Eigen and Coupled Modes on Nanoparticle Aggregate Arrays

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Abstract

Novel class of artificial optical antennas, like architectures made of noble metal nano-objects, are of great interest in biosensing applications of nanoplasmonics due to their unique and tunable spectral properties.

Silver colloid spheres wrapped with L-cysteine covering were studied experimentally by UV-visible spectroscopy and TEM and numerically by the COMSOL Multiphysics® software package. The experimental studies revealed that the Ag NP-Cys core-shell composites prefer to compose aggregates of versatile geometry. To inspect the origin of UV and red-shifted maxima simple one and two dimensional chain geometries were selected.

The RF Module of COMSOL makes it possible to apply eigenvalue study as well as time-dependent frequency study based on the same model, as a result one can first search for eigenfrequencies and for belonging eigenmodes by solving the homogeneous Helmholtz' equation.

Next step is illumination of the optical system by appropriate isotropic electromagnetic waves to excite all possible modes, this way the equations to be solved become inhomogeneous. Perfectly matched layers with perfect magnetic conductor were used to bound vertically the optical system, which is treated as a laterally infinite domain. Floquet periodic boundary condition was applied in finite element modeling by supposing ordered arrays of aggregates. Since the PMLs and dielectric losses make the problem nonlinear, the eigenvalue equation was linearized and solved in proximity of frequencies corresponding to the measured absorption peaks. During modeling we paid attention to the symmetry features of our models by using a mesh with appropriate symmetry. The eigenfrequency study showed the possibly of different resonant eigenmodes excitation at the UV and red-shifted peaks, which possessed even and odd parity, respectively. (Figure 1, Figure 2)

This study provided the typical resonant frequencies of the periodic aggregate array of very closely packed Ag NPs. It was also demonstrated that by using excitation (illumination) in close proximity of these frequencies one can achieve very large EM-field confinement.

Reference

Anikó Szalai, Áron Sipos et al. Comparative study of plasmonic properties of cysteine functionalized gold and silver nanoparticle aggregates, Plasmonics. 8, 53-62 (2013)

Figures used in the abstract

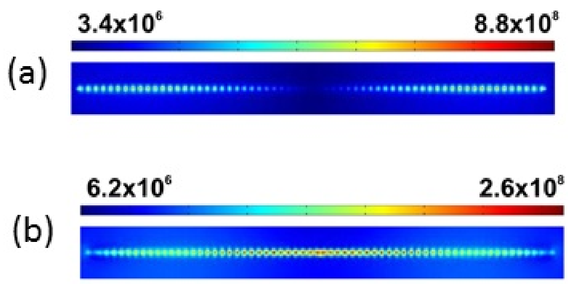

Figure 1: The normalized E-field of two eigenmodes: one corresponding to an eigenfrequency at the UV (a) and another eigenfrequency at the red-shifted peak (b) on a Floquet-periodic array of linear aggregates.

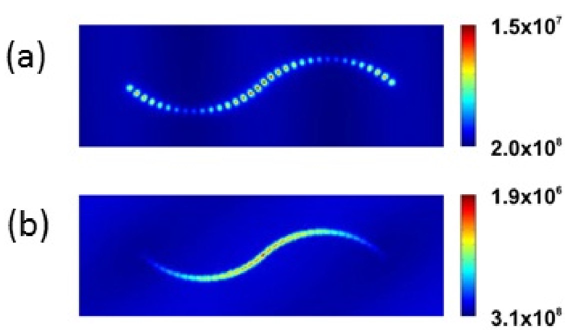

Figure 2: The normalized E-field of the eigenmodes : one corresponding to an eigenfrequency at the UV (a) and another eigenfrequency at the red-shifted peak (b) on a Floquet-periodic array of wavy aggregates.