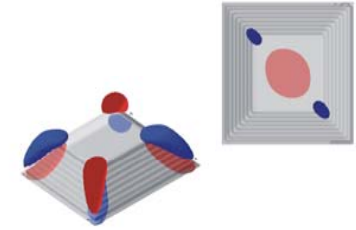


next**nano**<sup>3</sup>  
Stefan Birner  
Schmalkaldener Str. 34  
D-80807 Munich  
+49-89 35 89 53 34

[www.nextnano.de](http://www.nextnano.de)  
[stefan.birner@nextnano.de](mailto:stefan.birner@nextnano.de)



# nextnano<sup>3</sup>

semiconductor software solutions

---

Stefan Birner

# Goal: Business plan & Spin-off

**Our vision:** To establish nextnano<sup>3</sup> as the de facto standard simulator for the next generation of electronic and optoelectronic semiconductor nano devices and materials.



- Stefan Birner, MPhys  
EXIST-Seed funding: 40.000 €

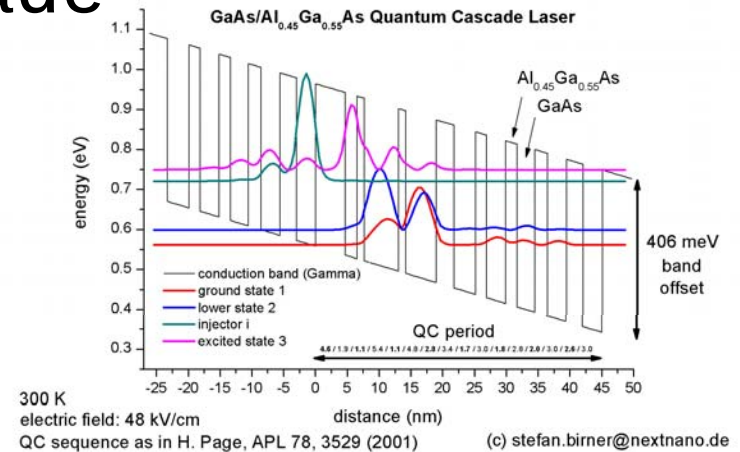


- Partner: Prof. Dr. Peter Vogl  
Theoretical Semiconductor Physics  
Walter Schottky Institute, TU Munich

# The downscaling continues...

... at least for the next decade

- **quantum** effects
- **new** devices (e.g. QCLs)
- **new** materials



## Our customers:

Prof. Dr. Joel Schulman, HRL Laboratories\* (USA):

"Now that I've got next**nano**<sup>3</sup> working, I am very impressed. I can see many uses for it. "

*And a few weeks later...*

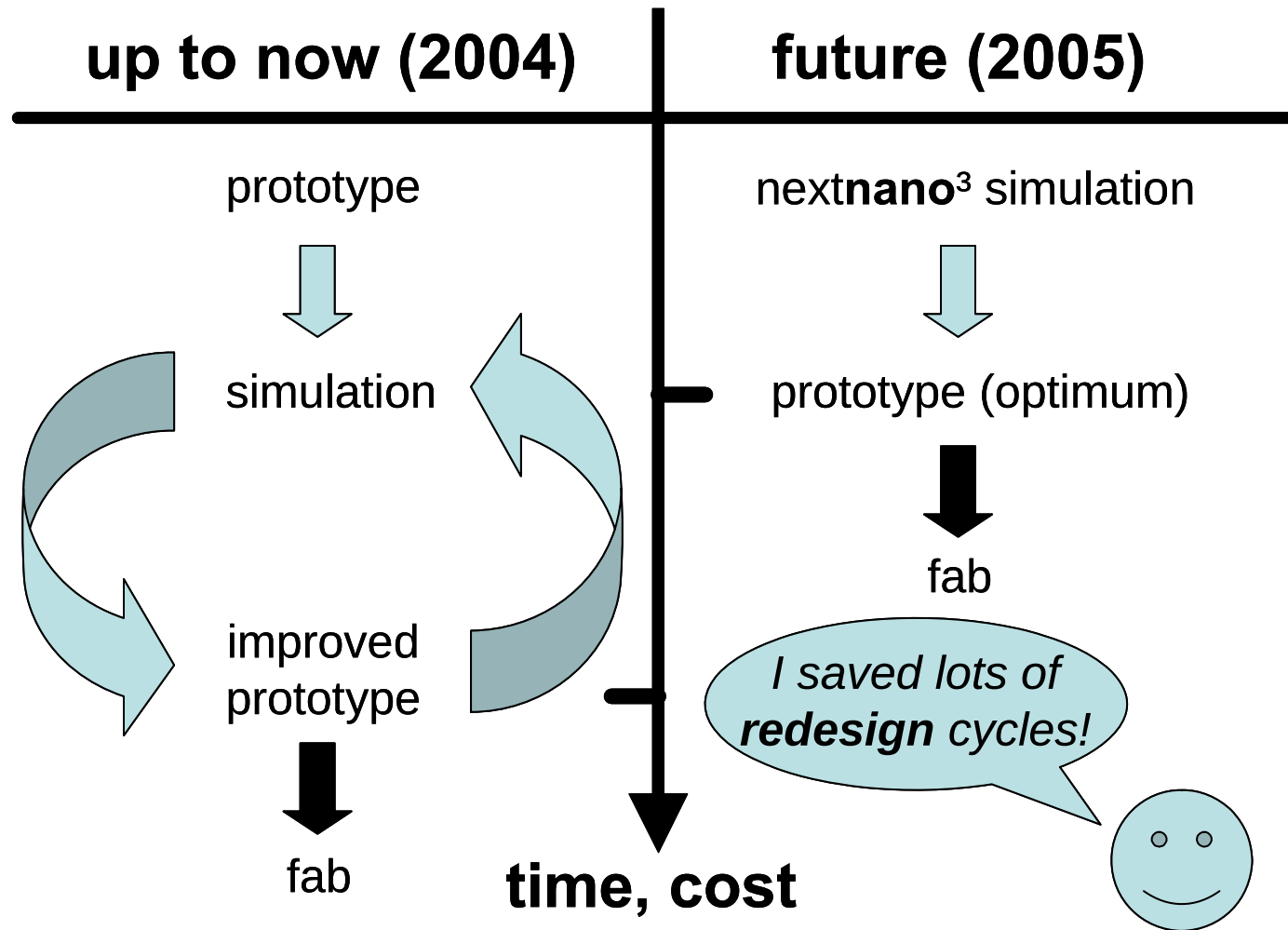
"We have been using next**nano**<sup>3</sup> very heavily recently to help design quantum dots with gates for a quantum computer application."

\*HRL is owned by The Boeing Company, General Motors and Raytheon Company.

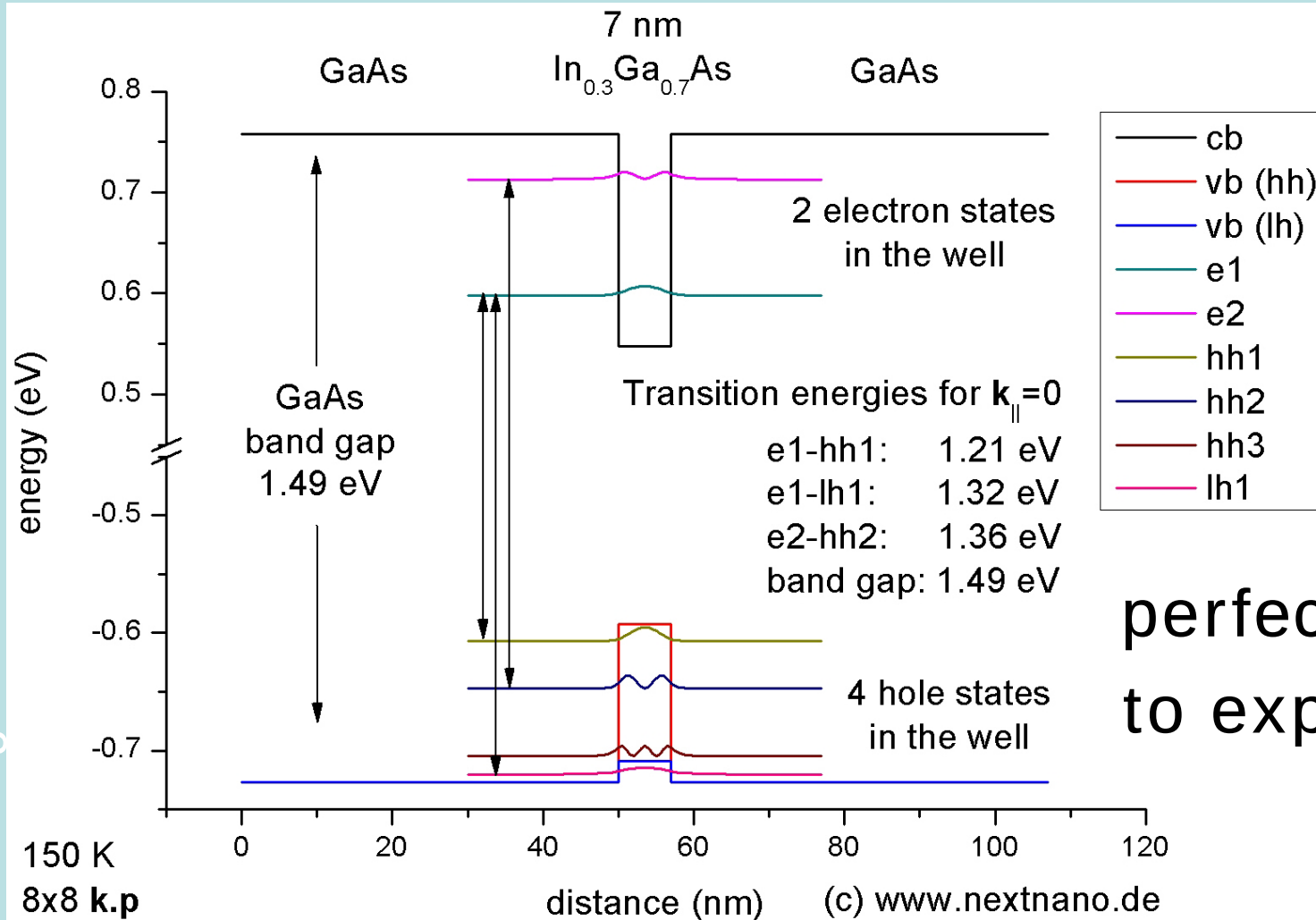
# Software for nano devices

- **Simulation of nano semiconductor devices**
  - electrical properties (current)
  - optical properties (lasers, sensors)
  - 1D/2D/3D, **quantum** physics (!)
- **Customers:** semiconductor industry (silicon), optoelectronics industry (III-V semiconductors), defense, research institutes, universities
- **Annual market size:** \$100 million
- so far: 1000 downloads per year

