GaN quantum dots as optical transducers for chemical sensors

DOTSENSE

- DOTSENSE -

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Germany

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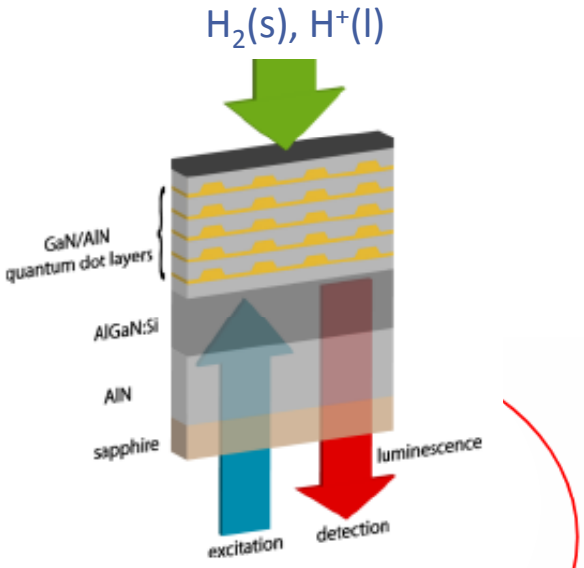
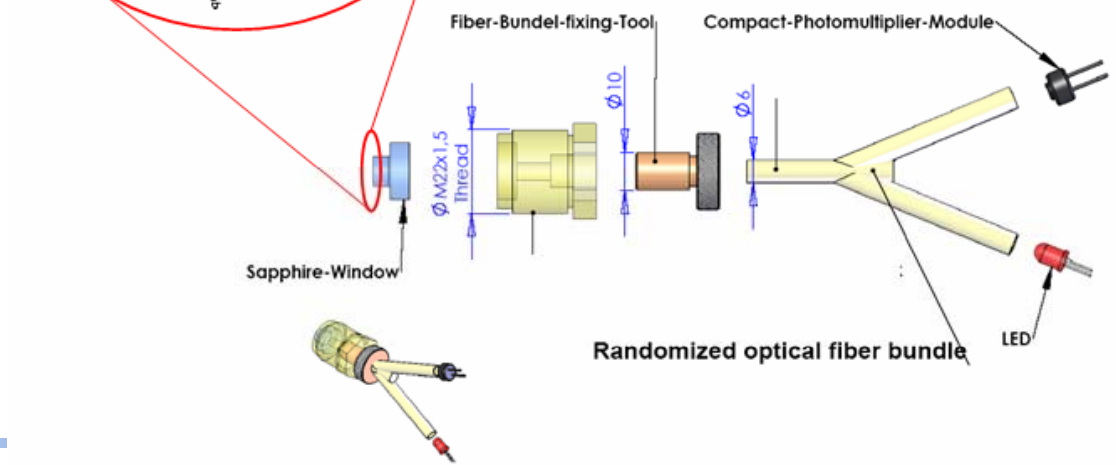
Objectives



Development of nano-optical transducers based on (In)GaN quantum dots for chemical sensors operating in liquid and gaseous environment

- Chemically resistive InGaN QD stack in AlN matrix
- Efficient photoluminescence ad room temperature and above
- Reduction of necessary electrical feedthroughs
- Built-in separation of media

