# Surface concentration mapping of InAs/GaAs quantum dots

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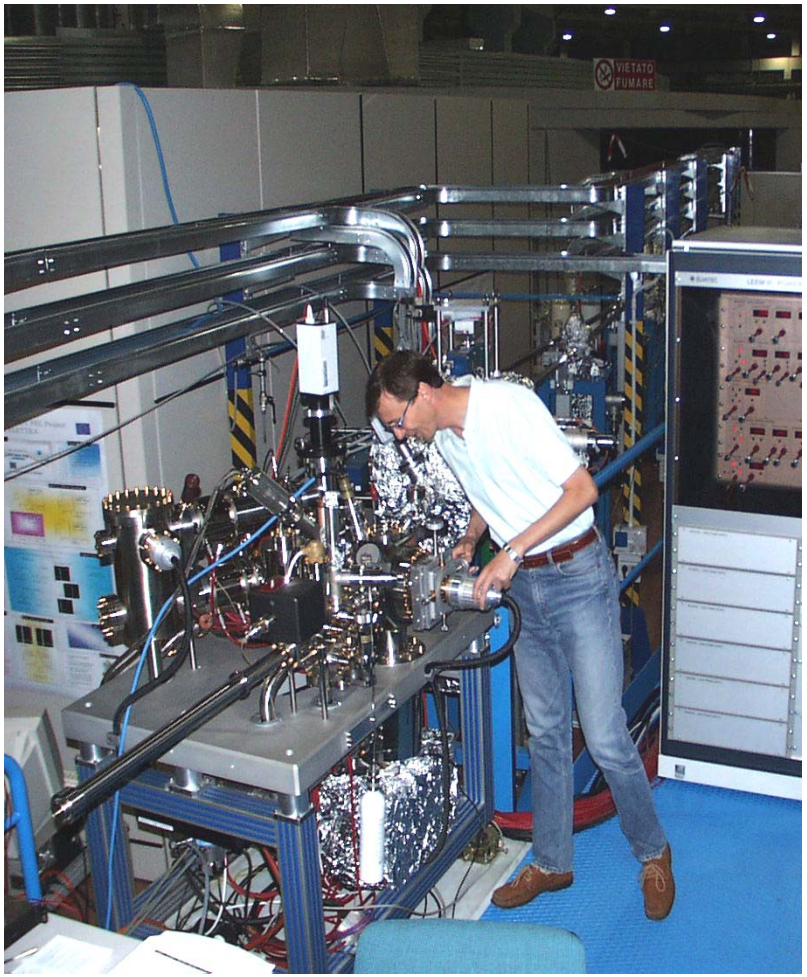
# Motivation

- Quantum Dot Applications based on their particular electronic properties (confinement)
- Strain-driven self-assembly (SK-growth)
- Model systems: InAs/GaAs, Ge/Si
- Intermixing and alloying allow for partial strain relaxation
- Composition (gradients) within the dot influence energy levels and shift the emission wavelength

