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ISTITUTO NAZIONALE DI OTTICA

15 febbraio 2013

Titolo:
Antenne Ottiche

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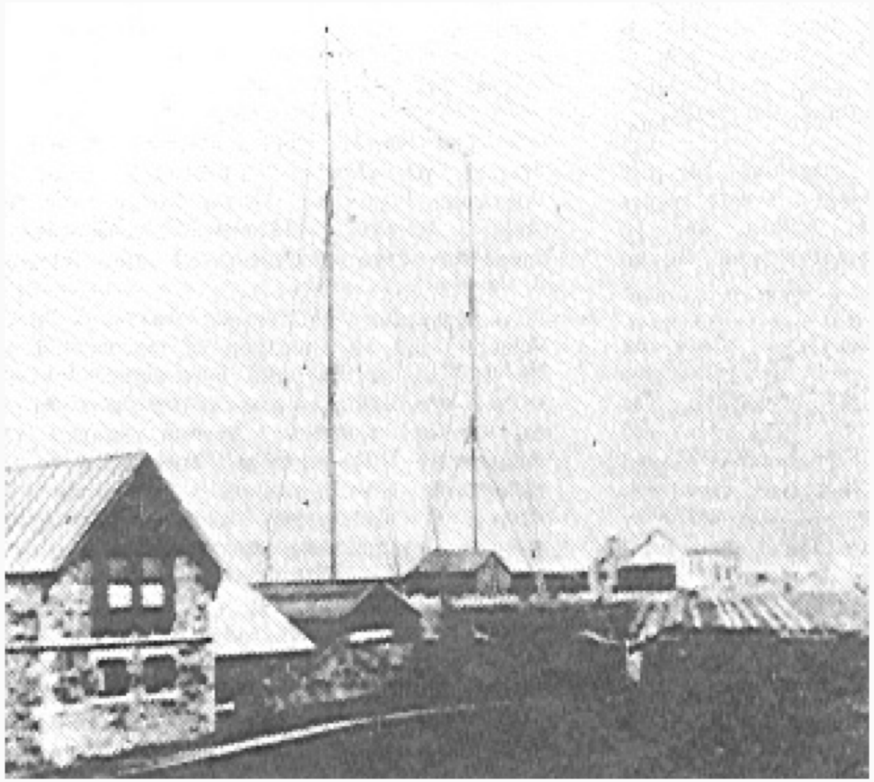
RF antennas

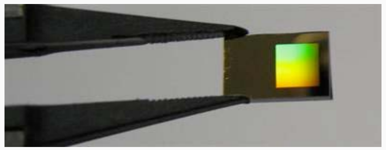


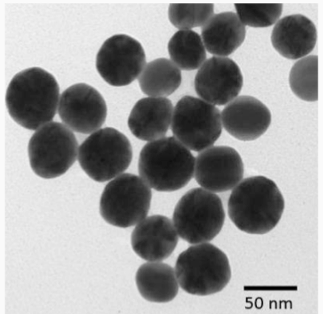
Marconi's antenna system at Poldhu, Cornwall (Dec. 1901). Photo: J. Belrose

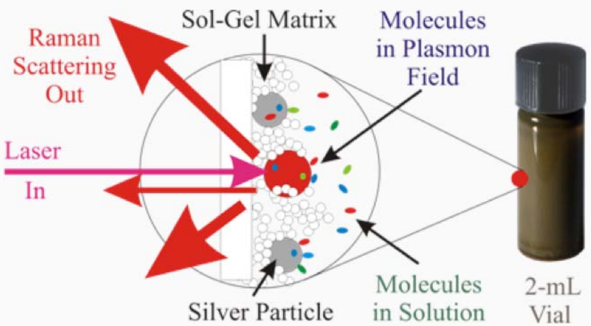
Working today!

Surface-enhanced Raman spectroscopy (SERS) systems for threat / narcotics detection:

Klarite SERS substrates – for most Raman spectrometers / D3 Technologies



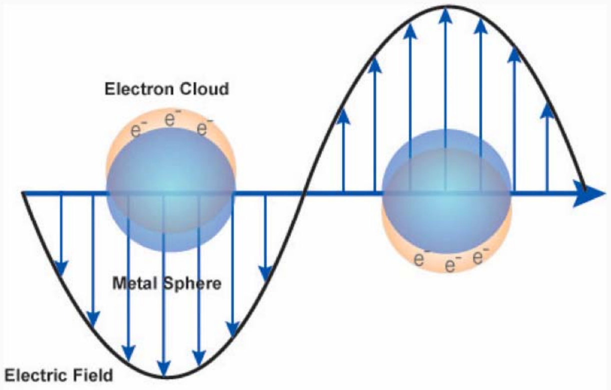


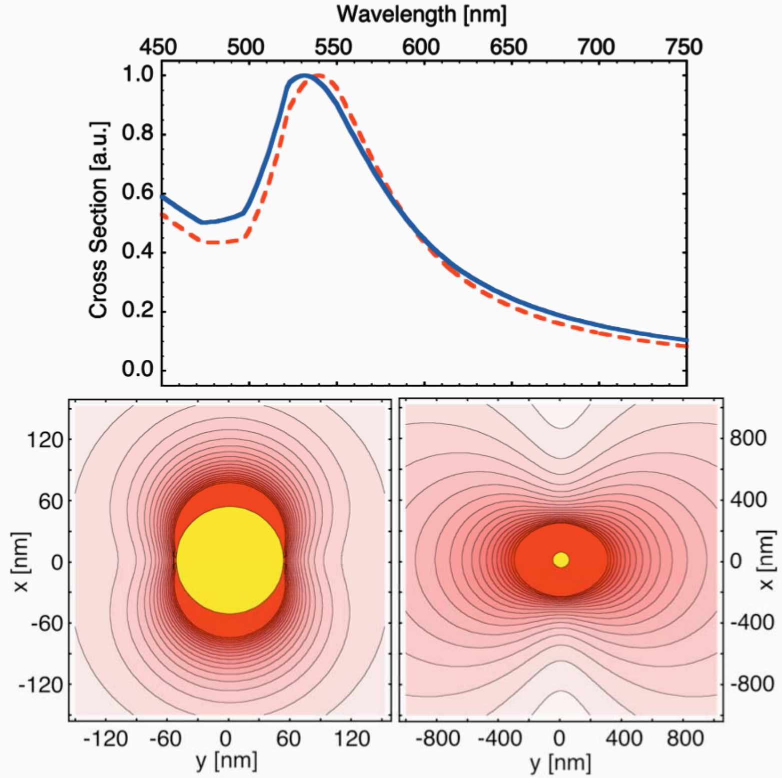


SERS vials – sol-gel substrates for liquids analysis / Real Time Analyzers, Inc.

