Heuristic Optimal Design of Diffractive Waveguide for AR Display with Metasurface

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Augmented reality (AR) is the next-generation technology that supplements information about objects based on the real world. AR enhances the real world by providing additional information. When applied to a head-up display (HUD) in vehicles, AR can offer convenience and safety to drivers. For this purpose, AR-HUD utilizing optical diffractive components within a waveguide must be able to deliver high-quality information to the driver [1]. Many of the currently researched AR-HUD utilize a waveguide based on exit pupil expansion (EPE). Additionally, most EPE-based waveguides incorporate diffractive optical elements (DOE) on their surfaces. However, EPE-based waveguides using these DOE exhibit several inherent issues and drawbacks.

Firstly, regarding non-square input, such as a liquid crystal on silicon spatial light modulators (LCoS SLMs) commonly found in many commercial products, they often have shapes that aren't perfectly square. Consequently, as observed in Fig. 1(a), when collimated light is incident on the EPE-based waveguide, seams are present in the output. In this study, as depicted in Fig. 1(b), we demonstrate achieving a seamless output by altering the structure of the waveguide. Furthermore, employing the Fourier modal method (FMM) based electromagnetic analysis tool, we analyze the diffraction efficiency of the DOE based on its fill factor. Adjusting the fill factor for different replicated regions of the input optimizes uniformity in the output.

When formalizing the diffraction, reflection, and transmission components at the expander and out-coupler, there are difficulties in optimizing uniformity in the output. Heuristic optimization is employed to address complex aspects that are not adequately considered through mathematical equations or limited information. Utilizing heuristic optimization, as shown in Fig. 1(c), ensures that replicated points in the output achieve uniformity of 75% or higher. As depicted in Fig. 1(d), imaging at long distances through computer-generated hologram (CGH) can also be observed.

Additionally, to overcome the efficiency limitations arising from using a binary DOE and to design a single waveguide that fulfills RGB full color requirements, we employed FMM-based adjoint inverse design to create the metasurface. Fig, 1(e) depicts the optimized metasurface designed through adjoint inverse design, diffracting all three RGB wavelengths at the same angle.

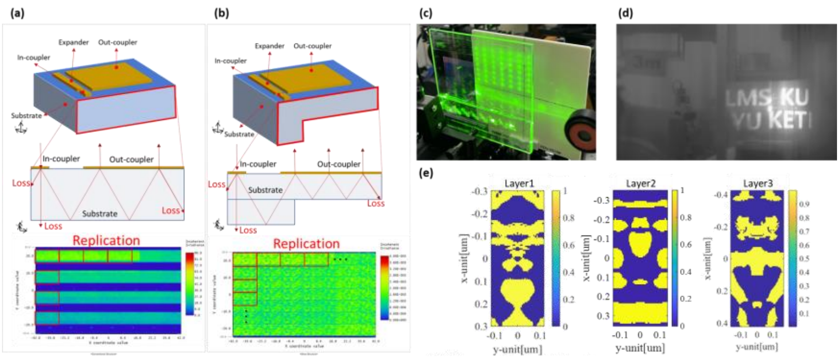

Fig. 1 (a) Conventional waveguided and output result. (b) alternated waveguide with seamless output result. (c) experimental setup for optimized uniformity measurement. (d) result of CGH imaging experiment. (e) three of metasurfaces optimized using FMM-based adjoint inverse design.

References

[1] Waldern, J.D., Grant, A.J. and Popovich, M.M. (2020), 5-4: Invited Paper: Current Challenges in Augmented-Reality Waveguide Display Technology. SID Symposium Digest of Technical Papers.