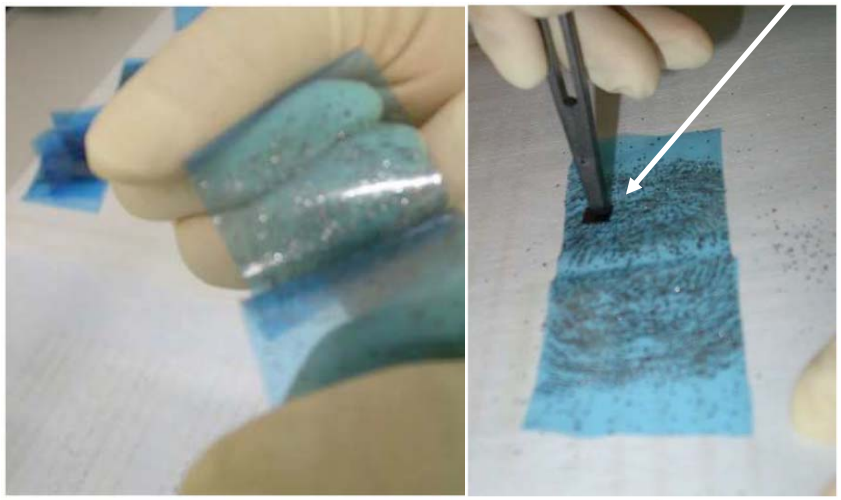
F. Sols et al., PRL 99, 166803 (2007)

C. Stampfer et al., APL **92**, 012102 (2008)

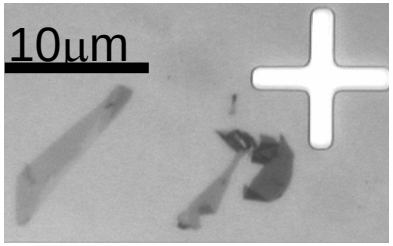
C. Stampfer et al., Nano Letters **8** (8), 2378 (2008)

Fabrication of graphene quantum dots

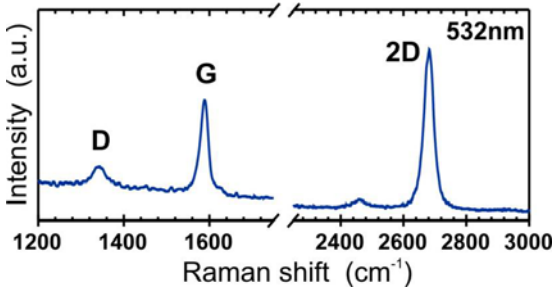
1) Graphene deposition



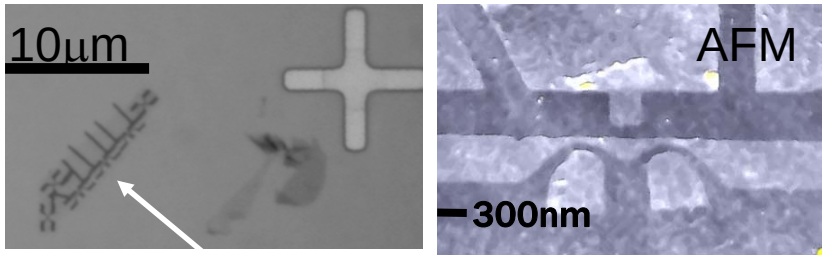
2) Identification of single layer flakes



