Dielectric and metallic photonic crystals with applications in communications

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Outline

- Simulation of PMMA and SU8 photonic crystals (PCs) using the plane wave expansion (PWE) and finite difference time domain (FDTD) methods.

  PMMA PCs working in visible region (bandgap centered at 650 nm).

  SU8 PCs working in infrared region (bandgap centered at 1550 nm).
- Fabrication of two dimensional photonic crystals (PCs) obtained by direct patterning of dielectric materials: positive (PMMA) and negative (SU8) electronoresist and by lift-off process of metallic gold layer. Both types of structures were performed using electron-beam lithography technique (EBL)
- Near field scanning optical microscopy characterization of metallic photonic crystals realized from gold nanodisks on glass substrate with applications in plasmonics are presented.

- Photonic crystals periodic arrays of scatterers with a lattice constant comparable with the wavelength of the incident light
- Interaction of the EM fields - scatterers lead: constructive and destructive interference effects allowed and forbidden states for light propagation.
- band structure with a certain dispersion in the Brillouin zone
- geometrical parameters of the crystal - system of crystallization, lattice constant, shape, size, refractive index contrast.
- bandgaps – frequency ranges where the propagation of the light is forbidden

Possibility to manipulate optical radiation

APPLICATIONS

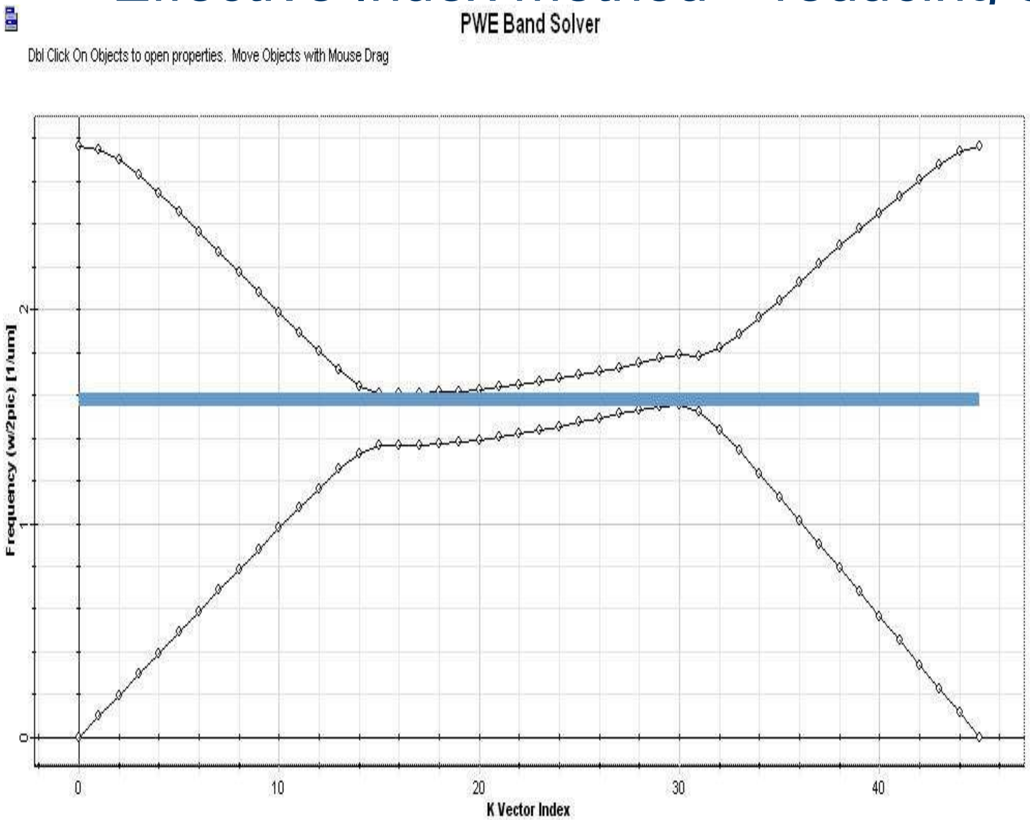
- photonics : low -loss, sharp bents waveguides
- PC optical fibers (holey fibers)
- Optoelectronics (laser diodes, VCSELS)
- cavity electrodynamics .

