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Purcell Effect in Plasmonic and Dielectric Optical Nanoantennas

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Abstract

Light-matter interactions in condensed media at room-temperature are fundamentally limited by electron-phonon coupling. For instance, while the excitation cross-section of an isolated atom, or of a single quantum emitter at cryogenic temperatures, can reach one half of the wavelength of light squared (meaning that nearly 100% of incoming photons will interact for a diffraction-limited excitation); this value is reduced by 6-7 orders of magnitude for a fluorescent molecule or for a colloidal quantum dot at room temperature because of homogeneous phonon broadening. In order to render the exceptional optical properties of single quantum systems (such as single-photon emission and nonlinearities) efficiently accessible at room temperature and in condensed media, it is essential to enhance and optimize these interaction cross-sections.

In this presentation, I will detail some of our recent work towards this goal. In particular, I will describe how DNA-based self-assembly can be used to introduce, in a deterministic way, a controlled number of quantum emitters in the nanoscale hot-spot of a plasmonic resonator. Using this approach, we can enhance single-photon emission from fluorescent molecules by more than two orders of magnitude in a weak-coupling regime [1]. Using five organic molecules, it is also possible to reach a strong-coupling regime with a single dimer of gold nanoparticles [2].

An alternative platform to plasmonics, in order to enhance light-matter interactions at room temperature, is the use of nanoscale optical resonators made of high-index dielectric materials such as silicon or gallium phosphide. I will discuss some of our recent work on the use of silicon resonators to enhance or inhibit spontaneous emission from electric [3] or magnetic optical emitters [4]; as well as the development of colloidal dielectric resonators to enhance quadratic or cubic nonlinear optical properties.

References

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