PROJECT ABSTRACT

Metamaterials are artificially structured materials whose properties derive from structure instead of function of their constituent units and exhibit properties not usually observed in nature, such as negative refraction and electromagnetic cloaking for optical metamaterials and negative Poisson's ratios for mechanical metamaterials. However, conventional metamaterials are limited because they are composed of the same building units (same shape and material) and with the same spacing among neighbors. Multi-scale, multi-material nanomaterials—**proposed hierarchical nanoscale metamaterials**—offer advantages over traditional metamaterials since their collective properties can be manipulated by the interplay of *short*-range and *long*-range interactions as well as *function* of the building units. This proposal aims to design materials with multiple length scales starting at the nanoscale, and combined with modeling, realize entirely new classes of surface metamaterials with exceptional optical, electronic, and quantum properties. This proposal is organized into four main objectives, including: (1) the development of multi-scale and multi-material fabrication tools that can achieve tunable periodicity and controlled disorder; (2) the design of hierarchical optical metasurfaces by the multi-scale fabrication of periodic ordered nanoparticle arrays; (3) the creation of monolithic polymer and 2D electronic metamaterials by controlling disorder in 3D over multiple length scales; and (4) the exploration of quantum atomic meta-lattices by assembling atoms on nanostructured potentials. Anticipated outcomes of multi-scale nanoscale metamaterials that show unprecedented phenomena include multi-color nanoscale lasing and achromatic focusing, strain-induced and structure-tunable electronic modulation, and new states of quantum matter.