Plasmonic and magnetoplasmonic nanostructures characterized by Scanning Near-field Optical Microscopy

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Grupo de Nanoestructuras magnéticas y magnetoplasmónicas

http://www.imm.cnm.csic.es/magnetoplasmonics

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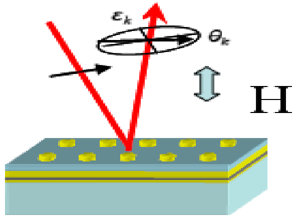
IMM nano nano

Magnetic Nanostructures
MN-MP
Magneto Plasmonics



Outline

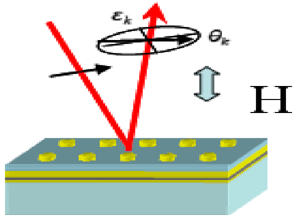
Introduction: Motivation & our approach

Techniques: Extinction, FDTD simulations, **SNOM**

Results:

- rectangular nanostructures
- circular nanostructures

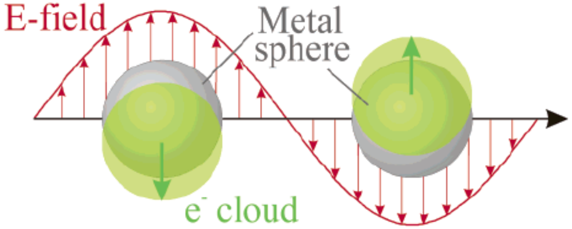
Conclusions



Motivation: new optical devices based on metals

Localized Surface Plasmon (LSP)

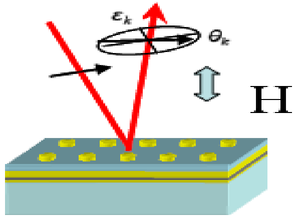
Electron cloud oscillation at the dielectric/metal interface



Can be excited with light of appropriate frequency irrespective of the wavevector of the exciting light. The resonance depends on: shape, material, dielectric environment

- Strong localization of EM field in subwavelength volumes: ***Optical nanodevices***
- Very sensitive to metal-dielectric interface: ***Sensors***

Magnetoplasmonic nanostructures: active nanostructures, i.e. their plasmonic properties can be controlled by an applied magnetic field



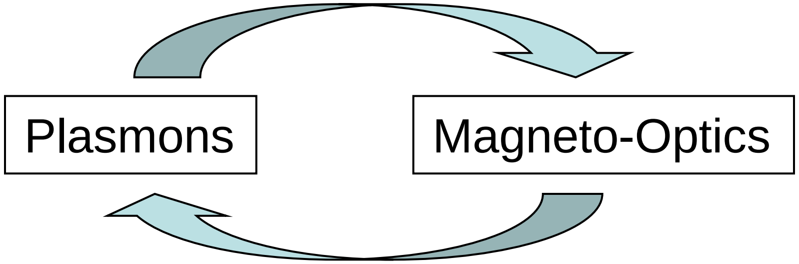
Magnetoplasmonic nanostructures

noble metal (plasmonic) + ferromagnet (magneto-optical)

Introducing a ferromagnetic material:

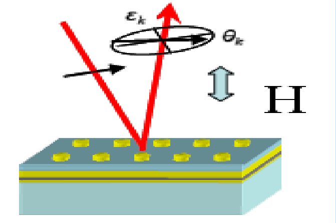
Magneto-Optical activity at low magnetic fields

Control of MO activity with plasmon excitation


Plasmons

Magneto-Optics

Control plasmon properties with magnetic field



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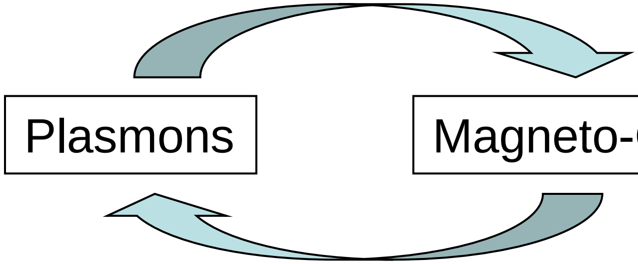

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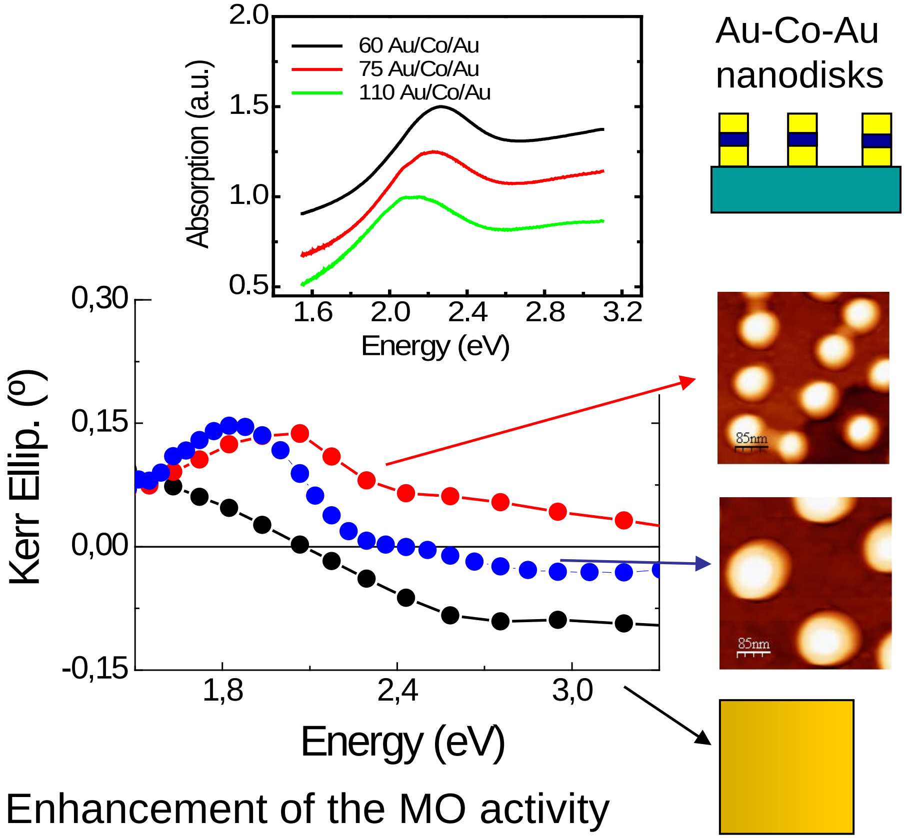
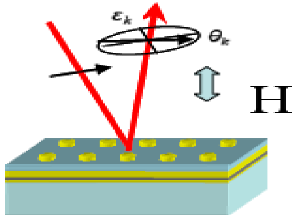


Enhancement of the MO activity in the LSPR spectral region

González-Díaz et al., Small 4, 202 (2008)



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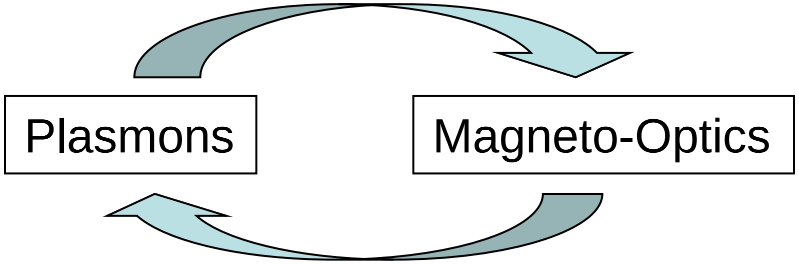
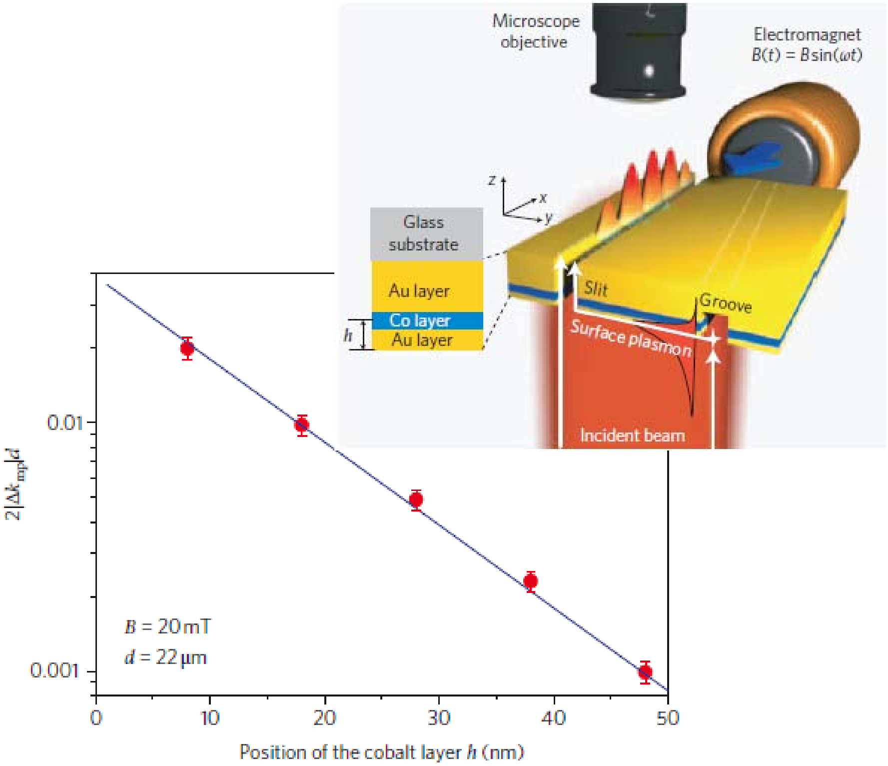


