Raman Confocal Microscopy with the Highest Spatial Resolution

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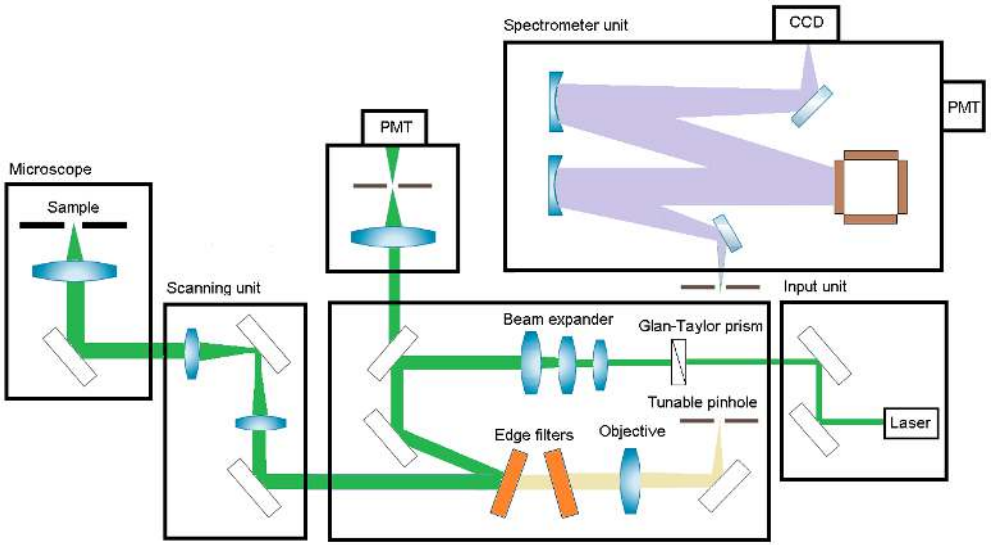
SOL instruments

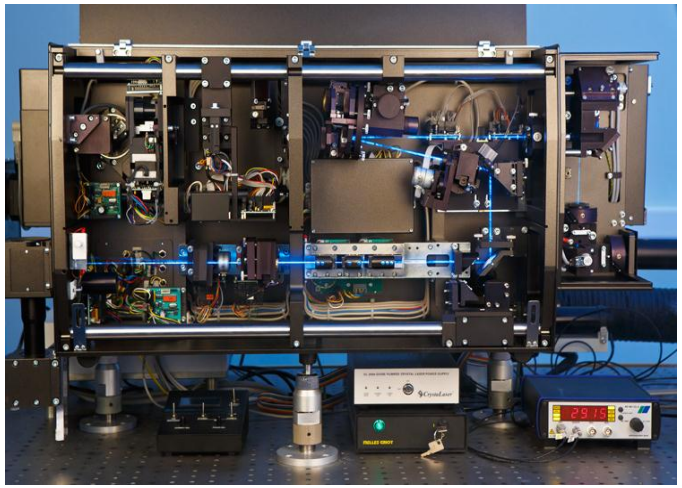
High spatial resolution chemical imaging / analysis is a target for many researchers in nanotechnology and biology.

Confocal microscope equipped with spectrograph is a good choice for non-destructive chemical analysis with Raman spectroscopy

www.solinstruments.com

3D Raman Confocal Microscope Confotec®





Layout of the Raman instrument – Confotec NR500 (SOL instruments)

Raman confocal microscope "Confotec NR500" (SOL instruments Ltd.) was developed as a highest spatial resolution device

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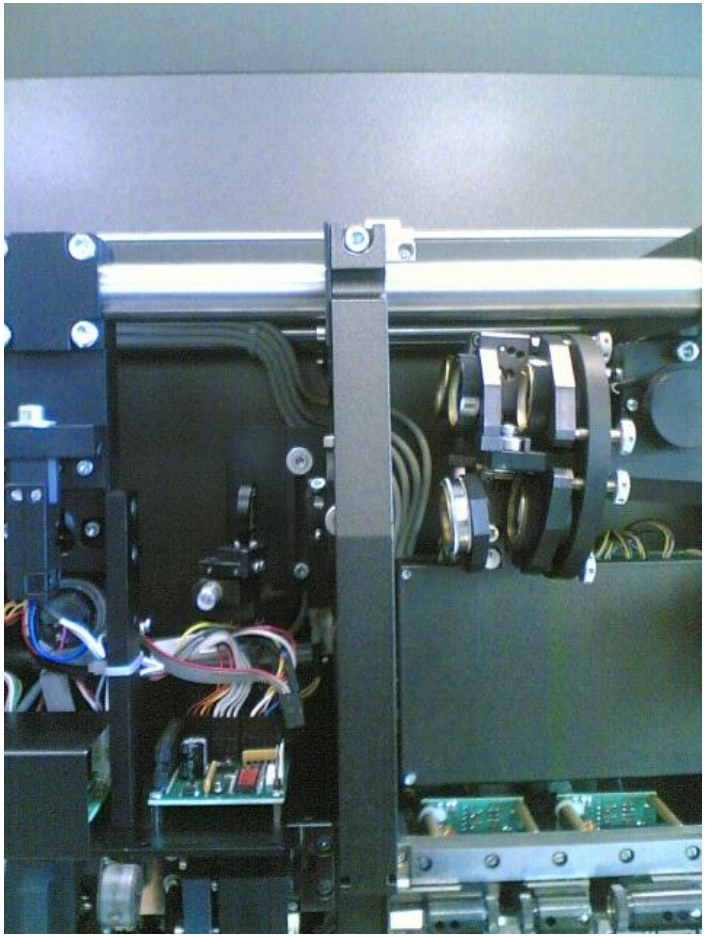
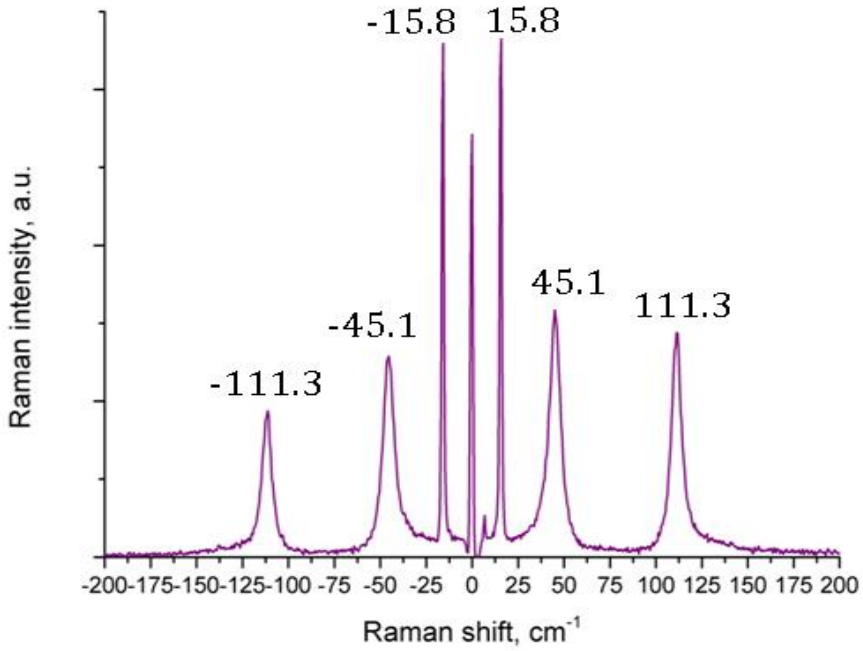
Ultra-low frequency Raman measurements of CdI2 (Cadmium Iodide) using a Confotec NR500 system

