Nanoplasmonics

Control and optimization of up-conversion process in rare-earth metallic nanocrystals and plasmonic nanolaser

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About ten years ago we have proposed to use metallic nanoparticle plasmon resonances for enhancement nonlinear optical processes in rare-earth ion doped nanocrystals. During these years many interesting theoretical and experimental researches in this field have been published. Highly photochemically stable nanoparticles, in which up-conversion luminescence can be excited – so-called up-conversion nanocrystals (UC-NCs) – exhibit widely separated (up to 500 nm) narrow luminescence bands in the visible (VIS) region located far from the excitation near-infrared (NIR) laser radiation, and thus can be more easily identified compared to organic luminophores and semiconductor nanoparticles. Due to a deep penetration of exciting infrared (IR) radiation, the absence of parasitic fluorescence of biomolecules and the absence of phototoxicity and photobleaching upon near IR excitation, UC-NCs can be efficiently used as fluorescent probes in biological studies and fluorescence diagnostics (FD). The doping of such nanoparticles with Gd3+ ions provides the additional possibility of combining fluorescence visualization with magnetic resonance imaging.

This year a single-particle spaser design with well-defined and unidirectional stimulated emission and highly effective laser output have been realized. By using a semishell-capped system design, it was shown that the laser emission can be guided and improved over previous spaser designs based on full-shell spasing nanocavity. The optical extinction properties of the semishell resonator (referred to as SSR) strongly depend on the incidence angle; nevertheless, spaser emission exclusively propagates along a specific direction. The power flow from the SSR is one order of magnitude higher than that from its full-shell resonator counterpart (referred to as FSR). Such system opens up a new avenue for applications of high-intensity nanolasers.

We theoretically discussed last approach allowing the use of rare-earth nanocrystals as gain material for the integration within the nanolaser design. Thus, the proposed design is more compatible with semiconductor photonics and can be applied to fabricate lab-on-a-chip photonic circuits.