Seminar for Postgraduates (Experimental- and Solid State Physics)

Interactions of Vector Beams in Structured Epsilon-Near-Zero Media

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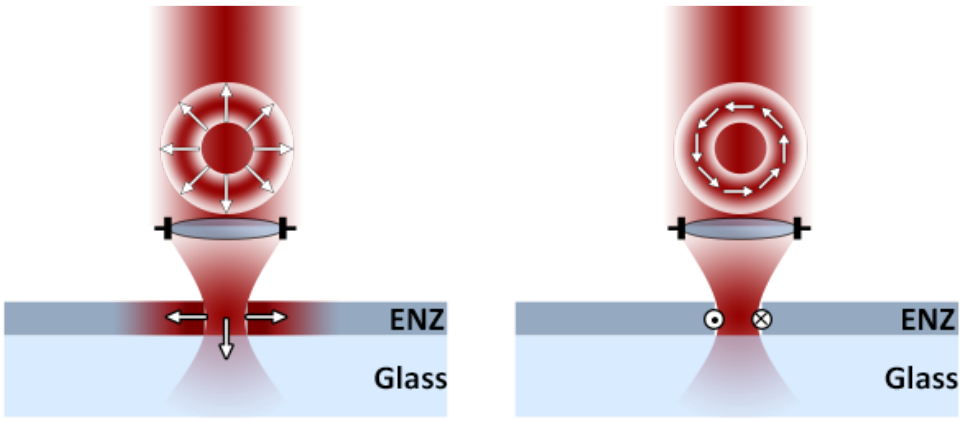

Epsilon-near-zero (ENZ) materials have been shown to host exotic nonlinear optical effects which enable broadband optical responses[1], require smaller interaction lengths[2], and disobey conventional approaches to modeling nonlinear optical properties[3]. In this work, we investigate the interactions between tightly focused vector beams and structured ENZ materials. Depending on the combination between the polarization of the incident field and the geometry of the ENZ environment, strong field enhancements can be produced that are unique to the ENZ regime. In order to first achieve a linear characterization of our system, a simple hole geometry is considered for the structured ENZ medium. Each individual hole is then probed with tightly focused vector beams. The transmission properties of these holes are measured via power-based scanning methods and are compared to finite-difference-time-domain simulations. As opposed to the expected transmission properties of such holes in metallic films[4], the ENZ regime suppresses the transmission of the holes where it's traditionally found to be a maximum. This indeed indicates that a legitimate response from the ENZ regime can be observed depending on the polarization distribution of the incident field and the structure of the ENZ medium. Under appropriate configurations, this can be exploited to achieve nonlinear optical responses without the traditionally high incident intensities and large length scales.

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[1] Alam, M. Z., Schulz, S. A., Upham, J., De Leon, I., & Boyd, R. W. (2018). Large optical nonlinearity of nanoantennas coupled to an epsilon-near-zero material. *Nature Photonics*, *12*(2), 79-83.

[2] Reshef, O., De Leon, I., Alam, M. Z., & Boyd, R. W. (2019). Nonlinear optical effects in epsilon-near-zero media. *Nature Reviews Materials*, *4*(8), 535-551.

[3] Reshef, O., Giese, E., Alam, M. Z., De Leon, I., Upham, J., & Boyd, R. W. (2017). Beyond the perturbative description of the nonlinear optical response of low-index materials. *Optics Letters*, *42*(16), 3225-3228.

[4] Kindler, J., Banzer, P., Quabis, S., Peschel, U., & Leuchs, G. (2007). Waveguide properties of single subwavelength holes demonstrated with radially and azimuthally polarized light. *Applied Physics B*, *89*(4), 517-520.