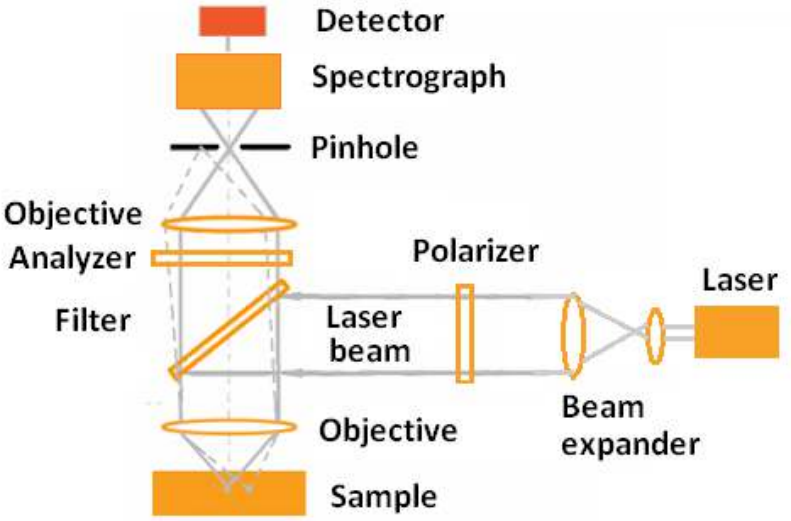




Confocal Ray Diagram

A pinhole blocks the scattered light which is coming from the out-of- focus points.

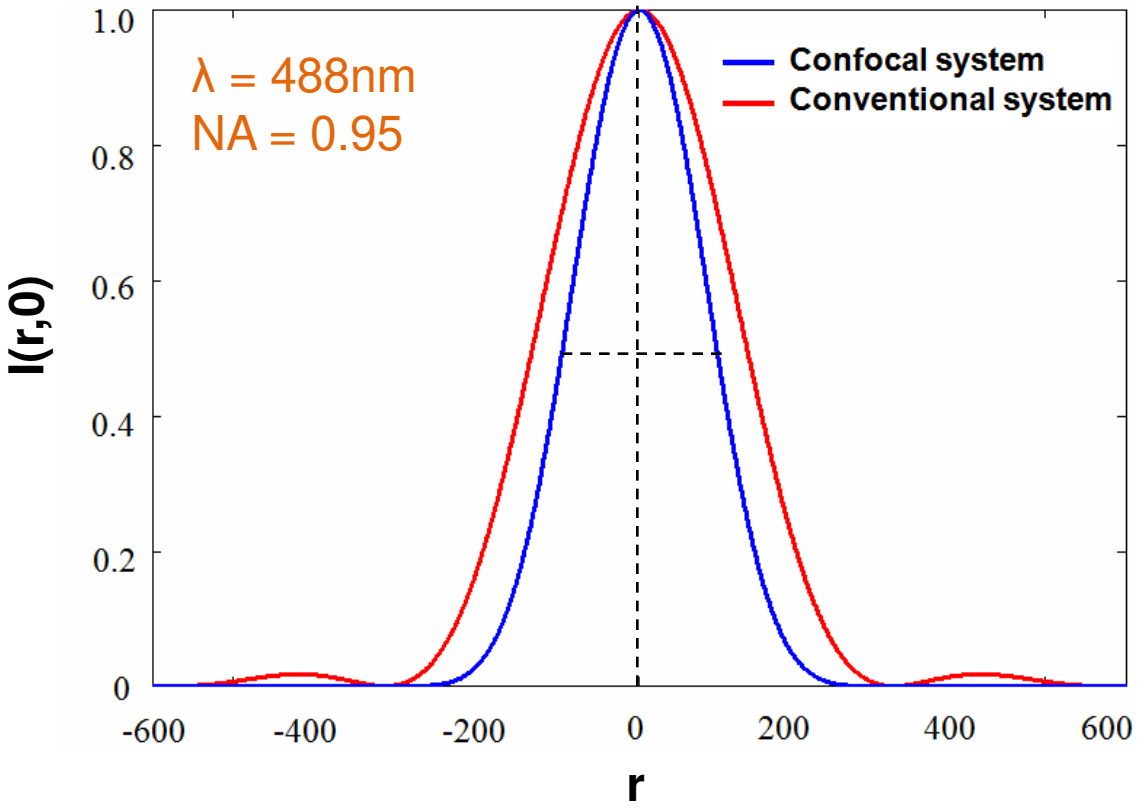
Confocal apertures define the volume from which signal is collected.



Confocal Micro-Raman:

- Use of pinhole aperture to decrease off-focal rays
- Much smaller background
- 3D information
- Slightly higher lateral resolution

Comparison of Lateral Resolution Properties

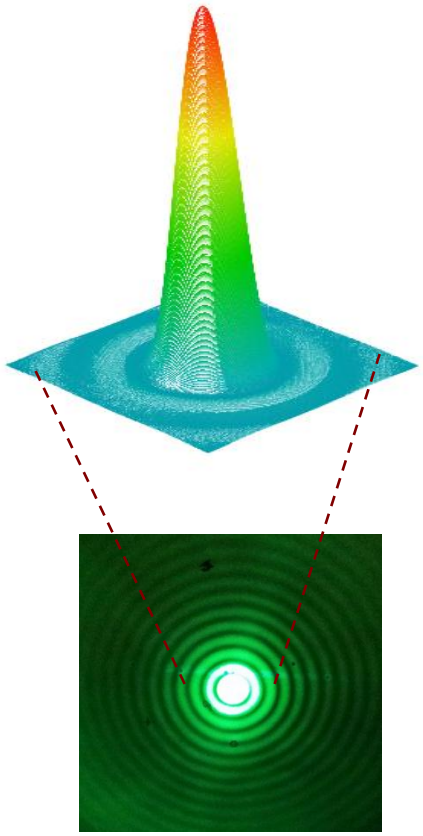


Lateral resolution is 1.39 times better

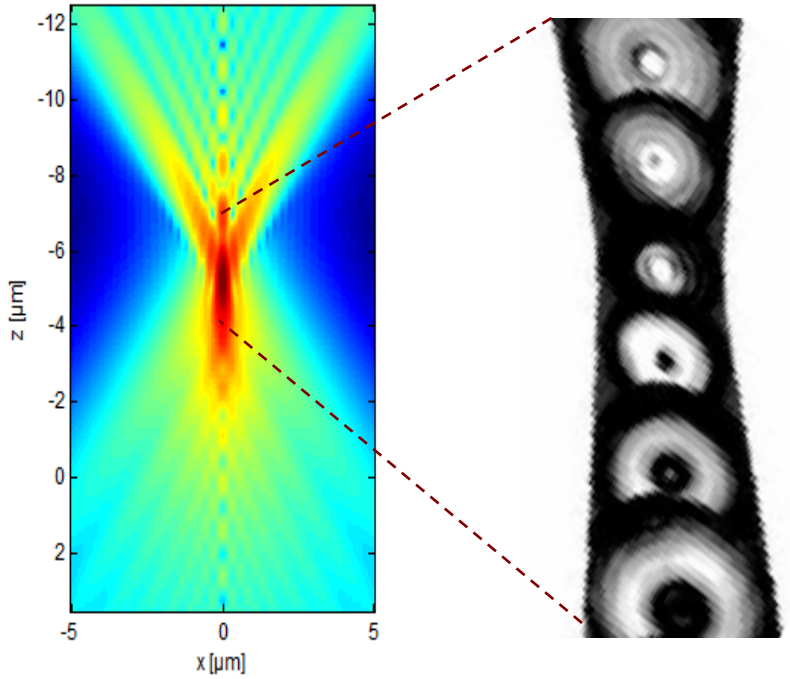
See also: L R Qiu, X M Ding and J Liu, Journal of Physics: Conference Series 13 (2005) 422–425

