Second year of PhD

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Scuola Normale Superiore

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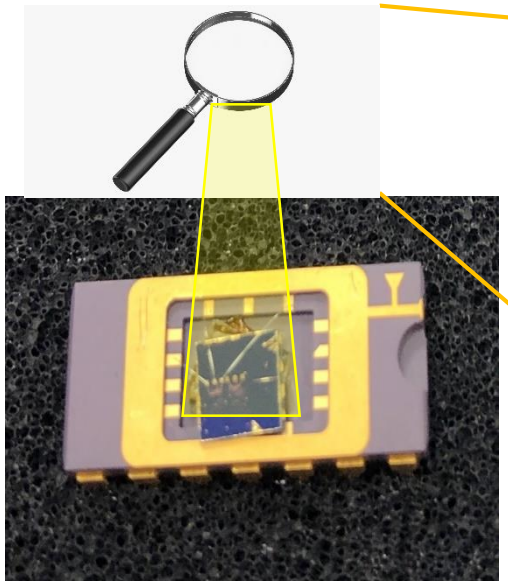
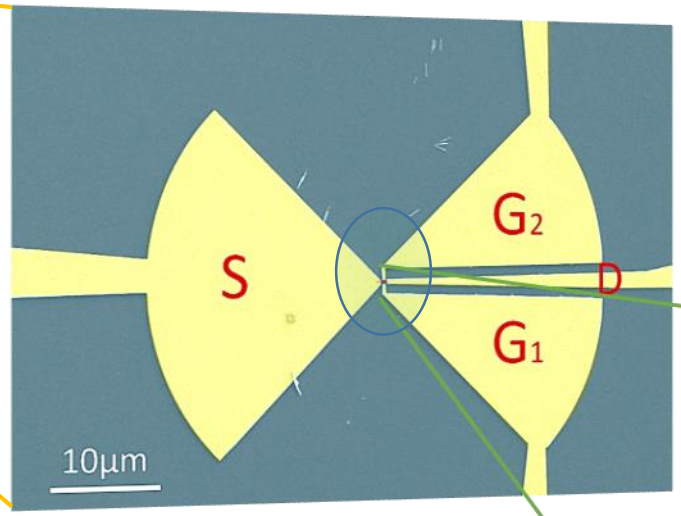
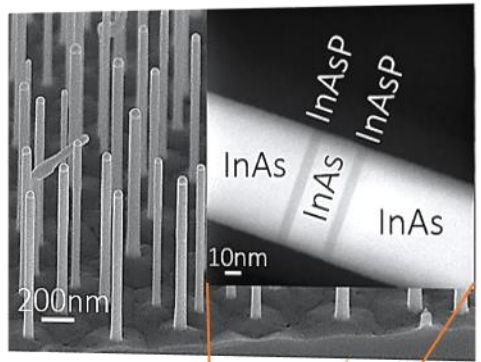
Highly sensitive Nano-detectors at THz frequencies



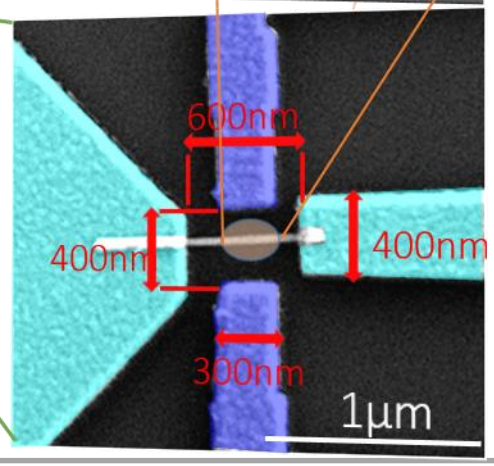
Nano-detector mounted on dual-line chip



THz Nano-detector



Semiconducting QD



Field Effect Transistor

i) First demonstration of InAs Quantum Dot Single Electron Transistor as Highly sensitive Nanodetector in THz Frequency Regime

1) Physical Principle

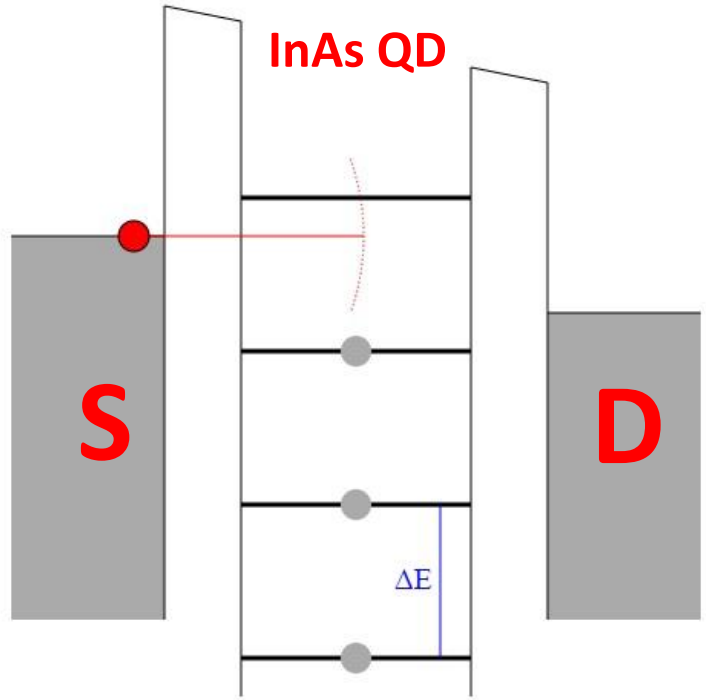
Coulomb Blockade

1. The bias voltage must be lower than the elementary charge divided by the self-capacitance of the QD: $V_{bias} \leq e/C$

