POLIMA
Center for Polariton-driven
Light-Matter Interactions

SDU
Mads Clausen Institute

PROJECT TITLE

Mie voids for light–matter interactions

Proposed by: Christos Tserkezis

Possible supervisor(s): Christos Tserkezis, Ida Juliane Bundgaard, Christian Nicolaisen Hansen

PROJECT DESCRIPTION

While nanoscale light–matter interactions have been dominated in the last 20 years by metallic nanostructures, characterised by the excitation of plasmons (free-electron oscillations) which provide tremendous confinement of light, the intrinsic Ohmic losses in metals are often a prohibitive factor for some applications. An alternative approach whose popularity has been steadily growing in the last decade is based on the so-called Mie resonances in nanoparticles (NPs) made of high-index dielectric like silicon [1]. These NPs provide smaller enhancement and confinement of light, but come with low loss in the visible, and a combination of optical modes of different characters, including magnetic multipoles, that provide additional flexibility in tailoring light–matter interactions. Owing to these properties, Mie NPs have been attracting growing interest for activities in weak and strong emitter–cavity coupling [2], but the optimum set-up that will surpass plasmonic structures in performance is yet to be identified.

One limiting factor for such activities has been the fact that, with field enhancement happening mainly *inside* the dielectric NP, all the appealing properties that Mie-resonant systems exhibit are not completely accessible to quantum emitters. An alternative set-up that was very recently proposed is the complementary structure of a Mie void [3], as shown in Fig. 1. Here, air holes are perforated in high-index substrates, leading to confinement of light in the cavity. The aim of this project is to study analytically, based on Mie theory and its extensions, the optical properties of Mie voids in various materials, and then introduce a quantum emitter, either as a point dipole in the centre of the void, or as a layer of aggregated organic molecules at the surface of the void, or completely filling the cavity. Depending on time, comparison with numerical methods can also be done (e.g. COMSOL, boundary-element methods), and voids of shape other than spherical can be explored.

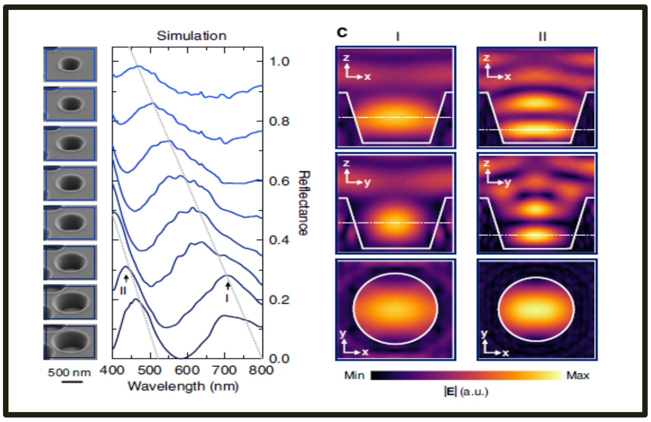

Figure 1: Light enhancement and confinement in Mie voids. Air holes of different sizes, perforated in a silicon substrate, sustain tuneable optical modes. Light is strongly confined within the holes, forming different kinds of standing-wave patterns depending on the size of the hole and the wavelength. Such voids are thus promising hosts for quantum emitters.

[1] A. Evlyukhin et al., *Demonstration of magnetic dipole resonances of dielectric nanospheres in the visible region*, Nano Lett. **12**, 3749 (2012).
[2] C. Tserkezis et al., Mie excitons: understanding strong coupling in dielectric nanoparticles, Phys. Rev. B **98**, 155439 (2018).
[3] M. Hentschel et al., *Dielectric Mie voids: confining light in air*, Light: Sci. Appl. **12**, 3 (2023).