- **Detection of pH and hydrogen in aerospace applications**



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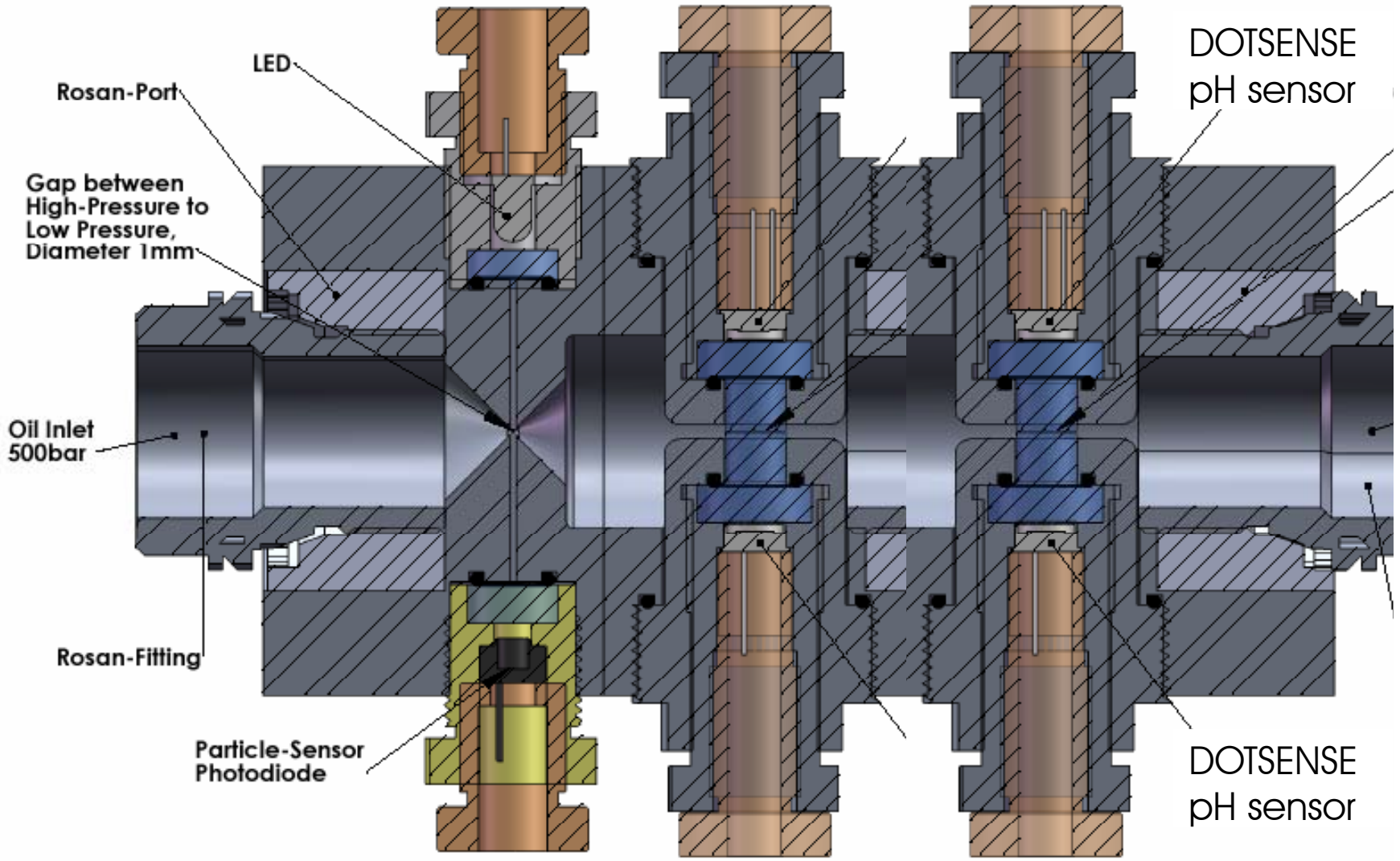

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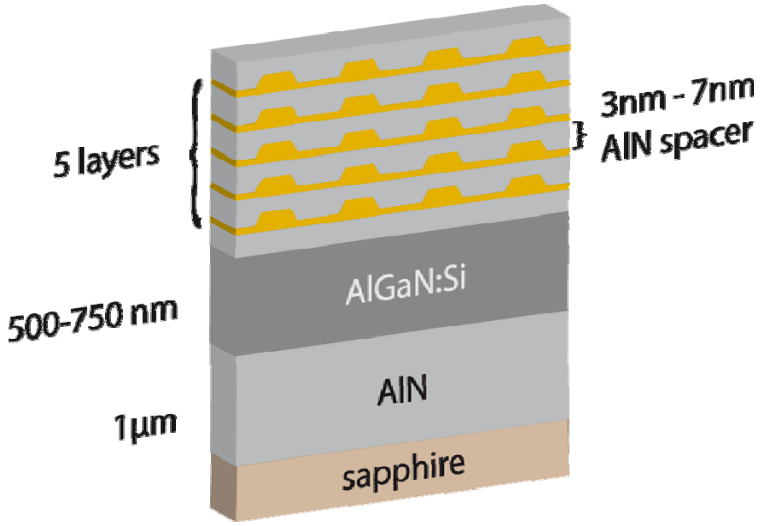
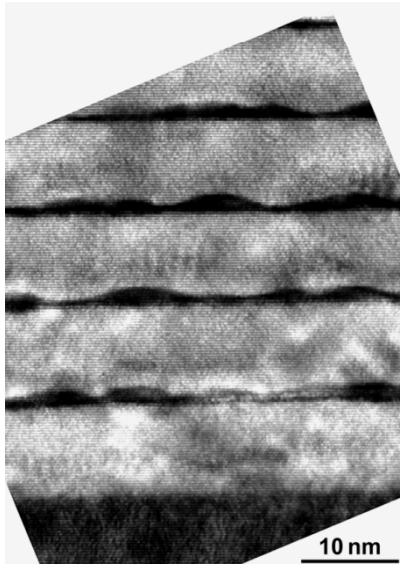
Scientific objectives