# The SPELEEM at ELETTRA

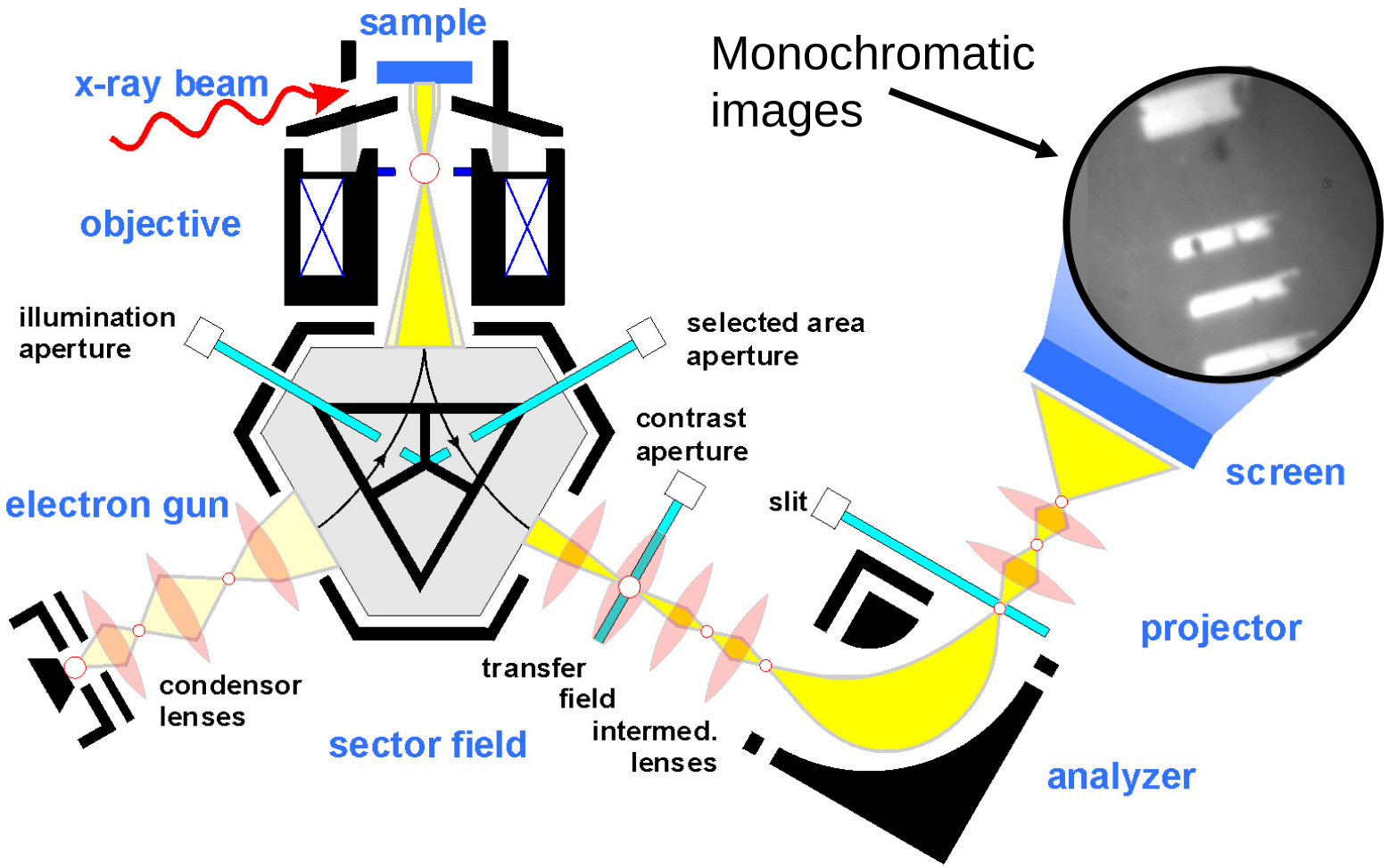



- Best energy resolution: 250 meV
- Best lateral resolution: 25 nm

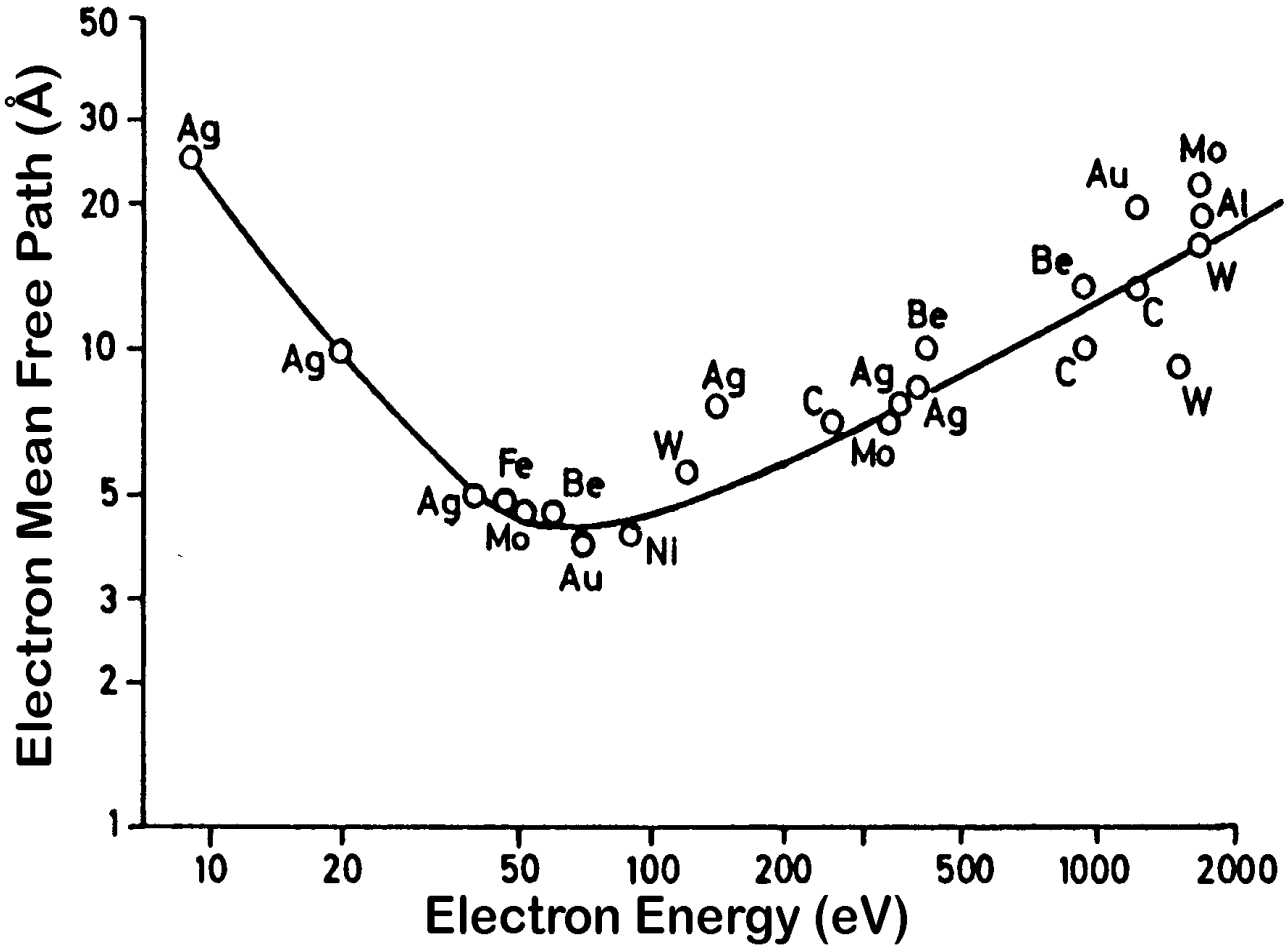
- Variable polarization
- 20 - 1000 eV
- Photon flux $10^{13}$ ph/s
- Small spot (2μm x 25μm)

