Center for Polariton-driven
Light-Matter Interactions

Mads Clausen Institute

PROJECT TITLE

Scattering of light by a nonlocal metallic cylinder

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PROJECT DESCRIPTION

The interaction of light with metallic nanoparticles (NPs) is dominated by free-electron oscillations, the so-called plasmons. When the size of these NPs is comparable to the wavelength λ of the incident light, they behave like classical antennas for visible light, resonating e.g. at $\lambda/2$: classical-electromagnetic (EM) tools are adequate to fully capture their optical response. But when the NPs are considerably smaller than the wavelength, nonlocal and quantum effects substantially alter the optical response of the NP. Free electrons acquire considerable spatial extent as a result of Pauli's exclusion principle, and as a consequence inner electrons screen the interaction of the outer ones with the positive ionic background. The possibility of colliding with each other or with the boundaries of the NP also increases, leading to enhanced losses and increased damping of the plasmonic oscillation. The non-negligible extent of the electronic wave functions outside the assumed boundary also starts playing a role (so-called spill out), with the NP effectively appearing to light as larger [1].

Due to the prohibitive computational cost of a fully-quantum description, one promising route to capture these effects relies on the so-called Feibelman parameters: surface-response functions that describe to what (spatial) extent free electrons and the corresponding induced currents cross the assumed NP boundaries [2]. These can be absorbed in the EM boundary conditions, allowing to extend the use of tools from classical electrodynamics and electrical engineering to the extreme nanoscale. Analytically, this method has been presented for spheres and flat surfaces, but its implementation for infinitely-long cylinders is still missing. The student will repeat the classical solution for scattering of light by a cylinder [3], and then modify it to account for Feibelman parameters. They will then prepare the corresponding numerical code in their favourite language, to study the influence of quantum corrections on the optical response of thin metallic wires, thus allowing to understand ultrathin plasmonic waveguides, fibres, and interconnects.

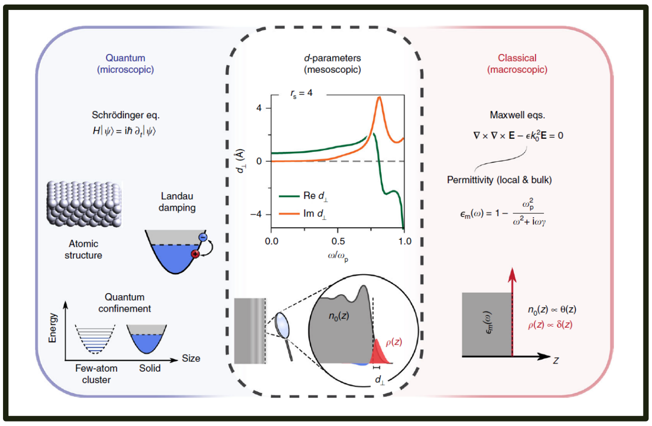

Figure 1: Comparison between the classical (macroscopic) and quantum (microscopic) description of plasmonic nanostructures. The project lives in the intermediate mesoscopic world, where aspects of the quantum description of free electrons are implemented in an otherwise classical-EM treatment, through surface-response functions, the so-called Feibelman parameters.

[1] P. A. D. Gonçalves et al., *Plasmon–emitter interactions at the nanoscale*. Nat. Commun.**11**, 366 (2020).
[2] P. J. Feibelman, *Surface electromagnetic fields*, Prog.Surf. Sci. **12**, 287 (1982).
[3] C. F. Bohren and D. R. Huffman, *Absorption and Scattering of Light by Small Particles* (Wiley, 1982).