Sensing mechanism:
Detection of chemically induced variations of the surface potential by detection of changes in photoluminescence characteristics





HRTEM image of the GaN/AlN QD stack

- growth by plasma assisted MBE on AlN buffer
- growth temperature 730°C-750 °C
- conductive $Al_xGa_{1-x}N$:Si -layer (back contact)
- compressive stress induces Stranski-Krastanov growth of QDs

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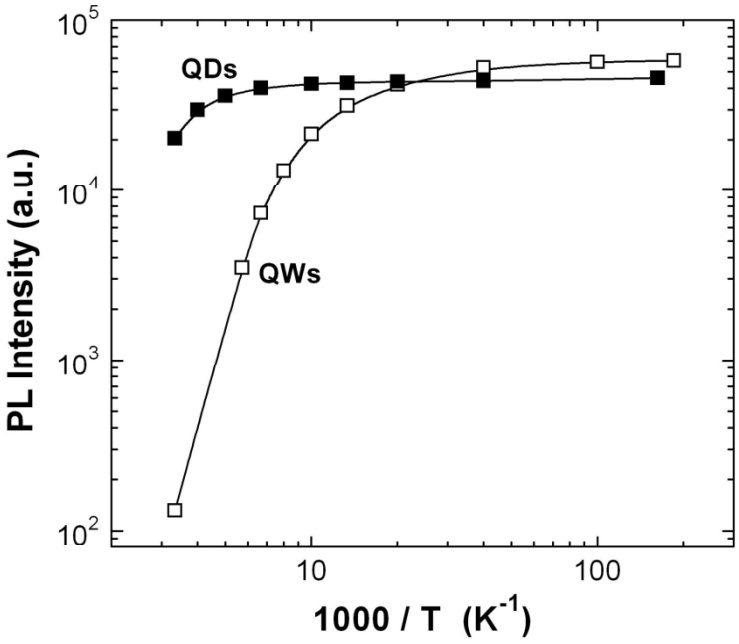
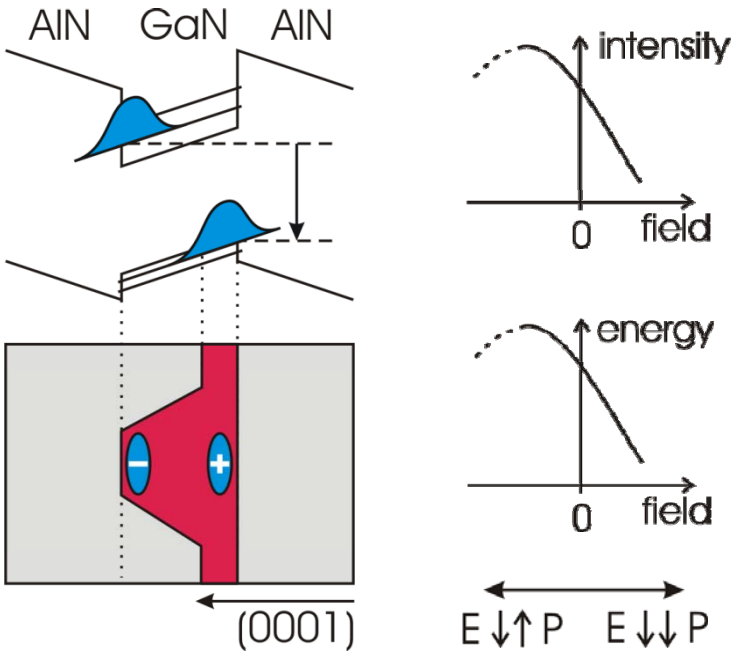
Scientific background and objectives