Intensity Distributions in the focal point

Airy disc radial intensity distribution



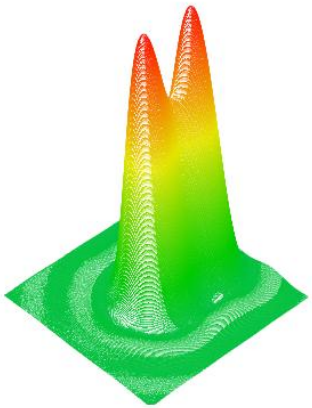
Axial intensity distribution

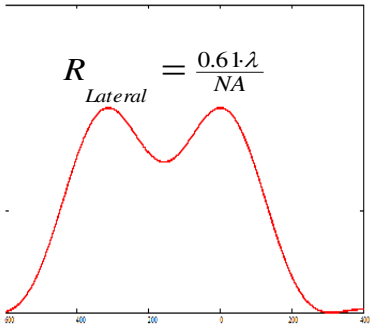


Lateral (XY) spatial resolution

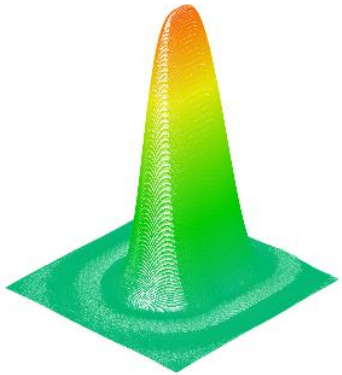
λ=488 nm, NA=0.95

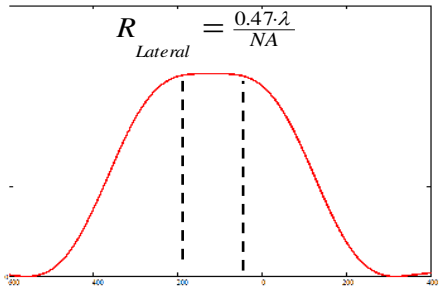
Rayleigh criterion (313 nm)



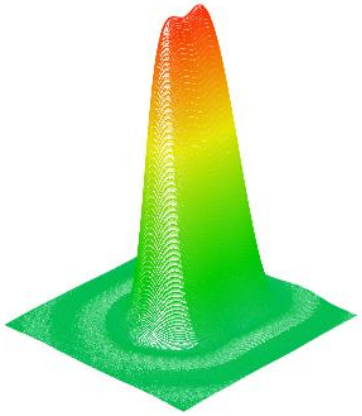


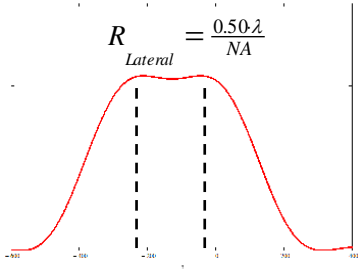
Sparrow criterion (241 nm)



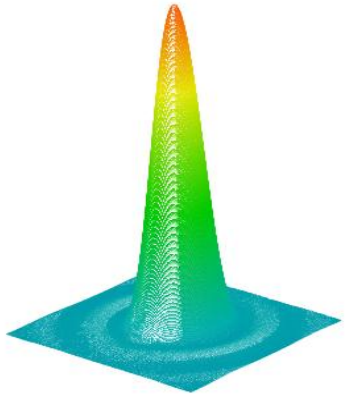


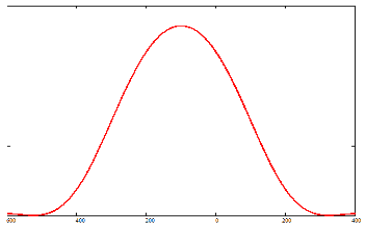
Abbe criterion (257 nm)





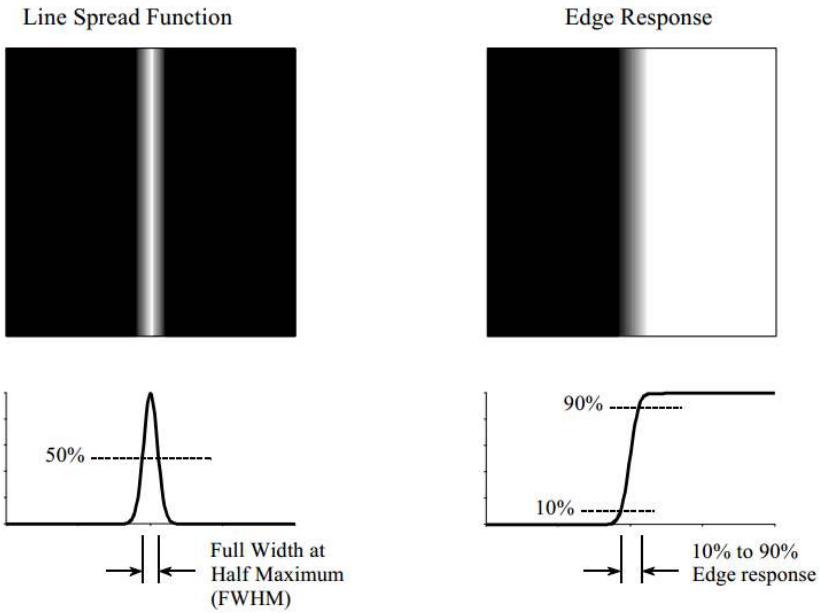
Unresolved





Experimental estimation of spatial resolution

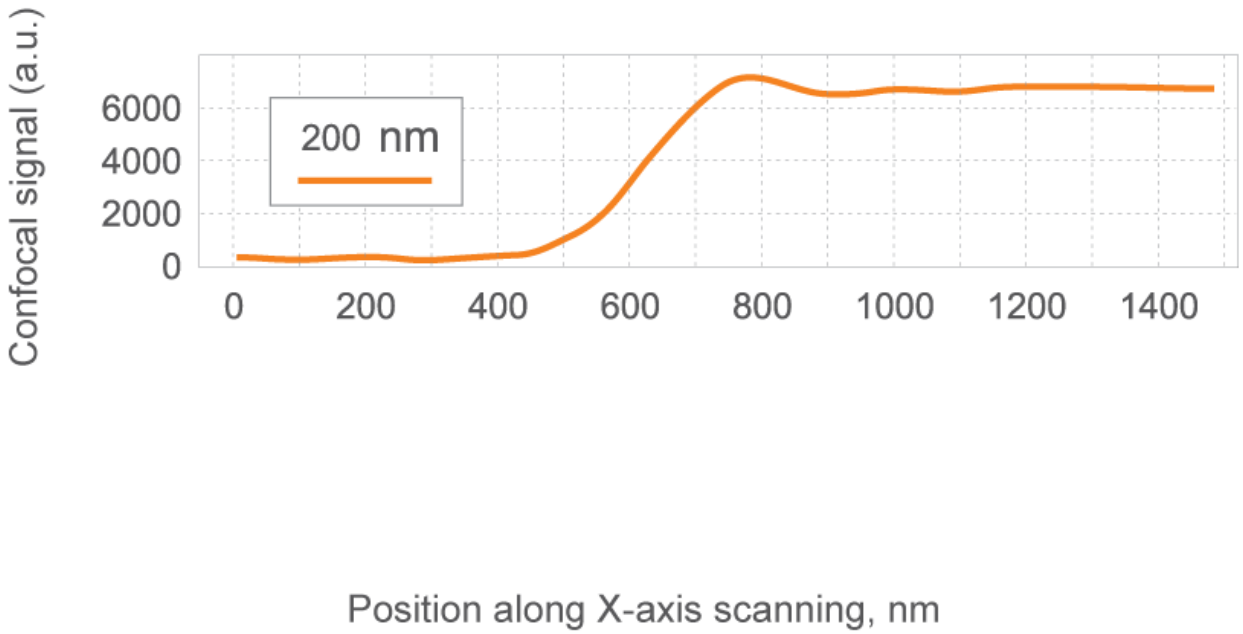
Lateral resolution estimation (XY resolution):



