# *Linear optical techniques at NAST: High Spatial Resolution Raman Scattering (HSRRS) and Reflectance Anisotropy Spectroscopy (RAS)*

Wolfgang Richter

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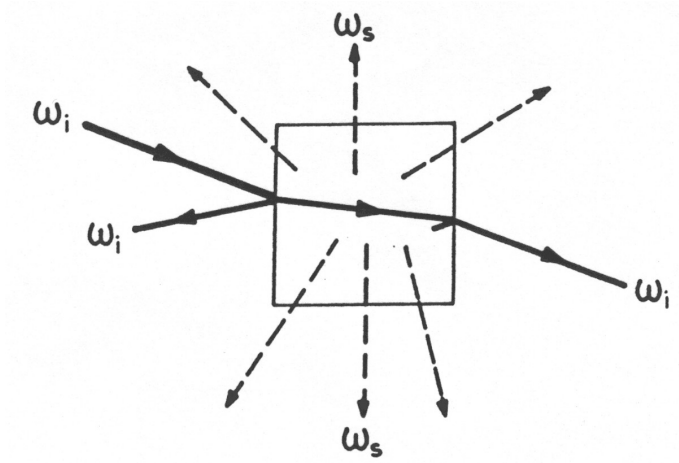
Markus Breusing, Linda Riele, Vasiliki Stamelou,
Claudio Goletti, Beatrice Bonanni, Gianlorenzo Bussetti, Piero Chiaradia,
Sarah Cirilli, Adriano Violante

***NAST and U Roma „Tor Vergata“***

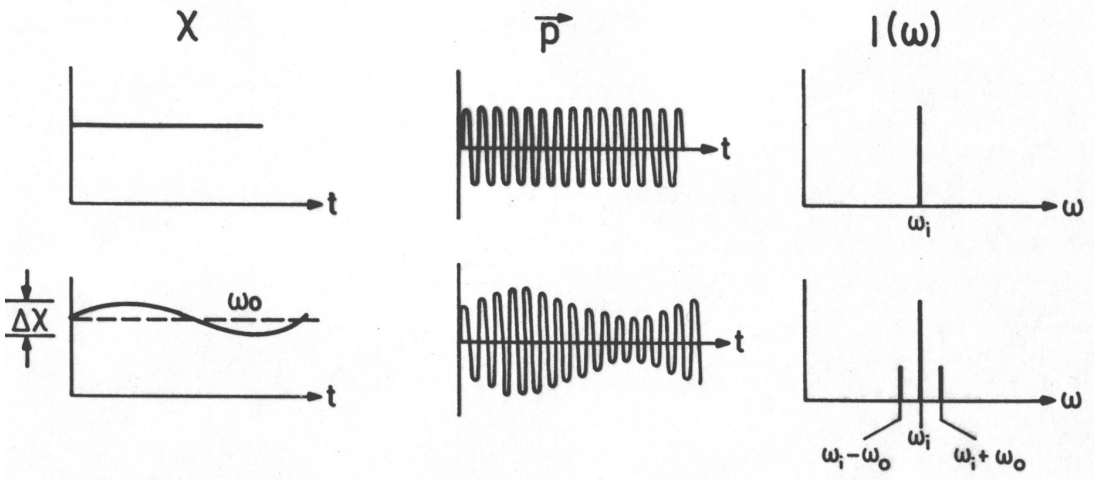
# Raman Scattering: inelastic light scattering




inelastic scattering

$$\vec{p} = V \cdot \hat{\chi} \cdot \vec{E}_i \exp i\omega_i t$$

——— geometrical optics (elastic scattering)




frequency



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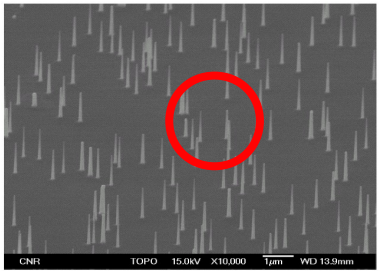
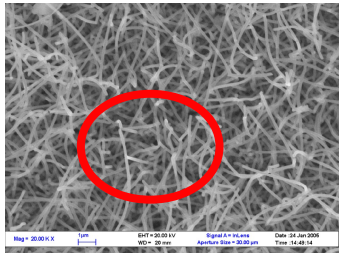
# *Why high spatial resolution (nanometer ) Optics?*

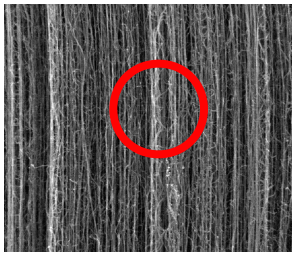
- **Epitaxial methods have strongly increased the potential of producing high quality NANO-structures (dots, rods,tubes)**



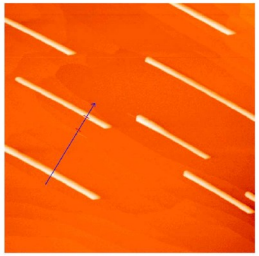

GaAs nanorods



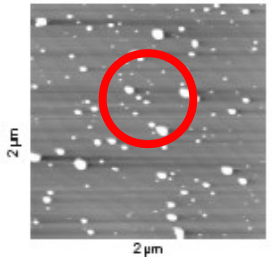
Si –Nano wires



C - nanotubes



Pb - wires




InAs - QDs

- **Optical techniques important : optical properties, electronic states, devices**

- **But: diffraction limit (~300 nm, *Far Field*) >> NANO‘s < 30 nm**

- **A chance for the optical *NEAR Field* ?**



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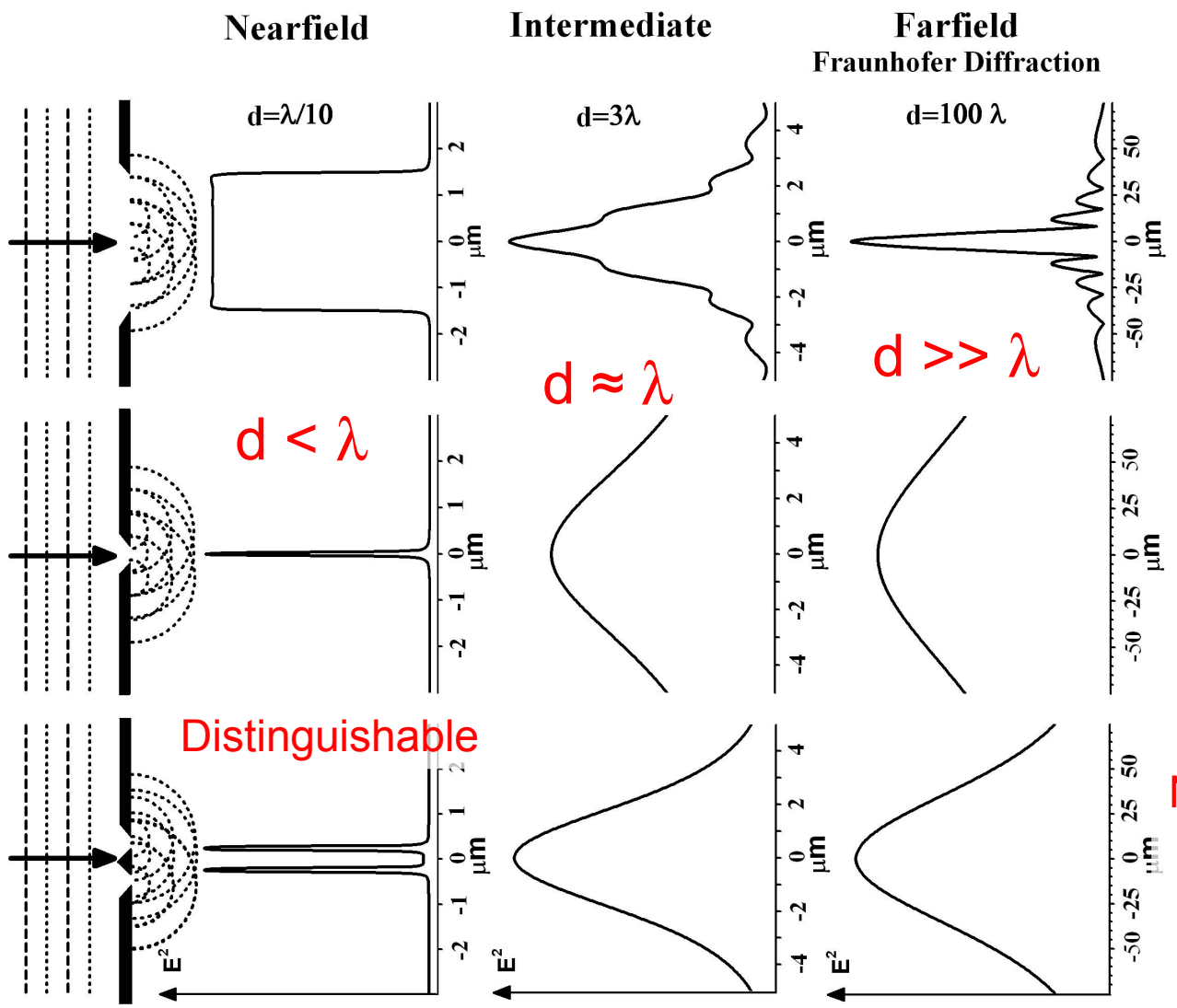
# Resolution Beyond Diffraction Limit: Nearfield




$$p_{min} = \frac{\lambda}{2 \sin(\alpha)}$$

Not Distinguishable in far-field!