Efficient photoluminescence of QD ensembles at room temperature and above



External electric field interferes with strong polarization fields in GaN QDs

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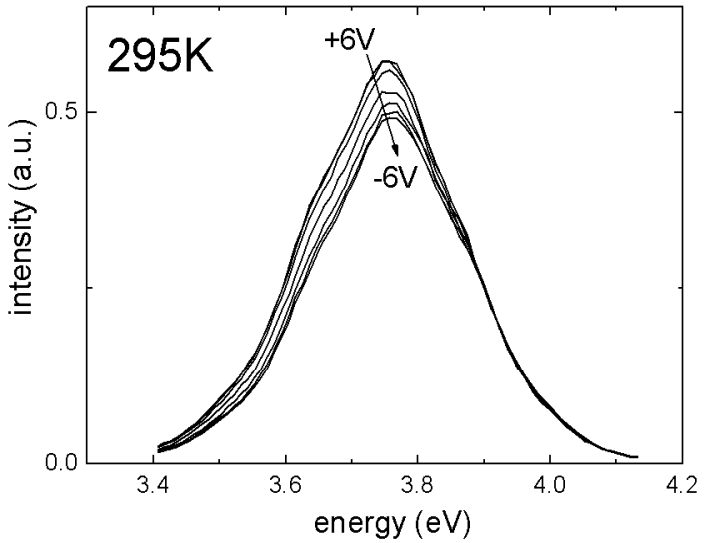
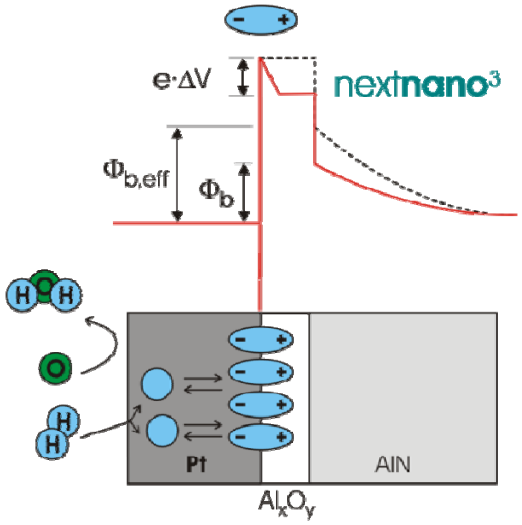
Scientific background and objectives

Application of external electric field

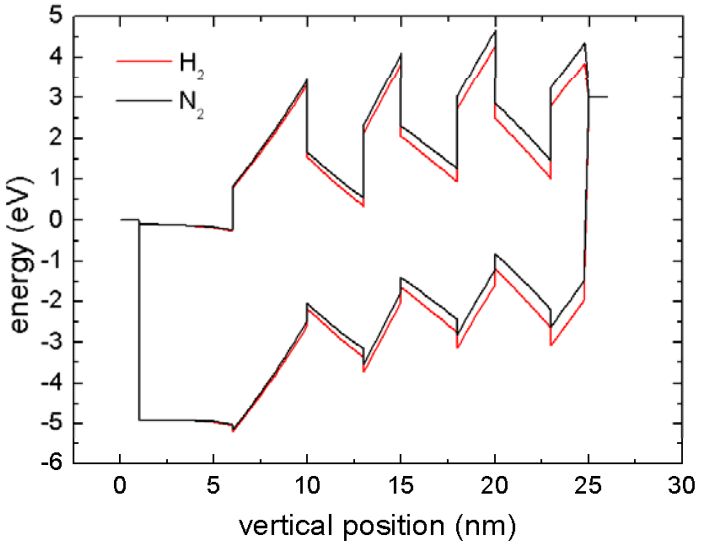


Quenching and blue-shift of PL signal upon increase of external electric field
→ Influence of photocurrent



