Directional Plasmonic Nanoantennas to enhance the Purcell Effect

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We will present plasmonic nanoantennas, composed of silver nanocubes strongly coupled to gold films, which are the optical and infrared (IR) frequency counterparts to the well-established patch antennas used in microwave frequencies for mobile communications. These nanoantennas are ideal platforms to boost several photodynamic processes, such as spontaneous emission. Interestingly, they can be built based on bottom-up chemical synthesis approaches and their radiation spectrum can be easily controlled.

In our presentation, fluorescent emitters will be embedded in the dielectric nanogap region (<10nm) between the 'nanopatch' nanoantenna, composed of a silver nanocube, and the metallic film, where strong local field enhancement is generated. Cavity-like plasmonic modes are excited and confined in this highly subwavelength area. We will experimentally demonstrate Purcell factor enhancements of ~1000 from fluorescent molecules embedded in the gap. In addition, directional emission (84% collection efficiency) combined with high quantum efficiency (>50%) will be reported (G. Akselrod, C. Argyropoulos *et al.*, Nat. Photonics 8, 835-840, 2014).

Accurate numerical methods to calculate the radiative emission rate and nonradiative decay rate of the fluorescent emission will be demonstrated (C. Ciracì, A. Rose, C. Argyropoulos, and D. R. Smith, J. Opt. Soc. Am. B 31, 2601-2607, 2014). The theoretical predictions are in perfect agreement with the experimental results. In particular, we will present full-wave simulations precisely incorporating the nanoscale environment to accurately compute the useful fraction of energy emitted as radiation, known as the radiative quantum efficiency. When we combine the knowledge of the Purcell factor and the quantum efficiency, the enhancement in the emitters' radiative rate can be computed, which is a key property towards obtaining efficient ultrafast nanophotonic communication systems.

We envision that the current work will reveal design rules for several new nanoantenna systems leading to efficient nano-lasers, ultrafast light emitting diodes (LEDs), and single photon sources.