Color Holographic Image Generation Using Pulse-modulated MEMS SLM

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ABSTRACT

The holographic display using the pulse-modulated MEMS SLM can provide a large viewing zone angle, i.e. over 40 degrees. This study develops two techniques to enable the color image generation: one uses an RGB coupler array, and the other uses an RGB fiber array. The experimental varication is shown.

1 Introduction

Although holography provides ideal three-dimensional (3D) images which are free from the visual fatigue, the conventional holographic displays using the spatial light modulators (SLMs) can provide a small viewing zone angle of several degrees [1]. Recently, we have proposed the use of the MEMS SLM with the short laser pulse illumination for the holographic displays, which dramatically increases the viewing zone angle to over 40 degrees [2].

This study proposes two techniques to enables the color image generation for the holographic displays using the pulse-modulated MEMS SLM.

2 Theory

The holographic display using the pulse-modulated MEMS SLM utilizes the time-multiplexing technique to increase the viewing zone angle [2]. The screen of the MEMS SLM consists of a two-dimensional array of the MEMS mirrors which quickly rotate to change their states between off- and on-states. The MEMS SLM is illuminated by short laser pulses during the rotation state of the MEMS mirrors, which is not conventionally used for the image generation. Because the direction of light reflected by the MEMS mirrors changes depending on the illumination timing of the short laser pulses, the viewing zone can be scanned so that the viewing zone is enlarged by the time-multiplexing manner. When the rotation angle of the MEMS mirrors is denoted by $\pm\alpha$, the viewing zone angle can be enlarged to 4α.

For the color image generation, the time-multiplexing technique using a single MEMS SLM and the space-multiplexing technique using three MEMS SLM can be used. The majority of previous works of the holographic displays using the MEMS SLMs [3–6] make use of the former technique for the color image generation because of the high-speed operation of the MEMS SLMs. This study also uses the time-multiplexing technique. Therefore, the time-multiplexing technique is used for both the enlargement of the viewing zone and the color image generation. Two time-multiplexing techniques are examined.

Figure 1 illustrates the technique for the color image generation using the RGB coupler. The R, G, and B laser diodes are used as the light sources and the R, G, and B laser lights are combined by the RGB coupler. The MEMS SLM is illuminated by the combined laser lights from the normal direction. The R, G, and B diodes emit light sequentially with the synchronization of the hologram pattern generation by the MEMS SLM for the corresponding colors. The viewing zones are scanned on the observation plane without gaps for each color by properly scheduling the pulse generation timing of the three lasers.

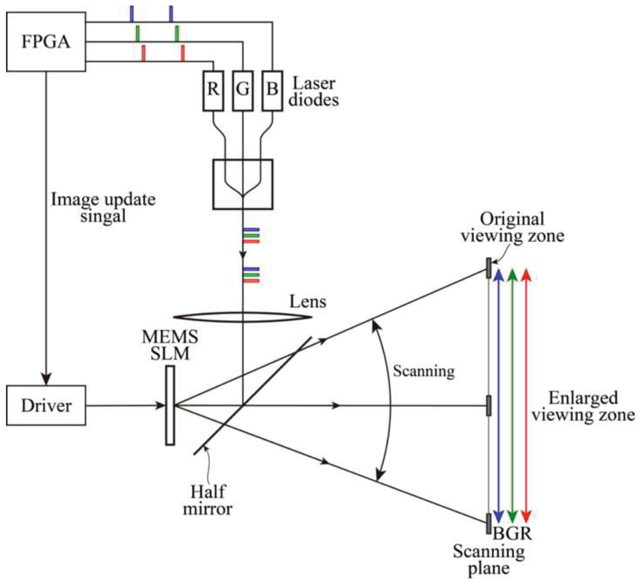


Fig. 1 Color image generation using an RGB coupler.

Figure 2 depicts the technique for the color image generation using the RGB fiber array. The R, G, and B laser lights are not combined and are densely aligned one-dimensionally so that the three laser lights separately illuminate the MEMS SLM. Because the illumination directions are slightly different for the three colors, the directions of lights reflected by the MEMS mirrors are also different for the three colors. Thus, the enlarged viewing zones are slightly shifted on the observation plane for the three colors. Therefore, the common viewing zone for the three colors becomes narrower than that for each color.

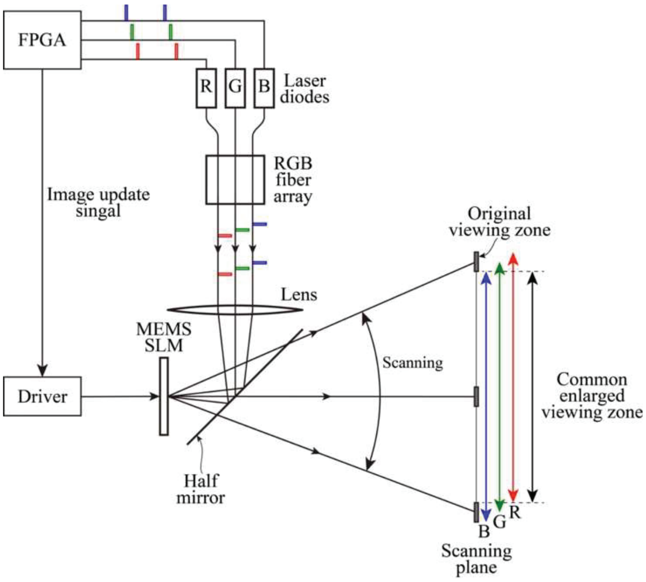


Fig. 2 Color image generation using an RGB fiber array.

3 Experiments

The proposed color generation techniques were verified experimentally.

