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Volume holographic optical element used for light coupling in XR's near-eye glass

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ABSTRACT

In this report, we will present the recent-developing technology in volume holographic optical elements (VHOE) [1] used for near-eye glass. We will introduce the simulation model first, and the design principle of VHOE. Finally, we will present the visual effect with the VHOE in a near-eye glass.

1 Introduction

Holography was first proposed and demonstrated in 1948 by Denis Gabor [2]. The principle of holography is to record the interference pattern of two or more light waves by a recording medium. Through proper incidence of a reading light, the diffracted light can be encoded with the designed wavefront, which can be used to perform 3D display or wavefront reconstruction. A hologram can be applied to serve as an optical element, and a so-called holographic optical element (HOE). A HOE is regarded as a hologram with neglectful thickness, and allows multiple-order diffractions. Thus the diffraction efficiency is relatively low. In contrast, a hologram with domain thickness is said volume hologram, which can perform serve Bragg condition in diffraction. Such an optical element is called a volume holographic optical element (VHOE). Volume holograms can be divided into two categories, one is the transmission type and the other is the reflection type. Through proper control of the grating strength, which is the product of the interaction length and the refractive index change, the diffraction efficiency could reach 100%. However, the diffraction efficiency of the two types acts in different styles, as shown in Fig. 1. This is one of the important characteristics of designing a VHOE.

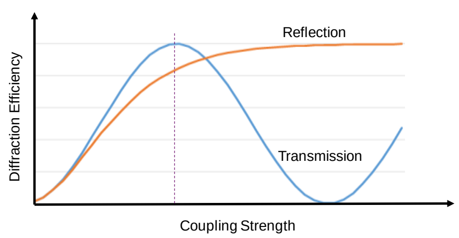

Fig. 1 Diffraction efficiency vs. coupling strength.

The reason why VHOEs are important to a near-eye glass is the see-through function, which is a necessary function for a near-eye glass of AR and MR. VHOE has been applied to head-up displays (HUD) for decades. In an AR near-eye glass, the VHOEs play the roles of in-coupling and out-coupling on the glass so that the image by the tiny projector can be directed to the human eyes through multiple internal total reflections in the glass, as shown in Fig. 2. The in-coupling VHOE is used to diffract the projected image to the light guide. The out-coupling VHOE is used to direct the guiding light to the human eye.

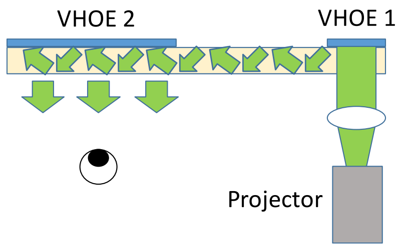

Fig. 2 The structure of a near-eye glass with two VHOEs.

2 Simulation Model

The most common method for simulating a CHOE is called coupled mode theory [3-5]. However, the wavefront should be planar even if the absolute diffraction efficiency can be obtained. The problem is raised when the wavefront is not planer. To solve this problem, two simulation methods are applicable. One of them is the so-called VOHIL model [6-7], where there is no limit to the recording wavefront, but only the relatively diffraction efficiency is available. In fact, the model is applicable under weak coupling. Even the absolute diffraction efficiency is not obtainable, and strong diffraction efficiency is not in the calculation scope, it is still the best way to simulate the diffraction under complicated conditions.

The principle of VOHIL can be illustrated as follows. All the exposure area generates tiny scattering points which bear the phase difference between the signal light and the reference light. When a reading light is incident on the recording area, every scattering point reradiates a spherical wave with an initial phase related to the reading light and the recorded phase difference. Under some simplified conditions, the diffraction efficiency can be obtained through integration along one direction and a simple formula can be obtained to calculate the diffraction efficiency. However, a more precise simulation can be obtained when the integration is through all the recording areas. Figure 3 shows an example of the geometry of a reflection-type VHOE when the wavelength of the writing light is 532 nm. The calculation of the diffraction efficiency of the spatial-dispersion relation is shown in Fig. 4. Figure 4(a) is through 1D simulation, and Fig. 4 (b) is through 3D simulation.

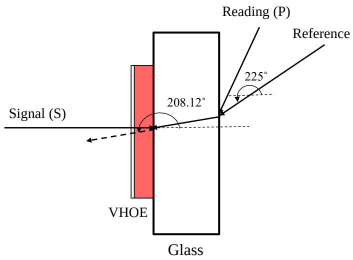

Fig. 3 The geometry of a reflection-type VHOE.

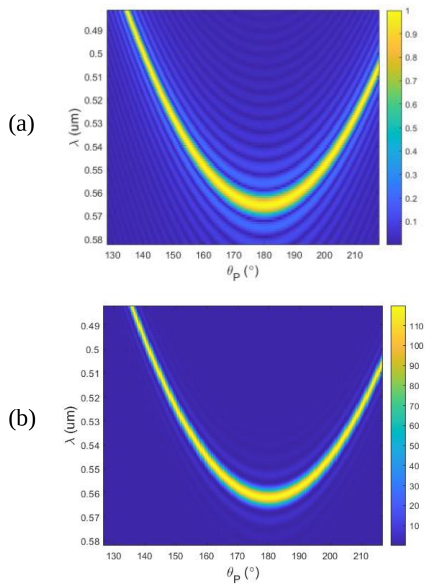

Fig. 4 The spatial-dispersion relationship in the reconstruction with (a) 1D model and (b) 3D model.

3 VHOE for Light Coupling

The precise simulation of the diffraction condition is useful and necessary when we apply a VHOE to the light guide in a near-eye glass, shown in Fig. 2. To avoid strict Bragg condition, a lens is used to collimate the projection light before it is incident on the in-coupling VHOE. The in-coupling VHOE is used to diffract the incident image of normal incidence along a certain slanted angle so that the diffracted light can be propagated along the light guide and is incident on the out-coupling VHOE. The mechanism of the out-coupling VHOE is similar to the in-coupling VHOE, so that the diffracted light is direct to the human eye. Figure 5 shows an example of the out-coupling image caught by a camera.

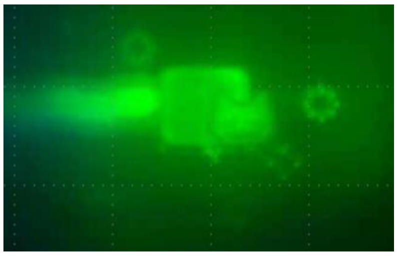

Fig. 5 The image out-coupling from a near-eye glass caught by a camera.

More precise designs and the corresponding experiments will be delivered in the talk. The important features of an AR/MR near-eye glass, such as FOV and eye box extension will be discussed.

4 Summary

In this report, we will present our study in VHOE and its application in the light guide of an AR/MR near-eye glass. 1D and 3D VOHIL models are applied to the major simulation to figure out the characteristic of the VHOE with complicated diffraction. Then we construct VHOEs attached to the light guide to redirect the diffracted light so that the diffracted light can propagate along the glass. The second VHOE will direct the projection of light into the human eye. More designs for extending the FOV and eye box will be presented in the oral presentation.

Acknowledgment

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