SPP resonances

Lycurgus cup, Roman period, IV b.C.

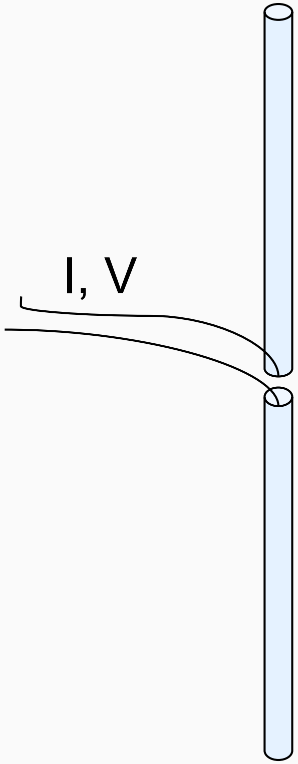




Dipolar polarizability: $\alpha(\omega) = 4\pi a^3 \dfrac{\varepsilon(\omega) - \varepsilon_b}{\varepsilon(\omega) + 2\varepsilon_b}$

C.F. Bohren, and D.R. Huffman
Absorption and scattering of light by small particles (Wiley, 1983)

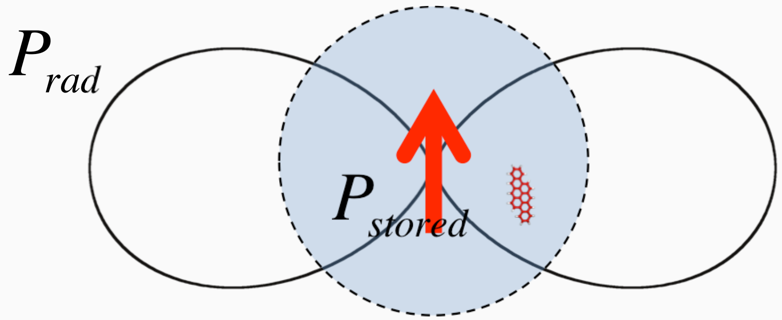
Dipole antenna



$$E \approx \frac{1}{r^3} + \frac{k}{r^2} + \frac{k^2}{r}$$

$$H \approx \frac{k}{r^2} + \frac{k^2}{r}$$

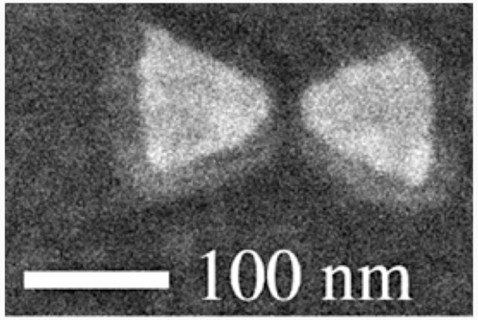
$$r_B = \frac{1}{k} \approx 100 \text{ nm}$$

