OPTICAL REVIEW Vol. 10, No. 5 (2003) 339–341

A Color Holographic Reconstruction System by Time Division Multiplexing with Reference Lights of Laser

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(Received June 5, 2003; Accepted July 14, 2003)

3D-TV systems by holography technique have been studied in the world. In this paper, we report a color holographic reconstruction system by time division multiplexing method with reference lights of laser. The method can reconstruct a color holographic image by switching reference lights of red, green and blue colors at certain intervals. We can observe a color holographic image using red and green lasers as the reference lights, a high minute liquid crystal display (LCD) panel as a spatial light modulator (SLM) and electro-shutters as the shuttering device of the laser lights in the optical system. This approach has some advantages. Namely, the structure of the optical system can be simple and the number of LCD panels in the optical system can be decreased.

Key words: 3D-TV, computer generated hologram, hologram, holography, liquid crystal display, time division multiplexing

1. Introduction

In recent years, 3D-TV systems has been studied by the computer generated hologram (CGH) technique since an object light can be reconstructed. However, this requires a device which can display a minutely interference fringe of CGH. The interval of the interference fringe is almost the same as the wavelength of a reference light because holography utilizes the phenomena of diffraction and interference of a light wave.

Benton at the MIT Media Lab developed holographic display systems which used an acoustic optical modulator (AOM) as a spatial light modulator (SLM).[1] An AOM device is a one-dimensional SLM, so that a 3D-TV system with an SLM in principle has only a horizontal parallax. The reconstructed 3D image from the system is large since the diffraction angle of the AOM is wide. However, this optical system becomes a complex structure.

On the other hand, a 3D-TV system with a liquid crystal display (LCD) as a SLM is also well-known.[2,3] A LCD device is a two-dimensional SLM, so that the 3D-TV system with the device can have full parallax, but the reconstructed 3D image from the system is small since the diffraction angle is narrow. The optical system becomes a simple structure. As the devices, transmissive LCD has been mainly used. We have used a reflective LCD because this can generally be made minutely as compared with a transmmisive LCD.[4] A reflective LCD has high optical efficiency and minute pixel pitch, allowing us to obtain a bright and large 3D image.

To date, this field has been studied primarily for a monochrome reconstruction image. Sato studied a color holographic display system in 1994.[5] Takano *et al.* has proposed a system with a white light source in 2002,[6] and we also have proposed such a system.[4]

In this paper, we propose a new method of color holographic reconstruction by time division multiplexing.[7] The method can reconstruct a color holographic image by switching reference lights of red, green and blue colors at a certain time. We call this method Time Division Multiplexing Computer Generated Hologram (TDM-CGH).

In §2, we describe a color holographic display system by TDM-CGH. In §3, we show the results of the optical experiment, and in §4, we describe conclusions of the method.

2. A Color Holographic Reconstruction System by TDM-CGH

TDM-CGH is a simple method whitch consists of two processes. We fitst describe the computational process.

The calculation of CGH is a simple arithmetic operation:

$$I(x_\alpha, y_\alpha) = \sum_j^N A_j \cos\left(\frac{2\pi}{\lambda_t}\sqrt{((x_\alpha - x_j)^2 + (y_\alpha - y_j)^2 + z_j^2}\right). \quad (1)$$

Here, the indices α and j show the hologram and the object, N is the total number of object points, A_j is the intensity of the object, x_α and y_α are the horizontal and vertical components of the grid on the hologram, x_j, y_j and z_j are the horizontal, vertical and depth components of the grid on the object and λ_t is the wavelength of the reference lights. The wavelength is generally constant for a monochrome reference light, however λ_t becomes variable for a time since we switch reference lights at certain intervals.

In the following discussion, we use red and green lasers as reference lights because we could not get a blue laser. However, we will be able to add a blue laser to the following optical system briefly. Figure 1 shows how holograms are processed by TDM-CGH. The holograms are made as follows.

(1) We prepare an original image with color components on a computer.
(2) We divide the image into each color component. In Fig. 1, the image is divided into the red component and the green component.
(3) We compute holograms from the divided images. A hologram corresponding to the red component is computed with the wavelength $\lambda_{t_1} = 633$ nm of reference light at a time t_1 and a hologram corresponding to

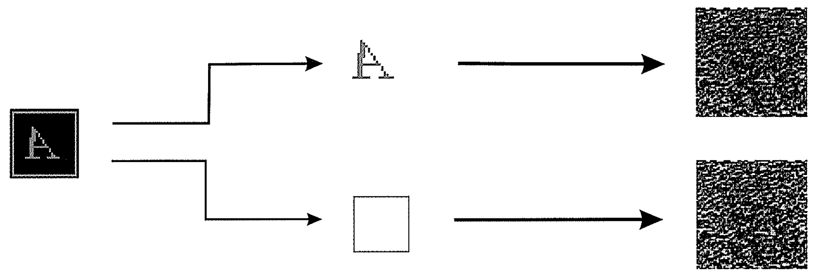


Fig. 1. Computation process of TDM-CGH.

