Elements of Nanophotonics

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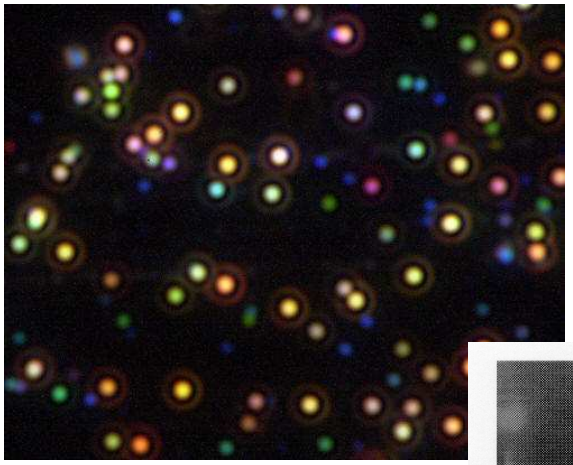
Information, script, etc:
http://nano.physik.hu-berlin.de/lehre/nanophotonics

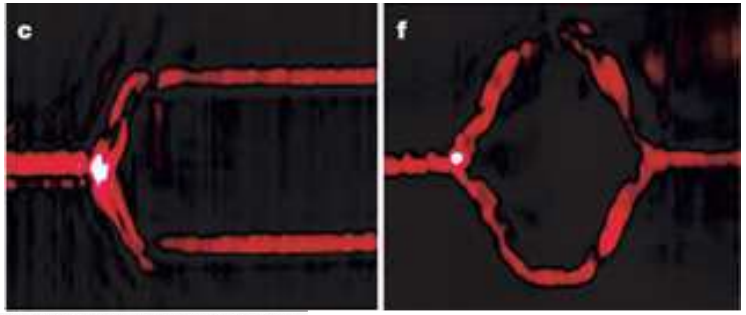
Contents

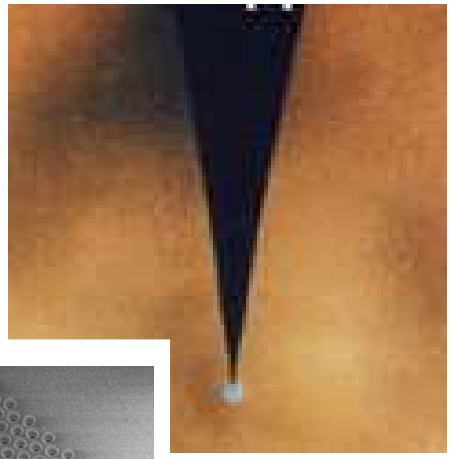
Literature

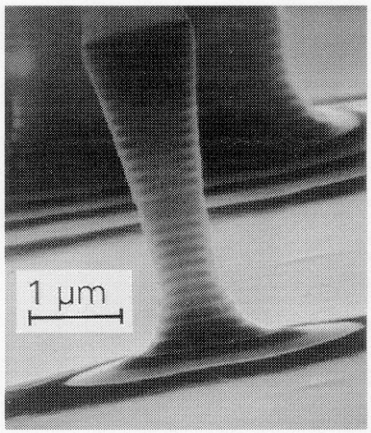
- L. Novotny, B. Hecht, „Nano-Optics“, Cambridge
- S. Maier, „Plasmonics – Fundamentals and Applications“, Springer
- P. N. Prasad, “Nanophotonics”, Wiley
- S. Kawata, M. Ohtsu, M. Irie, „Nano-Optics“, Springer
- additional literature and recent papers during the lecture