# Benefit: Less redesign cycles

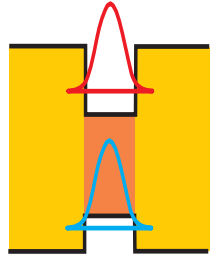


# Optical absorption: Quantum Well nextnano<sup>3</sup> & Infineon Technologies

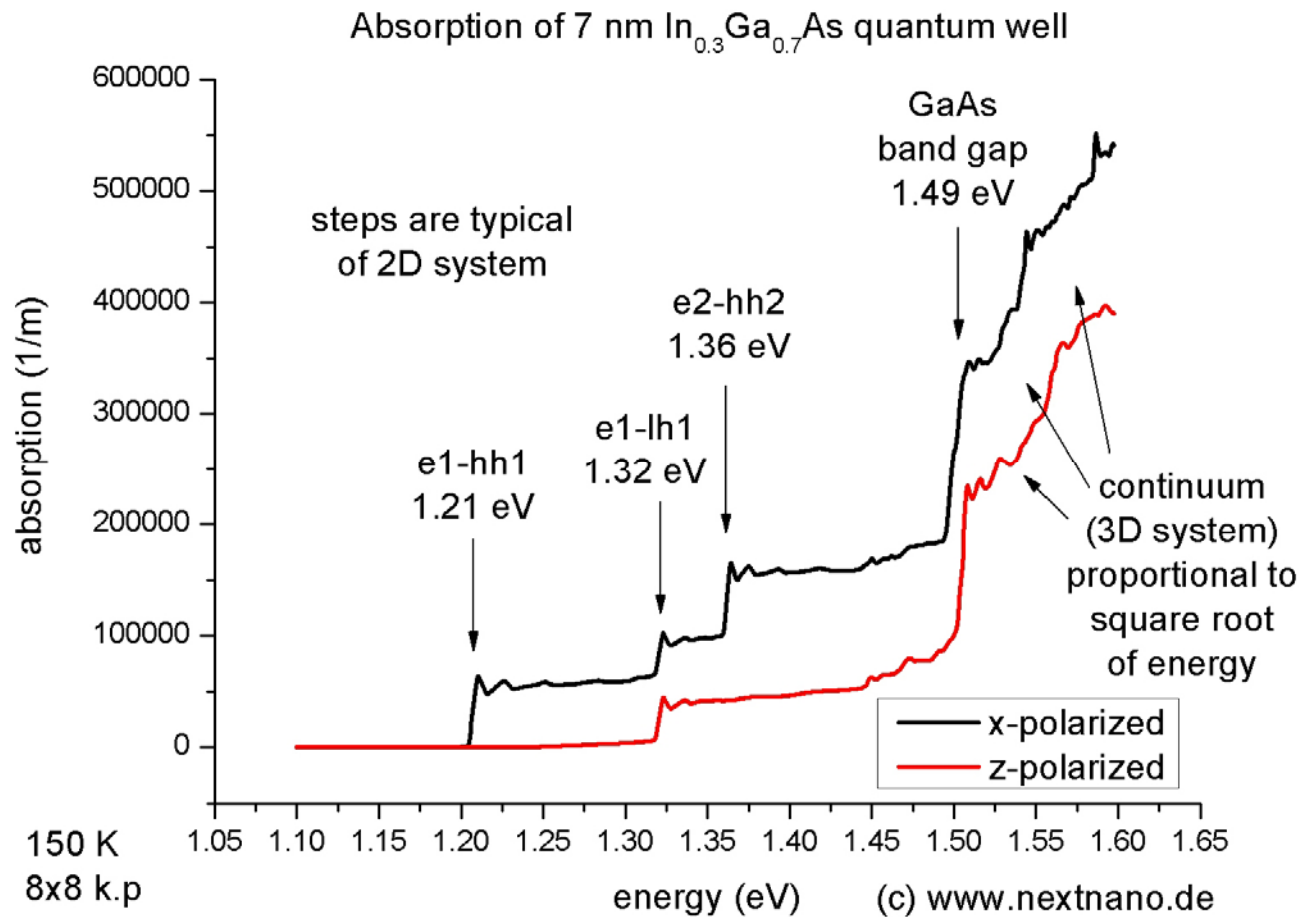


perfect match  
to experiment !

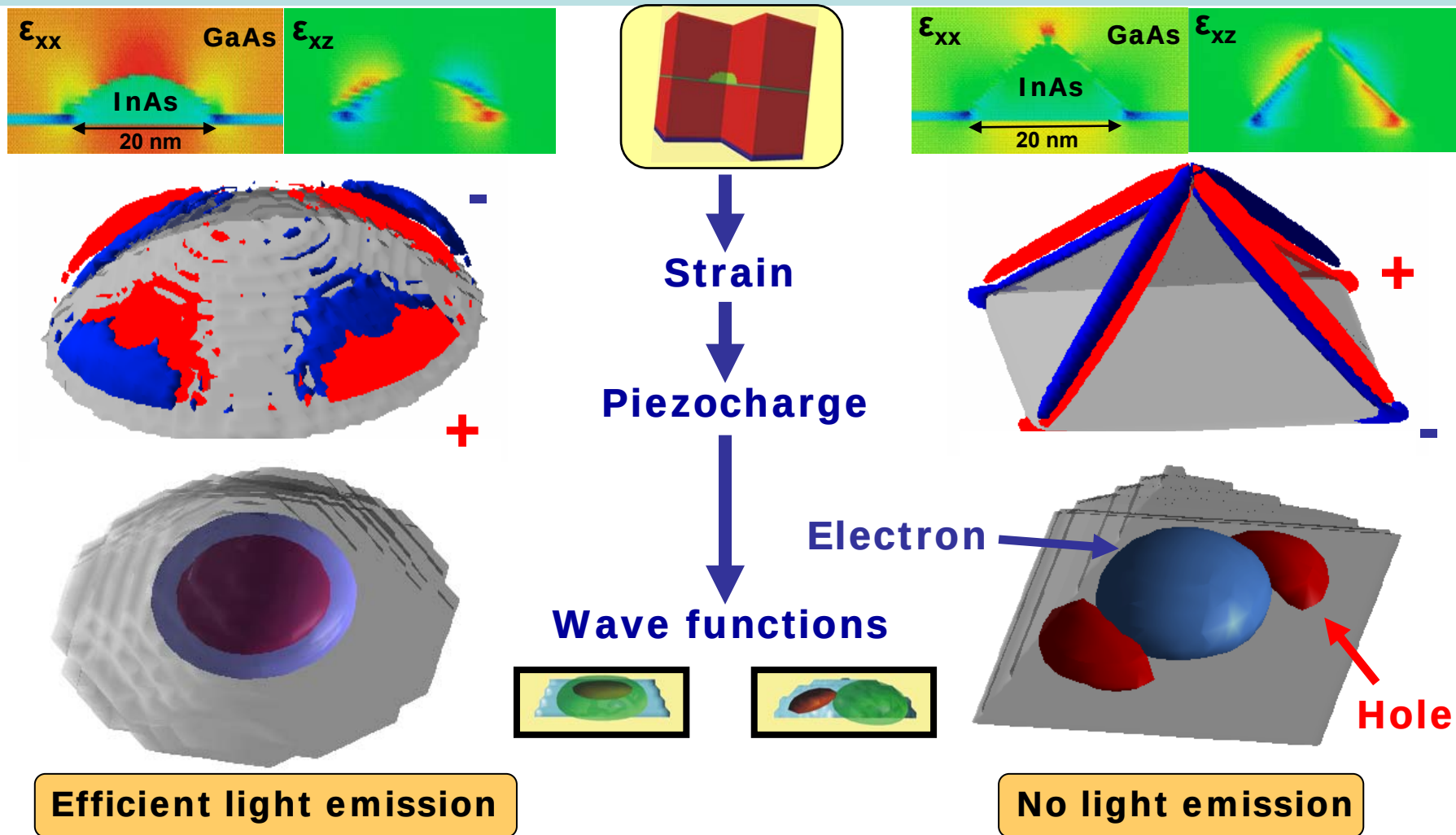
# Optical absorption: Quantum Well nextnano<sup>3</sup> & Infineon Technologies



- optimize design by simulation !

