POLIMA
Center for Polariton-driven Light-Matter Interactions

SDU
Mads Clausen Institute

PROJECT TITLE

Polaritons in a plasmonic nanoparticle-on-mirror arrangement

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PROJECT DESCRIPTION

Plasmons are the free-electron oscillations induced by light in metallic nanostructures. They constitute prominent elements in modern nanotechnology due to their ability to strongly enhance and confine light at the nanoscale. This confinement can be exploited to control light–matter interactions, by placing quantum emitters in plasmonic cavities. Among the most promising such emitters are excitons (electron–hole pairs) in transition-metal dichalcogenides (TMDs), two-dimensional (2D) layered materials. The interaction of plasmons with excitons in such systems enables the excitation of hybrid polaritons, coherent states that promise applications in lasing, optical communications, and quantum information processing [1].

One of the simplest and most efficient plasmon–exciton architectures is the so-called nanoparticle-on-mirror (NPoM) set-up of Fig. 1, which allows the realisation of a large number of very similar samples in a cost-effective manner. To study such systems theoretically, semi-analytic or fully numerical methods from computational electrodynamics are often employed. These, however, fail to capture the role of quantum effects related to the localisation of light in dimensions comparable to intrinsic quantum length scales for the electrons in the metal, such as the Fermi wavelength and the electron mean free path [2].

The aim of this project is use the semi-analytic MATLAB code developed in Ref. [3] in collaboration with KU Leuven, to first understand how the coupling of the plasmonic NP with the underlying film is affected by quantum effects, and subsequently introduce a TMD as spacer between the two components, to further establish the role of nonlocality in plasmon–exciton coupling.

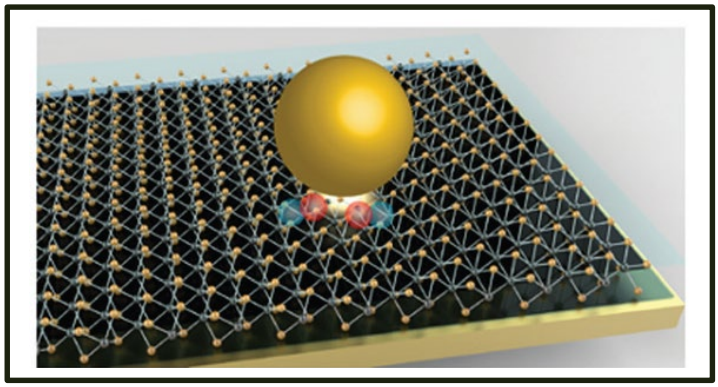

Figure 1: A typical plasmon–exciton NPoM set-up: a gold NP is separated by a gold film through a monolayer TMD. The hybrid plasmon mode formed by the interaction of the NP with its mirror image in the film couples to excitons in the TMD, creating a plasmon–exciton (plexciton) polariton.

[1] J. Sun et al., *Strong plasmon–exciton coupling in transition metal dichalcogenides and plasmonic nanostructures*, Nanoscale **13**, 4408 (2021).
[2] S. Boroviks et al., *Extremely confined gap plasmon modes: when nonlocality matters*, Nat. Commun. **13**, 3105 (2022).
[3] X. Yan et al., *A dedicated modeling scheme for nonclassical optical response from the nanosphere-on-mirror structure*, IEEE Trans. Micr. Theor. Techn. **72**, 2095 (2024).