# The SPELEEM instrument

Spectroscopic Photo-Emission and Low Energy Electron Microscope

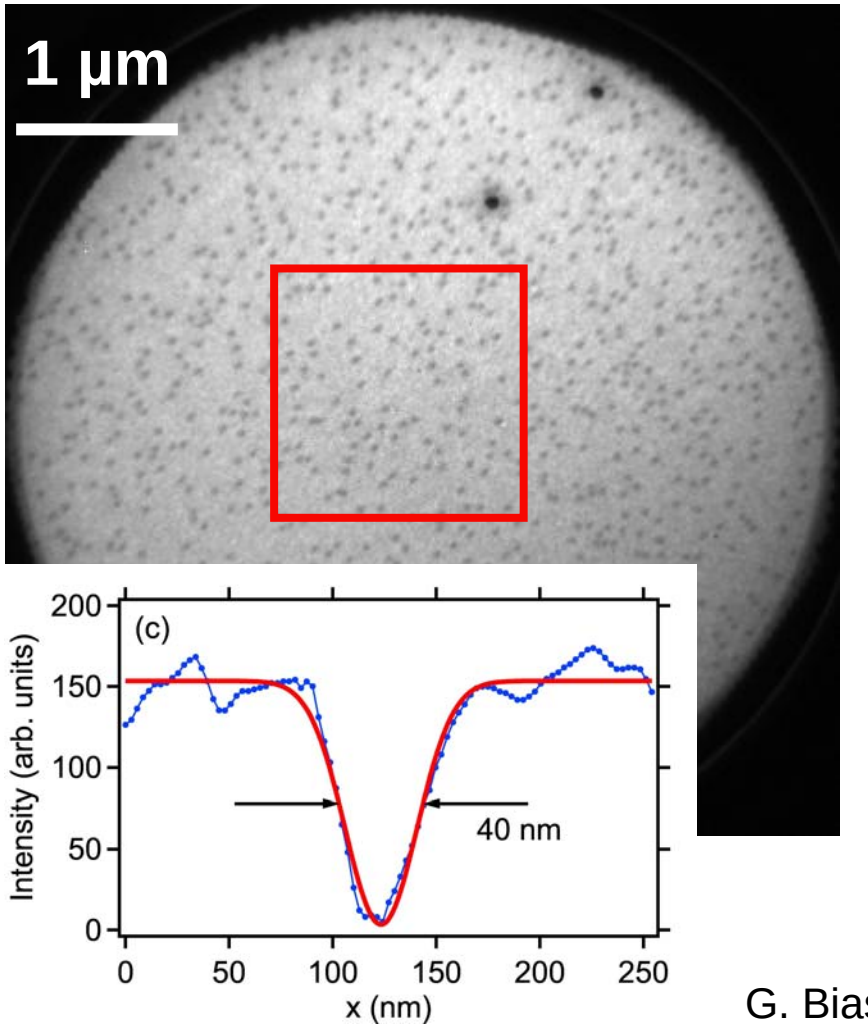


# Photoelectron Mean Free Path

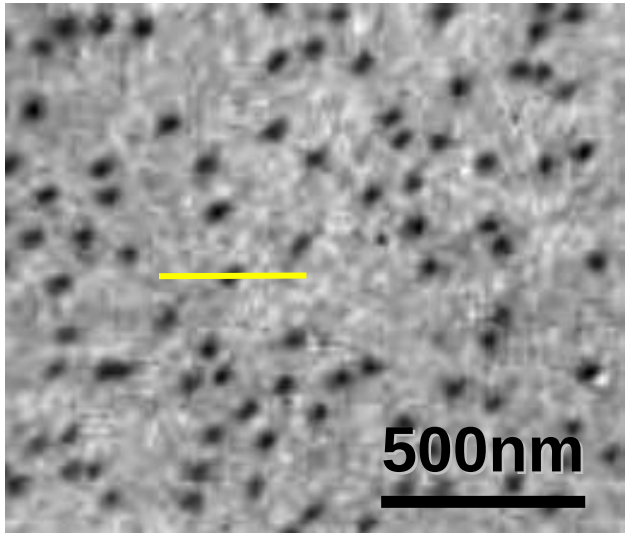



M. P. Seah and W. A. Dench: Surf. Interface Anal. **1** (1979) 2.

# InAs/GaAs Islands (LEEM)

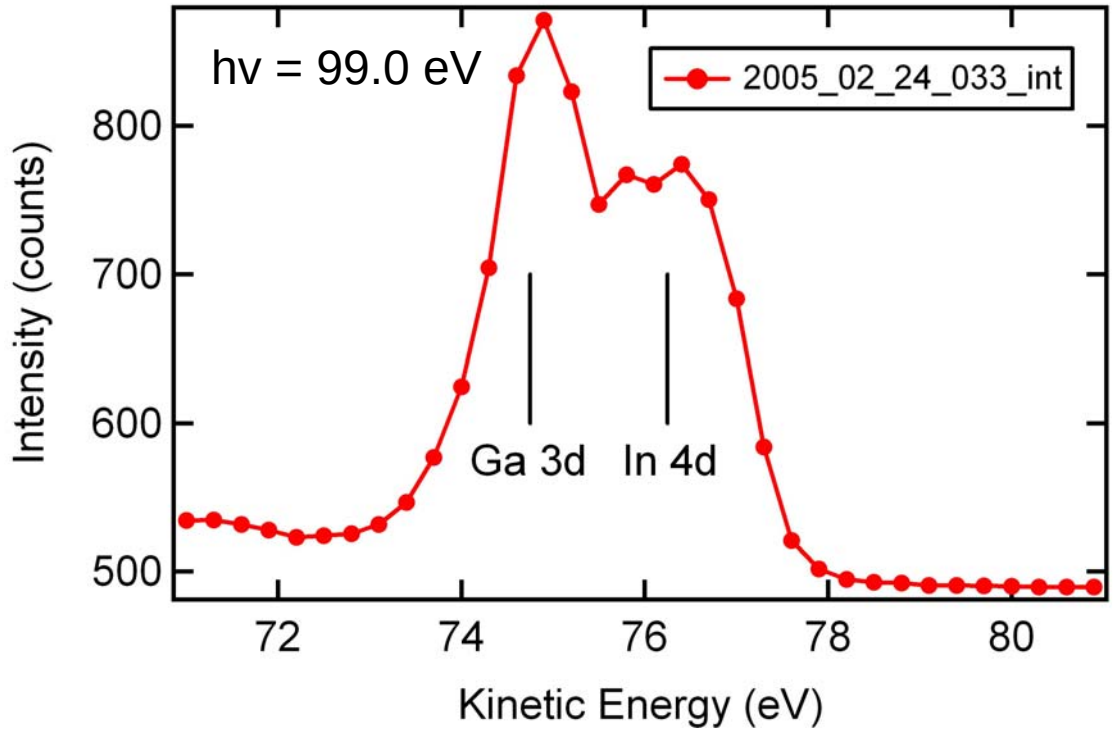