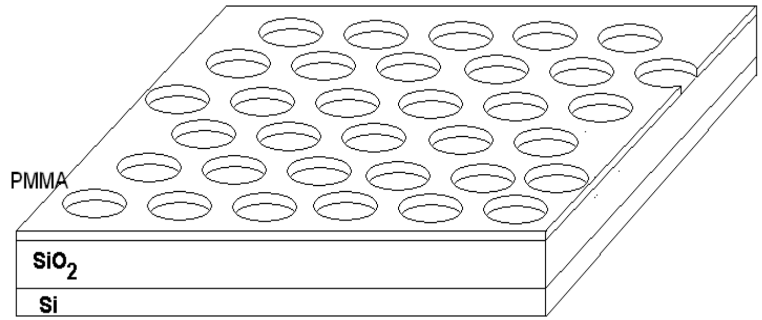
Simulations

Plane Wave Expansion (PWE)

Finite Difference Time Domain (FDTD)

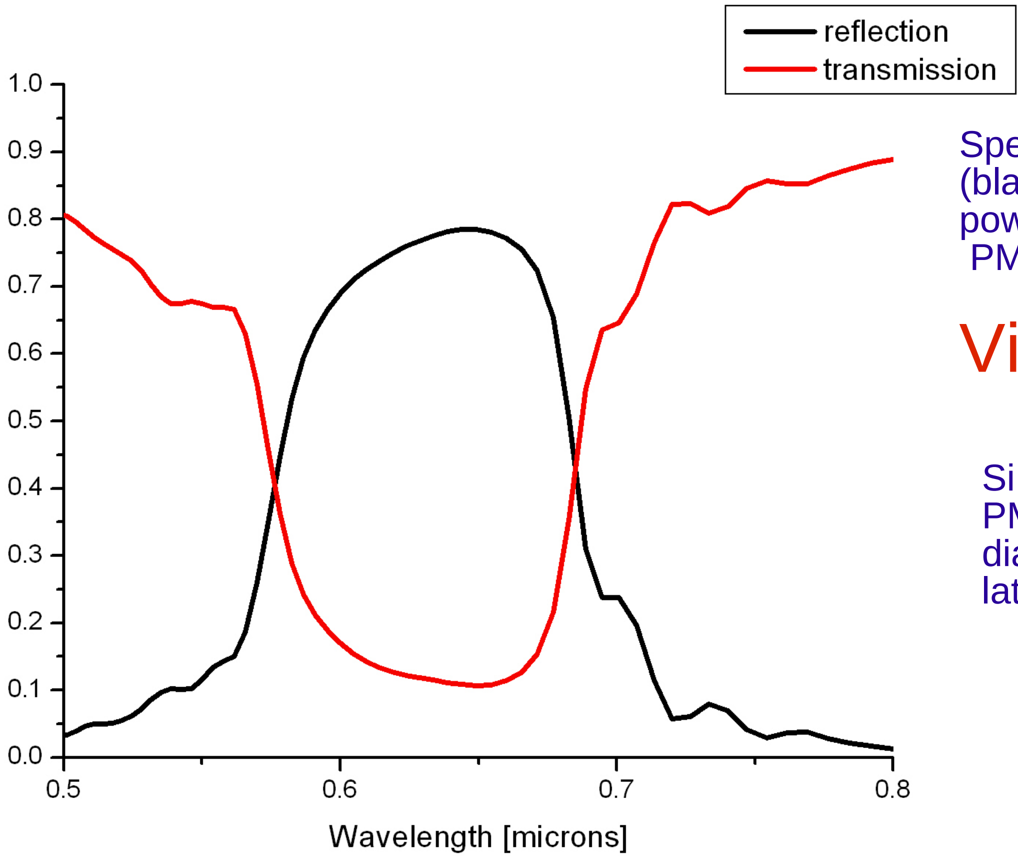
Effective Index method – reducing 3D to 2D





band structure of the two-dimensional PC consisting of a hexagonal array of holes realized in an infinitely thick layer of PMMA; the band gap is reprezented by the blue region.

