Meta-Electromagnetics and Meta-Optics

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Abstract—Metamaterials and plasmonic optics have become exciting platforms for controlling and harnessing light and electrons in unprecedented ways. As these fields reach a certain level of development, new directions and novel possibilities are appearing in the horizon. Balancing the simplicity with the complexity in metamaterials becomes one of the key issues, and consequently modularization, functionalization, and parameterization of metamaterials may be exploited for new functionalities and possibilities in such interesting platforms that may include nonlinearity, anisotropy, chirality, non-reciprocity, and non-locality. The new paradigm of “meta-electromagnetism” offers new and transformative grounds for innovation in the field of electromagnetics and optics. In this talk I will give an overview of some of our most recent results in this area and will forecast some future possibilities.

I. DISCUSSION

The field of metamaterials and its predecessors “complex media” and “artificial dielectrics” have a rich history. One of the earliest forms of artificial materials seems to date back to the late part of the 19th century [1]. Owing to the advent of nanotechnology, this field in its modern form has seen unprecedented growth in recent years, and has attracted considerable attention [2-3]. The fact that one can design and tailor the material parameters such as the electromagnetic parameters of permittivity and permeability allows one to obtain unusual electromagnetic properties not easily found in nature, but of course physically realizable. In other words, the parameter space has been expanded due to this ability of tailoring materials parameters. Various novel electromagnetic characteristics have been explored in many different metamaterial categories by various groups all over the world.

As this field reaches a certain level of development, one sees new opportunities in innovation of the next generation of metamaterials. As is often the case, when the complexity of structures is increased, one needs to balance that with the simplicity in the design. It is this balance between the simplicity and complexity that leads to features such as parameterization, modularization, functionalization, and conceptualization that often provide new directions and novel possibilities in the development of a field. The field of metamaterials is indeed encountering the need for such a balance between the complexity in its physics and the simplicity in its engineering design.

In my group, we have been exploring various phenomena in the field of metamaterials and plasmonic optics. We have been investigating the concepts of optical lumped nanocircuit elements (metatronics) [4-9], digital metamaterials [10], epsilon-near-zero (ENZ) metamaterials that offer several exciting features such as the supercoupling effects [11-15], controlling the flow of photons using the combination of nonreciprocal structures with metamaterials, providing the possibility of one-way flow of photons [16] and its implication in the cavity electrodynamics, mixing ENZ materials with magneto-optical structures [17], nonlinear metatronic elements [18], controlling coherence in the ENZ metastructures [19], transplanting the concept of metamaterials into the field of quantum electronics, providing the methods for tailoring the effective mass of electrons (“meta-electronics” and “transformation electronics”) [20], signal-processing metamaterials [21], subwavelength optical circulators [22-23], graphene transformation optics and graphene metamaterials [24-26] and various other phenomena. In all these, we consider the issues of modularization, parameterization, and functionalization of metamaterials.

In this talk, I will discuss an overview of some of these concepts, present physical intuition behind the results, and forecast future possibilities.

REFERENCES