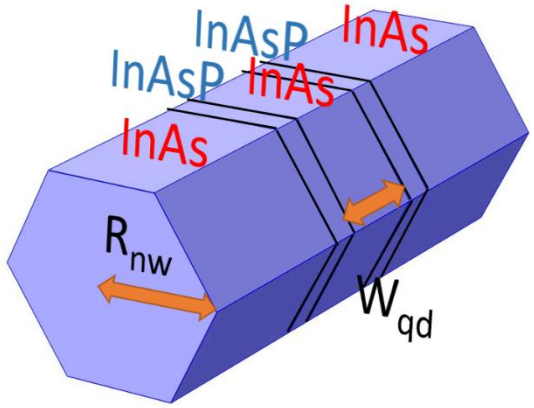
2. The thermal energy (K_BT), must be below the charging energy: $K_BT \leq e^2/C$

3. The tunneling resistance R_t must be greater than h/e^2

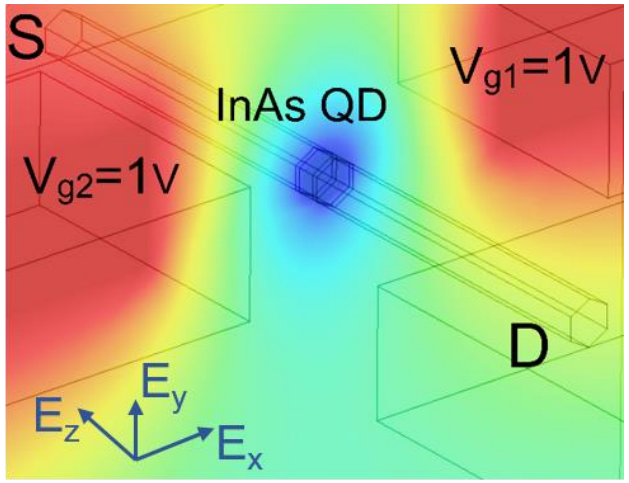
τ (tunneling time) $\leq 10^{-15}$ S



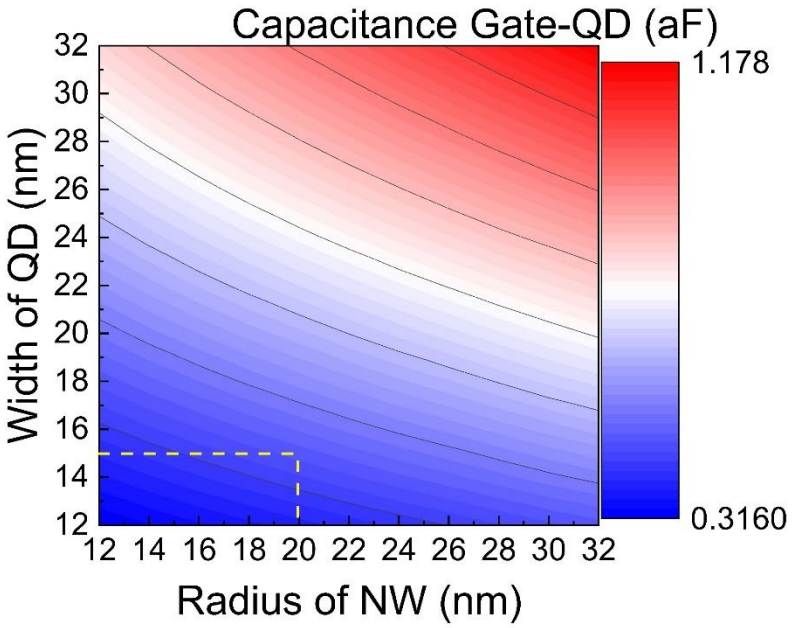
2) Simulation step



3D architecture in the numerical simulation showing the QD geometry, due to a hexagonal Wurtzite structure of grown NWs[50] from the cubic basis

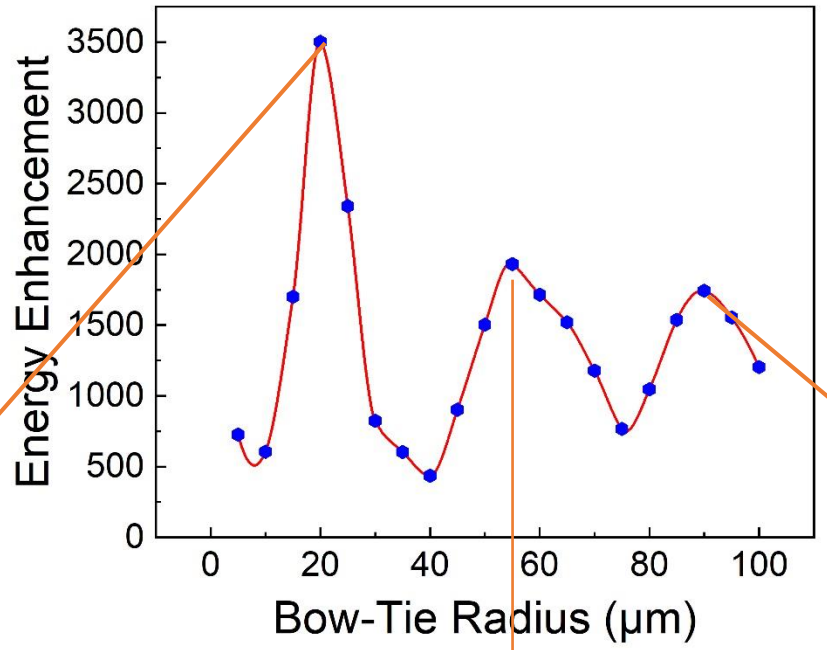


3D simulated image of distributed electrostatic potential around prismatic InAs QD in the presence of external applied electric field into our FET

