T-Glasses: Light-Weight High Efficient Augmented Reality Smart Glasses

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Keywords: Augmented reality, smart glasses, pin mirror

ABSTRACT
LetinAR's T-Glasses are optical see-through augmented reality glasses that use PinMR (pin mirror) and PinTILT (pin mirror total internal reflection minimized lightguide technology) method. With those advanced technologies, lightweight and glasses-like form factor can be achieved with plastic injection molded waveguide.

1 Introduction

For AR (augmented reality) and MR (mixed reality) technology's popularization, there are still many hurdles to overcome, including visual performance, wearability, and design for social acceptance [1]. To achieve these goals, development of thin and lightweight optical combiners is the key that can enable features in glasses such as a design which shows natural appearance and provides wearable comfort.

There are several methods for optically combine the real and virtual world. We would like to introduce some of the representative optical combiner method. First, bird-bath architecture is a well-kwon AR optical see-through architecture which is composed of half mirror and concave mirror for collimating the display [2]. It shows decent image quality since it is basically a simple magnifier composed of on-axis optical systems, but it requires bulkier optical dimension in order to increase the field-of-view (FOV) because the size of the display is directly correlated to the size of the field of view. For this reason, bird-bath type optic combiners require much thicker lens compared to the that of normal pair of glasses resulting in limitation of design freedom.

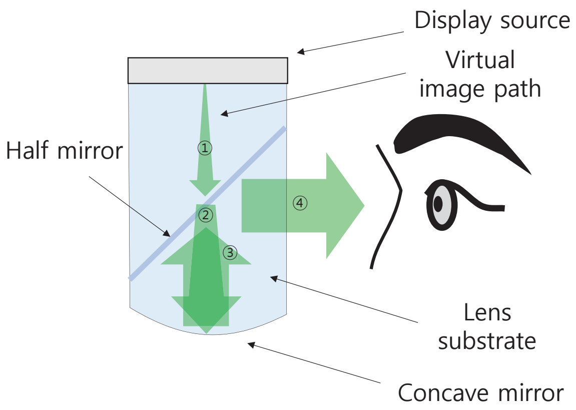

Fig. 1 Schematic diagram of bird-bath optics

Waveguide combiners using diffractive optical element (DOE) or holographic optical element (HOE) can have large eye box overcoming the etendue of simple magnifier optics using an exit-pupil-expansion (EPE) or exit-pupil-replication technique. Also, optical folding within the waveguide using total internal reflection (TIR) makes the thickness of the combiner very thin. Most of the commercially available DOE based optic combiners have thickness of single waveguide less than 0.5 mm. However, DOE waveguide requires high optical surface qualities to maintain the image quality which restrict the choice of material to the glasses wafer. Because glasses with higher refractive indices have higher material density compared to the optical plastics, waveguide combiners made of glasses have some disadvantages in weight in see-through optical module assembly.

In this paper, we present an innovative optical combiner made of injection molded plastic substrate. The presented combiner technology developed by LetinAR enables the development of new types of binocular augmented reality glasses so called T-Glasses. T-Glasses use two micro-OLED (organic light-emitting diode) displays directly in-coupled on top of the waveguides for each eye, providing 22 degrees of diagonal FOV with 640 × 400 of spatial resolution. They show the minimized form factor of binocular AR optics like regular pair of glasses as shown in Fig. 2.

Fig. 2 Picture of T-Glasses

2 LetinAR's waveguide technology

2.1 PinMR and PinTILT

LetinAR's PinMR combiner is an optical combiner method composed of an array of full mirrors. Each pin mirror in the array is smaller in size than a human pupil, so the real-world scene is imaged through the portion of the pupil unblocked by pin mirrors. Figure 3 illustrates the see-through principle of a single PinMR element. The pin mirror reflects the virtual image, but the mirror only blocks the central portion of the crystalline lens of the eye so that the real object can be imaged with the outer portion of the crystalline lens of the eye.

