Solar energy collection by window

Utilization of localised surface plasmon resonance in metallic nanopartiles to collect solar power by window areas of the buildings.

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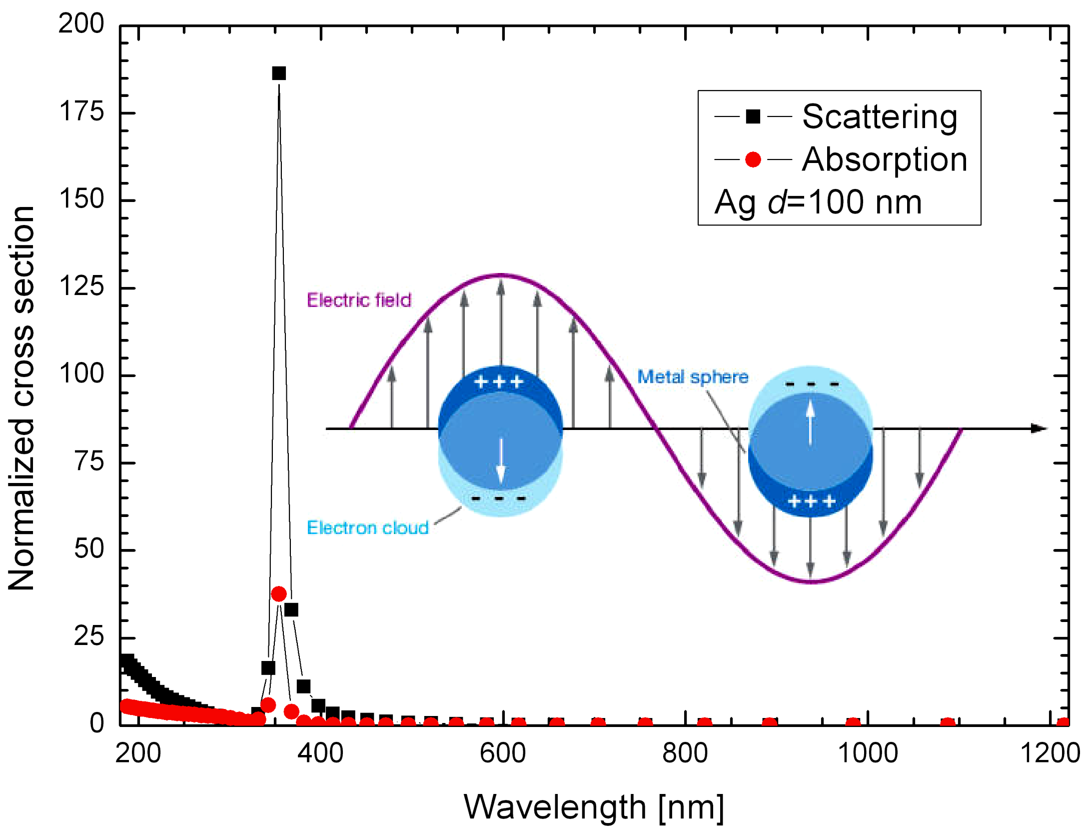
Localized surface plasmon resonance



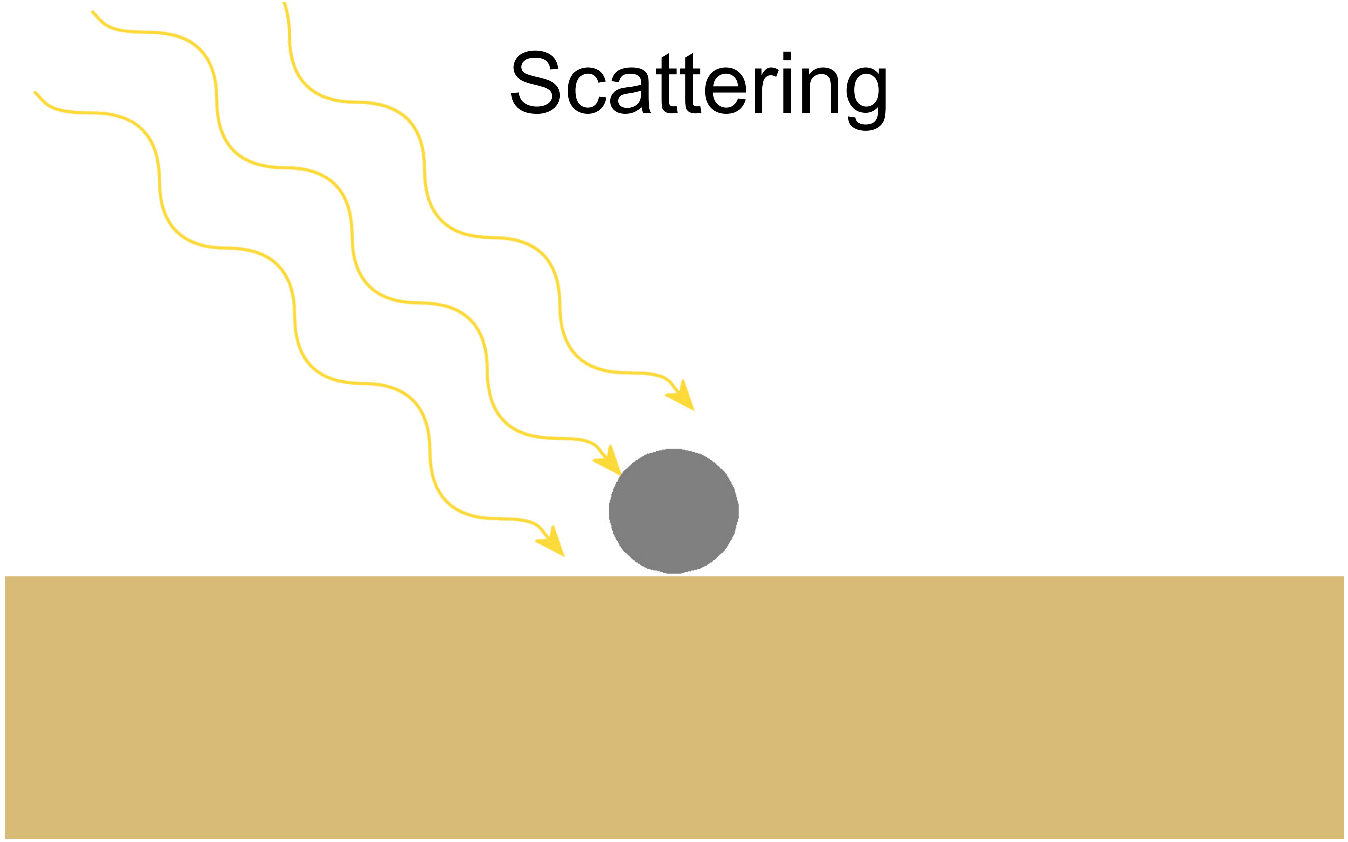
- Property of metallic nanoparticles smaller than a wavelength of the light:
  - Strong absorption and scattering on the resonance wavelength
  - Resonance comes from a resonance of mechanical oscillation of the electron cloud

  → Localized Surface Plasmon, i.e. LSP

[Optical data from Johnson and Christy: Phys.Rev. B 6, no.12, 1972.]