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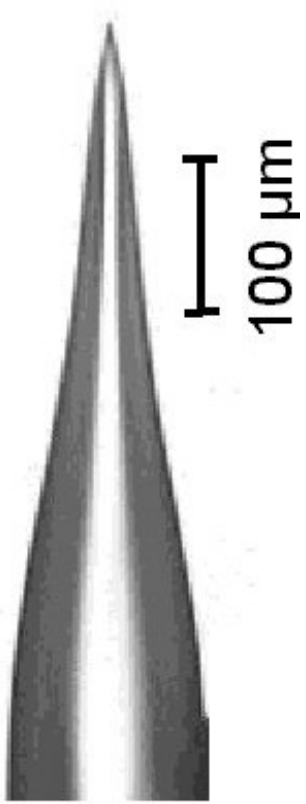
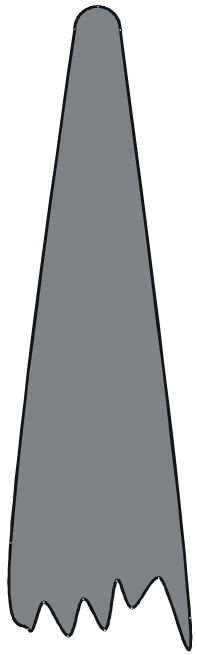
# Optical Nearfield Probes

***Glasfiber***




**Metallic tip**

Tip Diameter ~50 nm





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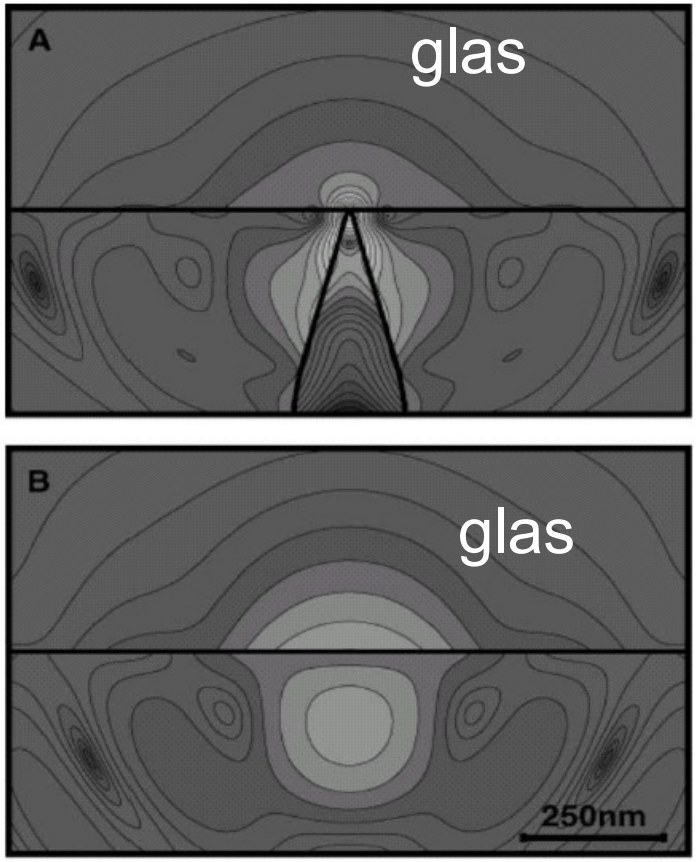
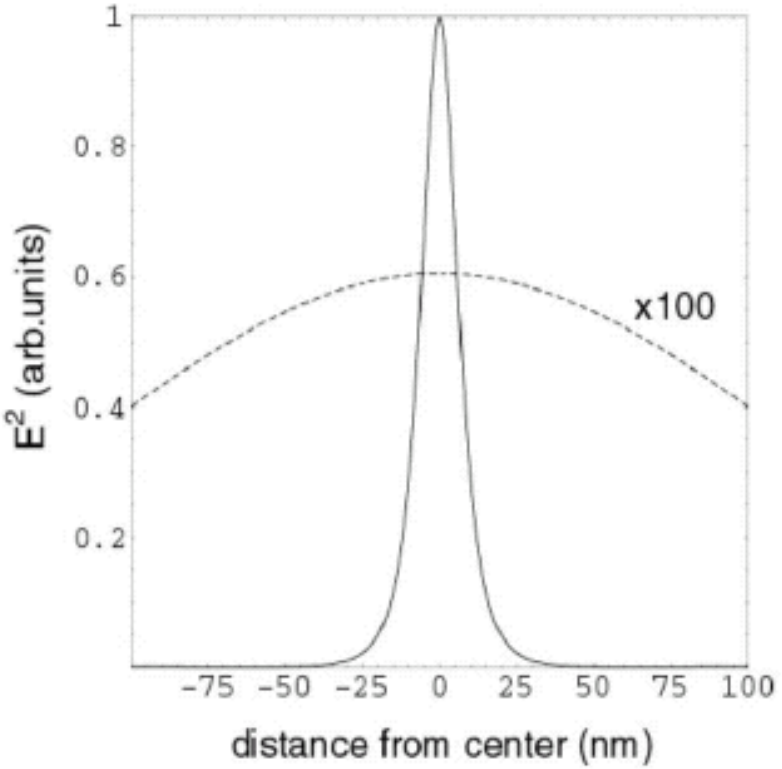
# Plasmonic field enhancement by metal tip

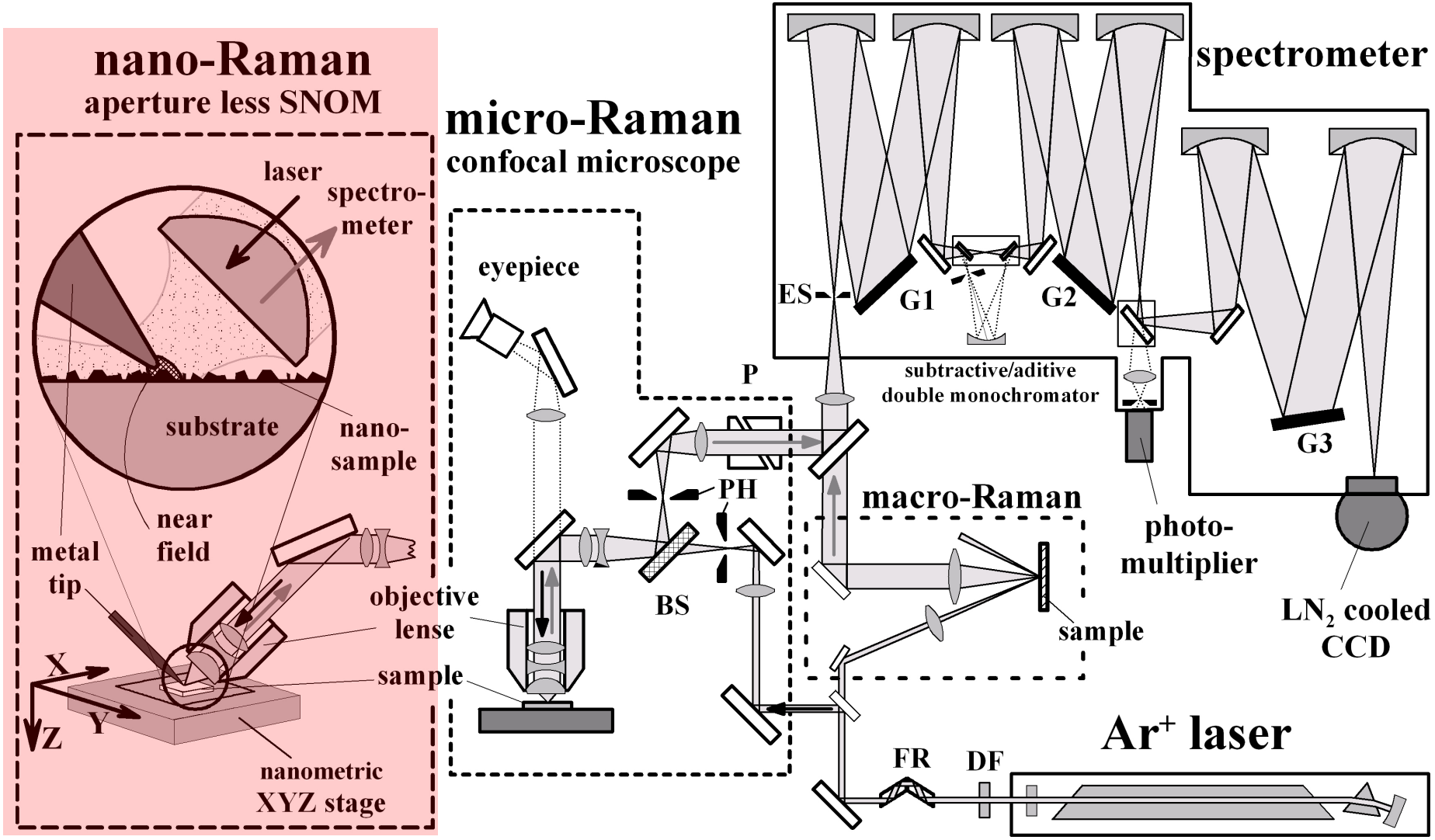



$$\omega_{Laser} \sim \omega_{Plasmon}$$

Bennett B. et al, IEEE J. SELECTED TOPICS IN QUANTUM ELECTRONICS, VOL. 8, 1051 (2002)

# Raman –optical set-up: Nano, micro, macro



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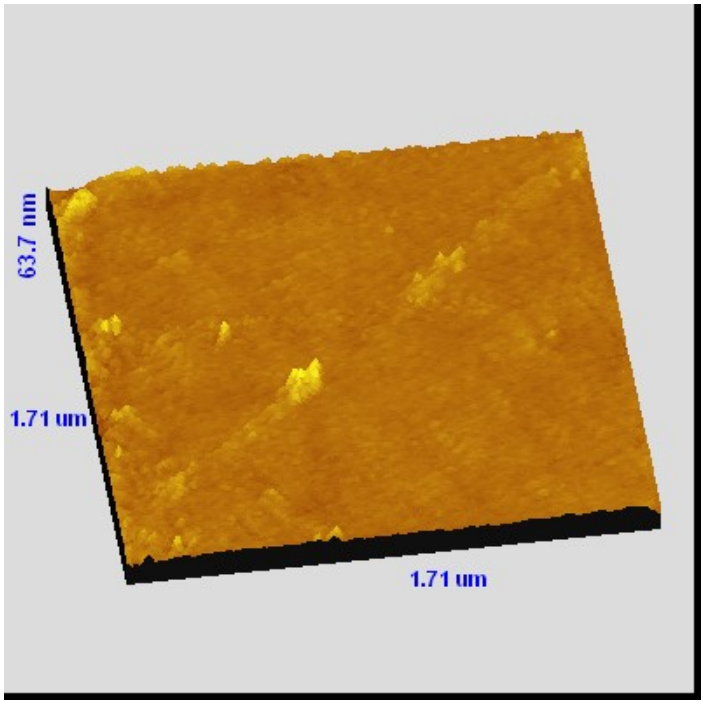
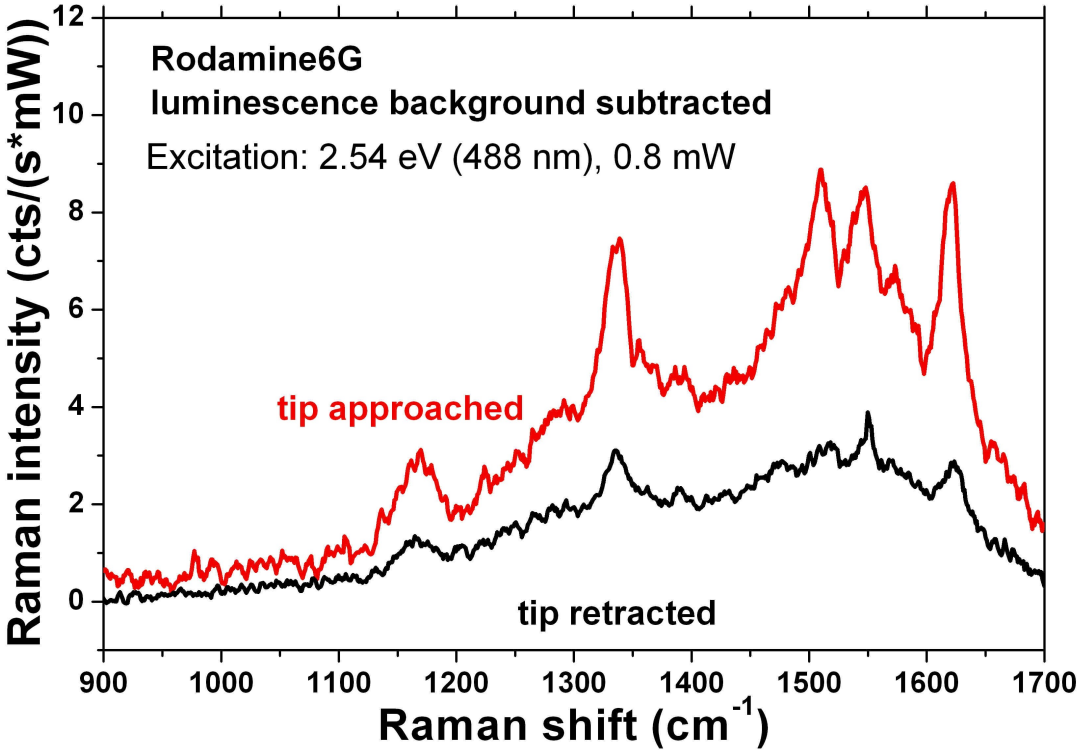
# *Rhodamin 6G on Ag(110)*

