Tunable Metamaterials

Dragomir N. Neshev
Nonlinear Physics Centre and Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), Research School of Physics and Engineering, Australian National University, Canberra ACT 0200, Australia
Dragiomir.Neshev@anu.edu.au

Abstract: We review our recent studies on photonic metamaterials infiltrated with liquid crystals and show that their properties can be easily tuned by external optical fields, thus enabling the realization of highly tunable and nonlinear metamaterials.
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1. Introduction

The ability of optical components to change their properties with light intensity is a highly desirable functionality in photonics. However, the use of optical nonlinearity in natural materials is limited by the required ultra-high light intensities. An important way for enhancement of nonlinearity is provided by the field concentration and subwavelength confinement in metamaterials structures, where the field enhancement can influence both their electric and magnetic properties. However, because the thickness of the currently available metamaterials structures is of the order of an optical wavelength or smaller, a sizable overall nonlinear response can only be achieved by a substantial change in the dielectric properties of their sub-components.

2. Liquid crystal infiltrated metamaterials

A notable path for demonstration of such enhanced nonlinearity is provided by embedding the metamaterials with dielectrics exhibiting a giant nonlinear response such as liquid crystals (LCs). In this way the large change of refractive index of the LCs due to molecular re-orientation can counteract the sub-wavelength thickness of the structure. However, the nonlinear optical response of negative index metamaterials is still unexplored. In this contribution we present our recent experimental studies on tunable and nonlinear photonic metamaterials infiltrated with LCs and show that their properties can be tuned by external electric or optical fields. In particular, we show that fishnet metamaterials infiltrated with nematic LCs can exhibit strong nonlinear response at moderate laser powers. We show that this nonlinear response can be fine-tuned with a biasing electric field, opening new opportunities for electrically tunable nonlinear metamaterials.

3. Coupling of magnetic metamaterials with quantum emitters

Furthermore we present some recent results on infiltration of magnetic metamaterials with quantum dots, revealing the enhancement of spontaneous emission of the QDs due to the coupling with the metamaterials and the interplay between its magnetic and electric dipole modes.