PROJECT II.4

Computational Nanotechnology

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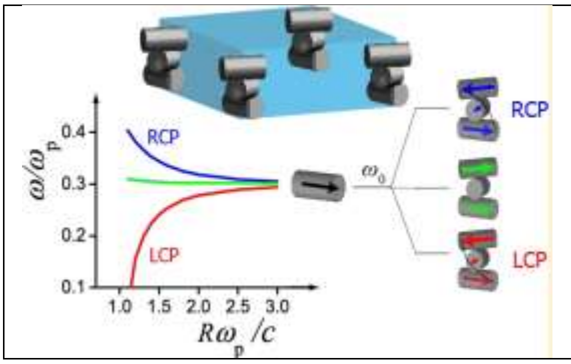
OBJECTIVES

Our research is focused on photonics and plasmonics, as well as elastic wave propagation in periodic media. We use multiple scattering methods and in-house-developed simulation software to study optical, elastic and acoustooptic properties in the nanoscale.

MAIN RESULTS in 2012

Chiral plasmonic nanostructres

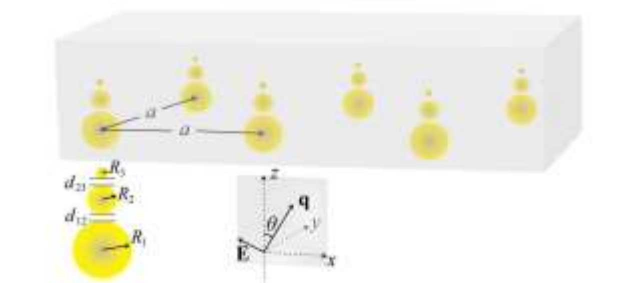
Artificial plasmonic architectures consisting of either chiral metallic building units or nonchiral metallic nanoparticles arranged in chiral geometries such as pyramids, tetrahedra, helices, and so on provide unique opportunities to achieve extraordinary optical activity effects, which can be tuned within a wide range from near-infrared to ultraviolet frequencies and offer impressive possibilities, among others, in the design of subwavelength components for polarization-control applications in miniaturized optical devices. Research on chiral plasmonic architectures is at the frontier of nanophotonics also because of potential applications in biology, chemistry, and optics of novel metamaterials. These structures can be realized in the laboratory using modern nanofabrication methods like lithography, or even molecular self-assembly.



Unit cell of a tetragonal structure with a basis of three mutually twisted metallic nanorods and a schematic view of the formation of hybrid plasmon modes in the three-nanorod helical metamolecule. The bottom left diagram shows the variation of the eigenfrequencies of these modes as a function of the interparticle distance, as obtained by a point-dipole model.

Plasmonic nanolenses

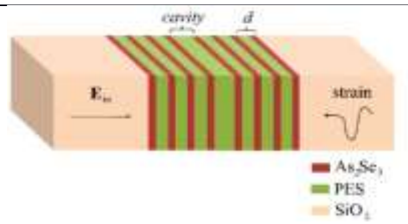
Plasmonic nanoantennas and nanolenses, consisting of two or more metallic nanoparticles in proximity, have recently attracted much interest due to their ability to produce highly confined electromagnetic fields in the interparticle region, thus leading to enhanced Raman scattering, fluorescence, absorption, and nonlinear effects. Of particular interest are nanolenses consisting of self-similar chains of metallic nanospheres with decreasing radii and separations. When such a nanolens is optically excited, a hot-spot, where the local EM field is enhanced by orders of magnitude, is formed in the region between the two smallest spheres. Our study shows that the interaction between the hot-spot modes of an isolated nanolens with the Rayleigh–Wood anomalies of the periodic lattice leads to a further enhancement of the local field intensity, which can be controlled by an appropriate choice of the geometrical parameters involved.



Schematic view of a square lattice of nanolenses in a glass matrix. Each nanolens consists of three silver spheres with decreasing radii R_1 33.8 nm, R_2 13 nm, and R_3 5 nm, and separations d_{12} 7.8 nm and d_{23} 3 nm. The nanolense achieves strong concentration of the electromagnetic field in the region between the two smaller spheres.