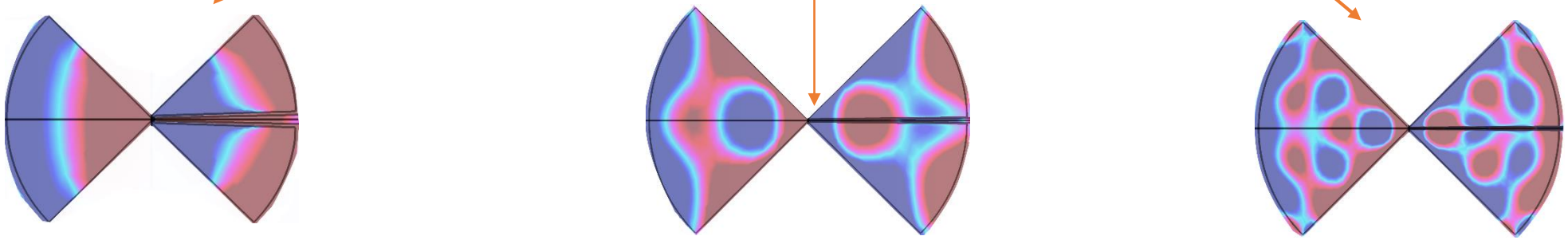


Color map of simulated gate-QD capacitance (C_{gd}) as a function of size of QD (W_{qd}) and radius of NW (R_{nw})

2) Simulation step



Bow-tie antenna simulation representing the energy enhancement at the position of SET owing to the presence of antenna, depicted as a function of bow-tie radius (R_b) for an impinging frequency of 2.8THz.

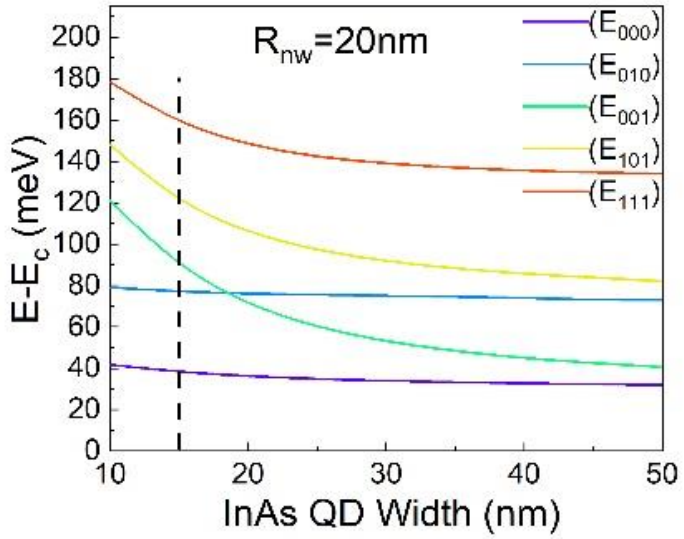


out-of-plane maps of electric field component for R_b = ***20μm***, ***55μm***, and ***90μm*** corresponding to the λ/2, 3λ/2, 5λ/2 resonances

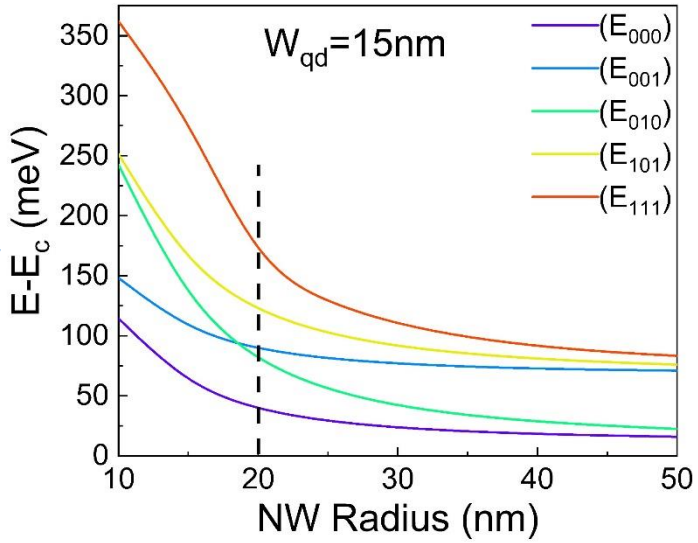
2) Simulation step

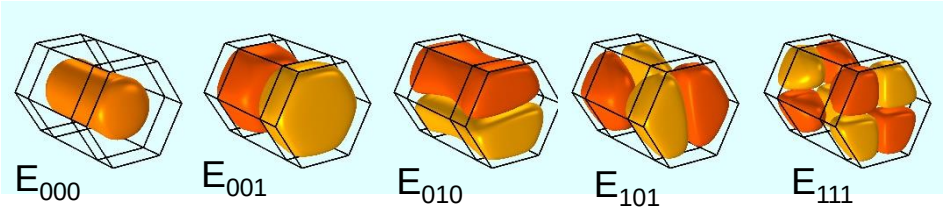
Numerical results related to the simulation of different energetic electron states in quantum dot.

