Advanced Electromagnetic Wave Control in Metamaterials

Metamaterials provide control over the material properties through engineering of their subwavelength elementary units, the meta-atoms. An electromagnetic wave impinging on a metamaterial induces the excitation of local currents whose distribution is defined by the meta-atoms architecture, the constituent materials which can be metals, dielectrics, semiconductors or 2D materials, and the details of the electromagnetic wave. Essentially, these locally induced currents act as subwavelength localized current-charge sources and correspond to multipole moments, mainly low order moments of electric and magnetic character, that contribute uniquely to the scattered field and collectively produce a far-field response than can be perceived much like a material property. The meta-atoms design allows the selective combination or isolation of these multipole electromagnetic contributions and leads to unveiling exotic electromagnetic phenomena.

In fact, metamaterials have opened the path to novel electromagnetic features, providing the most known, negative effective permeability and negative refractive index (usually achievable by combining negative effective permittivity and permeability) and the more recently investigated, artificial chirality, sustaining toroidal excitations and topological photonic states. The enhanced electromagnetic wave manipulation enabled by metamaterial–based structures has led to fascinating applications which among else include ultrathin electromagnetic sheets for wavefront shaping, shielding and polarization control, software-defined wave control, graphene-based ultrafast modulators, topologically protected unidirectional propagation, energy harvesting, chiral lasing and more. In this talk we will review basic principles and the main theoretical framework of emerging metamaterial induced exotic phenomena and discuss interesting implementations in technologically relevant spectral areas, i.e., microwaves, THz and the near-IR / mid-IR.

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