

# Vector-Beam Nonlocal Metasurfaces Controlling Local Geometric Phase

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Recent advancements have enabled nonlocal metasurfaces (MSs) to manipulate wavefronts spatially and spectrally [A.C. Overvig and A. Alù, “Diffractive Nonlocal Metasurfaces,” *Laser Photonics Rev.*, vol. 16, 2100633, Jul. 2022]. The bilayer configuration of such nonlocal MSs provides control over quality-factor and geometric phase for arbitrary polarizations [A. Overvig, Y. Kasahara, G. Xu, and A. Alù, “Demonstration of a polarization-agnostic geometric phase in nonlocal metasurfaces,” *arXiv*, Feb. 25, 2023], enabling local geometric phase manipulation for any polarization state, including linear and elliptical polarization. Such flexibility offers the possibility of controlling the geometric phase for vector beams, optical beams characterized by spatially varying polarization states across their cross-section. The generation of vortex vector beams has been demonstrated using local MSs [Y. Bao, J. Ni, C. Qiu, “A Minimalist Single-Layer Metasurface for Arbitrary and Full Control of Vector Vortex Beams,” *Adv. Mater.*, vol. 32, no. 6, 1905659], which, however, lack spectral shaping capabilities, notable feature of the nonlocal MSs.

In this work, we demonstrate nonlocal MSs resonating exclusively for a custom vector beam from a designated angle. We designed a nonlocal MS for a vector beam [Fig. 1(a)] defined by:

$$\vec{E}_{\text{in}} = e^{-i\Phi_{\text{HOPS}}} \frac{1}{2} \begin{pmatrix} 1 \\ i \end{pmatrix} e^{i(k_0 \sin \theta_{\text{in}} - 2k_G)x} + e^{i\Phi_{\text{HOPS}}} \frac{1}{2} \begin{pmatrix} 1 \\ -i \end{pmatrix} e^{i(k_0 \sin \theta_{\text{in}} + 2k_G)x},$$

where  $\Phi_{\text{HOPS}}$  represents the longitude on the higher-order Poincaré sphere (HOPS) [G. Milione, H. Sztul, D. Nolan, and R. Alfano, “Higher-order Poincaré sphere, Stokes parameters, and the angular momentum of light,” *Phys. Rev. Lett.*, vol. 107, 053601, Jul. 2011] and  $k_G$  is the encoded momentum in the phase-gradient nonlocal MS, which assigns the selected angle. These beams possess linear polarization rotating as a function of spatial position  $x$ . Our MS resonates for this rotating linear polarization while imparting different reflection phases in space. The designed nonlocal MS [Fig. 1(a)] exhibits shifted dispersion in momentum space, a hallmark of phase-gradient nonlocal MS. Angle-resolved transmission spectra [Fig. 1(b)] from full-wave simulations confirm this dispersion shift. Additionally, we fabricated this MS, demonstrating anomalous reflection. Updated experimental results will be presented during our talk.

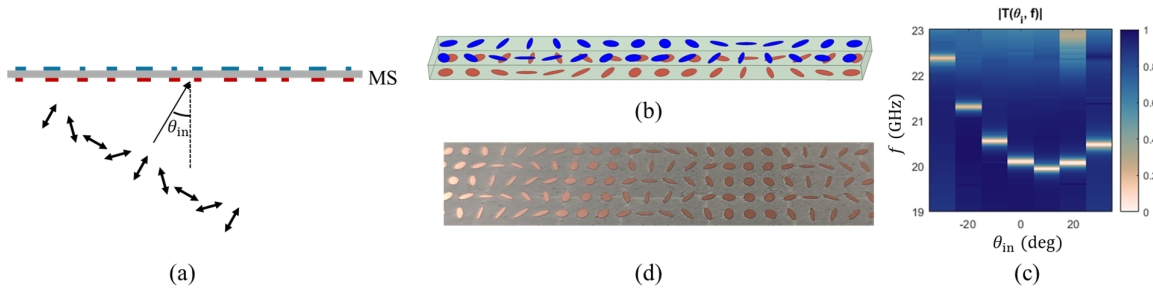


Figure 1. (a) Schematic of the vector beam. (b) Supercell of the vector beam nonlocal MS with a linear phase gradient. (c) Simulated angle-resolved transmission spectra showing momentum-shifted dispersion. (d) Photograph of the fabricated sample.