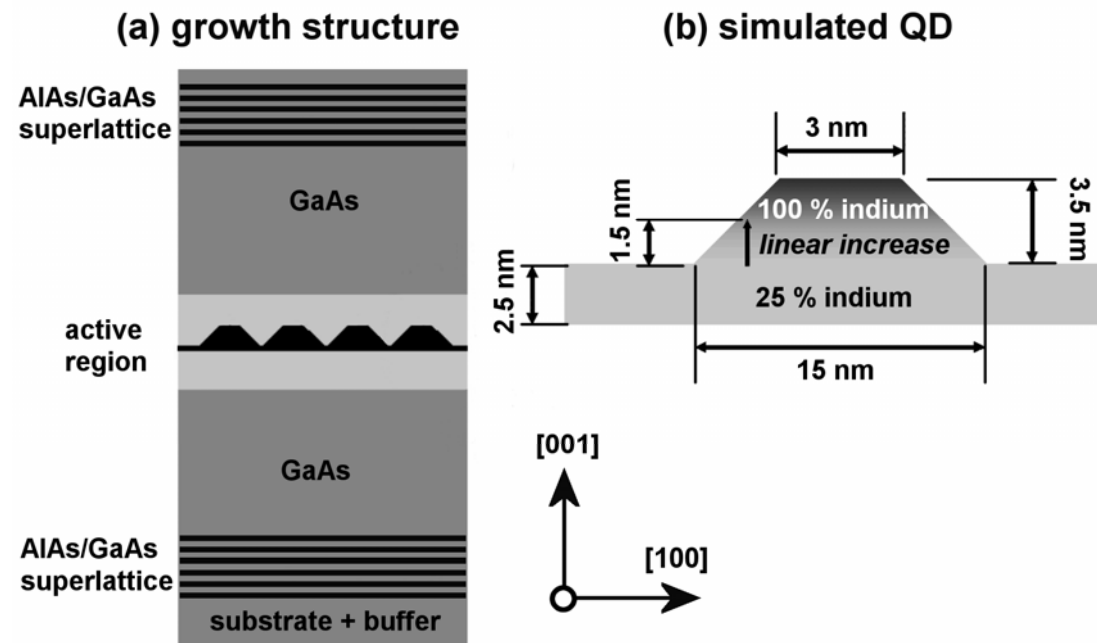


# Quantum Dot Lasers nextnano<sup>3</sup> & Infineon Technologies

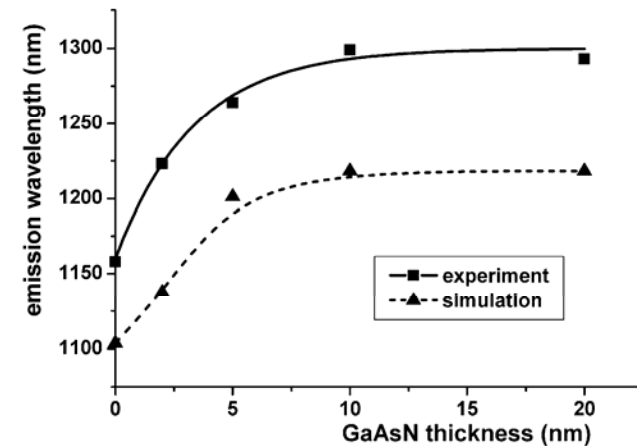
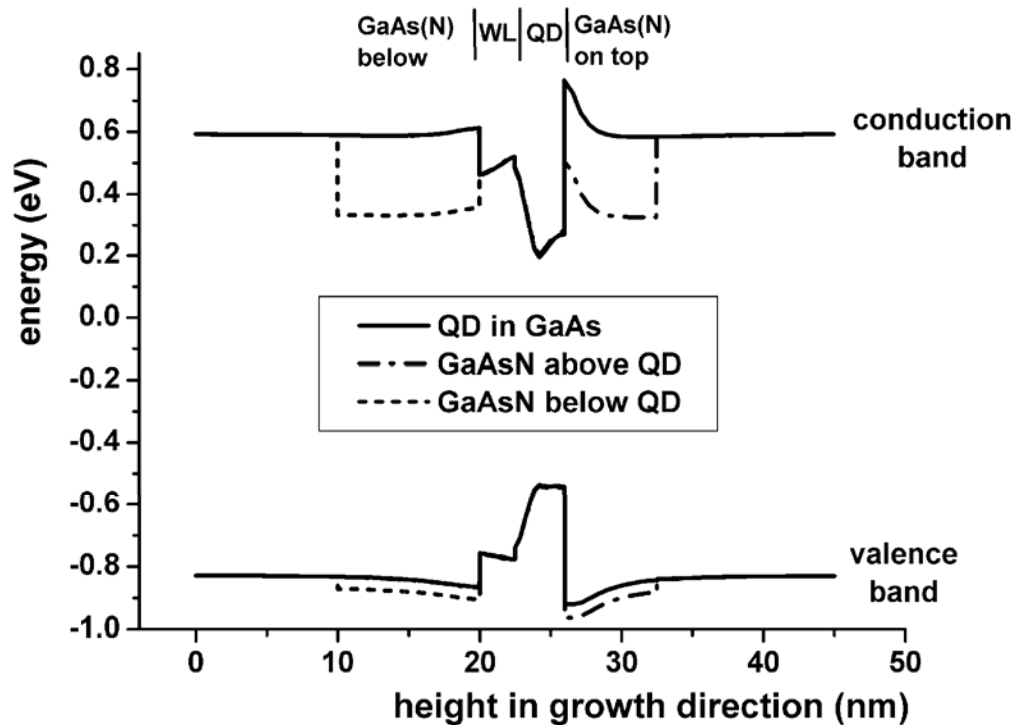


# Example: Diluted Nitrides

- Diluted nitrides: GaAs<sub>N</sub> / InGaAs<sub>N</sub>  
=> conduction band energy
- QDs: Variation of capping material

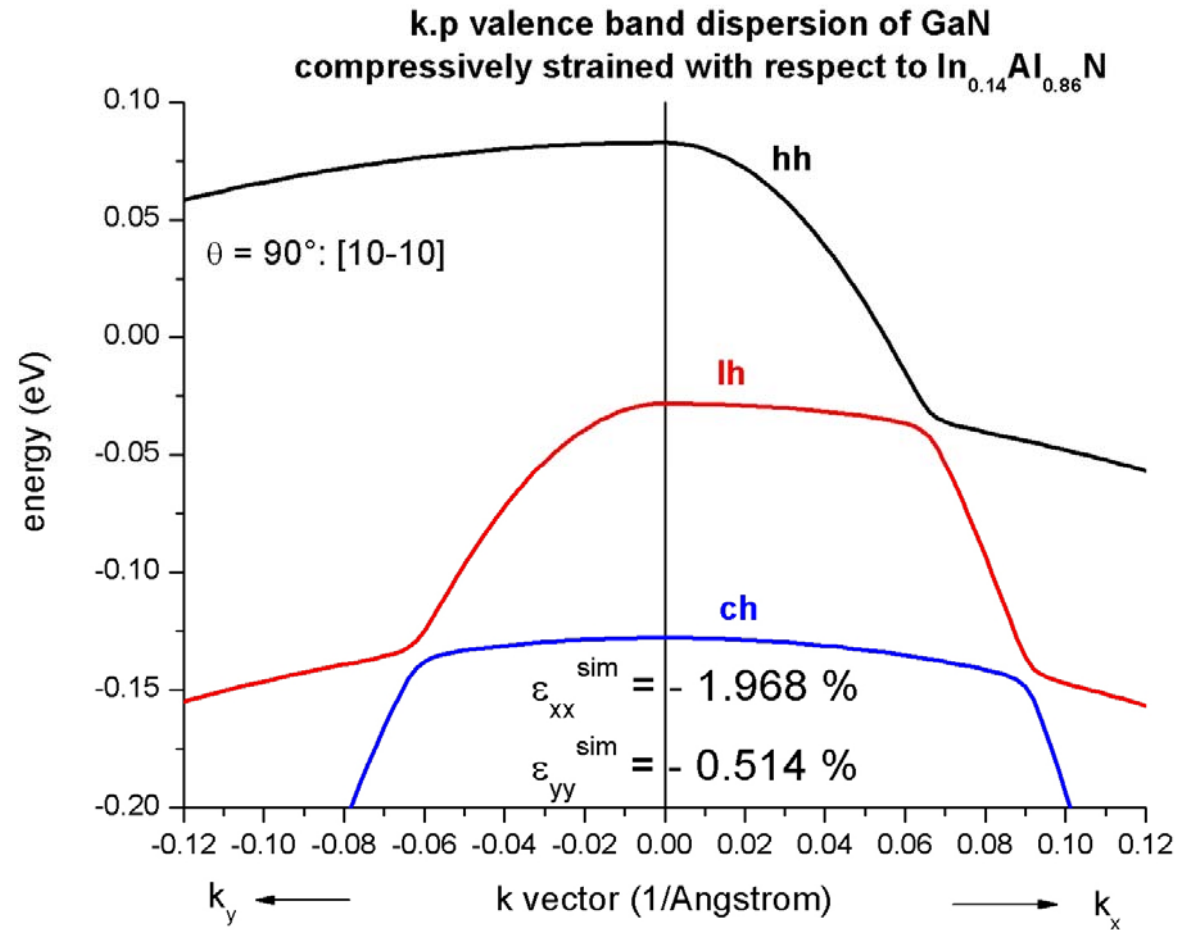
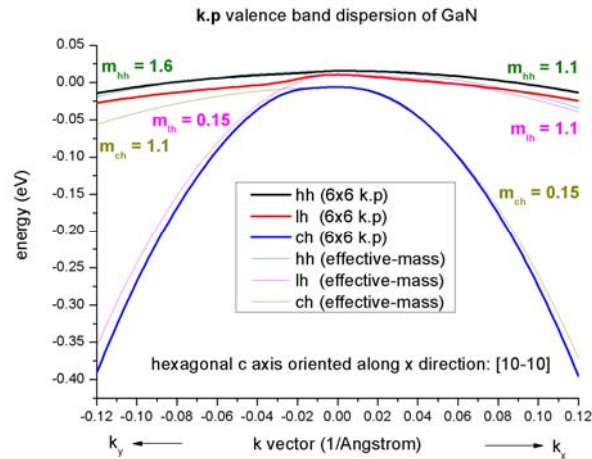