Spontaneous light emission in simultaneous photonic-phononic cavities

It has long been recognized that the spontaneous emission of an excited atom is not an inherent property of the atom but also depends on its environment, since the latter can drastically alter the vacuum fields that drive the excited atom to its ground state. In this respect, enhanced spontaneous emission has been demonstrated inside dielectric multilayer microcavities, slabs, dielectric particles, and waveguides. Recently, there is a growing interest on dynamic photonic structures, controlled by elastic waves, and consequent phenomena. Elastic waves can change the geometry and refractive index of a photonic cavity, and thus modify its optical properties. The interplay between optical and elastic waves is exploited in the emerging field of cavity optomechanics, where the optical pressure of localized light in a cavity produces an elastic wave through mechanical deformation. Additionally, it has been shown that appropriately designed cavities that support simultaneously photonic and phononic localized resonant modes, so-called phoxonic cavities, allow for strong nonlinear acousto-optic (AO) interactions. We have theoretically studied the modulation of spontaneous light emission of active centers through elastic waves in multilayer phoxonic structures that support dual photonic-phononic localized modes, in the bulk or at the surface. Our results show that strong dynamic modulation of the spontaneous emission can be achieved through an enhanced acousto-optic interaction when light and elastic energy are simultaneously localized in the same region.



A multilayer dual photonic-phononic cavity structure between two Bragg mirrors. Both electromagnetic and elastic waves (of different frequencies) can be localized inside the cavity to achieve enhanced acoustooptic interaction. Several materials can be used for the multilayers.

PROJECT OUTPUT in 2012

Publications in International Refereed Journals

1. *Diffractive chains of plasmonic nanolenses: combining near-field focusing and collective enhancement mechanisms,*
   E. Almpanis, N. Papanikolaou, B. Auguié, C. Tserkezis, and N. Stefanou
   Opt. Lett. 37, 4624 (2012)
2. *Tuning the spontaneous light emission in phoxonic cavities,*
   Almpanis, E., Papanikolaou N., Gantzounis, G. and Stefanou N.
   J. Opt. Soc. Am. B, 29, pp. 2567-2574 (2012)
3. *Giant Optical Activity of Helical Architectures of Plasmonic Nanorods,*
   Christofi, A., Stefanou, N., Gantzounis, G., and Papanikolaou, N.
   J. Phys. Chem. C, 116 (31), 16674−16679 (2012)

Published Conference Proceedings

1. *Helical assemblies of plasmonic nanorods as chiral metamaterials,*
   Christofi, A., Stefanou, N., Gantzounis, G., and Papanikolaou, N.
   Proc. of SPIE Vol. 8423, 84230A (2012)
2. *Acousto-optic interaction enhancement in dual photonic-phononic cavities,*
   Papanikolaou, N., Gantzounis, G., Almpanis, E., Stefanou N.
   (2012) Proc. of SPIE Vol. 8425, 84250M

Conference Presentations

1. *Helical assemblies of plasmonic nanorods as chiral metamaterials,*
   Christofi, A., Stefanou, N., Gantzounis, G., and Papanikolaou
   SPIE Photonics Europe, Brussels April (2012)
2. *Acousto-optic interaction enhancement in dual photonic-phononic cavities,*
   Papanikolaou, N., Gantzounis, G., Almpanis, E., Stefanou N.
   SPIE Photonics Europe, Brussels April (2012)
3. *Efficient control of spontaneous light emission by elastic waves,*
   E. Almpanis, G. Gantzounis, I.E. Psarobas, N. Papanikolaou, C. Tserkezis, N. Stefanou, B. Djafari-Rouhani, Y. Pennec, V. Laude, A. Martinez
   E-MRS Strasburg, 14-18 May (2012)
4. *Tuning the spontaneous light emission in phoxonic cavities,*
   E. Almpanis, G. Gantzounis, N. Stefanou, N. Papanikolaou,
   "Son et Lumiere: phononics and photonics at the nanoscale", Les Houches, France, 17-28 September (2012)
5. *Tuning the spontaneous light emission in phoxonic cavities,*
   E. Almpanis, G. Gantzounis, N. Stefanou, N. Papanikolaou
   5th International Conference on Micro-nanotechnologies and MEMS, Crete, Greece, 7-10 October (2012)