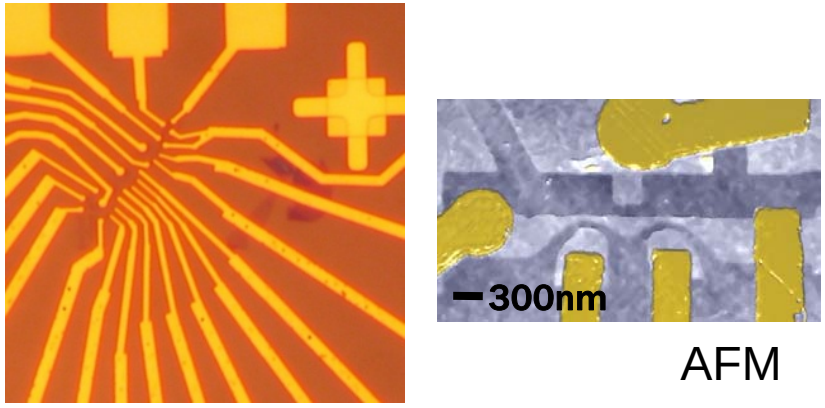
Raman spectroscopy



3) eBeam lithography, RIE etching



4) eBeam lithography, metallization

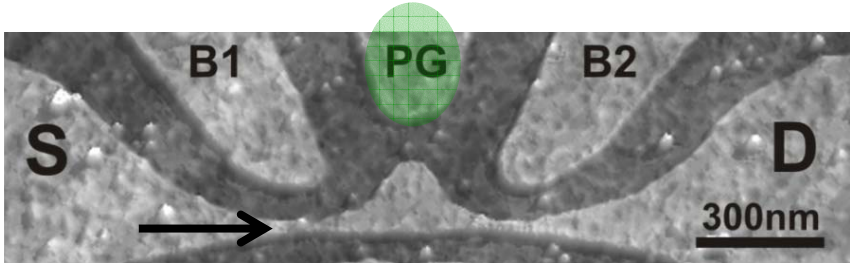


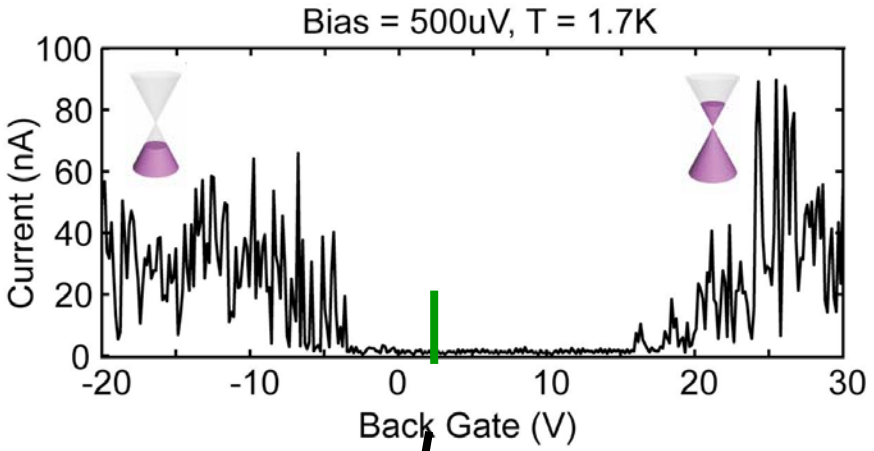
AFM

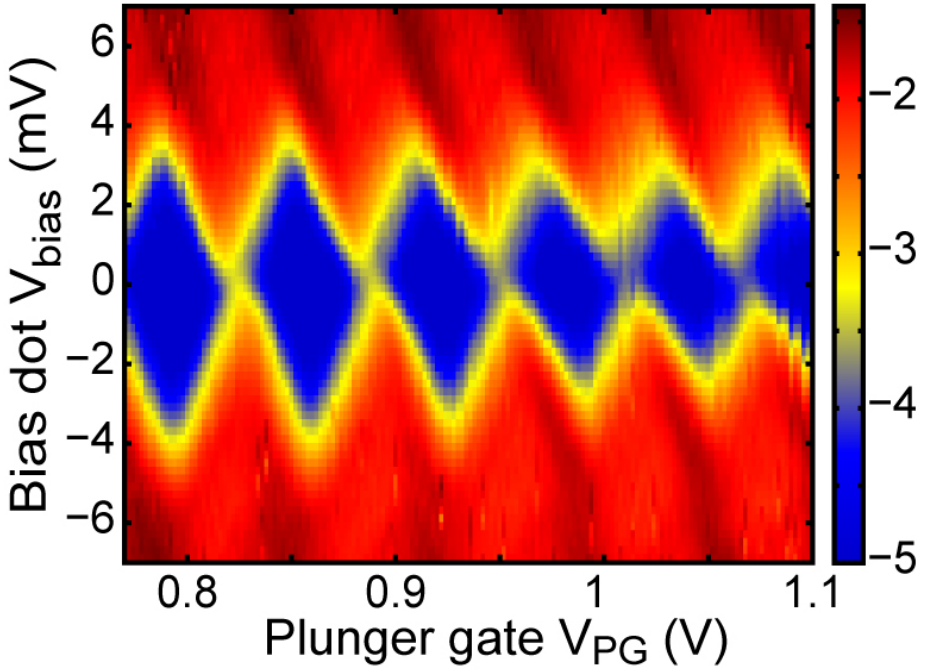
See Poster 16 Session I of S. Dröscher
Structuring graphene using AFM lithographie