# Example: Diluted Nitrides

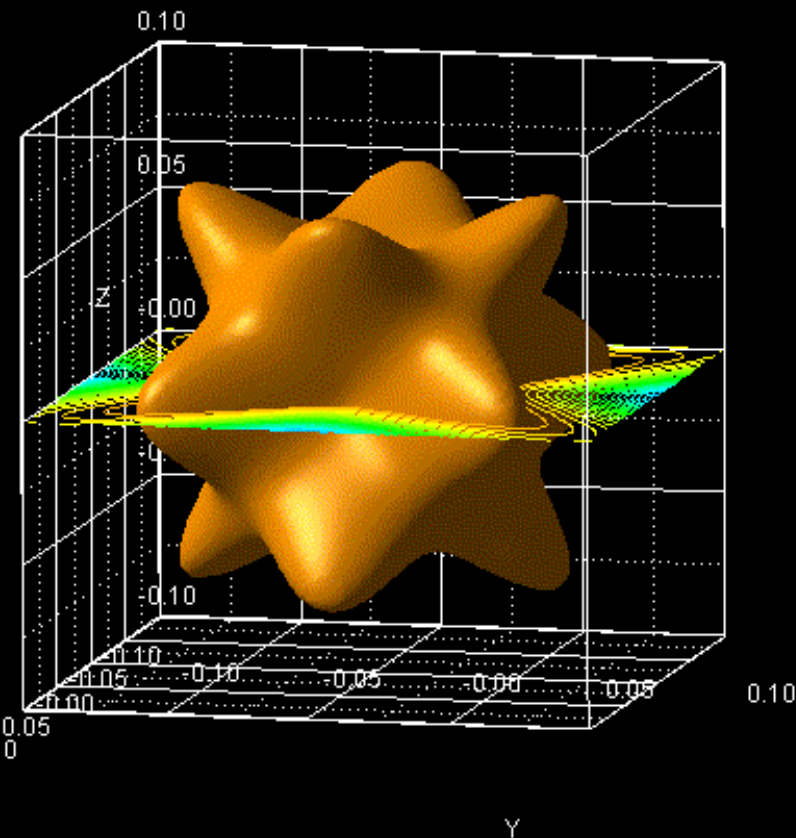
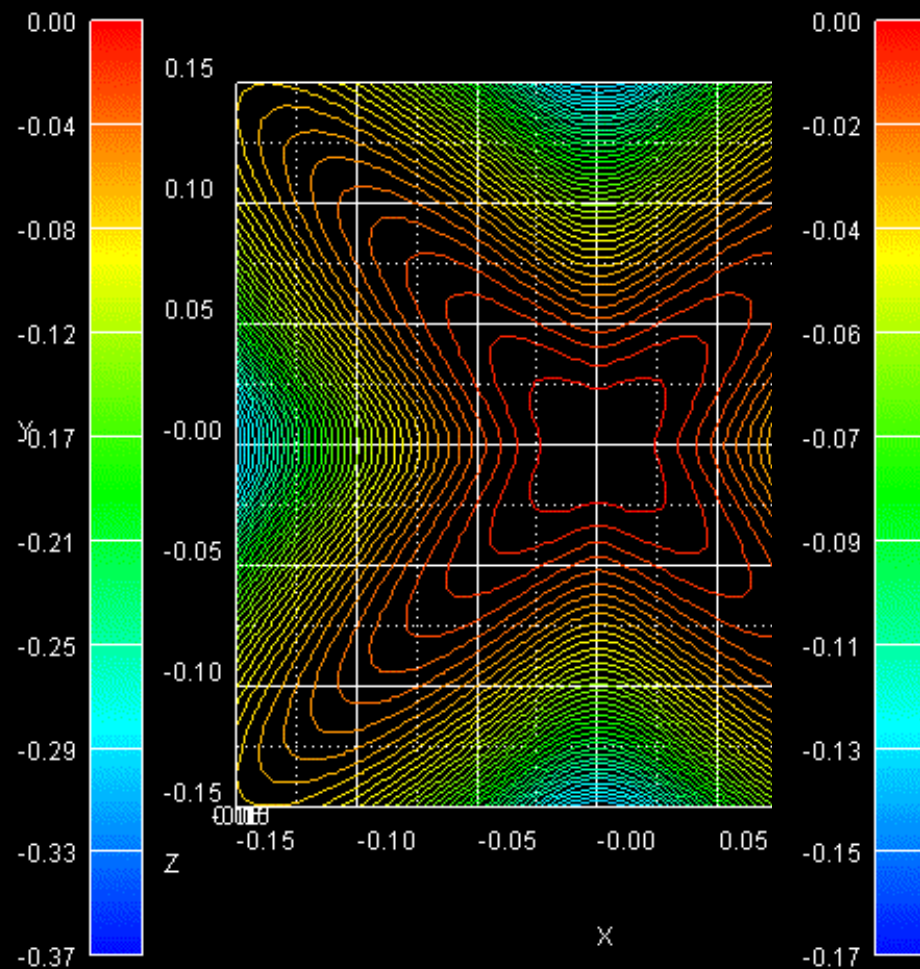


- QWs: Use absorption spectra to extract band offsets
- Infineon Technologies, CPR Photonics Group

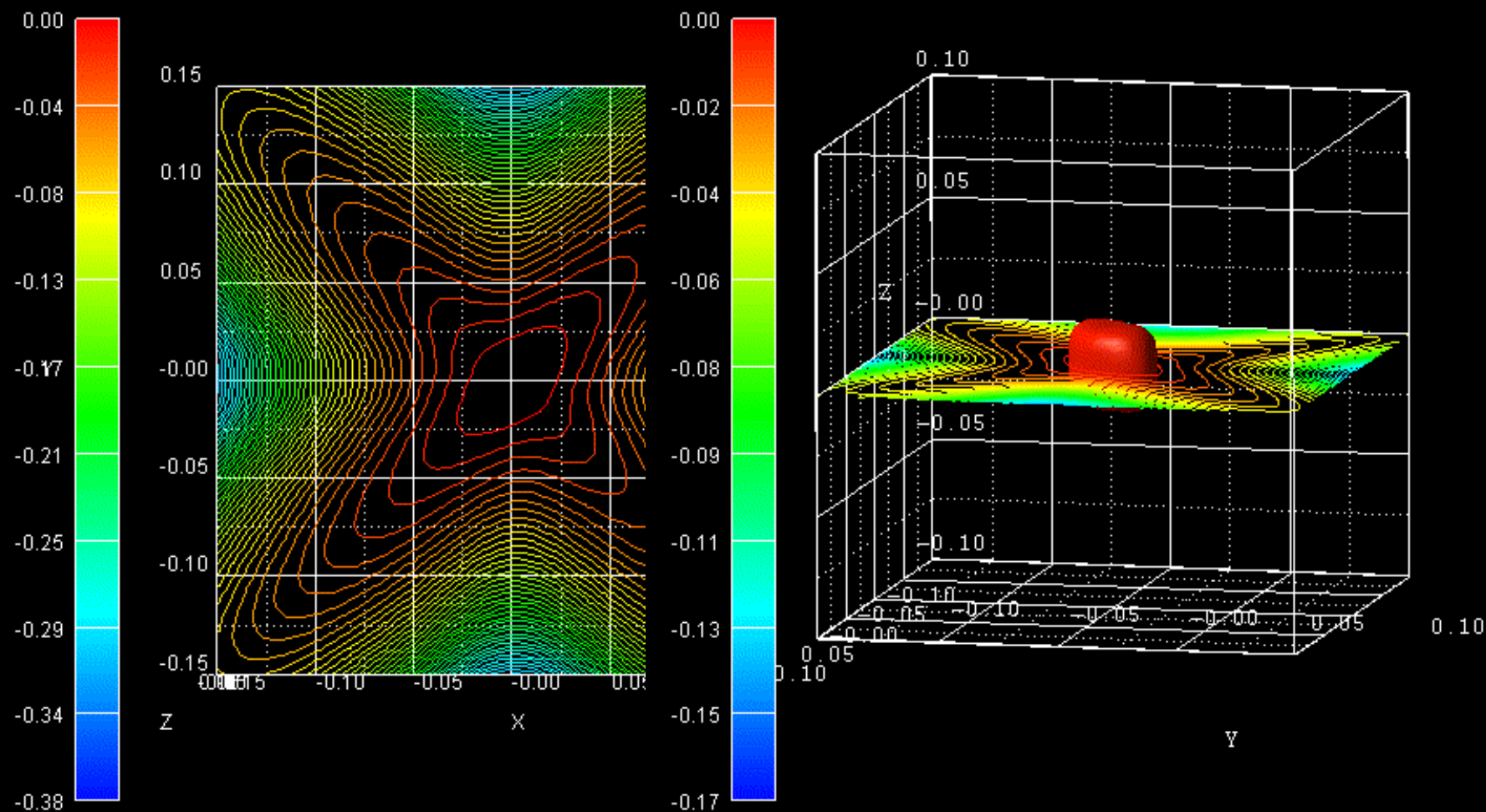
# E(k) dispersion in GaN



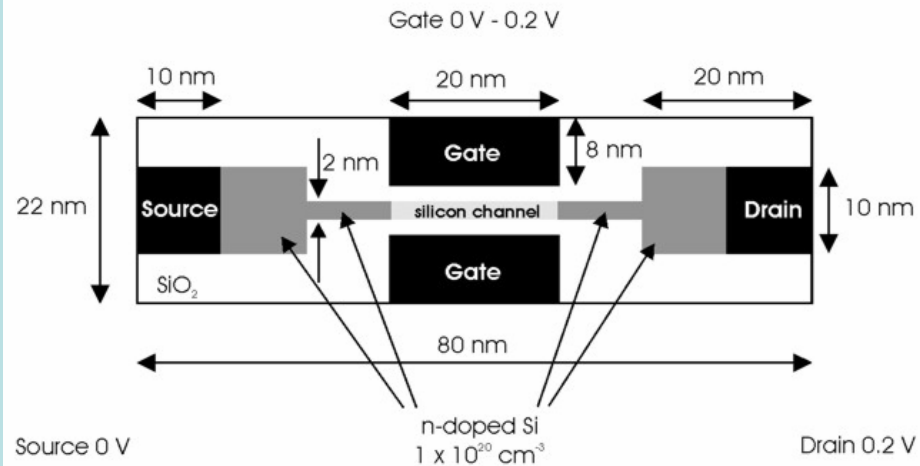
# Unstrained silicon: $E(k)$ nextnano<sup>3</sup> & Freescale



