Wrocław University of Technology

Temperature dependent emission linewidth and the exciton dephasing in large and asymmetric III-V semiconductor quantum nanostructures

A. Musiał, G. Sęk, A. Maryński, M. Kozub, J. Misiewicz

Institute of Physics, Wrocław University of Technology, Poland

Laboratory for Optical Spectroscopy of Nanostructures

A. Löffler, S. Hein, A. Somers, S. Höfling, S. Reitzenstein*, J. P. Reithmaier**, M. Kamp, A. Forchel

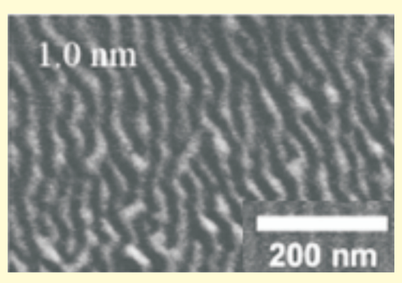
Technische Physik, Universität Würzburg & Wilhelm Conrad Röntgen-Center for Complex Material Systems

* Institute for Solid State Physics, Technische Universität Berlin

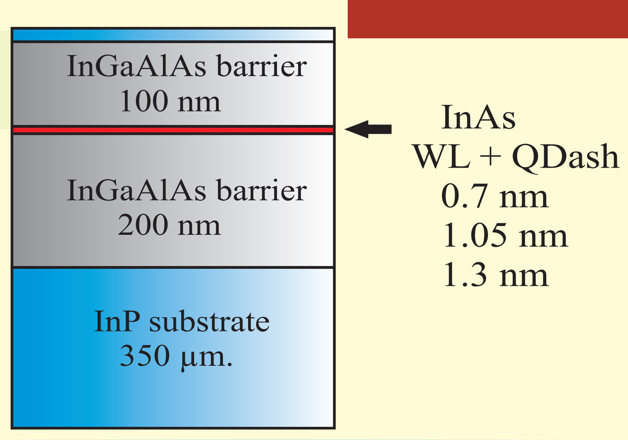
** Institue of Nanostructures Technology and Analytics, University of Kassel

INVESTIGATED STRUCTURES

InAs/InGaAlAs/InP

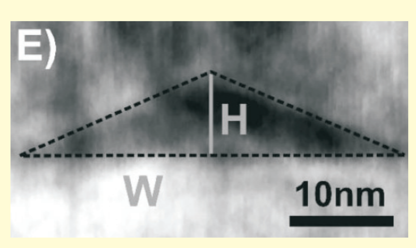


SEM image of the sample surface



Layer arrangement of InAs/InGaAlAs/InP samples

- InAs nanostructures elongated in [1-10] direction grown by MBE on (001) InP substrate (3.4% lattice mismatch) - quantum dashes
- Typical geometry
  - triangular cross-section with constant H/W
  - width = (12 - 20) nm
  - height = (2 - 3.5) nm
  - length: 100 - few hundreds nm
  - lateral aspect ratio: above 5

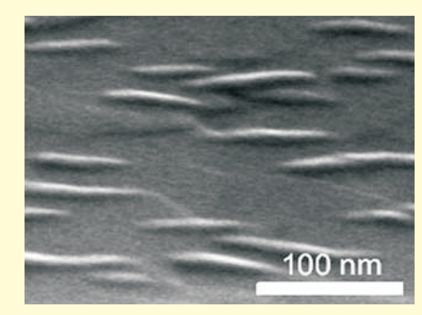


Cross-sectional TEM image A. Sauerwald et. al., *Appl. Phys. Lett.* **86**, 253112 (2005)

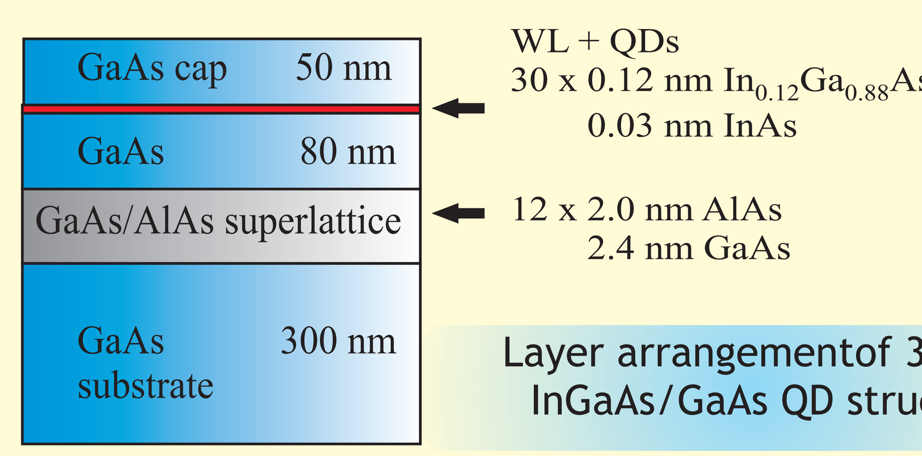
- Surface density: > 10^{11} cm^{-2}
- Intermediate confinement regime
  - exciton coherence volume >> nanostructure volume
  - energy level separation = exciton binding energy
- Additional carrier trapping on potential fluctuations within individual QDash structure (e.g., width fluctuations)