## Organic molecules on Ag STM image




## Enhancement of Ramanspectra by metallic Tip



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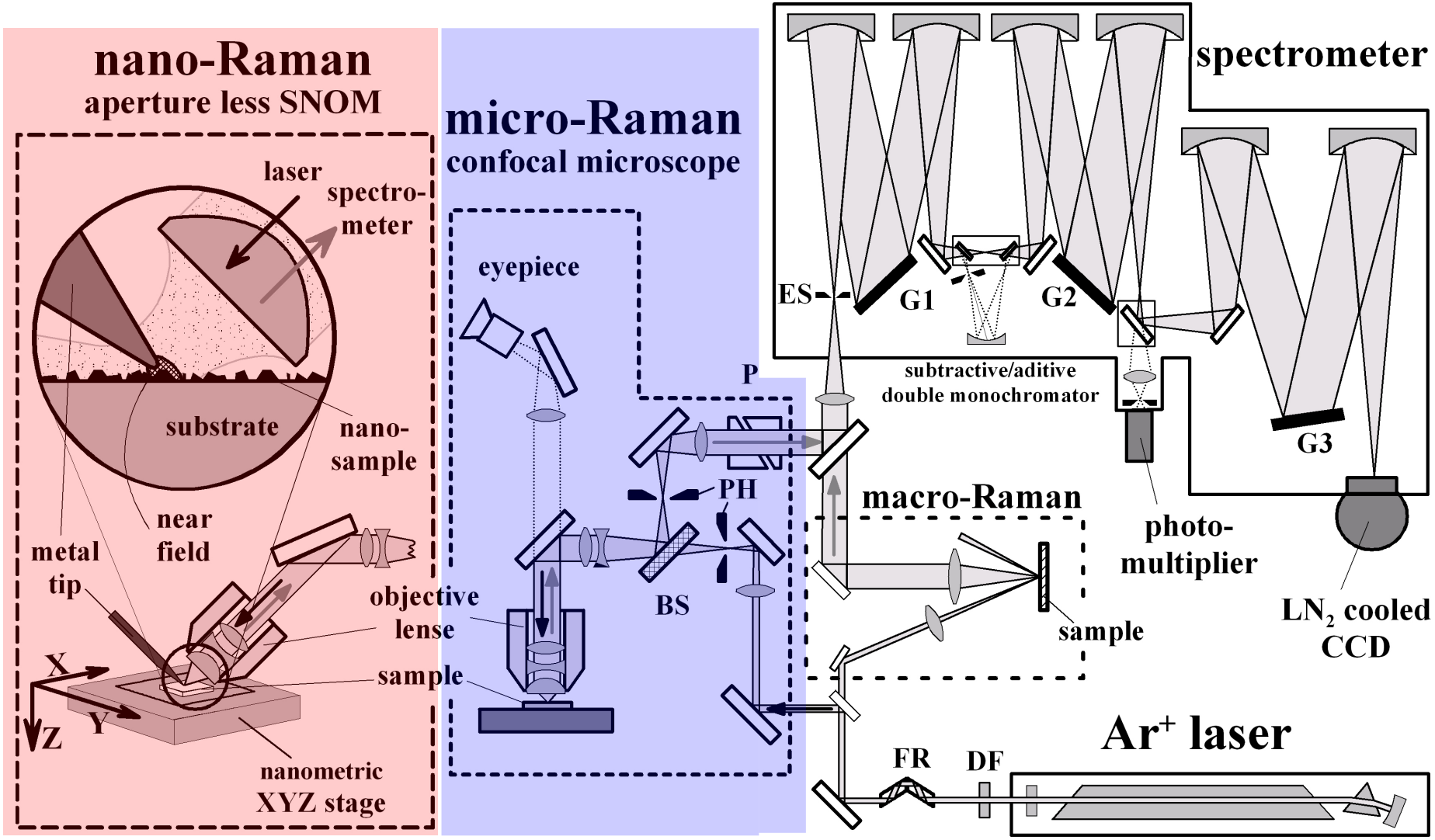
# Raman –optical set-up: Nano, micro, macro



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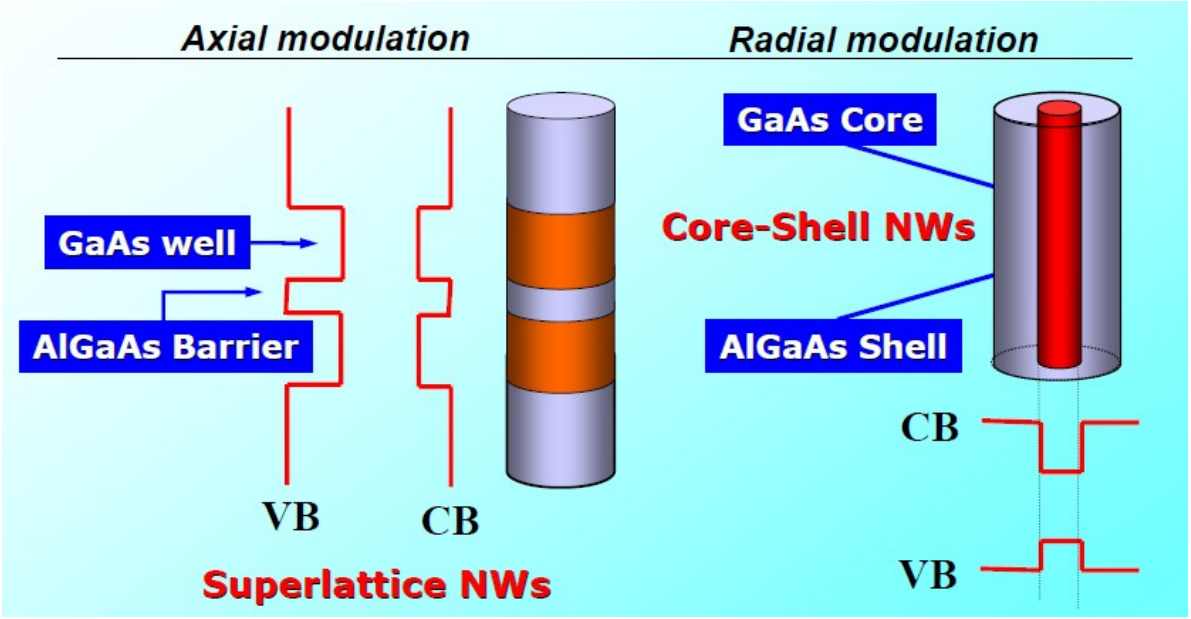
# AlGaAs nano-structures with heterojunctions



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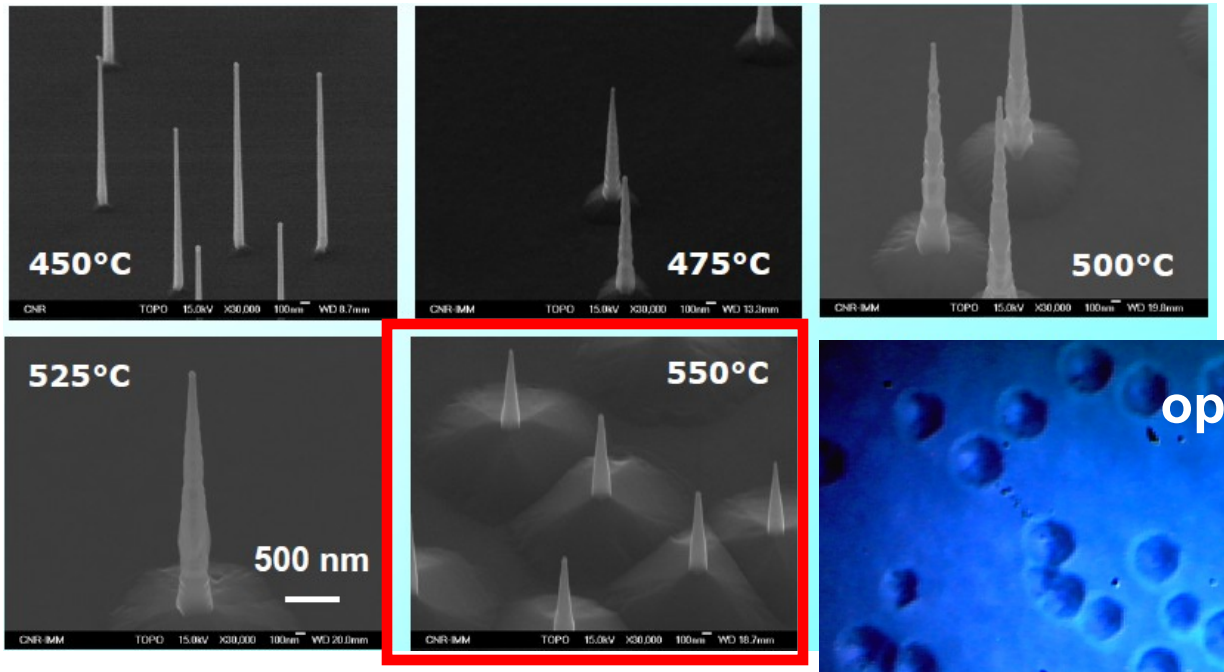
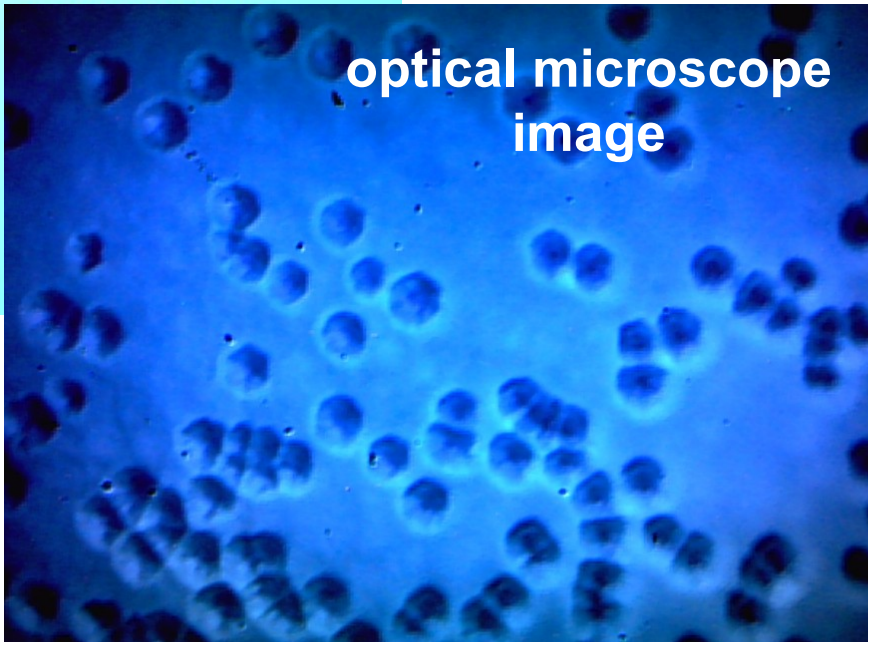
# *"Finding" Single Nanostructures*