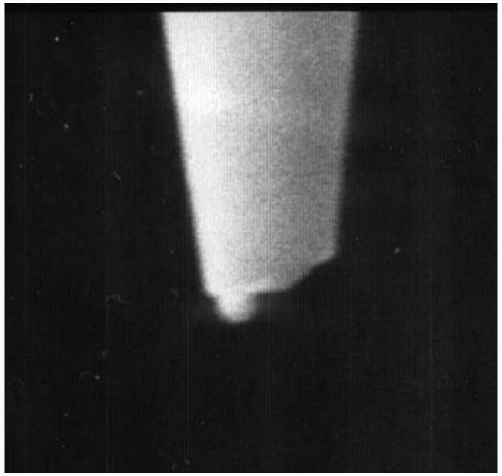


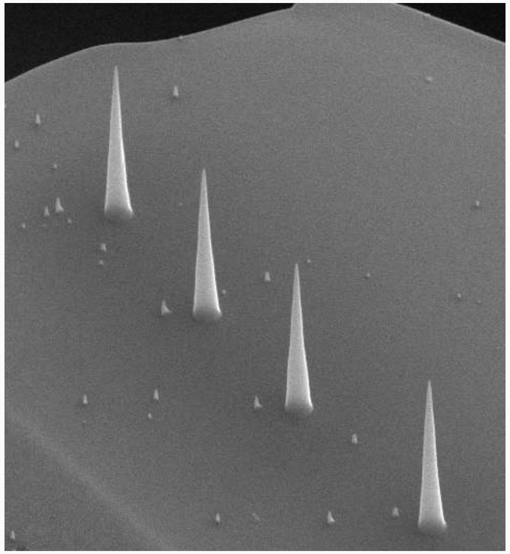
$$P = P_{rad} + P_{stored}$$

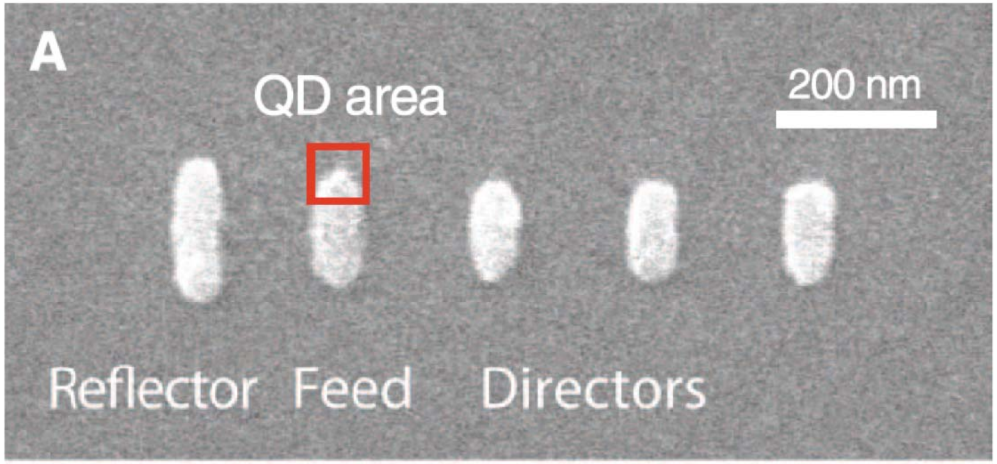
$$P_{stored} \approx \frac{1}{(kr)^3}$$

Optical antennas

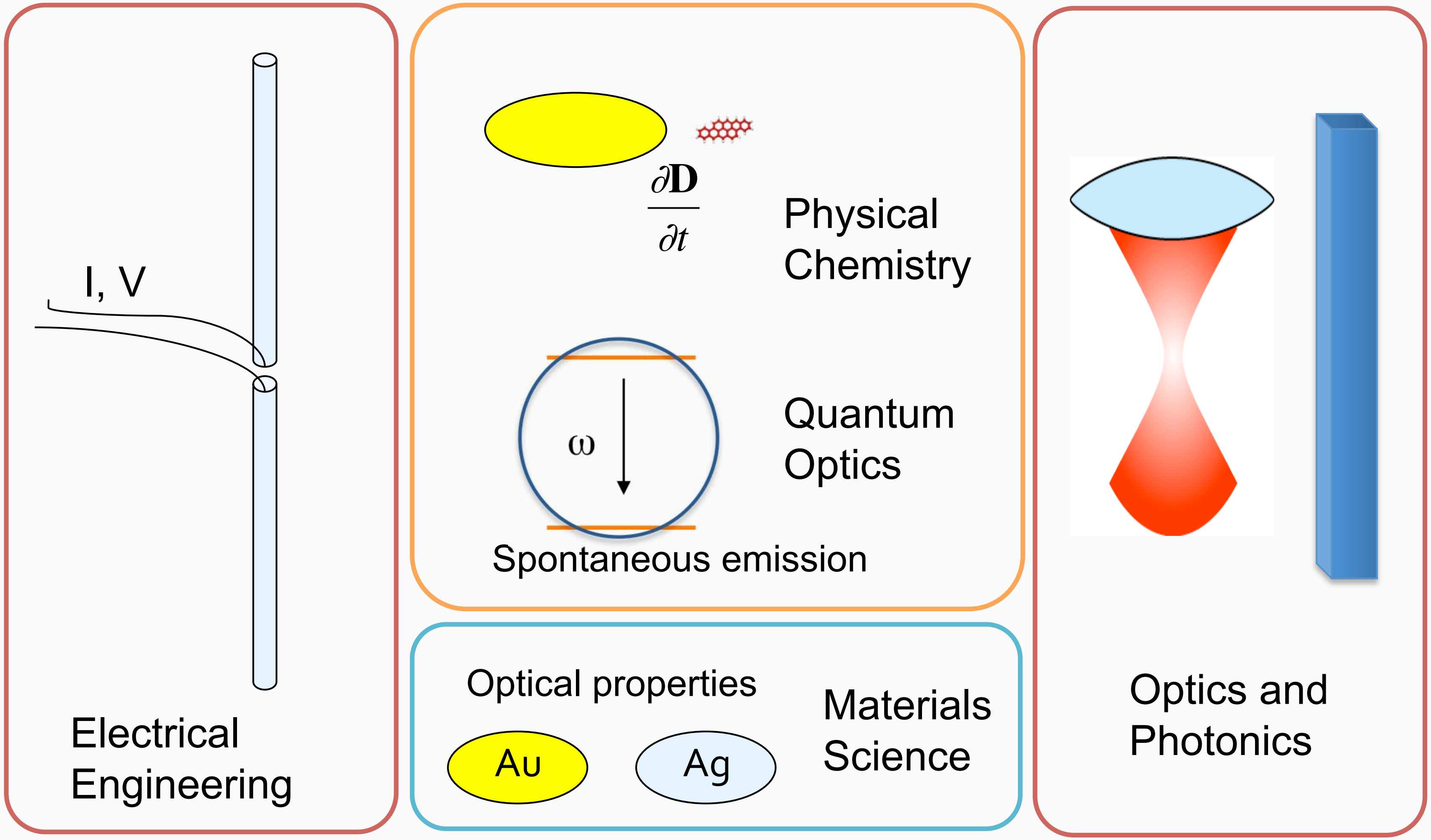








Optical antennas



M. Agio, A. Alù, Optical Antennas (Cambridge University Press, 2013)

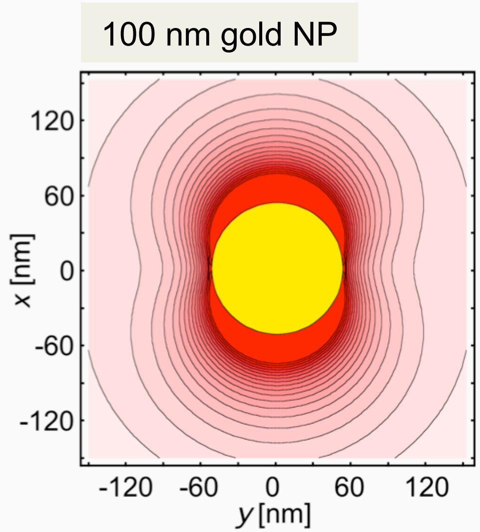
SM fluorescence

field enhancement

$$S_o \propto \eta_o |\mathbf{E}_o|^2, \qquad \eta_o = \frac{\gamma_r^o}{\gamma_t^o}, \quad \gamma_t^o = \gamma_r^o + \gamma_{nr}^o$$

$$S \propto \eta |\mathbf{E}|^2$$

quantum efficiency
(radiation efficiency)