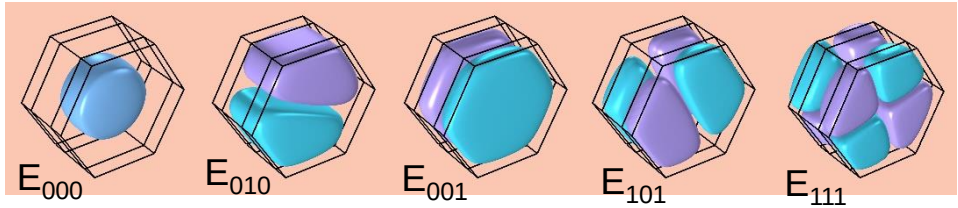
The distribution of electron wave function (orbital configuration) for each energy level is depicted.



The energy levels are more sensitive to the changes in the ***R_{nw}*** than to the changes in the *W_{qd}*

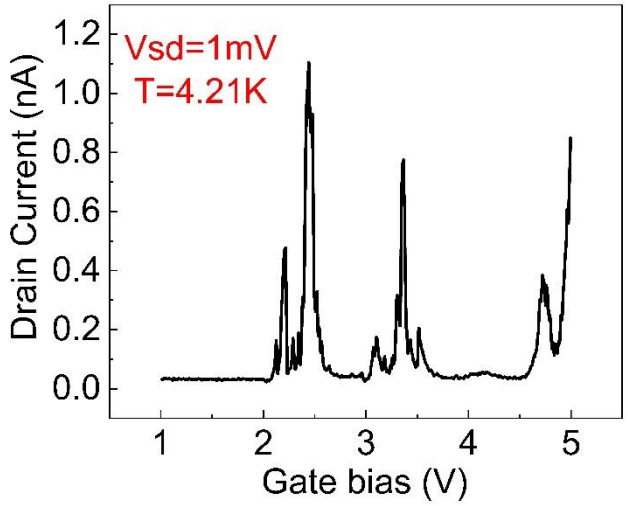




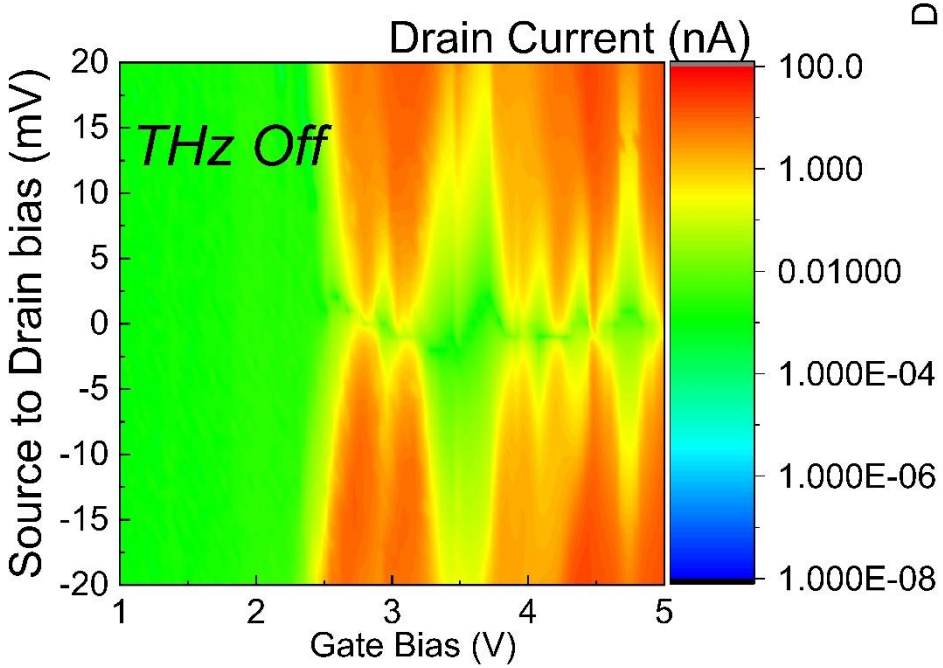


2) Experimental step

Quantum Transport experiment

