From Electronics to Metatronics to Graphene Metamaterials

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Abstract

We discuss the concept of optical metatronics, i.e., metamaterial-inspired optical nanocircuitry, in which the metamaterials and plasmonic optics can bring together three fields of "electronics", "photonics" and "magnetics" seamlessly under one umbrella – a paradigm which I call the "Unified Paradigm of Metatronics". We present an over view of our most recent analytical, numerical and experimental results in developing the optical metatronics. We also show how this concept can be merged into the platform of graphene, which is one-atom-thick carbon layers, leading to the possibility of one-atom-thick infra-red metamaterials and transformation optics. Future directions in these topics will also be forecasted.

1. Introduction

Metamaterials are engineered composite media with exciting electromagnetic and optical properties. This field has been experiencing unprecedented development in recent years due to numerous potential applications. There has also been significant interest and development in the field of plasmonic optics due to the breakthroughs in nanotechnology and nanooptics, and exciting potentials for merging of nanooptics and nanoelectronics. In my group, we have been investigating various areas of metamaterials and plasmonic optics. As one such area, we have been developing the concept of "metatronics", i.e., metamaterial-inspired optical nanocircuitry as a unifying paradigm to bring the fields of "electronics", "photonics" and "magnetics" together under the same umbrella, and treating them and bridging the gaps among them seamlessly. [see e.g., 1-10]. In this novel optical nanocircuitry, 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 optical nonlinear lumped elements. Using various analytical techniques and numerical simulations, and recently through a set of experimental efforts at the IR and microwave wavelengths [10], we have demonstrated that such optical nanocircuitry may lead to a novel platform for tailoring and manipulating optical signals. 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 [10]. The same way that "electrons" have played the crucial role in "electronics" and "spins" in "spintronics", the optical electric fields and displacement field currents in metamaterial nanostructures can play an analogous role in the field of "metatronics", leading to the possibility of nanoscale data processing [2].

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. Independent of the fields of metamaterials and plasmonic, in recent years there has been explosion of interest in the field of graphene [see e.g., 11-18]. 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 [18]. We theoretically show that the graphene can be unique paradigm for THz and IR metamaterials. In my group we are also merging the concept of metatronics with graphene metamaterials, providing the possibility of THZ and IR lumped circuit elements with graphene, and expanding the notion of metatronics to a wider range of electromagnetic spectrum.

I will give an overview of our group's most recent results in these fields

2. References

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