Active Coated Nano-Particles for Sensor Applications

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Current research in optical metamaterials has demonstrated that including lossless plasmonic materials to achieve a negative permittivity in the spherical shell of a coated nano-sized particle (CNP) can lead to novel optical properties such as resonant scattering as well as transparency or invisibility. However, in practice, plasmonic materials have high losses at optical frequencies. It is observed that with the introduction of active materials, the intrinsic absorption in the plasmonic shell can be overcome and new optical properties can be observed in the scattering and absorption cross-sections of these CNPs. In addition, a "super" resonance accompanied by negative absorption cross section, i.e. optical amplification, is observed with a magnitude that is greater than that for a tuned, resonant passive CNP. For example, absorption and scattering cross sections have been obtained for a CNP consisting of a core described by a rare-earth doped silica gain model and a silver shell. This gain model is adopted from a Stark-split three level system model. The silver shell is described by permittivity and permeability values which have been obtained from experimental data; these values include the known size dependent dispersion effects. These silver shell-gain core results are used to demonstrate the feasibility of realizing a lossless CNP: This observation suggests the possibility of realizing a highly sub-wavelength laser with dimensions more than an order of magnitude below the traditional half-wavelength cavity length criteria. Contrasting results for a gold shell-gain core have also been obtained.

In addition to these optical properties, the optical response of the active CNP is further explored when the particle is in the presence of a changing environment. Specifically we investigate the use of active coated nano-particles for nano-sensing applications. Simulation results of the optical properties of an active CNP with a 24nm radius active silica core and a 6nm thick plasmonic shell made of silver that has been functionalized by an additional spherical outer layer of varying thickness and refractive index will be presented. In particular, the effects of the functional-layer thickness and refractive index on the super-resonant state of the active CNP will be discussed. It will be shown that the wavelength and optical gain required to excite the SR state may provide *both* a spectral and a power signature usable for nano-scale sensing and that these signatures may be used to identify the dimensions and optical properties of the functional layer. The theoretically predicted performance of the CNP based sensor will be compared to more conventional surface plasmon wave (SPW) sensors and it will be shown that the CNP sensor has distinct advantages over the more traditional SPW sensor.