FDTD Simulations



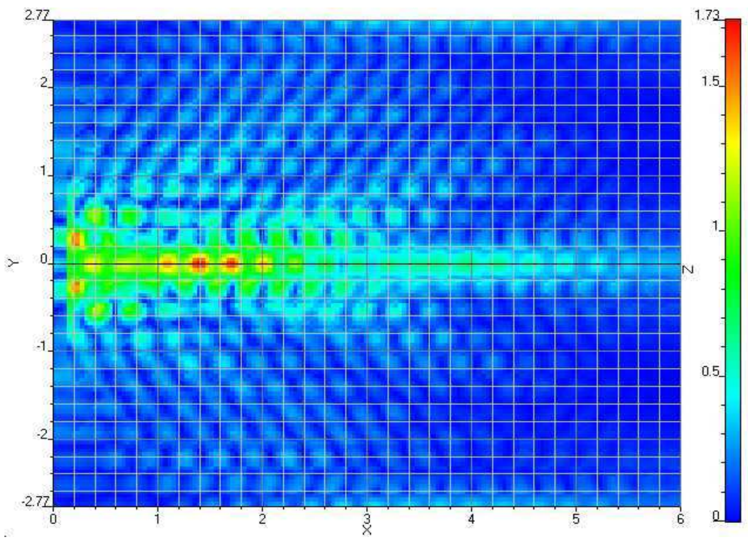
Spectrum of the reflected (black line) and transmitted power (red line) of a 3-D PMMA photonic crystall

Visible spectral range

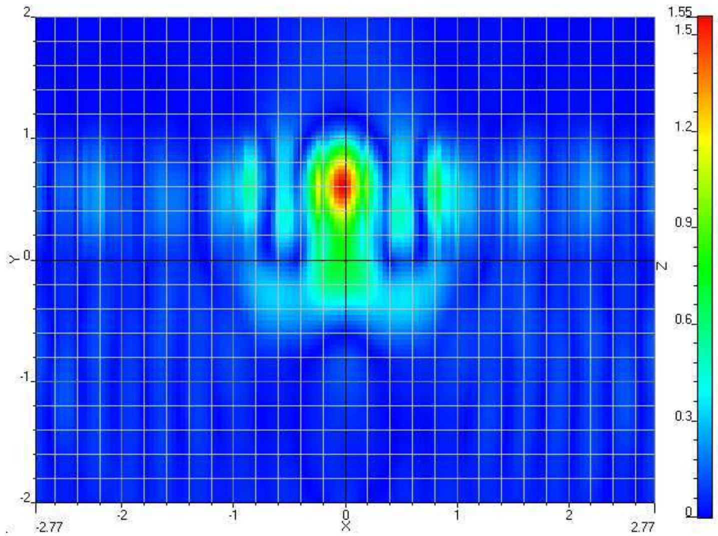
Si – SiO2 - PMMA
PMMA thickness 1 micron
diameter 240 nm
lattice constant 320 nm

FDTD Simulations – PC waveguides

photonic crystal waveguide – one or more lines of defects

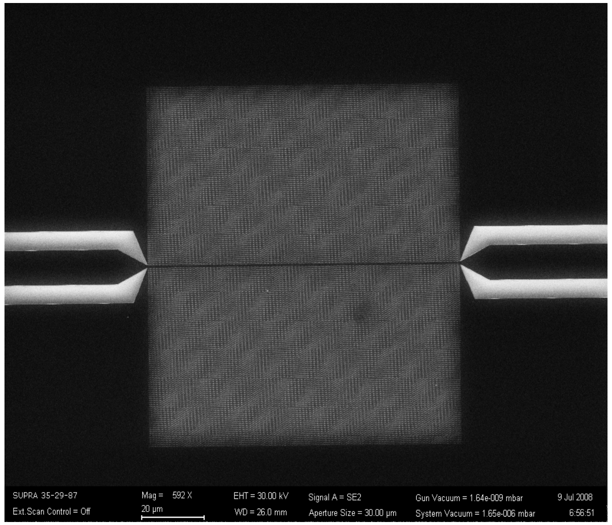


Field configuration along the propagation direction



Field configuration in a cross-section perpendicular to the propagation direction.