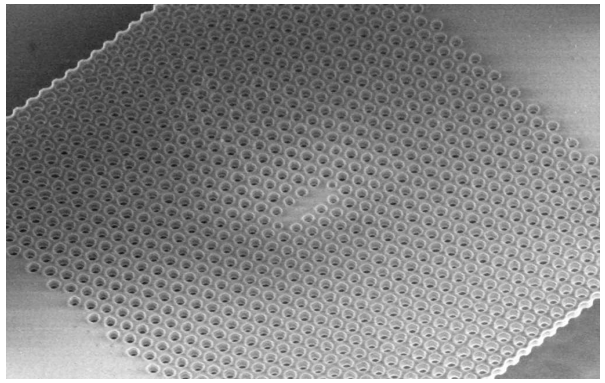
Nano-Photonic Structures

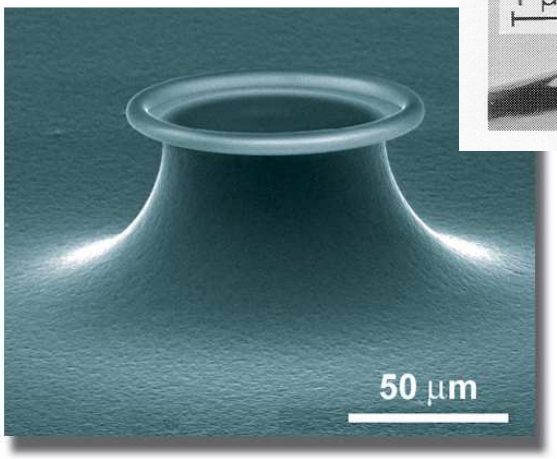


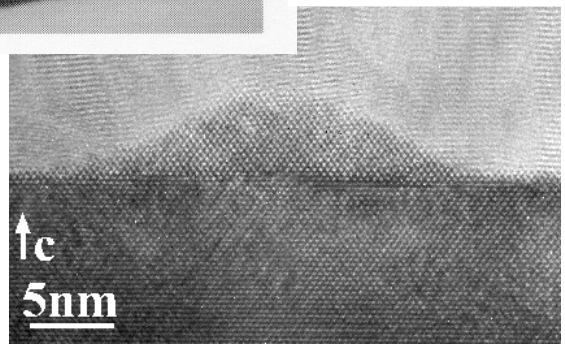


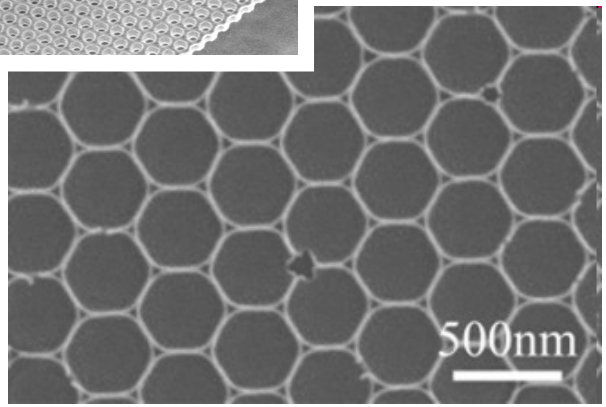












Diffraction Limit in Nano Optics

In free space: light propagation determined by dispersion relation $\omega = c \cdot k$

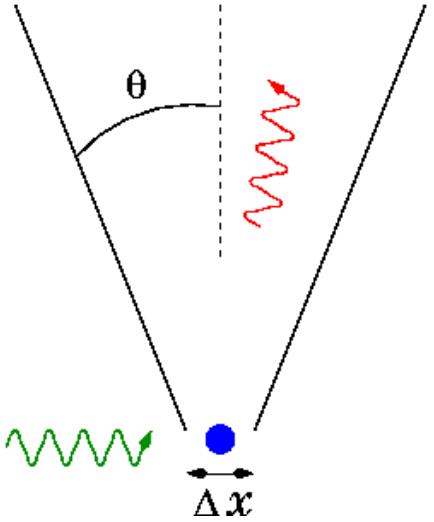
with $k = \sqrt{k_x^2 + k_y^2 + k_z^2}$

Heisenberg´s uncertainty relation between spatial position of a microscopic particle and ist momentum in the same direction:

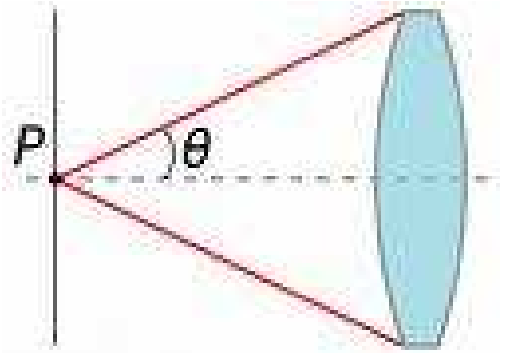
$$\Delta(\hbar k_x)\Delta x \geq \hbar/2$$

For photons behind a microscope objective this reads

$$\Delta x \approx \frac{\lambda}{2\mathrm{NA}} \qquad (\ \mathrm{NA} = \mathrm{n}\sin\theta\ )$$

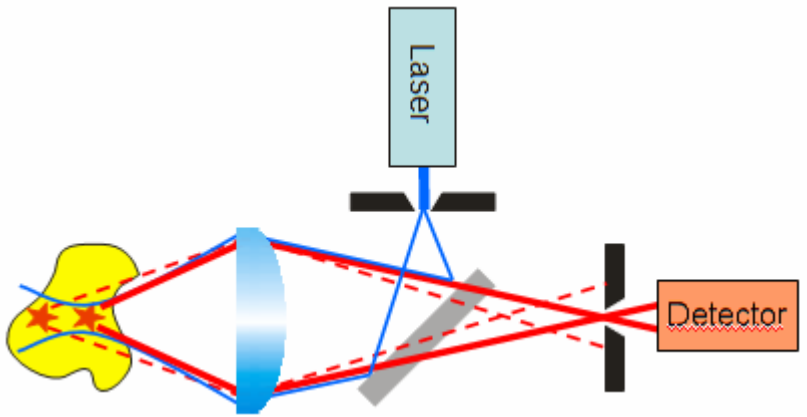


This is called the diffraction limit and sets a maximum for the resolution that can be achieved with conventional optics

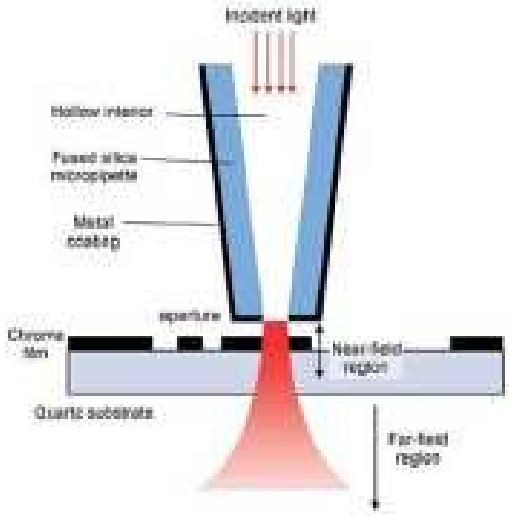


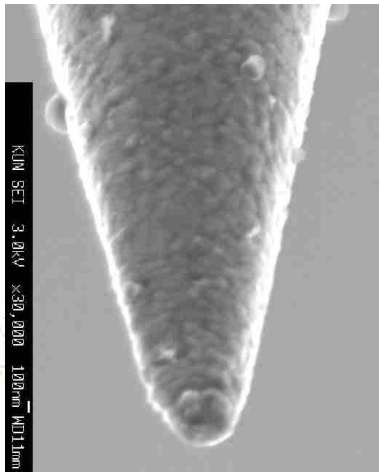
Beyond the Diffraction Limit

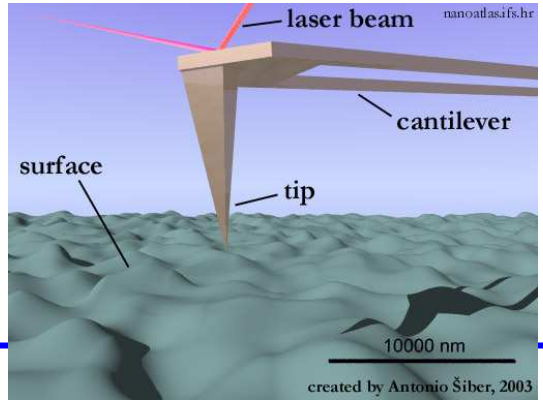
Confocal Microscopy



Scanning probe microscopy
(SNOM, AFM, …)