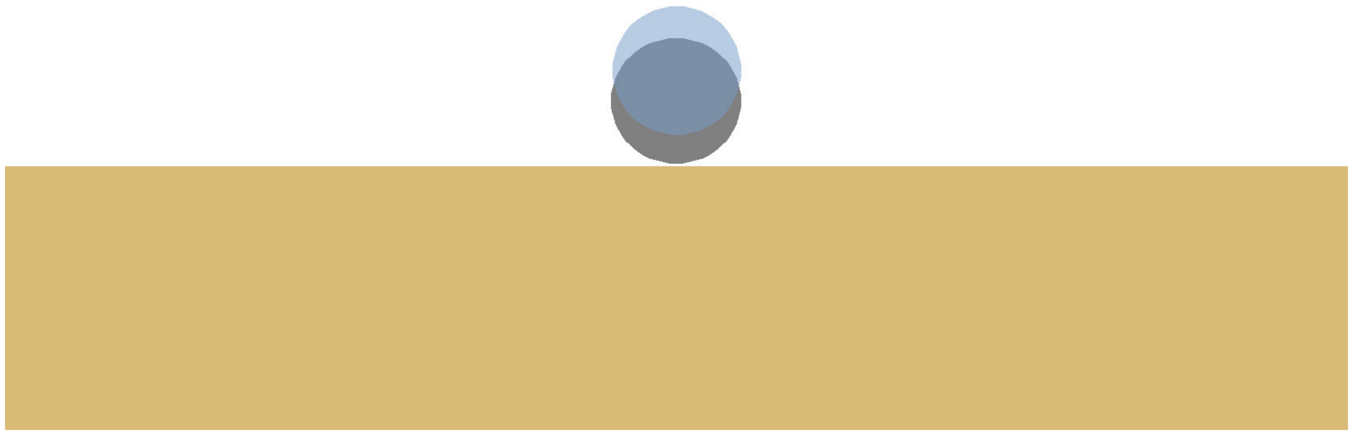
Localized surface plasmon resonance

Scattering

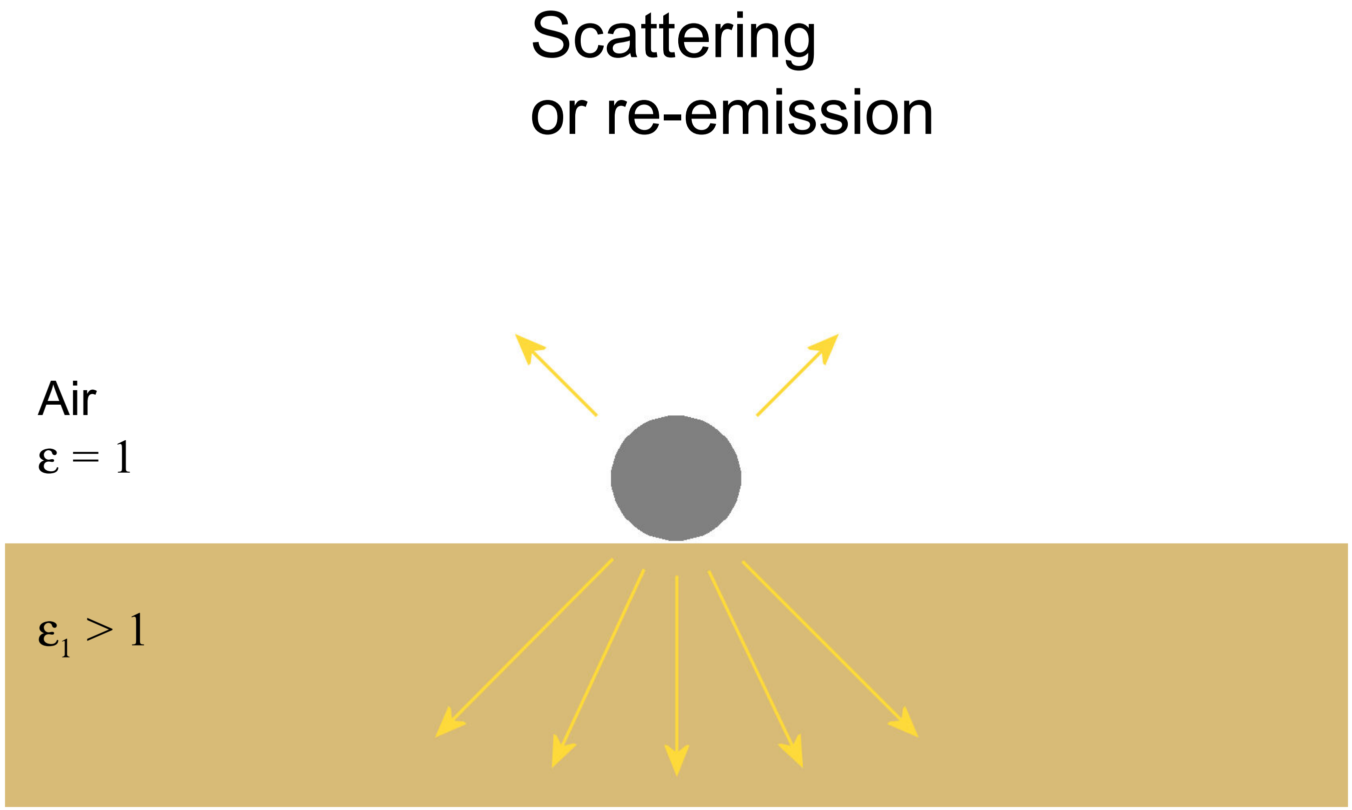


Localized surface plasmon resonance

Exitation of LSP

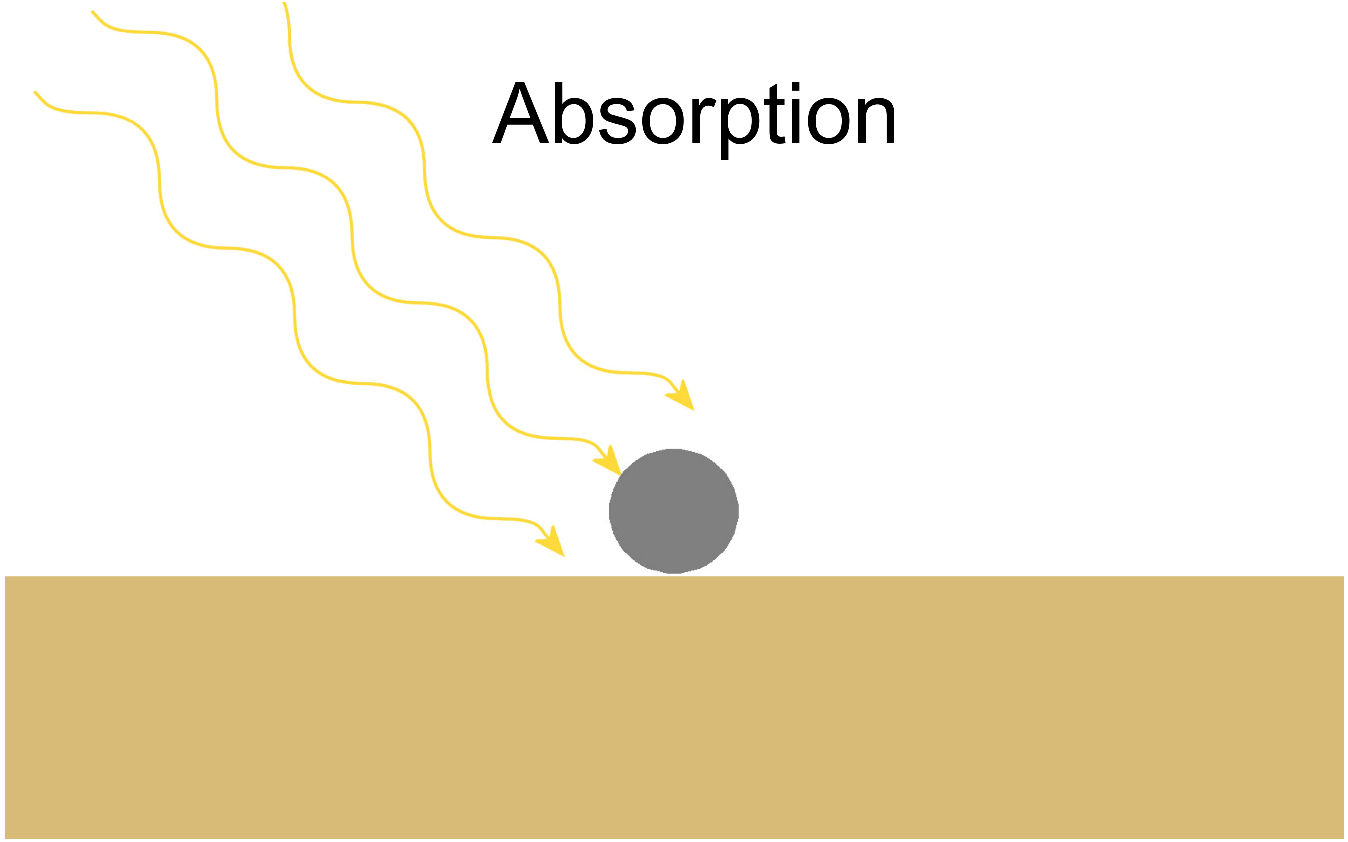


Localized surface plasmon resonance



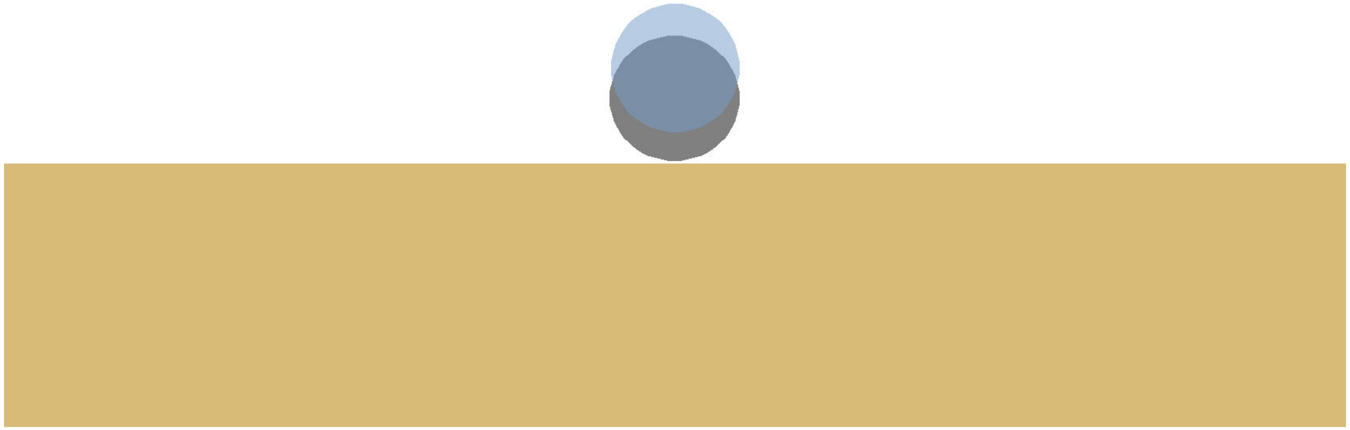
Localized surface plasmon resonance

Absorption