# Strained silicon: Uniaxial along [110] nextnano<sup>3</sup> & Freescale

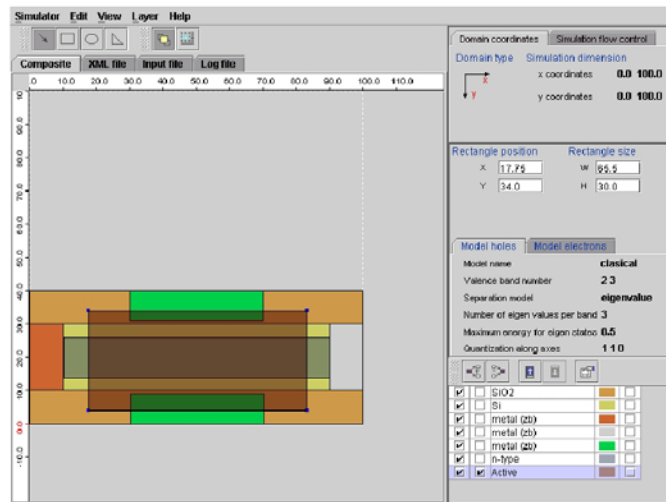


# Double Gate MOSFET nextnano<sup>3</sup> & Infineon Technologies



## Nano MOSFET\*

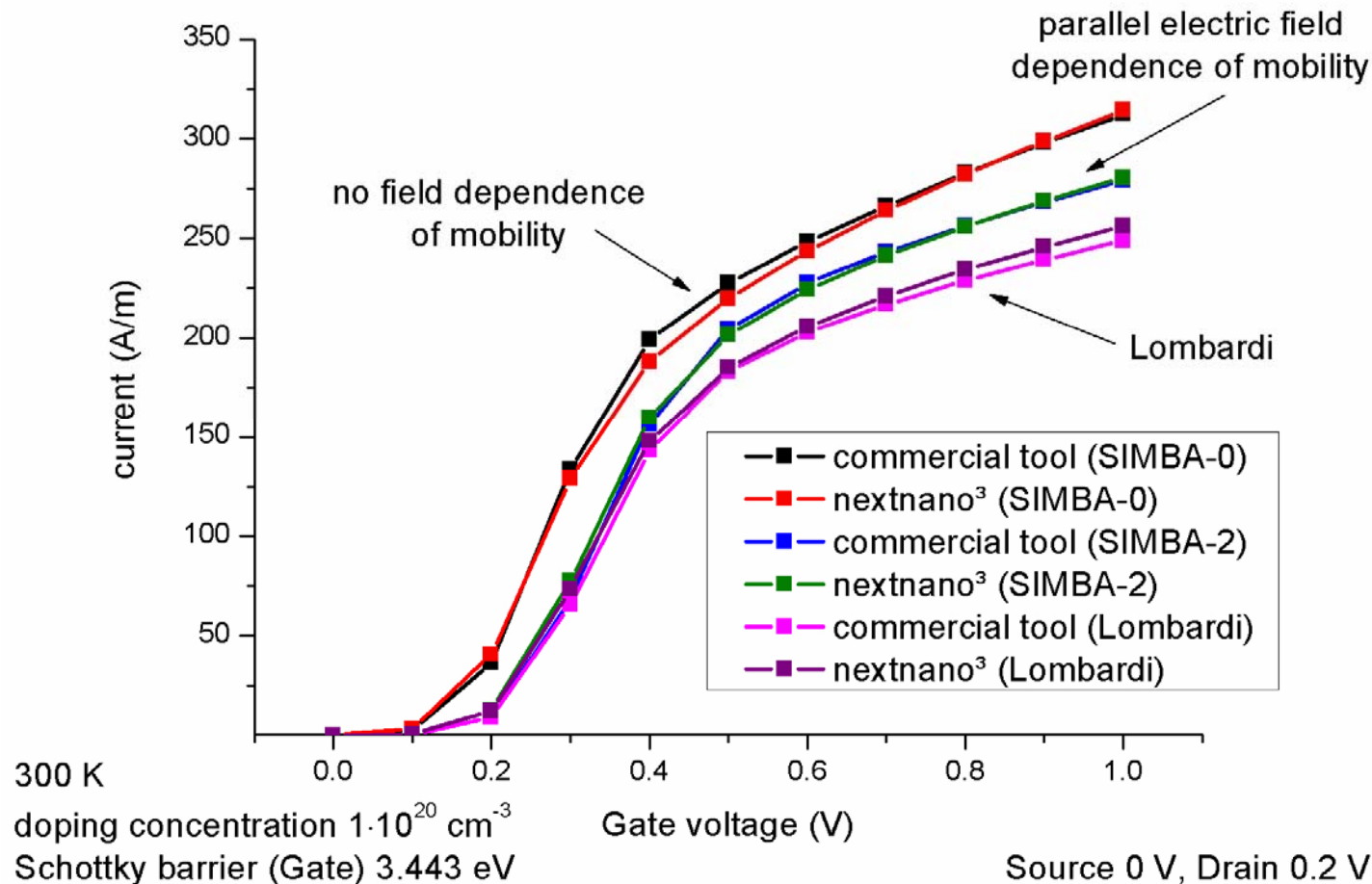
\* metal oxide semiconductor  
field effect transistor



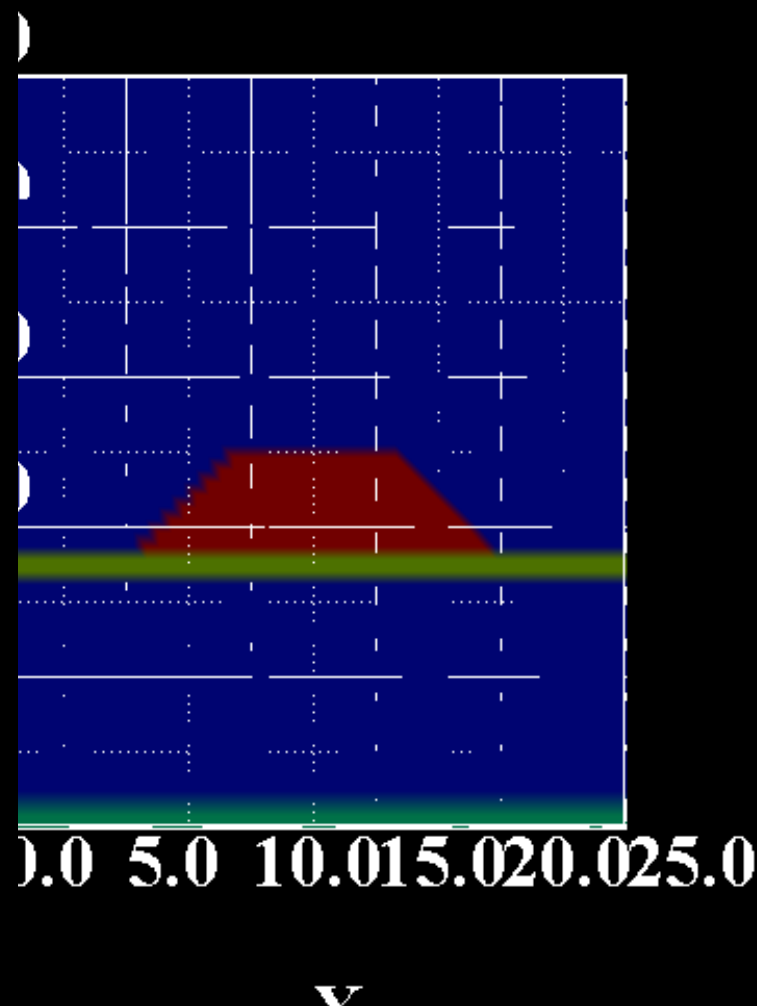
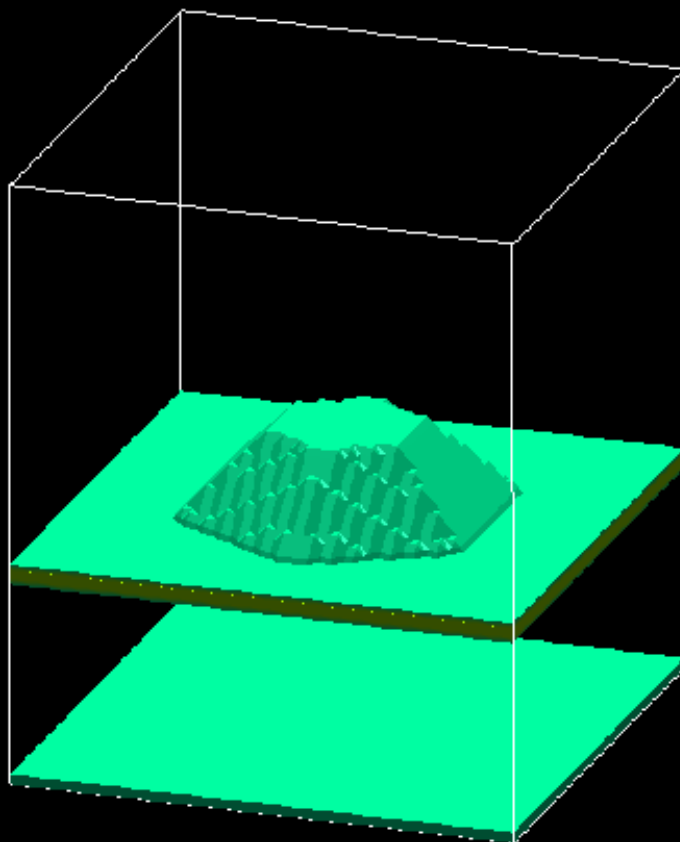
Future: strained silicon

