Purcell factor of photonic and plasmonic nanoantennas

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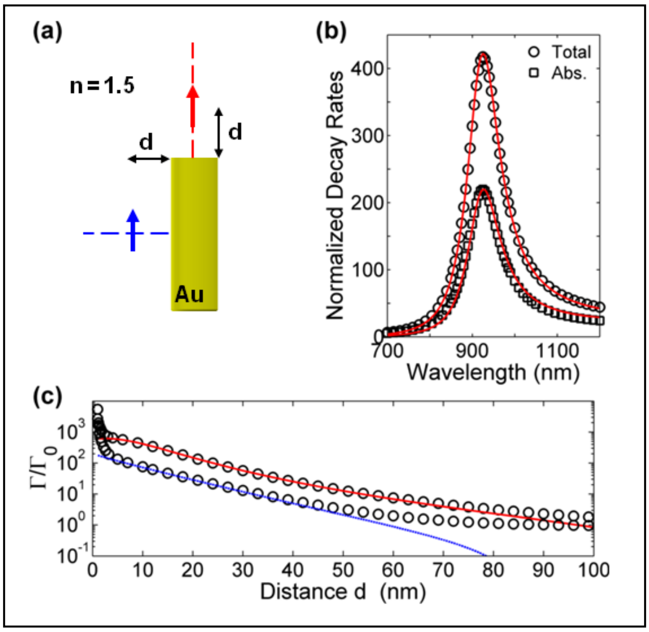
The spontaneous emission of a quantum emitter is a cornerstone of nano-optics, with the objective to control light absorption and emission at the nanometre scale. At the heart of the engineering lies the emitter-cavity coupling. A figure of merit for this coupling is the famous *Q*/*V* ratio introduced by Purcell in 1946. During the last decennia, the Purcell factor has been essentially used to fashion purely dielectric microcavities that confine light at the wavelength scale.
In this work, from first-principle calculations based on Maxwell's equations and the Fermi's golden rule, we propose a self-consistent theoretical framework of the coupling between a dipole emitter and a cavity quasi-normal mode. The latter is a solution of Maxwell's equation without source and with a complex frequency $\tilde{\omega}$. It is an advanced representation of a resonance ($2Q = \mathrm{Re}(\tilde{\omega})/\mathrm{Im}(\tilde{\omega})$). The formalism allows us to derive a generalized Purcell formula valid for any nanocavity quasi-normal mode with radiative leakage, absorption and material dispersion, including the important case of plasmonic nanoantennas. Our findings are not marginal, as they greatly impact and expand our current understanding of coupling between low Q-resonance and dipoles and solve a longstanding problem related to the normalization of quasi-normal modes. For instance we show that

1. the contribution of a quasi-normal mode to the total power radiated by a source may be detrimental (it may reduce the emission), even when the frequencies of the source and the mode are matched.
2. a detuning between the quantum emitter and cavity frequencies does not necessarily result in a Lorentzian lineshape response, as it is presently accepted by everyone.



All our findings are carefully checked and validated by comparison with fully-vectorial numerical results obtained for distinct cavity constructs representative of modern studies in quantum plasmonics. The following figure shows an example of such a test for a gold nanorod (diameter *d* = 30 nm and length *L* = 100 nm) embedded in a host medium of refractive index 1.5 (see (a)). Figure (b) shows the normalized decay rates (total and absorption) calculated with the Green-tensor approach (solid curves) and with the proposed model (circles or squares). The dipole is on-axis, parallel to the nanorod axis (red arrow) at a distance *d* = 10 nm from the metal surface. In (c), we show the same for the resonance frequency as a function of *d*. The work is presently submitted for publication.