Visual Field Redirection for Central Vision Loss: Passive Metasurface Design and Computational PRL Prescription

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Central vision loss affects over 200 million worldwide, arising from macular diseases that result in central scotomas while peripheral vision remains largely intact. Current compensatory approaches, primarily eccentric viewing, require unnatural off-axis gaze and intensive behavioral adaptation, leaving a critical gap for viable solutions that conventional optical devices cannot fill. This work presents a passive metasurface engineered to perform a rigid angular transformation of the visual field, steering central visual input toward healthier peripheral retinal regions. Using adjoint-based topology optimization via finite-difference time-domain simulation, unit cells are designed to optimize directional transmission toward prescribed target angles. Multiple design strategies are evaluated for steering robustness and generalization beyond trained directions, including a scalable multi-zone framework derived from pupil-intercept geometry for full-aperture coverage. Simulations demonstrate consistent angle-dependent beam steering aligned with the target transformation, supporting feasibility of passive metasurface-based eyewear as a power-free solution that mimics eccentric viewing under natural forward gaze. Novea, a web application developed in this work, provides the first quantitative, retinal damage map-based PRL prescription framework, jointly optimizing retinal health, acuity falloff, and task-specific visual demand. Combining a digital Amsler grid diagnostic tool and a quantitative PRL optimizer, Novea delivers a complete diagnosis-to-prescription workflow applicable to both metasurface specification and eccentric viewing guidance. Novea has been clinician-reviewed and is ready for early clinical validation; no equivalent system exists in current practice.

Awards Won:

Fourth Award of $600