# Double Gate MOSFET nextnano<sup>3</sup> & Infineon Technologies

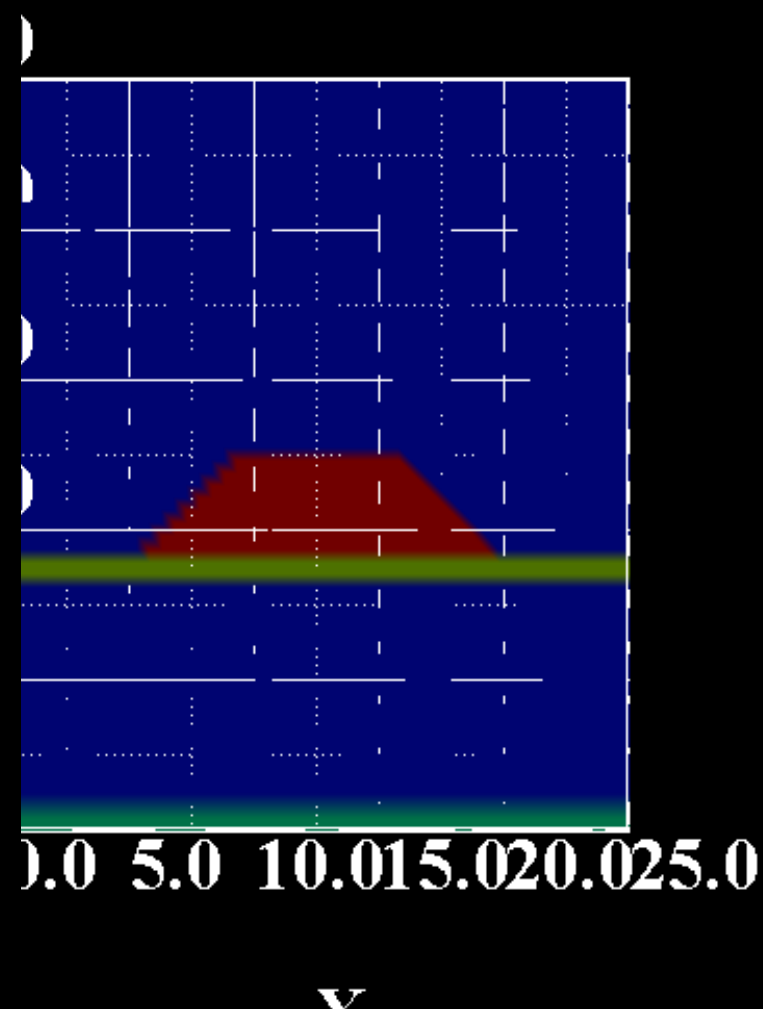
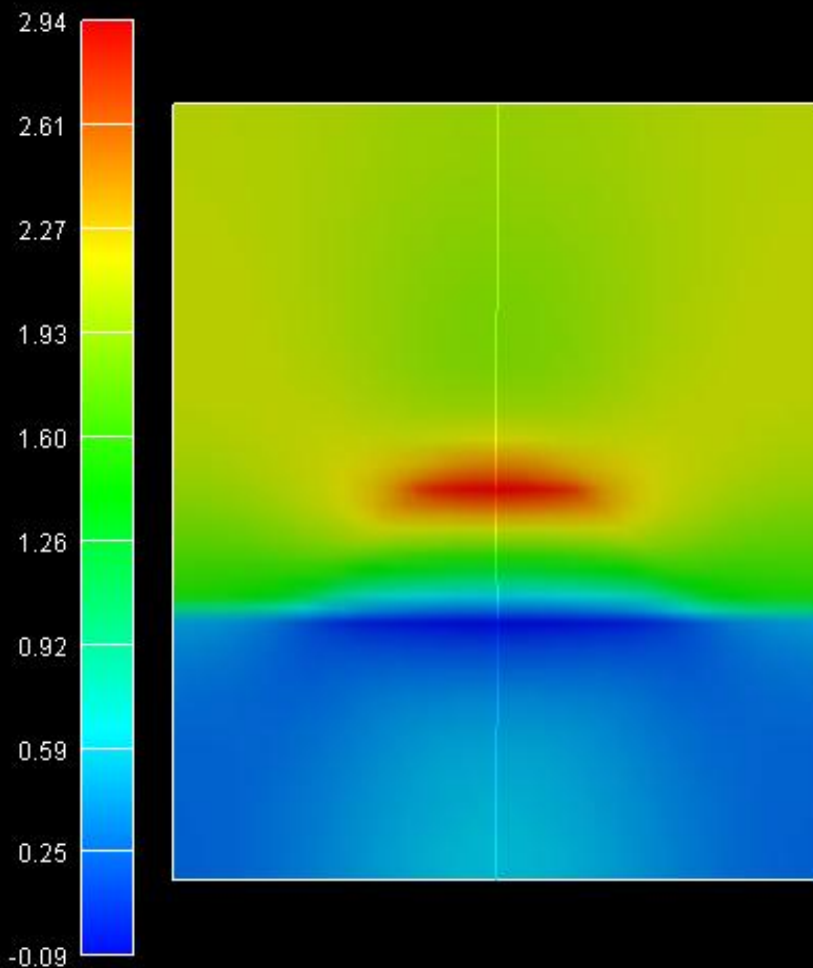
Current-voltage (I-V) characteristic of a 2 nm Si Double Gate MOSFET



