

**KIT** Near-field optics

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3. Near-field optics

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3.4 Scanning near-field optical microscopy : Methodology

- 3.4.1 Probe concepts and fabrication
- 3.4.2 Surface distance control
- 3.4.3 Optical characterization
- 3.4.4 Artifacts

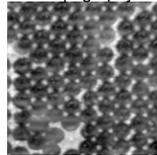
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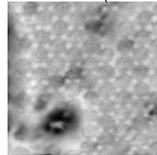
**KIT** Artifacts

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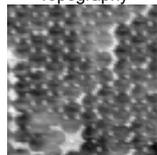
Topography



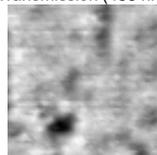
Transmission (633 nm)



Topography



Transmission (488 nm)



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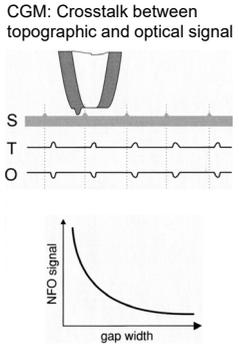
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**KIT** Topographic Artifacts

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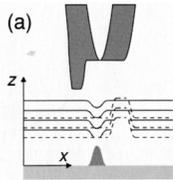
**Modes of operation:** constant gap mode (CGM) and constant height mode (CHM)

CGM: Crosstalk between topographic and optical signal

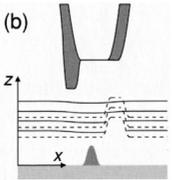


Recorded scan lines for both, CGM and CHM

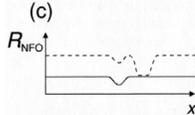
(a)



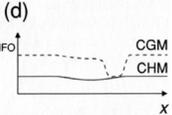
(b)



(c)



(d)



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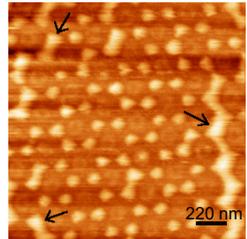
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**KIT** NSOM Image Contrast

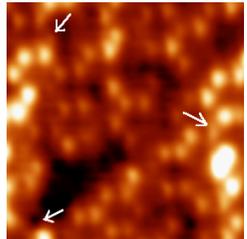
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Transmission image (CHM) of a regular metallic pattern

Topography



Transmission (CHM, inverted)



The images have not been taken simultaneously!

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Nanooptics 20/4 D. Molenda, Diploma thesis (2001)

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## Near-field optics

3. Near-field optics

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3.5 Scanning near-field optical microscopy : Applications

- 3.5.1 Single molecule imaging
- 3.5.2 Imaging of single proteins in biological membranes
- 3.5.3 Autocorrelation measurements
- 3.5.4 Fluorescence Correlation Spectroscopy
- 3.5.5 Observation of single protein transport through a biological membrane

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## Fluorescence Imaging

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## Detection of Single Molecules

### Avalanche-Photodiode

SPCM

optoelectronics.perkinelmer.com

Darkcount rate : < 50 Counts/s  
Temporal resolution : < 350 ps

Hecht (2003)

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## Imaging of Single Molecules

Betzig and Chichester, Science 262, 1422 (1993)

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**KIT** **Fluorescence of Single Molecules**

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Betzig and Chichester (1993); Veerman et al. (1999)

**KIT** **Field Components at a Circular Aperture**

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**KIT** **Field Pattern of an Oriented Dipole at a Circular Nano-Aperture**

