

# Experimental Validation of Dispersion-Engineered Nonlocal Metasurfaces: Tunable Wavefront Selectivity

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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]. These MSs offer tailorable selectivity to frequency and transverse-momentum. While frequency selectivity through symmetry-breaking perturbations is well-established, tailoring transverse-momentum selectivity remains underexplored. This capability enables transitions between wavefront-selective and wavefront-insensitive devices, further enhancing nonlocal MSs with already rich properties: quality-factor and geometric-phase control 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].

We experimentally demonstrate tunable wavefront selectivity using a bilayer nonlocal MS unit cell with metallic walls [Fig. 1(a)]. Building on prior simulations [Y. Kasahara, A. Overvig, G. Xu, and A. Alù, “Dispersion Engineered Nonlocal Metasurfaces with Customizable Wavefront-Selectivity,” in *Proc. IEEE Antennas Propag. Soc. Int. Symp.*, Portland, OR, USA, Jul. 2023], which showed dispersion engineering from positive to negative curvature and flatband regimes, we validate this experimentally. Metallic walls interfere with energy localization in nonlocal resonant modes, thereby controlling the band curvature of the dispersion relation. Two devices were fabricated and measured: one with flatband dispersion [Fig. 1(b)] and the other with negative-curvature dispersion [Fig. 1(c)]. We also design and fabricate two metalenses: one using positive-curvature dispersion (wavefront-selective) and the other with flatband dispersion (wavefront-insensitive). Reflected field measurements show the flatband metalens focuses regardless of the incident wavefront [Fig. 1(d)], while the positive-curvature metalens focuses efficiently only for specific wavefronts, not for plane-wave illumination [Fig. 1(e)]. These results confirm that dispersion-engineered MSs enable precise wavefront selectivity, advancing their functionality with quality-factor and geometric-phase control for arbitrary polarizations.

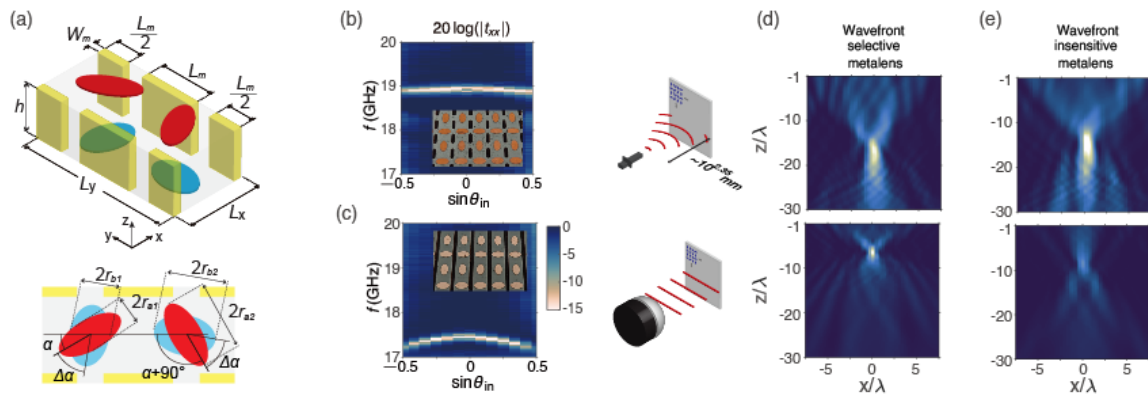


Figure 1. (a) Unit cell of the dispersion-engineered MSs. Angle-resolved transmission spectrum of (b) the flatband dispersion device and (c) the negative-curvature dispersion device. Measured reflected field from (d) the wavefront-insensitive metalens and (e) the wavefront-selective metalens.