$In_{0.3}Ga_{0.7}As/GaAs$

- Low strain (2% lattice mismatch) InGaAs quantum dots elongated in [1-10] direction grown by MBE on GaAs substrate
- Typical geometry
  - Length: 50 - 100 nm
  - Height: 3 - 5 nm
  - Width: 20 - 30 nm
  - Lateral aspect ratio: 2 - 5
- Surface density: 5 x 10^9 cm^{-2}
- Shallow confining potential
- Weak confinement regime
  - biexciton binding energy
  - E_{XX} = (1 - 3) meV
  - X to XX lifetime ratio 0.5



SEM image of the sample surface



Layer arrangementof 30 % In InGaAs/GaAs QD structure

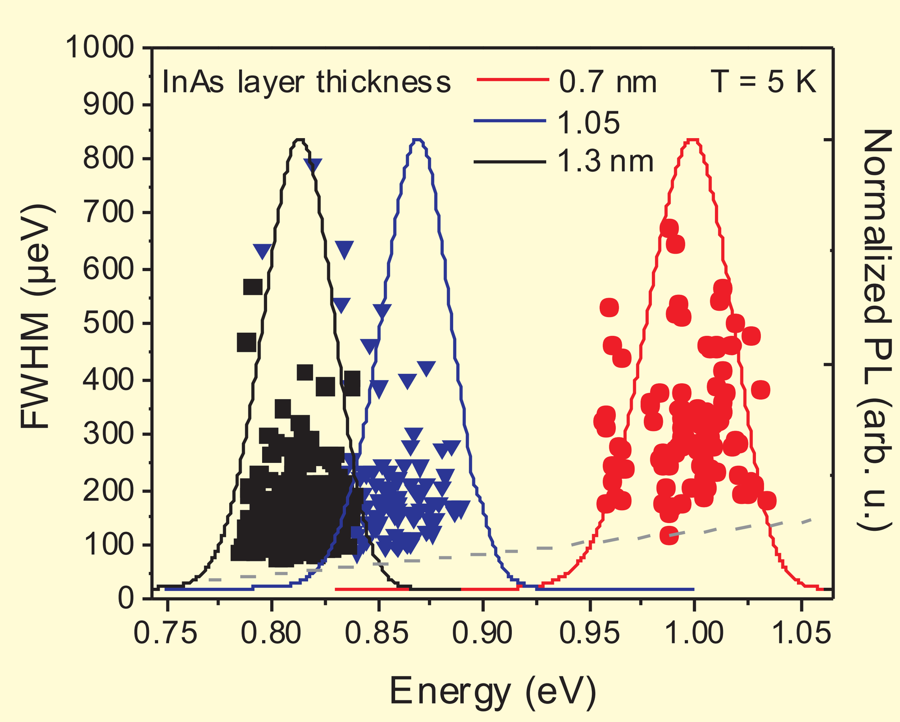
MOTIVATION

- Interaction with the environment reduces the coherence of the carrier excitations in epitaxial nanoobjects embedded in the solid state matrix
- Reduced decoherence effects expected for large nanostructures
- Fundamental study: identification of exciton dephasing mechanisms for anisotropic epitaxial nanostructures with different lateral aspect ratio (LAR)
- Applications: single photon sources and microlasers at 950 nm and 1.55 μm (2nd telecom window)