- Electron Microscopy
- LEEM
- 5 µm FOV
- $E_{kin}$ = 7.6 eV




G. Biasiol et al.: Appl. Phys. Lett. **87** (2005) 223106.

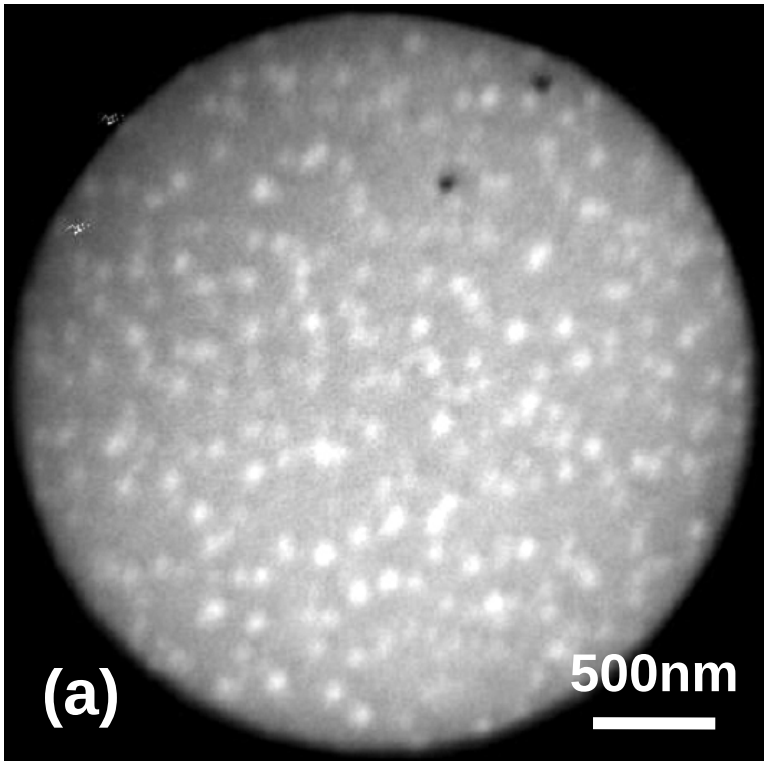
# “Integral” Core Level Spectra

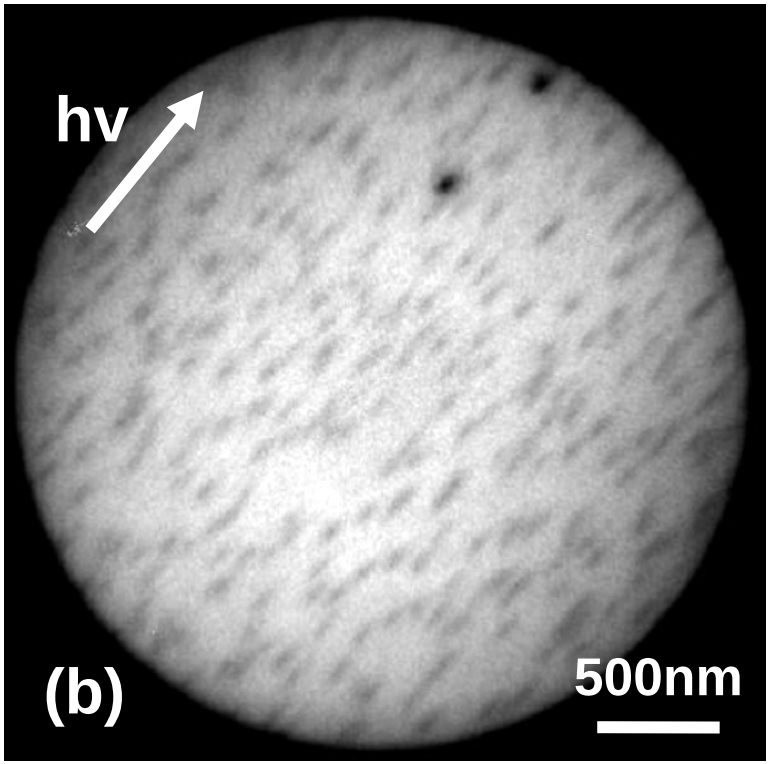



- Spectra taken from a 1 µm x 1 µm sample area.
- III-V stoichiometry after decapping confirmed.

