Analysis of Optical System Combined with Expander and Output Grating for Improving Field of View of Augmented Reality Device

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1. Introduction

Augmented reality (AR) is the significant technology of head-mounted-display (HMD) which is one of the next-generation displays, and has received great attention in recent years.[1] AR displays have been studied for a long time with folded freeform optics in optical design. Recently, diffraction optics based flat plate integrated optics technology has been introduced to dramatically reduce the form factor of optical systems.

The diffractive optical element(DOE) based AR display system consists of combiners with three different gratings in three areas. The three areas are composed of input, expander, and output grating structures, and the user can observe the AR image through the specific functions generated by the three grating structures. In such an optical system, the field of view (FOV) is greatly influenced by the incidence angle of the input grating structure. When the angle of the incidence bundle rays increase, the angle of the output bundle rays from the output grating structure increase and the FOV also increases. However, when the angle of the incidence bundle rays increase, the area of the expander grating structure widens accordingly. As a result, the size of the combiner is increased, it significantly decreases the characteristics of the head mounted display (HMD).

In this paper, we have suggested an optical system that combines an expander grating and an output grating as part of a study on improving FOV of AR display.

2. General Instructions

Based on geometric optics, we have modeled the newly proposed optical system. The physical values of the model were analyzed using Fourier modal method (FMM) which is for investigating the electromagnetic characteristics of the multiplication structures of the expander and output grating structure, respectively.

Fig.1(a) shows the geometric model of the optical system that combines the expander and the output grating structure described previously. Fig.1(b) shows a simulation of one ray tracing in the model in Fig.1(a). It can be seen that the vertically incidence ray passes through the input grating structure. Next, the replicating and the output of the rays occur simultaneously in the region where the expander and the output grating structure are combined, respectively.

As a result, the output light beams pass at the same angle as the incidence light beams. Fig.1(c) shows the light distribution of the output beams. Since the diffraction efficiencies in all regions are the same, the intensity of light is decreasing as the distance from the input grating structure increases. We need to optimize this phenomenon to produce even light intensity. Fig.1(d) shows the result of simulation of proposed structure based on geometric optics. In Fig.1(d), the target image is entirely observed.

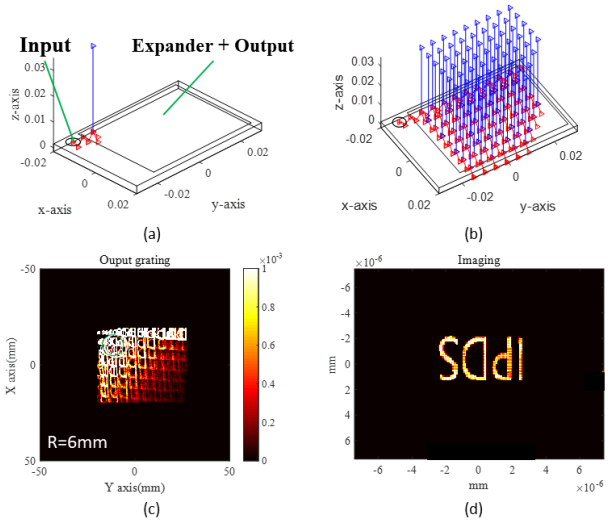

Fig 1. (a) Geometric model of optical system combined with expansion and output grating structures (b) Ray tracing simulation (c) Light distribution of output beam (d) Result of imaging simulation

3. Conclusions

In this paper, we propose an optical system that combines the expander and output grating to improve FOV and reduce the form-factor of AR display. And, it has been verified by the simulation based on geometric optics and electromagnetic field analysis. The ultimate goal of this study are to propose the design conditions for an ideal AR display optical system and to implement the DOE that could be applied to RGB full color.

References

[1] JY Hong, CK Lee, S Lee, B Lee, D Yoo, C Jang, J Kim, J Jeong, B Lee. "See-through optical combiner for augmented reality head-mounted display: index-matched anisotropic crystal lens." *Scientific Reports 7 (1), 2753* (2017)