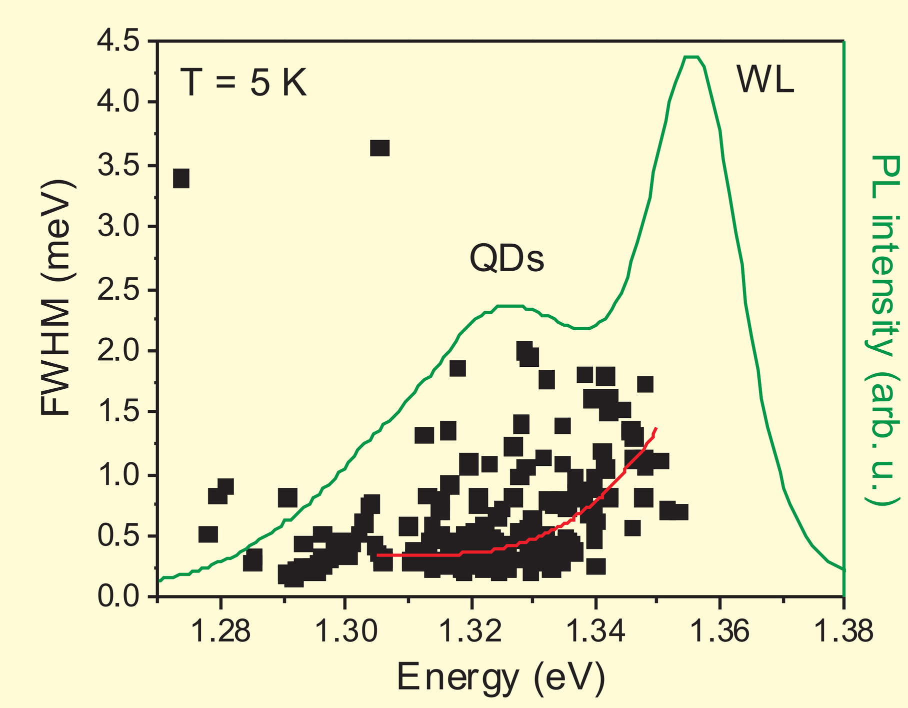
MICROPHOTOLUMINESCENCE RESULTS

Low-temperature (5 K) full width at half maximum (FWHM) of single emission lines

- FWHM = (50 - 200) μeV
- spectral diffusion-limited linewidth
- no phonon-related features

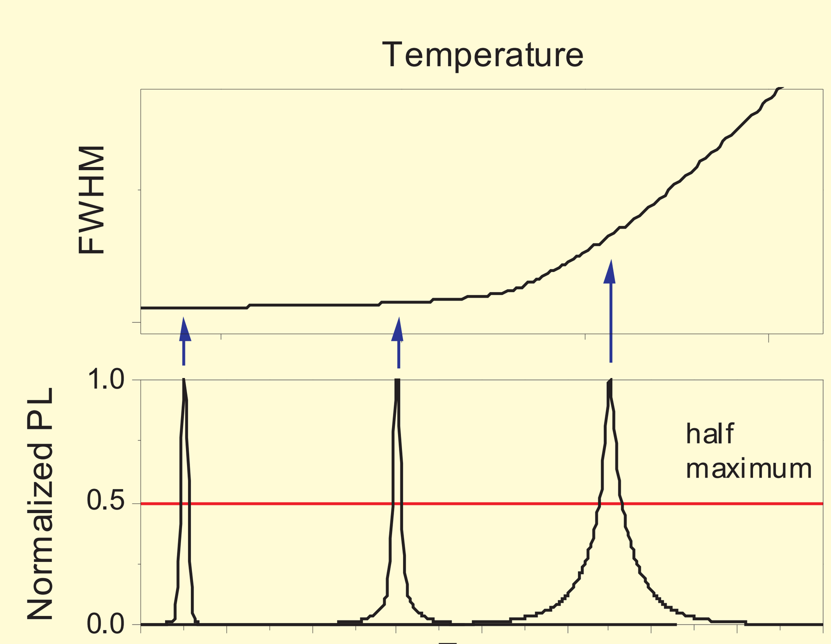


- FWHM = (200 - 500) μeV
- spectral diffusion limited linewidth -
  - fluctuating charge environment
  - a) WL states of localized character
  - b) carriers trapped on mesa sidewalls
- no phonon-related features