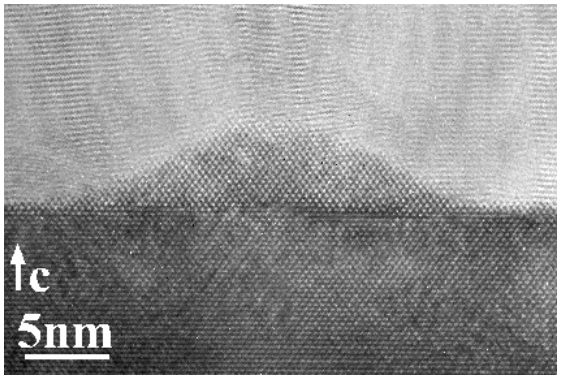




Single Quantum Emitters

Single quantum emitters (quantum dots, nanocrystals, dye molecules, …):

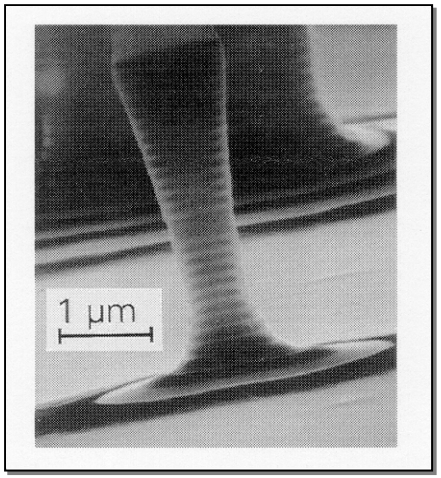
- Local probes
- Sources for single photons in quantum information processing
- Novel light devices (laser, LEDs, detectors)
- Electronic devices (single electron transistors, MOSFETs)



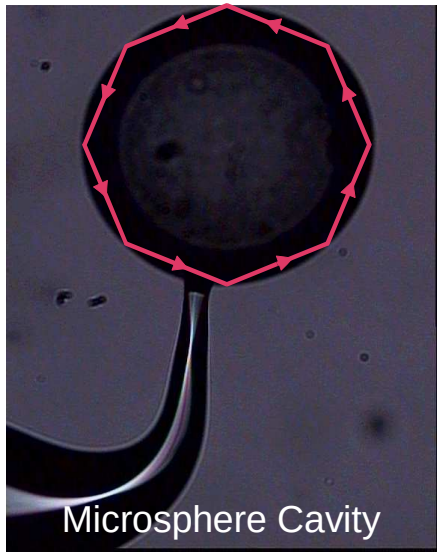
Microresonators

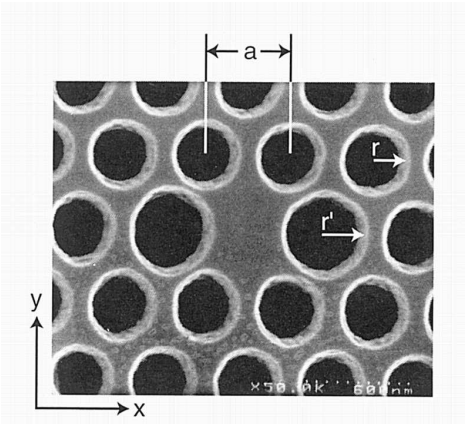
Microresonators as Efficient Traps for Light

- **Narrow resonances & tight confinement**
- Enhancement of emission rates
- Strong interaction of matter with confined light
- **Interfaces** and **quantum gates** for quantum information