Fabrication



Thermally grown SiO_2 layer - thickness 1.7 µm

PMMA electronresisit was spin-coated – 2 succesive layers of 500 nm PMMA

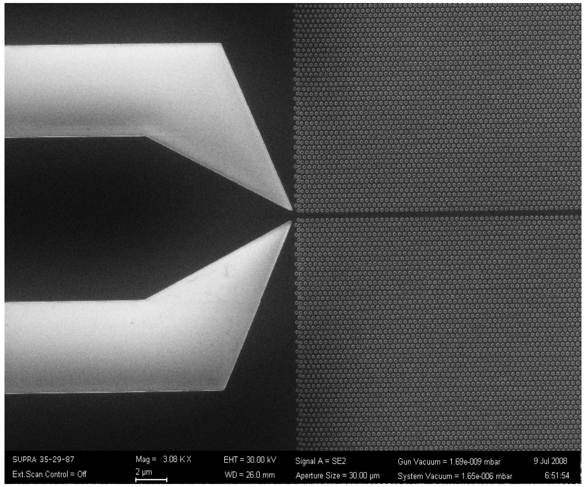
Thermal treatment: - 2h 160 ^{o}C

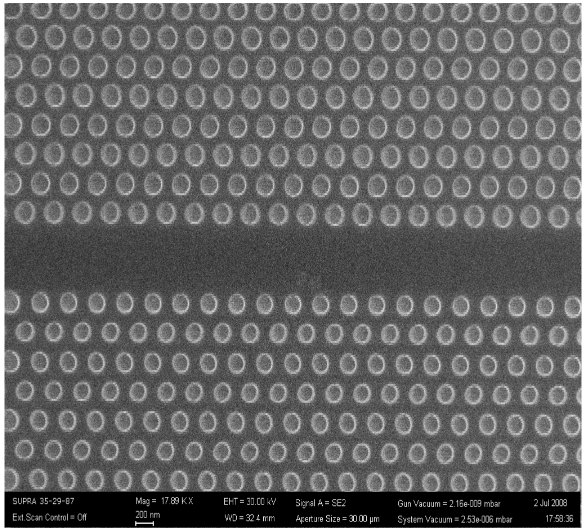
Nanolithography: RAITH e-Line nanoengineering workstation

15 kV accelerating voltage, beam current of 300 pA.

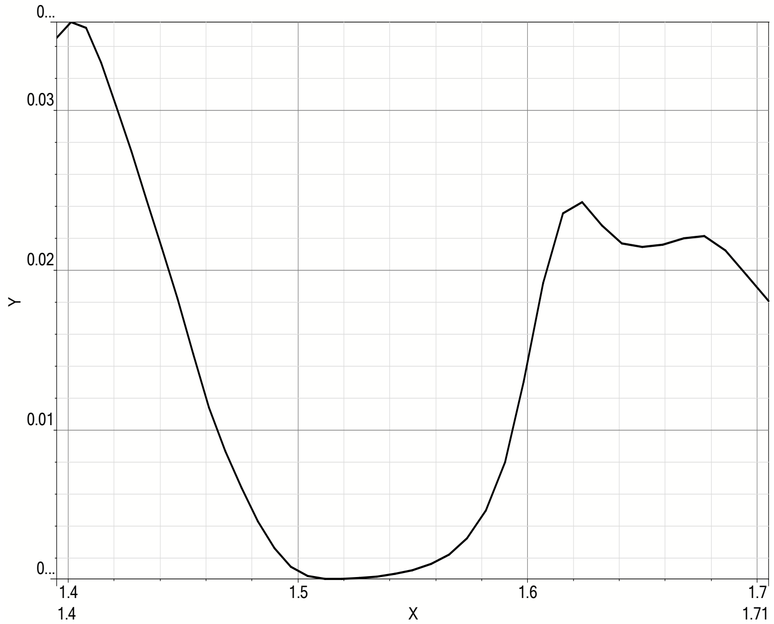
Clearing dose was 200 pC/cm^2 for areas and 0.2 pC/dot for dots.

Solution of 3:1 IPA:MIBK, for developing.