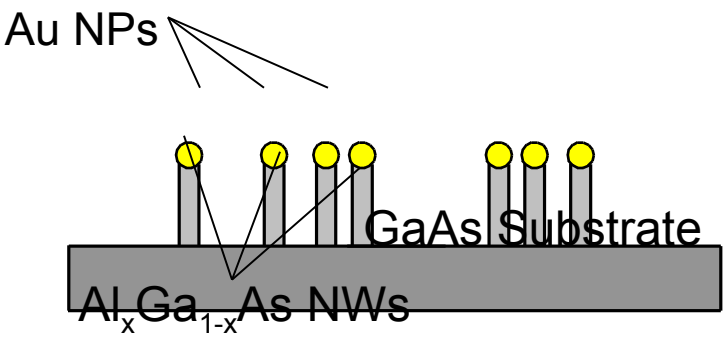
free standing $Al_xGa_{1-x}As$ NWs

FE-SEM micrographs
30,000x magnification




Grown by VLS method at different temperatures with different Al concentration



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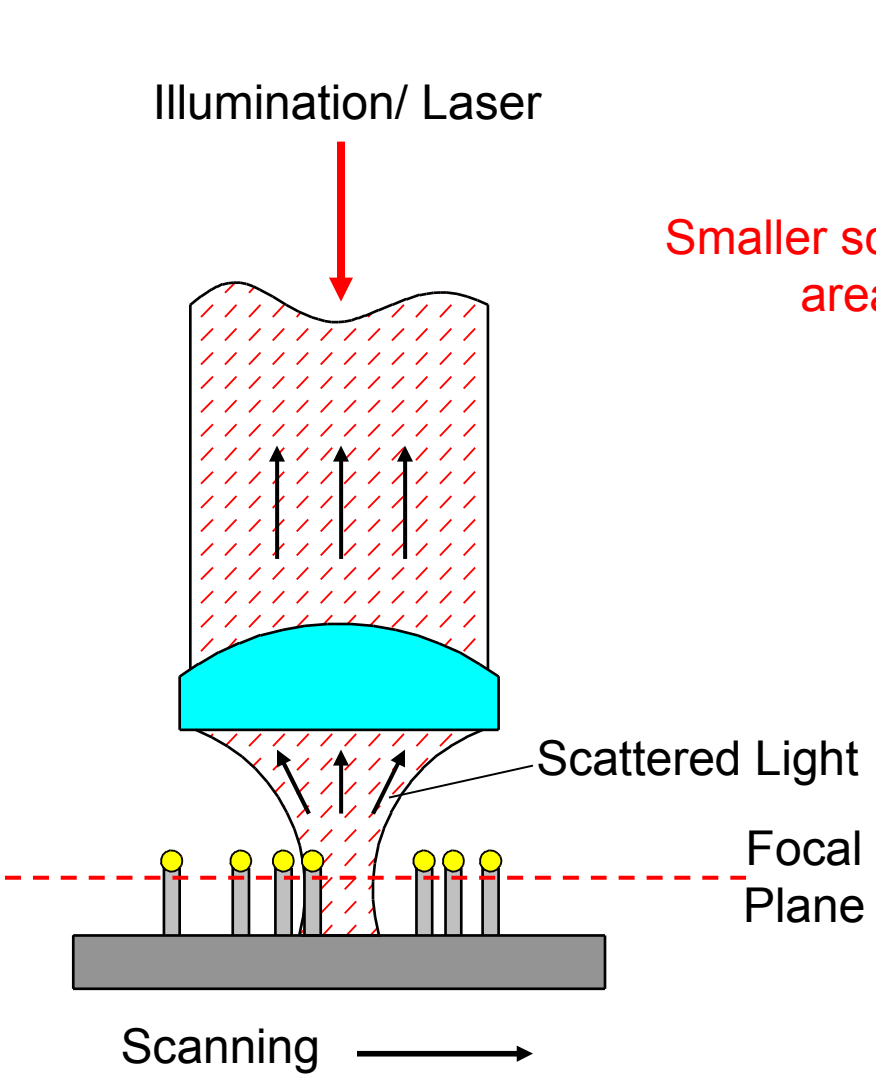
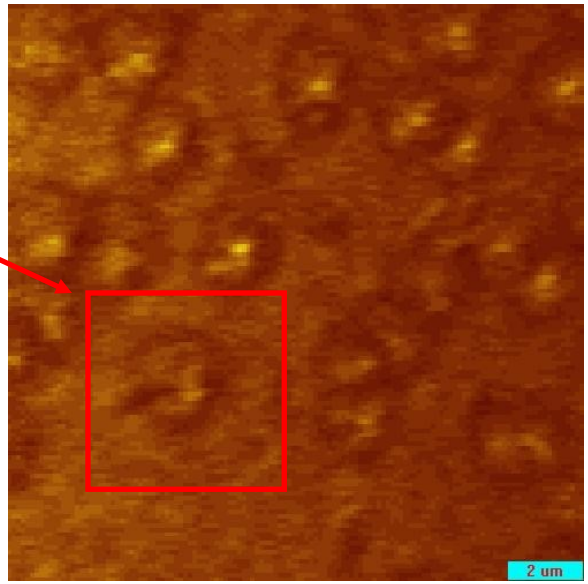
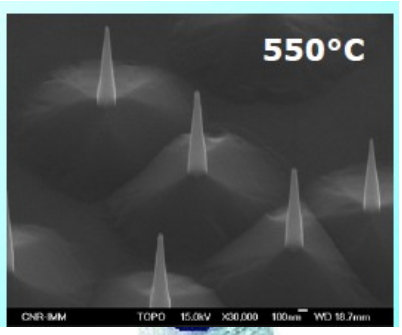
# *Rayleigh Imaging of $Al_xGa_{1-x}As$ NWs*




Rayleigh Micrograph

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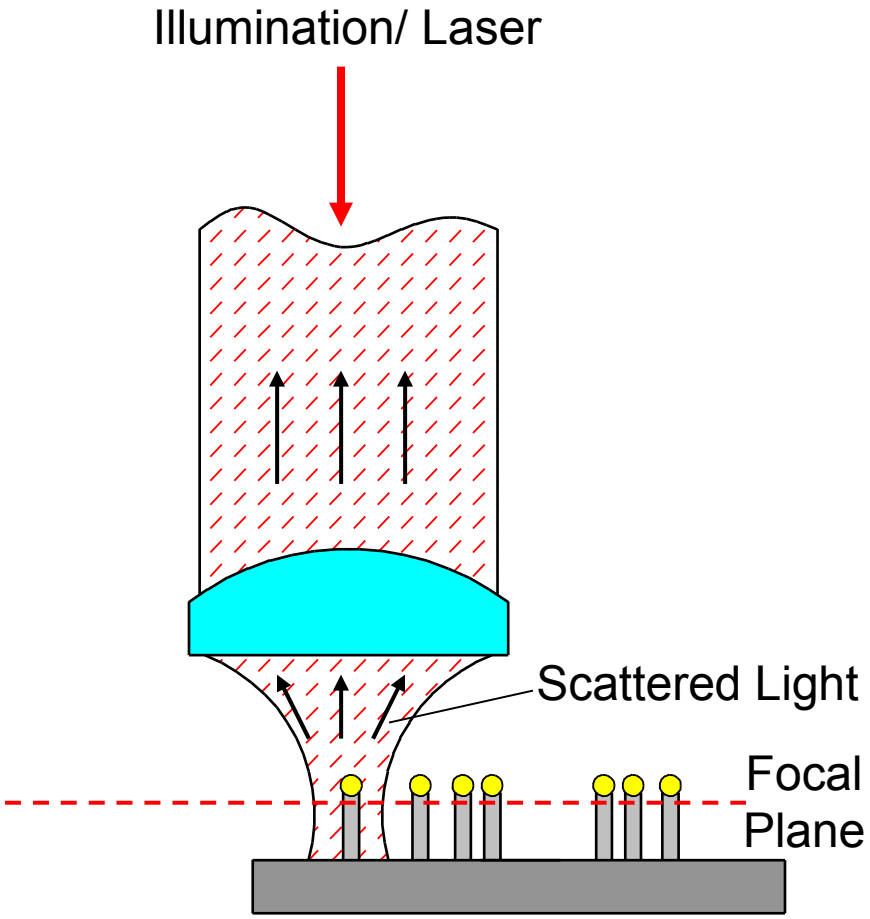
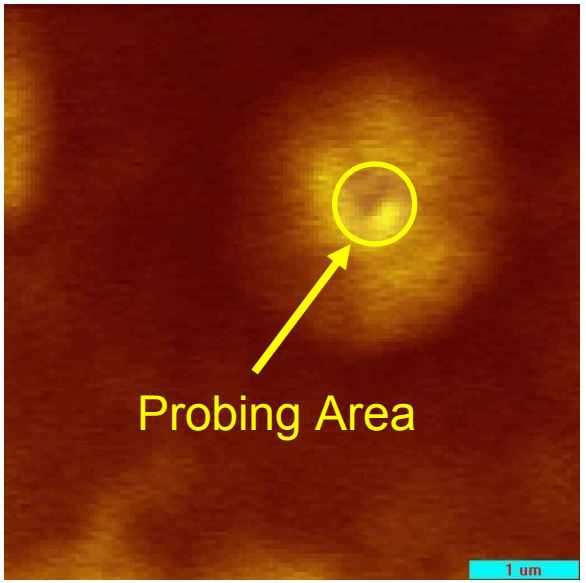
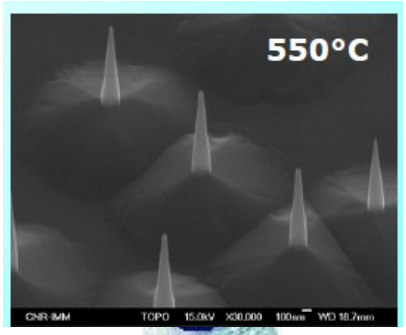
# Raman Spectra of $Al_xGa_{1-x}As$ NWs




