Controlling light emission, scattering and propagation at the nanoscale with metal, semiconductor and hybrid nanowires

R. Paniagua-Domínguez, D. R. Abujetas, **J. A. Sánchez-Gil**

Instituto de Estructura de la Materia
Consejo Superior de Investigaciones Científicas (IEM-CSIC)
Serrano 121, 28006 Madrid, Spain
j.sanchez@csic.es

Abstract

In this talk, a variety of configurations of interest in Nanophotonics will be described that exploit the resonant optical properties of metal, semiconductor and hybrid nanowires, to control light emission, scattering and propagation at the nanoscale.

First, we investigate photoluminescence from finite semiconductor nanowires, theoretically and experimentally demonstrating their behavior as efficient optical nanoantennas [1], with directional emission of polarized light given by the material and also by the nanowire geometry and dimensions, which determine the Fabry-Perot-like guided/leaky mode resonances [2]. We anticipate the relevance of these results for the development of nanowire photon sources with optimized efficiency and controlled emission.

Second, the spectral properties of similar Fabry-Perot-like resonances occurring in metal nanorods (of plasmonic nature in this case) are shown with emphasis on the corresponding line-shapes, revealing theoretically and experimentally that their asymmetry is governed by mode parity [3]: Surface plasmon resonances of odd mode parity present Fano interference in the scattering cross-section resulting in asymmetric spectral lines. Contrarily, modes with even parity appear as symmetric Lorentzian line-shapes. The emergence of either constructive or destructive mode interference is explained with a semi-analytical 1D line current model. This simple model directly explains the mode-parity dependence of the Fano-like interference. Plasmonic nanorods are widely used as half-wave optical dipole antennas. Our findings offer a perspective and theoretical framework for operating these antennas at higher order modes [4].

Finally, hybrid metal-semiconductor core-shell nanowires are proposed as building blocks (meta-atoms) of 2D optical metamaterials [5]. The concept of overlapping dipolar electric and magnetic resonances occurring at core-shell nanospheres, stemming from, respectively, plasmon (metal core) and lowest-order magnetic (high-index dielectric shell) resonances, was proposed to achieve 3D isotropic optical negative-index metamaterials (NIMs) [6]. Recently, it has been extended to hybrid core-shell nanowires, leading to 2D isotropic optical NIMs which exhibit extremely low-losses (at the expense of the reduced dimensionality and polarization dependence) [5]. Note that, in this configuration, the resonances involved in the NIM behavior occur in the plane perpendicular to the nanowires, and no mode bouncing (Fabry-Perot-like) at the nanowire ends is required, unlike in the previous ones.

References

[1] G. Grzela, R. Paniagua-Domínguez, T. Barten, Y. Fontana, J. A. Sánchez-Gil, and J. Gómez Rivas, “Nanowire Antenna Emission,” Nano Lett., **12** (2012) 5481.

[2] R. Paniagua-Domínguez, G. Grzela, J. Gómez Rivas and J. A. Sánchez-Gil, “Enhanced and directional emission of semiconductor nanowires tailored through leaky/guided modes,” Nanoscale, **5** (2013) 10582.

[3] F. López-Tejeira, N. Verellen, R. Paniagua-Domínguez, D. Vercruysse, D. Denkova, L. Lagae, P. Van Dorpe, V. V. Moshchalkov, and J. A. Sánchez-Gil, “Mode Parity-controlled Fano and Lorentz Resonances Arising in Plasmonic Nanorods,” Nano Lett., (2012) accepted.

[4] F. López-Tejeira, R. Paniagua-Domínguez, J. A. Sánchez-Gil, “High-Performance Nanosensors Based on Plasmonic Fano-like Interference: Probing Refractive Index with Individual Nanorice and Nanobelts,” ACS Nano, **6** (2012) 8989.

[5] D. R. Abujetas, R. Paniagua-Domínguez, and J. A. Sánchez-Gil, “Ultra low-loss, isotropic 2D optical negative-index metamaterial based on hybrid metal-semiconductor nanowires,” Sci. Reports, **3** (2013) 1507.

[6] R. Paniagua-Domínguez, F. López-Tejeira, R. Marqués and J. A. Sánchez-Gil, “Metallo-dielectric core–shell nanospheres as building blocks for optical three-dimensional isotropic negative-index metamaterials,” New. J. Phys., **13** (2011) 123017.