Purcell factor for plasmon-enhanced metal photoluminescence

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We developed an analytical model for plasmon-enhanced metal photoluminescence (MPL) in small metal nanostructures. We find that interference between the direct and plasmon-assisted processes leads to the blueshift of MPL spectral peak relative to surface plasmon resonance in scattering spectra observed in numerous experiments.

Photoluminescence of noble metals and metal nanostructures has attracted continuing interest fueled, to the large extent, by its numerous applications. In bulk metals, the underlying mechanism of metal photoluminescence (MPL) is radiative recombination of photoexcited d-band holes and upper-energy sp-band electrons via momentum-conserving interband transition, while much brighter MPL has been reported from various metal nanostructures supporting localized surface plasmons (LSP). The origin of bright MPL from plasmonic structures is excitation of the LSP by a recombining electron-hole pair followed by the LSP radiative decay [1]. However, persistent differences in the lineshape and peak positions between the MPL and scattering spectra, such as the blueshift of MPL spectral peak relative to the LSP resonance, have widely been reported for diverse nanostructures [2]. At the same time, the calculation of MPL Purcell factor for structures used in the experiment demands extensive numerical calculations.

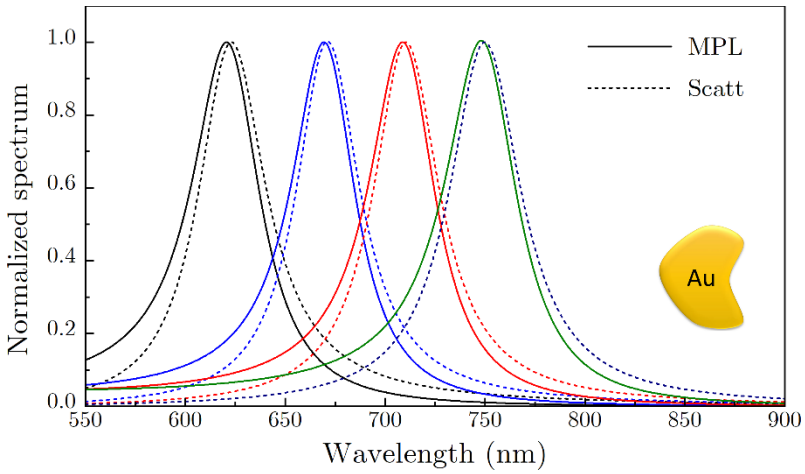

Fig. 1 Normalized MPL and scattering spectra for gold nanostructures with characteristic size 40 nm at various LSP wavelengths. The MPL spectra are blueshifted relative to scattering spectral at the *same* LSP wavelength.

Here, we present an analytical model for MPL from plasmonic structures of *arbitrary* geometry with characteristic size below the diffraction limit. For such systems, we derive an explicit expression for the MPL Purcell factor, which can be used to characterize the plasmonic enhancement of both interband and intraband MPL [3]. We trace the observed blueshift of MPL spectral band relative to LSP resonance in scattering spectra to destructive interference between the direct and LSP-assisted recombination processes (see Fig. 1). We find that the lineshape of MPL spectrum has universal form determined solely by the metal dielectric function and LSP frequency. Our results can be used for modeling and interpretation of experimental MPL spectra without significant numerical effort.

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References

[1] Dulkeith, E. Niedereichholz, T. Klar, T. A. Feldmann, J. von Plessen, G. Gittins, D. I. Mayya, K. S. Caruso, F. 2004. *Phys. Rev. B*, 70, 205424 (2004).

[2] Fang, Y. Chang, W.-S. Willingham, B. Swanglap, P. Dominguez-Medina, S. Link, S. 2012. *ACS Nano*, 6, 7177-7184.

[3] Shahbazyan, T. V. 2022. arXiv:2212.04685.