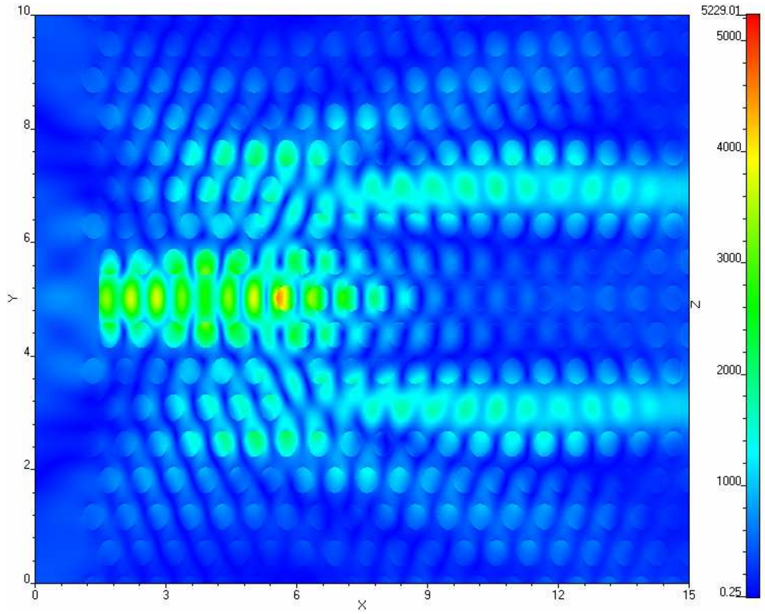




SU8 PC 3D FDTD Simulations



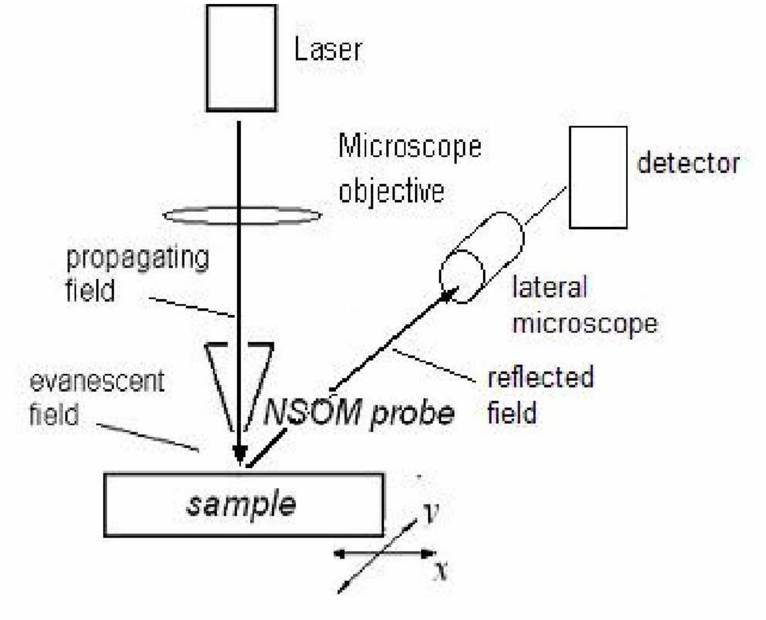
The spectrum of transmitted power

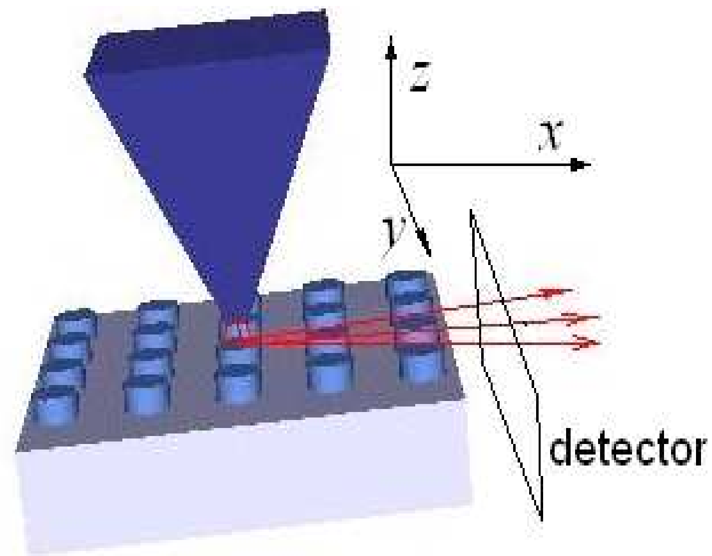


Radiation propagation in a Y-junction

Infrared domain (1550 nm)