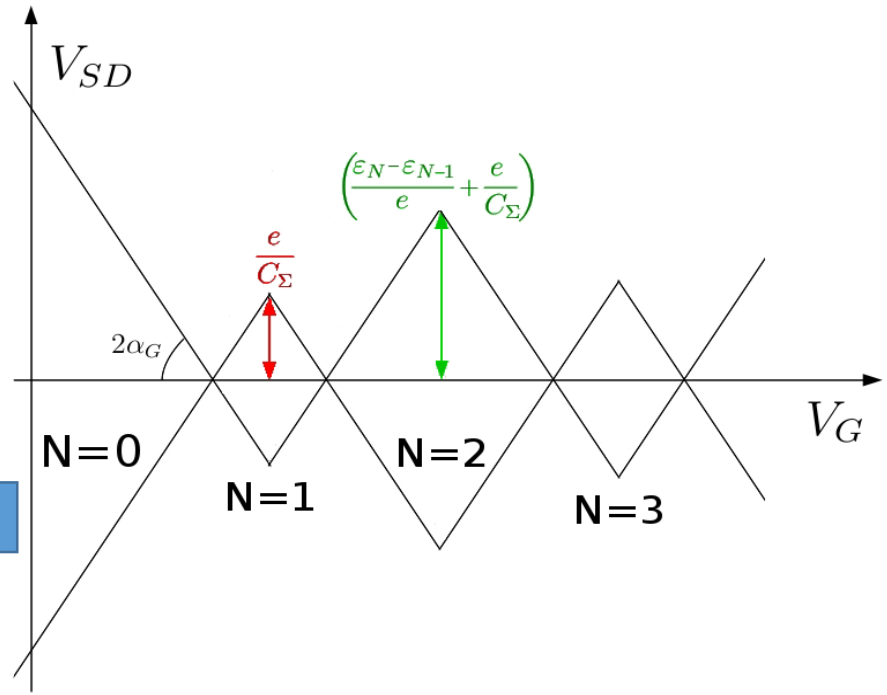


Conductance curve collected from transport measurement. It shows for particular values of applied gate bias, transition through QD occurs and its is equal to zero elsewhere.



Coulomb blockade diamonds

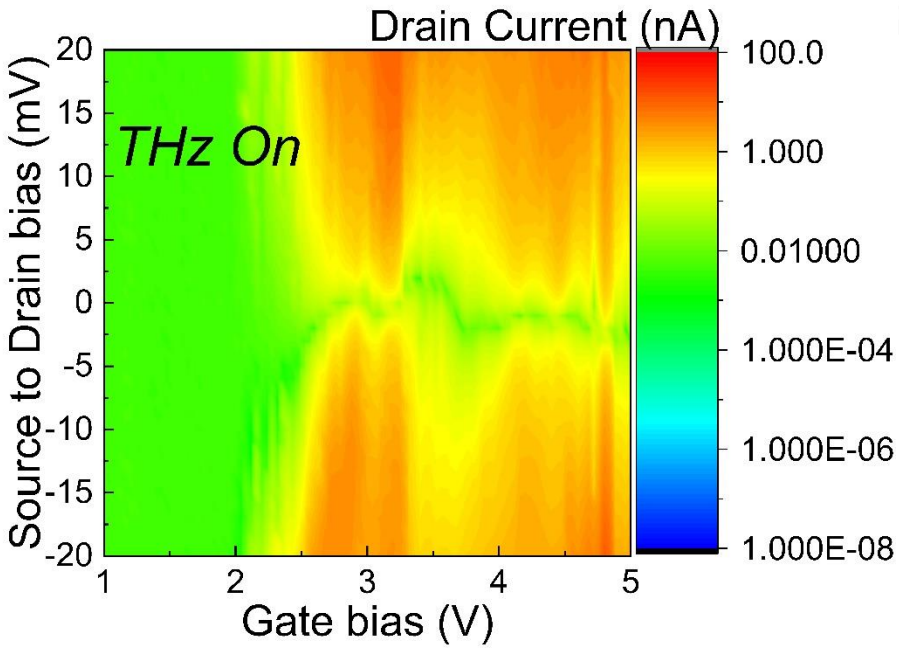
V_{SD} * V_G plane

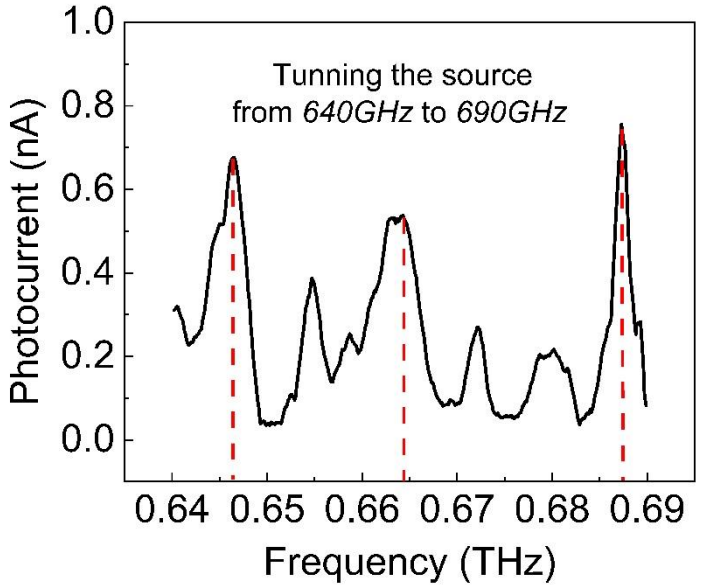


2) Experimental step

Optical measurement in low temperature (4.21K)