G. Biasiol et al.: Appl. Phys. Lett. **87** (2005) 223106.

# XPEEM Core Level Imaging




In 4d XPEEM image

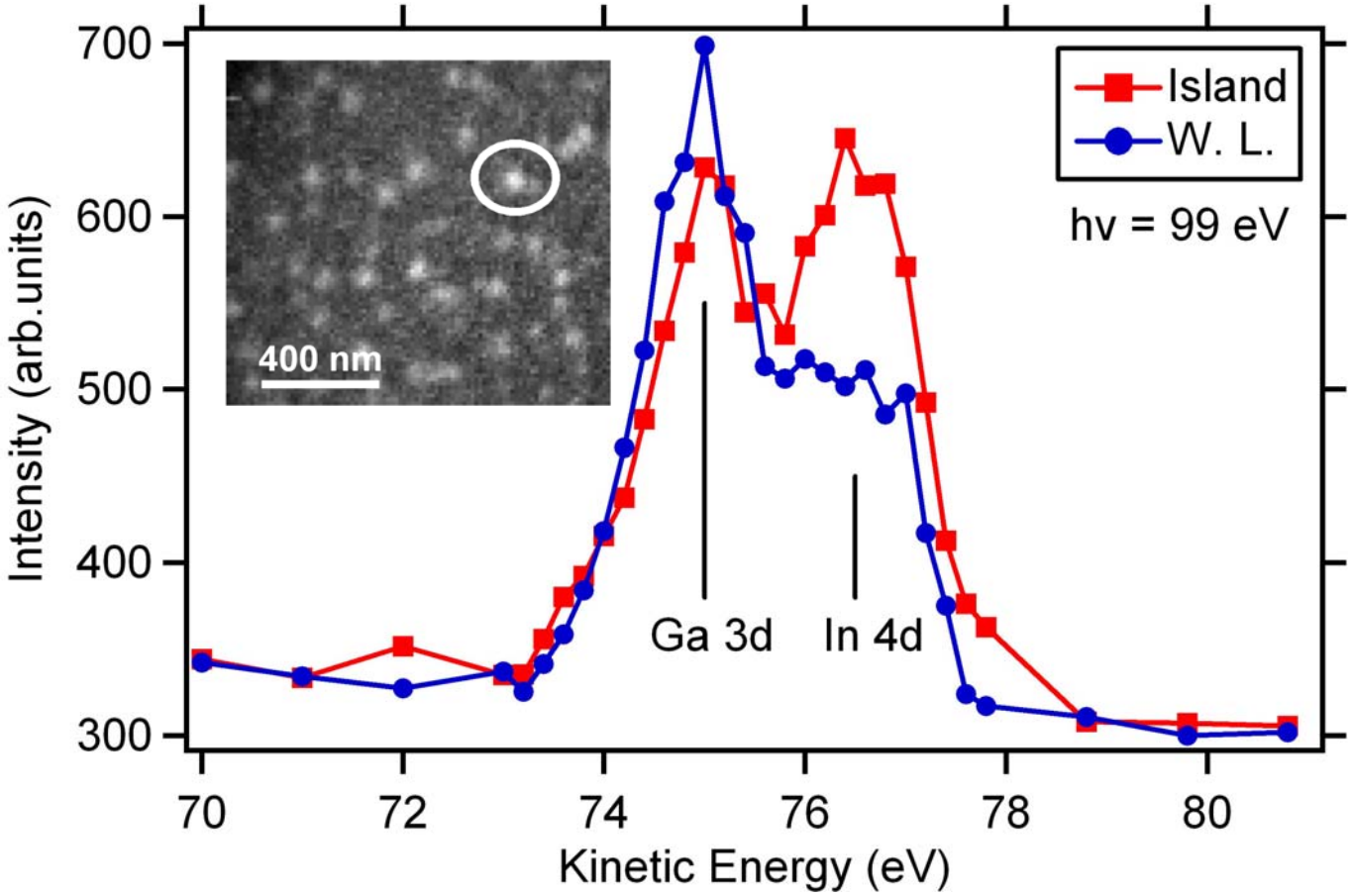
hv = 99.0 eV, $E_{kin}$ = 76.25 eV

Ga 3d XPEEM image

hv = 99.0 eV, $E_{kin}$ = 74.75 eV

G. Biasiol et al.: Appl. Phys. Lett. **87** (2005) 223106.

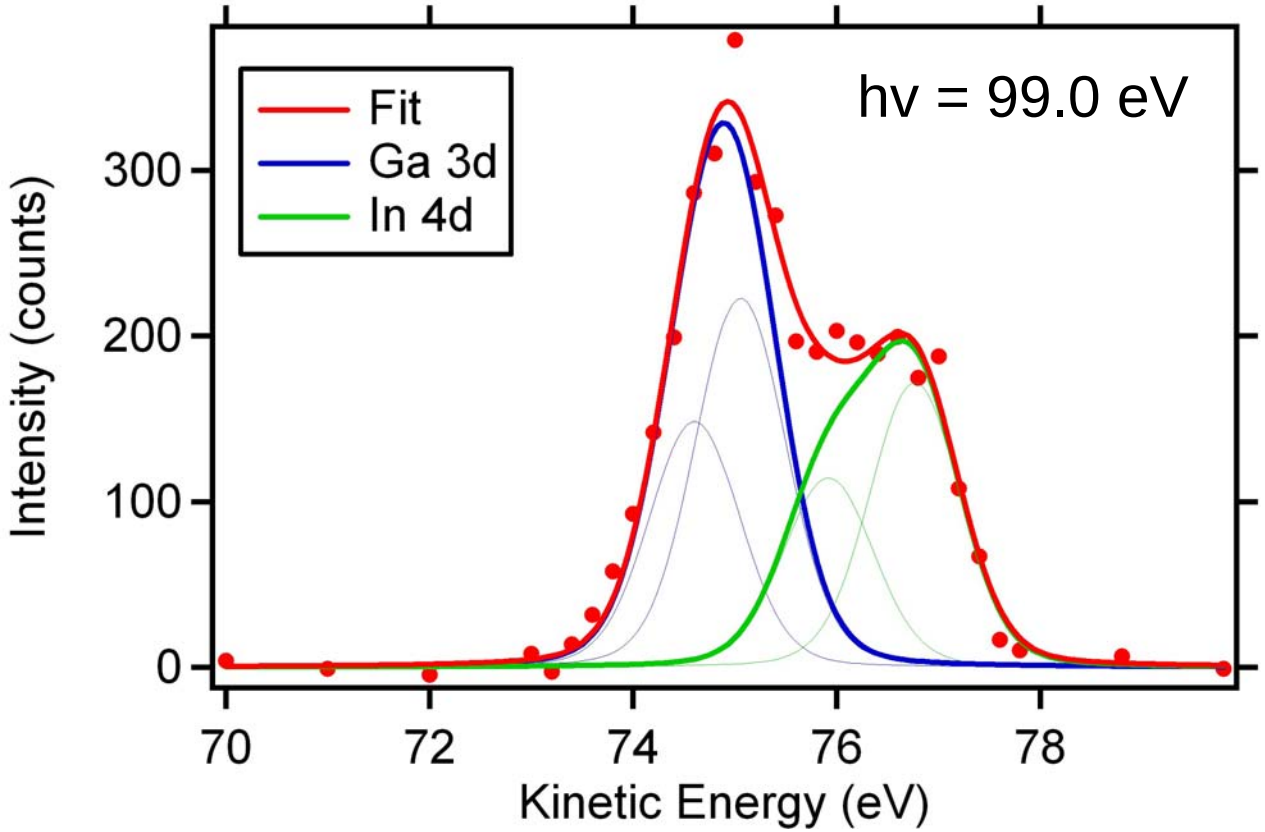
