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Single-photon superradiance: effects of the dielectric environment and accuracy of the rotating-wave approximation

Thursday, 27th October - 13:30: Poster Session - Poster

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Introduction:

The electromagnetic environment influences the spontaneous-emission rate of a quantum emitter, but also the collective decay (superradiance and subradiance) of a collection of emitters. In a solid, dephasing due to phonons often but not always spoils the collective decay. The present study of collective decay in a 2D material close to a plasmonic surface is especially relevant for a remarkable class of lifetime-limited defect emitters in hexagonal boron nitride.

Methods:

We employ a multiple scattering theory where collective emission is described by the Green function of the macroscopic Maxwell wave equation. We calculate the propagator between various quantum emitters positioned in a multilayer medium [in preparation, 2022]. We also determine how much the propagator differs from the Green function when making the common rotating-wave approximation (RWA) [J. Phys. B 55, in press (2022)].

Results:

We consider emitters embedded in a thin high-index dielectric layer with either air or metal as a substrate. Both configurations allow for guided modes. The guided and surface-plasmon modes are shown to play a significant role in the collective decay (super- and subradiance) of emitters at all lateral separations considered. The relative orientation of the emitters w.r.t. each other and to the interfaces of the medium determine whether the guided modes enhance or inhibit collective decay. The largest effect is found for dipoles oriented along the plane. Making the RWA only affects the real part of the induced inter-emitter interactions. For free space, the RWA may lead to induced interatomic interactions that are wrong by up to a factor of two, in contrast to a scalar model where the “RWA error” even diverges in the near field.

Discussion:

Collective emission in layered systems is affected by guided modes, with the strongest effect for dipoles oriented along the planes, which is the most common orientation for emitters in 2D materials. Making the RWA in the light-matter interaction has subtle effects: it affects neither single-emitter spontaneous-emission rates, nor the collective emission rates of two identical emitters. But for three or more identical emitters or for two slightly detuned emitters, the RWA does influence the calculated collective rates.