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# Active Coated Nanoparticles - Scattering Properties and Fano Resonances

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Our ability to effectively control light-matter interactions on nano-scale has a notable impact on a variety of applications of great societal importance [1]. Nanoantennas formed as either plasmonic and/or dielectric nanoparticles (NPs) have recently attracted much attention in this respect due to their ability to support localized electromagnetic modes [1-5]. While dielectric realizations are favorable due to their low material losses, plasmonic NPs, on the other hand, offer truly impressive field localization levels due to the excitation of surface plasmons [2]. This is particularly pronounced in active plasmonic-based configurations where gain is used to overcome the intrinsic plasmonic losses, leading to novel phenomena with significantly enhanced, and in some cases, reduced scattering responses [4, 5]. A particularly interesting feature recently reported for passive plasmonic-based as well as dielectric NPs is that of Fano resonances; these occur when a discrete localized mode couples to a continuum of modes [6-9]. When this happens, the resonance profiles follow an asymmetric line-shape with both a minimum and a maximum in the scattering response. Due to the sharp transitions from minimum (practically zero) to maximum responses, Fano resonances are very appealing for optical switching devices, plasmon-induced transparency, sensing, as well as cloaking applications [6-9].

In this work, we build upon these previous research efforts and report on deep Fano resonances in several *active* plasmonic-based coated NPs, as opposed to previously considered *passive* NPs. We study, in analytical terms, infinitely long cylindrical coated NPs; the core is either silver or silica, while the surrounding shell is either silica or silver, respectively. The particle is excited with a uniform plane wave, and the gain, modeled with a constant frequency model, is immersed in the silica part of the NPs. General scattering features are reported for a variety of such NPs, and will be discussed in the presentation. Moreover, detailed near- and far-field analytical results are shown for specific NPs which exhibit rather asymmetric scattering cross section profiles (dominated by the dipole mode) which follow Fano resonance shapes. In particular, we report on theoretical designs displaying a dynamic range of 120 dB in the scattering cross section (minima $\sim -67$ dB; maxima $\sim 53$ dB) with a distance of some 25 nm in wavelength between the minimum and maximum responses. We have found that Fano resonances in such active NPs are much more profound with the silver-core and silica-shell, than in the opposite case. The scattered fields at the minimum response are essentially zero, making the active NPs useful for potential (invisible) sensor design [10], while the frequency proximity of the observed large and tiny responses may prove useful in duplexer designs, and for reduction of coupling to nearby sources.

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