Cascaded Field Enhancement with Self-Similar Antennas

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Optical antennas consisting of plasmonic materials provide extreme light localization and small mode volumes, thereby boosting the sensitivity and signal-to- noise ratio in applications ranging from single photon sources to photodetection. Optical antennas can also be employed to efficiently control and manipulate light on the nanometer scale and to achieve directional emission.

Different optical antenna designs have been studied over the past years, ranging from colloidal single-particle antennas to more sophisticated multi-element antennas. Antenna gain is the most common figure-of-merit for the performance of antennas and while general design criteria have been developed for the radiowave and microwave frequency regimes, these criteria are not directly scalable to optical antennas. The reason is that because of the finite electron density, optical radiation penetrates into metals and gives rise to an effective wavelength shortening, which leads to an increase of kinetic inductance and a reduction of radiation efficiency. Thus, the directed design and optimization of optical antennas remains an open challenge.

In this presentation we will demonstrate that high antenna gains can be achieved by self-similar antennas [1,2]. These self-similar antennas consist of arrays of gold nanoparticles of different size. The local field enhancement is probed by single molecule fluorescence using fluorophores with high intrinsic quantum efficiency (Q_o > 80%). Using a self-similar trimer antenna consisting of a 80nm, 40nm and 20nm gold nanoparticle, we demonstrate a fluorescence enhancement of 40 and a spatial confinement of 15 nm. Compared to a single gold nanoparticle, the self-similar trimer antenna improves the enhancement-confinement ratio by more than an or- der of magnitude. Self-similar antennas hold promise for high-resolution imaging and spectroscopy, ultrasensitive detection and efficient single photon sources.

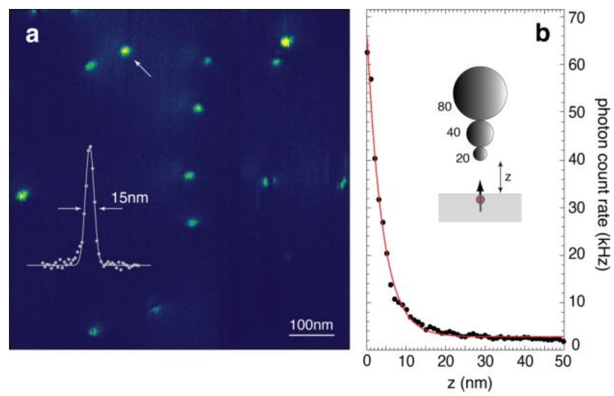

Fig. 2: Excitation of single molecule fluorescence with a trimer antenna consisting of an 80 nm, 40 nm, and 20 nm gold nanoparticle. (a) Fluorescence image of the single molecule sample. Inset: Line-cut through the single fluorescence spot marked by the arrow. (b) Fluorescence from a single z-oriented molecule recorded as a function of distance from a trimer antenna. The steep rise of fluorescence counts for separations smaller than 15 nm is due to strong field localization along the z-axis at the apex of the trimer antenna.

References:

[1] K. Li, M. I. Stockman, and D. J. Bergman, *Phys. Rev. Lett.* **91**, 227402 (2003).

[2] C. Höppener, Z. J. Lapin, P. Bharadwaj, and L. Novotny, *Phys. Rev. Lett.* **109**, 017402 (2012).