Conditions for Electric Field Enhancement in ε-near-zero Slabs under TM-Polarized Oblique Incidence

Salvatore Campione* [(1)], Domenico de Ceglia[(2)], Maria A. Vincenti[(2)], Michael Scalora[(3)] and Filippo Capolino[(1)]

(1) Department of Electrical Engineering and Computer Science, University of California, Irvine, CA, 92697, USA, http://capolino.eng.uci.edu/
(2) Aegis Technologies Inc., 410 Jan Davis Dr., Huntsville, AL, 35806, USA
(3) US Army Charles M. Bowden Research Center, RDECOM, Redstone Arsenal, Huntsville, AL, 35898, USA

Artificial composite materials have been proven to be viable candidates to increase the degrees of freedom in the interaction of electromagnetic (EM) fields with matter. Composite materials (MTMs) add very interesting possibilities to control EM waves from microwaves to optical frequencies. As a subset of MTMs, artificial composite materials that exhibit ε-near-zero (ENZ) properties have attracted a great deal of attention in view of their potential applications, including tunneling of electromagnetic energy, highly directional beaming, cloaking devices, boosting of optical nonlinearities and low-threshold nonlinear effects.

Although the linear properties of ENZ slabs of finite thickness under oblique incidence have been previously investigated by varying thickness and permittivity values, currently there is a need to better understand the origin of strong field enhancement effects occurring when the ENZ slab has subwavelength thickness, i.e., far from any Fabry-Pérot resonance of the ENZ etalon. In this paper we provide a comprehensive analysis of transmission, reflection and absorption coefficients, and local field enhancement as a function of the ENZ permittivity and incident angle. In particular, we analyze angular and spectral features for three distinct physical conditions that can result into large field enhancement inside the slab and thus improve the efficiency of applications where large fields are required. We will analyze MTM slabs composed of plasmonic nanoshells that exhibit an effective ENZ band in the visible range (with and without a damping-compensation mechanism).

We demonstrate that without damping-compensation the MTM slab may induce a field enhancement for wide angular and frequency bands. Instead, when material losses are partly compensated we observe a much stronger field enhancement for very narrow angular and frequency bands. These results may be exploited to develop exotic and extreme nonlinear optical phenomena, such as optical multistability and switching, and devices for the generation of coherent light sources in the UV and extreme-UV.