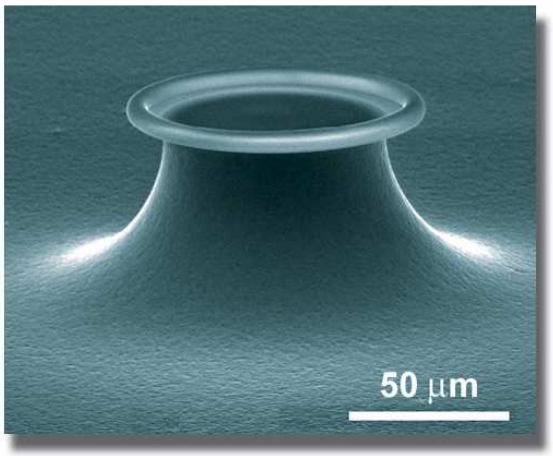


Micropillar Cavity





Photonic Crystal

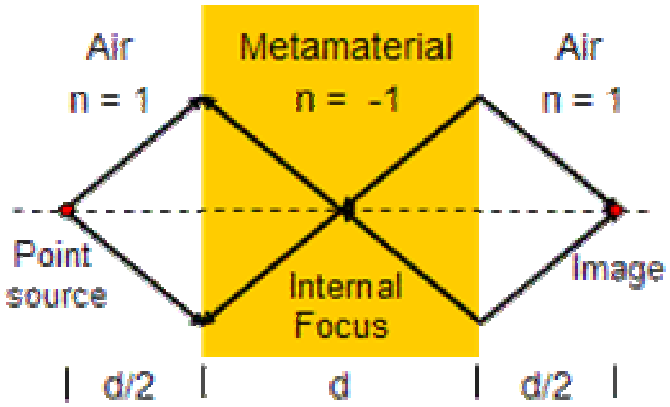


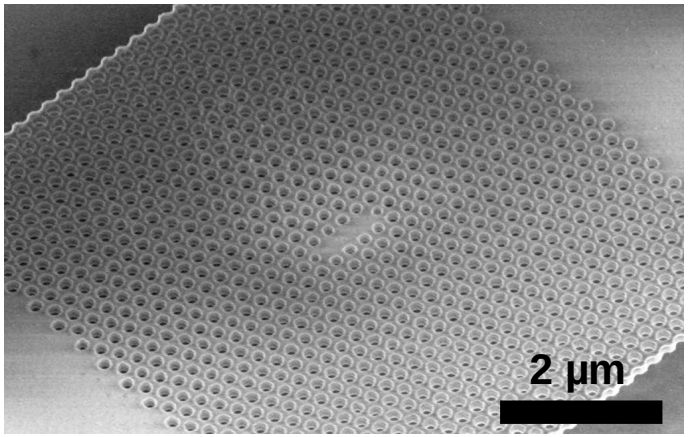
Microtoroid Cavity

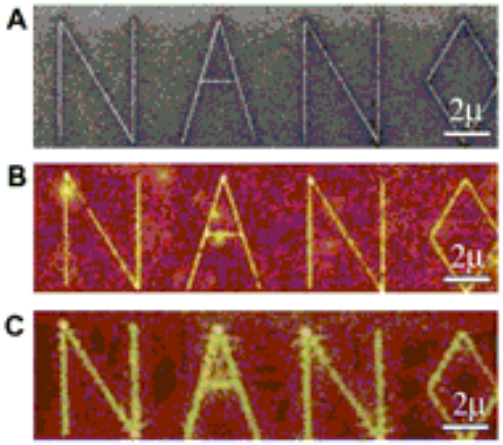
Optical Metamaterials

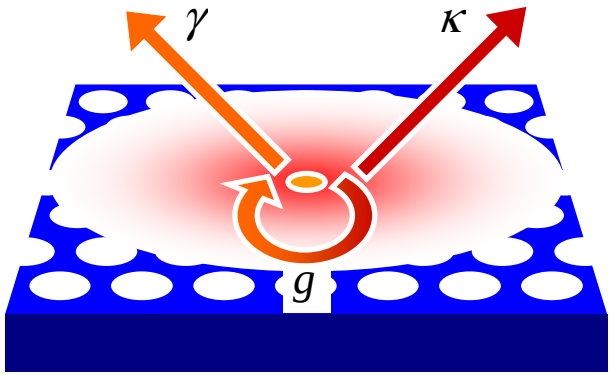
Metamaterials: artificial materials with sub-wavelength structures