decay rates

antenna efficiency

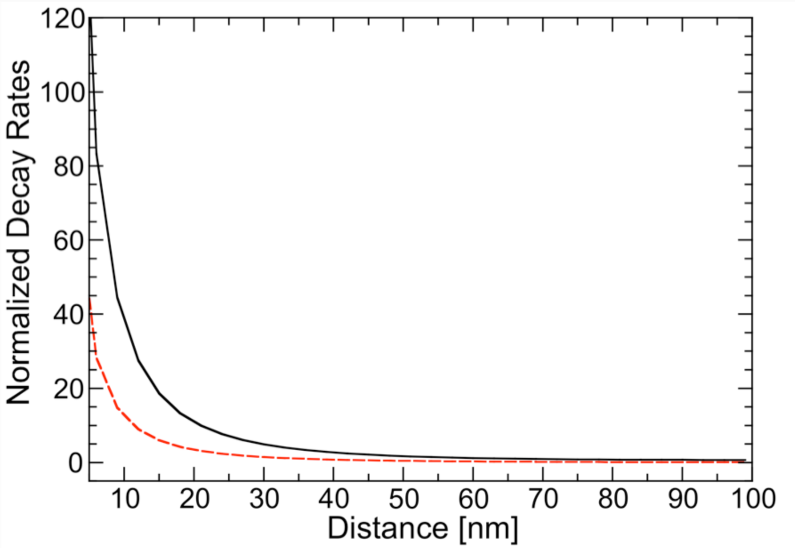
$$\eta = \frac{\gamma_r}{\gamma_t} = \frac{\eta_o}{(1-\eta_o)\dfrac{\gamma_r^o}{\gamma_r} + \dfrac{\eta_o}{\eta_a}}, \qquad \eta_a = \frac{\gamma_r}{\gamma_r + \gamma_{nr}}$$

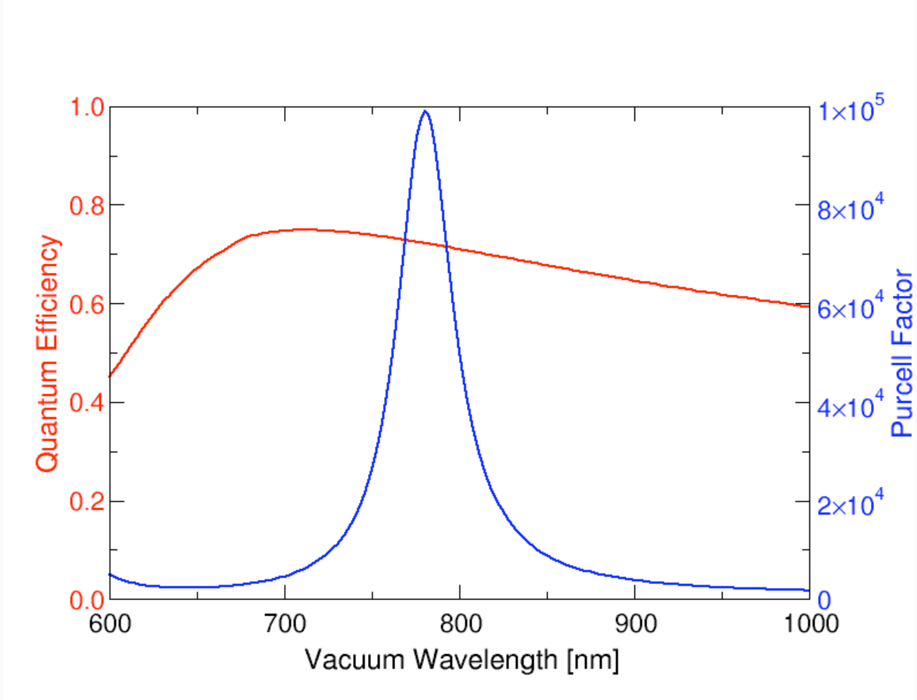
$$\gamma_t = \gamma_r + \gamma_{nr}^o + \gamma_{nr}$$

Fluorescence spectroscopy:
$\sigma = 10^{-15}$ cm^2 – $A = 10^{-10}$cm^2: $K_s = 10^{-5}$

$$\frac{|\mathbf{E}|^2}{|\mathbf{E}_o|^2} \approx \frac{\gamma_r}{\gamma^o}$$

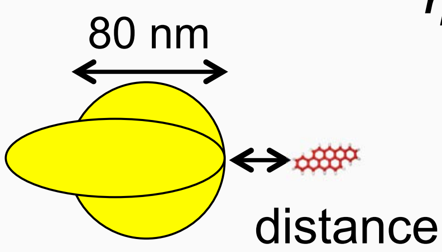
Quenching





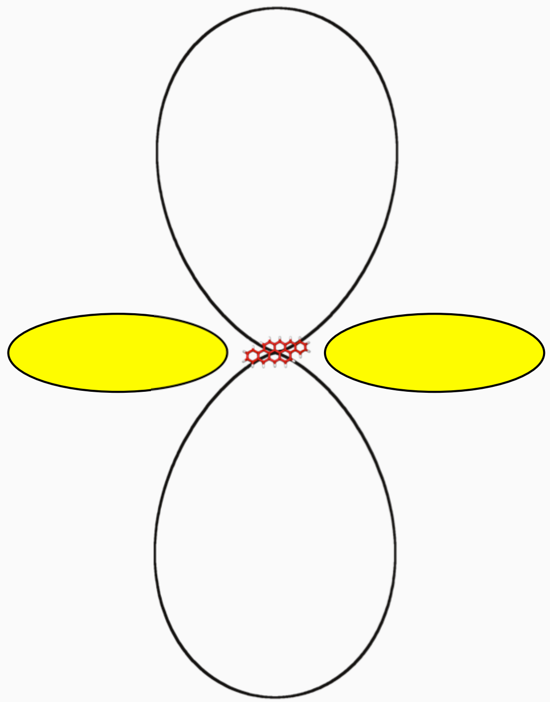
$$\eta_a = \frac{\gamma_r}{\gamma_r + \gamma_{nr}}$$