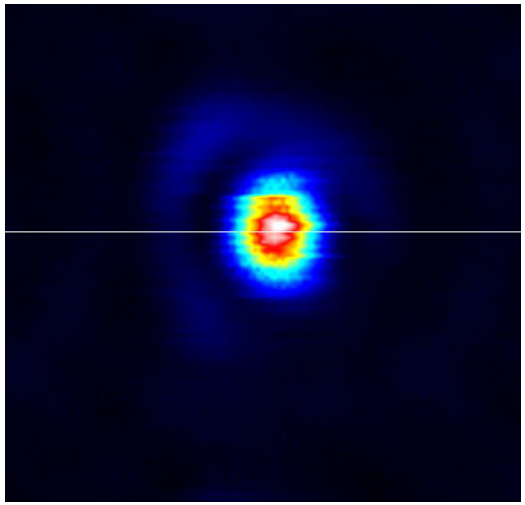
The line spread function (LSF) is the derivative of the edge response.
The width of the LSF is usually expressed as the Full-Width-at-Half-Maximum (FWHM).
The width of the edge response is usually quoted by the 10% to 90% distance.

Axial resolution estimation (Z resolution): Defocus Response

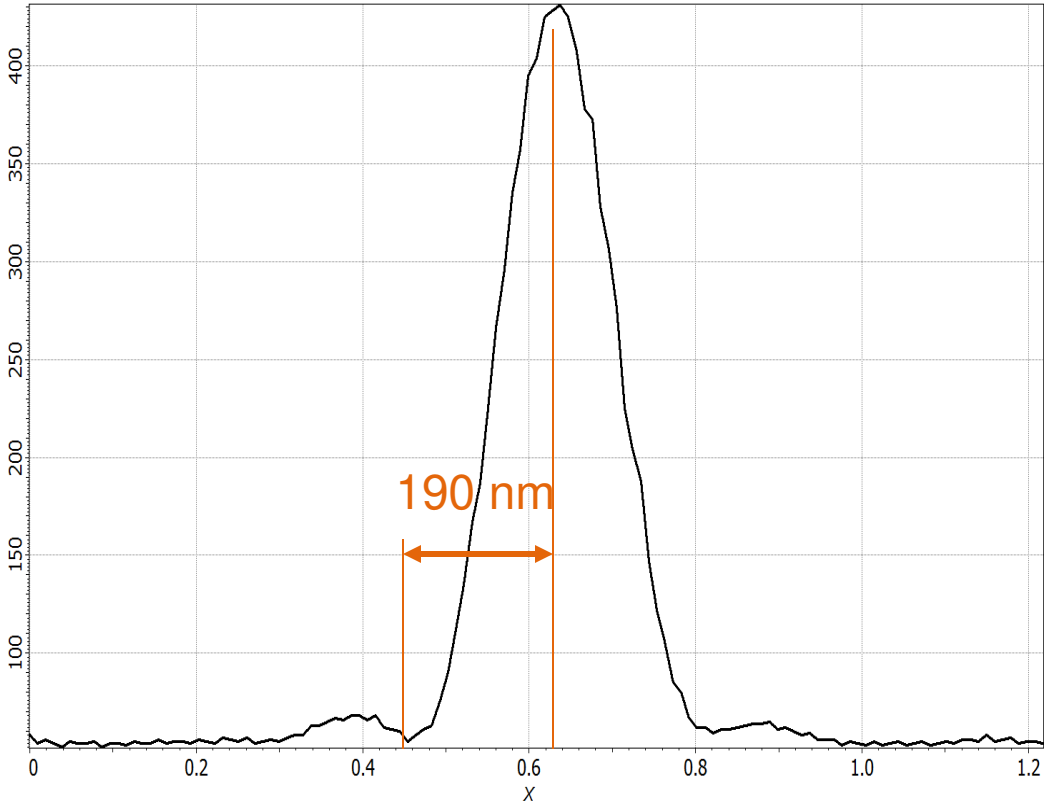
Si edge response function



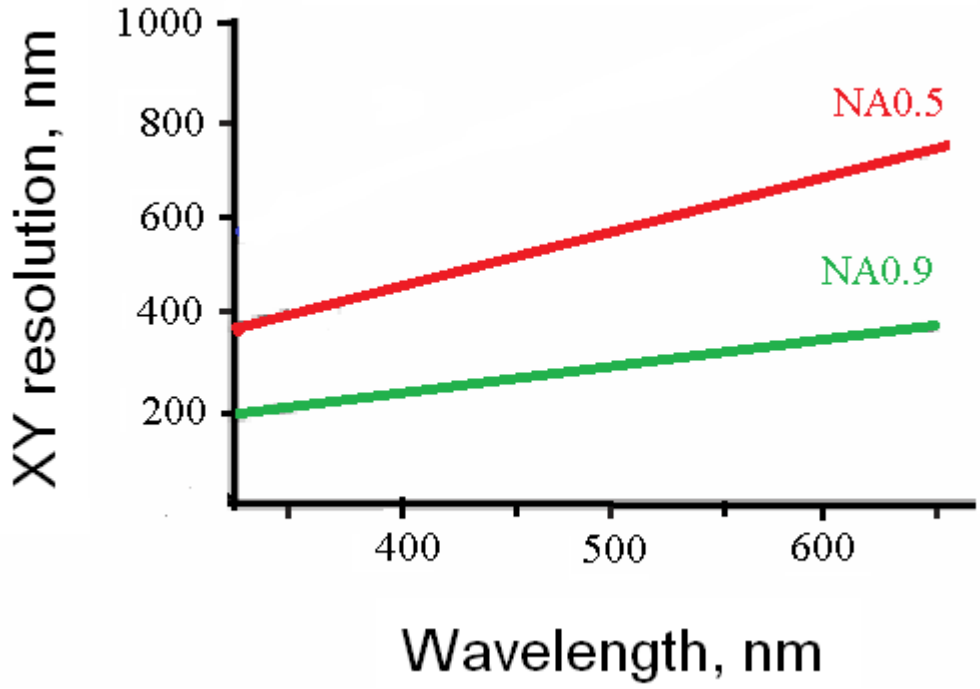
Point Spread Function: Experimental measurement