► a novel „turning knob“ for controlling light propagation



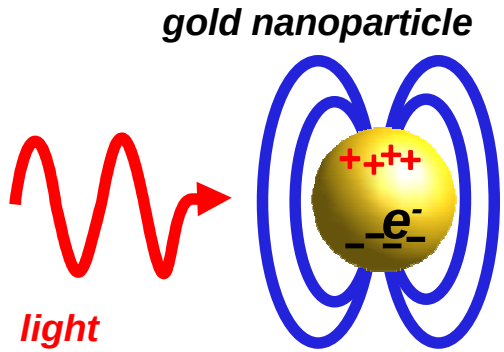


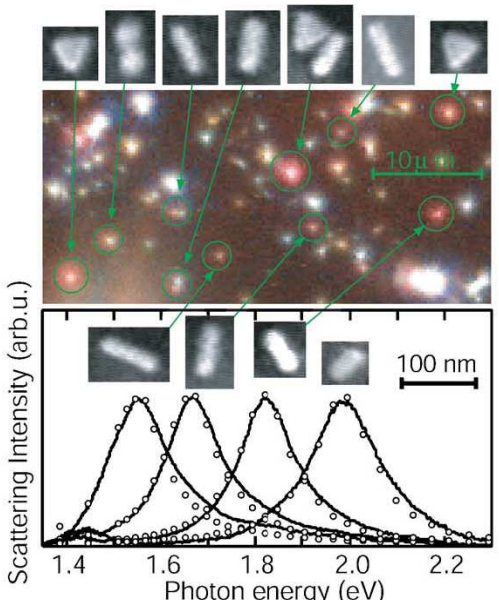




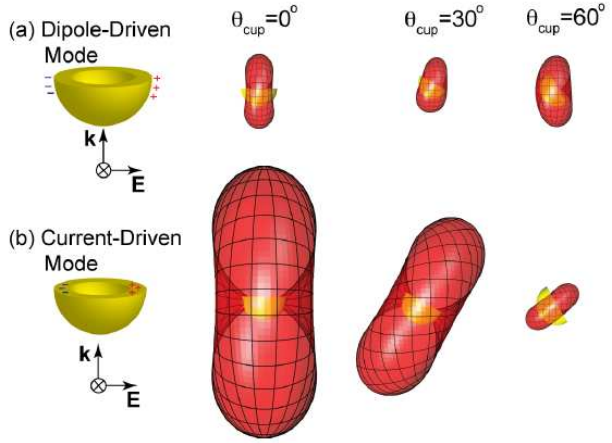
Plasmonics: Nano-Antennas

- **Plamson resonances in small particles** (<<λ): external el.mag. field causes charge oscillations
- strong resonances of the extinction
- utilization of nanoparticles as „**nano-antennas**“, to collect & redirect the emission of nano-emitters





[Maier and Atwater, JAP 98, 011101 (2005)]



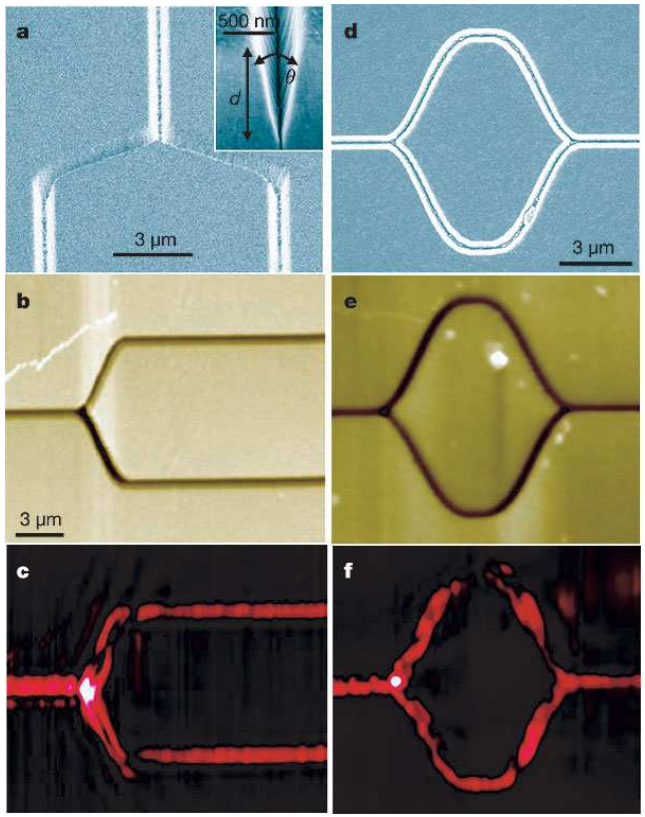
N.Halas, abstract thu2o1,
Nanometa conf.2009, Seefeld

