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Title:Quantitative study of the enhancement of bulk nonlinearities in metamaterials

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Abstract:Artificially structured metamaterials offer a means to enhance the weak optical nonlinearities of natural materials. The enhancement results from the inhomogeneous nature of the metamaterial unit cell, over which the local field distribution can likewise be strongly inhomogeneous, with highly localized and concentrated field regions. We investigate the nonlinear enhancement effect in metamaterials through a numerical study of four nonlinear metamaterial designs comprising arrays of metallic structures embedded in nonlinear dielectrics and operating around 10 THz. Through full-wave simulations and by employing an extended version of the transfer-matrix-based nonlinear parameter retrieval method, we confirm and quantify the enhanced nonlinearities, showing bulk quadratic nonlinear properties that are up to two orders of magnitude larger, and cubic nonlinear properties that are up to four orders of magnitude larger than the bulk nonlinear dielectric alone. Furthermore, the proposed nonlinear metamaterials support a variety of configurable nonlinear properties and regimes, including electric, magnetic, broadband, and low loss, depending on the particular geometry chosen. Finally, we use the retrieved parameters in a coupled-mode theory to predict the optimal crystal lengths and conversion efficiencies of these structures, displaying the possibility of efficient and subwavelength nonlinear devices based on metamaterials.

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