Maximal Coupling of Light into 2D Polaritons

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Polaritons in 2D materials have been extensively studied over the past decade due to their fundamental interest and as a platform for applications in telecommunications and sensing. The wavelength of these polaritons is generally small compared to that of a free-space photon of the same frequency, making them very attractive to manipulate light at deep-subwavelength distances. However, it simultaneously introduces a challenge in the coupling between propagation light and plasmonic modes, since the momentum mismatch between the two makes the in/out-coupling of this process intrinsically weak [1].
In this work [2], we demonstrate that a small scatterer placed at a suitable distance from a planar surface can produce complete coupling of a focused light beam to surface polaritons (Fig. 1a). We present rigorous closed-form analytical prescriptions for the modulation of the incident light beam that maximizes this coupling, depending on the characteristics of both scatterer and surface. We subsequently use the derived expressions to provide a rigorous theoretical analysis of extremal focused light coupling to plasmons in silver films and graphene, as well as coupling to phonon polaritons in hexagonal boron nitride films and waveguide modes in silica waveguides. We corroborate these analytical results by performing rigorous numerical simulations for realistic setups, which exhibit a very strong enhancement of light absorption into surface plasmons under the prescribed optimal conditions (Fig. 1b,c). Our results open a practical route to circumvent the long-standing photon-polariton wavelength mismatch problem in nanophotonics.

REFERENCES

[1] E.J.C.Dias and F.J. García de Abajo, "Fundamental Limits to the Coupling between Light and 2D Polaritons by Small Scatterers." ACS Nano 13, 5184 (2019).
[2] E.J.C.Dias and F.J. García de Abajo, "Complete Coupling of Focused Light to Surface Polaritons." Optica 8, 520 (2021)

FIGURES

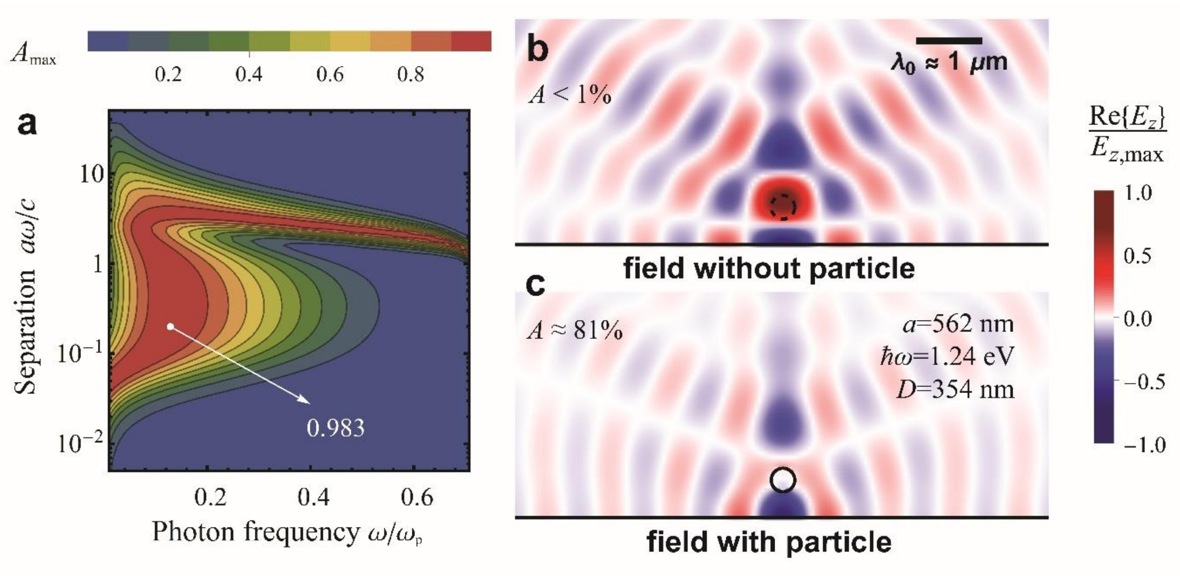

Figure 1: (a) Dependence of the maximum coupling fraction $A_{\max}$ on light frequency ω and particle-surface separation a for a point dipole placed above a semi-infinite Drude metal film with plasma frequency ω_p and damping $\omega_p/100$. Copuling approaches 100% for a wide range of these two parameters. (b,c) Numerical simulations of the near-field under optimal illumination in the (a) absence and (b) presence of a Si spherical scatterer with diameter D (represented by open and solid circles, respectively) at a distance a from the surface of a Ag semi-infinite film. The presence of the Si sphere enhances absorption into silver plasmons to $\sim 80\%$.