Several quantum interference effects near plasmonic nanostructures

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Plasmonic structures present the key advantage of an anisotropic electric modal density, which orinats from collective oscillations of free electrons in metals and leads to a nanoscale large vacuum anisotropy. Another advantage is that evanescent fields near these plasmonic structures can excite single quantum emitters, enabling a nanoscale realization of atom-light interactions that traditional techniques cannot access.

First, we investigate the resonance fluorescence of a two-level single molecular system interacting with a plasmonic nanostructure [1]. Specific regions of space are identified, where a balance exists between the near-field enhancement and the modification of the decay rate, such that the fluorescence spectrum of the molecule exhibits the Mollow triplet and the emission photons are antibunched. The utilization of such quantum phenomena at the vicinity of custom-designed plasmonic nanostructures paves the way for applications in nanoscale quantum devices and quantum information processing.

Then, in the coherently trapped populations of a four-level atom, we demonstrated the quantum beats with different mechanism, which originate from the interference between transition channels with different dipole moments [2]. The beat frequency is determined by the intrinsic atomic parameters, i.e., the spacing of upper levels and ratio of dipole moments. The resonant plasmonic nanoantenna, as a candidate for the creation of anisotropic vacuum, was proposed to achieve the nanoscale realization of the quantum beats, spontaneous emission cancellation, and Rabi oscillation in two-photon correlations through the enhanced nearfield and modified decay rates.

At last, the mechanism behind anisotropic vacuum control of spontaneous emission linewidths in a fourlevel atom is theoretically demonstrated: if the polarization angle bisector of the two dipole moments lies along the major/minor axis of the effective decay rate ellipse, constructive/destructive interference narrows/widens the fluorescence center spectral lines [3]. Spectral line narrowing is observed as atoms approach a metallic nanowire and linewidth nanoscale pulsing appears following the periodically-varying decay rates within the periodic metallic nanostructure. We propose a resonant plasmon nanostructure that can modify the linewidth, intensity, and sideband of resonance fluorescence at the nanoscale through an anisotropic decay rate and an enhanced near field.

References