Metaplasmonic Structures, Optical Nanocircuits, and Wireless Nanosystems

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Abstract

Here we present an overview of our recent works on metaplasmonic-based structures, devices, and optical nanocircuit elements and nanosystems, and we show how these concepts may bring the whole machinery of circuit theory and design into the nanoscale through plasmonic optics, and how these concepts may open doors to exciting possibilities and directions in the field of nanooptics. We will briefly discuss several ideas for nanocircuit functions, optical nanoantennas for beam shaping and "photonic wireless at the nanoscale", nanospectrometer for molecular spectroscopy, and negative-refraction optical metamaterials using lumped optical circuit element inclusions.

1. Concepts

In the microwave and optical domains, metamaterials with unconventional constitutive parameter values (i.e. negative or near-zero) exhibit interesting properties in their interaction with microwave and optical waves [see e.g., 1-4]. Negative-permittivity plasmonic media, such as noble metals in the infrared and optical frequencies, and epsilon-near-zero (ENZ) materials, such as plasmonic materials near their plasma frequencies, can be exploited for synthesis of novel metaplasmonic structures with properties that enable many concepts from the microwave domains to be brought into the IR and visible wavelengths. For example, the well-known notion of lumped circuit elements has been extensively exploited in the radio frequency (RF) and microwave domain for many years. The "modularization" of such lumped elements has provided useful concepts for the design and synthesis of larger and more complex circuits, and circuit theory and design has been a useful paradigm in electrical signal processing at those frequency domains. Another rich field is antenna design for transmitting and receiving signals in the RF and microwave domains. Utilizing the concept of metamaterials and plasmonic media, we have transplanted some of these RF and microwave notions into the THz, IR, and optical domains. With this approach, nanocircuit elements such as nanoinductors, nanocapacitors, and nanoresistors can be envisioned at optical frequencies by properly arranging plasmonic and nonplasmonic nanostructures [5-8]. Designs of optical nanoantennas inspired by some of the microwave concepts can also benefit from these metaplasmonic concepts. We have also utilized these nanocircuit concepts to suggest ideas for negative-refraction optical metamaterials, optical nanoantennas for nanobeam shaping, e.g., spectrum analysis of molecular spectroscopy, to name a few [5-20]. This will open doors to exciting possibilities in the future optical nanoelectronics and nanosystems, and may likely lead to new paradigms for information processing, detection, and storage at the nanoscale.

2. References

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