Propagation of morphology dependent resonances in sets of nanocylinders in front of supertransmitting slits

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Microcylinders and microspheres, as well as their arrangements such as in photonic molecules and waveguiding chains, have been a subject of active research. These microcavities present new effects on enhancement, confinement, spectroscopic splitting and transport of optical energy [1]. On the other hand, near field optics has shown the relevance of some of these effects at the subwavelength scale. This takes place via eigenmodes such as whispering gallery modes (WGM) in sets of dielectric nanoparticles, and localized surface plasmons (LSP) in metallic ones.

In addition, extraordinary, or enhanced, optical transmission through subwavelength apertures is a resonant effect that has received much attention in connection with its importance for light concentration, detection and wavefront steering [2]. Here we inquire on the interplay between the transmission characteristics of nanoapertures and its coupling to morphology dependent resonances (MDR) in nanocylinders in front of them; these being WGMs, and LSPs.

When the apertures make a metallic grating, the set of particles is a photonic crystal (PC). The role of Mie resonance propagation in both dielectric and metallic PCs has been a subject of interest as regards its influence on the crystal bandgap size and position. An interplay between both the band structure and the excitation of particle resonances rules the enhancement and propagation of the light through the PC-slit grating system. This process is favored by the high field concentration inside, or around, the particles, for either WGMs or LSPs, respectively.

We address different sets of either dielectric or metallic nanocylinders in front of a subwavelength metallic slit [3]. Next, we extend this study to photonic crystals close to gratings of such slits. The effects on light transmission and localization in the system when morphology-dependent resonances are excited in the particles, are analysed.

Calculations are done both by the finite element method and using FDTD simulations. We discuss the effect of these excitations on extraordinary transmission by either the slit or the array.

We show the dominant role of the MDR over the aperture resonances, as regards the resulting transmitted intensity and its concentration in the cylinders. When sets of these particles are placed in front of the slit, like linear or bifurcated chains, with or without bends, one can control the localization and enhancement of MDRs by appropriate design of the parameters. So that these surface waves are coupled by both waveguiding of the nanocylinder eigenmodes and by scattered propagating waves.

For the case of PCs, by changing the crystal parameters we can select the frequency range in which a partial PC bandgap and a MDR appear. This allowing us to manipulate the light transmitted through the grating [4].

The excitation of Mie resonances of nanocylinder sets and PCs placed in front of subwavelength slits, dramatically enhances the extraordinary resonant transmission that these apertures would produce alone. The transmitted intensity concentrated either inside or on the nanoparticles (according to whether they are WGMs or LSPs, respectively), is scarcely influenced by the transmission characteristics of the slits, and can be further enhanced by introducing corrugation on the slab surface by focalization onto the particle set.

We conclude that the arrangements of metallic nanoparticles is not superior to that of dielectric ones as regards localized enhancements of transmitted light. In addition, transmission by WGMs is substantially less dissipative than by LSPs. These last are useful, notwithstanding, when they play the role of e.g. *nanoantenna* or *spaser* emitters.

References

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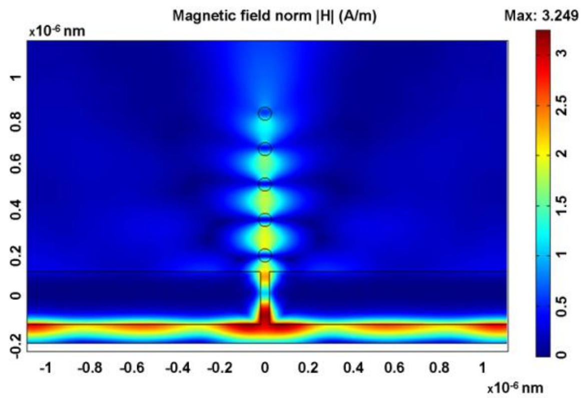
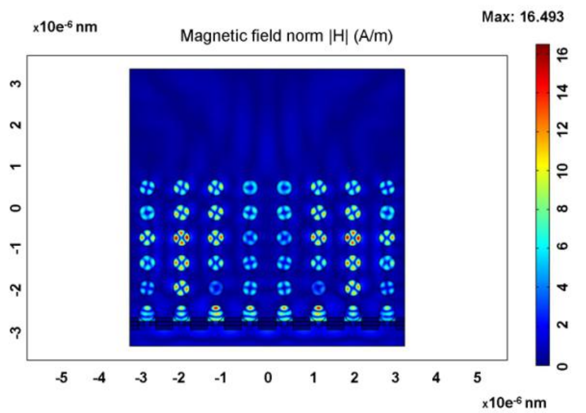
[3] F. J. Valdivia-Valero and Manuel Nieto-Vesperinas, Opt. Express, **18** (2010) 6740.
[4] F. J. Valdivia-Valero and Manuel Nieto-Vesperinas, Opt. Commun., (2010) « article in press ».

Figures



Map of |H| when a linear chain of Ag cylinders (radius= 30nm; distance between cylinders= 100nm) is at 346nm from a slit practized in a Tungsten slab (slab width= 2610nm; slab thickness= 237.55nm; slit width= 39.59nm). A p-polarized plane wave at λ= 400 nm incides from below. Localized surface plasmons are excited around the cylinders.



A Si cylinder photonic crystal (radius= 200nm; horizontal period= 826.87nm; vertical period= 600nm) in front of a perfectly conducting corrugated grating (refractive index= i32; period= 826.87nm; slab width= 8·period; slab thickness= 283.5nm; slit width= 118.12nm; corrugation period= period; corrugation amplitude= 99.2244nm). A p-polarized plane wave at λ= 945 nm incides from below. Whispering gallery modes are excited inside the cylinders.