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SHAPING THE OPTICAL AND THERMAL PROPERTIES OF PLASMONIC NANOSTRUCTURES FOR BIOLOGICAL APPLICATIONS

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Metallic nanostructures supporting localized surface plasmon resonances have the potential to both generate intense local optical fields and act as efficient nano heat sources, opening up to plenty of new science and applications in areas ranging from integrated optics to biomedicine. In this contribution, we discuss the specific engineering of both optical and thermal properties of resonant plasmonic nanosystems and detail some of their respective biological applications that have been developed within the group.

In a first part, we will focus on the control of the subwavelength optical confinement in different configurations of electromagnetically coupled metal nanostructures. Special attention is paid to gap antennas formed by two adjacent gold nanorods separated by a subwavelength dielectric gap. We discuss the use of two-photon induced luminescence (TPL) micro-spectroscopy as an efficient tip less method to probe the actual electromagnetic mode distribution along the structures and monitor its evolution with the illumination wavelength. Our experimental data are very well corroborated by 3D numerical simulations [1].

The efficient concentration of light fields down to the nanoscale volumes is particularly attractive for applications involving the interaction of photons with very small amounts of matter, down to the single molecule level. Here after, we will discuss the applicability of optimized structures to both ultra sensitive nano-optical trapping and label less bio-chemical sensing. The strong field intensity gradient within the gap of coupled antennas has been first used to create 3D sub-wavelength optical traps able to overcome the limits of conventional optical tweezers created by focusing a laser beam with a high NA objective. In a first stage, we demonstrate efficient parallel trapping in water of 200nm polystyrene beads in a array of gold antennas. Beyond, we also show that our approach applies to the non-invasive manipulation of living E-coli bacteria [2]. We also investigate how the near-field coupling between adjacent plasmonic nanostructures could be used to enhanced the sensitivity of plasmonic sensors in detecting single or few molecular binding events.

Beyond their ability to create strongly confined and enhanced optical fields, plasmonic nanoparticles can be used as efficient nano heat sources of particular interest to material sciences and biomedical photothermal therapy. While several prior works have demonstrated first evidences of thermal assisted growth of semiconductor nanowires and cancer cells destruction, to date there is no unified study of the thermal properties of plasmonic nanoparticles aiming at optimizing their heating properties. Here, we first present a systematic numerical study of the heating efficiency of different geometries of gold nanoparticles, focusing on the morphology effect at constant volume. Interestingly, our results reveal that the criteria for achieving high temperatures are significantly different from those to get strong field enhancement at the particles surface. In order to verify our numerical predictions, we have developped a novel optical method which enable for the first time to map the distribution of the temperature increase near plasmonic nanoparticles with a spatial resolution of 300nm and an accuracy of 0.1ºC [3].

References:

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