Hydrogen adsorption

- dipole layer leads to reduced barrier height and reduced electric field
- shift of transition energies (red) and change of intensity (increase)



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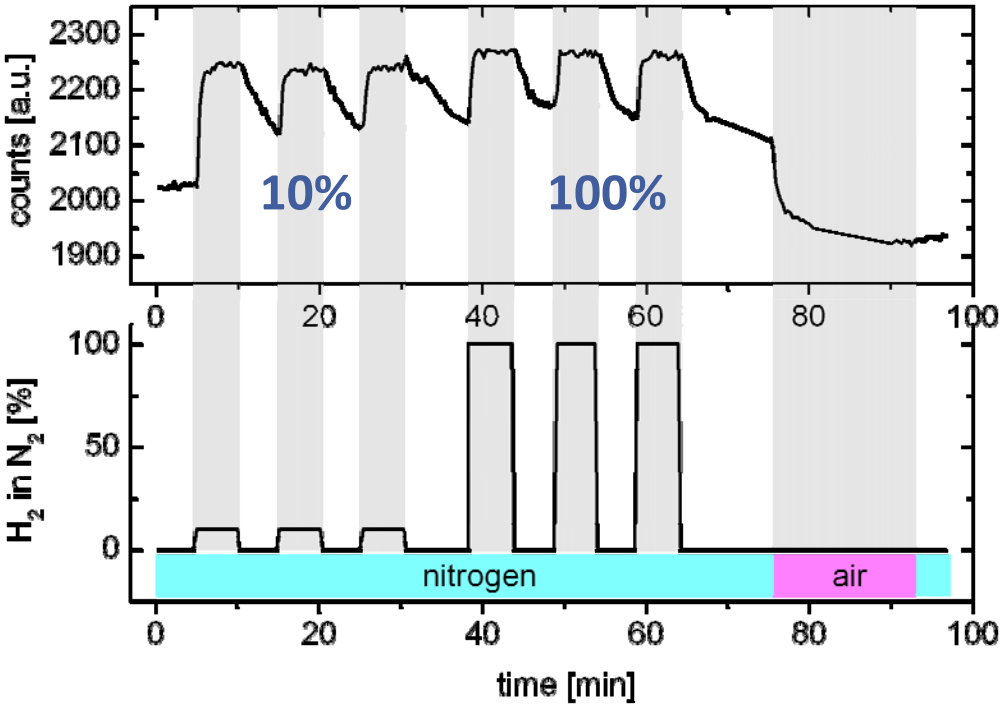
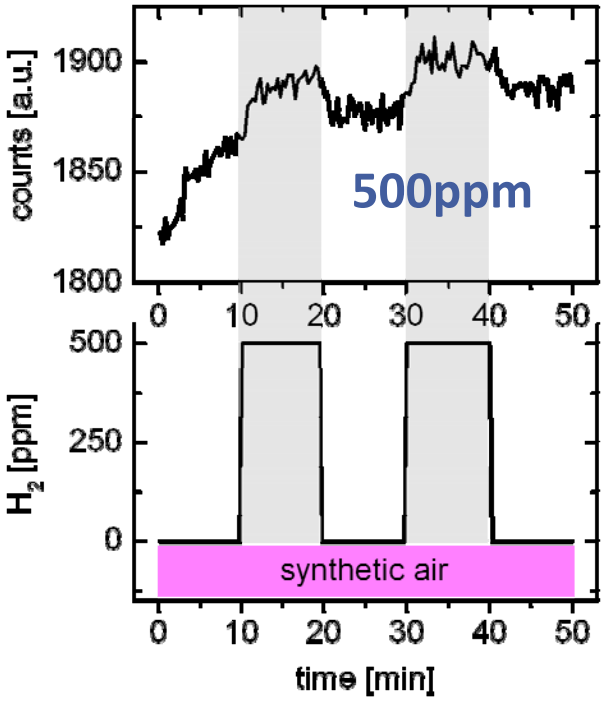
Scientific background – detection of hydrogen