Plasmonics: Waveguides

Light can be guided and confined on **sub-wavelength scales**

► realization of highly compact **integrated plasmonic elements**

► **interfaces** between **integrated electronics** and **optics**



passive plasmonic waveguide structures:
a beam splitter and a Mach-Zehnder interferometer

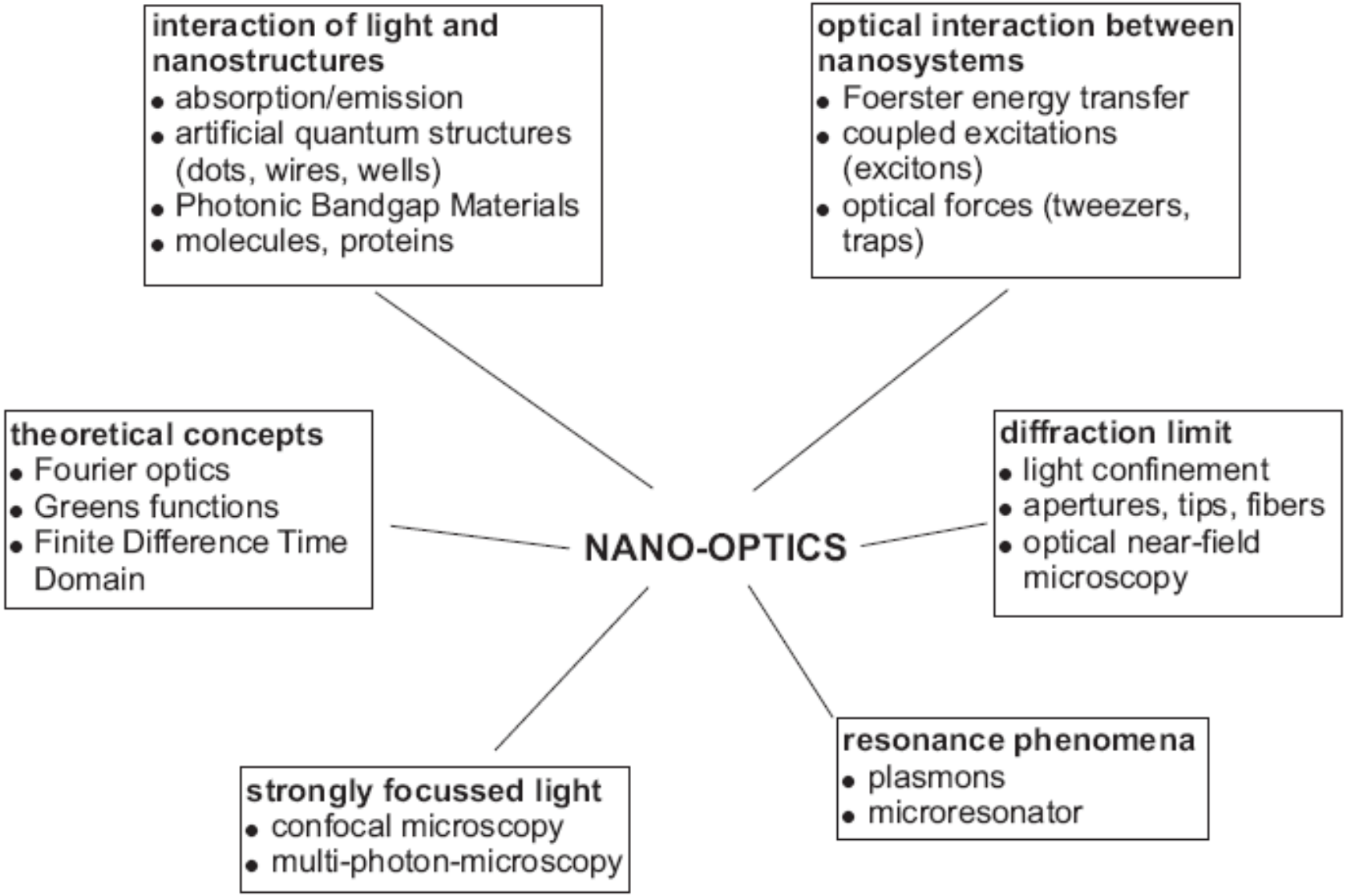
SEM images

topography

near field image

[Sergey et al., Nature 440, 508 (2006)]

Nano Optics


interaction of light and nanostructures
• absorption/emission
• artificial quantum structures (dots, wires, wells)
• Photonic Bandgap Materials
• molecules, proteins
optical interaction between nanosystems
• Foerster energy transfer
• coupled excitations (excitons)
• optical forces (tweezers, traps)
theoretical concepts
• Fourier optics
• Greens functions
• Finite Difference Time Domain
NANO-OPTICS
diffraction limit
• light confinement
• apertures, tips, fibers
• optical near-field microscopy
strongly focussed light
• confocal microscopy
• multi-photon-microscopy
resonance phenomena
• plasmons
• microresonator

Timetable

place:

NEW14,
Seminarraum 3.101

times:

Mon & Tue.,
11:15 - 13:00

Sommersemester 2009											
April			Mai			Juni			Juli		
1	Mi		1	Fr		1	Mo	Feiertag	1	Mi	
2	Do		2	Sa		2	Di	Lecture	2	Do	
