

Ultimate control of light, essential for any optical applications and tools, hinges on the ability to structure passive and active elements appropriately. To perform basic tasks such as guiding, focusing, and others using various elements it is important to understand and predict their optical responses. The aim of this project is to develop knowledge on low-loss dielectric nanoresonators with an internal nanostructure for enhanced light-matter interactions, superior coupling to active and passive optical elements/inclusions, directional emissivity and radiation. This control is envisioned to be accomplished by controlling three scales: the macro-scale (microns) of arrays of optical antennas, the nano-scale (100s of nm) of the geometry of individual antennas, and most importantly the single-nanometer-scale of the internal nanostructure of each antenna. In simple terms, this project will focus on analyzing how each scale individually and jointly affects the optical responses of the studied optical elements and how these relate to the envisioned goals of controlling light.

Homogeneous dielectric nanoresonators have recently appeared as a low (or almost zero) loss alternative to plasmonic nanostructures for manipulating light at the nanoscale. This is because in addition to low losses, dielectric resonators offer a much richer resonance spectrum, as magnetic resonances appear alongside electric ones. This gives greater flexibility in tailoring their properties to match desired applications, whether it is sensing or directional scattering. In this project we intend to expand the range of their optical properties by introducing in them an internal nanostructure. This internal nanostructure will take on the form of mesoporous voids or flat multilayers.

In the first case the effective properties of the mesoporous resonator should remain isotropic, however, the voids will open up its internal structure, which contains the strongest electric and magnetic fields, to influence of outside factors. We intend to investigate how the voids affect the resonances of such structures, how the enhanced fields evolve in the presence of voids, and finally how feasible it is to utilize such resonators for enhanced interaction with metal or molecular inclusions. The hope is that being able to directly overlap these inclusions with enhanced fields will greatly enhance the radiative efficiencies of molecules, direct their scattering patterns in predetermined directions and enhance light absorption in catalytic metal inclusions for light-assisted catalysis.

In the second type of structure – the flat multilayered resonator – the main focus is on the anisotropic properties which result from the layered arrangement of material. This means that for an otherwise symmetric structure, e.g. sphere, its resonances will depend on the direction of incidence and polarization direction. Combined with the ability to shape the structure geometrically, this gives unprecedented control of the spectral properties. In the project we intend to study how such a rich spectral behavior can be utilized for controlling light emission from such structures, what could be utilized in dielectric mirrors, heat sources, or sensing.