Localized surface plasmon resonance

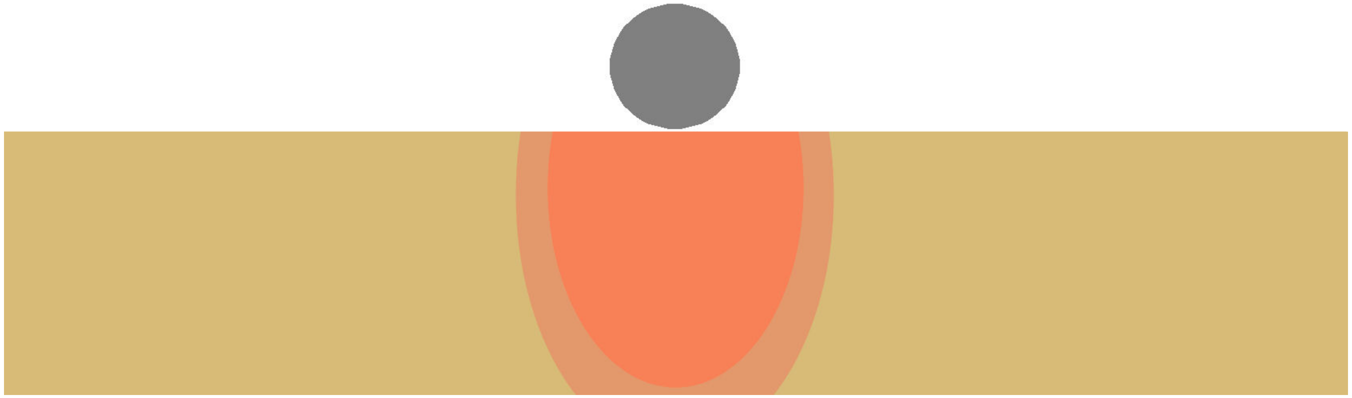
Exitation of LSP



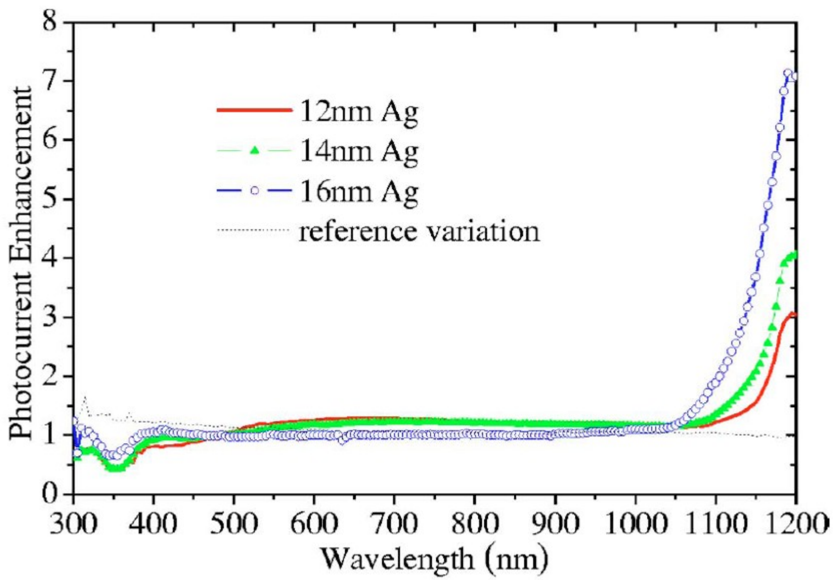
Localized surface plasmon resonance

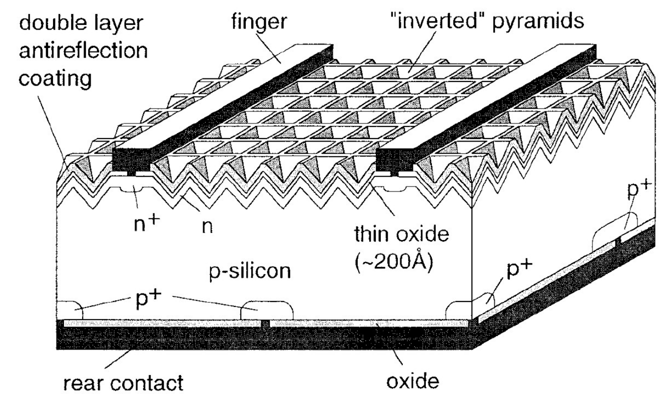
Field enhancement near the particle

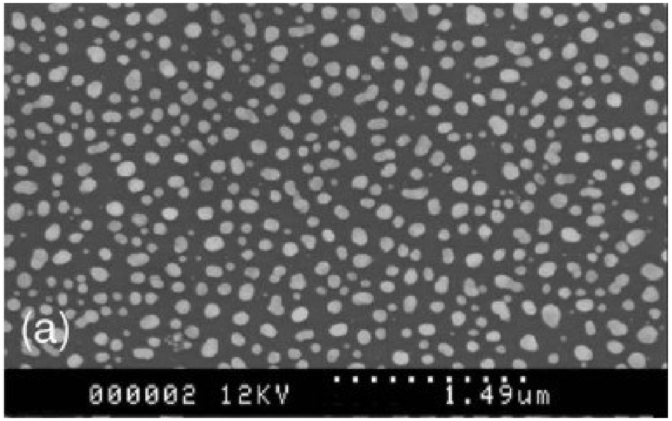
→ More efficient generation of electron-hole pairs



