Dielectric Gap-nanoantennas for Low-loss Field Enhanced Spectroscopy

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Submicron spheres made of low-loss dielectric materials with moderately high refractive index, such as Silicon, show spectrally distinct and well defined electric and magnetic dipolar resonances at optical-near infrared frequencies [1]. This magneto-dielectric response leads to antenna effects that generate enhanced scattering and enhanced local fields. In addition, submicron silicon particles qualify as good dielectric nanoantennas due to both absence of absorption and directional scattering properties [2]. Here, we study the potential of submicron silicon dimers as building blocks for low-loss field-enhanced spectroscopy and sensing of magnetic activity. We perform a full electrodynamical study of submicron silicon dimers and address their antenna properties in the optical and near-infrared range of the spectrum.

An analytical dipole-dipole model is developed to understand the basic interactions responsible for the antenna properties. The electric-electric, magnetic-magnetic and the electric-magnetic dipole interactions are the basic interactions responsible for the far-field optical response of a Si dimer of 150 nm radius and 10 nm gap, as shown in Fig. 1. This configuration also shows a significant near-field enhancement in the dimer gap, which makes it a good candidate as a dielectric antenna for field-enhanced spectroscopy.

Furthermore, dielectric antennas have been proven to control the emission from electric and magnetic dipolar emitters coupled to the antenna modes [3]. We thus study the enhancement of the fluorescence of electric and magnetic dipolar emitters when coupled to the antenna modes of the silicon dimer. Fig. 2 and Fig. 3 show the radiative rate enhancement (Γ_R/Γ_0) and quantum efficiency of the emission for an electric and magnetic dipolar emitter, respectively, oriented both along and perpendicular to the dimer axis, placed in the geometrical center of the dimer. Reduced quenching and high quantum efficiency of emission are some of the clear advantages of dielectric nanoantennas over metallic ones.

References

[1] A. Garcia-Etxarri et al., Opt. Express. **19**, 4815 (2011)
[2] J. M. Geffrin et al., Nat. Comm. **3**, 1171 (2012)
[3] Mikolaj K. Schmidt et al., Opt. Express. **20**, 13636 (2012)

Figures

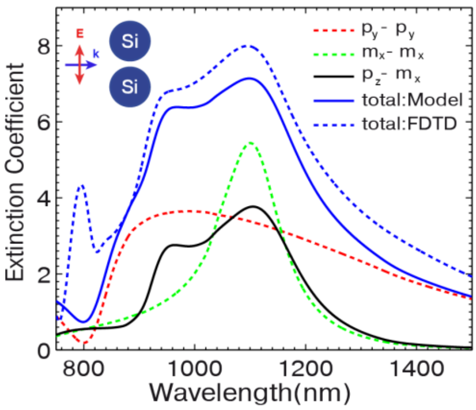

Fig. 1: Extinction spectra of two interacting electric and magnetic dipoles calculated using the dipole-dipole model compared with the full electrodynamical calculation (FDTD) for a Si dimer of radius 150 nm and gap 10 nm. This basic model provides a full understanding of the extinction spectrum.

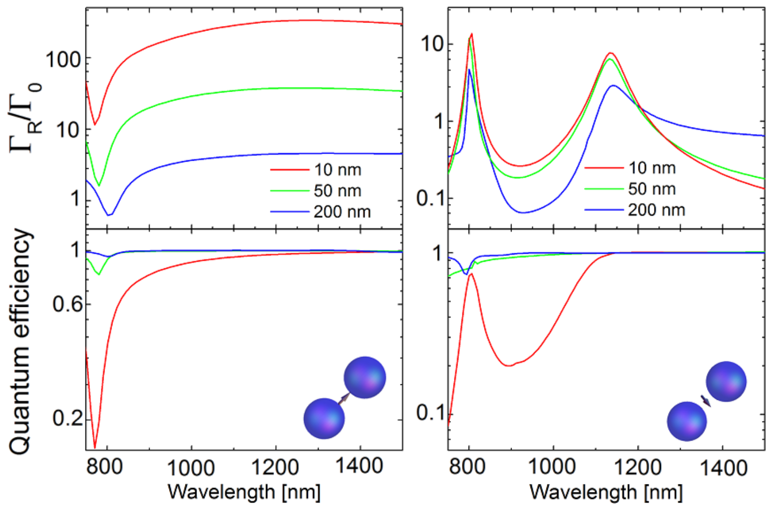

Fig. 2: Radiative decay rate enhancement and quantum efficiency of emission of an electric dipole emitter placed in the dimer gap for different orientations of the emitter calculated for different dimer gaps.

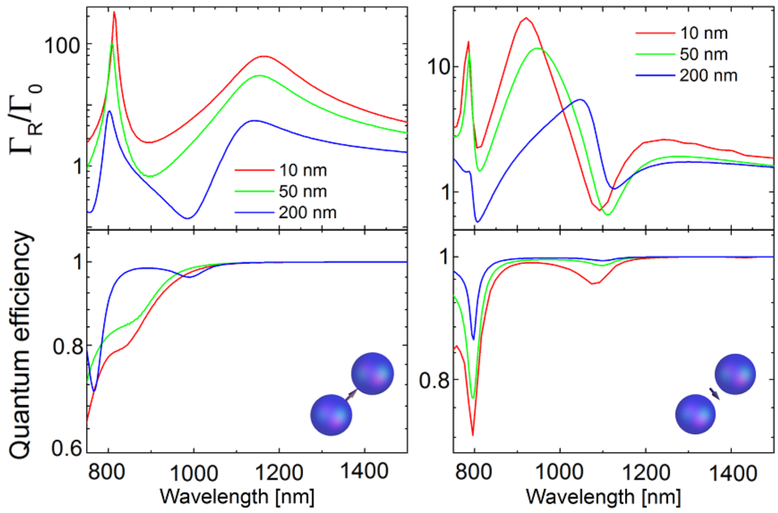

Fig. 3: Radiative decay rate enhancement and quantum efficiency of emission of a magnetic dipole emitter placed in the dimer gap for different orientations of the emitter calculated for different dimer gaps.