Lasing Effects of a Single Core-Shell Nanoparticle

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In recent years, there has been growing interest in plasmonic materials, owing partly to their ability in manipulating optical signals under sub-wavelength dimensions. Various elements and devices made of plasmonic materials, such as waveguides, optical nanoantennas, supper lens and nanocircuit elements, have been explored theoretically or experimentally by various groups worldwide. It has also been suggested that using plasmonic material one can achieve electromagnetic resonance at dimensions much smaller than free space wavelength (See e.g., Jingjing Li and Nader Engheta, "Ultracompact sub-wavelength plasmonic cavity resonator on a nanowire" presented at the *URSI-USNC National Radio Science Meeting, Boulder, CO*, January 4-7, 2006, p. 53). Furthermore, it is known that core-shell concentric nanospheres with either shell or core made of plasmonic material can exhibit plasmonic resonance scattering, and the frequency of such resonance can be altered by changing the ratio of the core/shell radii (see e.g., Andrea Alù and Nader Engheta, *J. Appl. Phys*., 97, 094310, 2005)..

In the present work, we consider another canonical problem related to the core-shell nanoparticles, namely, we explore a method for realizing the lasing effect in these nanoparticles by making use of the gain medium in such resonant structures. We consider a single concentric spherical nanoparticle with a core made of a gain medium while the shell made of a plasmonic material, or vice versa. The source-free eigenvalue problem of such a structure is then solved analytically. It is shown theoretically that when the material parameters and the core/shell radii ratio are properly chosen there exists a source-free eigensolution, implying a balance between the role of gain medium in the core and the plasmonic material in the shell, even though the size of the particle is much smaller than the free space wavelength. In such a lasing mode for this single nanoparticle, electromagnetic energy radiates away from the particle with a pattern similar to that of a short electric dipole. It appears that the resonant effect due to the plasmonic shell causes the buildup of strong electromagnetic field inside the gain-medium core, leading to a possible optical gain with radiation with certain coherent pattern – a phenomenon similar to a conventional laser but achieved in a particle with deep sub-wavelength size and volume. Possible methods of pumping the gain medium will also be discussed.

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