Literature results from solar cells



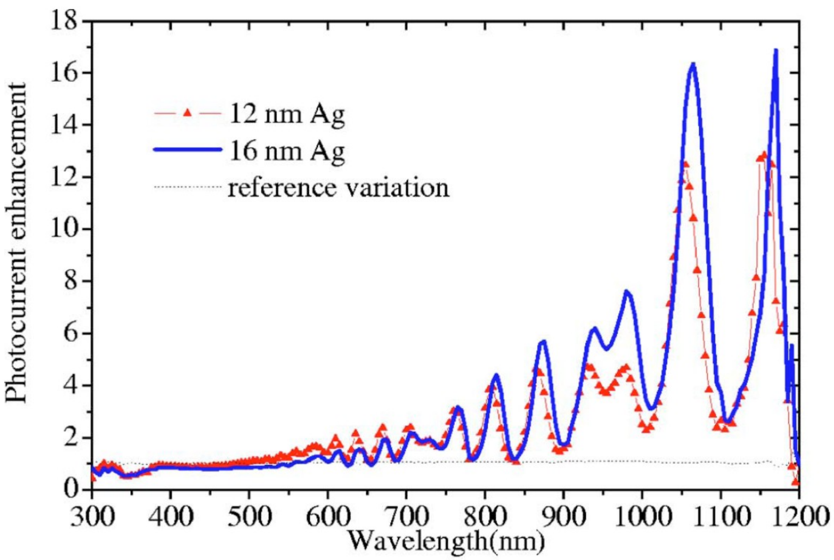


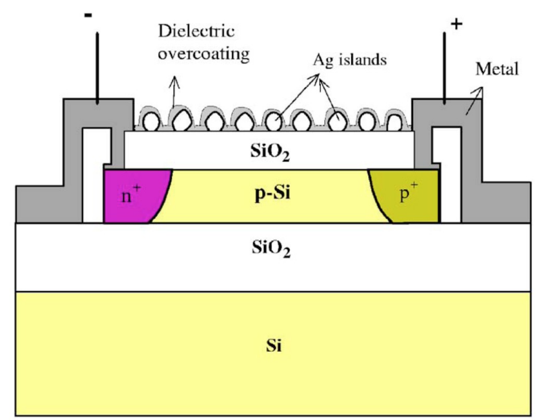


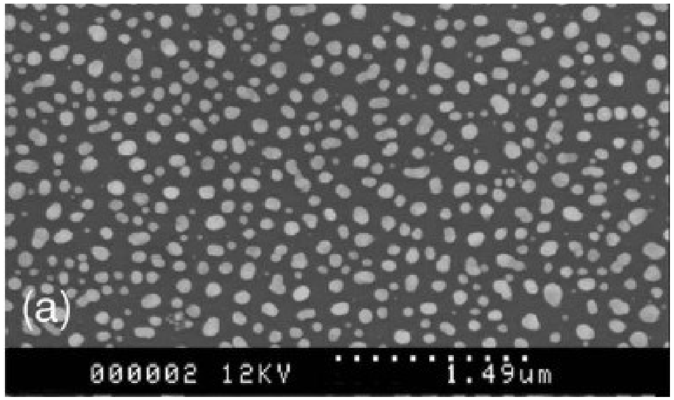
- 3 - 7 time improvement in photocurrent
- 19% Increase in short circuit current

[Pillai *et al*. J.Appl.Phys.101, 093105, 2007.]
[Image of PERL cell: Zhao *et al*. Prog. Photovolt: Res. Appl. 7, 1999.]

Earlier result from solar cells: SOI waveguide



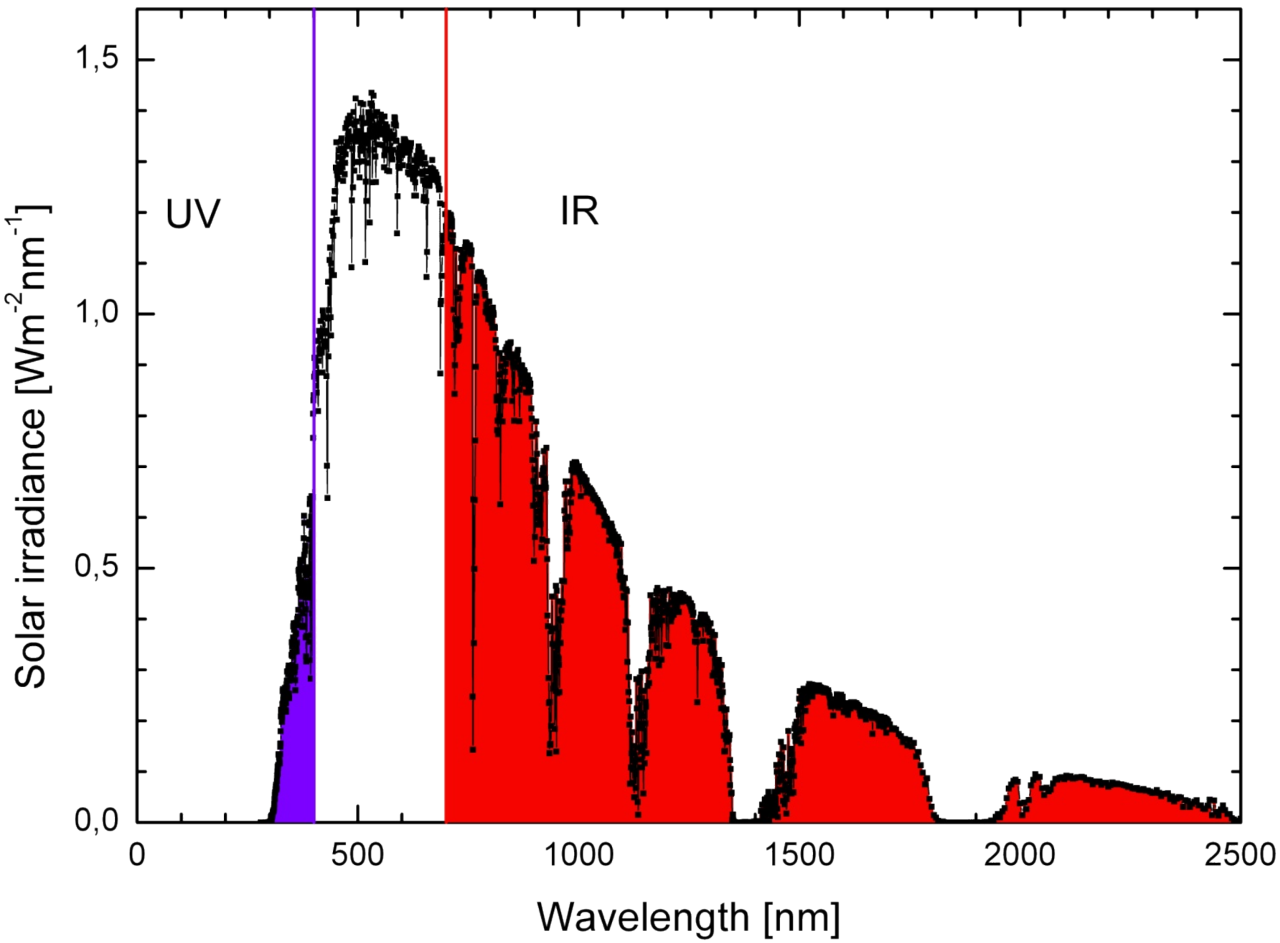




- 13 - 17 time improvement in photocurrent
- 16 - 33% Increase in short circuit current

[Pillai *et al*. J.Appl.Phys.101, 093105, 2007.]
[Image of SOI test device: Pillai *et al.* Appl.Phys.Lett. 88, 161102, 2006.]