Optical antennas could increase K_s to 1



L. Rogobete, F. Kaminski, M. Agio, V. Sandoghdar, Opt. Lett. (2007)
X.-W. Chen, M. Agio, V. Sandoghdar, Phys. Rev. Lett. (2012)
M. Agio, Nanoscale (2012)

Radiation pattern



Antenna max directivity:

$$D = \frac{4\pi}{P_{\mathrm{rad}}} \max\left\{P_{\mathrm{rad}}(\theta,\varphi)\right\}$$

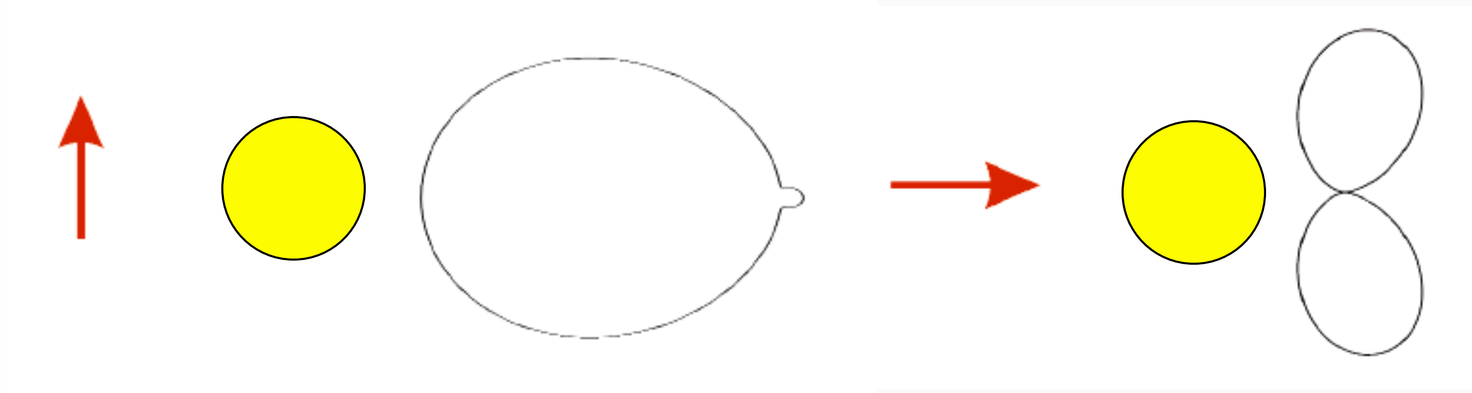
Antenna max gain:

$$G = \frac{4\pi}{P} \max\left\{P_{\mathrm{rad}}(\theta,\varphi)\right\} = \eta_a D$$

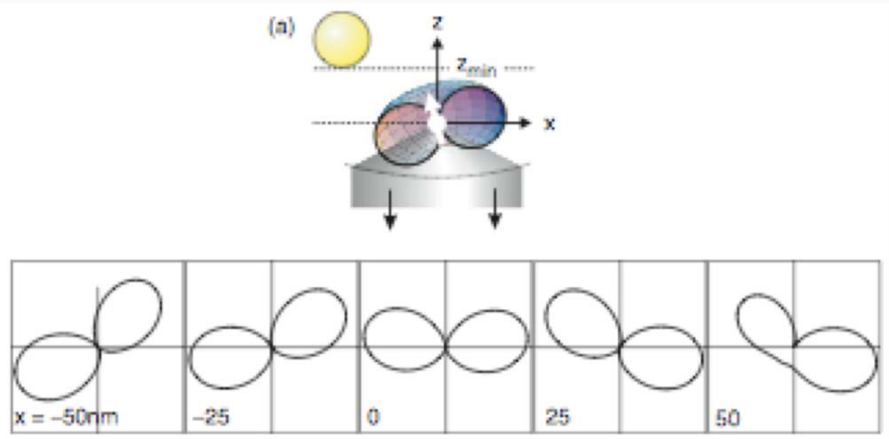
Effective aperture:

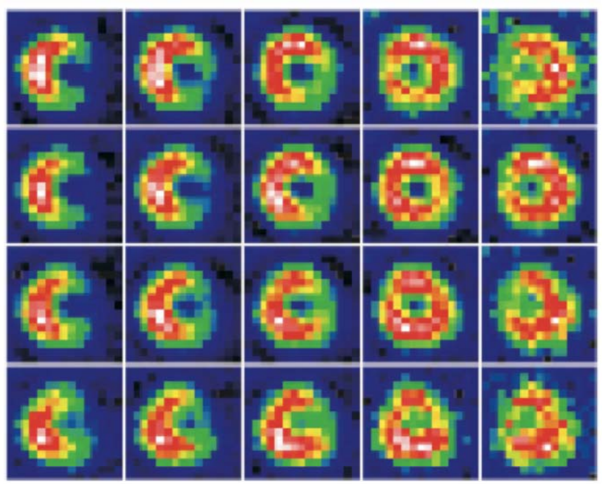
$$\sigma \propto \sigma_{\mathrm{d}} G$$

Redirecting light emission



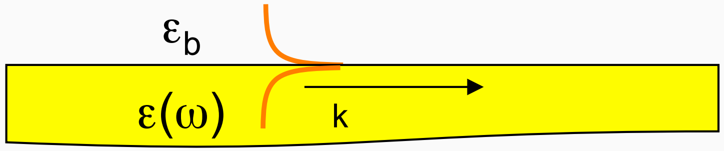
Modification of the emitter radiation pattern using metal nano-particles
(L. Rogobete, PhD thesis, ETH Zurich 2006)



