Optical Composite Nanoparticles with Broadband Finite Absorption in the Limit of Infinitesimally Small Losses

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In this work we show that two conjoined subwavelength cap-shaped structures may be used as an efficient energy-harvesting nanostructure with unbounded absorption efficiency. Following an analytical method based on coordinate transformation, we show that anomalous plasmonic resonances arise when one of the two nanostructures is plasmonic, resulting in adiabatic focusing of surface plasmons toward the particle corners, which are responsible for large absorption efficiency over a wide and controllable frequency range. Over this continuous bandwidth our proposed composite nanostructure shows finite amount of absorption even in the limit of no intrinsic material loss.

The scattering problem is solved in the quasi-static limit in the bipolar coordinate system and a general closed-form solution is derived that eliminates all the errors commonly associated with highly oscillatory distributions in resonant structures with sharp corners. Our solution is then extended to the general electrodynamic problem, which is used to find the absorption and scattering properties of the proposed nanoparticle. The absorption performance is shown to be unaffected by radiation losses, and finite absorption may be obtained even in the limit of negligible (but mathematically nonzero) losses in the constitutive materials. Physical insights are provided regarding the nature of this apparent paradox and the dielectric wedge boundary-value problem is used to fully describe the phenomenon characteristics and origins. Properties and design parameters of various related configurations are discussed, together with their advantages and possible configurations that may be experimentally realized and tested.

We analyze in special detail the double conjoined half-cylinder configuration, as a special case of a more general class of plasmonic nanostructures with anomalous absorption properties. Compact closed-form solutions for the fields and the absorption coefficients are obtained in this case, which allow discussing in more detail the unconventional absorption properties and its physical mechanisms. The counterintuitive behavior of these configurations is then discussed for potential applications in nonlinear optical devices, lasing, sensing, and energy-harvesting devices.