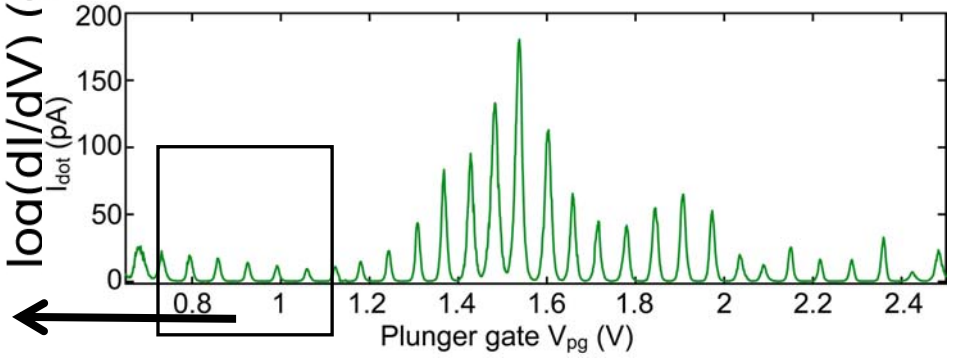
Coulomb Blockade in graphene Quantum Dots

See Poster 33 Session I of F. Molitor

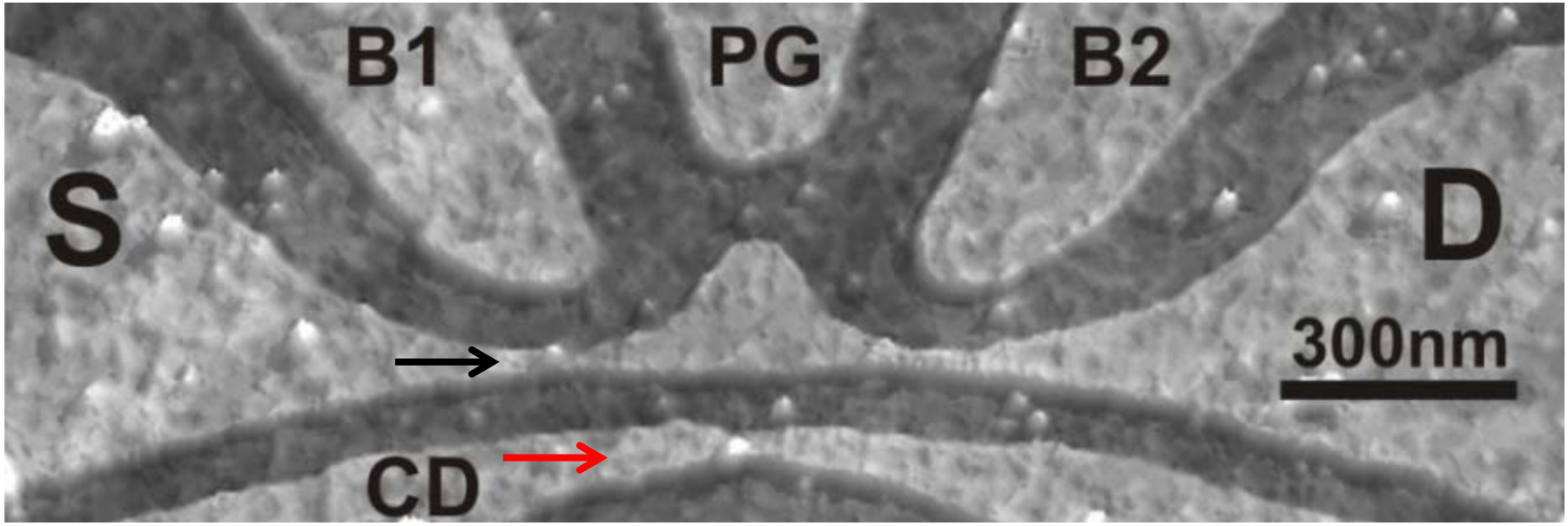






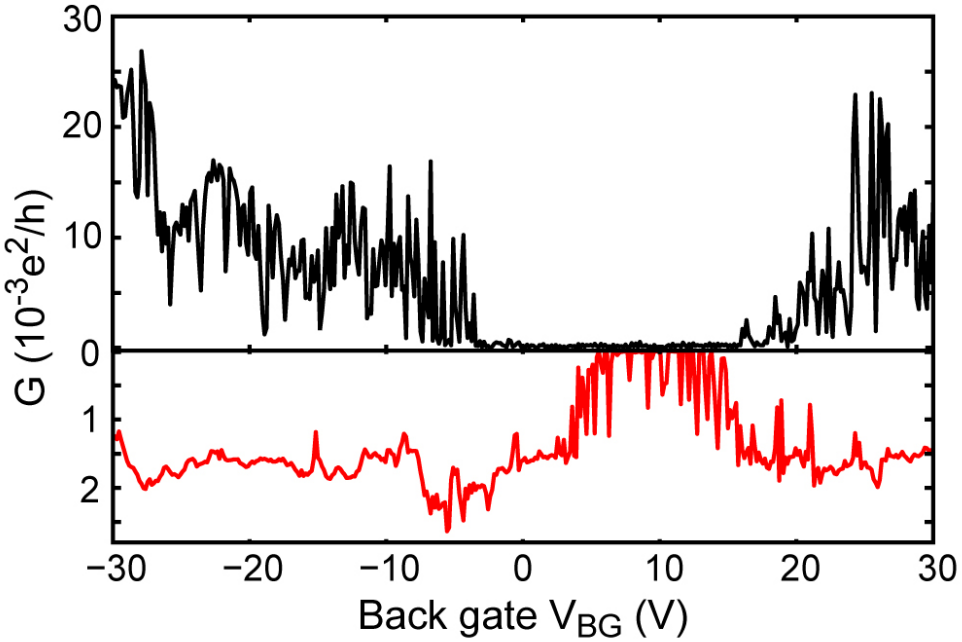


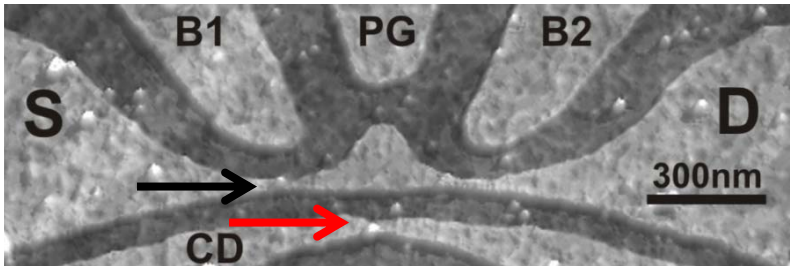
Charge Detection



- Sense charges with a nearby graphene constriction
  - No limitations by the source drain current →
  - Experiments with single electrons (holes) in the weak coupling regime