# XPEEM Local Spectra




Integration area 25 nm x 25 nm, energy resolution ≈ 1 eV

G. Biasiol et al.: Appl. Phys. Lett. **87** (2005) 223106.

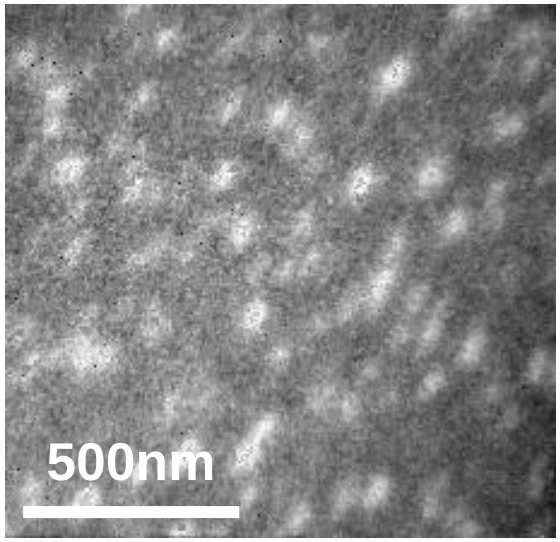
# Core Level Line Profile Analysis



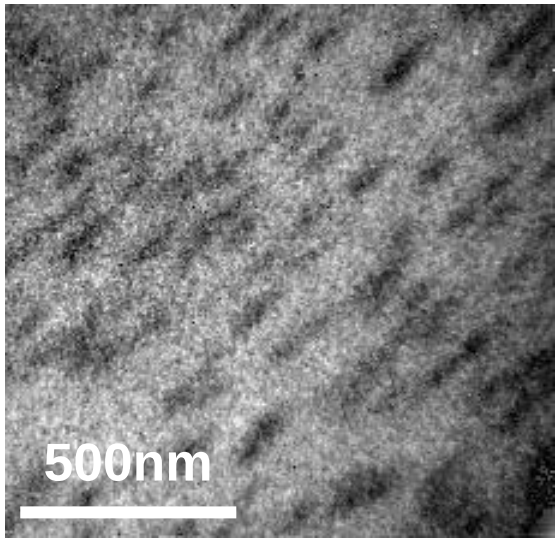

Spectrum from Wetting Layer, Shirley Background subtracted
Gauss 1 eV, Lor 0.16 eV, BR 1.5, SO: Ga 3d 0.45 eV, In 4d 0.85 eV