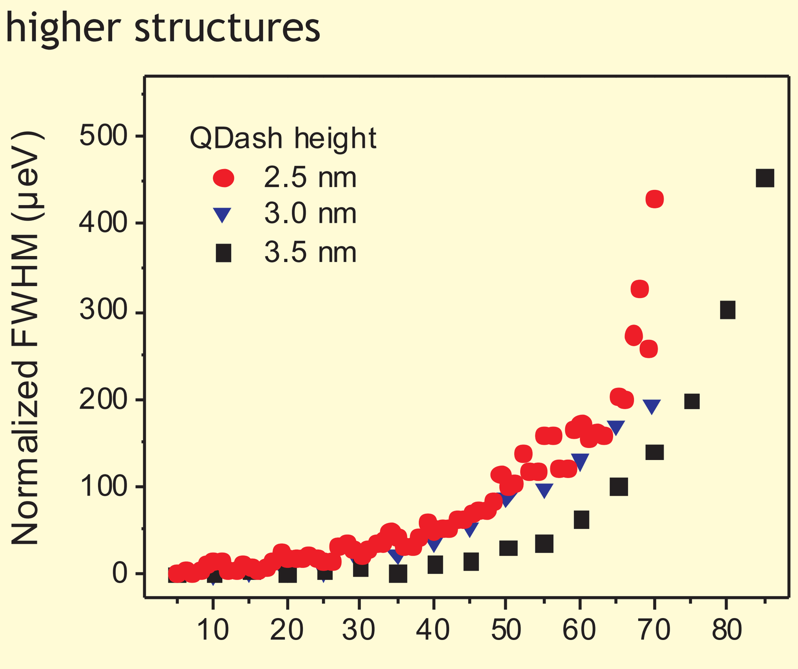
Temperature dependence of FWHM

- slow increase followed by more abrupt increase
- increased phonon-induced decoherence (acoustic phonons)
- increased contribution of phonon sidebands to the overall emission



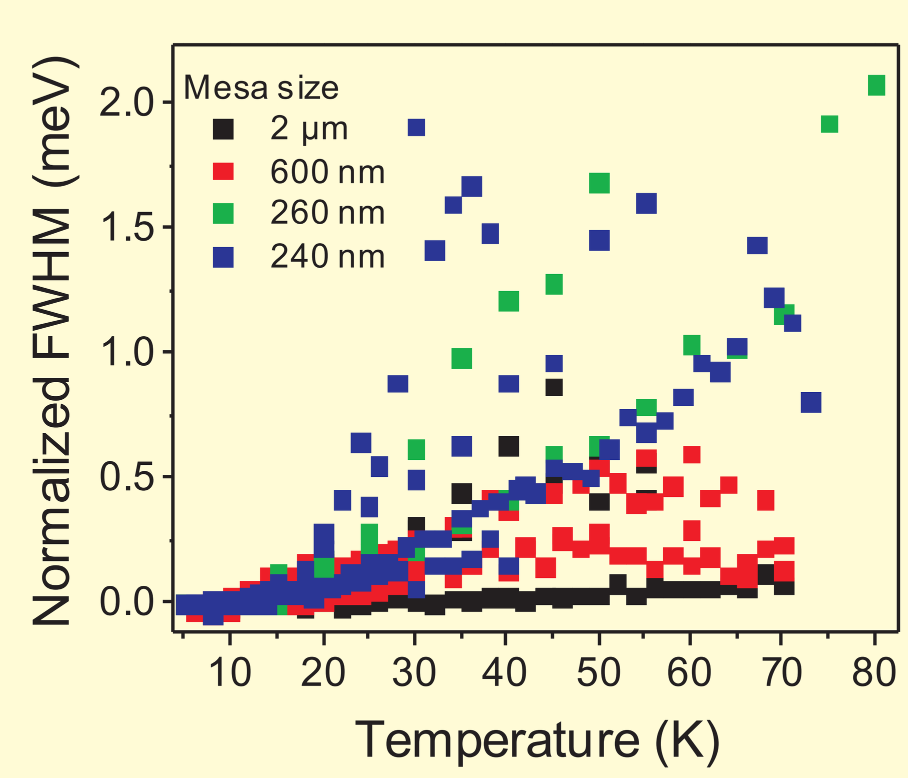
Influence of QDash height

- lower sensitivity of FWHM to temperature changes for higher structures



Spectral diffusion effects

- smaller mesa size = stronger spectral diffusion
- larger low-temperature FWHM value
- faster FWHM increase with temperature



CONCLUSIONS

- spectral diffusion-limited linewidth of single emission lines
- no phonon related features at low temperatures
- phonon-induced decoherence important at elevated temperatures
- smaller FWHM for InAs/InP QDashes
  - deeper confining potential
  - interaction with localized WL states in the case of InGaAs/GaAs Qds
- similar temperature behaviour due to similar exciton probability density distribution

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