Repositioning



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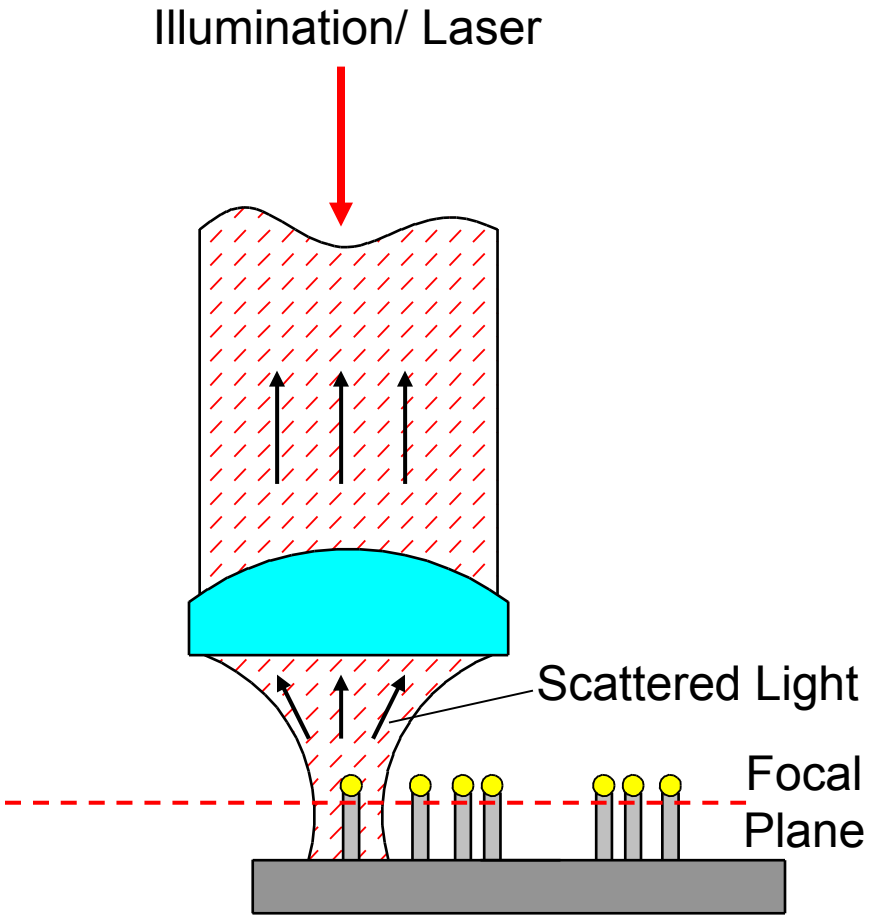
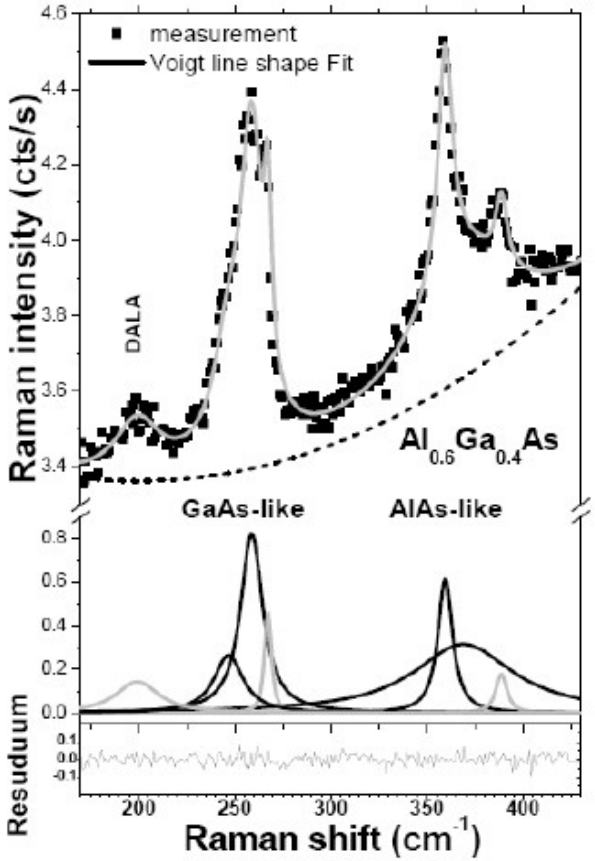
# Raman Spectra of $Al_xGa_{1-x}As$ NWs




Stable positioning



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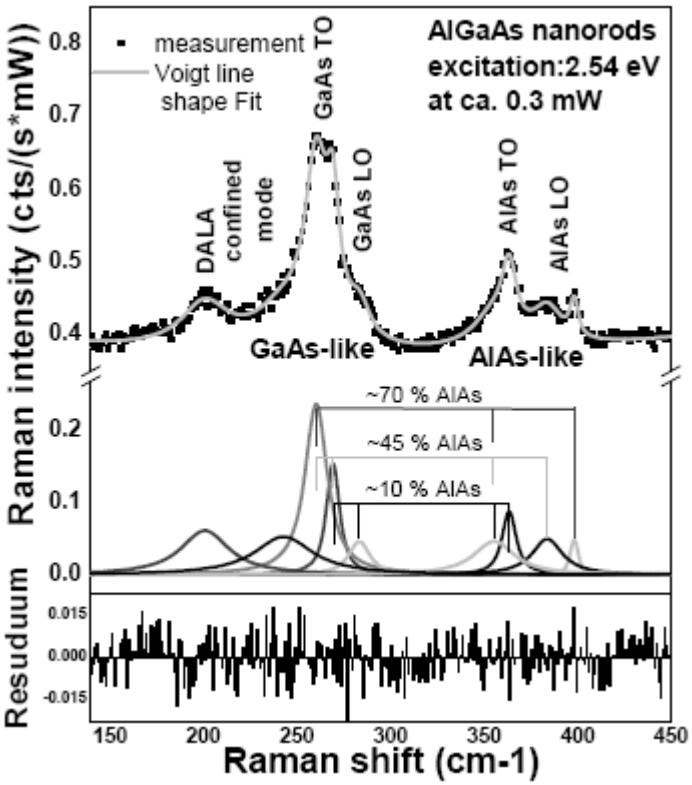
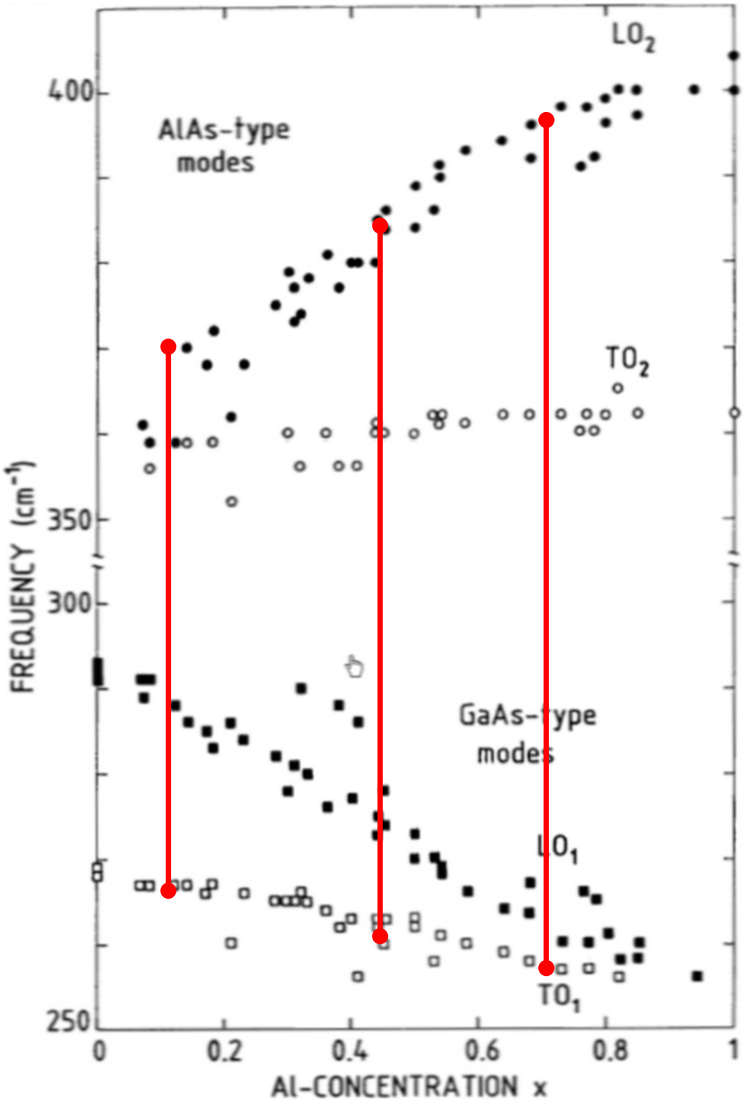
# Determination of Al Content