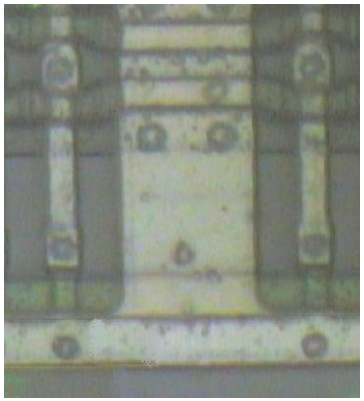
UV laser reflection,
NA=0.95



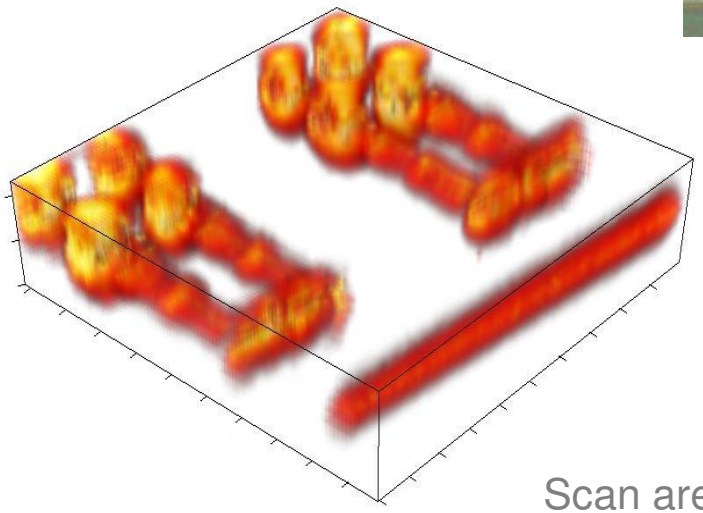
Lateral spatial resolution



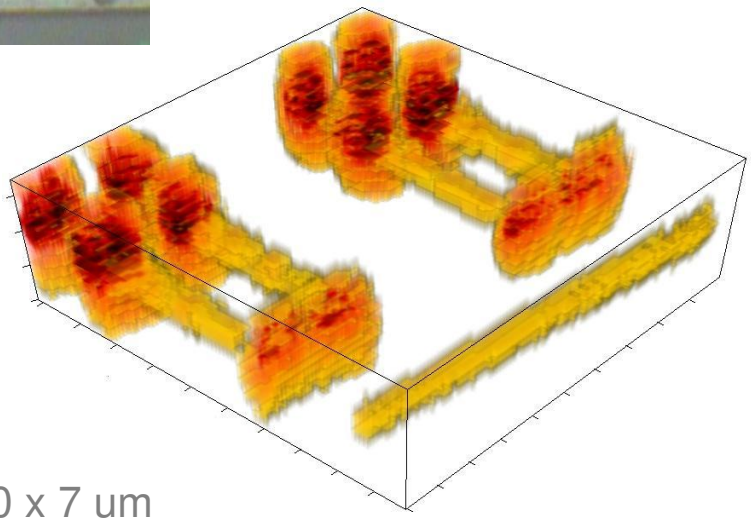
3D Raman imaging capability



Intensity distribution (Si peak)



Si peak position



Scan area: 50 x 50 x 7 um

Spatial resolution enhancement techniques in microscopy

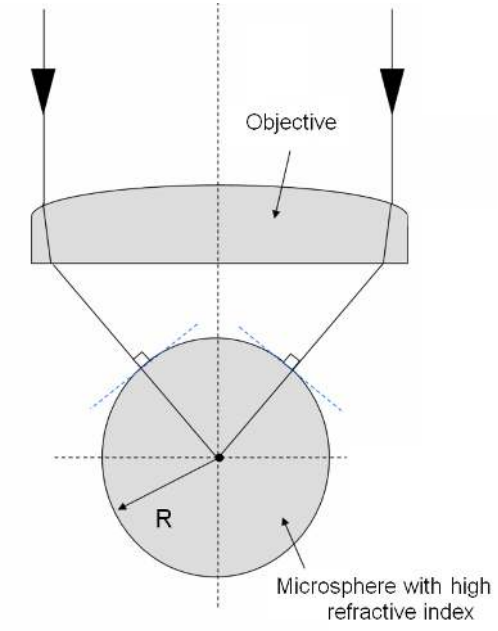
Several approaches and methods for further spatial resolution improvement below the diffraction limit:

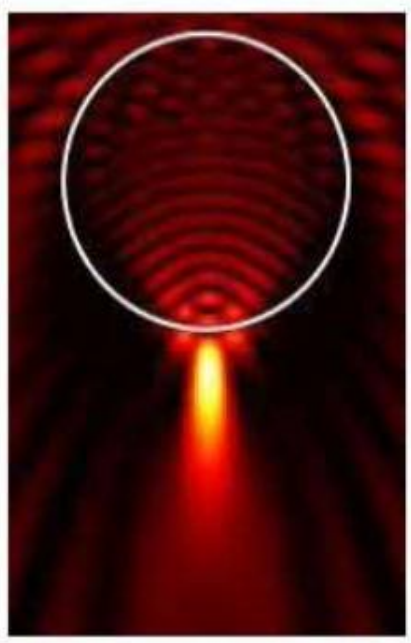
Nanojet (Near-field Raman imaging using an optically trapped dielectric microsphere)

Special illumination / detection (structured laser beam illumination)

Tip Enhanced Raman scattering

New technique: Photonic nanojet enhancement

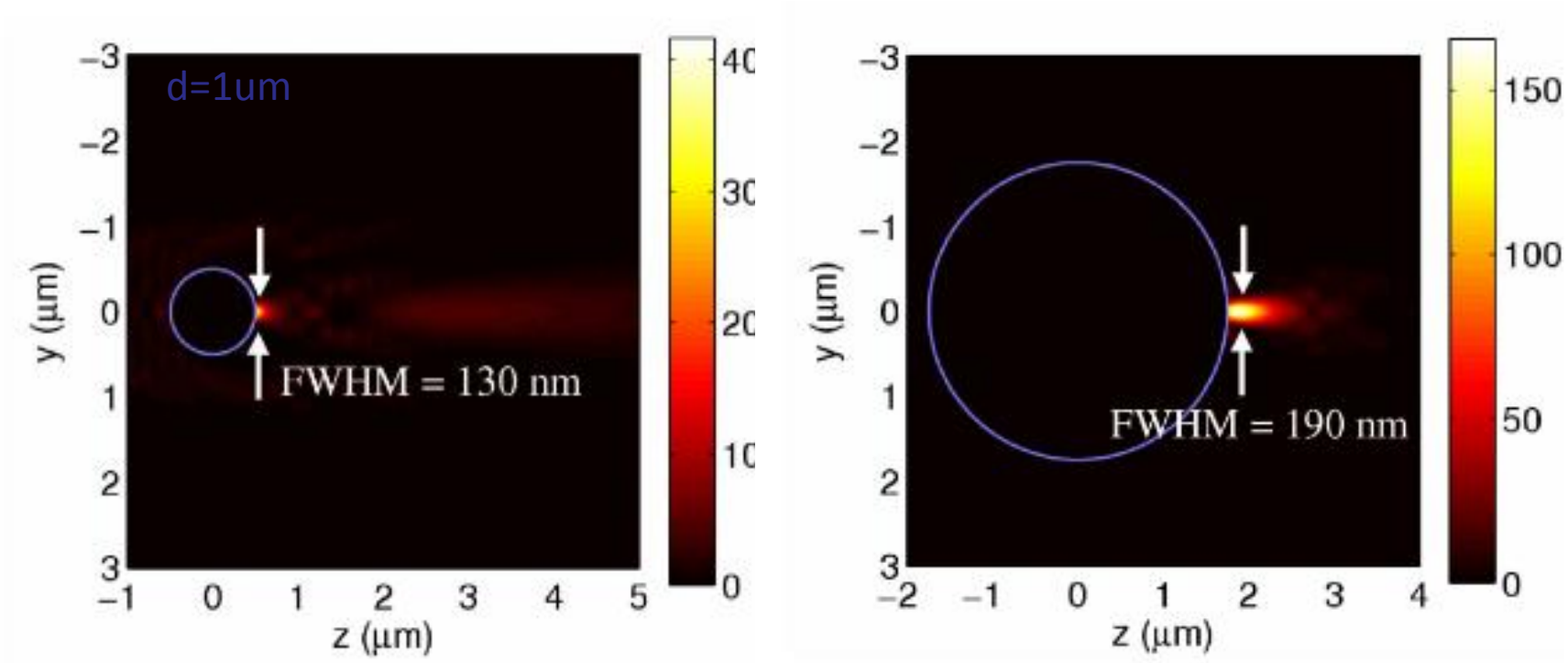




- Spatial Resolution can be achieved bellow diffraction limit
- Raman signal may be enhanced by small particle