Introduction



Solar spectrum (AM15) UV: 30 W/m^2 IR: 860 W/m^2

Solar energy collection by window

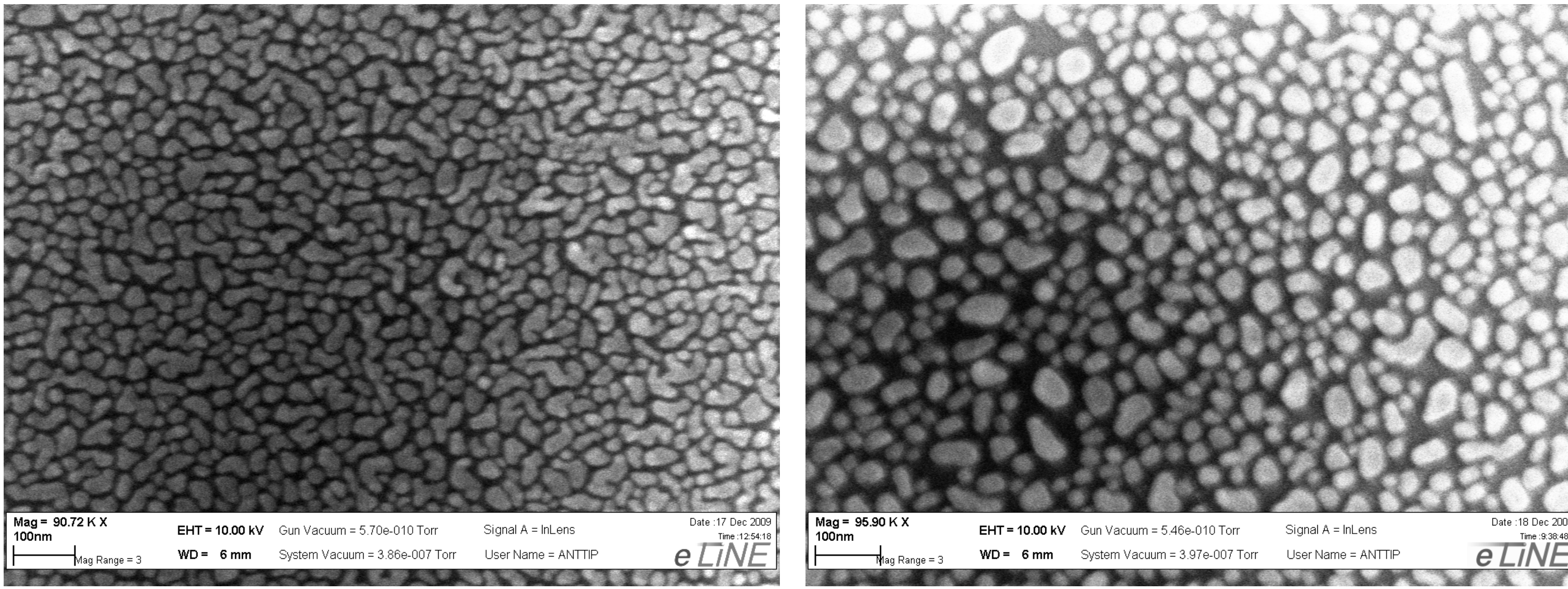
- Aim is to develop a solar energy collector integ-rated to a window area of buildings
- By utilizing metal nanoparticles and LSPR one can selectively collect only IR
- Benefits:
  - IR energy is collected for further utilization while visible light is passed nearly unaffected
  - IR radiation is not let to interior → Prevents excess heating of the room
  - In warm areas cooling of house can be reduced

Currie *et al.* Science **321** (2008) 226.

NP deposition

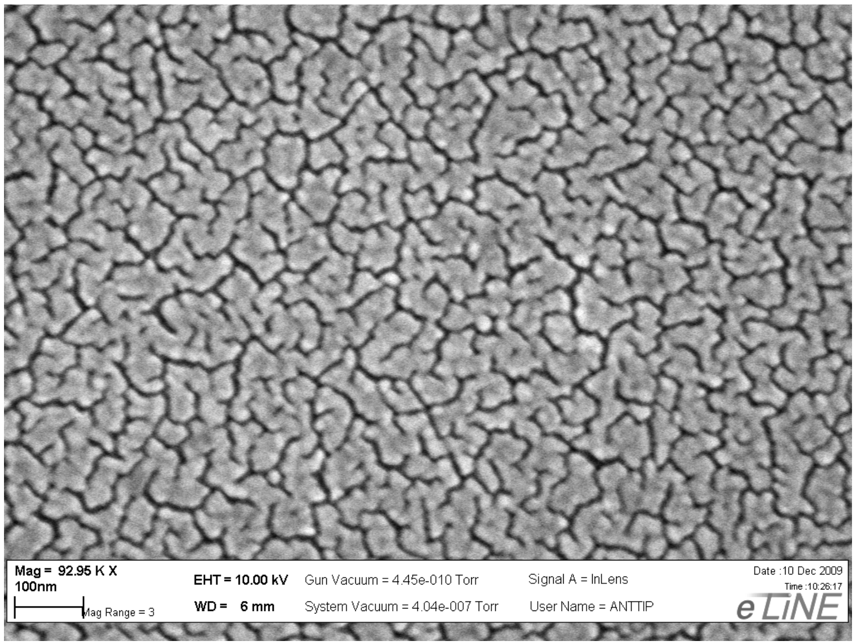
- Goal: high coverage, large area →
- Evaporation
- Controlled parameters
  - Deposition rate: 0.1 – 10 Å/s
  - Deposited thickness
  - Substrate heating: room temp – 100 °C
  - After deposition: annealing (up to 400 °C)

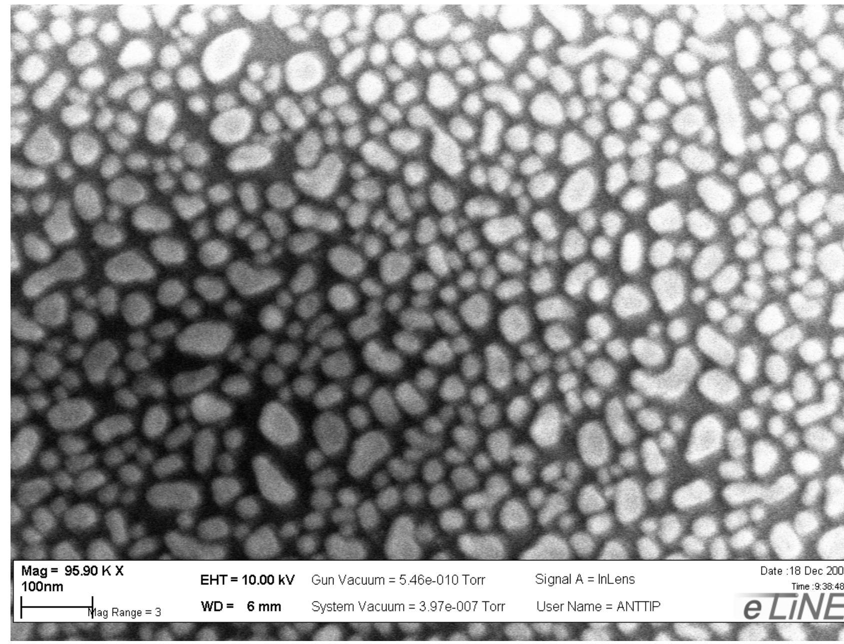
NP deposition



Effect of annealing: Au thickness: 5 nm, deposition rate: 1 Å/s. Before (left) and after (right) annealing at 350 °C.

