Holographic Contact Lens Display: Generation of Focusable Images for Eyes

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1. Introduction

Augmented reality (AR) devices have the potential to replace smartphones. Recently, the developments of AR head-mounted displays and AR glasses have been accelerated. The contact lens display is an ultimate AR device because it provides clear vision without any obstacles. The contact lens display can also be used for the enhancement of human vision. However, there are many issues to be solved to realize the contact lens display. We have adopted the holographic technique to address the image formation problem [1]. The use of holographic technique enables the production of visual information at the same distance as real objects.

2. Principle

When a display device is embedded in a contact lens, as shown in Fig. 1(a), the lens of the eye cannot focus on the display screen due to its close proximity to the eye. To address this problem, previous techniques have added micro optical elements to all display pixels and cancel the lens power of the eyes, as shown in Fig. 1(b). In this study, we propose the use of the holographic technique to enable the eyes to naturally focus on the produced images. As shown in Fig. 1(c), a display device embedded in a contact lens displays hologram patterns, which generate a wavefront emitted from three-dimensional (3D) images located far from the eyes. Thus, the eyes can focus on the 3D images.

Figure 2 illustrates the optical system of the holographic contact lens display. The thin laser backlight employing a holographic optical element (HOE) emits horizontally polarized laser light to illuminate the phase-only SLM which displays phase-only holograms, i.e., transparent holograms. The phase-only SLM modulates the phase of the horizontally polarized light. The polarizer transmits the vertically polarized light from the outer scene, which is not modulated by the SLM. Because of the wavelength selectivity of the HOE, the HOE backlight has high transmittance for light from the outer scene. The phase-only SLM also has high transmittance because it does not modulate the amplitude of light.

Typical contact lenses can have a thickness of as little as approximately 0.1 mm. When a liquid-crystal SLM is used for the phase modulation, the liquid-crystal layer has several microns thick. The thickness of the proposed system is dominated by the thickness of the laser backlight, which can be reduced by use of the HOEs.

3. Experimental Verification

The proposed technique was verified using a bench-top experimental system. A transmission-type twisted nematic liquid-crystal SLM was used as the phase-only SLM. A photopolymer was used as the HOE material. Figure 3 shows the experimentally obtained see-through images.

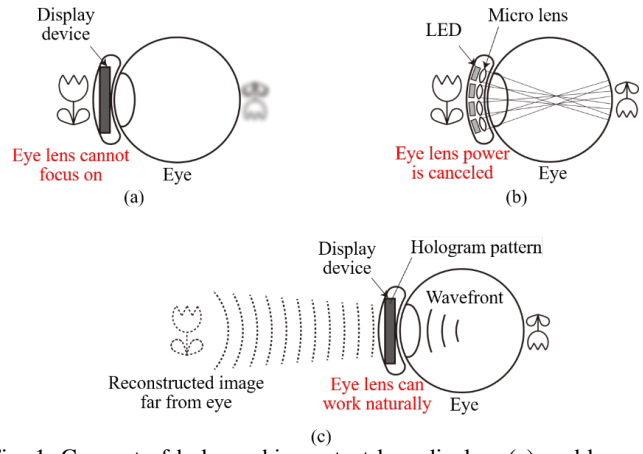

Fig. 1. Concept of holographic contact lens display: (a) problem, (b) conventional solution, and (c) proposed technique.

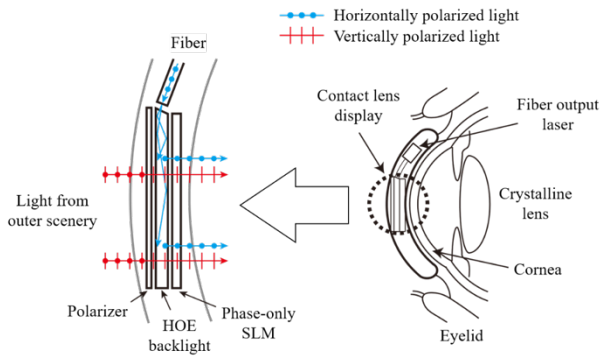

Fig. 2. Structure of holographic contact lens display.

Fig. 8. Captured see-through image.

4. Conclusions

The image formation technique for the contact lens displays using transparent holograms and its experimental verification are explained.

Reference

[1] Junpei Sano and Yasuhiro Takaki, Opt. Express **29** (2021) 110568.