PL intensity at fixed wavelength





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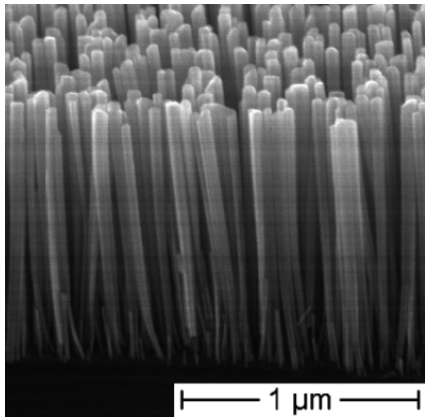
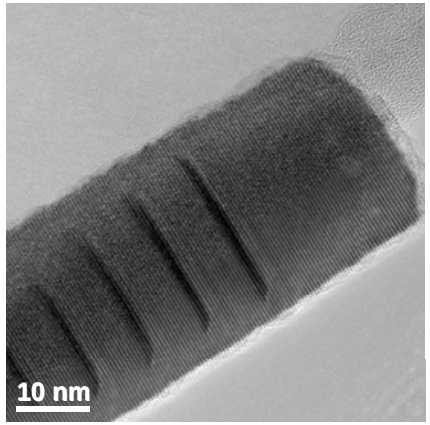
Scientific background – alternative approach

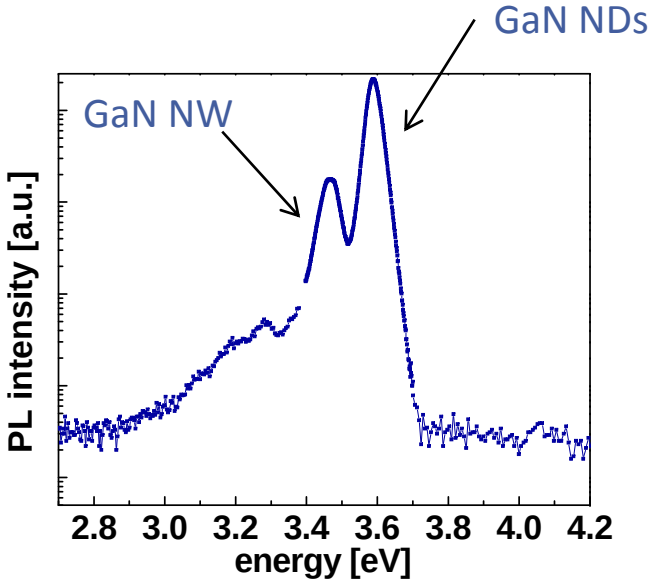
Self assembled growth of InGaN nanodiscs (NDs) inserted into GaN nanowires (NWs)



GaN NWs on Si(111)



TEM image of GaN NDs between AlN barriers*



PL spectrum of ND superlattice at 4K

- more homogeneous height distribution compared to QDs
- narrow PL emission
- lateral impact of adsorbed molecules

**TEM analysis by J. Arbiol, J.-R. Morante, University of Barcelona*

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Scientific objectives

- Growth and characterization of InGaN QDs and nanodiscs on polar surfaces and on surfaces with reduced polarization fields
- Investigation of photoluminescence evolution in external electric fields
- Microscopic understanding of quenching mechanism and light-induced charge transport in QD stack
- Optimization of QD superlattice to achieve maximum sensitivity (In-content, QD-size, spacer thickness..)
- Integration of QD optochemical transducers with commercially available light emitters and detectors
- Demonstration of operation of DOTSENSE devices

