Nonlinear Metamaterial and Plasmonic Structures

Yuri S. Kivshar

Nonlinear Physics Centre, Research School of Physics and Engineering,
Australian National University, Canberra ACT 0200, Australia
e-mail: *ysk124@rsphyse.anu.edu.au*

Theory of nonlinear metamaterials [1] predicted that the hysteresis-type dependence of magnetic permeability on the field intensity may allow dramatic changes of the material properties. As the first step towards creating tunable nonlinear metamaterials we studied dynamic tunability of the magnetic resonance of a single nonlinear split-ring resonator [2] and revealed different tuning regimes of metamaterial. At higher powers the nonlinear response of the split-ring resonator becomes multi-valued, indicating that the memory effect can be potentially observed in nonlinear metamaterials. Recently, we fabricated the first tunable nonlinear magnetic [3] and nonlinear electric [4] metamaterials by placing varactors in each of the split-ring resonators or each of the electric resonators of the structure. We measured a very pronounced shift of the resonance, and observed a change of the transmission through the nonlinear metamaterial with split-ring resonators for different power levels [3]. We observe experimentally the intensity-suppressed and intensity-induced transparency, when the frequency of the incoming wave is at the left edge of the resonance. The achieved nonlinear suppression of the beam transmission is 20 dB for magnetic metamaterial [3], and almost 50dB for electric metamaterial [4].

Left-handed materials at optical frequencies are closely related to plasmonics. We aim to study the fundamental nonlinear effects in plasmonics [5] and, as the first step, we found the families of guided modes of a nonlinear slot waveguide and revealed that the symmetric mode undergoes the symmetry breaking and becomes primarily localized near one of the interfaces. We discuss self-focusing of a plasmon beam at large powers and soliton formation even in the presence of losses. In addition, we analyze phase matching in planar metal-dielectric nonlinear waveguides supporting highly localized plasmon polariton modes and reveal that quadratic phase matching between the plasmon modes of different spatial symmetries becomes possible in the planar waveguide geometry.

References

[1] A.A. Zharov, I.V. Shadrivov, and Yu.S. Kivshar, Phys. Rev. Lett. **91**, 037401 (2003).
[2] D. Powell, I. Shadrivov, Yu. Kivshar, and M. Gorkunov, Appl. Phys. Lett. **91,** 144107 (2007).
[3] I. Shadrivov, A.Kozyrev, D.van der Weide, Yu.Kivshar, Appl. Phys. Lett. **93**, 161903 (2008).
[4] D. Powell, I. Shadrivov, and Yu. Kivshar, Appl. Phys. Lett. **95,** 084102 (2009).
[5] A.R. Davoyan, I.V. Shadrivov, and Yu.S. Kivshar, Opt. Express **16**, 21209 (2008).