3	Fr		3	So		3	Mi		3	Fr	
4	Sa		4	Mo	Lecture	4	Do		4	Sa	
5	So		5	Di	Lecture	5	Fr		5	So	
6	Mo		6	Mi		6	Sa		6	Mo	Lecture
7	Di		7	Do		7	So		7	Di	Seminary
8	Mi		8	Fr		8	Mo	Lecture	8	Mi	
9	Do		9	Sa		9	Di	Seminary	9	Do	
10	Fr		10	So		10	Mi		10	Fr	
11	Sa		11	Mo	Lecture	11	Do		11	Sa	
12	So		12	Di	Lecture	12	Fr		12	So	
13	Mo		13	Mi		13	Sa		13	Mo	Lecture
14	Di		14	Do		14	So		14	Di	Lecture
15	Mi		15	Fr		15	Mo	Lecture	15	Mi	
16	Do		16	Sa		16	Di	Seminary	16	Do	
17	Fr	Introduction	17	So		17	Mi		17	Fr	
18	Sa		18	Mo	Lecture	18	Do		18	Sa	
19	So		19	Di	Seminary	19	Fr		19	So	
20	Mo	fällt aus	20	Mi		20	Sa		20	Mo	
21	Di	fällt aus	21	Do		21	So		21	Di	
22	Mi		22	Fr		22	Mo	Lecture	22	Mi	
23	Do		23	Sa		23	Di	Lecture	23	Do	
24	Fr		24	So		24	Mi		24	Fr	
25	Sa		25	Mo	Lecture	25	Do		25	Sa	
26	So		26	Di	Seminary	26	Fr		26	So	
27	Mo	Lecture	27	Mi		27	Sa		27	Mo	
28	Di	Lecture	28	Do		28	So		28	Di	
29	Mi		29	Fr		29	Mo	Lecture	29	Mi	
30	Do		30	Sa		30	Di	Seminary	30	Do	
			31	So					31	Fr	

Seminar topics

- “Superluminal” tunneling
- Single molecule probes for the electric field
- Fluorescence spectroscopy of single molecules
- Optical tweezers
- Sub-wavelength waveguides using surface plasmons
- Quantum optics with surface plasmons
- Super lenses
- Cavity optomechanics