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Taming Light and Electrons with Metamaterials

NADER ENGHETA, Department of Electrical and Systems Engineering, University of Pennsylvania

In recent years, in my group we have been working on various aspects of metamaterials and plasmonic nano-optics. We have introduced and been developing the concept of "metatronics," i.e. metamaterial-inspired optical nanocircuitry, in which the three fields of "electronics," "photonics" and "magnetics" can be brought together seamlessly under one umbrella - a paradigm which I call the "Unified Paradigm of Metatronics." In this novel optical circuitry, the nanostructures with specific values of permittivity and permeability may act as the lumped circuit elements such as nanocapacitors, nanoinductors and nanoresistors. Nonlinearity in metatronics can also provide us with novel nonlinear lumped elements. We have investigated the concept of metatronics through extensive analytical and numerical studies, computer simulations, and recently in a set of experiments at the IR wavelengths. We have shown that nanorods made of low-stressed Si_3N_4 with properly designed cross sectional dimensions indeed function as lumped circuit elements at the IR wavelengths between 8 to 14 microns. We have been exploring how metamaterials can be exploited to control the flow of photons, analogous to what semiconductors do for electrons, providing the possibility of one-way flow of photons. We are now extending the concept of metatronics to other platforms such as graphene, which is a single atomically thin layer of carbon atoms, with unusual conductivity functions. We study the graphene as a new paradigm for metatronic circuitry and also as a "flatland" platform for IR metamaterials and transformation optics, leading to the concepts of one-atom-thick metamaterials, and one-atom-thick circuit elements and optical devices. I will give an overview of our most recent results in these fields.