Plasmons

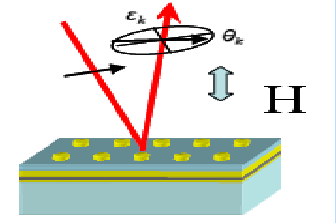
Magneto-Optics

<u>Control plasmon properties with magnetic field</u>

Modulation of the plasmon wavevector



Temnov et al., Nature Photonics 4, 107 (2010)



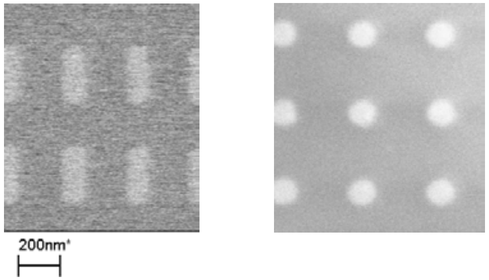
Our approach

Goal: To identify the EM field distribution associated with each LSPR mode

Techniques:

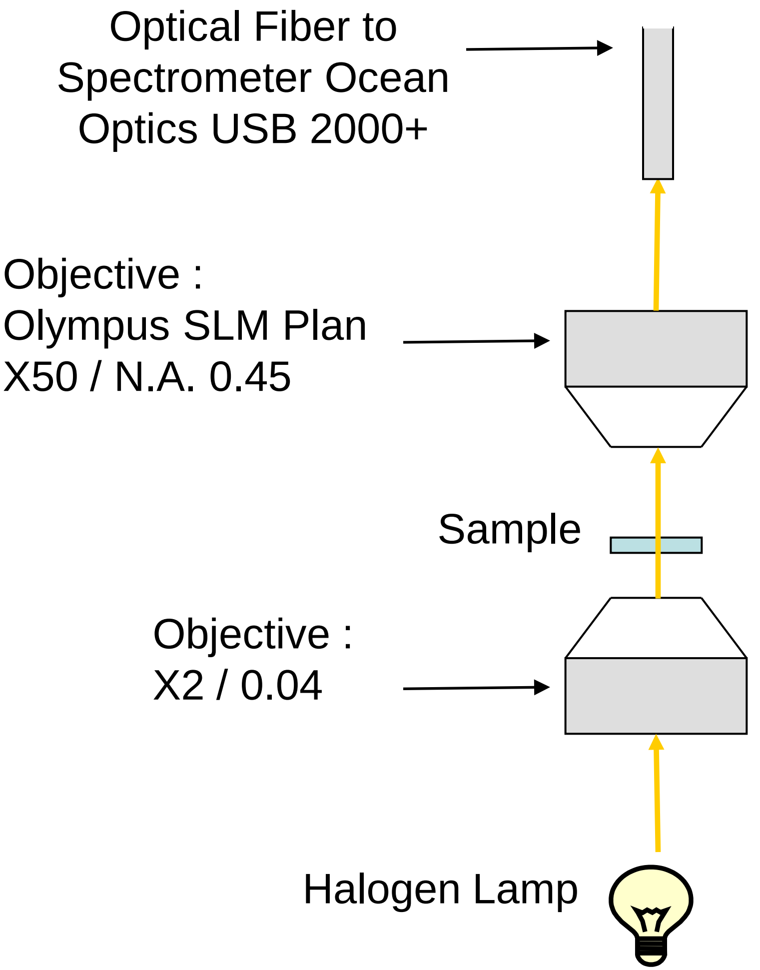
- Exctinction spectroscopy: LSPR wavelength
- FDTD simulations: understanding modes
- SNOM: observation of the EM field distribution near the surface

Nanostructures: prepared by e-beam lithography & thermal evaporation



Gold nanostructures onto BK7 glass with rectangular and circular shape

Extinction Spectra Setup



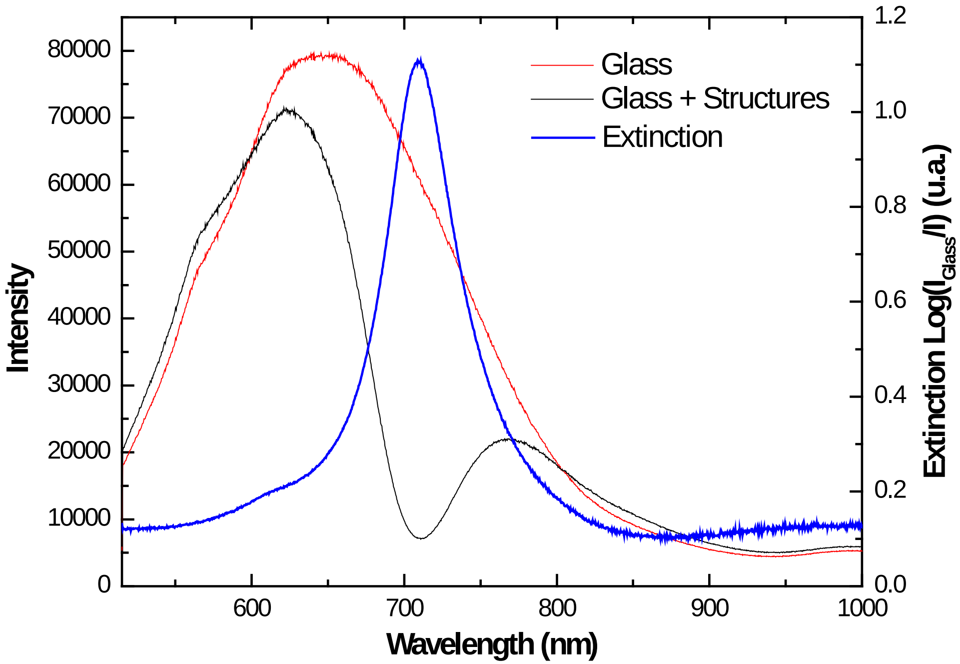
Optical Fiber to Spectrometer Ocean Optics USB 2000+

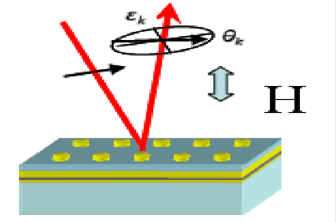
Objective :
Olympus SLM Plan
X50 / N.A. 0.45

Sample

Objective :
X2 / 0.04

Halogen Lamp

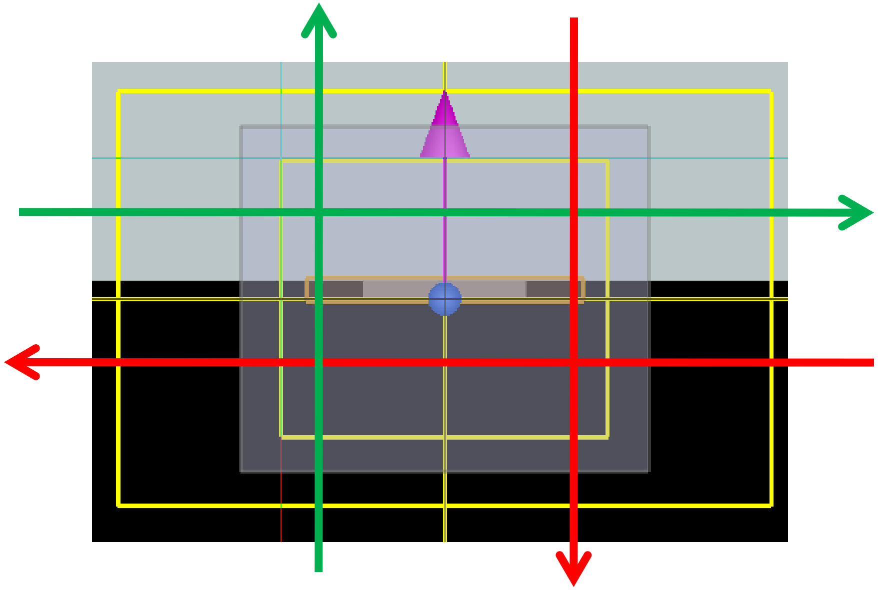


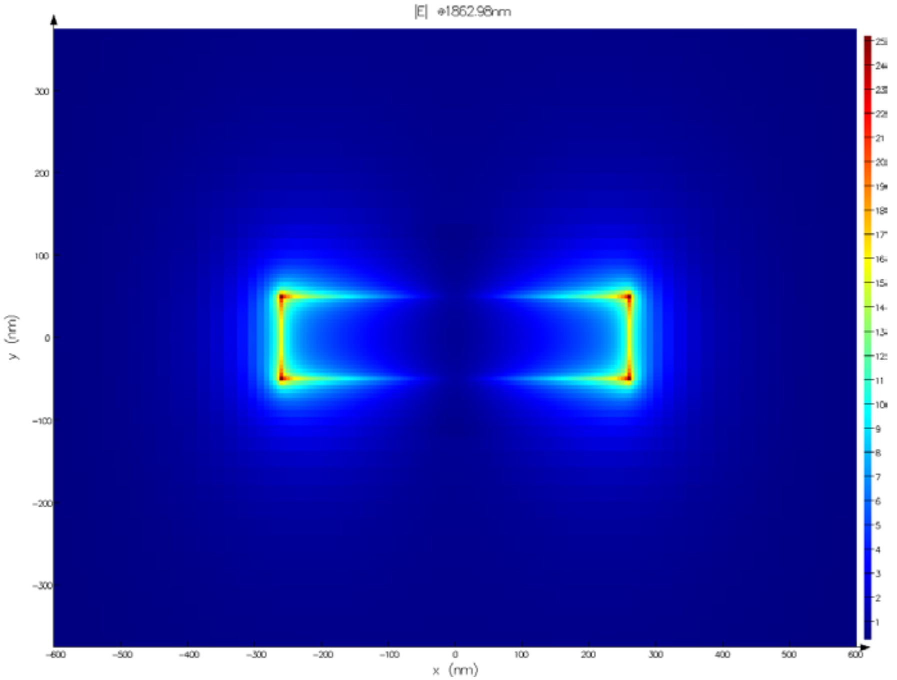


Simulations

FDTD code: Lumerical

Calculus of absorption and scattering cross-sections & simulation of the EM field distribution