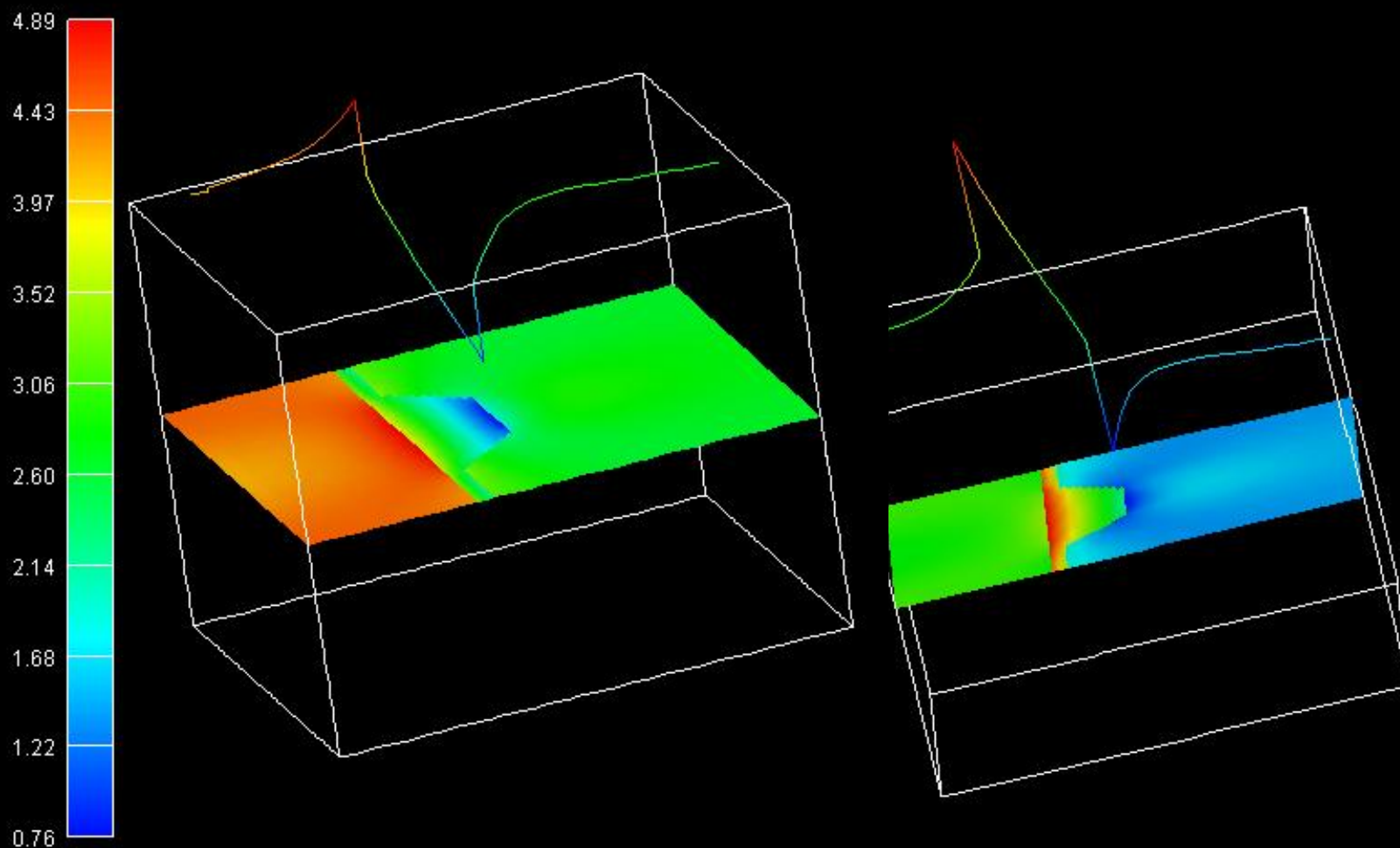
# Hexagonal GaN Quantum Dots



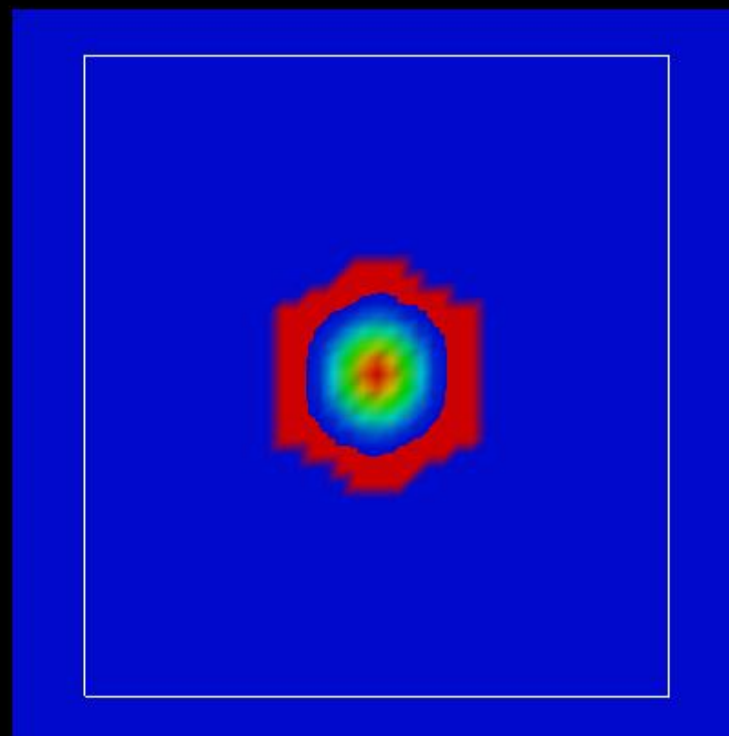
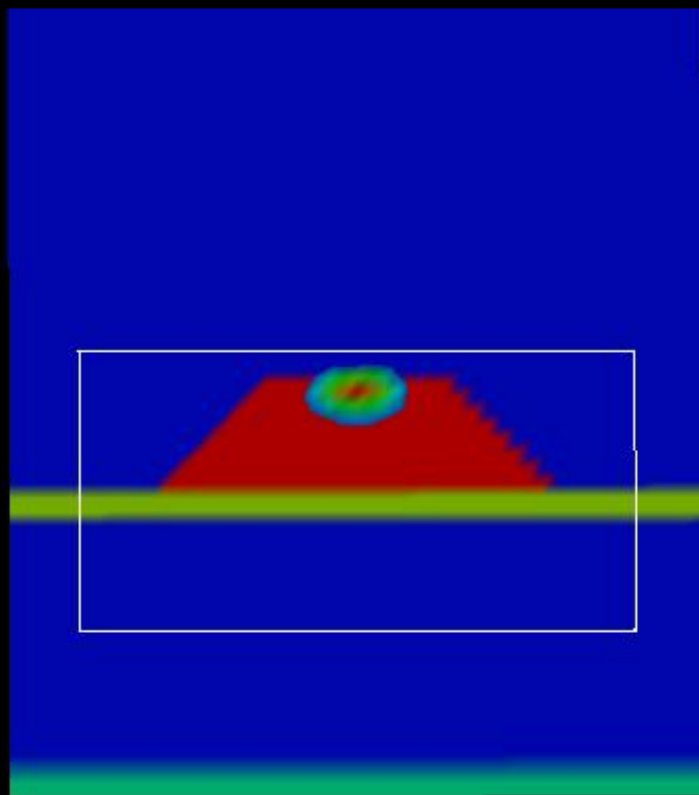
# Hexagonal GaN Quantum Dots



# Hexagonal GaN Quantum Dots

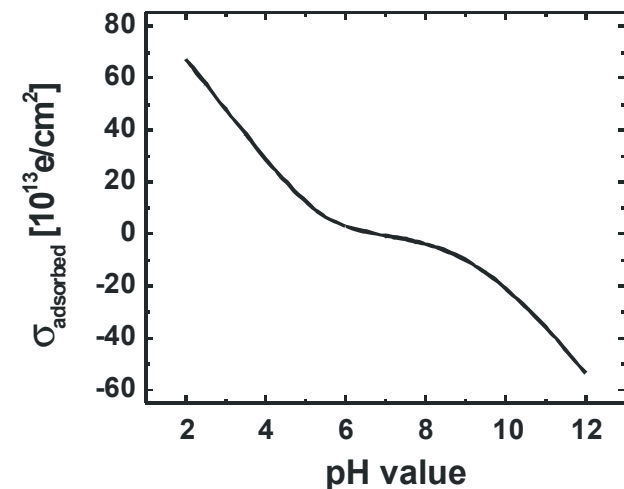
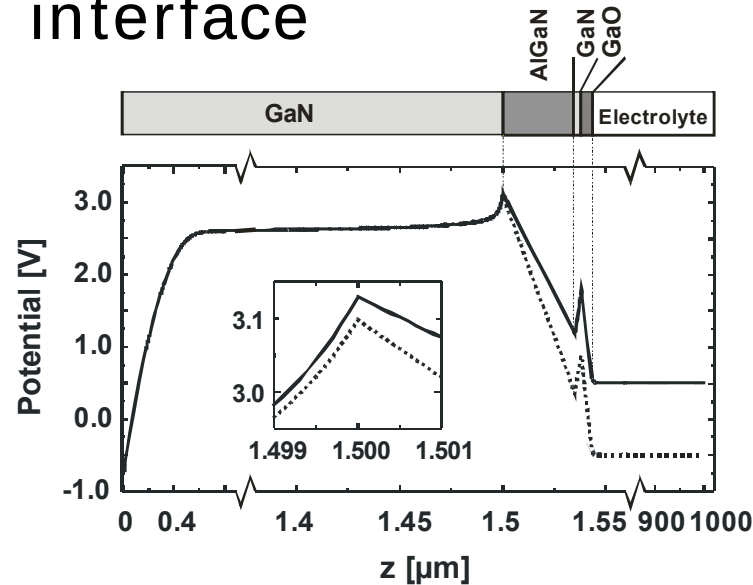
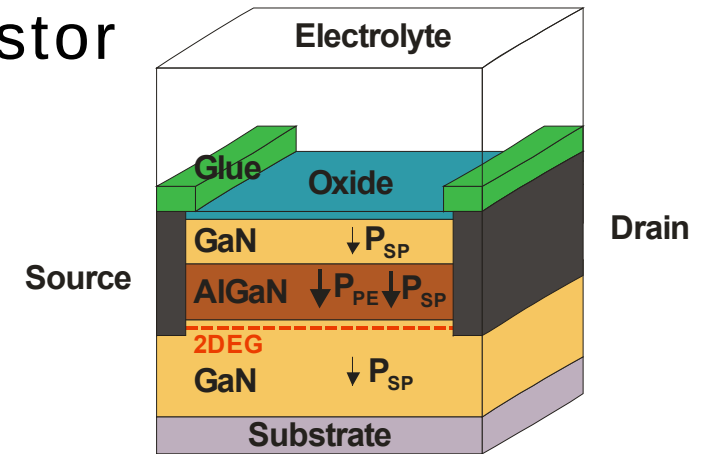