As the MEMS SLM, a digital micromirror device (DMD) was used. The resolution was 1,024×768, the pixel pitch was 13.68 μm, and the frame rate was 22,727 Hz. The rotation angle of the MEMS mirrors was $\alpha = 12^{\circ}$, and the rotation time was 3.83 μs. The wavelengths of the R, G, and B laser diodes were 640, 515, and 488 nm. The pulse width of the laser lights was 20 ns. The number of scanning points for each color was 64. The frame rate of the color image generation was 59.1 Hz. The pulse generation timing was controlled by an FPGA. Figure 3 shows the photograph of the experimental system.

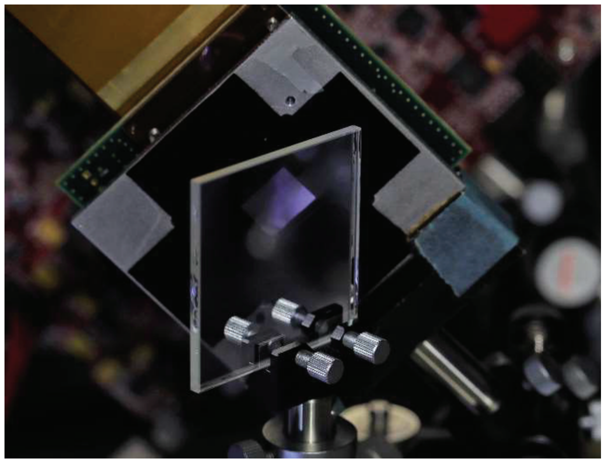
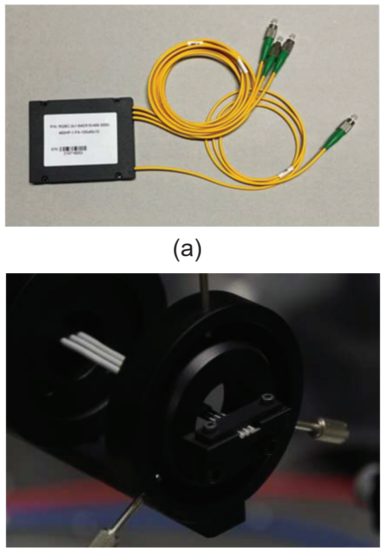


Fig. 3 Experimental system used for the color image generation.



(a)

(b)

Fig. 4 Devices used for the color image generation: (a) RGB coupler, and (b) RGB fiber array.

First, the technique using an RGB coupler was used for the color image generation. Figure 4(a) shows the RGB coupler used for the experiment. The generated color images are shown in Fig. 5. The color images were successfully generated. The measured viewing zone angle was 41°, which was equal to that for the monochromatic system [2]. The enlarged viewing zone angle was smaller than 4α because an undesirable light distribution appeared in the minus-end scan region, which were generated by the small vibration of the MEMS mirrors.

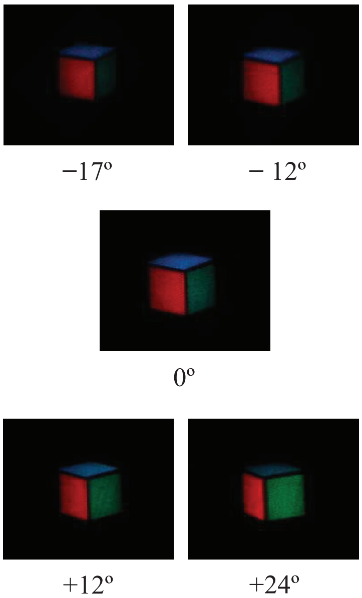


Fig. 5 Color images generated by the technique using the RGB coupler.

Next, the color image generation technique using an RGB fiber array was examined. Figure 4(b) shows the RGB fiber array used for the experiment. The RGB fibers were aligned with a pitch of 1.63 mm. The generated color images are shown in Fig. 6. The measured common viewing zone angle for the RGB colors was 37°, which was smaller than that of the previous monochromatic display system [2].

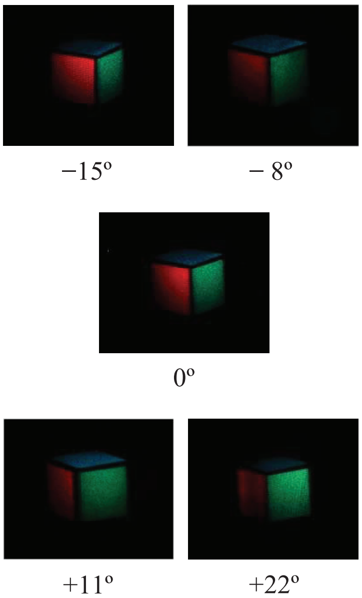


Fig. 6 Color images generated by the technique using the RGB fiber array.

4 Discussion

The two techniques proposed for the color image generation were compared.

The technique using an RGB coupler is a straight-forward way to modify the monochromatic display system to the color display system. Thus, the enlargement of the viewing zone angle was not impaired. However, the extra cost for the RGB coupler is required with the inevitable loss of light. The measured light losses of the RGB coupler were 0.81, 1.60, and 1.26 dB for R, G, and B laser lights, respectively.

The technique using the RGB fiber array does not require the additional cost. The three laser lights from the laser diodes were simply aligned one-dimensionally. In addition, this technique is energy efficient because the light loss does not occur for combining the three colors. However, the enlarged viewing zone angle was reduced by 4°.

5 Conclusions

This study developed the color image generation techniques based on the time-multiplexing scheme for the holographic displays using the pulse-modulated MEMS SLM. The two techniques were proposed and the color images were successfully generated using the both techniques. While the technique using an RGB coupler provided a wider viewing zone, the technique using an RGB fiber array had higher light efficiency.

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