tum yield induces a modulation of the far-field emission spectrum [see Eq. (1)], which can result in a significant suppression of strong coupling effects. This is evident in the case of the nanosphere (a), where the maximum of the radiative emission is centered onto the $l = 1$ dipolar surface plasmon at $\omega \simeq 3.5\,\text{eV}$. However, the optimal resonance frequency for the transition to the strong coupling regime is around $\omega \simeq 3.66\,\text{eV}$, as an effect of the excitation of higher-order strongly non-radiative plasmon modes. As a consequence, the vacuum Rabi splitting results strongly quenched in the far-field for the spherical geometry. This is not the case of the cone (b) and double cone (c) systems, for which the maximum of the radiative decay rate coincides with the maximum of the field enhancement, as a result of the excitation of the strongly radiative mode. In these cases, the fingerprint of vacuum Rabi splitting, even if partially modulated by the quantum yield, survives even in the far field spectrum.

The present results in terms of threshold oscillator strength are much closer to experimental realization than those reported in [16], on two respects: first, the calculations of this work are performed by taking realistic dielectric functions of Ag, which have a much higher dissipation (almost an order of magnitude) than for the Drude model assumed in [16]. Second, the conical shape of the nanoparticles results nowadays well accessible by an experimental point of view [29] and the configuration with the dipole *outside* the nanoparticle is also favourable for experimental probing by raster scanning of a nanotip [30]. Thus, the present calculations are believed to represent a significant step in the direction of tailoring the interaction between a dipole and a metal nanoparticle, in view of achieving the strong coupling regime.

4. Conclusion

In conclusion, we have numerically predicted the onset of strong electromagnetic coupling for low oscillator strength dipole emitters put in proximity of sharp silver nanotips. 20 nm Ag cones, either in a single or double configuration, turn out to be much more advantageous with respect to a 20 nm diameter Ag sphere, if an optimal aperture is selected. Despite the intuitive idea that decreasing the tip angle would lead to better localization of the surface plasmonic field, the threshold oscillator strength for the occurrence of strong coupling has a nonmonotonic behavior as a function of the aperture angle, with an optimal semi-aperture angle around $\pi/13$. This is in relation with the fact that small-aperture cones are characterized by surface plasmon modes with a broader frequency distribution and the threshold oscillator strength is mainly related to the modal width of surface plasmons.

Employing the numerical DDA approach together with quantum electrodynamics turns out to be a powerful predictive method, that can be applied to metal nanoparticles of any shapes. The systems here analyzed involve emitters and nanoparticles which can be realized with state-of-art techniques, and this could open new avenues towards the real observation of the reversible exchange of energy between a dipole emitter and the electromagnetic field in plasmonic nanosystems.

Acknowledgment

This work was funded by Fondazione Cariplo under project no. 2010-0523. For computational facilities S. D. thanks NNL-CNRNANO, the Italian Institute of Technology (IIT), and the CINECA Consortium (ISCRA Award N. HP10C1ZQTO, 2011).