Electric Field Modulus @ Surface
L=520nm, 1st Order

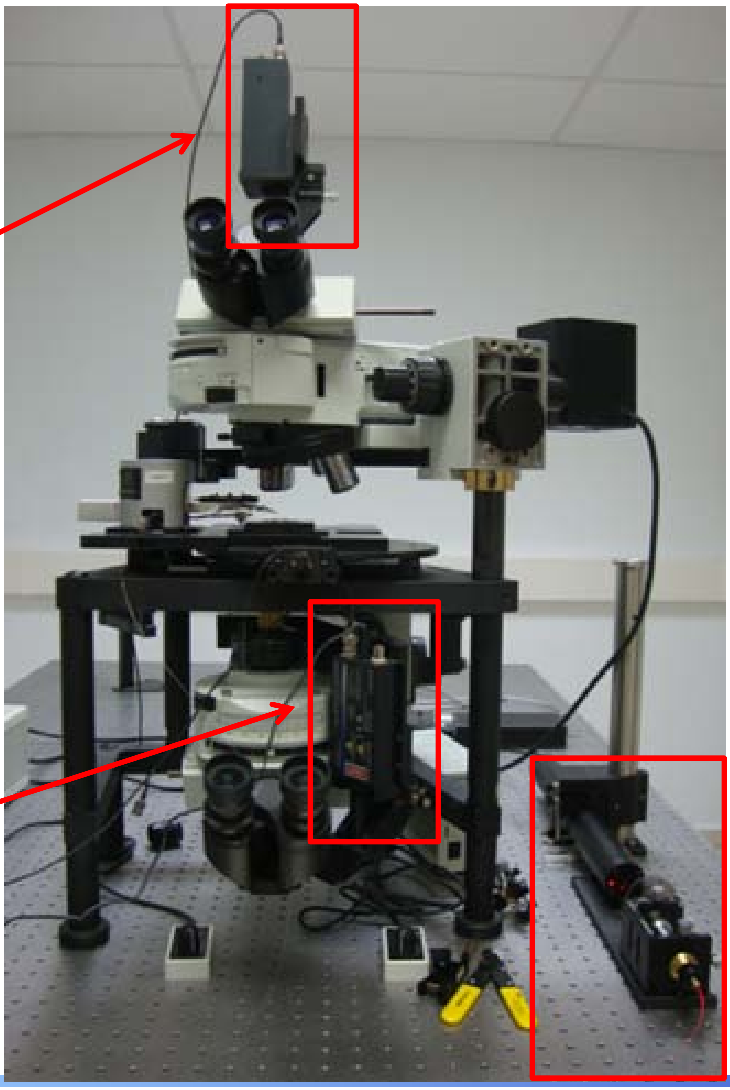
Scanning Near-Field Optical Microscopy (SNOM) setup

Photomultiplier tube

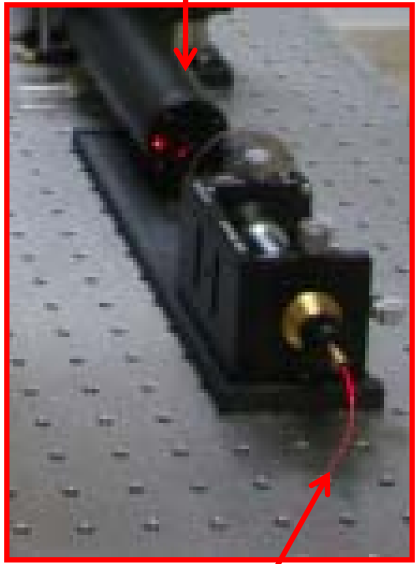
NANONICS
Multiview
4000

Avalanche Photodiode

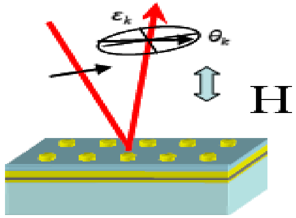
Analysis:
WSxM



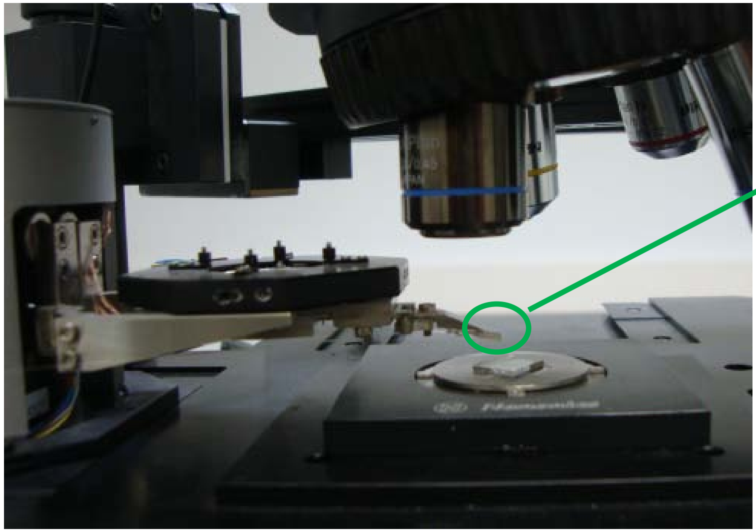
Laser



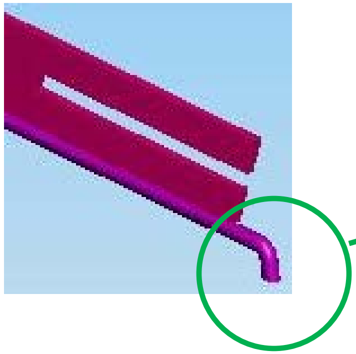
Optical Fiber



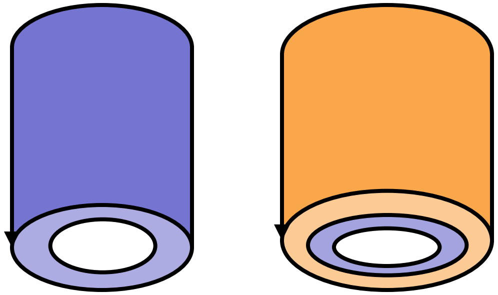
SNOM setup



Tunning fork & bent fibers

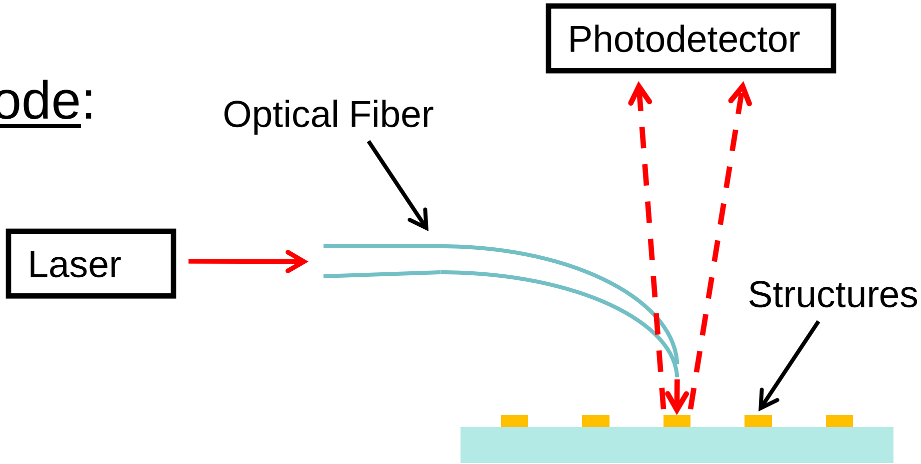


(Aperture: 50-150nm)

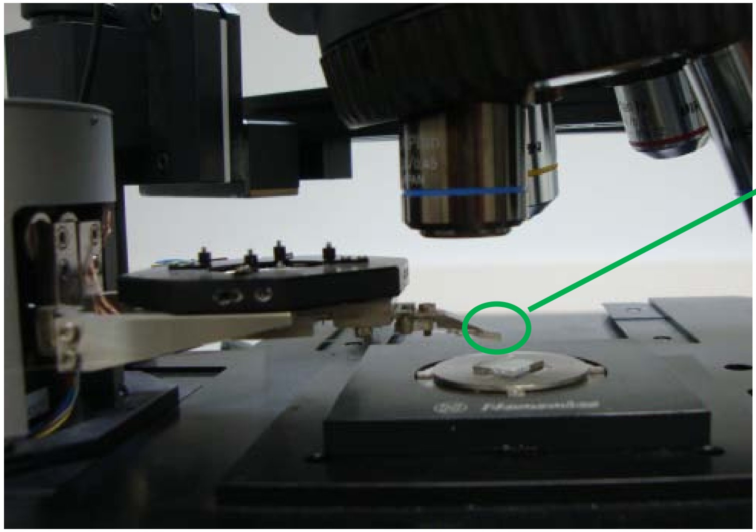


Uncoated or Coated

Scheme of the illumination mode:
(in reflection)



