Highlights

Other Materials - 2016

Enhanced nonlinear effects in pulse propagation through epsilon-near-zero media

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In recent years, unconventional metamaterial properties have triggered a revolution of electromagnetic research which has unveiled novel scenarios of wave-matter interaction. A very small dielectric permittivity is a leading example of such unusual features, since it produces an exotic static-like regime where the electromagnetic field is spatially slowly-varying over a physically large region. The so-called epsilon-near-zero (ENZ) metamaterials thus offer an ideal platform where to manipulate the inner details of the "stretched" field. Here we theoretically prove that a standard nonlinearity is able to operate such a manipulation to the point that even a thin slab produces a dramatic nonlinear pulse transformation, if the dielectric permittivity is very small within the field bandwidth. The predicted non-resonant releasing of full nonlinear coupling produced by the epsilon-near-zero condition does not resort to any field enhancement mechanism and opens novel routes to exploiting matter nonlinearity for steering the radiation by means of ultra-compact structures.

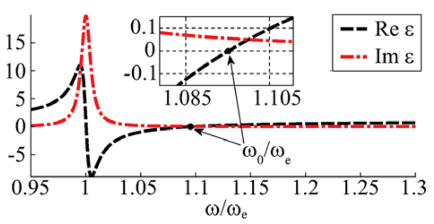

Figure 1. In the linear regime the slab has a dielectric permittivity ε(ω) with a standard Lorentz profile located at the resonant frequency ω_e and with a zero-crossing-point of its real part at ω_0. Dispersion parameters have been chosen in such a way that the imaginary part of the permittivity is low around zero-crossing-point so that $|\varepsilon(\omega)|$ is much smaller than one in a spectral bandwidth around ω_0 and the slab can support the ENZ regime.

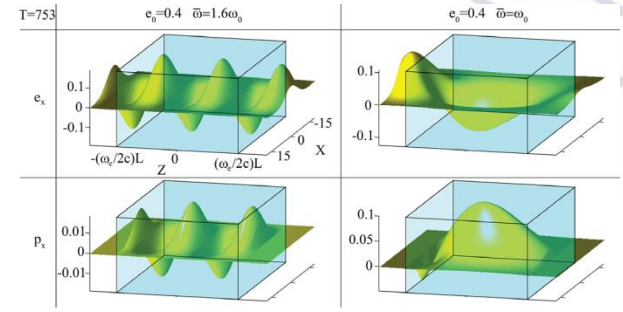

Figure 2. Mechanism supporting the full potential of the nonlinear wave-matter interaction in the ENZ regime. Spatial profiles of the dimensionless electric e_x and polarization p_x fields at the normalized time T = 753 of two pulses propagating within the slab of thickness L with normalized amplitude e_0 = 0.4 and central frequencies $1.6\omega_0$ (outside of the ENZ regime) ω_0 (in the ENZ regime). In the first case the electric field e_x is "large" only at the regions around the peaks of the wave and the time drift of such regions does not allow the polarization p_x to increase and to trigger the nonlinear wave-matter coupling. In the second case, in a physically large volume, the spatially slowly varying character of e_x yields the onset of the nonlinear regime.