Control of optical properties of hybrid nanomaterials

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The hybrid systems comprised of metal nanoparticles and the emitters, non-metal atoms or molecules, offer a number of important applications in modern nanotechnologies, from nanoscale ruler to surface plasmon resonance sensors to photobioreactors and solar fuel production. The key factor of the successful development in the field of nanoplasmonics with hybrid systems that may lead to profound innovations is the ability to manipulate nonlinear optical properties of quantum emitters as well as the dynamics of hybrid systems interacting with light. The control techniques make use of the shapes of nanostructures, structural properties of atomic and molecular emitters, their density and the layer thickness [1], as well as the properties of incident electromagnetic fields that induce collective effects between emitters and surface plasmon polaritons in nanostructures. The electromagnetic field control parameters include peak intensity, pulse duration, phase and amplitude modulation and many others. To gain insight into state dynamics, propagation affects of the electromagnetic fields and the nonlinear optical properties that hybrid systems may manifest, an accurate model describing the complexity of inherent properties of the constituents of these systems ought to be referred to. Here we describe an effective model that is based on the Maxwell equations for the electromagnetic fields combined with the Liouville von Neumann equation for quantum emitters. The numerical approach allows for taking into account variations in the local fields generated by quantum emitters referred to as the collective effects that develop upon propagation of the fields. Because the Hamiltonian in the Liouville von Neumann equation and the Maxwell equations are used without approximations, the developed solution may be accounted for as exact one with the optical effects nonlinear with respect to the electromagnetic fields accurately manifesting themselves.

[1] M. Sukharev, S.A. Malinovskaya, *Phys. Rev. A* **86**, 043406 (2012).