SNOM setup



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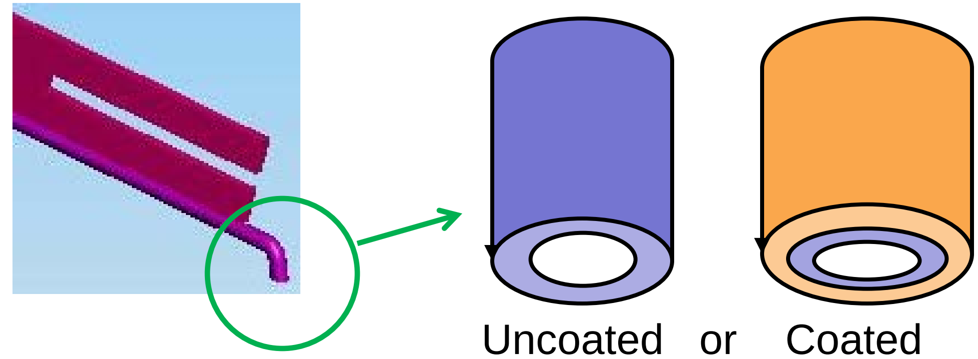
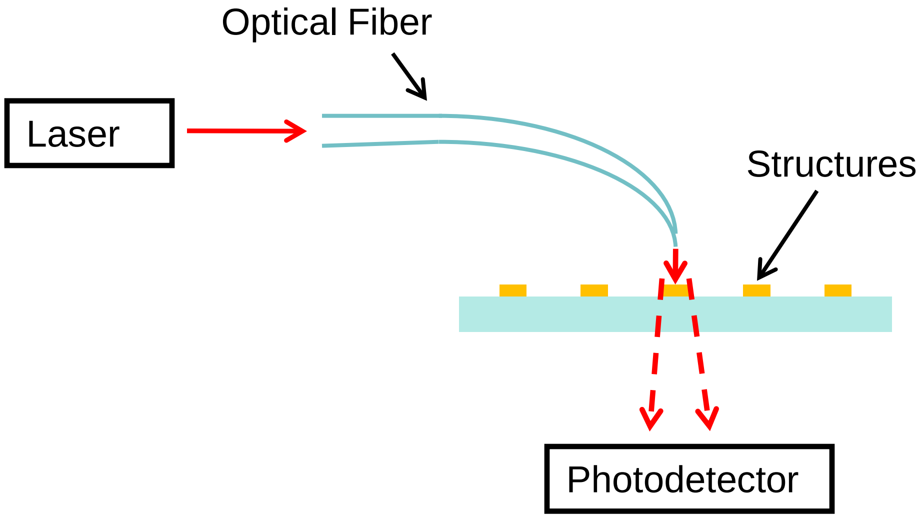
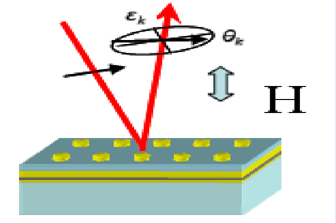


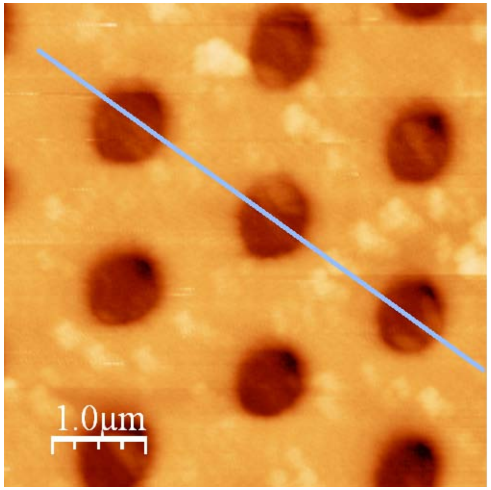
Scheme of the illumination mode:
(in transmission)