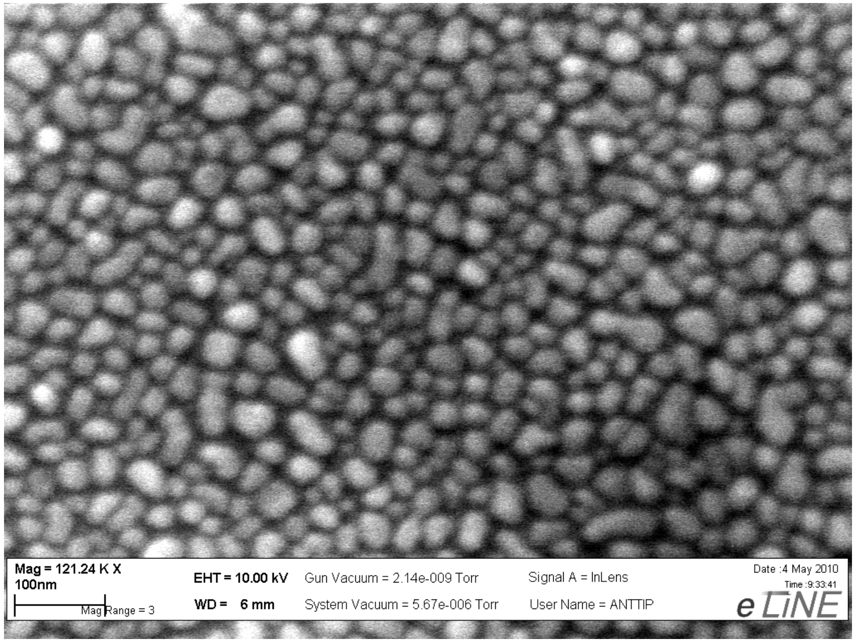
NP deposition

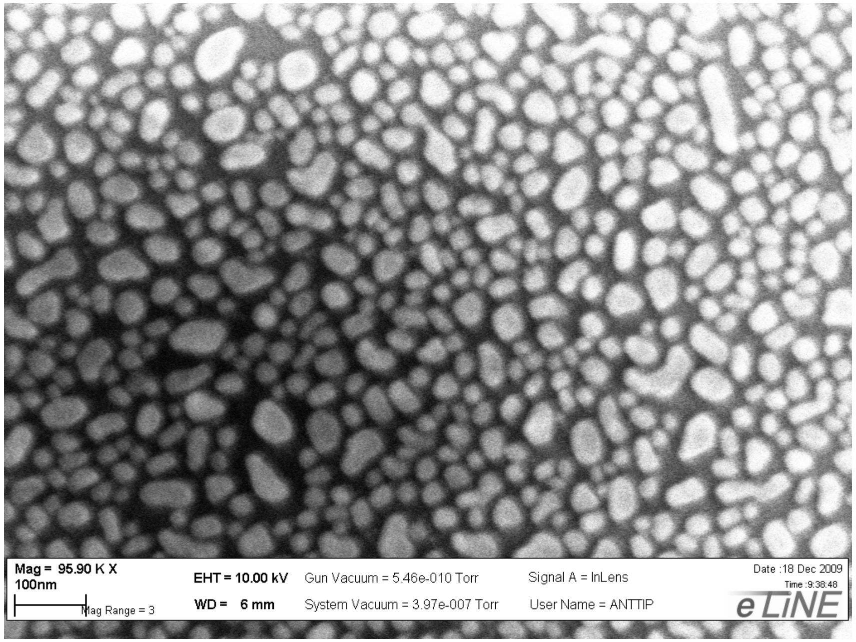




Effect of deposited thickness: Au thickness: 6 nm (left) 5 nm (right). Deposition rate: 1.0 Å/s. Both samples annealed @ 350 °C .

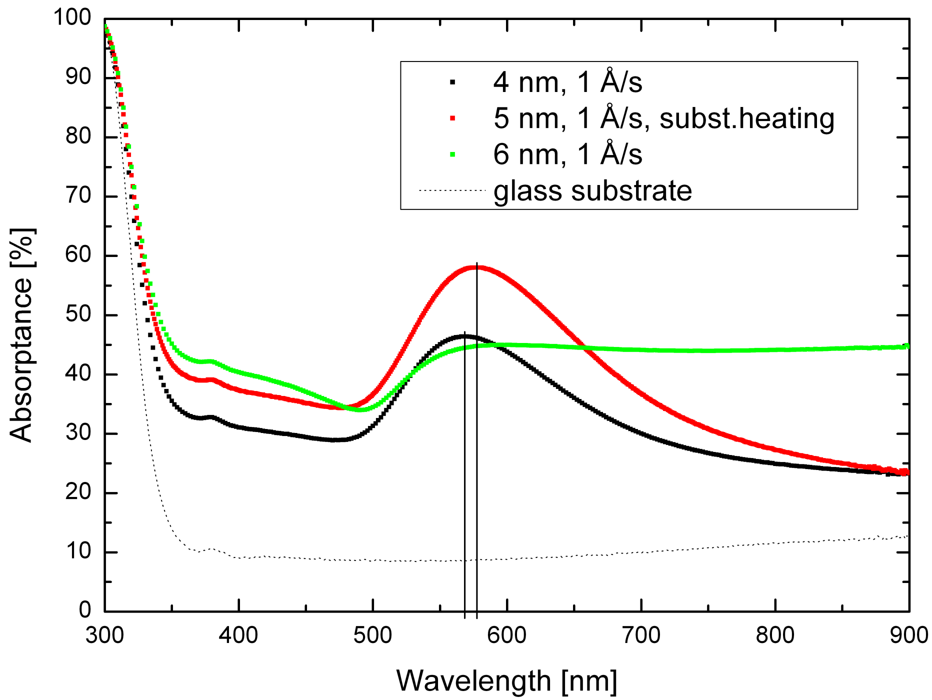
NP deposition





Effect of deposition rate: Au thickness: 5 nm. Deposition rate: 0.5 Å/s (left), 1.0 Å/s (right). Both samples annealed @ 350 °C .

NP deposition

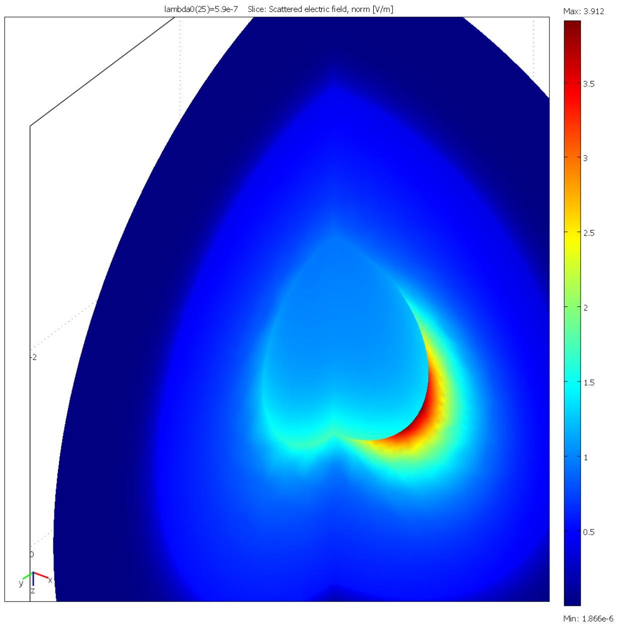


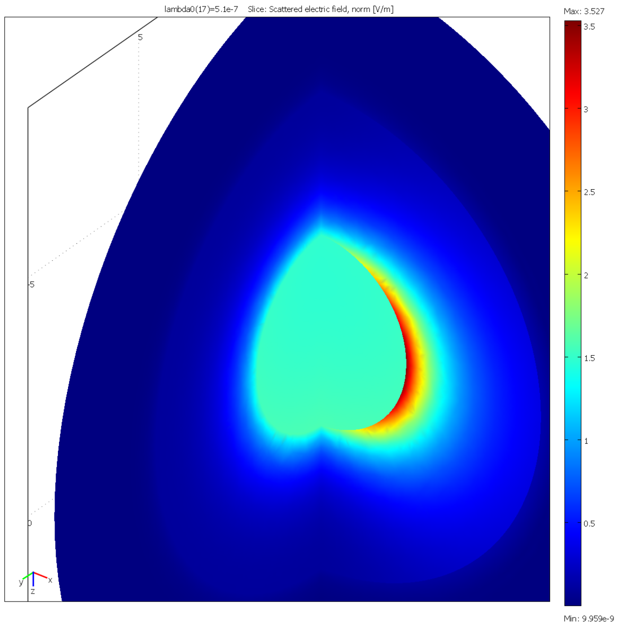
Absorption spectra of some Au films on glass substrate.

