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Optical nanoantennas: controlled emission of single photon sources

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Nanoscale quantum emitters are key elements in quantum optics and sensing. However, efficient optical excitation and detection of such emitters involves large solid angles, due to their omnidirectional interaction with freely propagating light and due to limits of diffraction. Optical nanoantennas offer both nanoscale localization and efficient interaction. Here we focus on the control of the interaction of single photon emitters (molecules, quantum dots) with radiation through metal nanorod antennas. First a novel analytical model is presented, which shows the continuous evolution of the properties of optical antennas as they become increasingly bound, i.e. plasmonic. The model accurately describes the complete emission process, the radiative decay rate, quantum efficiency, and angular emission, moreover gives a quantitative description of the gradual emergence of sub-radiant, super-radiant, and dark modes. Next we investigate experimentally the coupling of a single quantum dot to a nanorod of increasing length. The angular luminescence of the quantum dot is detected through increasingly higher order antenna modes. Simultaneously the emission is strongly polarized and enhanced. Direct confrontation with theory allows to determine the coupling efficiency of the quantum dot to the antenna. Finally, we present unidirectional emission of a single emitter by coupling to a nanofabricated Yagi-Uda antenna. A quantum dot is placed in the near field of the antenna so that it drives the resonant feed element of the antenna. The resulting quantum-dot luminescence is strongly polarized and highly directed into a narrow forward angular cone. The directionality of the quantum dot can be controlled by tuning the antenna dimensions. Thus our results show the potential of optical antennas to communicate energy to, from, and between nano-emitters.

A.G.Curto et al., Science 329, 930 (2010)