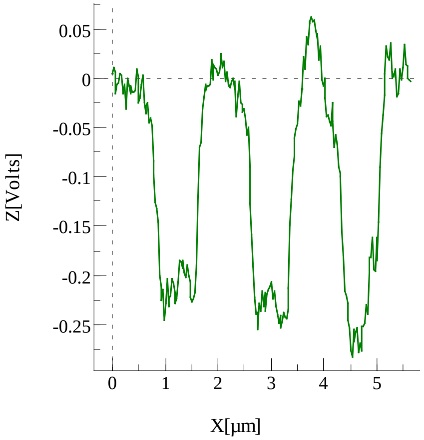




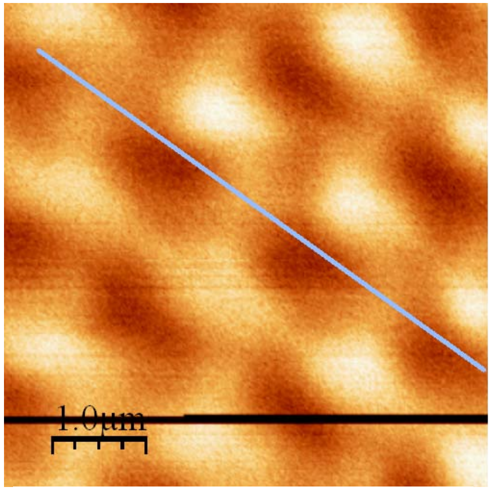
Photonic Crystal with a bad probe

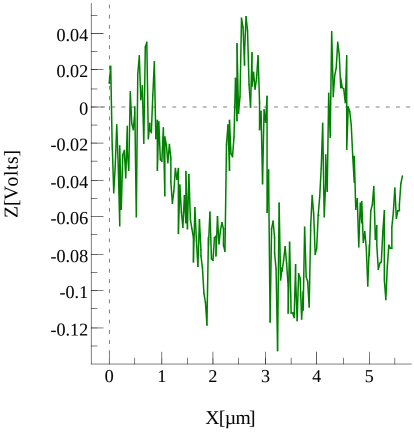
Topography



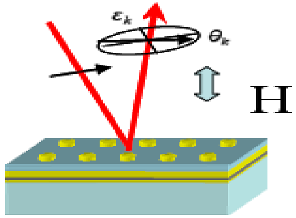


Optical signal



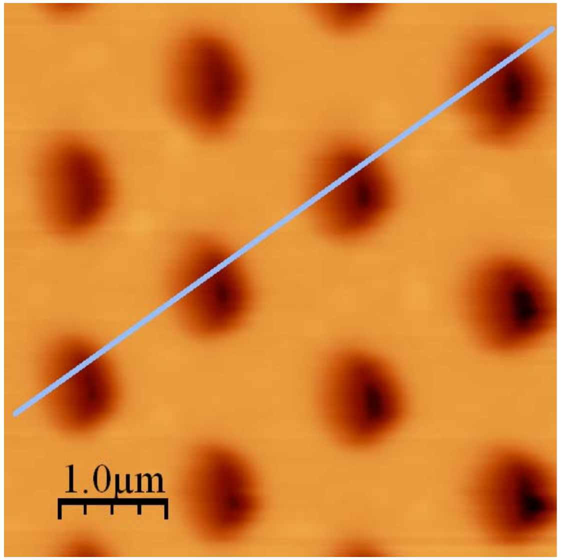


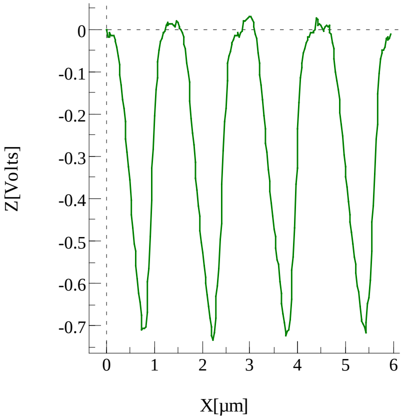
Reflection mode



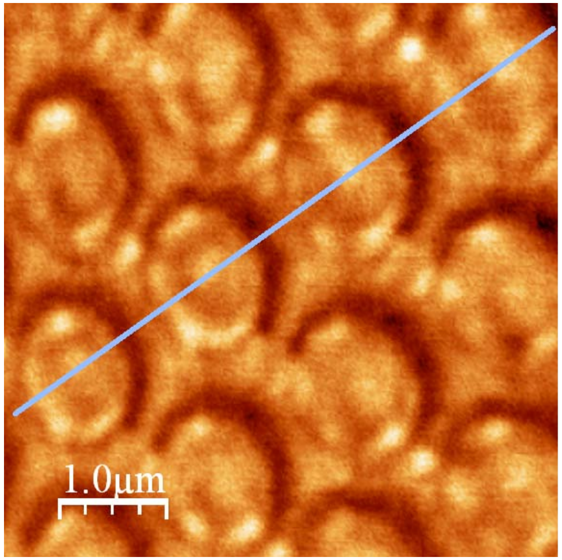
Photonic Crystal with a good probe

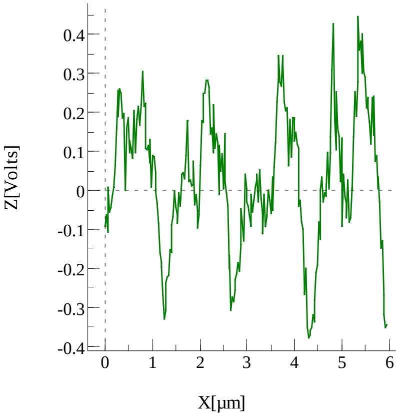
Topography



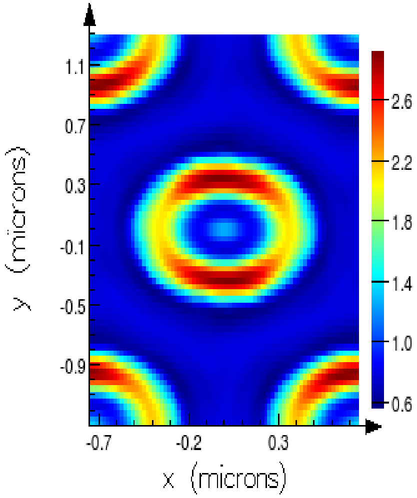


Optical signal

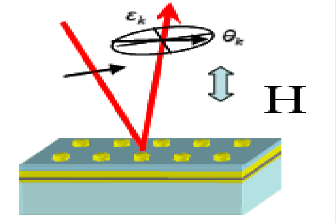




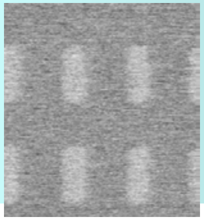
Simulation



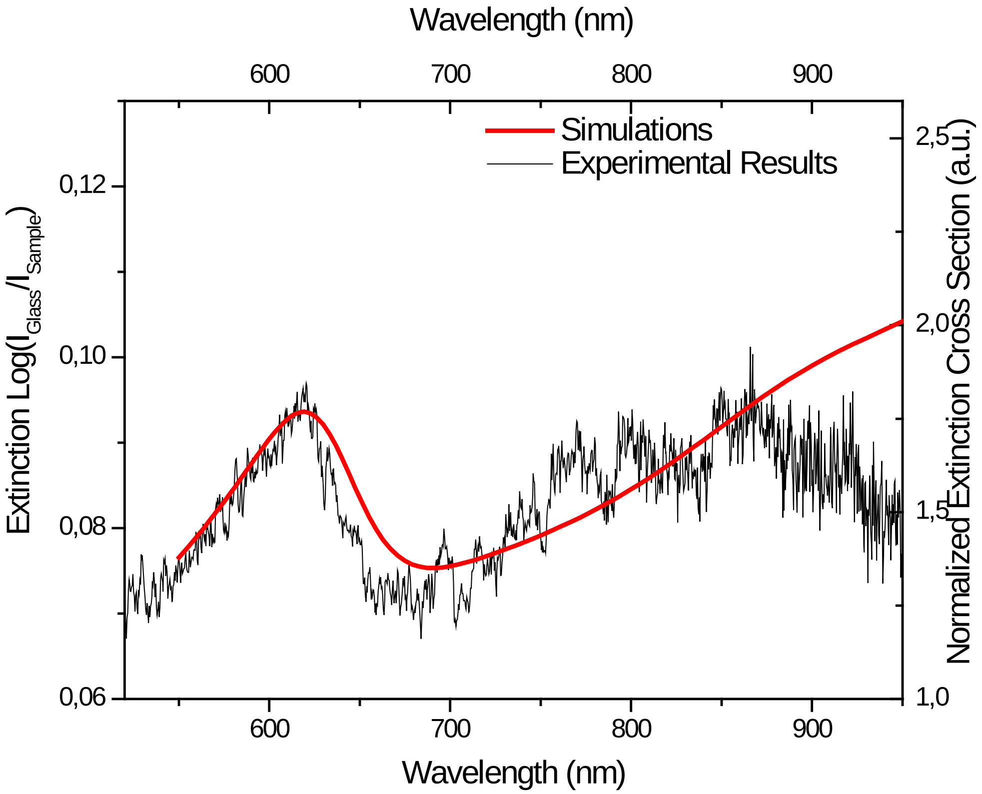
Reflection mode



Rectangles

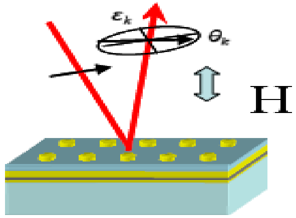


Extinction spectra *vs.* simulation



At 632 nm:
Resonance for
in-plane polarization
along the long axis

Rectangular nanostructures with Length: 400nm. Width: 200nm. Thickness: 60nm.
Array periodicity: 1000nm



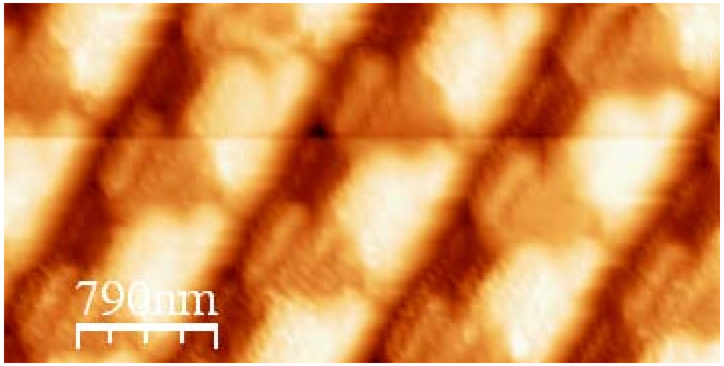
Rectangles

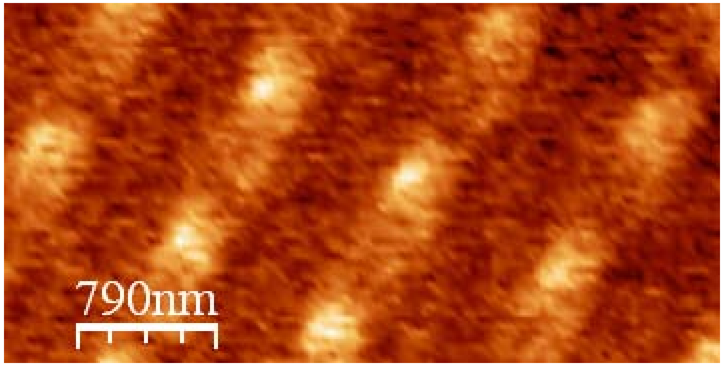
Tip

Topography

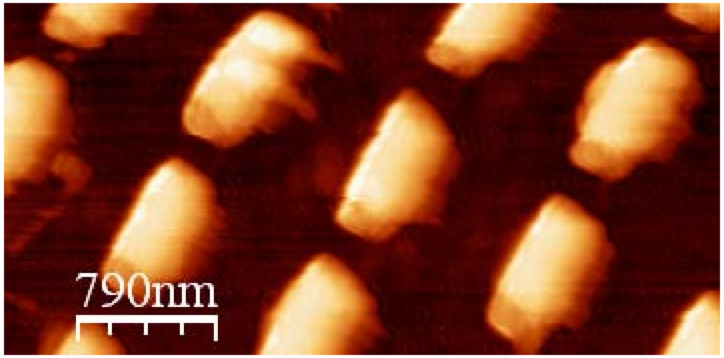
Optical signal

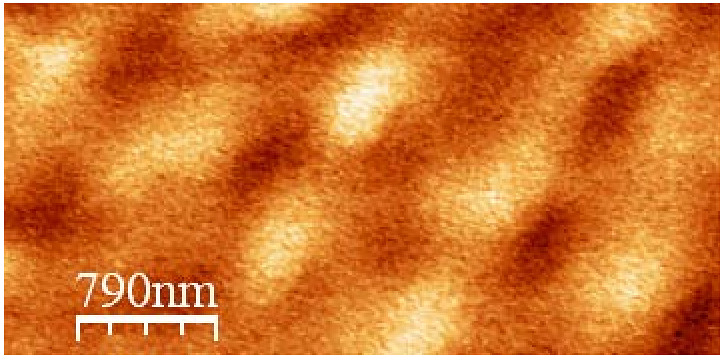
50nm ap.
50nm metallic
coating





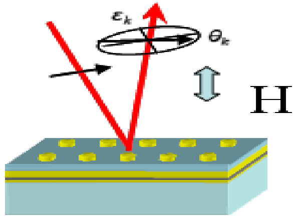
110nm ap.
Uncoated





Rectangular nanostructures with Length: 400nm. Width: 200nm. Thickness: 60nm.
Array periodicity: 1000nm

Reflection mode

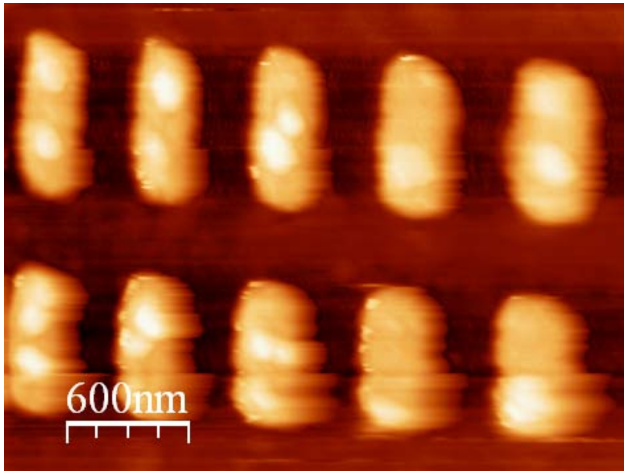


Rectangles

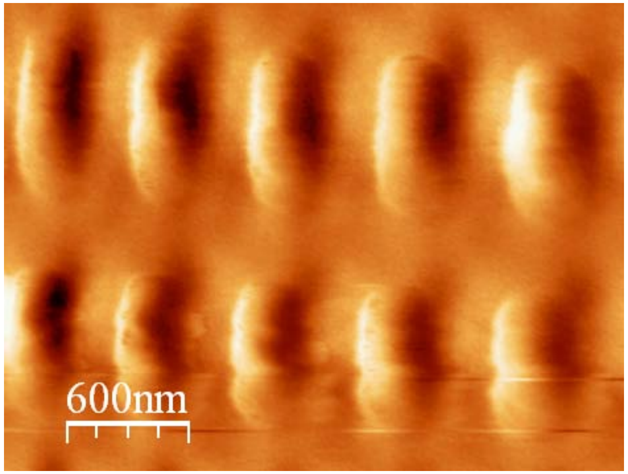
Tip

150nm ap.
50nm metallic coating

Topography

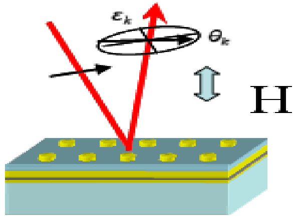


Optical signal



Rectangular nanostructures with Length: 500nm. Width: 100nm. Thickness: 60nm.
Array periodicity: 600nm