COMSOL simulations

- COMSOL
  - Finite element analysis software
  - Modeling & simulation of physical systems (fluid dynamics, thermal conduction, electromagnetism,…)
- Our simulations: the RF module
  - NPs
  - NPs with substrates & overcoats
  - 2D lattices of NPs ?
  - Coupling of NPs & 2D waveguides ?

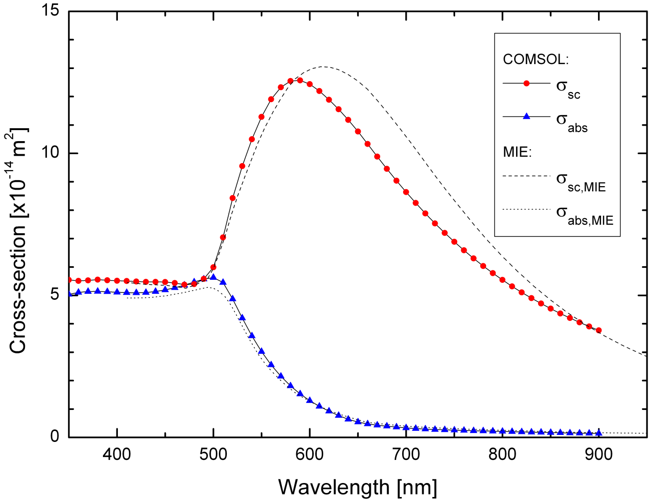
COMSOL simulations

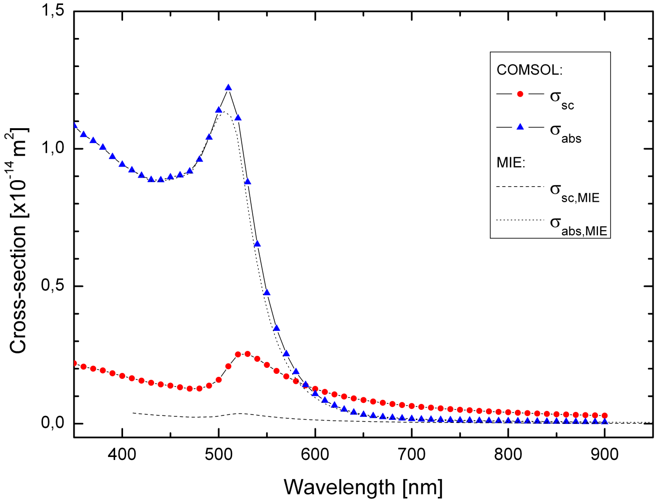




Scattered electric field (norm) around a spherical Au particle in air.
Left image: *R*=100 nm, *λ*=590 nm. Right image: *R*=40 nm, *λ*=510 nm.

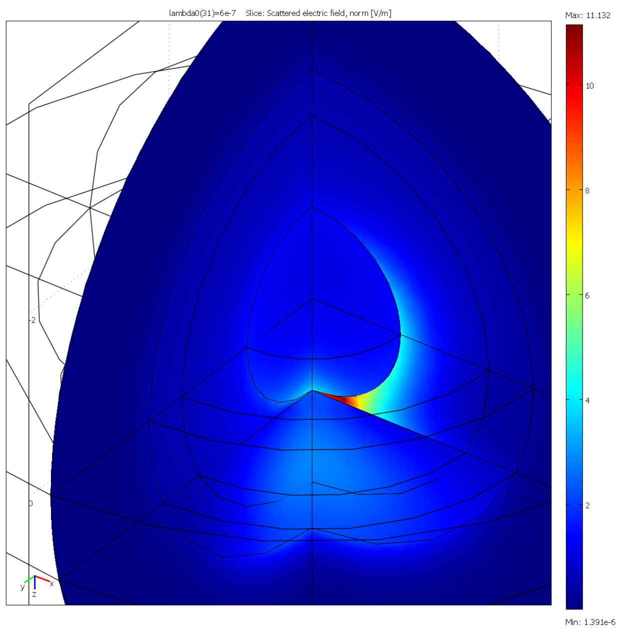
COMSOL simulations

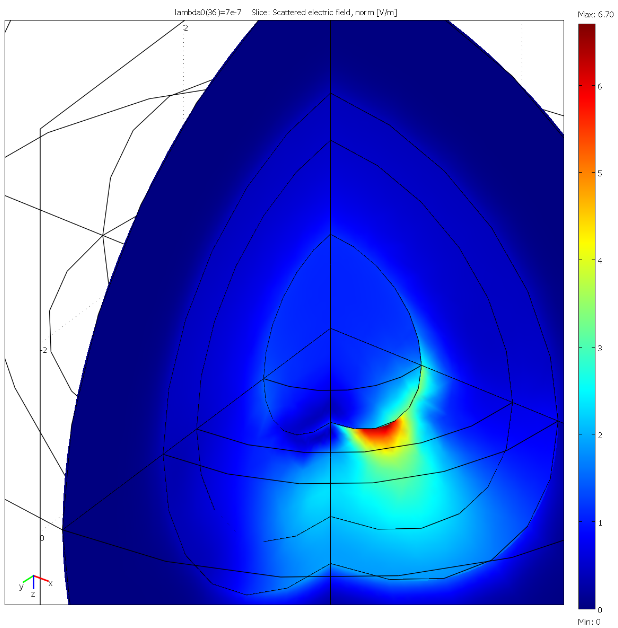




Scattering and absorption cross-sections for spherical Au particles as given by COMSOL-simulation (coloured plots) and Mie-theory (line plots). Left image: *R*=100 nm, right image: *R*=40 nm.

COMSOL simulations

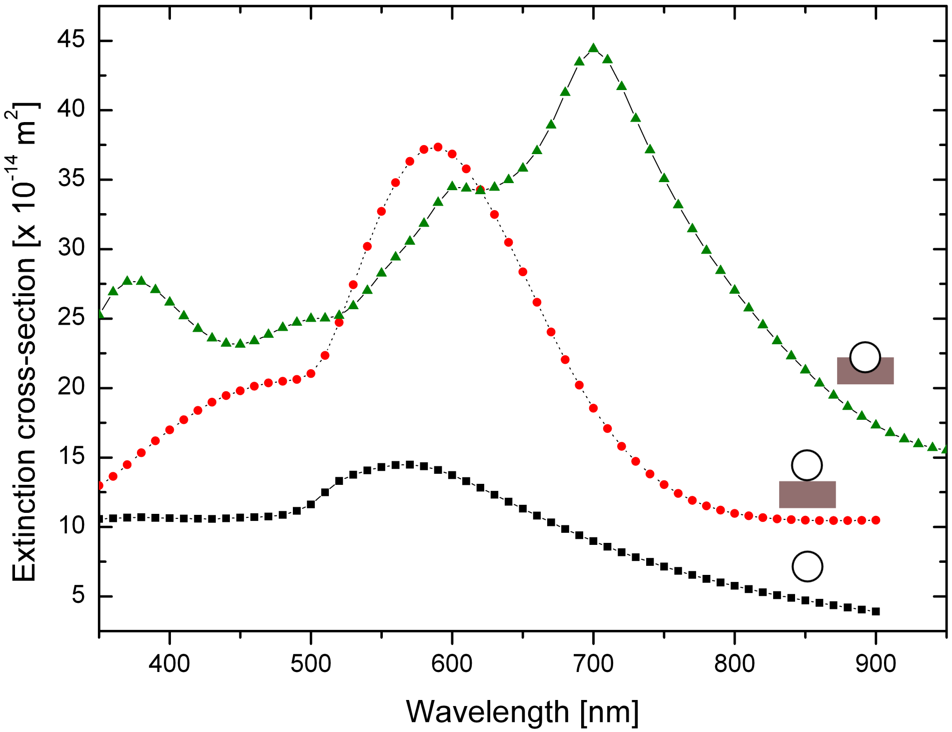




Scattered electric field around spherical Au particle deposited on (left) and half submerged into (right) dielectric material (TiO_2).

R=100 nm: λ=600 nm (left) and 700 nm (right).