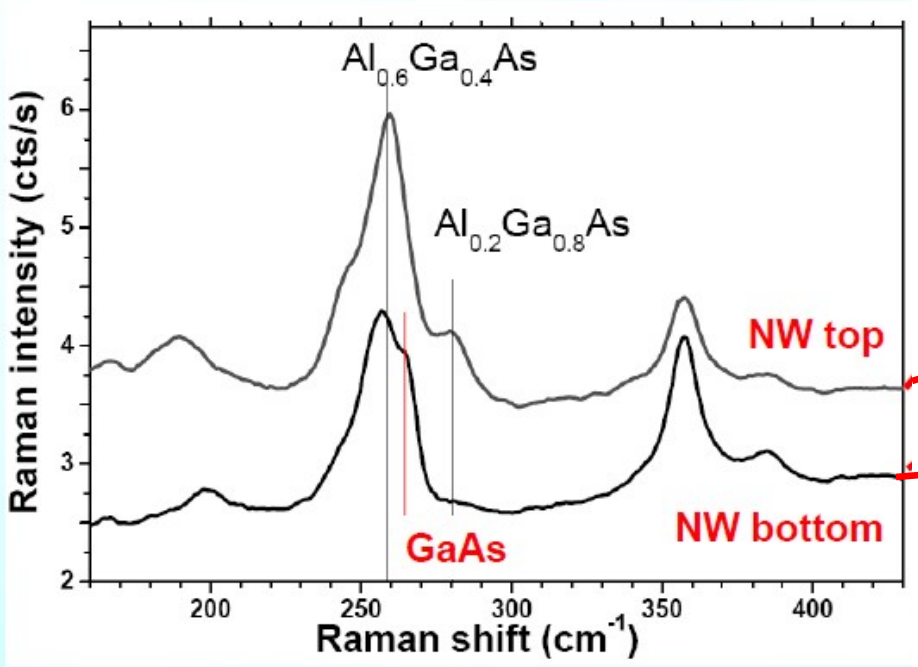


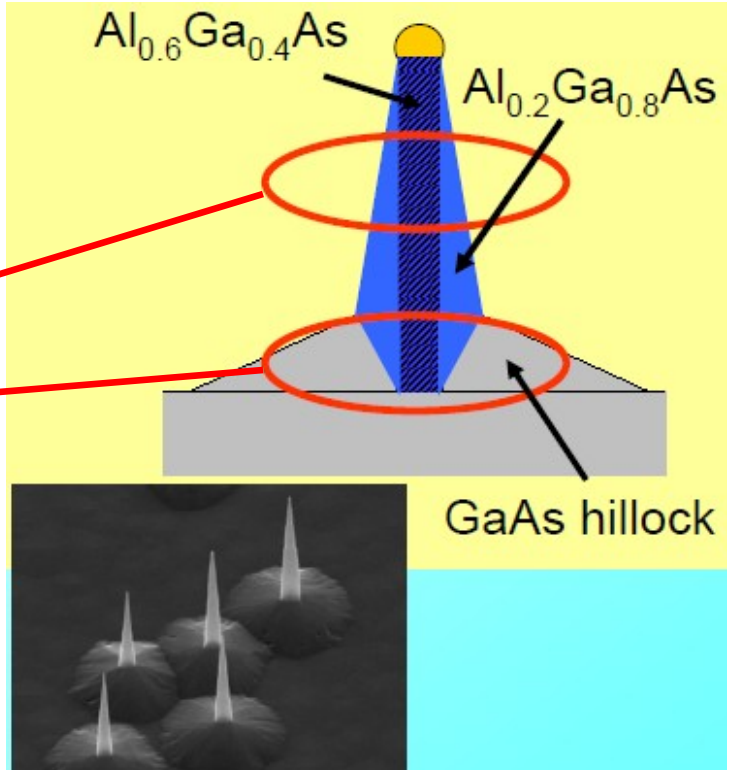



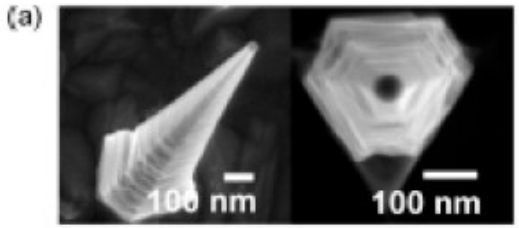


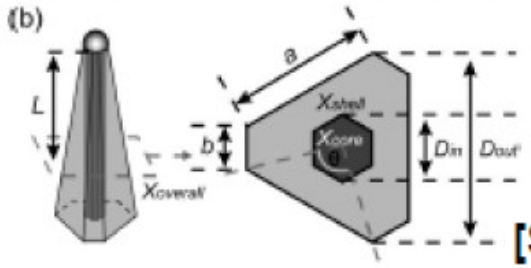

S. Adachi, Prop. of Aluminum Gallium Arsenide, INSPEC (1993).

# μ-Raman Spectra at Different Positions Along Wire




N. Lovergine, NanoSea (2008).

[S.K. Lim *et al.*, Nano Lett. 8 (2008) 1386]

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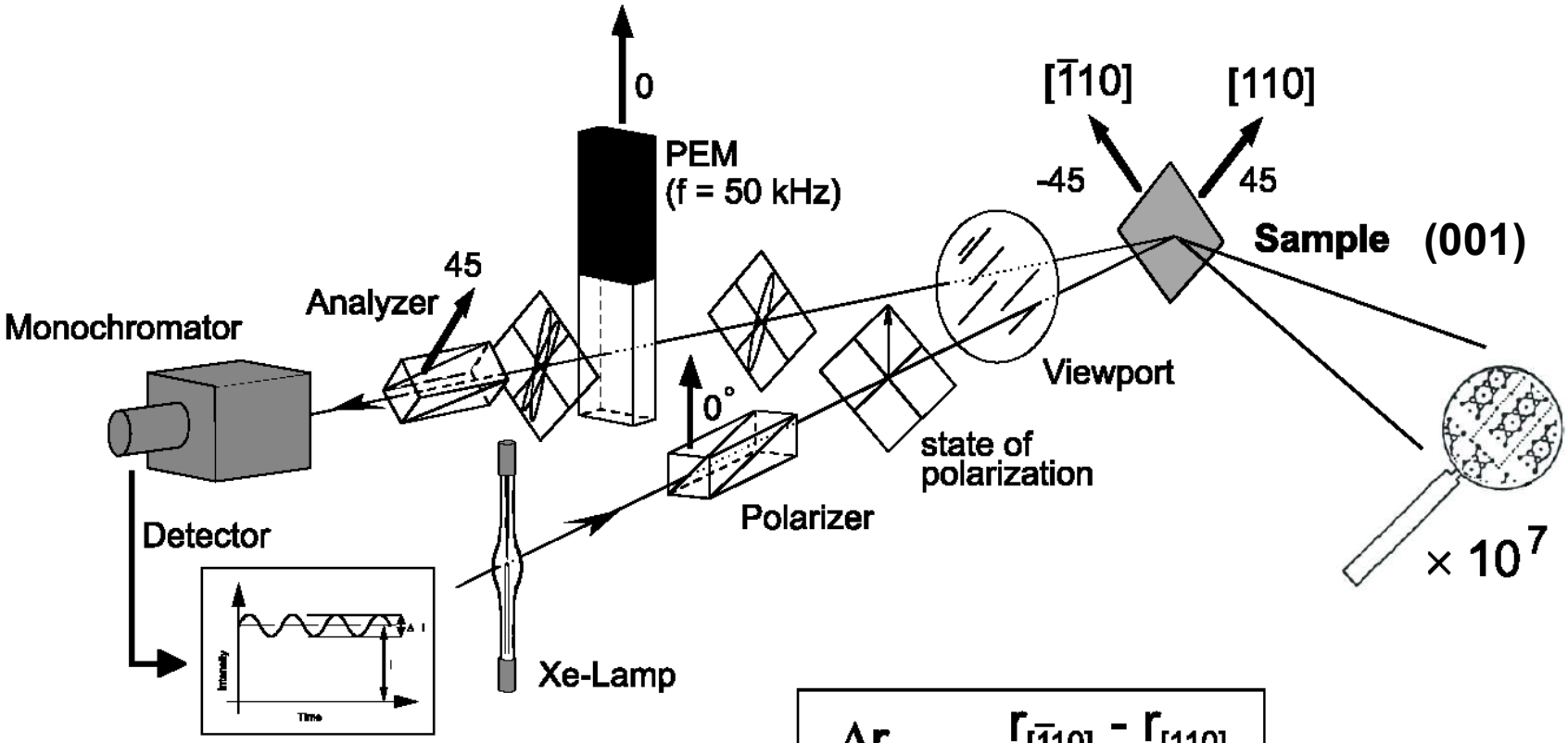
# Reflectance Anisotropy Spectroscopy on interfaces and thin layers

# *Reflectance **Anisotropy** Spectroscopy: setup example*




$$\frac{\Delta r}{r} = 2\,\frac{r_{[\bar{1}10]} - r_{[110]}}{r_{[110]} + r_{[110]}}$$

Aspnes 1985

**Signal in first order intensity independent !!**



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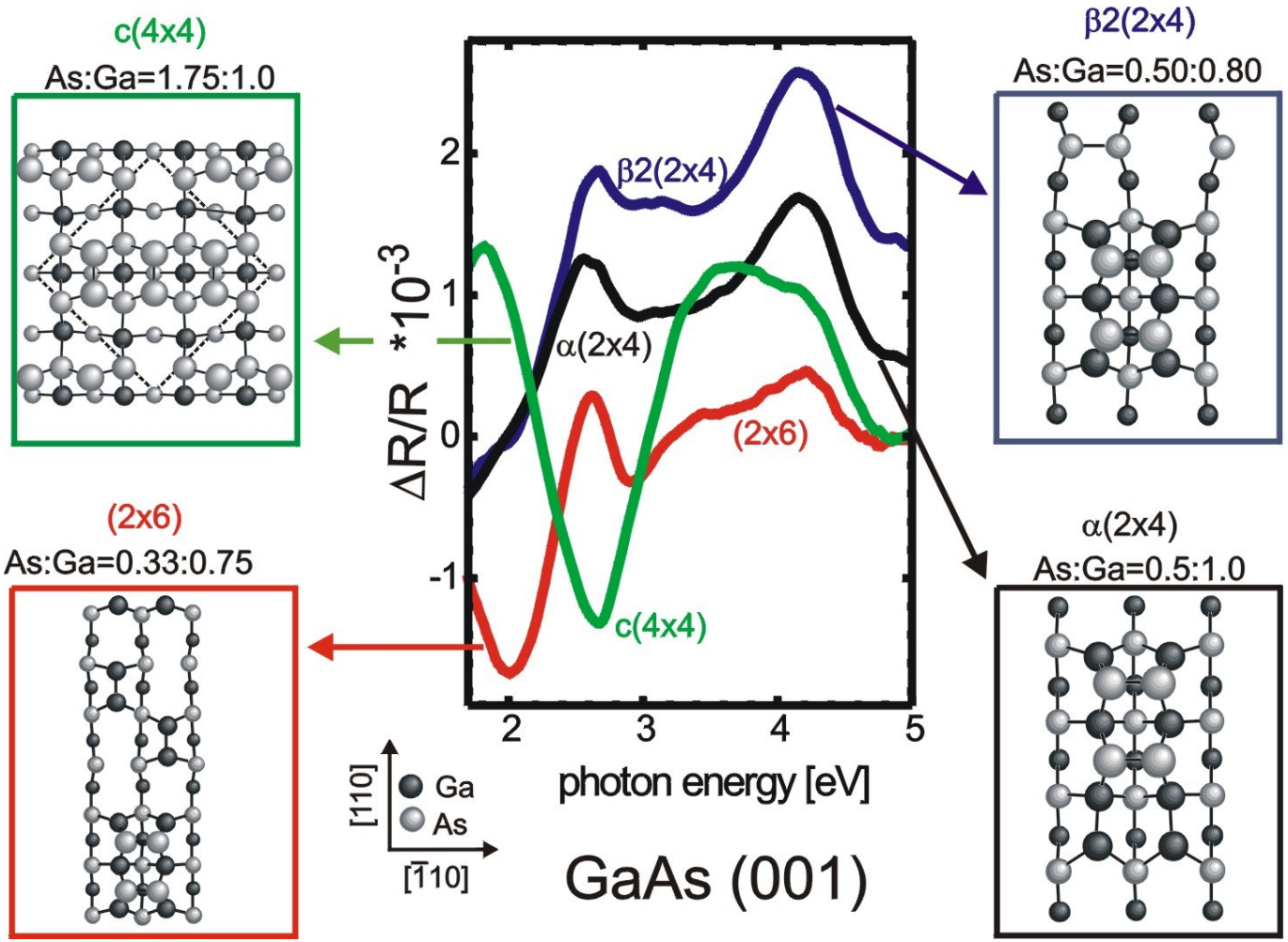
# RAS spectra and surface correlation for GaAs(001) surface reconstructions