G. Biasiol et al.: Appl. Phys. Lett. **87** (2005) 223106.

# 2D Fit of XPEEM Data




In 4d peak area
Min: 220, Max: 520




Ga 3d peak area
Min: 270, Max: 470

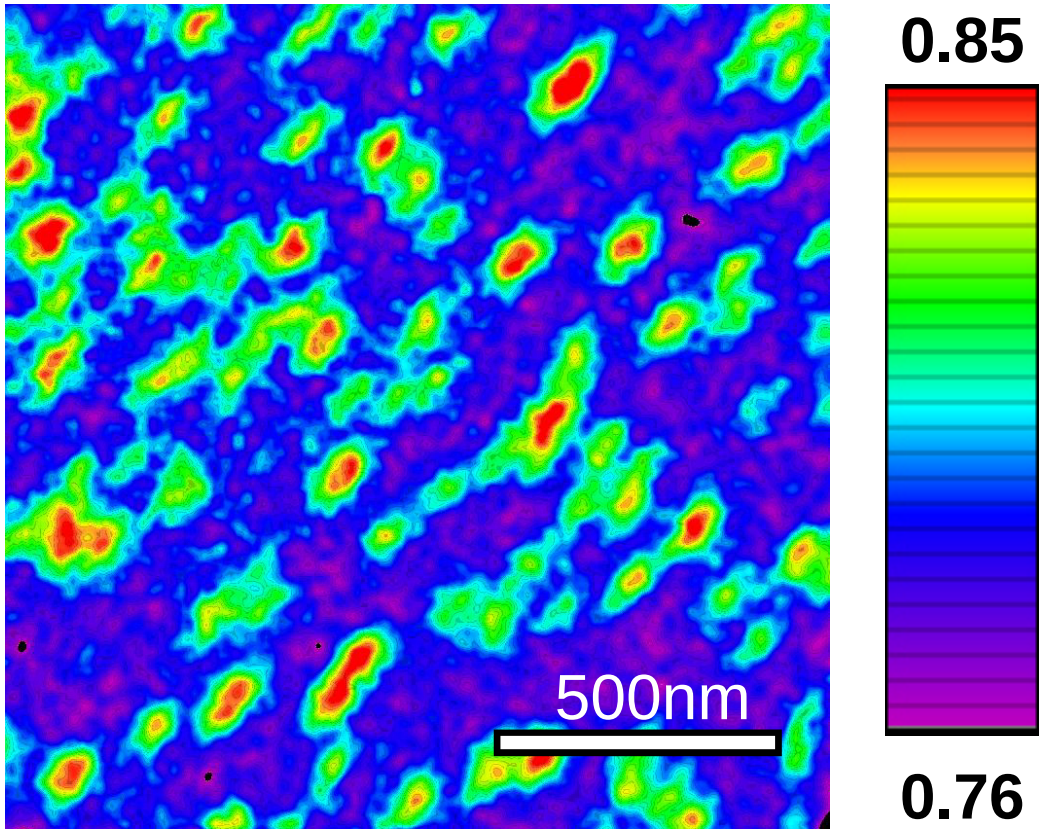
Ratio of Number of Atoms:

$$\frac{n_{In}}{n_{Ga}} = \frac{I_{In}}{I_{Ga}} \cdot \frac{\sigma_{Ga}}{\sigma_{In}}$$

G. Biasiol et al.: Appl. Phys. Lett. **87** (2005) 223106.

# Indium Surface Concentration Map

$$\frac{n_{In}}{n_{tot}} = \frac{I_{In}\sigma_{Ga}}{I_{In}\sigma_{Ga} + I_{Ga}\sigma_{In}}$$



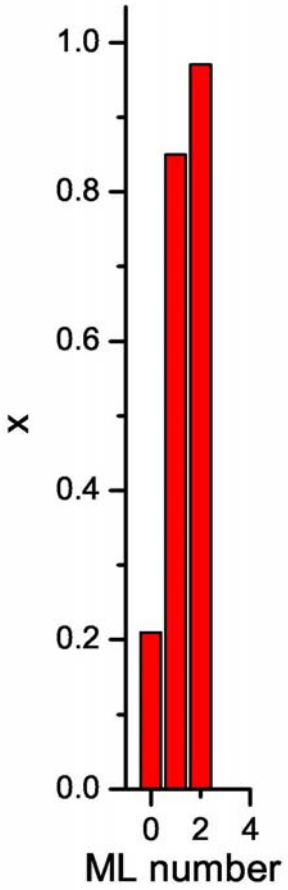

G. Biasiol et al.: Appl. Phys. Lett. **87** (2005) 223106.

# Wetting Layer Composition

- Segregation models predict the following ln concentration profile:
- Measured composition is average across topmost layers:

$$< x >= \sum x_i e^{-\frac{d_i}{\lambda}} \Big/ \sum e^{-\frac{d_i}{\lambda}}$$

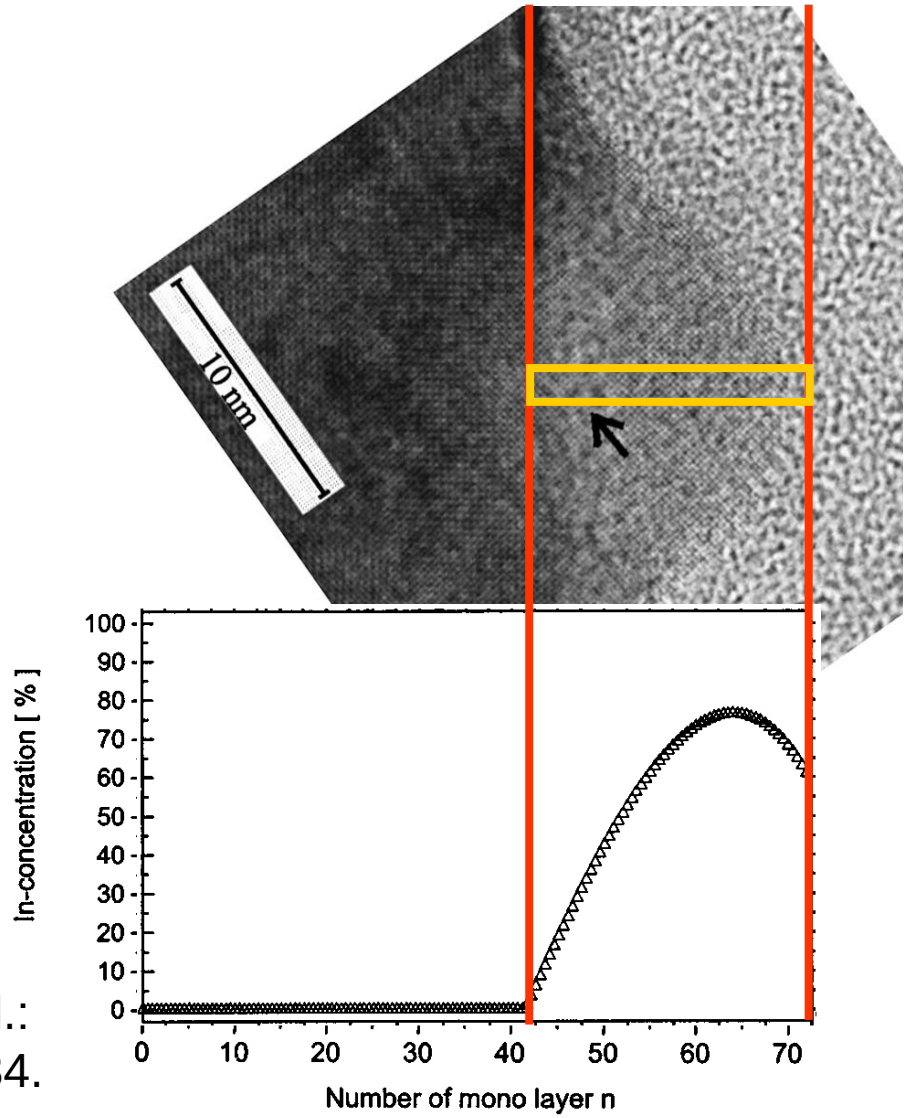
- Shown profile would be measured as x ~ 0.75, in agreement with our data.




O. Dehaese et al.:
Appl. Phys. Lett. **66** (1995) 52.

# Dot Composition from TEM

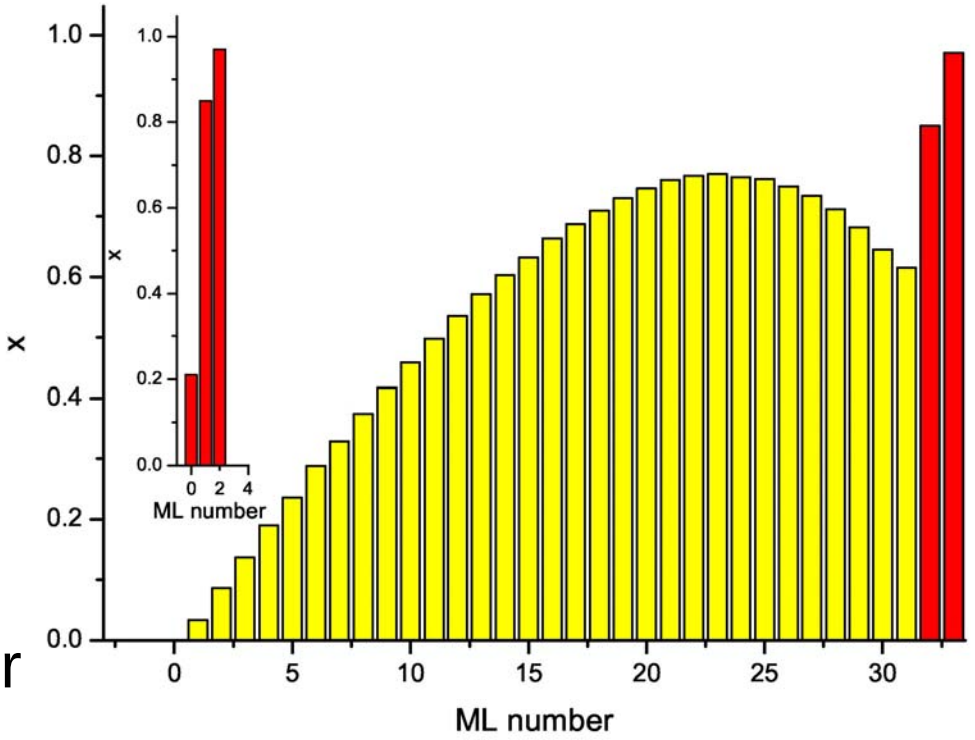
- At surface: x ~ 0.6
- Max of x ~ 0.8 at 10 ML below the surface
- We would measure this profile as x ~ 0.65
- Our data: x ~ 0.85




A. Rosenauer et al.:
Phys. Rev. B **64** (2001) 245334.

# Indium depth concentration profiles

- Strong In segregation also on surface of dots.
- Add double layer with x ~ 0.85 - 0.97 (like WL) to surface.
- We would measure this profile as x ~ 0.85, in good agreement with our data.




G. Biasiol et al.: Appl. Phys. Lett. **87** (2005) 223106.

# Conclusions

- Surface concentration maps of InAs/GaAs quantum dots by SPELEEM.
- Dot composition neither pure InAs nor homogeneous $In_xGa_{1-x}As$.
- In concentration decreases from center (high) to borders (low) of dots.
- In segregation ($x \sim 0.9$) on surface of dots and WL.
- Inportant information for a better understanding of buried QDs.