Quantum Effects in Nanoantennas and Their Applications in Tunability, Mixing, and Rectification

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Abstract- It has been recently shown that optical nanoantennas made of single or paired metallic nanoparticles can efficiently couple the propagating light into and from deeply subwavelength volumes. The strong light-matter interaction mediated by surface plasmons in metallic nanostructures allows for localizing optical fields to a subdiffraction-limited region, thereby enhancing emission of nanoemitters and offering the flexible control of nanofocused radiation. Here we theoretically study the nanodipole antennas with submicroscopic gaps, i.e. a few nanometers, for which there exists linear and high-order nonlinear quantum conductivities due to the photon-assisted tunneling effect. Noticeably, these quantum conductivities induced at the nanogap are enhanced by several orders of magnitude, due to the strongly localized optical fields associated with the plasmonic resonance.

In this talk, we will show that by tailoring the geometry of nanoantennas and the quantum well structure, a quantum nanodipole antenna with a gap size of few nanometers can induce linear, high-order quantum conductivities that are considerably enhanced by the surface plasmon resonance. We envisage here a number of intriguing nanophotonic applications of these quantum nanoantennas, including (i) modulatable and switchable radiators and metamaterials, with electronic and all-optical tuning (which is related to the two photon absorption), (ii) optical rectification for detection and energy harvesting of infrared and visible light, which are related to the relevant second-order quantum conductivity, (iii) harmonic sensing for the work function and the optical index of nanoparticle, e.g. DNA and molecules, loaded inside the nanogap, and (iv) high harmonic generation and wave mixing with nonlinear quantum conductivities.

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