Metallic photonic crystals



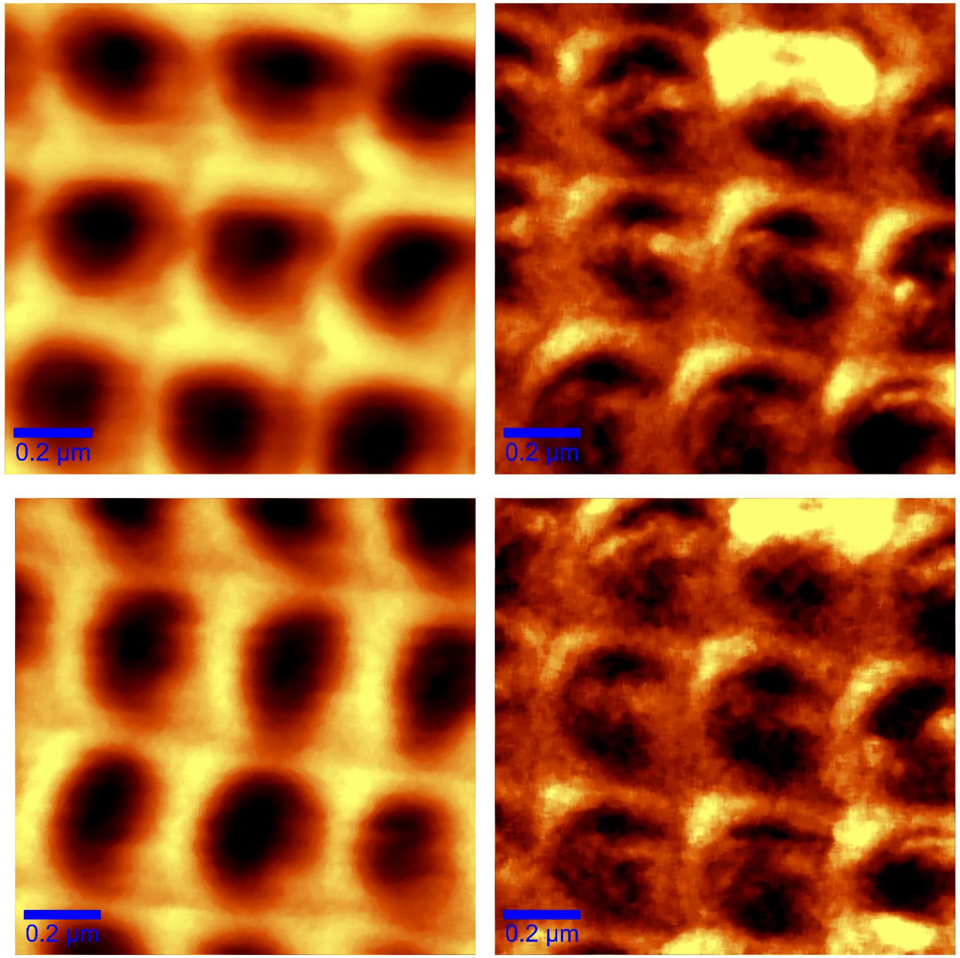


Surface plasmon – polariton (SPP) excitation

Sensing, waveguiding, fluorescence, ERS

FDTD Simulations   Nanolithography   Scanning Near – Field Optical Microscopy

SNOM Images



SNOM transmission (left) and reflection (right) images of a square array of gold disks deposited on a glass substrate for 532 nm. and 635 nm.

Geometrical parameters

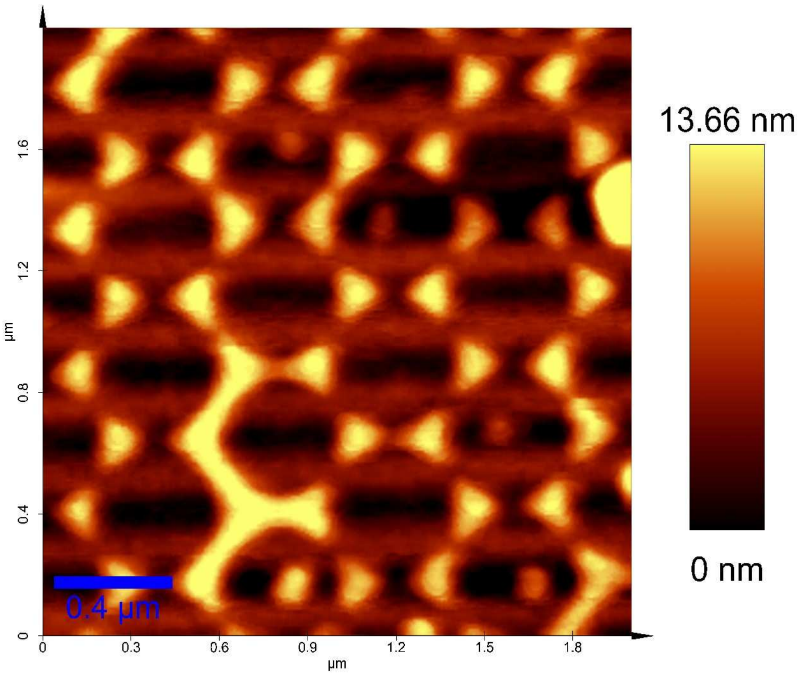
thickness 80 nm
diameter 200 nm
lattice constant 400 nm