Testing frequency = 0.665 THz

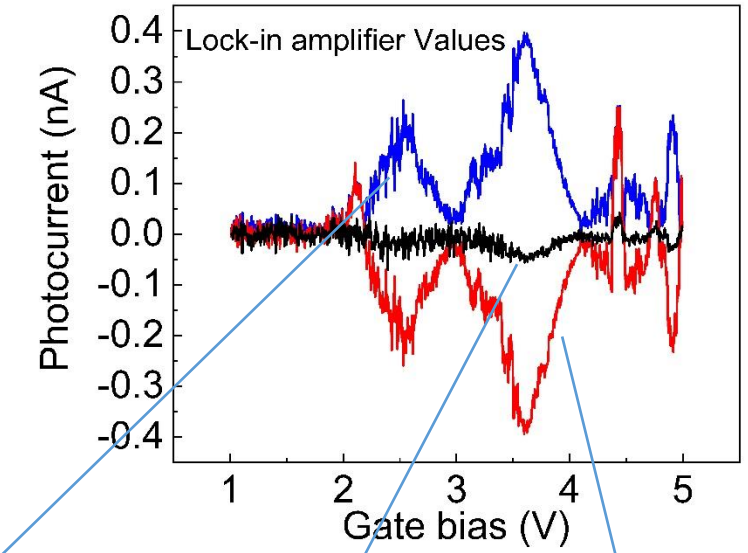




$Maximum\ responsivity$
$under\ 0.65THz$
$Rv = 25uA/W$

$R = sqrt(X^2 + Y^2)$

Quantized phtoresponse curve



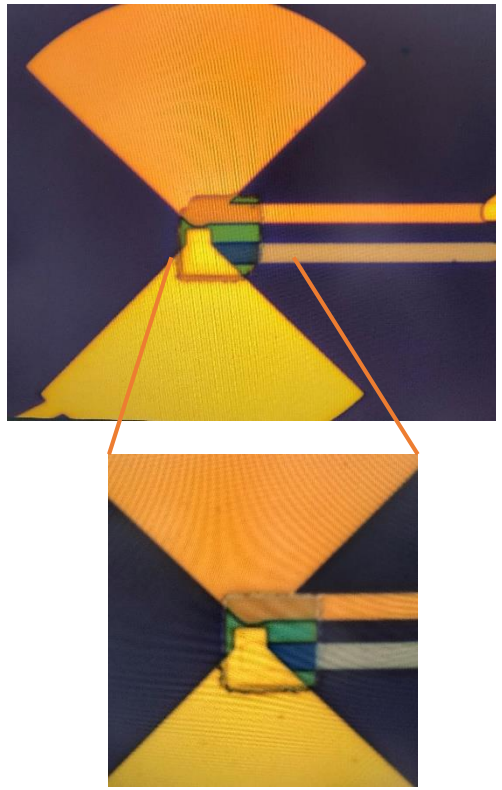
$Y = I_{sig}\ sin\theta$ Quadrature component

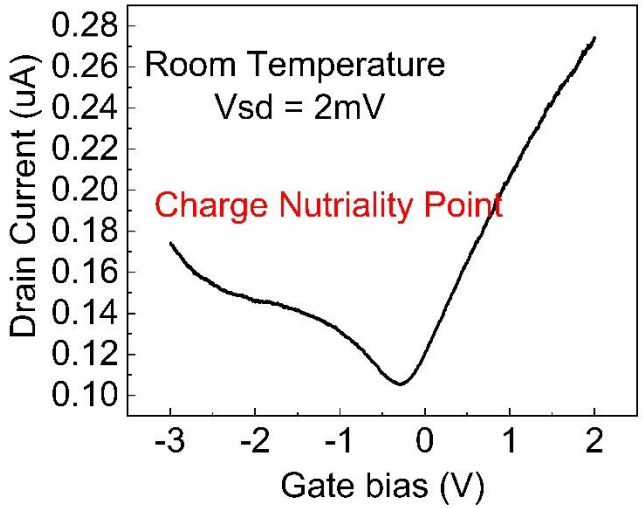
$X = I_{sig}\ cos\theta$ In-Phase component

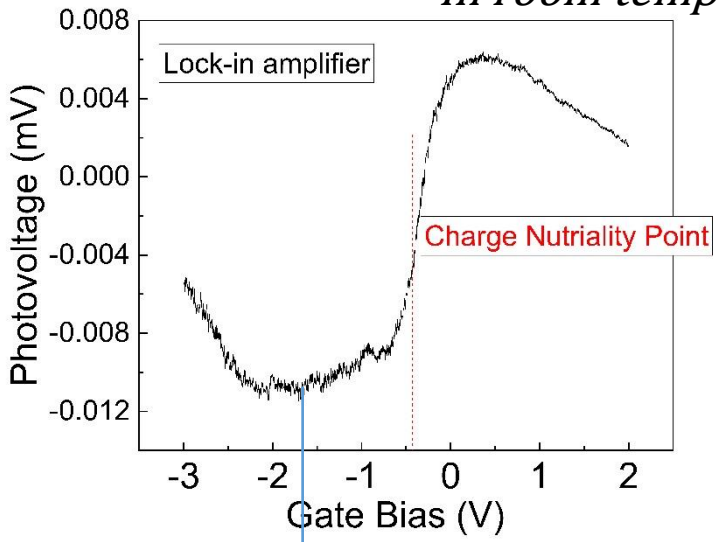
ii)) Highly sensitive THz photodetectors exploiting large area agraphene grown via Chemical Vapor Deposition (CVD) transistor as Terahertz Detector

Fabrication and characterization

$Maximum\ responsivity$
$In\ room\ temperature\ and\ under\ 0.65THz$
$Rv = 12V/W$