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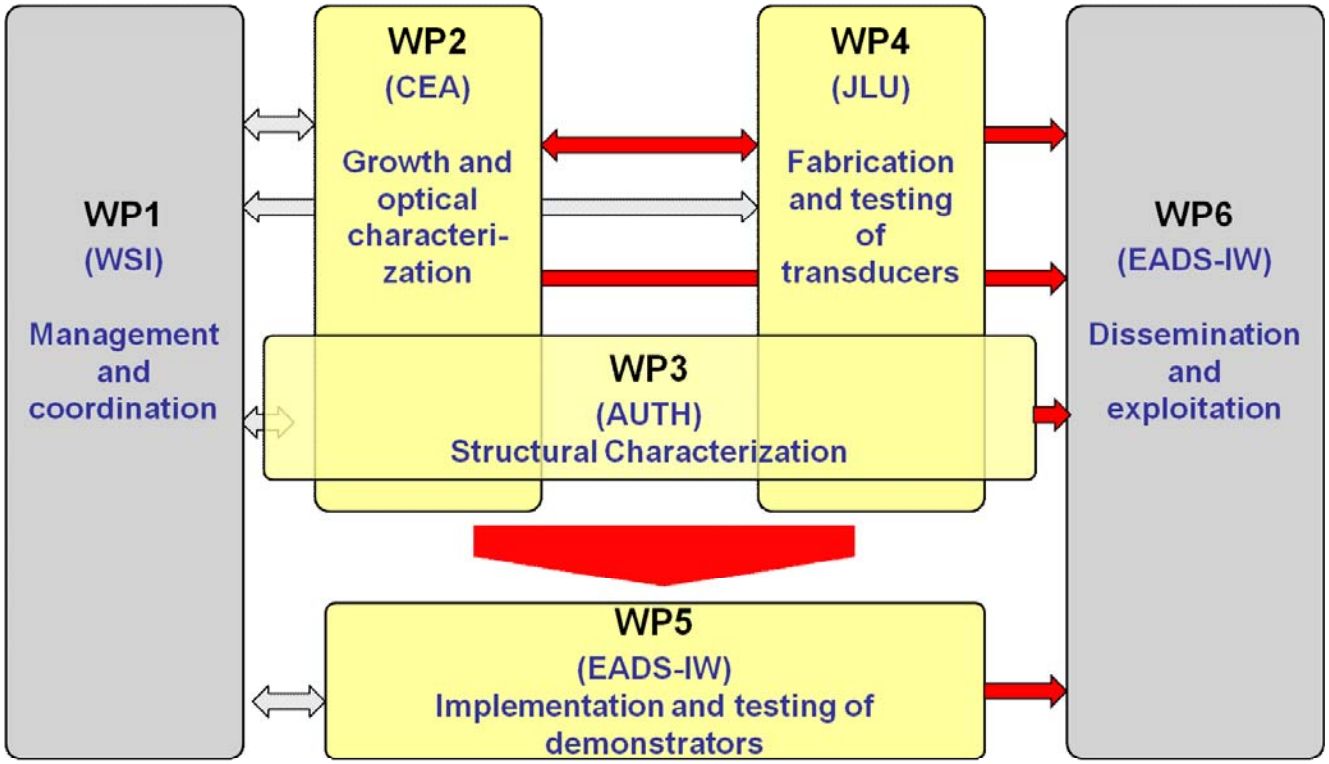
Organization of Work Packages and Consortium



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Organization of Work Packages and Consortium

Walter Schottky Institut, Technische Universität München, Germany (Coordinator) (WSI)
(Prof. M. Stutzmann, F. Furtmayr)
- Project coordination
- Processing and characterization of DOTSENSE transducers
- Growth and characterization of InGaN nanodiscs inserted in GaN NWs

Electron Microscopy Lab, Dep. of Physics, Aristotle University of Thessaloniki, Greece (AUTH)
(Prof. Philomela Komninou)
- Structural analysis of QDs and NDs by transmission electron microscopy
- Modelling of atomic structure, energy of defects and interfaces based on experimental results
- Quantitative comparison

Laboratory for Nanophysics and Semiconductors, CEA, Grenoble, France (CEA) (Dr. E. Monroy)
-Growth and characterization of InGaN QDs on polar surfaces and surfaces with reduced electric fields
-Structural characterization of QDs

EADS Innovation Works, Dept. Sensors, Electronics & Systems Integration, Ottobrunn, Germany (EADS-IW)
(Dr. A. Friedberger, Dr. A. Helwig)
- Specification of DOTSENSE devices for target application
- Planning, realization and testing of demonstrators
- Exploitation

I. Physikalisches Institut, Justus-Liebig-Universitöt Gießen, Germany (JLU) (Prof. M. Eickhoff, Dr. J. Teubert)
- Luminescence characterization of InGaN QDs and NDs
- Processing and characterization of DOTSENSE transducers
- Investigation of PL properties in electric fields