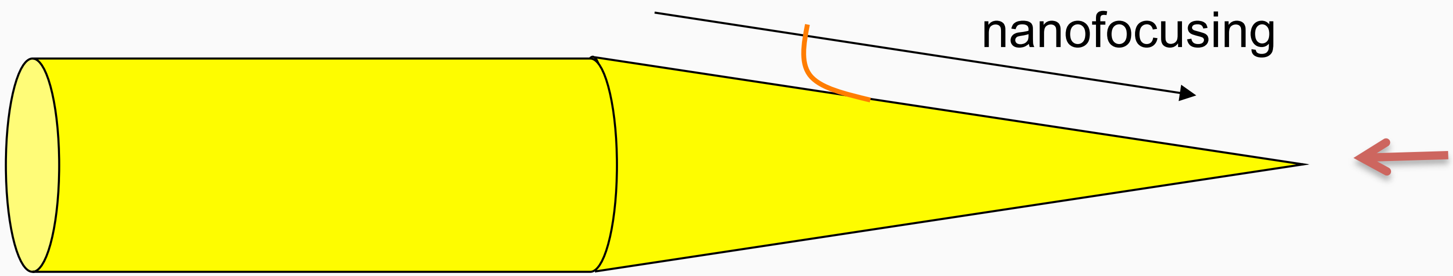


S. Kühn, G. Mori, M. Agio, V. Sandoghdar, Mol. Phys. (2008)

Traveling-wave antenna



H. Raether, Surface plasmons on smooth and rough surfaces (Springer, 1988)



F. Keilmann, J. Microscopy (1999)

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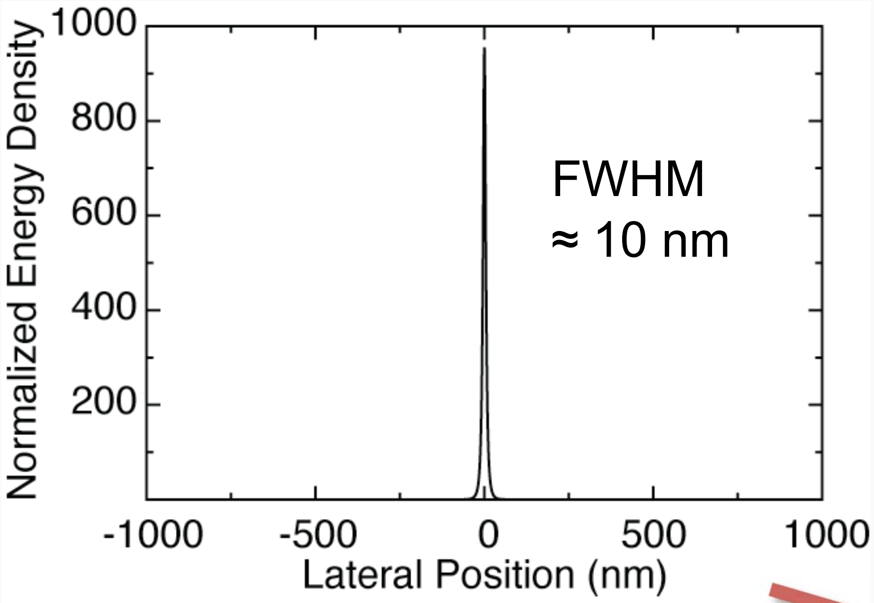
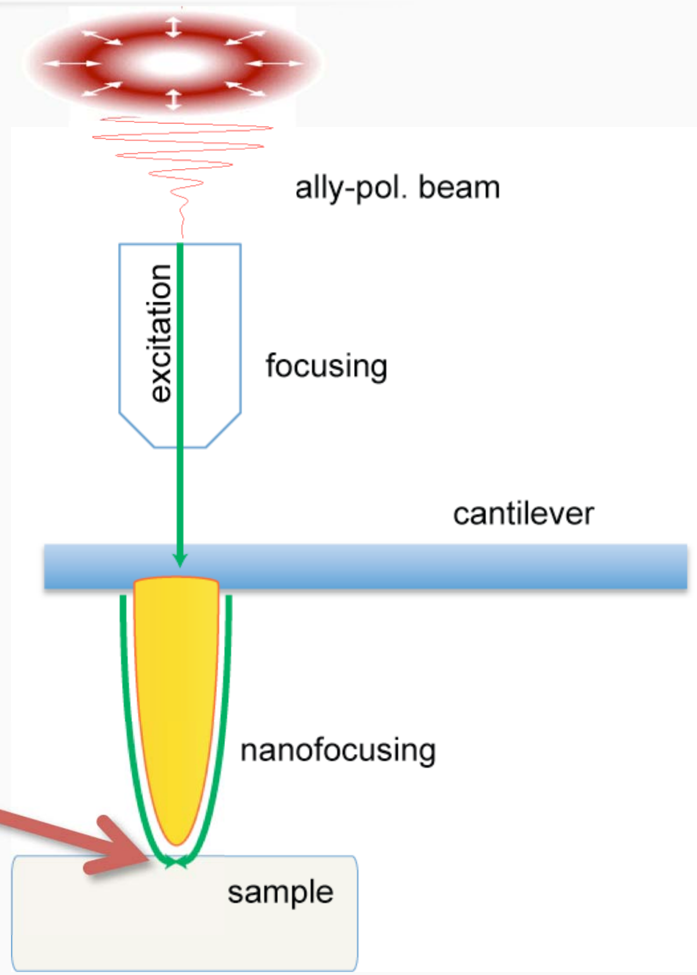
High-throughput SNOM





Implications for nonlinear & ultrafast nanoscopies
Direct detection of single emitters under ambient conditions
Heat delivery to the nanoscale

X.-W. Chen, V. Sandoghdar, M. Agio, Nano Lett. (2009)
X.-W. Chen, V. Sandoghdar, M. Agio, Opt. Express (2010)