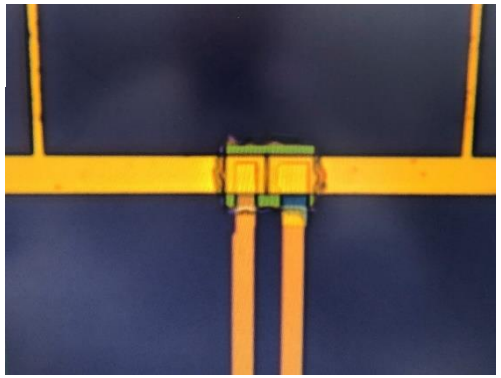






$$\frac{1}{\sigma}\frac{d\sigma}{dV_g}$$

$Speed\ of\ device\ measured\ under\ 3THz$: 40nS



Bow-tie dipole antenna

Linear dipole antenna

Publication:

Unveiling the detection dynamics of semiconducting nanowire photodtectors by THz near field nanoscopy

Authors: Eva Pogna, Mahdi Asgari, Leonardo Viti, Valentina Zannier, Lucia Sorba, Miriam Serena Vitiello

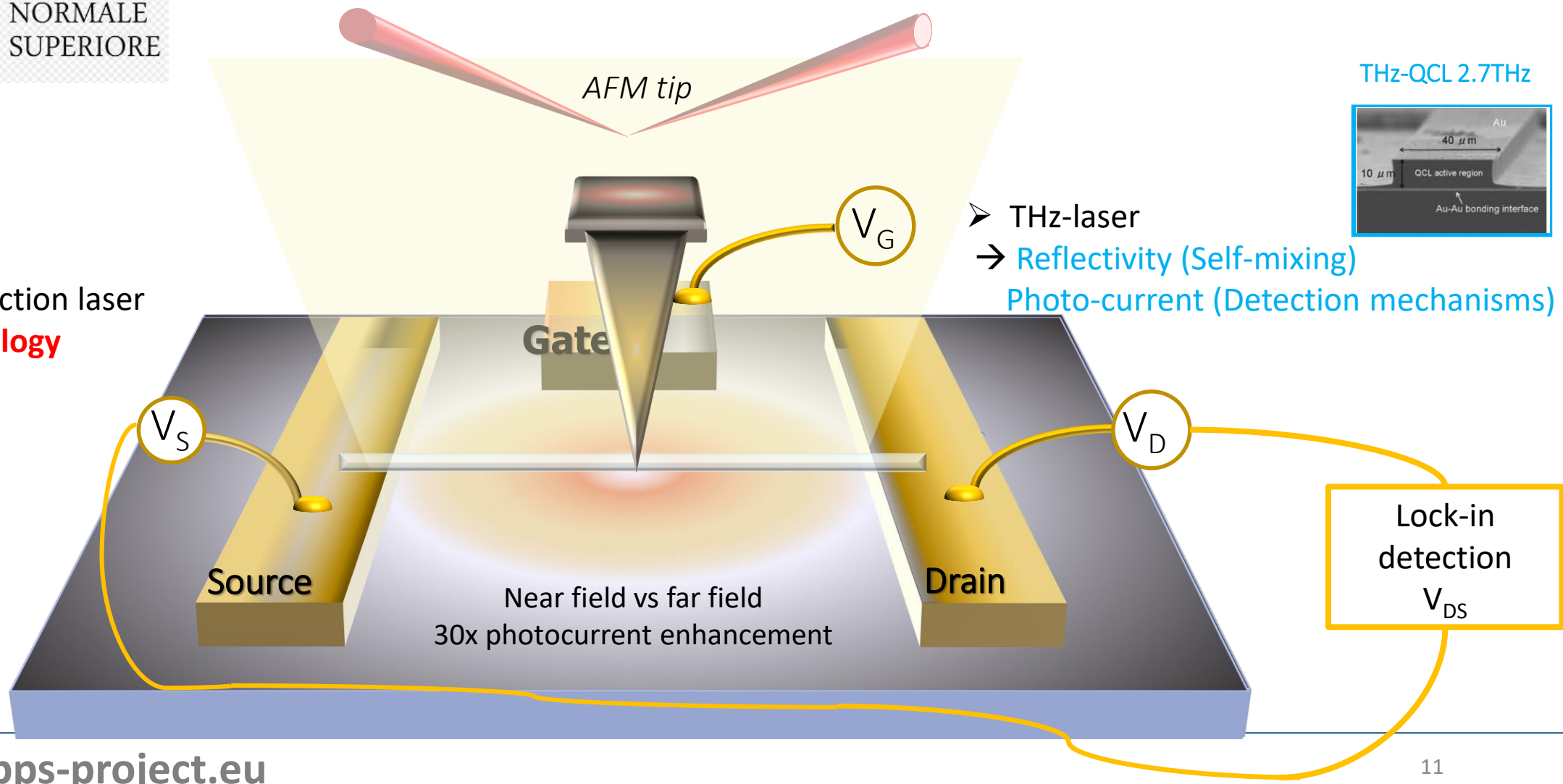
Nature, Light: Science & Applications

Near-Field THz Photocurrent Nanoscopy of InAs Nanowires FET

Light-induced photo-voltage by locally exciting the InAs NW with THz-coupled AFM tip

