Numerical Analysis for Diffractive Augmented Reality with Depth using a Metalens

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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 on flat plate integrated optics technology has been introduced to reduce the form factor of optical systems dramatically.

In this paper, we discuss about the depth perception among various optical issues in diffractive AR. Currently, diffractive AR devices display only the image without depth as virtual image. This allows the virtual image to float to the same location no matter where the user is focusing on the eye. Because of this reason, the accommodation effect does not occur to the user and causes cyber headache symptoms to user.

As a result, we proposed a method to display a virtual image with a depth perception in AR device using a metalens.

2. Numerical Simulation and Results

We designed the diffractive optical system for AR based on geometric optics. Figure 1 shows the ray tracing simulation of the diffractive AR combining system. When a light passes through the input grating structure, the diffraction is occurred on the direction of the expanded grating structure. After then, the next diffraction is occurred on the direction of the output grating structure by the expanded grating structure, and it is replicated at the same time. The replicated light continues to diffract and replicate continuously by the expansion grating structure, and the incident light on the output grating structure is output in a parallel direction to the input light. Through the process, we can duplicate one light to multitude of lights, which is forming a wide field of view.

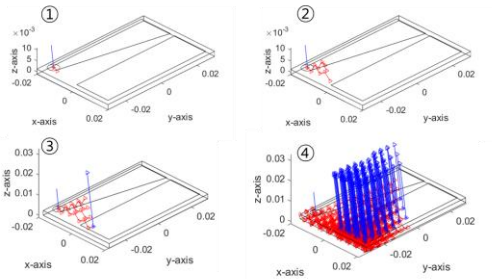

Fig. 1. Ray tracing of geometrical optical model

Such an optical system makes a virtual image as a two-dimensional image. This two-dimensional image means that the depth is not fixed but infinite. The reason of that the depth is infinite, is the same as the principle of a pinhole camera. This phenomenon occurs because all of the input light is output in a parallel direction. So that, we have to give some numerical function to adjust the depth on the output grating. Therefore, in this paper, we suggest a method of depth imaging algorithms using the convergence or divergence characteristics of the metalens.

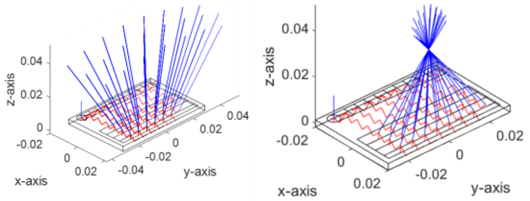

Fig. 2. Ray tracing of geometrical optical model using a metalens

Figure 2 shows the numerical geometric simulation result of adding a metalens to the conventional diffractive AR combining system. The light is scattered and focused on one point by the metalens on the output grating area. On the other hand, there is a problem that the metalens has chromatic aberration. Because of it, the virtual image is expected to look like RGB chromatic dispersion. Using this configuration of optical system, the chromatic dispersion is calculated, and if an image compensating inversely is input, the color matching will be occurred.

Consequently, if the wave field, which has convergence or divergence, enters the eye, we can see the three-dimensional image with depth of the target. This technique requires an accurate calculation of the focal length of the metlens.

3. Conclusions

In conclusion, we designed and analyzed a diffractive optical AR system with metalens for a virtual image with a depth. In addition, we calculated the focal length for depth and proposed the advanced diffractive AR device to see three-dimensional image with a depth.

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)