Nonlinear processes in plasmonic metamaterials

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Abstract- Experimental studies and numerical modeling of nonlinear optical processes in plasmonic metamaterials based on assemblies of metallic nanorods will be presented. Second- and third-order nonlinear optical response originating from a plasmonic component of the metamaterial will be discussed. Nanorod-based plasmonic metamaterials can be used for engineering strongly enhanced nonlinear optical properties with the required spectral and temporal response.

Metals exhibit strong and fast nonlinearities making metallic, plasmonic, structures very promising for ultrafast all-optical applications at low light intensities [1]. Combining metallic nanostructures in metamaterials provides additional functionalities via prospect of precise engineering of spectral response and dispersion. From this point of view, hyperbolic metamaterials, in particular those based on plasmonic nanorod arrays, provide wealth of exciting possibilities in nonlinear optics offering designed linear and nonlinear properties, polarization control, spontaneous emission control and many others [1-3]. Experiments and modeling have already demonstrated very strong Kerr-nonlinear response and its ultrafast recovery due to the nonlocal nature of the plasmonic mode of the metamaterial [3,4], so that small changes in the permittivity of the metallic component under the excitation modify the nonlocal response that in turn leads to strong changes of the metamaterial transmission.

In this talk, we will discuss experimental studies and numerical modeling of second- and third-order nonlinear optical processes in hyperbolic metamaterials based on metallic nanorods and other plasmonic systems where coupling between the resonances plays important role in defining nonlinear response [5-10]. Second-harmonic generation and ultrafast Kerr-type nonlinearity originating from metallic component of the metamaterial will be considered, including nonlinear magneto-optical effects. Nonlinear optical response of stand-alone as well as integrated metamaterial components will be presented. Some of the examples to be discussed include nonlinear polarization control, nonlinear metamaterial integrated in silicon photonic circuitry and second-harmonic generation, including magneto-optical effects.

Specifically designed plasmonic nanostructures and metamaterials provide a new class of optical media for ultrafast strongly-nonlinear processes, with numerous applications in optical communications, extraordinarily sensitive optical spectroscopies and sub-wavelength imaging technologies with engineered, enhanced nonlinear optical properties with the required spectral and temporal response.

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REFERENCES