Neaspec
s-SNOM

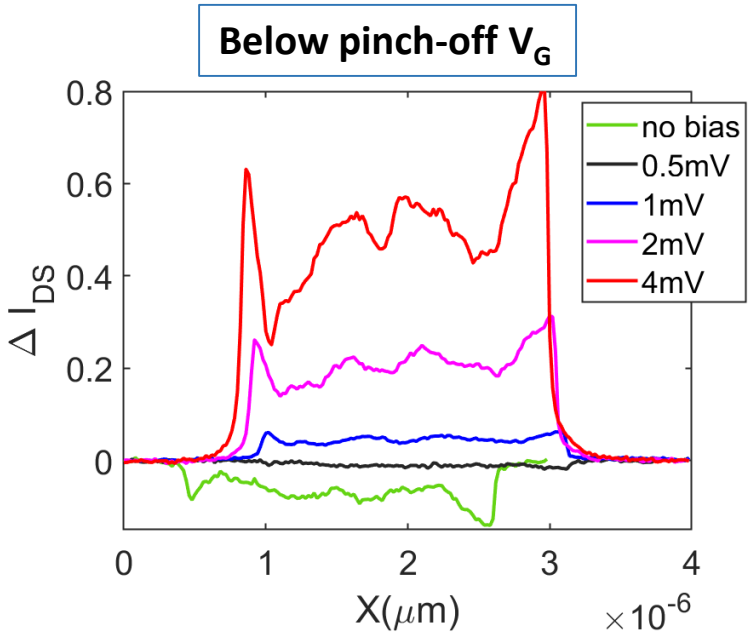
➢ Deflection laser
→ **Topology**

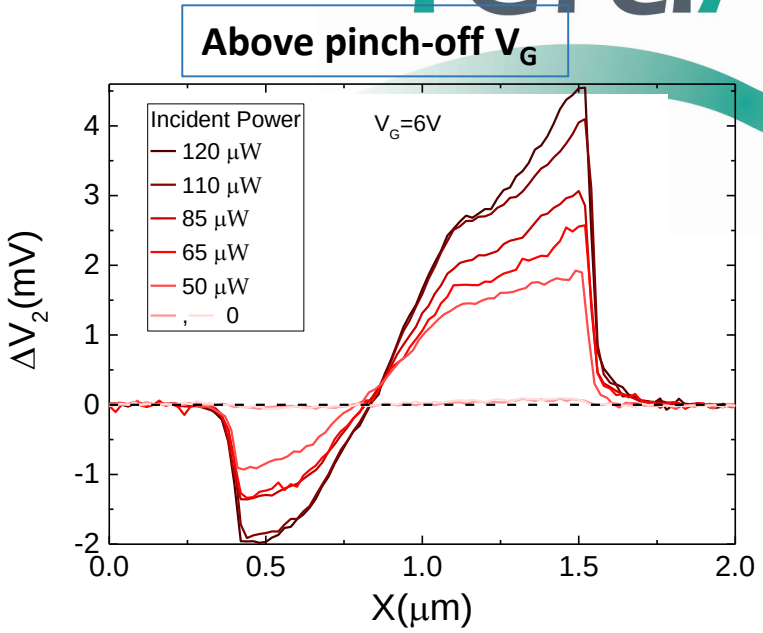


THz-QCL 2.7THz

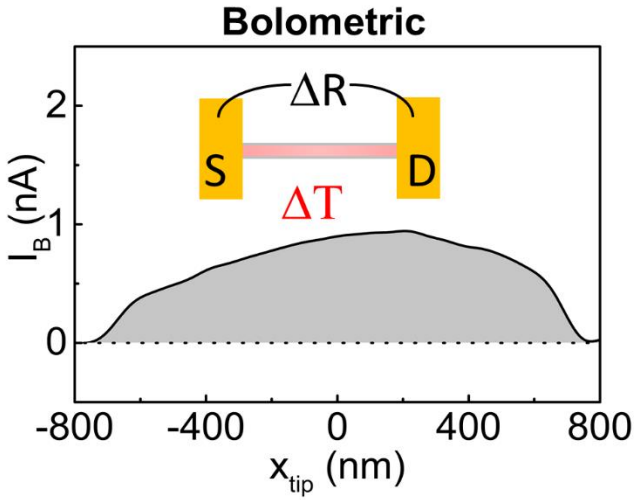
➢ THz-laser
→ Reflectivity (Self-mixing)
Photo-current (Detection mechanisms)

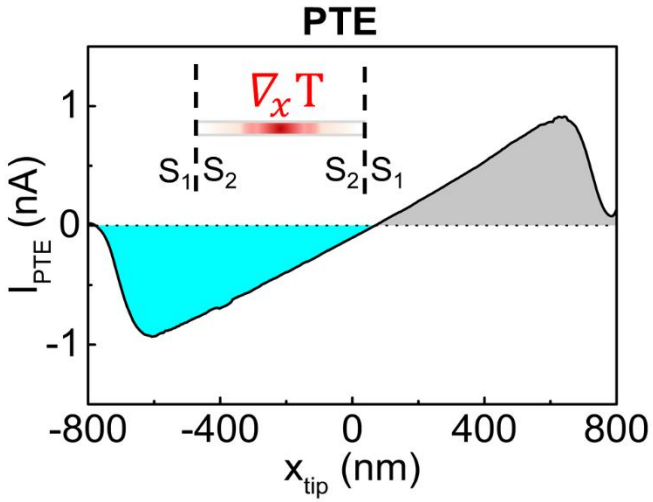
Bolometric and PTE effects as a function of tip position measured experimentally





Bolometric and PTE effects as a function of tip position measured via simulation





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Elisa Riccardi

and

Thanks for your attention