

Near-Zero-Index Materials for Time-Varying Media

Vladimir M. Shalaev

Purdue University

Summary

Very few scientific fields have become as pervasive in basic research and everyday life as nonlinear optics which ushered in tremendous achievements in areas like attosecond physics, ultra-broadband optical communication, and high-resolution sensing. The utility of nonlinear optics has therefore been a compelling motivator to increase generally weak light-matter interactions. In this pursuit, novel materials have been explored including materials where in a particular spectral region the real part of the permittivity (ϵ)-epsilon is near zero (ENZ) and materials whose losses in that spectral region are also low leading to a near-zero index (NZI). ENZs and NZIs increase light-matter interactions via the enhanced fields at the interface between the ‘normal’ and ENZ materials, the “slow-light” effects and relaxed phase matching conditions. One important class of novel ENZ/NZI materials is transparent conducting oxides (TCOs) whose lowlosses and high-tunability have made them a leader in NZI-enhanced nonlinear optics like Kerr nonlinearities^{1,2} and frequency generation. More recently, transparent conducting oxides have pioneered ultrafast optically-modulated nonlinear optics opening the door to exotic time-varying media phenomena such as negative refraction, time refraction³, time reflection, and photonic time crystals⁴⁻⁵.

(1) Alam, M. Z.; et al., *Science (1979)* **2016**, 352 (6287), 795–797.

(2) Caspani, L., et al., *Phys Rev Lett* **2016**, 116 (23), 233901.

(3) Shaltout, A. M., et al., In *Optics InfoBase Conference Papers*; 2016. doi:10.1364/CLEO_QELS.2016.FF2D.6

(4) Lyubarov, M., et al., *Science (1979)* **2021**, 428 (July), 425–428.

(5) Saha, S. et al., *Opt. Express* v. 31 (2023), pp.8267-8273