Photonic nanojet: Finite-difference time-domain (FTDT) simulation

Photonics nanojets produced by polystyrene microspheres
(n1=1.59, n2=1, λ=400nm):



Li, X., Z. Chen, A. Taflove, and V. Backman, Optics Express, 2005. 13(2): p. 526-533

Microsphere super-resolution focusing (nanojet) key properties

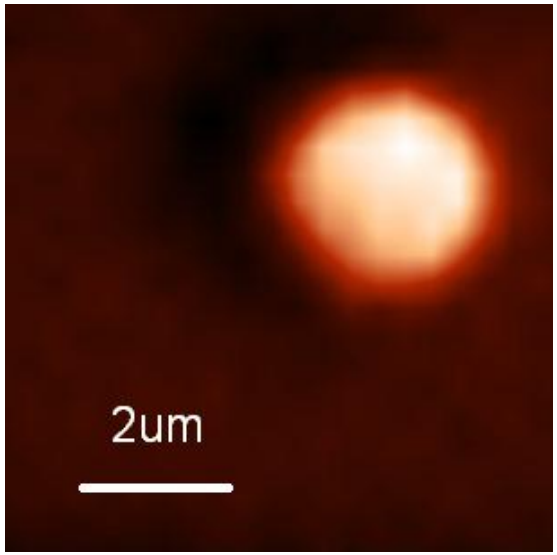
1. The transverse beam diameter of the nanojet can reach $\lambda/2n$, where λ is light wavelength and n is the refractive index of particle. In case of a polystyrene particle with n=1.6, the resolution limit is about 0.313λ.

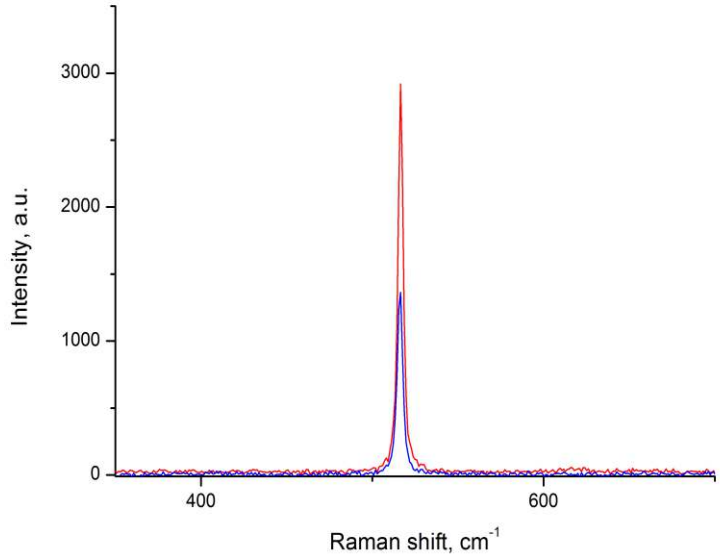
2. Nanojet can appear for a certain range of the diameter of the dielectric microsphere from 2λ to more than 40λ.

Nanoscience, 2016, 3, 193-210

Raman signal enhancement by a small particle

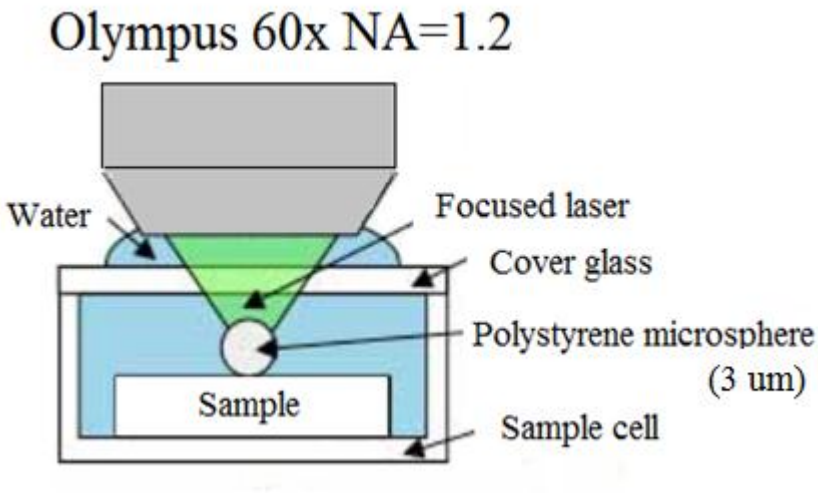
2D Raman Imaging of a polystyrene bead (λ=532nm, 100xNA0.95)





Nanojets can enhance the backscattering of visible light by several orders of magnitude.

Near-field Raman Imaging with Confotec Using Optically Trapped Dielectric Microsphere



Johnson Kasim, Yu Ting, et al.
OPTICS EXPRESS, 2008, Vol. 16, No. 11, 7976

The spot size of the beam (the full width at half maximum) was calculated to be 78 nm

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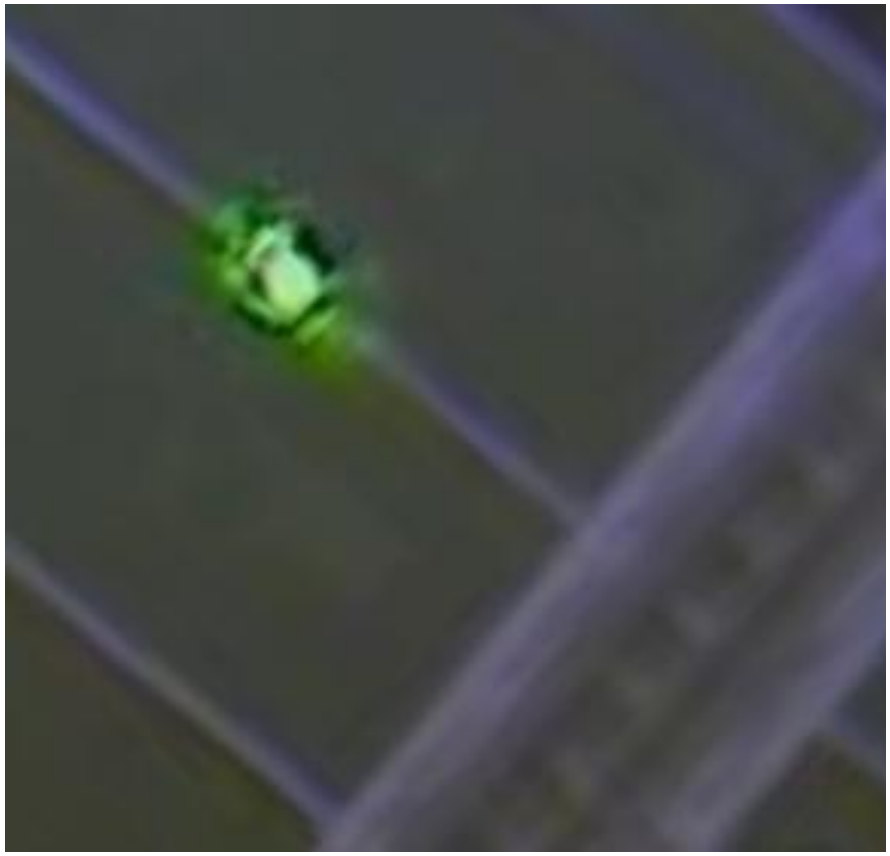
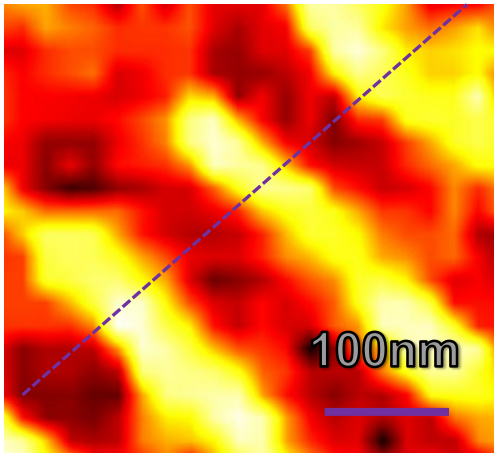
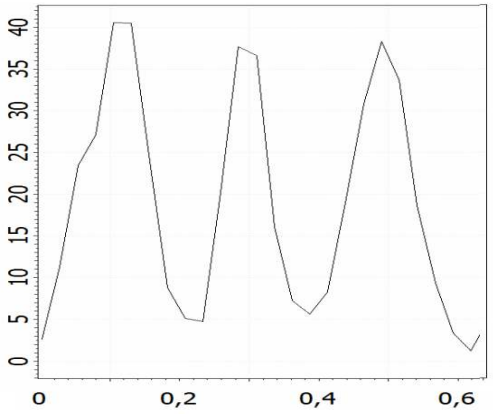
Near-field Raman Imaging with Confotec Using Optically Trapped Dielectric Microsphere