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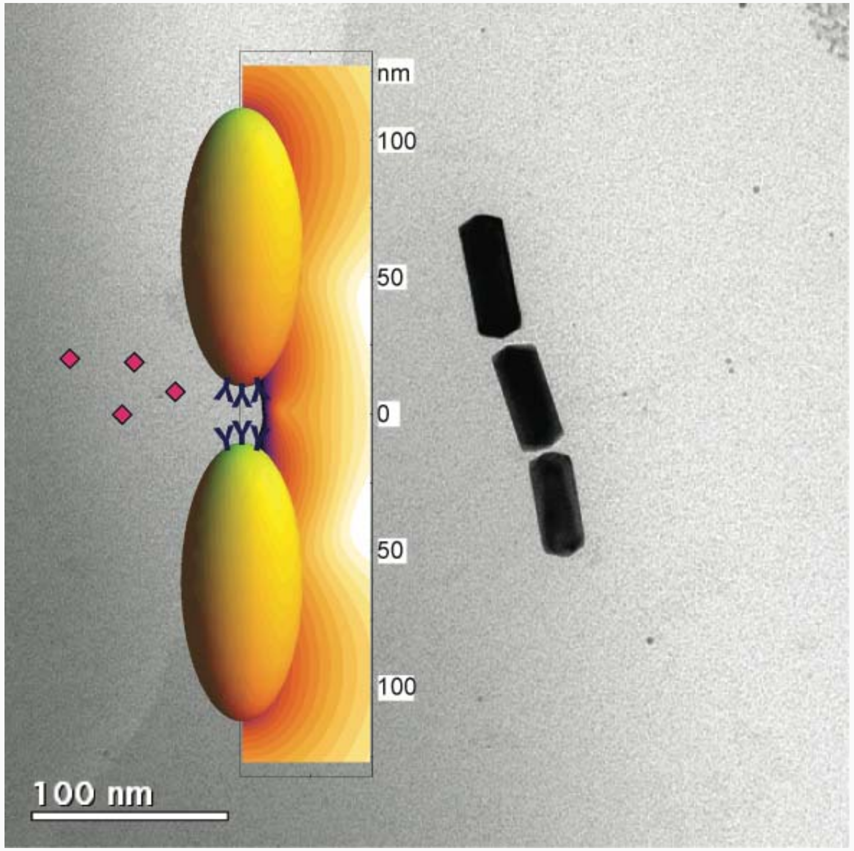
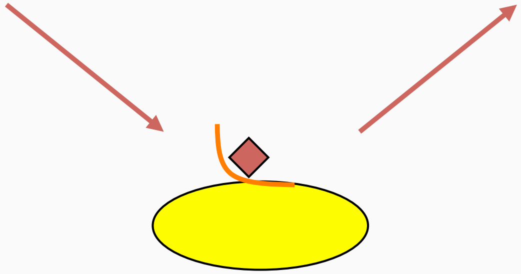
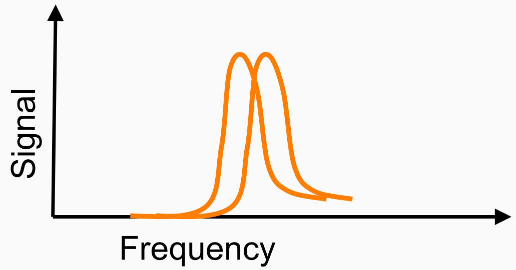
Nanoscale biosensors

