**Plasmonic Fano resonances become single-particle**

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## Abstract

Experimental and theoretical investigations have shown that metallic nanorods act as standing-wave resonators for localized plasmon resonances in the optical regime [1, 2], thus exhibiting geometrical half-wavelength resonances with spectral positions depending mainly on the length of the rods. This particular type of so-called “optical nanoantennas” have raised the prospect of significant improvements in fields such as photodetection [3], field-enhanced spectroscopy [2, 4], or control of emission direction in single-molecule light sources [5].

Generally speaking, most of device-oriented studies are focused on nanoantennas operating at the dipole-like resonance. However, structures with a high aspect ratio may support additional resonances that have usually been the subject of a more fundamental research work. Hence, several authors have already elucidated the scaling properties of high-order longitudinal modes, as well as their dependence on shape, size, orientation and dielectric environment by means of diverse approaches and techniques. Nevertheless, a relevant issue has yet to be addressed for multi-resonant nanoantennas, that is the emergence of asymmetric line profiles in single particle extinction or scattering spectra. Interestingly, such a feature seems to go almost unnoticed for the nanoplasmonics community, despite being apparent in some previous reports.

In Figure 1 we present the calculated scattering efficiency for a single silver spheroid surrounded by glass ($\varepsilon_d$= 2.25) under the assumption that incident field is p-polarized and impinges perpendicular to the long side of the rod. Different curves correspond to increasing values of total length L within the [100,400] nm range, whereas the polar diameter D is set to 30 nm for all calculations. As can be seen, the position of resonances increases linearly within the L range. For L/D>5, the peaks arising from resonances with n=1 and n=3 are clearly apparent, as it is the asymmetry of the line shape between them. This suggests the interaction of adjacent resonances to be compatible with a Fano-like interference model, where the lower resonance plays the role of continuum in canonical Fano line shape.

In this work [6], we show that these asymmetric line profiles can be easily understood in terms of the so-called Fano-like interference between localized plasmon resonances that has been recently reported for a variety of coupled metal nanoparticles [7,8]. Being more precise, we present a simplified analytical model that describes spectral features of a single-arm nanoantenna in terms of Fano-like interference. Contrary to the common assumption that interference does not play any role in total scattering or extinction of a single metallic particle, we find a good agreement with numerical results, which are attained through the separation of variables (SVM) [9], finite element (FEM) [10], and surface integral equation (SIEM) methods [11,12]. Furthermore, we make use of explicit analytical expressions for light scattering by spheroids to conclude that not only spectral but also spatial overlap (i.e. non-orthogonality) between interacting modes underlies the emergence of such single-rod resonances, for which evidence is found in a variety of single-particle nanoantennas, namely nanospheroids, nanorods with either flat or hemispherical ends and also infinitely long rectangular nanowires.

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## Figures

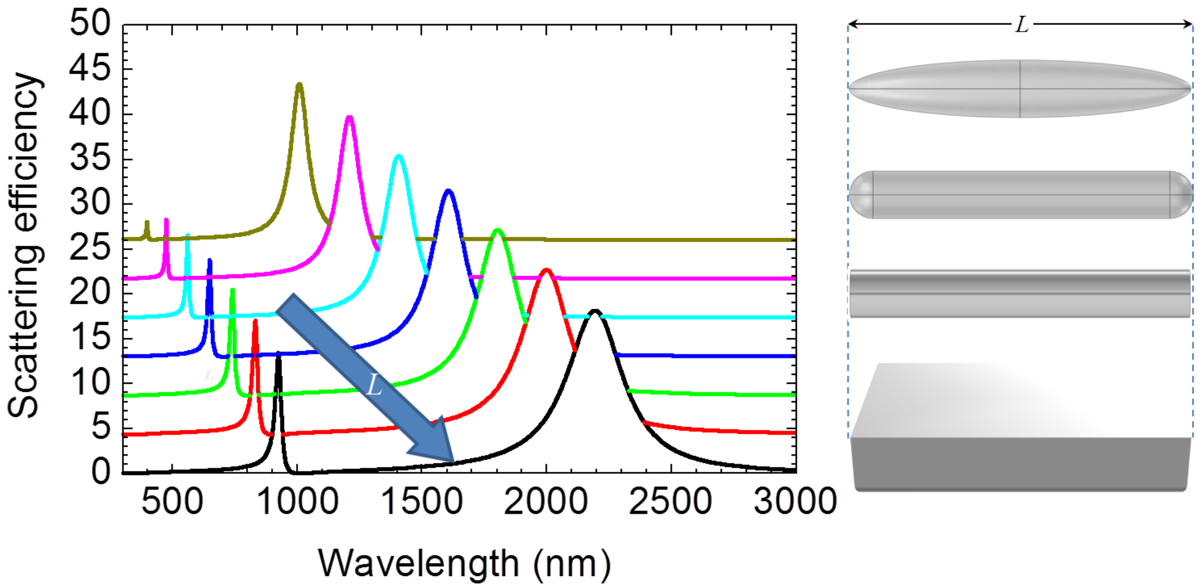


**Figure 1:** Calculated scattering efficiency as a function of wavelength for a single Ag spheroid (top right) surrounded by glass ($\varepsilon_d$ = 2:25). Incident field is p-polarized and impinges perpendicular to the rotation axis of the spheroid. Different curves correspond to increasing values of *L*, whereas *D* is set to 30 nm for all calculations. Right: Nanorod geometries for which evidence of Fano-like interference is found in [6].