Transforming Light with Tunable and Active Metamaterials

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One of the most unique properties of light is that it can package information into a signal of zero mass and propagate it at the ultimate speed. It is, however, a daunting challenge to bring photonic devices to the nanometer scale because of the fundamental diffraction limit. Metamaterials can focus light down to the nanoscale and thus enable a family of new nanophotonic devices. Metamaterials, i.e. artificial materials with rationally designed geometry, composition, and arrangement of nanostructured building blocks are opening a gateway to unprecedented electromagnetic properties and functionalities that are unattainable with naturally occurring materials. We review this exciting field and discuss the recent, significant progress in developing metamaterials for the optical part of the electromagnetic spectrum. Specifically, we report on our recent world's smallest nanolaser (collaborative work with Norfolk State University and Cornell), describe the phenomena of artificial magnetism across the whole visible and negative refractive indices in the optical range, and demonstrate a broadband cloaking in the visible based on tapered waveguides (collaboration with BAE and Towson University). Loss-free and active negative-index metamaterials will be presented. Finally, a new, powerful paradigm of engineering space for light with transformation optics, which can enable a family of new applications including a planar magnifying hyperlens and optical black hole, will be also discussed.