Reflection mode

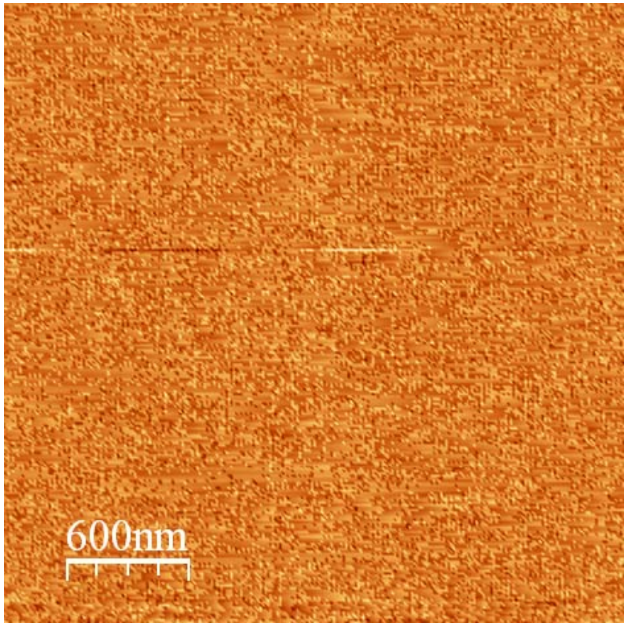


Rectangles

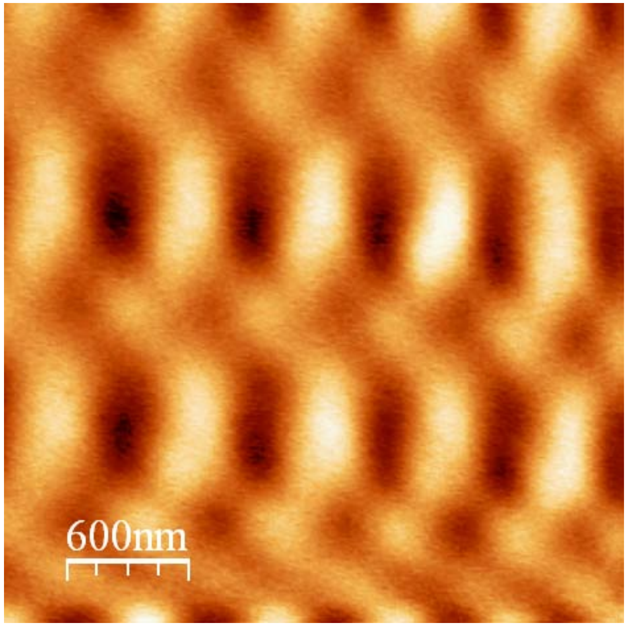
Tip

150nm ap.
50nm metallic
coating

Topography



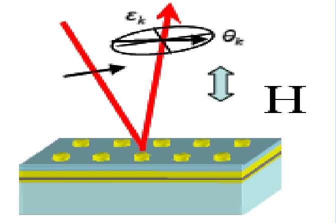
Optical signal



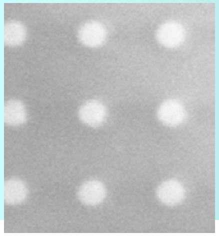
Constant plane at about 100nm

Rectangular nanostructures with Length: 500nm. Width: 100nm. Thickness: 60nm.
Array periodicity: 600nm

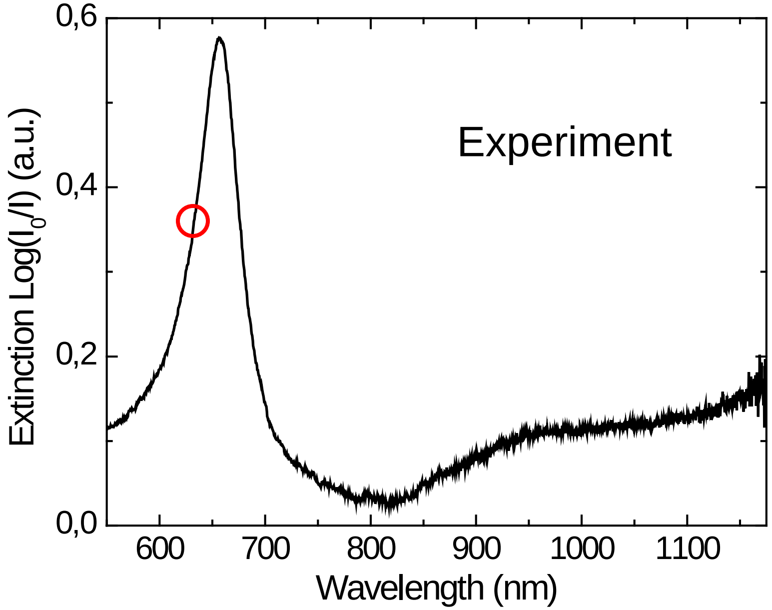
Reflection mode

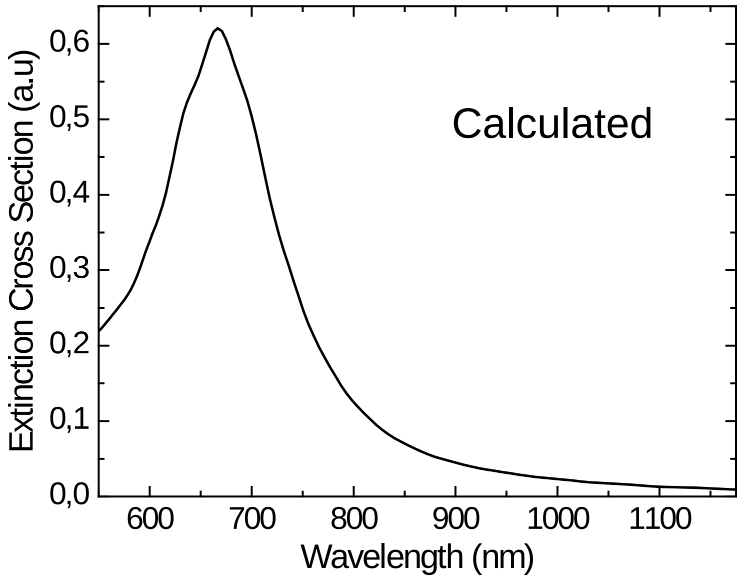


Circles



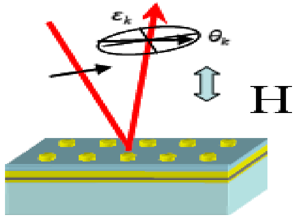
Extinction spectra *vs.* simulation





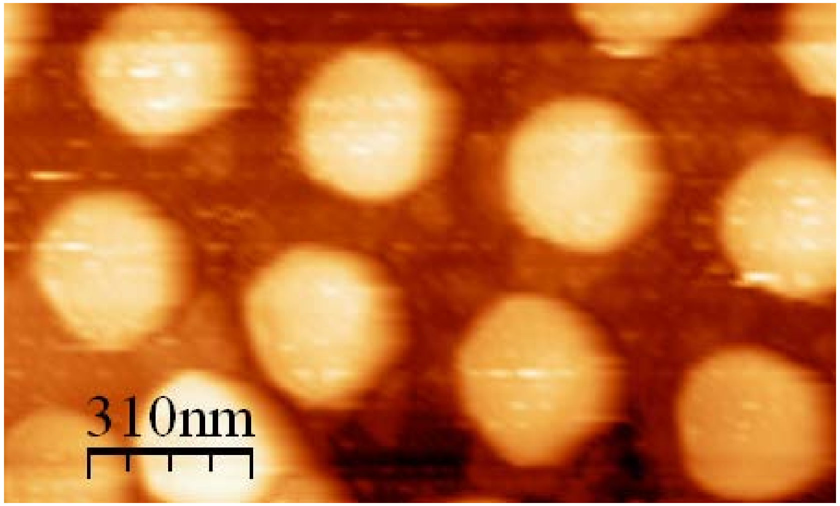
At 632 nm we are still exciting the LSP (but not in optimum conditions)

Circular nanostructures with Diameter: 175nm. Thickness: 60nm.
Array periodicity: 400nm

