Think, Generate, Optimize: Presenting a Novel Fully AI-Driven Design Framework for Metasurface Lenses

Rameshkumar, Dhanvine (School: Temasek Junior College)

The design of flat metasurfaces is crucial for innovations in LiDAR, AR and optical imaging. Recent advances in flat metasurface optics have enabled precise light manipulation, overcoming traditional limitations in size and efficiency of curved optical lenses. However, traditional design methods rely on computationally expensive and time-consuming Electromagnetic (EM) Simulations, hindering rapid development and innovation. This project proposes a fully AI-based framework that addresses these limitations, consisting of 2 integrated frameworks; an Inverse Design Framework and the Forward Modelling Framework. The inverse design framework uses a novel Wasserstein Conditional GAN enhanced with Feature-wise Linear Modulation (FiLM) for generating freeform metasurface unitcell designs based on spectral response conditions, and this is complemented with the Forward Modelling framework that uses deep learning to predict spectral responses of the generated flat metasurface designs. By replacing resource-intensive and time-consuming EM simulations and traditional design process, this approach accelerates the prototyping process, enabling faster design iterations to generate hundreds of optimized designs in minutes, compared to traditional EM simulations that take hours for similar task. It also facilitates the exploration of metasurface design spaces under given conditions with its generative capabilities, allowing for the realization of achromatic and wide field-of-view metalenses across various wavelength spectra. This is further improved by the generated freeform unitcells, which enable near-continuous phase control, providing flexibility. Overall, this approach paves the way for more efficient, scalable, and cutting-edge solutions in photonics and optical engineering.

Awards Won: