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Colored nanostructures for photovoltaic cells

Proposed by: Catarina Ferreira

Possible supervisor(s): Catarina Ferreira, Christos Tserkezis

When integrating photovoltaic (PV) cells into the roofs and façades of buildings, special care must be taken to their aesthetics, to fulfill societal demands. Therefore, in addition to high power conversion efficiency, PV cells for building integration must be designed to harmonize with the host building and its surroundings, for instance by appropriately tuning their colors. Traditionally, PV coloration is achieved by embedding absorptive dyes or pigments in the front cover glass, which severely impacts the light transmitted to the PV cell and consequently its efficiency. A promising alternative is to rely on nanoscopic optical effects (scattering, diffraction, interference) taking place in non-absorbing materials to generate structural colors with low optical losses. Previously, we have demonstrated the use of planar multilayer structures with controlled layer thickness to tune the color of Si PV cells with reduced efficiency losses, owing to constructive interference phenomena. In this project, we propose a different approach to achieve vivid colors based on light scattering effects (Mie resonances, lattice resonances) taking place in different nanostructure arrays.

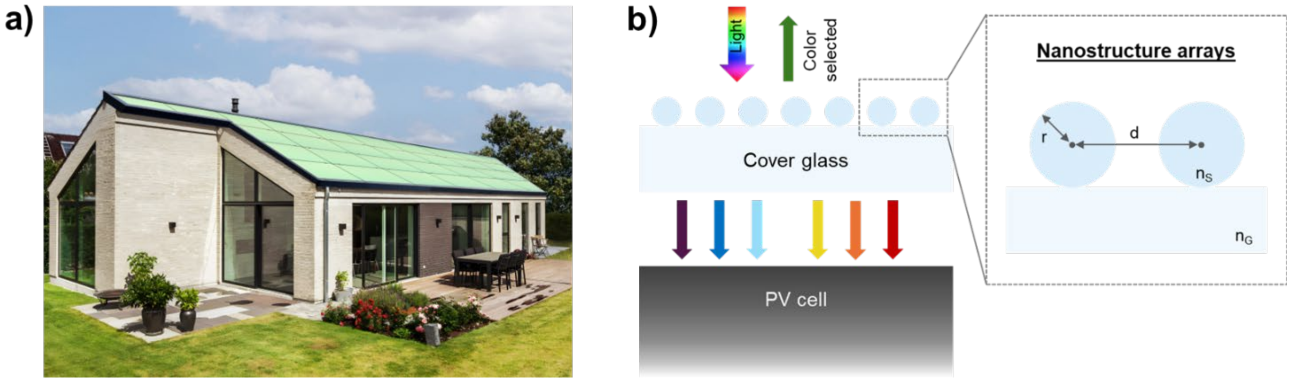

Figure 1. a) House containing green PV panels on the roof. b) Schematic representation of the dielectric nanostructure array proposed in this work to produce different structural colors for PV applications.

The aim of this project is to model and control the optical spectral properties of different arrays of dielectric nanostructures in order to tune the color reflected while maintaining the transmittance as high as possible, to ensure compatibility with PV devices. In particular, arrays of spheres made of different dielectric materials and with varying radius and spacing will be studied. An extension to cylindrical structures may be considered, if time allows. During the project, the student may opt for a fully analytical description based on Mie theory, for a numerical calculation relying on commercial finite element method (COMSOL), or for a combination of both methods. Regardless of the methodology chosen, the student is expected to explore the roles of size and periodicity, while understanding all the different physical mechanisms responsible for the final color.

[1] D. Wang et al., Nanophotonics **12**, 1019 (2023).
[2] C. Ferreira et al., Solar RRL, e202500674 (2025).
[3] A. Dorodnyy et al. – Laser Photon. Rev. **17**, 2300055 (2023).