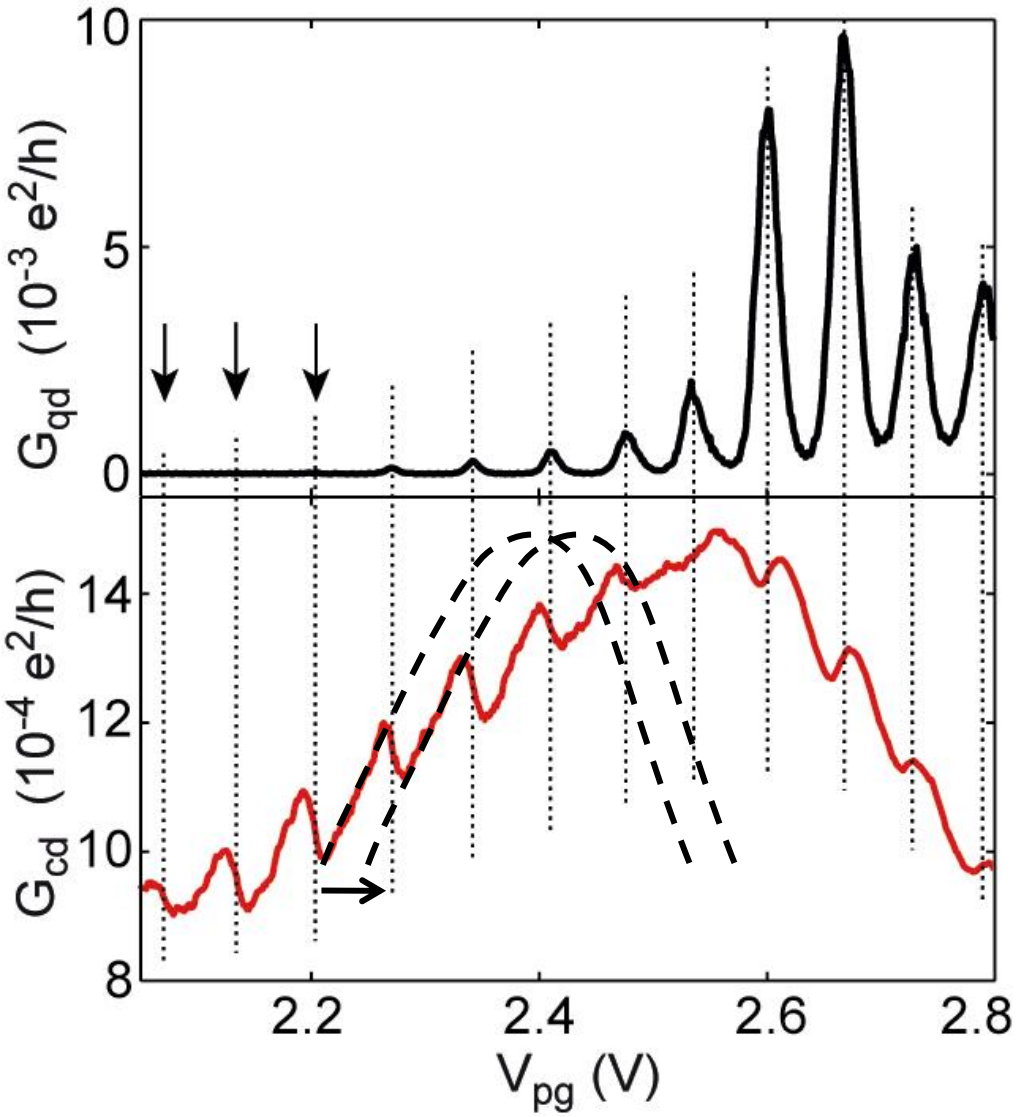
Gate characteristics

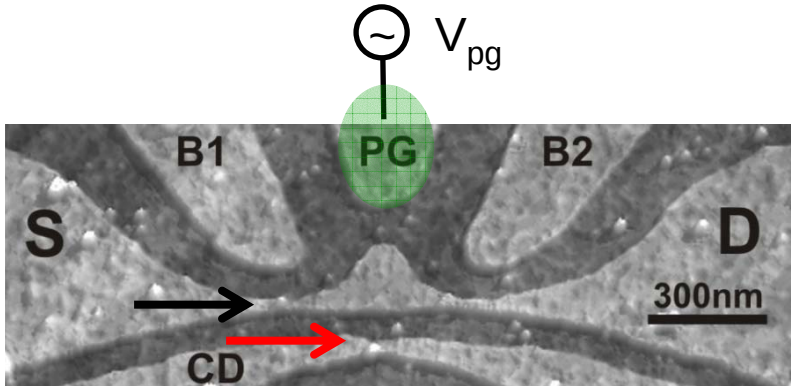




