Holographic Caustic Optical Element

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We propose a design of holographic optical element (HOE) that generates computational caustic light field distributions and uses hogel-based holographic printing technique to produce the caustic field HOE. The conservative computational caustic holographic optical element functions as a freeform optical surface, but we replace the freeform lens with a thin film, which provides more cost-effective and smaller form factor required caustics.

I. Introduction

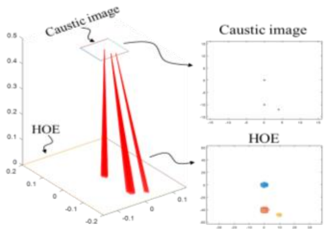
The conventional method to produce caustic image uses freeform lenses. In order to generate caustic image, the surface power of target image is calculated using refraction distribution computed by inverse raytracing from caustic image. In conventional caustics, the freeform refracting surface has several disadvantages such as long surface power calculation time and high fabrication cost. Recently, freeform lens recorded holographic optical element (HOE) is employed to bend the incident ray direction[1]. In this paper, we propose a recording system for hogel-based *holographic caustic optical element* (HCOE). The hologram printer records grating on the hologram that manipulates light direction. An incident ray is refracted based on the surface power where the ray intersects one point on HCOE. The HCOE lens steers incoming rays using diffraction to form intensity distribution of caustic image. The ray that intersects at HCOE plane meets Bragg condition[2] of volume holo-gram, so the ray is diffracted to one direction. Thus, the HCOE has many gratings on each portion. The HCOE has the property of transfer function as follows:

$$h(x,y)=\sum\sum\exp\left(j\mathbf{G}_{nm}\right)rect\left\{\frac{x-n}{\Delta x}\right\}rect\left\{\frac{y-m}{\Delta y}\right\},$$

where $\Delta x, \Delta y$ are the size of hogel which is recording unit in hologram printing method. $\mathbf{G}_{nm}$ is grating vector that determines the diffraction direction of rays.

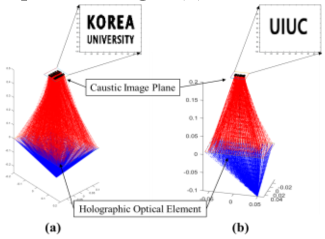
II. Design and Simulation Method

In order to design HCOE pattern for generating caustic image, backward calculation from the caustic image is required. Target caustic image consists of a set of unit image pixels and each unit pixel in the image plane has different intensity for expressing the brightness that can be represented by the number of hogel. Each hogel expresses a unit image pixel, and several rays from hogels are needed to be incident on a pixel to control the brightness of each image pixel. The way of assigning hogels to image pixels is taking the nearest hogels from the image pixels. As the



[Fig.1] Light rays refracted toward caustic image plane

diffracted rays from each hogel are incident on the nearest image pixel, the diffracted angles are minimum and therefore prevents unexpected interference between diffracted rays with large angle of diffraction. After assigning all the hogels on the HOE, each hogels are recorded using a 5-axis holographic printer to diffract the rays from the hogels to preliminarily assigned image pixels. Reference beam is incident on the recorded HOE and a caustic image appears on the image plane as shown in Fig. 1. The simulated result when the reference beam is incident on the entire area of recorded HOE is shown in Fig. 2. The blue rays are reference beams and the red rays are reconstructed object beams. Multiplexability property of HCOE is demonstrated in Fig. 2(b), which uses tilted reference beam to superpose different configurations of volume grating on the same HOE but generates different caustic image compared to Fig. 2(a).



[Fig.2] Multiplexability property of HCOE

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