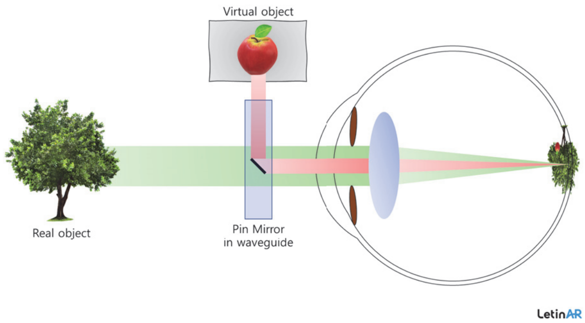

Fig. 3 Principle of Pin MR optical see-through combiner

LetinAR also developed a unique waveguide architecture called PinTILT whose TIR bounce is minimized to allow more optical tolerance for efficient manufacturing of optical plastic waveguides with injection molding method. Injection molding is a commonly applied mass lens manufacturing method for smart phone camera or other small optical devices. Plastic optical combiners are more mass-market oriented and have the possibility of lowering the product price during the consumer market's early stage.

Figure 4 shows the optical path of the PinTILT architecture. As shown in the figure, TIR occurs only two times at the front surface of the lens substrate. It also gives another benefit of PinTILT architecture that the rear surface (eye side) can be used for prescription integration.

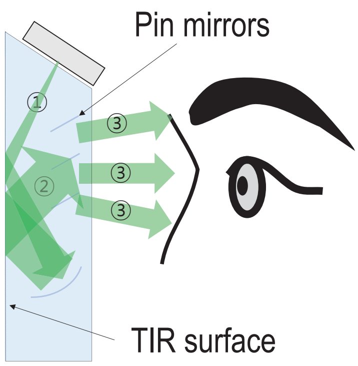

Fig. 4 Optical path of the virtual image of PinMR and PinTILT optical architecture

2.2 Comparison with the conventional birdbath architecture

Figure 5 compares the PinTILT and the birdbath architectures. Both have similar optical paths that start from the top-mounted displays and then are reflected up to the combiner mirrors by the bottom concave mirror collimator. The combiner mirrors outcouple the image to the viewers. However, the PinTILT design can reduce the thickness of the lens substrate by using TIR. In the PinTILT waveguide, 1D vertical pupil expansion is applied by segmenting the entrance pupil to ensure each portion of the entrance pupil corresponds to each row of pin mirrors. This correspondence enables the adjustment of virtual image distance other than infinity for mitigating VACs by tilting each row of pin mirrors (PinTILT) according to the designed virtual image distance. Because of the pupil-expansion method, it can provide a rich and immersive visual experience with a wide eyebox and large FOV.

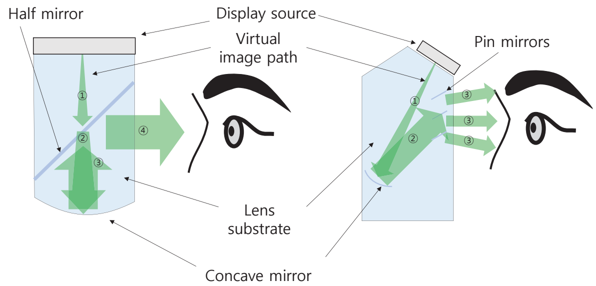

Fig. 5 Comparison of PinMR/PinTILT and bird-bath optical combiner architecture

3 Conclusions

We have described the optical architecture of LetinAR's small form factor waveguide technology. PinMR and PinTILT technologies allows wider optical tolerance for adoption of mass-manufacturing oriented development of optical combiners. It is also suitable for the realization of a compact and high-performance waveguide structure, and it enables the development of a lightweight and glasses-like small form factor AR glasses based on optical plastic lenses. We believe that PinMR and PinTILT method is one of the best candidates that will open the new epoch of the metaverse.

References

[1] Kress, B. (2020). Optical architectures for augmented-, virtual-, and mixed-reality headsets. SPIE Press, Bellingham, WA

[2] Nreal. (2020). Nreal – building mixed reality for everyone. https://www.nreal.ai/

[3] Soon-gi, P. (2021). Augmented and Mixed Reality Optical See-Through Combiners Based on Plastic Optics. Information display July/August 2021