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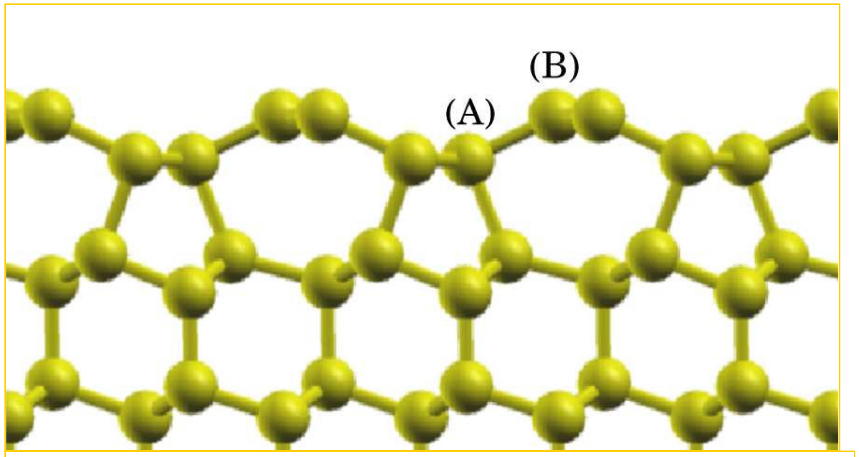
# Geometry of C(111)2x1

$T_{annealing} > 1173K$ ⇒ **Pandey Chain Reconstruction**



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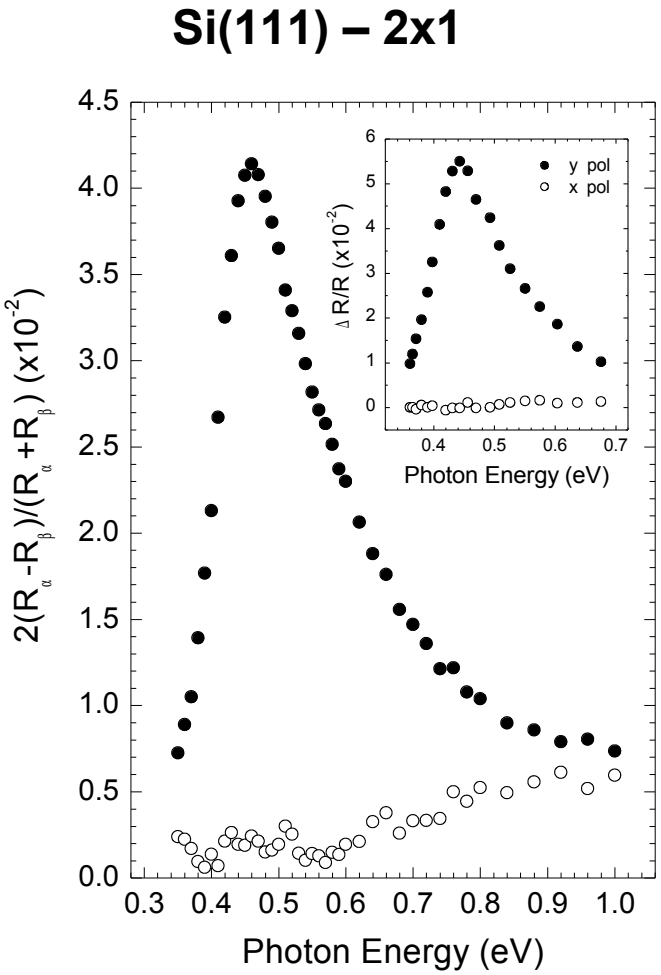
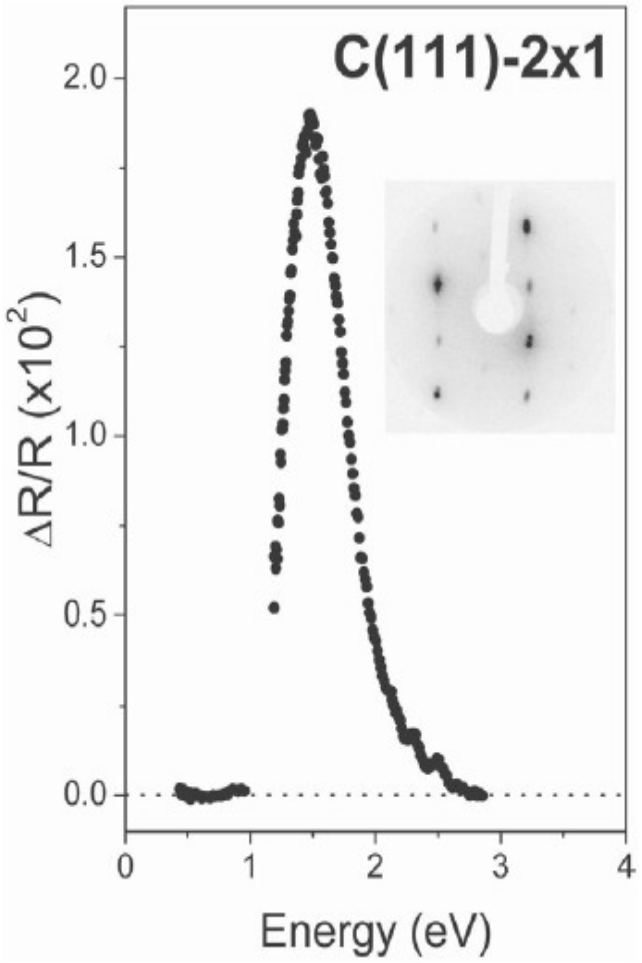
# RAS on C, Si, Ge (111) – 2x1




C.Goletti, F.Arciprete, G.Bussetti, P.Chiaradia, G.Chiarotti *Phys. Rev. B* ***66****, 153307 (2002)*



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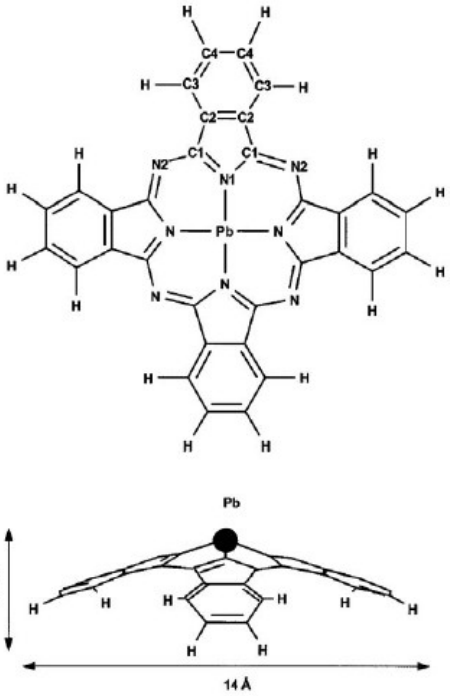
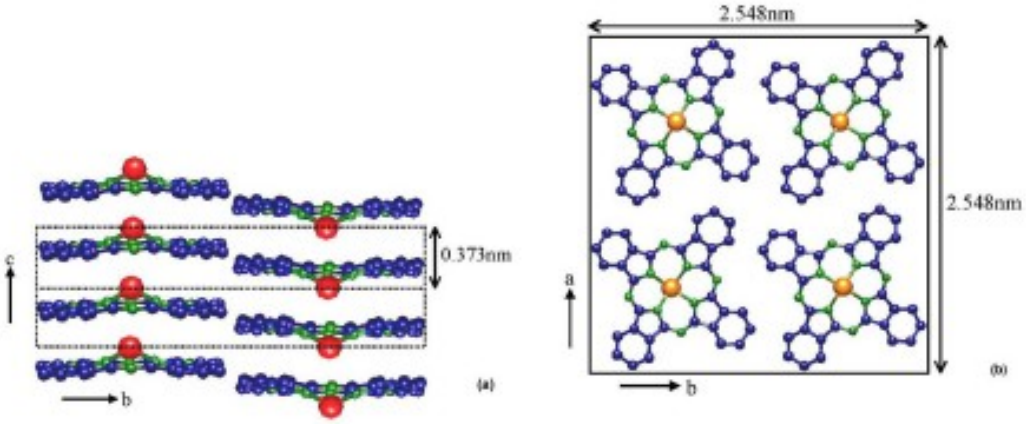
# Thin organic layers

# Pb-Phtalocyanines

## Pb-Phtalocyanine molecule




## Pb-Phtalocyanine crystal



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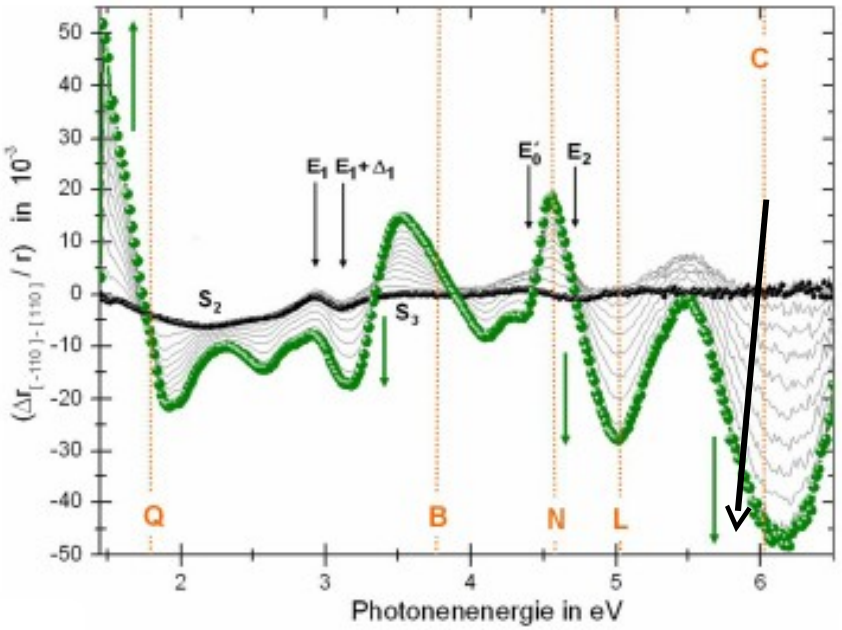
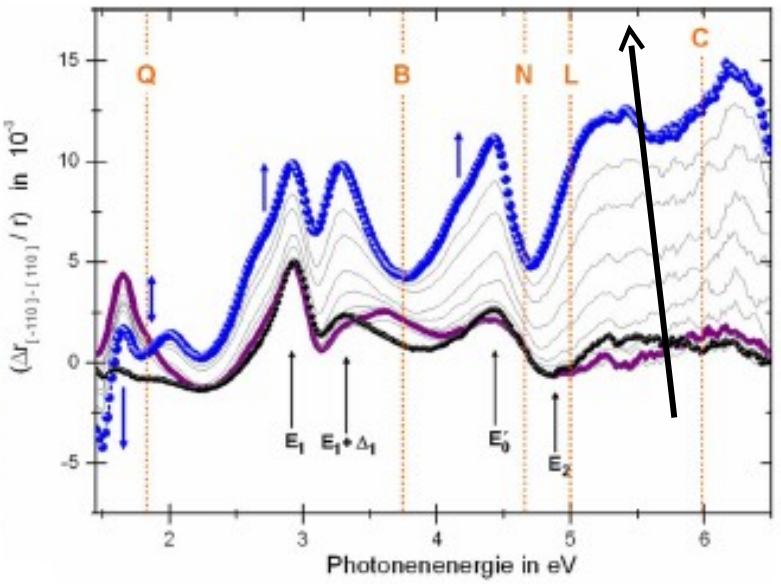
# *Pb-Phtalocyanine on GaAs surface reconstructions*