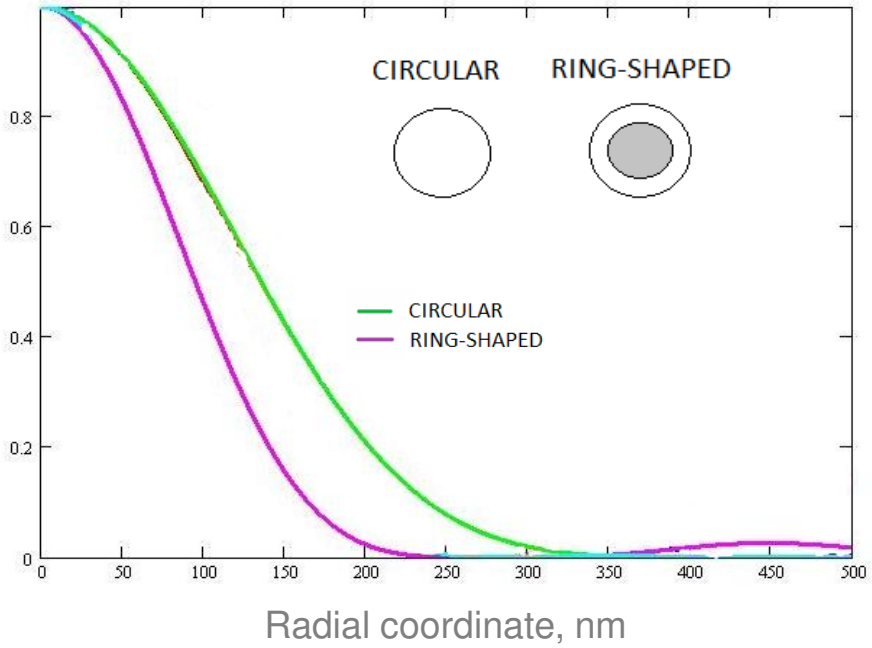






Illumination/Detection channel Tuning for Spatial Resolution Improvement

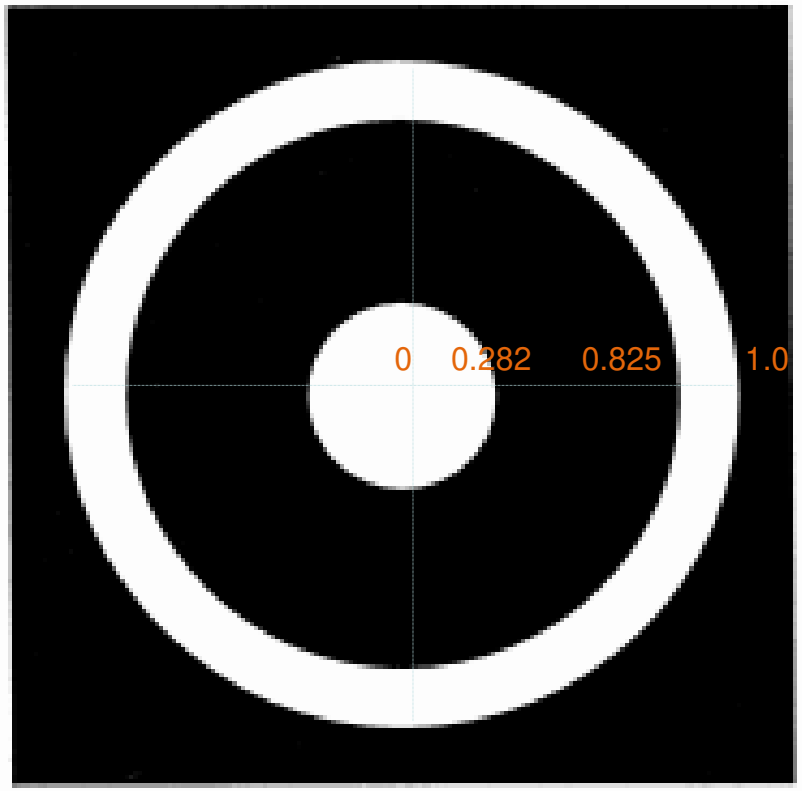
Optical system response function (PSF)

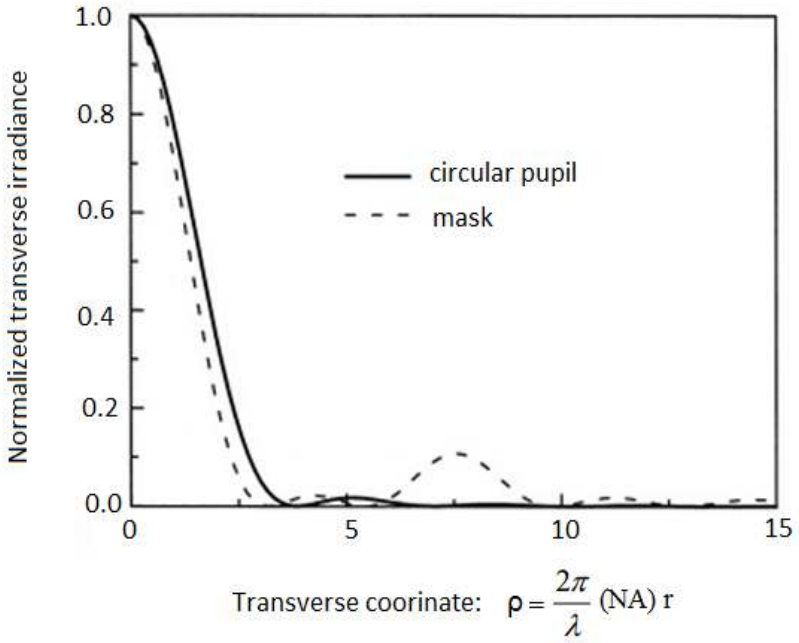


λ= 371 nm, NA=0.5

The lateral resolution with ring-shaped light Illumination is 1.18 times better than with circular illumination