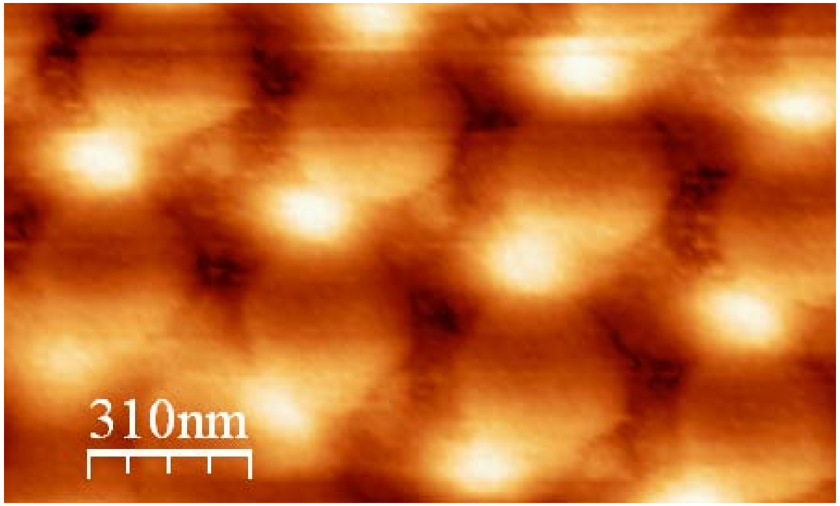


Circles

Topography



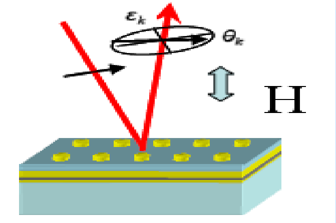
Optical signal



TIP: 80nm ap. , 50nm metallic coating

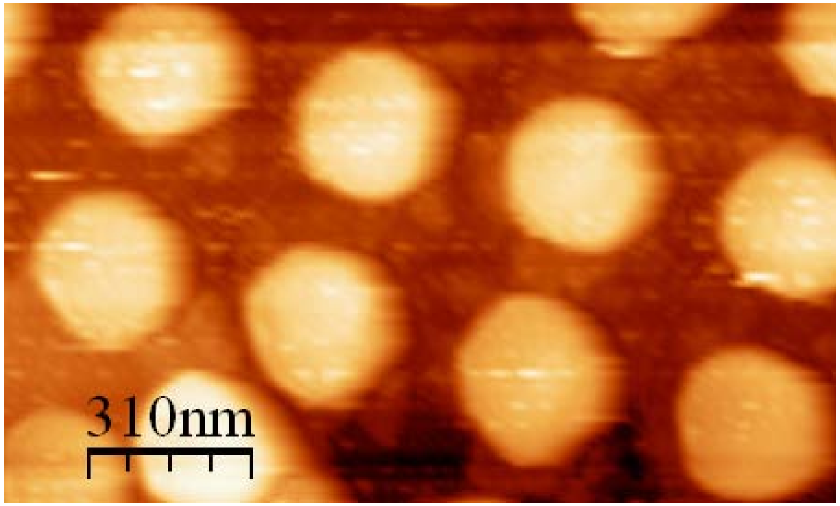
Diameter: 175nm. Thickness: 60nm.
Array periodicity: 400nm

Reflection mode

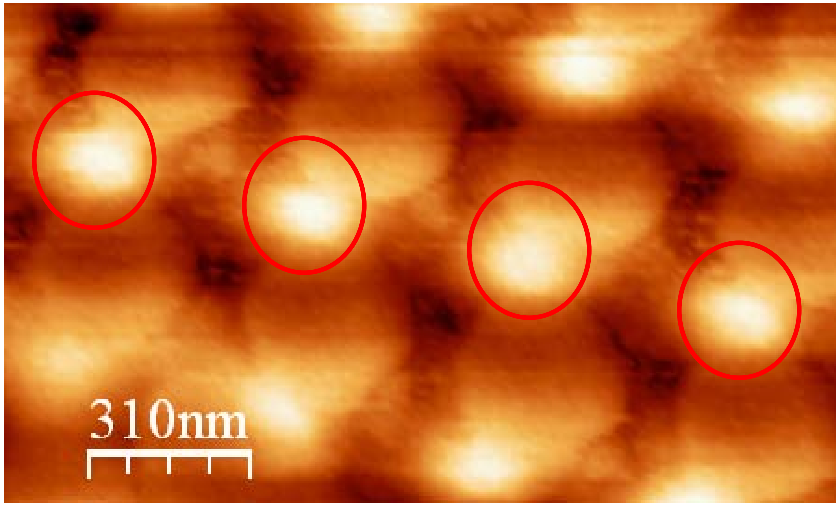


Circles

Topography



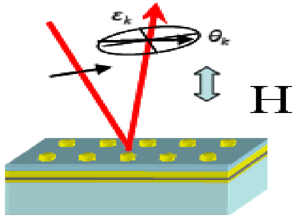
Optical signal



TIP: 80nm ap. , **50nm metallic coating**

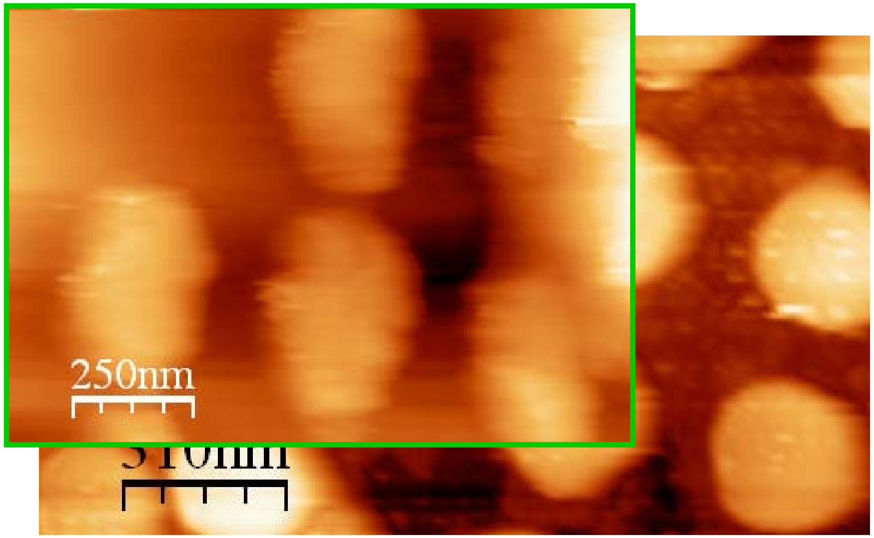
Diameter: 175nm. Thickness: 60nm.
Array periodicity: 400nm

Enhancement in the gap.
Interaction with the probe?

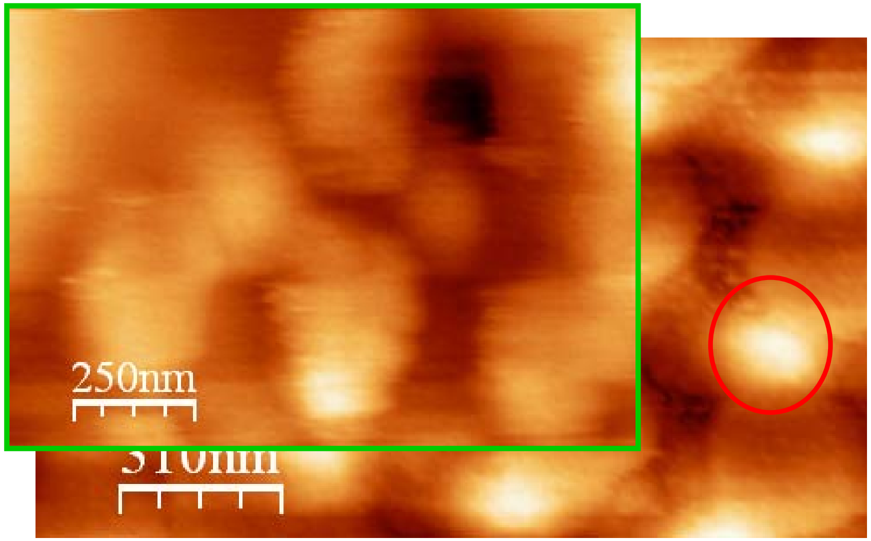


Circles

Topography



Optical signal



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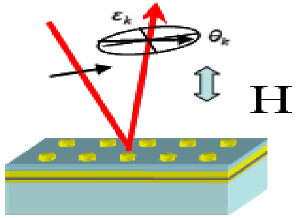
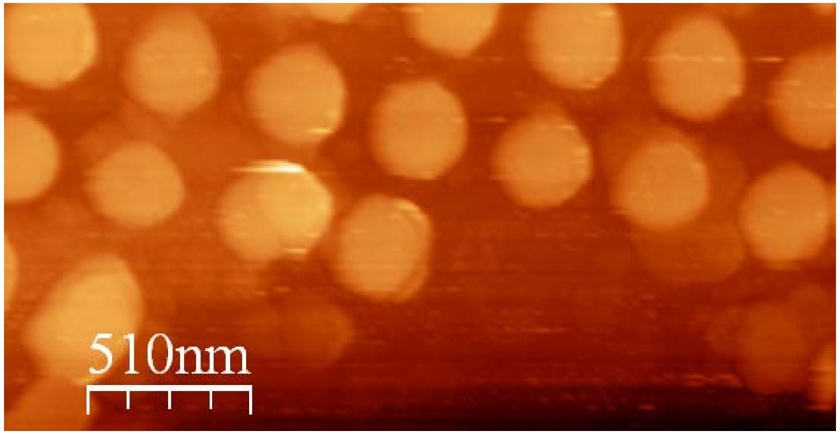
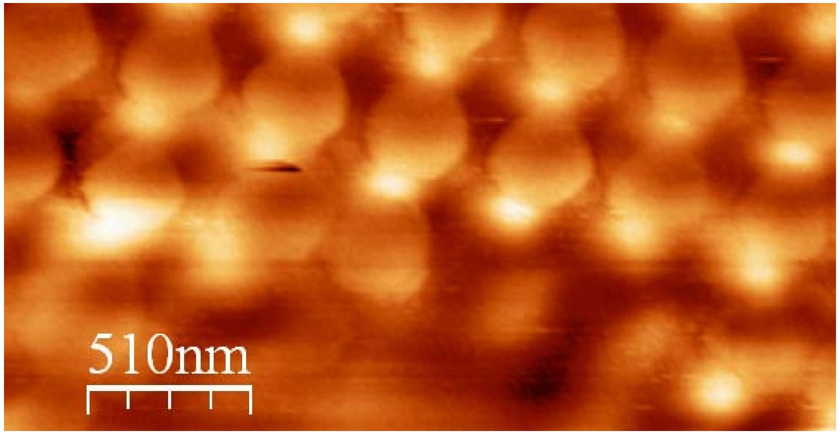