on **GaAs(4x2)**




on **GaAs(2x4)**




**Clean surface: black**
22 nm coverage: green or blue
Intermediate coverages: grey



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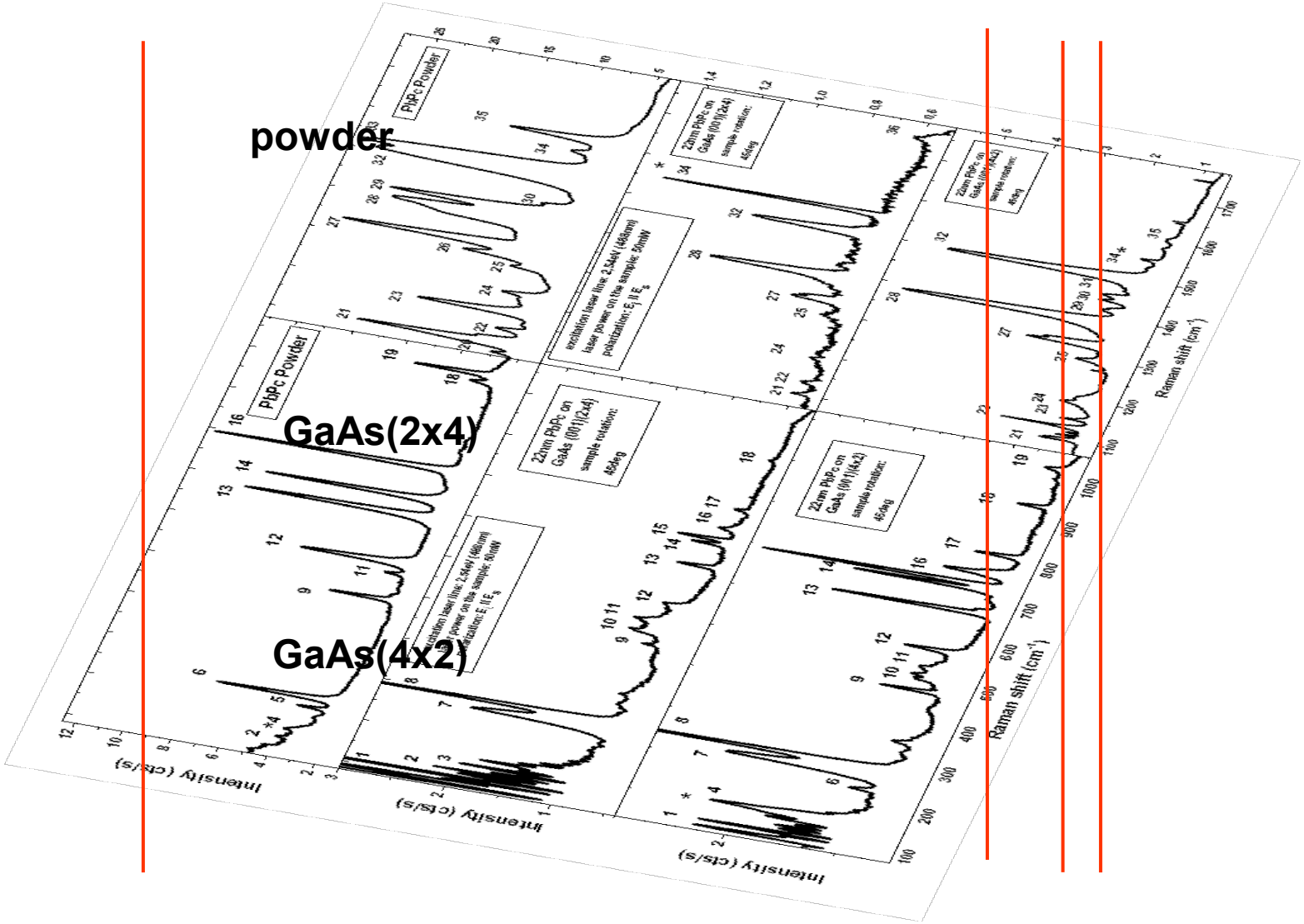
# *Pb-Phtalocyanin (20nm) on GaAs(001) (2x4) –middle- and (4x2) –bottom-*



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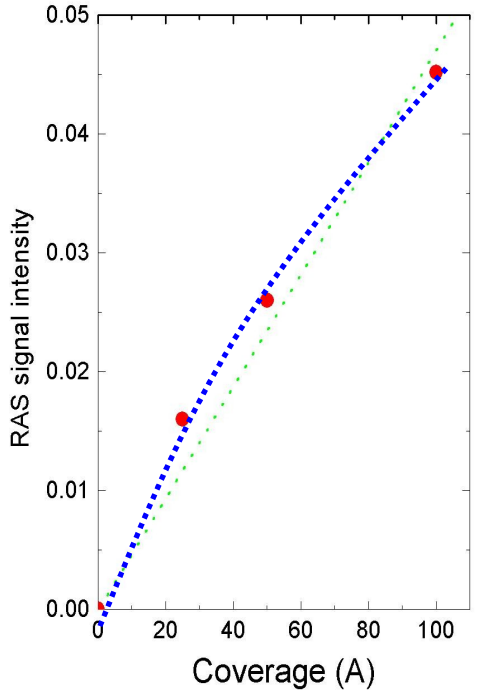
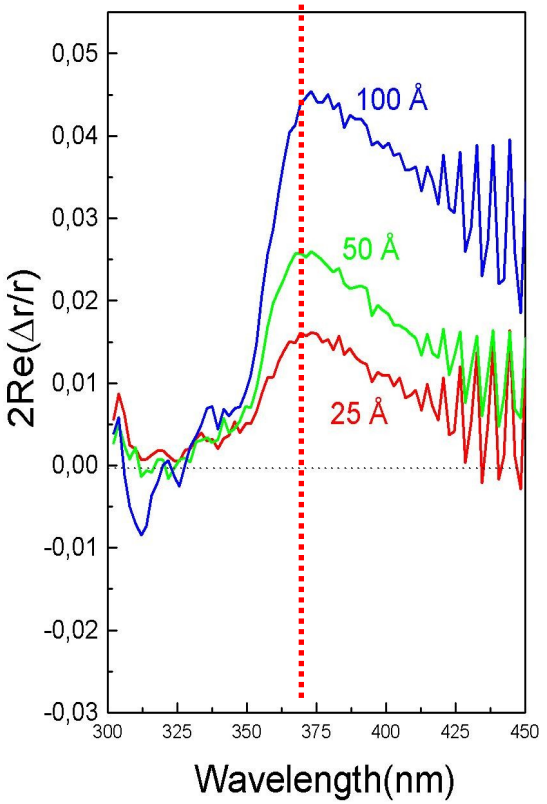
# Thickness monitoring of α-sexithiophene thin films




APPLIED PHYSICS LETTERS VOLUME 83, NUMBER 20 17 NOVEMBER 2003

**Highly sensitive optical monitoring of molecular film growth by organic molecular beam deposition**

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*Dipartimento di Scienza dei Materiali and Unità INFM, Università di Milano-Bicocca, Via Cozzi 53, I-20125 Milano, Italy*



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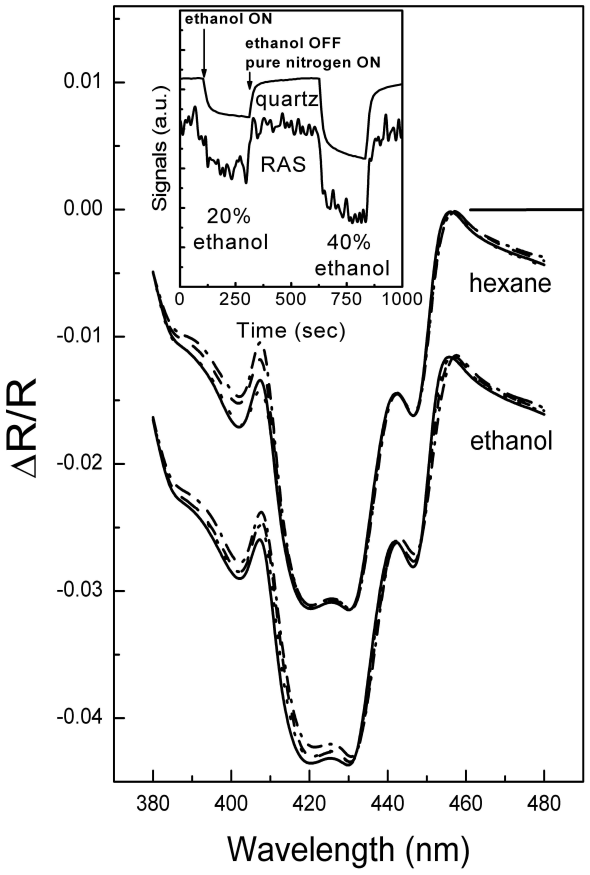
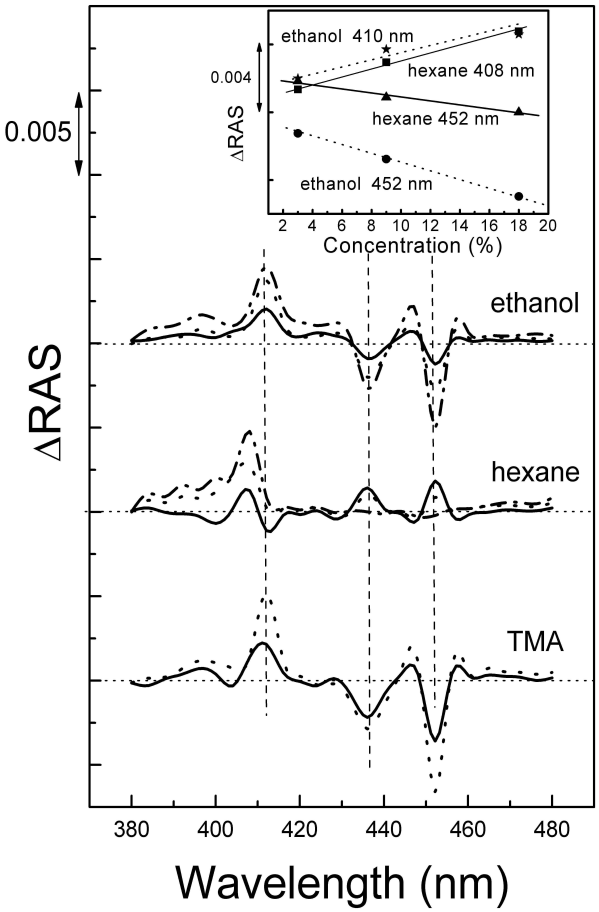
# Chemical vapor sensing by RAS: artificial nose



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- Optical analysis on nanostructures indispensable, but diffraction limited
- Diffraction limit can be achieved by confocal microscopy and overcome by nearfield optics
- Linear techniques (RAS, PL, T) can be easily applied on single (few) nanostructures

FINE