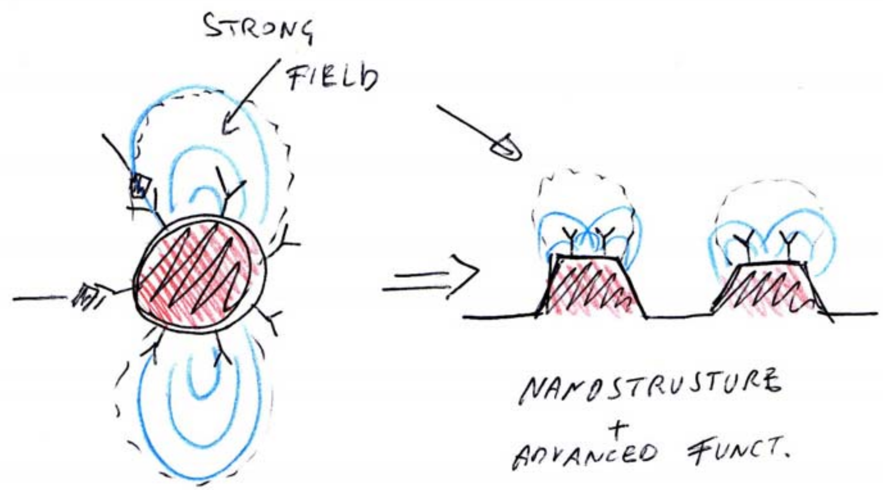


http://www.bioplasmonics.ethz.ch

Centro
Stefano Franscini
Swiss Federal Institute
of Technology Zurich

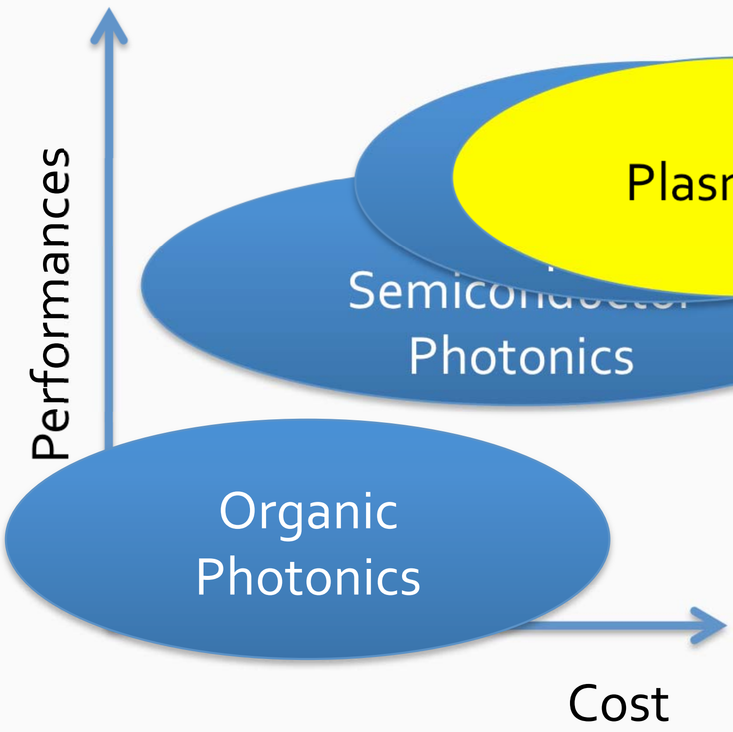


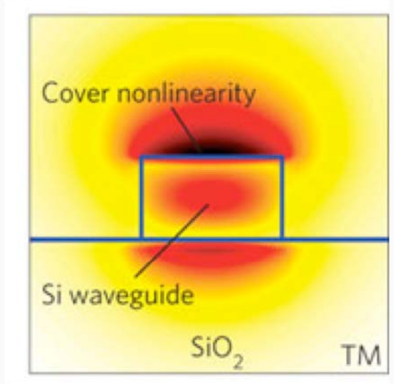


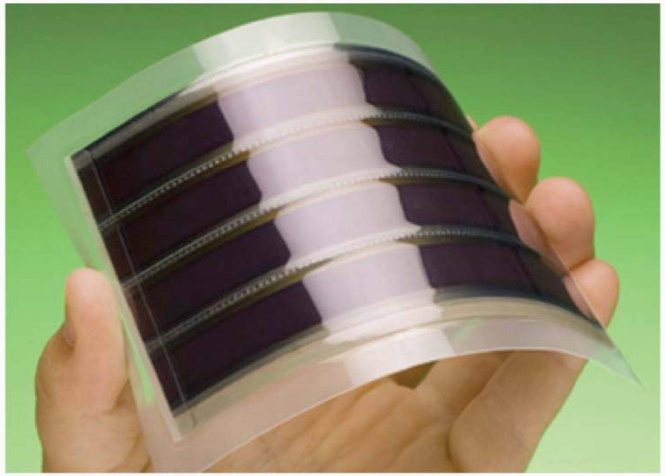


Optics and optoelectronics

Electronic-photonic integration is driven by complexity, performance and cost.

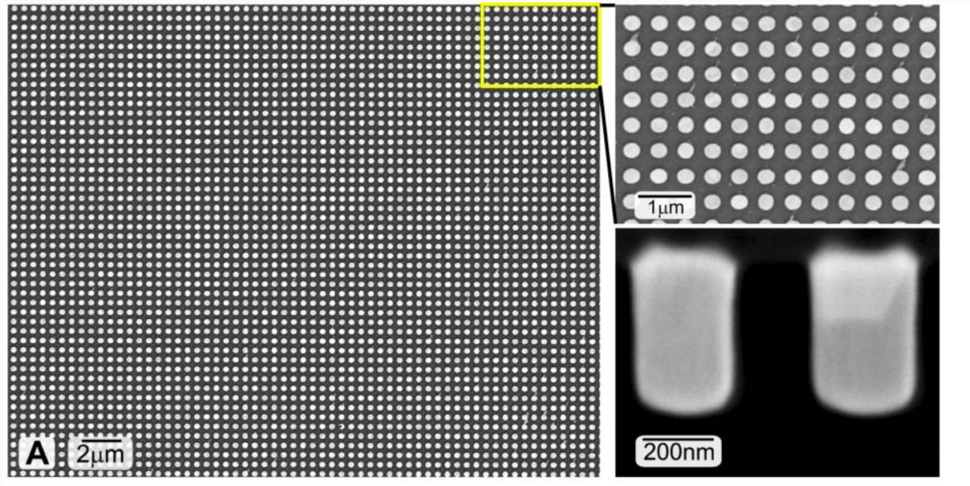


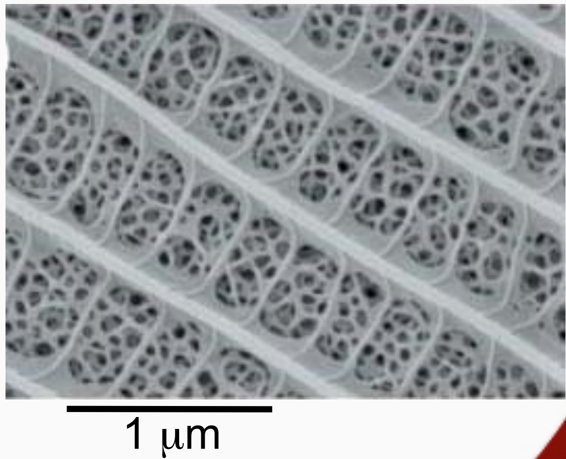


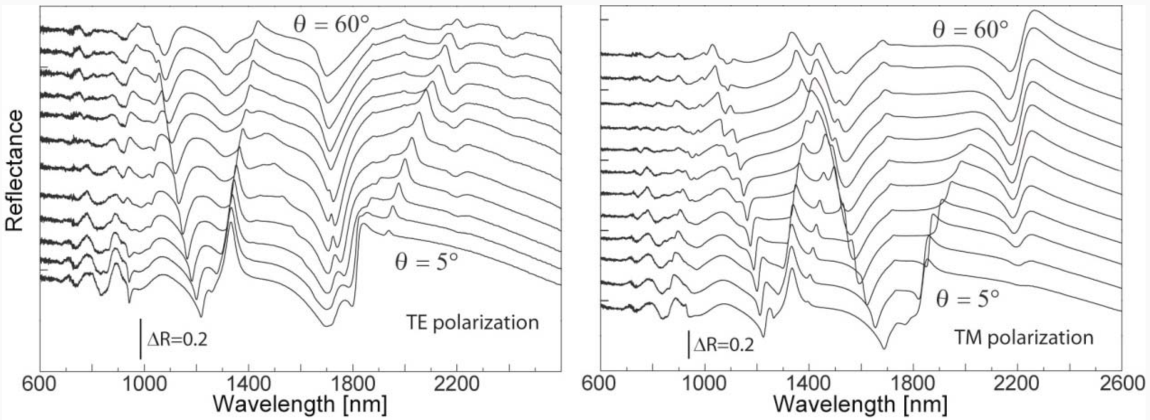


Antenna arrays

Innovative optical properties of periodically nanostructured metallo-dielectric composites







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Applications

- Life sciences:
  - Biosensors
  - Biolabels
  - Phototherapies
- Information technology:
  - Light sources
  - Light detectors
  - Light modulators
- Energy science:
  - Photovoltaics
  - Thermovoltaics
  - Cathalysis