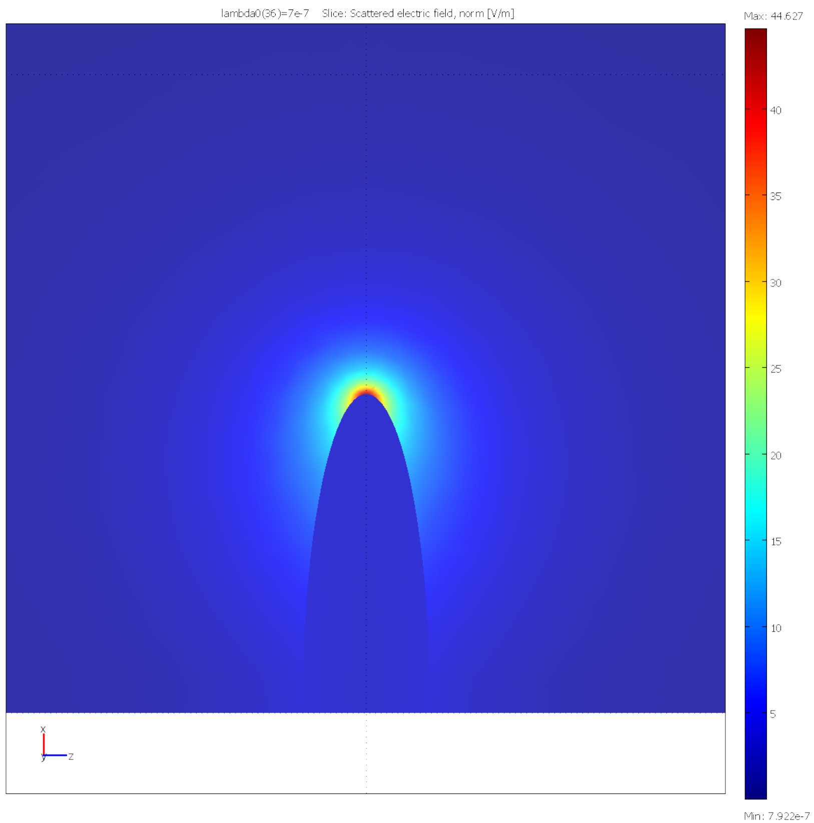
COMSOL simulations

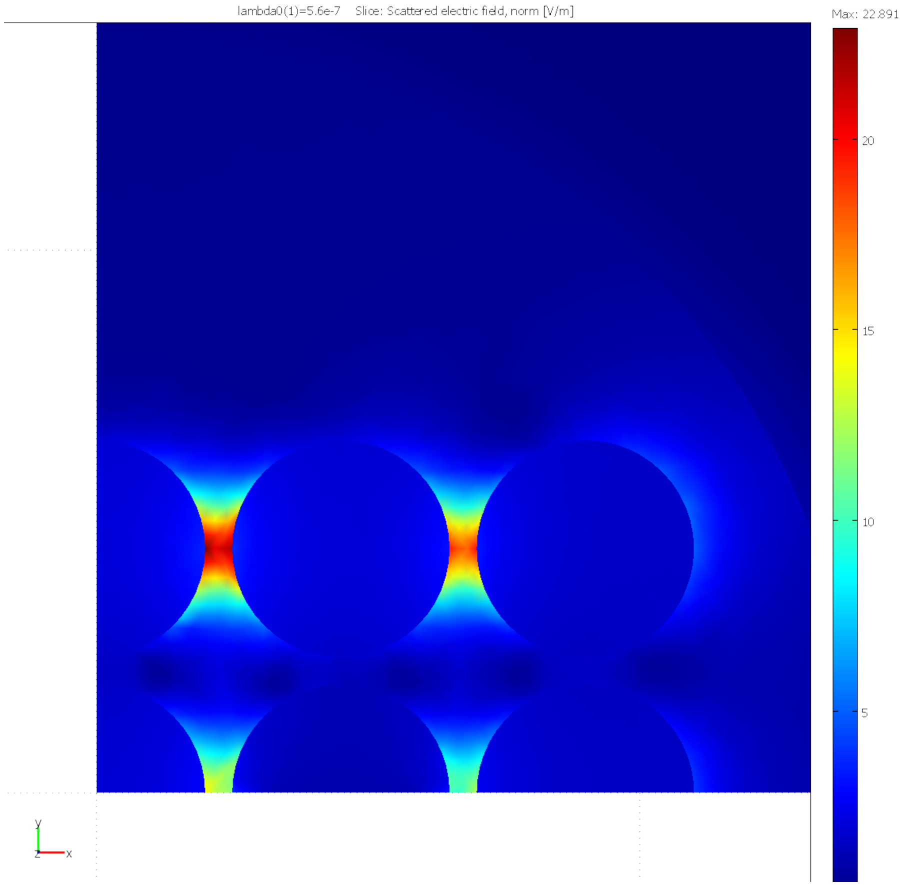


Extinction cross sections for spherical Au particles (*R*=100 nm) in air and on dielectric substrate (TiO_2), as given by COMSOL-simulation.

(Preliminary results)

COMSOL simulations





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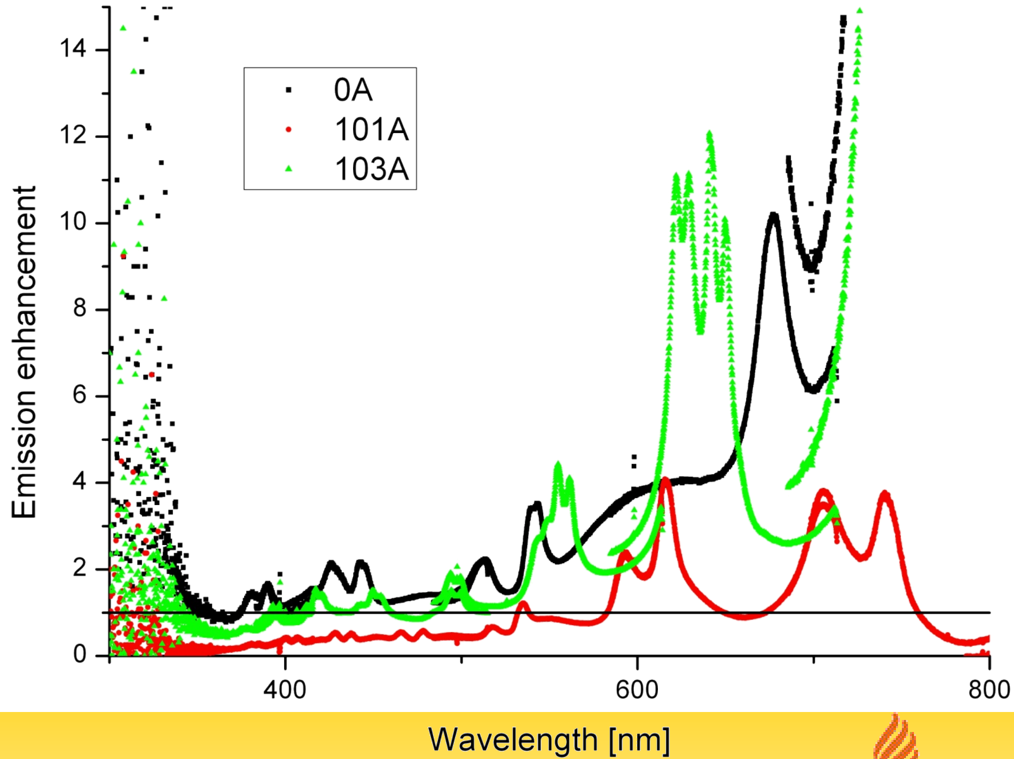
Waveguide

- Nanoparticles enhance scatterin to waveguide in the wavelengths of existing waveguide modes

- Measurement of the intensity at the end of a waveguide (preliminary result)



Conclusions

- Evaporation
  - Good NP coverage / density
  - Problem: small particle size
- COMSOL simulations
  - Tool for modeling NP properties beyond Mie-theory