Two-Scale Concept for Field Enhancement at Optical Frequency: Combination of Rayleigh Anomaly and Plasmonic Resonances

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We propose a novel architecture to achieve a large field enhancement at optical frequency by combining the Rayleigh anomaly and plasmonic resonances of nanoparticles. Metallic oligomers are well-known for their ability in providing giant field localization at subwavelength scale thanks to the role of surface plasmon polaritons. However, due to intrinsic nonlocality of the dielectric response of the metals along with their inherent loss, the field enhancement that can be achieved has an ultimate constraint. Consequently, it is of crucial importance to make use of another mechanism along with the plasmonic resonance to further enhance the field. One promising mechanism is to employ a periodic structure and make use of the constructive interference of the scattered fields from the structure. This interesting phenomenon, also known as Rayleigh anomaly, leads to sharp resonant-like peaks in the scattering, absorption and emission spectra in the wavelength close to the period of structure. In this work, we combine the localized surface plasmonic resonance (LSPR) with Rayleigh anomaly caused by 1-dimensional periodic set of nanorods. Particularly, we use a periodic set of metallic nanorods deposited over a substrate along with metallic oligomers between the nanorods, mixing two completely different fabrication methods, involving two different size scales. Appropriately, we call our proposed architecture, two-scale structure. In such a design, when the structure is illuminated with an incident beam, the coherent scattering from the nanorods (Rayleigh anomaly) boosts the field and transfers energy to the LSPR mode of the oligomers which leads to strong field enhancement. We carry out a thorough study of this structure by using an effective numerical model and compare it to the full-wave simulation results.