

Epsilon-near-zero Optics in Planar and Optical Fiber Platform

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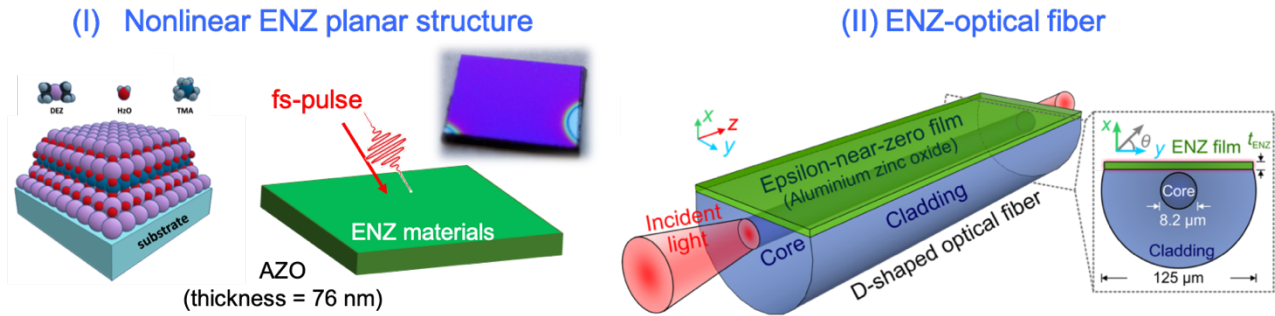
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The optical response of epsilon-near-zero (ENZ) materials has been a topic of significant interest in the last few years as the electromagnetic field inside media with near-zero permittivity has been shown to exhibit unique optical properties, including strong electromagnetic wave confinement, non-reciprocal magneto-optical effects, and abnormal nonlinearity.

This talk will review our recent development on a conducting oxide epsilon-near-zero nano-optics on planar and optical fiber platforms [1-5]. I will present a method to engineer the nonlinear refraction coefficients and the nonlinear absorption coefficients of Al-doped zinc oxide (AZO) ENZ thin films synthesized by atomic layer deposition (ALD) technique. Our results suggest that ENZ nonlinear refraction and nonlinear absorption properties of AZO films are enhanced by excitation of the ENZ modes and can be engineered by changing the mode-strengths via control over either the excitation angles or by ALD engineering of material dispersion/ film thickness. Measured values as large $n_2^{(eff)} \sim 10^{-9}$ mm²/W and $\beta_2^{(eff)} \sim 10^{-5}$ mm/W are obtained along with approximately an order of magnitude tunability.



In addition, I will also discuss the first experimental demonstration of optically confined ENZ resonance excitation in a side-polished optical fiber waveguide uniformly coated with AZO nanolayer. We observed a transmission resonance dip in the ENZ regime with on and off resonance difference of ~ 20 dB in an ENZ-optical fiber with a 30 nm-thick AZO layer, which is attributed to the coupling between the fundamental mode of the optical fiber and ENZ mode supported by the ultrathin AZO film. The ENZ-optical fiber provides a unique excitation platform of hybrid ENZ resonance with relatively long light-interaction length and eases the complexity of optical configuration without required sophisticated prism/grating coupling, which has potential applications in nonlinear and quantum zero index photonics, in-fiber optical sensing, lasers, and dispersion control.

Reference:

- (1) A. Anopchenko, *et al.* "Atomic Layer Deposition of Ultra-thin and smooth Al-doped ZnO for Zero-Index Photonics", *Materials Research Express*, **5**, 014012 (2018).
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- (5) J. Yang, K. Minn, A. Anopchenko, S. Gurung, H. W. Lee, "Coupling to Epsilon-near-Zero Mode on Ultrathin Atomic Layer Deposited Conducting Oxide Film in Optical Fiber", submitted (2019).