Azimuth angle  $\phi$

Pole angle  $\theta$

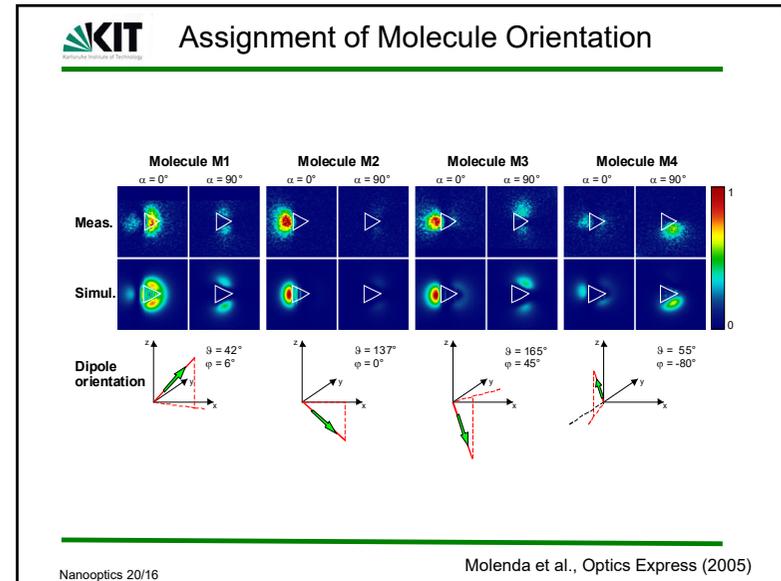
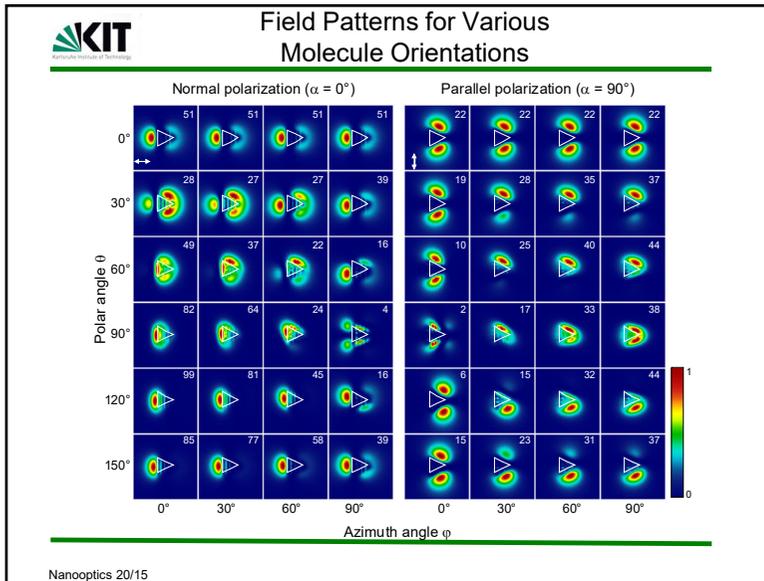
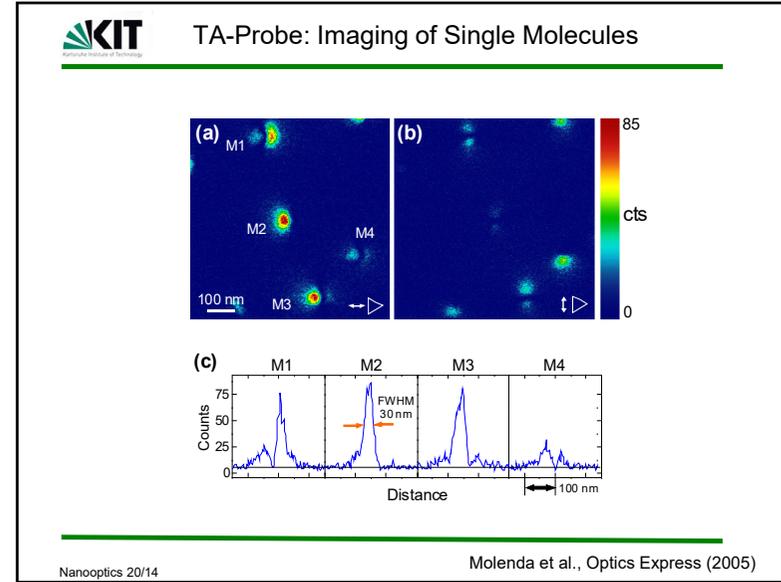
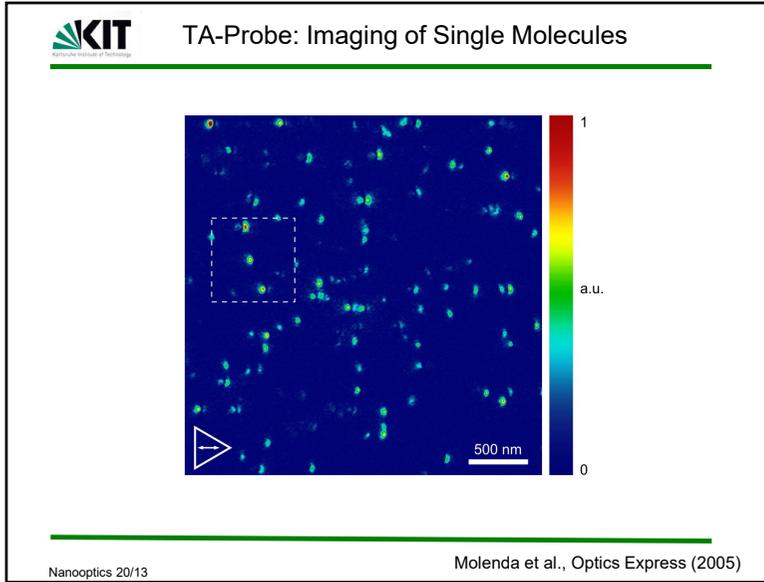
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Veerman et al. (1999)