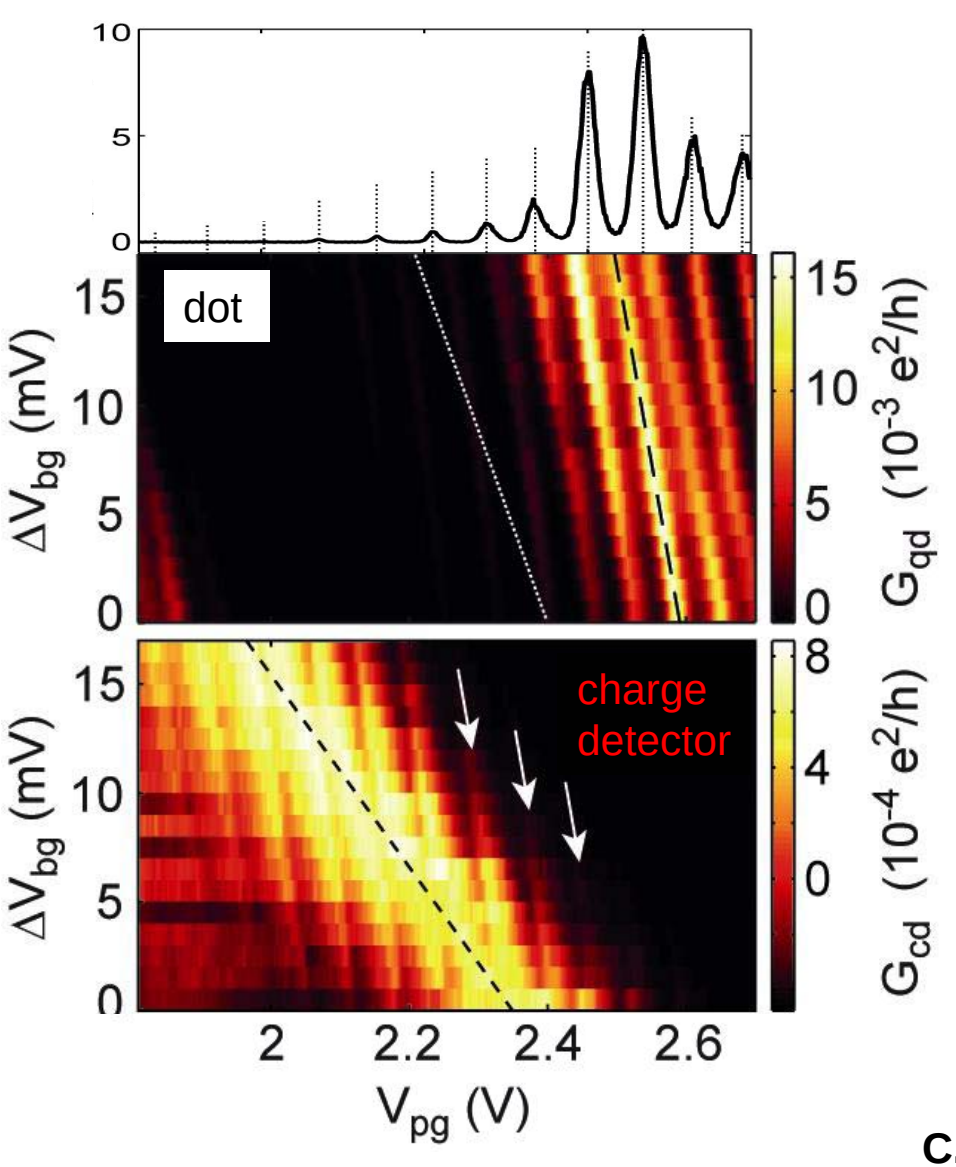
Observation of a transport gap in both devices

