MICRONOVA
CENTRE FOR MICRO- AND NANOTECHNOLOGY
TKK – HELSINKI UNIVERSITY OF TECHNOLOGY

NANO-OPTICS AND OPTICAL COHERENCE

OPTICS AND MOLECULAR MATERIALS

NANO-OPTICS AND LASER PHYSICS GROUP

Optical near field refers to the electromagnetic field at the immediate vicinity of the sample where the evanescent or non-propagating waves are strong. The near field is a primary example of a highly non-paraxial field and, in general, it is composed of three orthogonal electric field components. The conventional tools of electromagnetic coherence theory are, however, valid mainly for beam-like fields. We have put forward the definitions for the degree of polarization of general three-dimensional fields and for the electromagnetic degree of coherence. Currently, we are investigating the optical coherence in a near-field detection system, tightly focused electromagnetic fields (Figure 1), and systems consisting of interacting metallic nanocylinders exhibiting plasmon resonances.

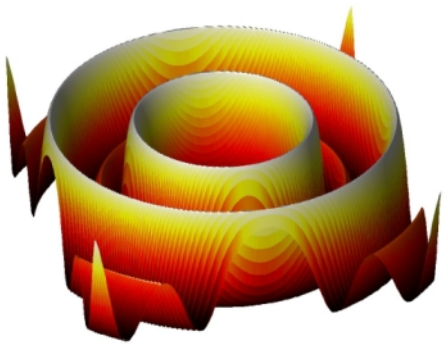

Figure 1. The distribution of the degree of polarization in the focal plane of an imaging system of numerical aperture 0.9. The incident field is taken to be unpolarized in the two-dimensional sense.

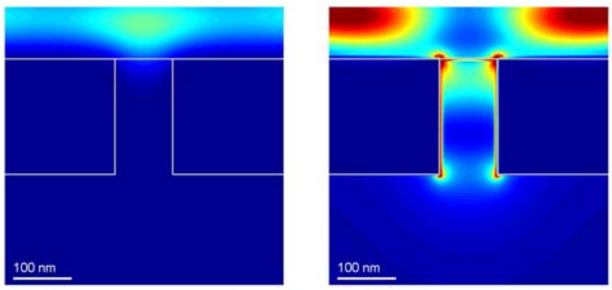

Figure 2. Intensity ($|E|^2$) distributions for s-polarized (above) and p-polarized (below) light (λ = 532.5 nm) around a nanoslit structured on aluminum film on a glass substrate.

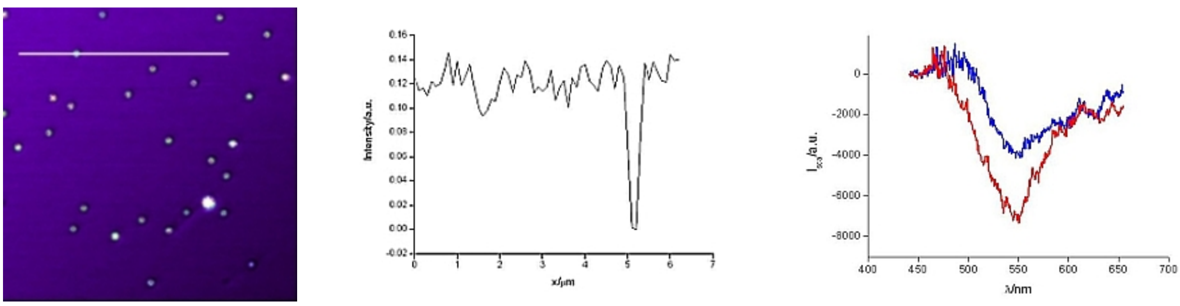

Figure 3. A confocal microscope image of 15 nm gold particles (left). The cross sections demonstrates the excellent focusability of our white-light source (middle). The scattering spectrum of two separate 10 nm gold particles (right).

We study experimentally the detection and spectroscopy of very small gold nanoparticles. Such particles are an interesting model system to study the transition from individual atoms to the optical properties of bulk matter. Nanoparticles also have important applications in chemical sensing and as labels in biology. In our first experiments we used supercontinuum light produced in a photonic crystal fibre to detect sub 10-nm gold particles. Figure 3 displays (on the left) a confocal microscope image of 15 nm gold particles. The cross section in the middle shows that the supercontinuum light can be focused to almost a diffraction limited spot.

The spectrum of the light scattered by an individual particle is shown on the right. The scattering spectrum displays a clear resonance which can be used to distinguish gold nanoparticles from other scatterers in a biological medium. This work was performed in the nano-optics group of professor Vahid Sandoghdar at ETH Zürich. We are currently continuing this work at HUT with experiments on the absorption spectroscopy of individual metallic nanoparticles.

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Recent Publications:

1. J. Lindberg, T. Setälä, M. Kaivola, and A.T. Friberg, *Spatial coherence effects in light scattering from metallic nanocylinders*, J. Opt. Soc. Am. A, accepted for publication.
2. M. Hautakorpi, J. Lindberg, T. Setälä, and M. Kaivola, *Rotational frequency shifts in partially coherent optical fields*, J. Opt. Soc. Am. A, accepted for publication.
3. K. Lindfors, T. Setälä, M. Kaivola, and A.T. Friberg, *Degree of polarization in tightly focused optical fields*, J. Opt. Soc. Am. A **22**, 561 (2005).
4. T. Setälä, J. Lindberg, K. Blomstedt, J. Tervo, and A.T. Friberg, *Coherent-mode representation of a statistically homogeneous and isotropic electromagnetic field in spherical volume*, Phys. Rev. E **71**, 036618 (2005).
5. M. Hautakorpi and M. Kaivola, *Modal analysis of M-type-dielectric-profile optical fibers in the weakly guiding approximation*, J. Opt. Soc. Am. A **22**, 1163 (2005).
6. T. Jouttenus, T. Setälä, M. Kaivola, and A. T. Friberg, *Connection between electric and magnetic coherence in free electromagnetic fields*, Phys. Rev. E **72**, 046611 (2005).
7. K. Blomstedt, T. Setälä, and A. T. Friberg, *Effect of absorption on the spatial coherence in scalar fields generated by statistically homogeneous and isotropic sources*, Phys. Rev. E **72**, 056604 (2005).
8. J. Lindberg, K. Lindfors, T. Setälä, M. Kaivola, A.T. Friberg, *Spectral analysis of resonant light transmission through a single sub-wavelength slit,* Opt. Express **12**, 623-632 (2004).
9. K. Lindfors, T. Kalkbrenner, P. Stoller, and V. Sandoghdar, *Detection and spectroscopy of gold nanoparticles using supercontinuum white light confocal microscopy*, Phys. Rev. Lett. **93**, 037401 (2004).
10. K. Lindfors, M. Kapulainen, P. Ryytty, and M. Kaivola, *High-sensitivity piezo-electric tube sensor for shear-force detection in scanning near-field optical microscopy*, Opt. Laser Tech. **36**, 651-656 (2004).
11. J. Lindberg, T. Setälä, M. Kaivola, and A.T. Friberg, *Degree of polarization in light transmission through a near-field probe*, J. Opt. A: Pure Appl. Opt. **6**, S59-S63 (2004).