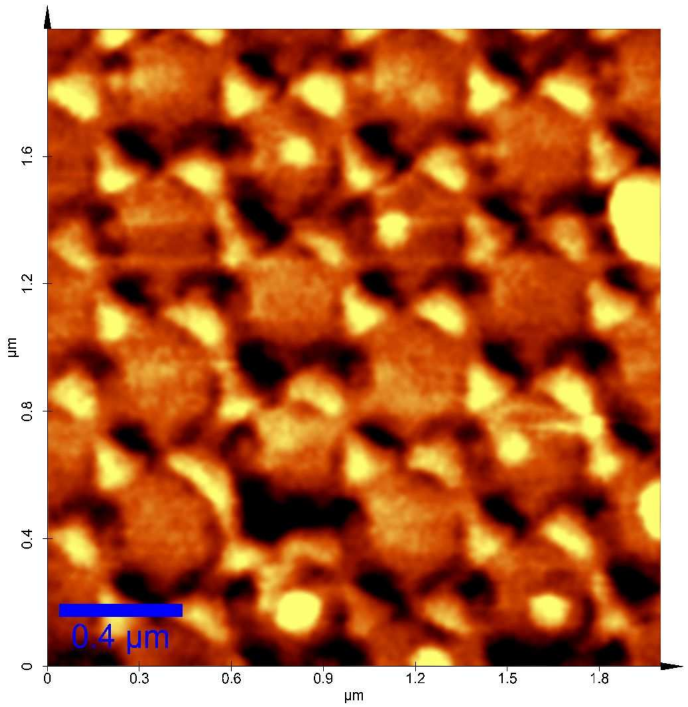
Fabrication

Nanolithography
Lift - off

C. Kusko et al IEEE Proc. CAS (2009)

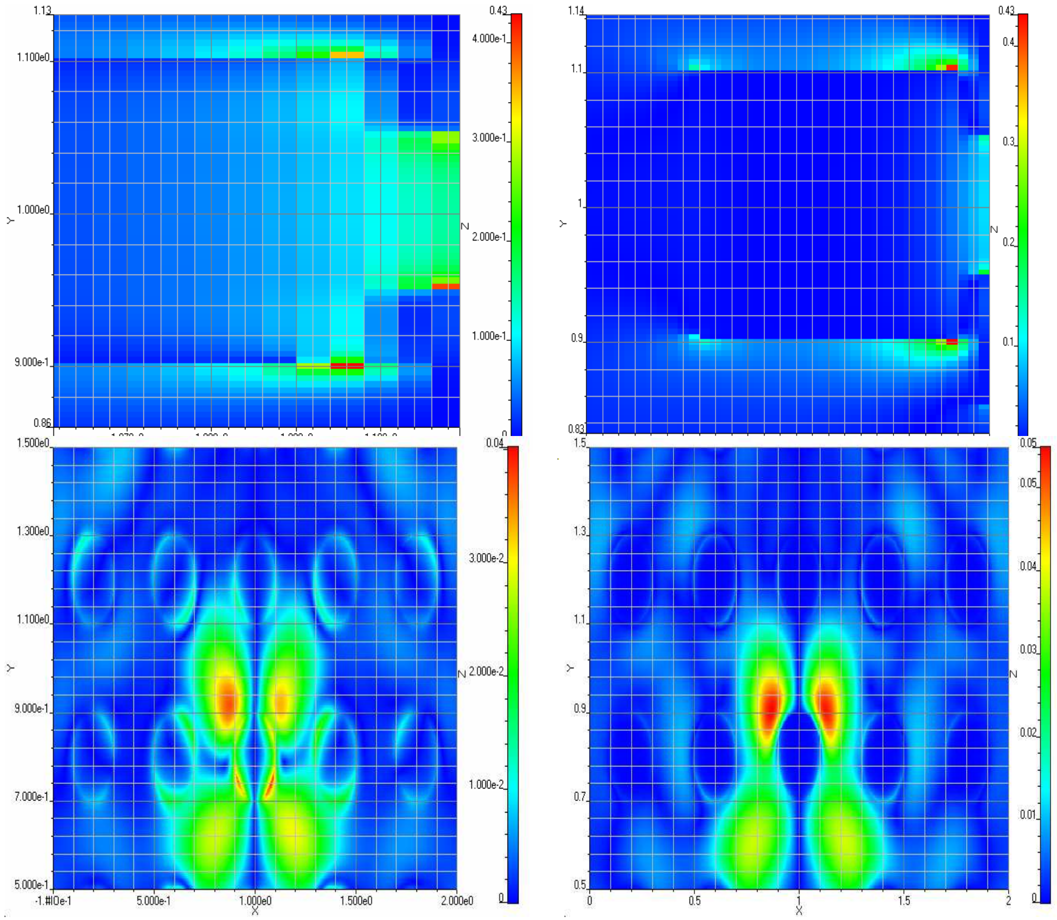
SNOM images





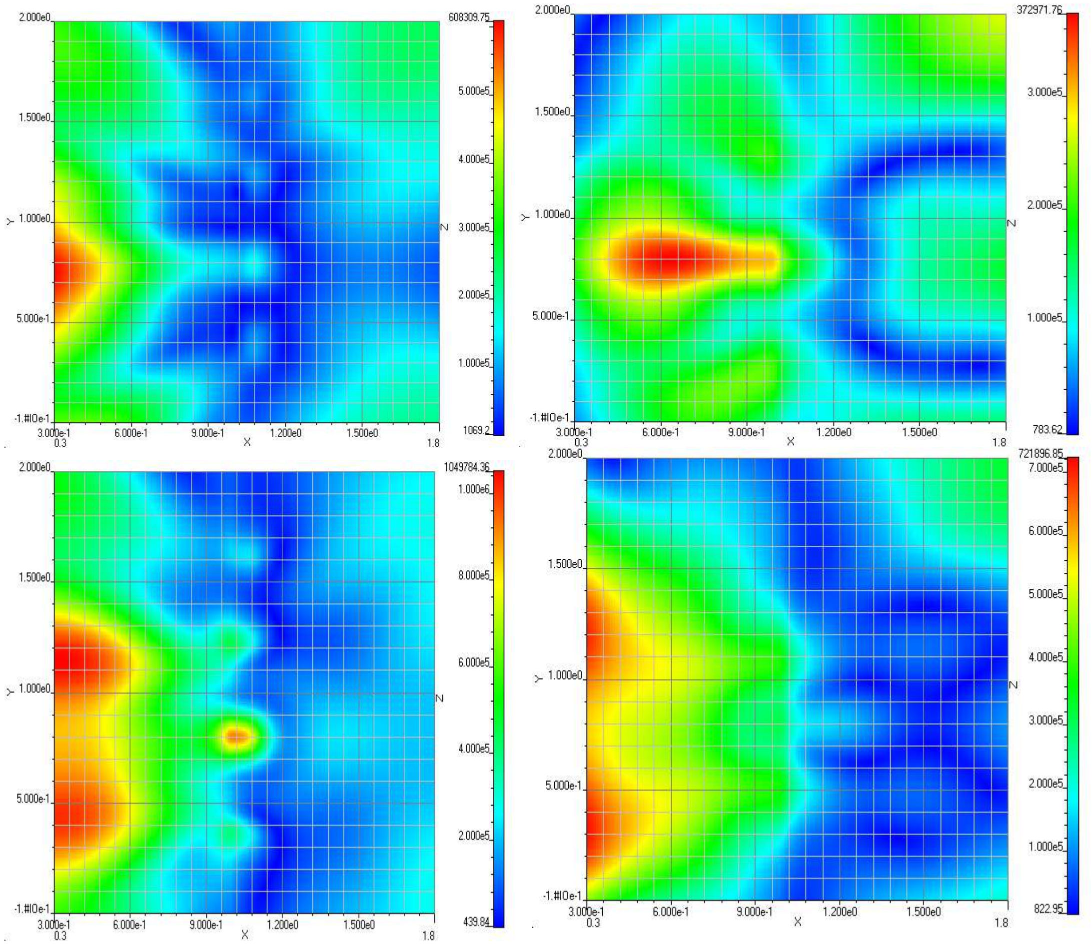
AFM topography (left) and reflection images (right) of a standard pattern of aluminium deposited on a glass substrate.

FDTD Simulations



Longitudinal cross section of the evanescent electric field Ex produced by the SNOM tip with a Au (left) and Al (right) disk.
Lower panels: Ex configuration in a (x-y) plane crossing the Au (left) and Al (right) disks.

FDTD Simulations



reflected field for a Au nanostructure when the SNOM tip is positioned above the disk (left) and between the disks above the glass substrate (right). Lower panels: the same for the Al nanostructure.

Conclusions

FDTD Simulations Nanolithography Scanning Electron Microscopy
Scanning Near – Field Optical Microscopy

PMMA PCs working in visible region (bandgap centered at 650 nm).
SU8 PCs working in infrared region (bandgap centered at 1550 nm).
Metallic photonic crystals presenting SPP modes