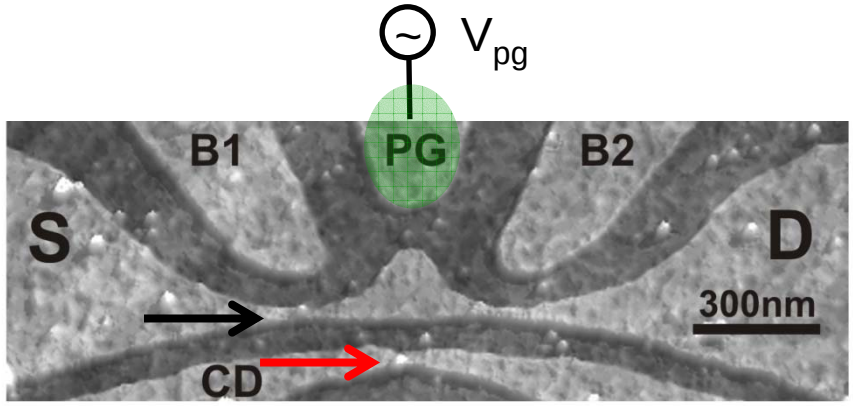
Charge detection

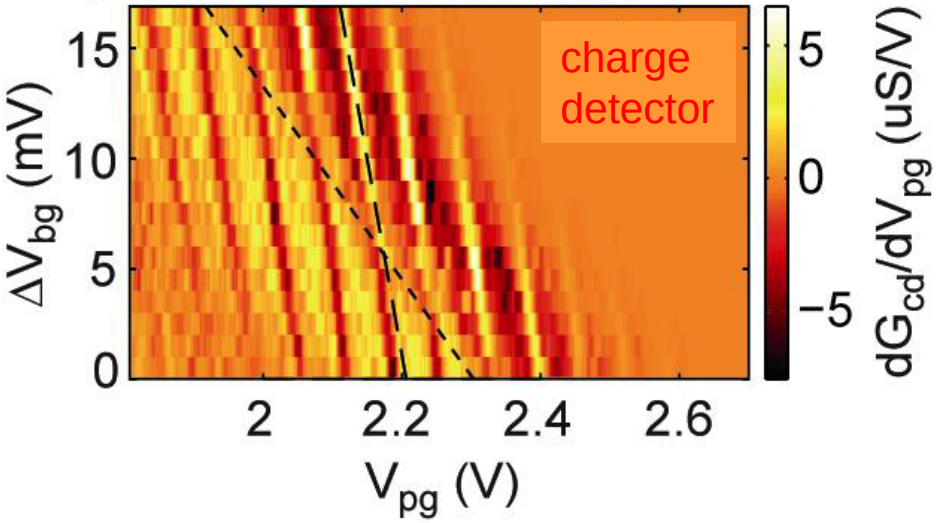




Charge detection







C. Stampfer et al., arXiv:0807.2710v1 (2008)

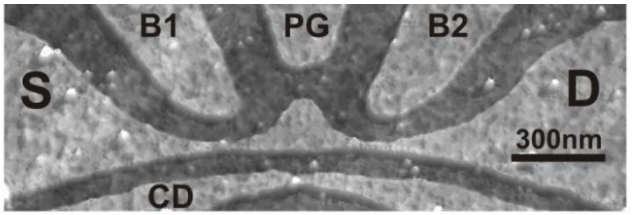
Excited States in Graphene Quantum Dots

See

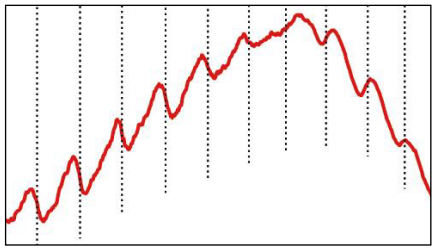
C. Stampfer et al., arXiv:0807.2710v1 (2008)

Summary - Graphene Quantum Dots

- Graphene Quantum dots



- Charge detection



- Excited States