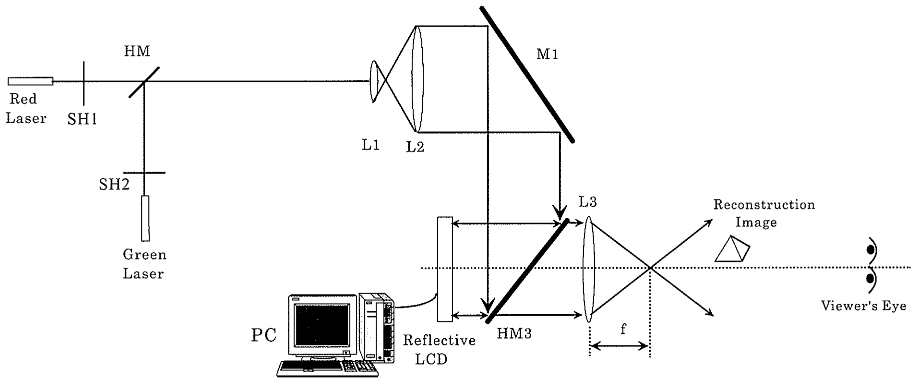


Fig. 2. Arrangement of optical system.

the green component with the wavelength $\lambda_{t_2} = 532$ nm of reference light at a time t_2.

Next, we describe the reconstruction process of TDM-CGH. Figure 2 shows the optical system with reference lights of the laser. SH1 and SH2 indicate electro-shutters for switching the reference lights, HM indicates a half mirror, M indicates a mirror and PC indicates a personal computer. L1 and L2 are lenses for collimating the red laser and green laser lights. L3 is a lens for expanding the viewing zone. The specifications of the reflective LCD in the figure, CMD8X6D, are shown in Table 1. SH1 and SH2 are controlled by electric signals of parallel port on the PC. The speed of the electro-shutter is approximately 10 Hz.

We can reconstruct a color image from the holograms as follows:

(1) We send the hologram data corresponding to the red component λ_{t_1} to the frame buffer of the LCD.
(2) We open SH1 by sending an electric control signal via the parallel port on PC. Then the LCD is illuminated by the red laser light of the reference light, and we close SH2.
(3) We send the hologram data corresponding to the green component λ_{t_2} to the frame buffer of the LCD.
(4) We open SH2 by sending an electric control signal via the parallel port on PC. Then the LCD is illuminated by the green laser light of the reference light, and we close SH1.

Table 1. Specfications of the reflective LCD.

Resolution	800×600
Pixel pitch	$12\,\mu\text{m} \times 12\,\mu\text{m}$
Active area	$9.6\,\text{mm} \times 7.2\,\text{mm}$
Refresh rate	255–360 Hz

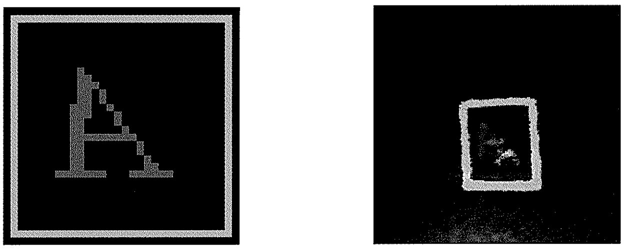
We can observe a color holographic reconstruction image by repeating the above steps (1)–(4). In the case of adding a blue color to a reconstruction image, we can realize to put a blue laser as a reference light and an electro-shutter into Fig. 2.

The advantage of TDM-CGH is the following:

- The number of LCD panels in the optical system can be decreased. Therefore, the structure of the optical system can be simple. Maeno *et al.* studied a large-scale optical system of a monochrome 3D-TV system with some LCDs to expand the viewing zone.[3] If we develop that in a color 3D-TV system, this will be a particular advantage.

3. Optical Experiment and Conclusions

The original object is shown in Fig. 3(a). Figure 3(b) shows the reconstruction image from the holograms by TDM-CGH. In Fig. 3(b), we can see the reconstructed frame in green and



(a) Original Image (b) Reconstruction Image

Fig. 3. Original image (b) Reconstruction image.

the letter 'A' in red. We recognize the problem of flicker in the reconstruction image because the speed of the electro-shutter is low. We will solve this problem by using a higher speed electro-shutter.

We can obtain a color holographic reconstruction image by TDM-CGH. This method has some advantages. Namely, the structure of the optical system can be simple and the number of LCD panels in the optical system can be decreased.

In our next work, we are planning to use a high speed electro-shutter and to do an experiment with mixed colors in a reconstructed image.

References

1) S. A. Benton: Proc. SPIE **Vol. IS# 08** (1991) 247.
2) N. Hashimoto, K. Hoshino and S. Morokawa: Proc. SPIE **1667** (1992) 2.
3) K. Maeno, N. Fukaya, O. Nishikawa, K. Sato and T. Honda: Proc. SPIE **2652** (1996) 15.
4) T. Ito, T. Shimobaba, H. Godo and M. Horiuchi: Opt. Lett. **27** (2002) 1406.
5) K. Sato: J. Inst. Televig. Eng. Jpn. **48** (1994) 1261 [in Japanese].
6) K. Takano, N. Minami and K. Sato: Proc. SPIE **4659** (2002) 61.
7) T. Shimobaba and T. Ito: IEICE Information and Systems Society Conf, 2001, **D-11-65** [in Japanese].