Structured light Illumination





Lateral resolution (XY) is 1.17 times better
Axial resolution (Z) is 1.15 times better

Manuel Martınez-Corral, et al.
Optics Communications ,165 (1999) 267–278

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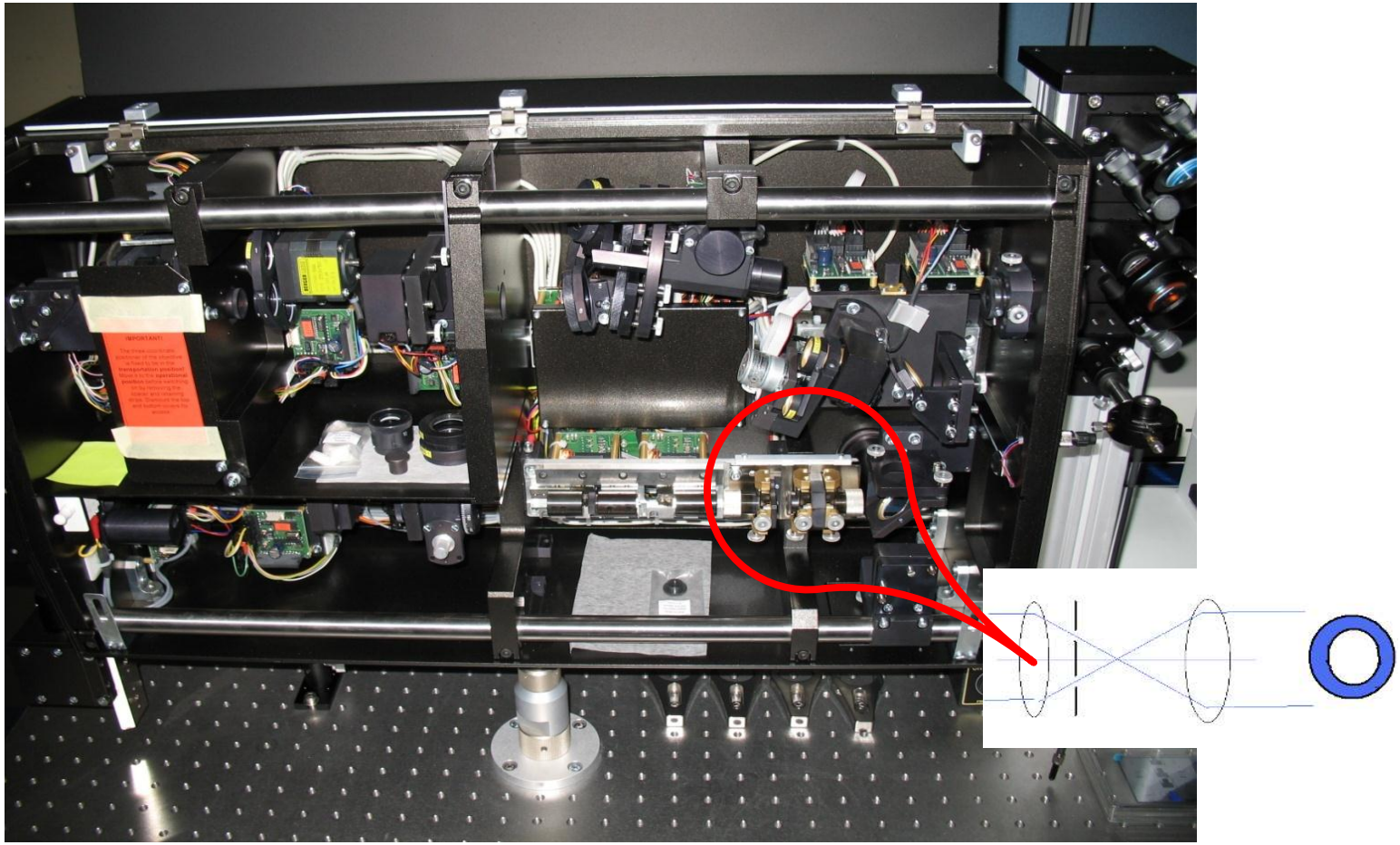
Structured light Illumination



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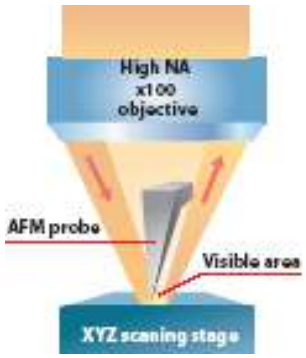
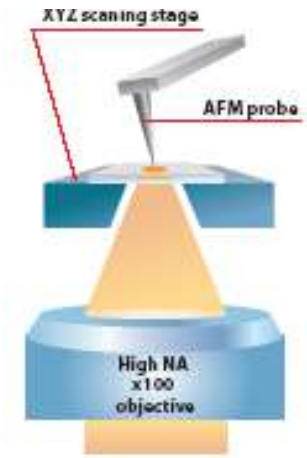
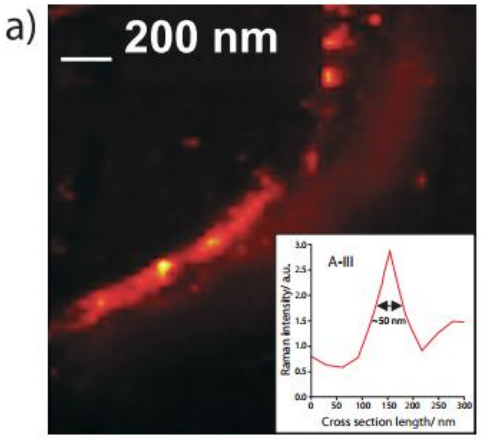
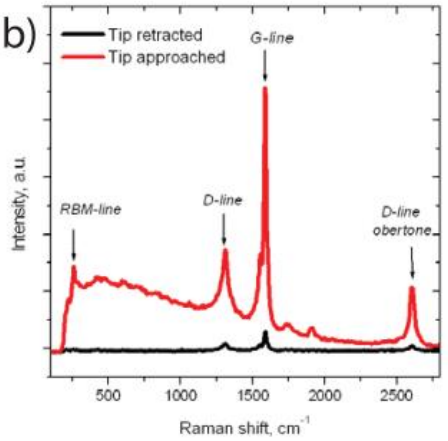
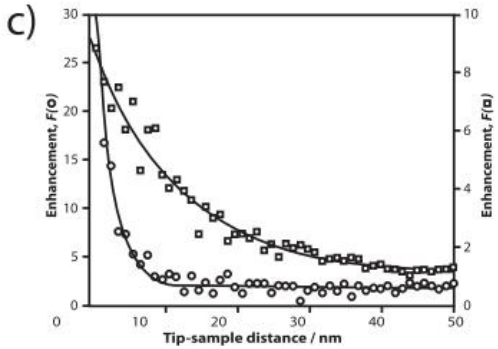
TERS (Near-field imaging) system











□ - *cantilever in non-contact mode, normal feedback*

○ - *wire on tuning fork, shear force feedback*

(a) TERS (nano-Raman) map of individual single-walled nanotube bundle. Lateral resolution is <50 nm.(b) Raman spectra from the bundle with (red) and without (black) enhancing TERS probe. (c) TERS enhancement factor vs. Tip-sample distance for vertically oscillating AFM cantilever and horizontally oscillating Au wire. S. Kharinstev, G.G. Hoffmann, P.S.Dorozhkin, G.de With and J.Loos
Nanotechnology 18 (2007), 315502

Thank you very much for your attention!

www.solinstruments.com