Circles

Topography



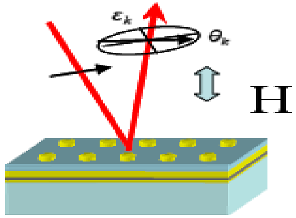
Optical signal



Diameter: 175nm. Thickness: 60nm.
Array periodicity: 400nm

TIP: 80nm ap. , 50nm metallic coating

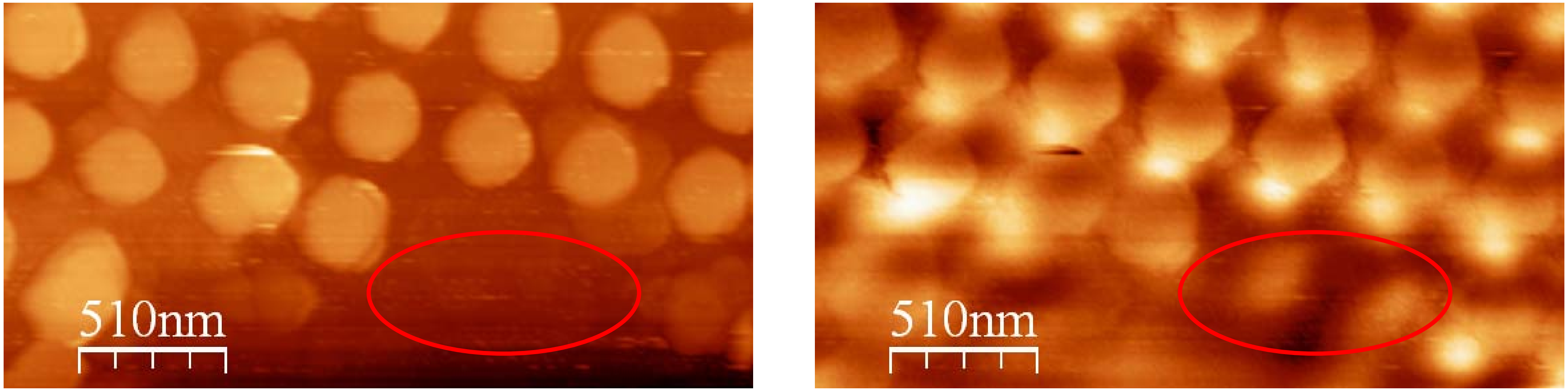
Reflection mode



Circles

Topography

Optical signal

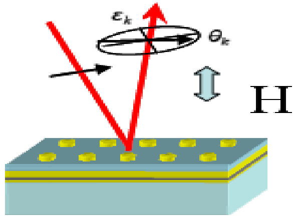


The optical signal is still modulated above missing circles: collective effect (interference)

Diameter: 175nm. Thickness: 60nm.
Array periodicity: 400nm

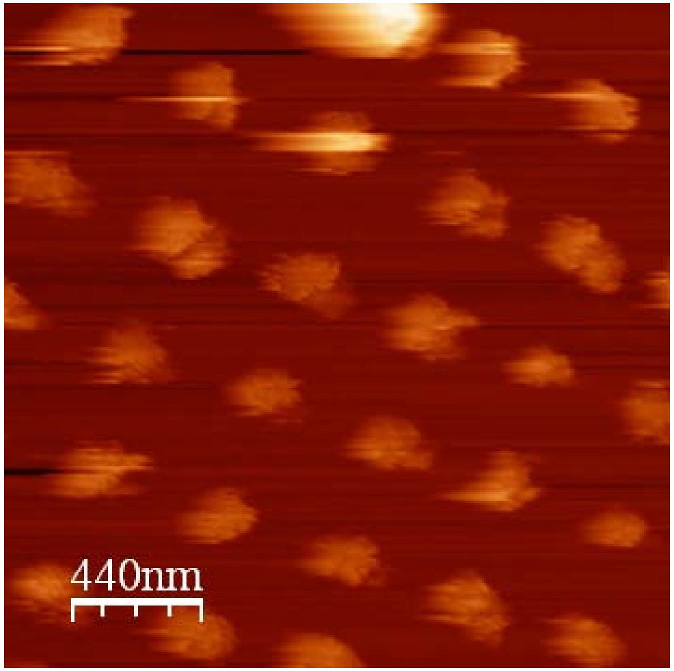
TIP: 80nm ap. , 50nm metallic coating

Reflection mode



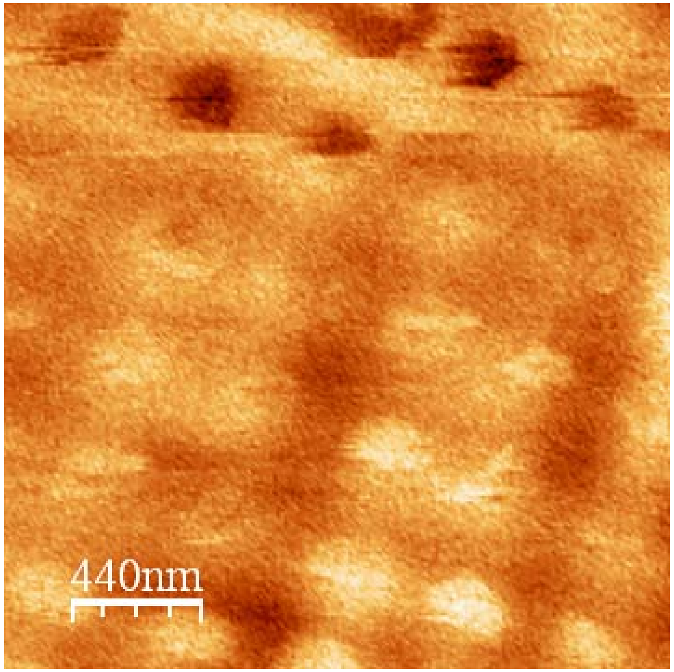
Circles

Topography



Contrast changes

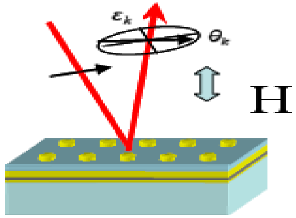
Optical signal



Diameter: 150nm. Thickness: 60nm.
Array periodicity: 400nm

TIP: 50nm ap. , 50nm metallic coating

Transmission mode



Magnetic Nanostructures & Magnetoplasmonics: staff

Gaspar Armelles
Optical and magneto-optical properties of nanostructures

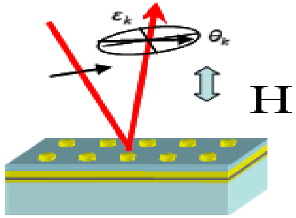
Alfonso Cebollada
Growth and epitaxy of nanostructures

Antonio García-Martín
Theory of optical and magneto-optical properties

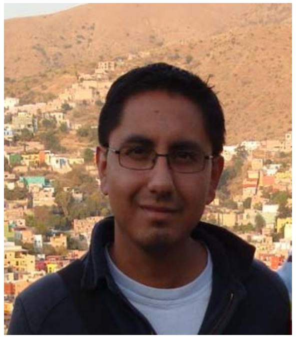
José M. García-Martín
Scanning probe techniques and nanomagnetism

María U. Gonzalez
2-D plasmonic elements

José V. Anguita
High resolution lithography and nanofabrication

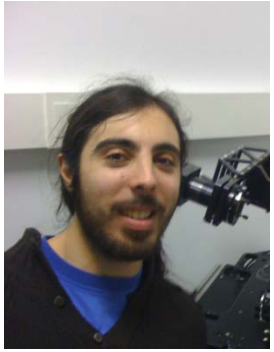


Postdocs, PhD students & technicians


Dr. David Meneses


Juan B. González-Diaz


Rui Fermento

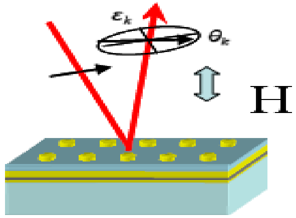

Elias Ferreiro


Patricia Prieto


Jorge F. Torrado


Diana Martín


Alan Vitrey



Magnetic Nanostructures
MN-MP
Magneto Plasmonics

Conclusions

- Extinction spectra helps to identify the laser needed for exciting the LSP resonance in the SNOM experiments

- SNOM can provide the EM field distribution associated with LSP resonances

- The probe plays an important role

- In the future: the EM field distribution in magnetoplasmonic nanostructures can help us to place the magnetic material in the proper location to optimize the MO enhancement

Funding:
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Spanish MICINN (“Magplas” MAT2008-06765-C02-01/NAN and
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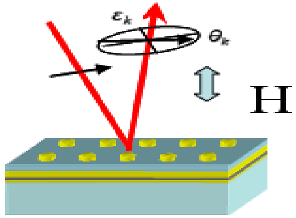
Comunidad de Madrid (“Nanobiomagnet” S2009/MAT-1726)



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¡ MUCHAS GRACIAS POR VUESTRA ATENCIÓN !

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