# Hexagonal GaN Quantum Dots

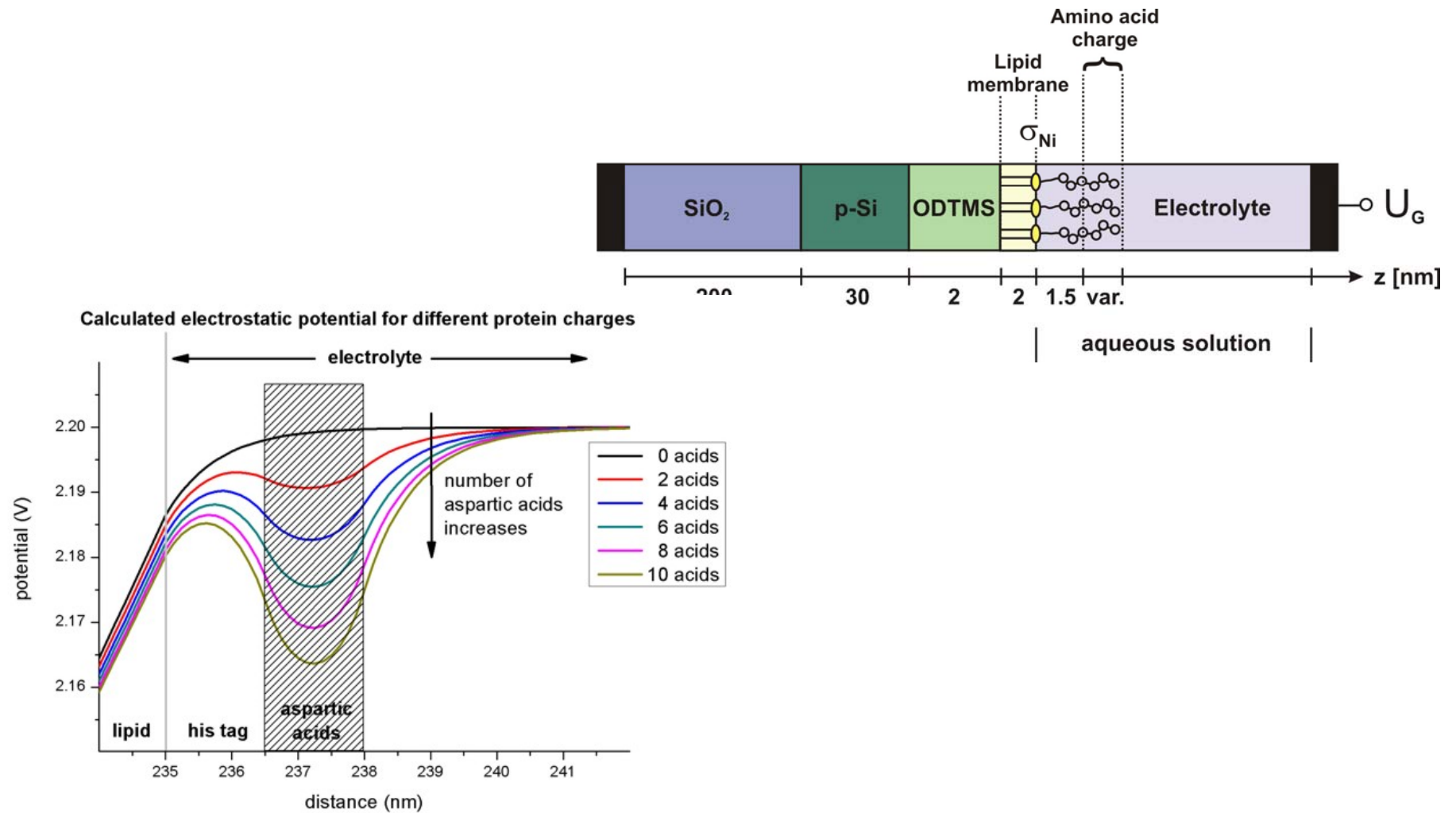


# BIO-nextnano<sup>3</sup> for Bio Chips

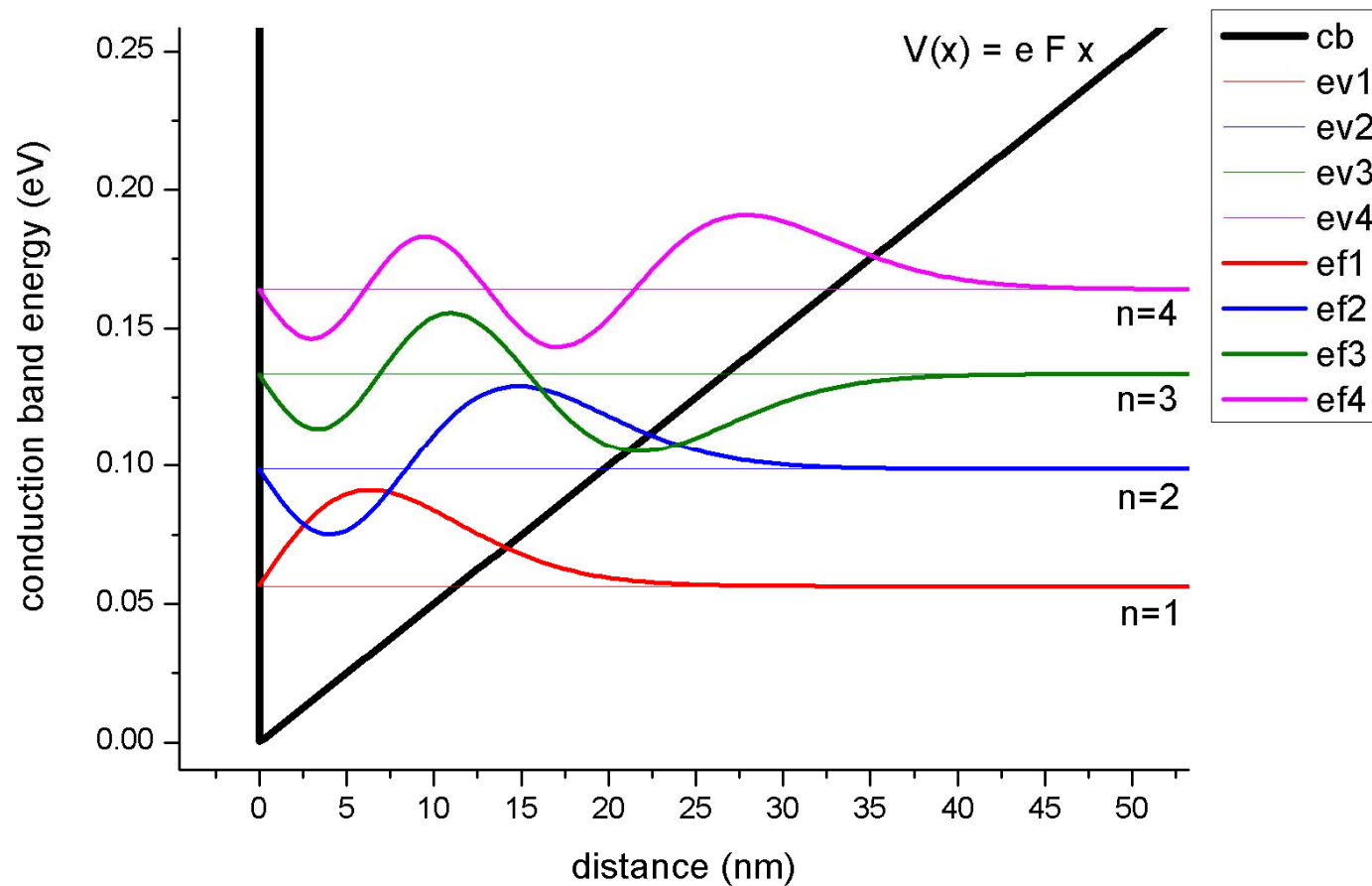
- Ion Sensitive Field Effect Transistor (ISFET) to detect ions, charged molecules, DNA, pH value
- electrolyte solution (ions)
- charge at oxide/electrolyte interface



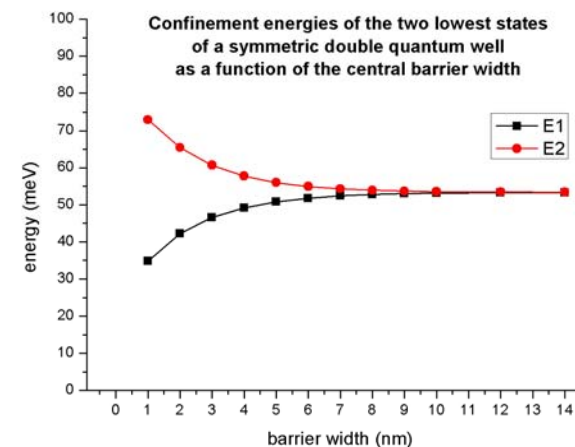
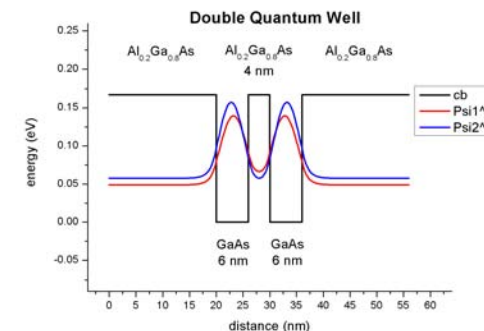
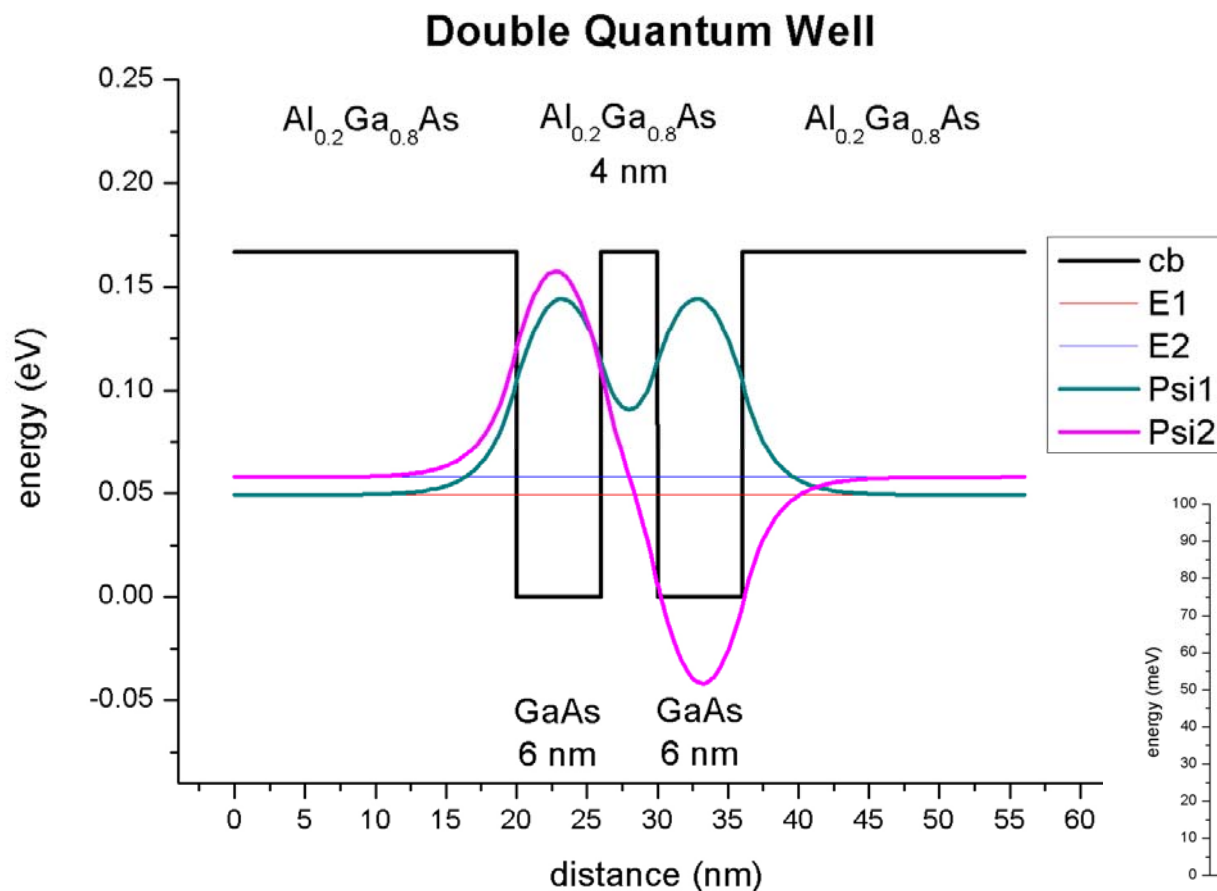
# BIO-nextnano<sup>3</sup> for Bio Chips



# Education: Triangular well



# Education: Double Quantum Well



# nextnano<sup>3</sup> features

- **Materials:** Si, Ge, Si<sub>x</sub>Ge<sub>1-x</sub>  
GaAs, AlAs, InAs, GaP, AlP, InP, GaSb, AlSb, InSb  
e.g. In<sub>x</sub>Ga<sub>1-x</sub>As, Al<sub>x</sub>Ga<sub>1-x</sub>As<sub>y</sub>P<sub>1-y</sub>, InGaAsN  
**Nitrides:** GaN, AlN, InN (zincblende & wurtzite)
- strain, piezo and pyroeffects, deformation potentials, 8x8 **k.p** theory, optics
- all crystallographic directions, e.g. [001], [311]
- Schrödinger-Poisson-Current solver in 1D, 2D & 3D
- magnetic field, superlattices
- BIO-nextnano<sup>3</sup> for bio chips (electrolyte)
- Device Editors (ICODE, Rome)

# Business model

- **Software including Fortran 90 source for free**
- **Online documentation is free**
- **Online Registration**
- **Support is not free (e.g. PayPal)**
- **Tutorial files (QCLs, MOSFETs) are not free**
- **Consulting + Workshops**
- **Programming of new features**

# NUSOD '05

- **Talks**

- Stefan Birner: T-shaped strained quantum wires  
Tu, 9:00
- Kwan Lee: InGaN quantum dots (Oxford)  
Tu, 9:50

- Software exhibition (Tu-Th)

- next**nano**<sup>3</sup> workshop on Friday, 13:30-17:00
  - QCSE (1D QW)
  - $E(\mathbf{k})$  dispersion in GaAs (bulk & strained)
  - Biaxial strain & deformation potentials
  - 3D QDs