**KIT** **Blinking of Single Molecules**

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Moerner & Orrit, Science 283, 1999



**KIT** TOA-Probe: Single Molecule Microscopy

The figure shows a schematic of a TOA-Probe setup at the top, where a probe tip is positioned above a surface. Below this is a large fluorescence image showing individual molecules. At the bottom left, a line scan plot shows 'Counts per pixel' on the y-axis (0 to 200) and 'Position (nm)' on the x-axis (0 to 80). The plot shows a peak in counts corresponding to a molecule's position. To the right of the plot is a zoomed-in view of a single molecule.

Nanooptics 20/17 Frey et al., PRL 2004

**KIT** TOA-Probe: Single Molecule Microscopy

The figure displays four panels of fluorescence images: (a) shows a molecule with a yellow spot; (b) shows a molecule with a white spot; (c) shows a molecule with a green spot at various angles (10°, 15°, 20°, 25°, 50°, 55°, 100°, 165°); (d) shows a molecule with a green spot at various angles (5°, 10°, 15°, 165°). To the right is a schematic of a 'tip dipole' with a vertical double-headed arrow and a 'dye' molecule below it with a horizontal double-headed arrow. Below the schematic is a 2x4 grid of fluorescence images showing different orientations.

Nanooptics 20/18 Frey et al., PRL 2004

**KIT** Optical Nanoantenna

**Purcell-Effect**  
By increasing the density of final states  $\rho$  for the photons emitted from a molecule its spontaneous life time  $\tau$  will decrease.

The figure includes an SEM image (a) of a gold trimer antenna, a color-coded intensity map (b) showing the antenna's structure, and a plot (c) of 'Photoluminescent Intensity (a.u.)' versus distance  $z$  (nm) from 0 to 40. The plot shows a sharp peak at  $z=0$  and a much lower intensity at  $z=40$ . An inset shows a C<sub>60</sub> fullerene molecule.

**Figure 5 | Example of a bottom-up fabricated optical antenna.** a, SEM image of a gold trimer antenna consisting of gold nanoparticles supported by a dielectric tip. The particle sizes are 180, 90 and 50 nm. b, Computed intensity near a trimer antenna irradiated at a wavelength of 650 nm. Adjacent contour lines differ by a factor of two in intensity. c, Fluorescence from a metallofullerene (Y<sub>2</sub>Ni@C<sub>60</sub>, pictured inset) as a function of its distance from a gold nanoparticle antenna. Because of the low intrinsic quantum yield of Y<sub>2</sub>Ni@C<sub>60</sub>, the antenna enhances the fluorescence by two orders of magnitude. Figure c reproduced with permission from ref. 98, © 2010 ACS.

Nanooptics 20/19 Novotny and Hulst, Nature Photonics (2011)

**KIT** Oral Exams

**Available dates**

- Mo, 26.02.2024
- Mo, 08.04.2024

Please send me an e-mail with your preferences.  
E-Mail: [naber@kit.edu](mailto:naber@kit.edu)

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