All-dielectric nanophotonics and metasurfaces
govern by Mie resonances

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Abstract: We demonstrate that Mie resonances can play a crucial role in all-dielectric meta-optics enhancing many optical effects near magnetic dipole resonances and driving new physical effects due to electric and magnetic multipolar interference.

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Natural materials exhibit negligible magnetism at optical frequencies, since the direct effects of the optical magnetic field on matter are much weaker than electric ones. However, in the last decades many researchers were trying to overcome this nature’s limitation by designing artificial subwavelength structures that allow a strong magnetic response in optics, even if such structures are made of non-magnetic materials. This progress became possible due to the advances of the field of electromagnetic metamaterials describing optical structures composed of subwavelength elements often called “meta-atoms” and localized fields they may support.

It has been already established that the use of metamaterial and artificial “meta-atoms” would allow to engineer magnetic permeability $\mu$ and strong magnetic response by achieving strong resonances in structured systems made of non-magnetic materials. Although real magnetism in its conventional sense is not available at high optical frequencies, it is possible to engineer the spatial dispersion and nonlocal electric effects in such a way to induce a strong magnetic dipole moment without other higher-order contributions, even though the involved materials do not present microscopic magnetization and their magnetic permeability is strictly unitary.

One of the first examples of “meta-atoms” is the metallic split-ring resonator where electrons can oscillate in two parallel arms in the opposite direction creating an efficient magnetic response. The concept of split-ring resonators was first introduced at microwaves to realize artificial magnetic inclusions with subwavelength footprint, and then it was translated to the optics exploiting the plasmonic features of metallic nanoparticles. By now, this concept was realized in many non-magnetic plasmonic structures ranging from nanobars and nanoparticle complexes often called “oligomers” to more complicated multilayered structures such as fishnet metamaterials with both elliptic and magnetic types of hyperbolic dispersion [1]. This opens many novel opportunities and new physics in the subwavelength photonics.

Thus, the subwavelength localization of light in nanophotonics was associated for many years with free electrons and electromagnetic waves at metallic interfaces studied by plasmonics. However, the recent developments of the physics of dielectric nanoparticles with high refractive index suggests an alternative mechanism of light localization via low-order dipole and multipole Mie resonances that may generate strong magnetic response [2].

This talk aims to review the recent developments in the field of all-dielectric resonant meta-optics and demonstrate many novel opportunities of the Mie resonances and multipolar effects that offer novel ways for enhancing many optical effects with magnetic dipole resonances, such as nonlinear harmonic generation, Raman scattering, and multipolar and multimodal interference effects which are associated with many interesting effects such as unidirectional scattering, magnetic Fano resonances, effective optical antiferromagnetism, generalized Kerker scattering, bound states in the continuum, and nonradiating optical anapoles. We further discuss other effects not yet exploited deeply in literature and envisage the prospect of achieving more flexible and advanced nanoscale control of light relying on the concepts of full phase and amplitude engineering achieved with broadband all-dielectric metasurfaces.

References