Holographic Display Using Pulse-Modulated MEMS SLM with HOE Illumination System

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ABSTRACT

The holographic display using the pulse-modulated MEMS SLM provides a wide viewing zone without the pixel pitch reduction of the SLM. In this study, the illumination system which consists of a waveguide substrate and two HOEs is developed for the pulse-modulated MEMS SLM to increase the brightness of holographic images.

1 Introduction

Holography can produce ideal three-dimensional (3D) images that do not cause visual fatigue. However, its electronic implementation is difficult because it can provide small viewing zone angles of several degrees using conventional spatial light modulators (SLMs).

We have previously proposed the use of a MEMS SLM and a spatial scanner to enlarge the viewing zone angle [1-3]. The MEMS SLM operates at a high framerate and the spatial scanner scans the viewing zone so that the viewing zone angle is enlarged using the time-multiplexing technique. We have also proposed the illumination of the MEMS SLM by short laser pulses to remove the spatial scanner from the scanning holographic display system [4]. In this system, the pulse-modulated MEMS SLM displays hologram patterns and scans the viewing zone, simultaneously. However, the use of short laser pulses decreases the light intensities of the reconstructed images. The double pulse illumination technique was developed to increase the light intensities of the reconstructed images [5].

The use of a waveguide employing holographic optical elements (HOEs) was proposed to reduce the illumination system size for holograms [6]. In this study, we introduce the HOE illumination system to increase the intensities of the reconstructed images produced by the pulse-modulated MEMS SLM.

2 Holographic Display Using Pulse-Modulated MEMS SLM

First, the previously proposed holographic display system using the pulse-modulated MEMS SLM [4] is briefly explained.

As shown in Fig. 1, short laser pulses illuminate the MEMS SLM which consists of a 2D array of MEMS mirrors. The MEMS mirrors rotate in a short time to change between an on state and an off state. During the rotation of the MEMS mirrors, short laser pulses illuminate the MEMS SLM. When the pulse timing is changed, the light reflecting direction changes. Thus, light reflected by the MEMS mirrors is scanned by controlling the pulse generation timing. Consequently, the viewing zone is electronically scanned.

Fig. 2 shows the illumination system used for the pulse-modulated MEMS SLM. Because the MEMS SLM is illuminated from the normal direction, the maximum light efficiency of the illumination system is 25%. Recently, we proposed the double pulse modulation technique to increase the light intensity of the reconstructed images [5]. The laser pulses are generated when the MEMS mirrors rotate from the off state to the on state and also when they rotate from the on state to the off state. This technique doubles the light intensities of the reconstructed images.

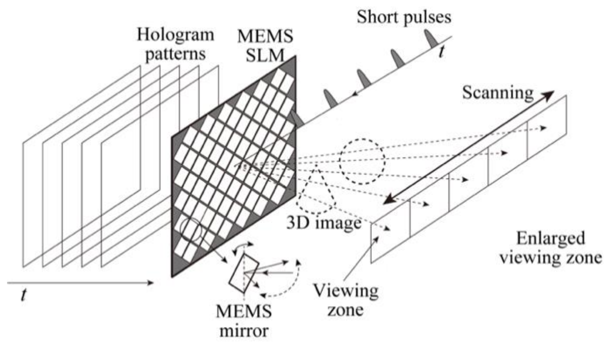

Fig. 1 Holographic display system using pulse-modulated MEMS SLM.

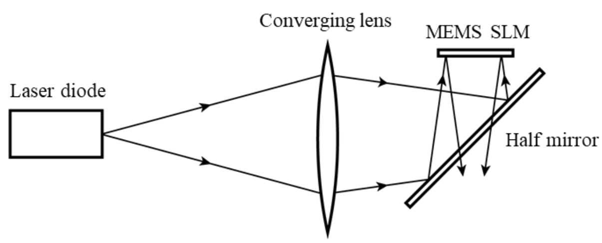

Fig. 2 Illumination system used for previous display system using pulse-modulated MEMS SLM.

3 Proposed System

This study proposes the pulse-modulated MEMS SLM with the HOE illumination system as shown in Fig. 3. The illumination system consists of a waveguide substrate and two HOEs and has the same function as the illumination system shown in Fig. 2. A diverging light from a laser diode is collimated by the HOE1 and the collimated light propagates inside the waveguide substrate. Then, the HOE2 redirects light to illuminate the MEMS SLM. The HOE2 also converges light to generate the viewing zone at the light converging point.

Recently, the use of photopolymers greatly improves the diffraction efficiency of the HOEs to 0.8~0.9 [7]. When the diffraction efficiency of the HOE1 and HOE2 are respectively denoted by η_1 and η_2, the light efficiency of the proposed illumination system becomes $\eta_1\eta_2$, which might be higher than that of the previous illumination system. The proposed technique also reduces the size of the illumination system.

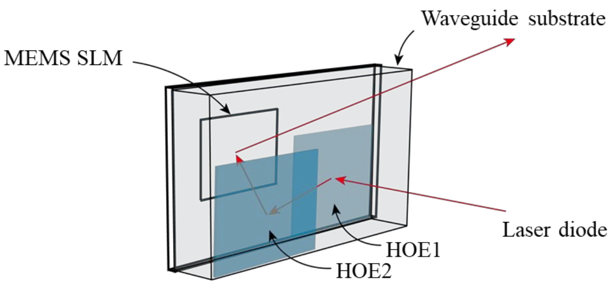

Fig. 3 Proposed pulse-modulated MEMS SLM with HOE illumination system.

4 Experiments

The photopolymer used to fabricate the HOEs was Bayfol HX 200 (Covestro AG). The collimated light propagates inside the waveguide with an angle of 60° from the normal to the HOEs. The size of the waveguide substrate was 58 × 50 × 15 mm^3. Fig. 4 shows the fabricated HOE illumination system.

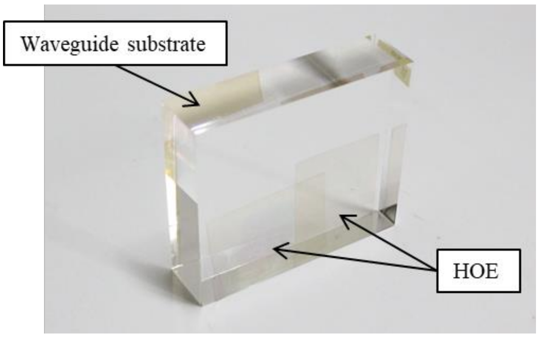

Fig. 4 Fabricated HOE illumination system.

The MEMS SLM used for the experiment was Discovery™ 4100 (Texas Instruments, Inc.) The rotation angle of the MEMS mirrors was ±12° and rotation time was 3.83 μs. The frame rate was 22,727 Hz. A laser diode with a wavelength of λ = 640 nm was used. An FPGA was used for pulse signal generation. The pulse width was 20 ns. Fig. 5 shows the constructed holographic display system using the HOE illumination system. As shown in this photograph, the display system became small and thin.

The reconstructed images produced by the proposed technique is shown in Fig. 6. The double pulse modulation technique was used. For comparisons, those obtained by the previous illumination system using a half mirror and the single pulse modulation are also shown in Fig. 6. The brightness of the reconstructed images increased using the proposed technique. The measured light intensity at the center of the viewing zone was 155 nW for the proposed technique, while that for the previous technique was 31 nW. The reconstructed images could be clearly observed under the normal room light condition.

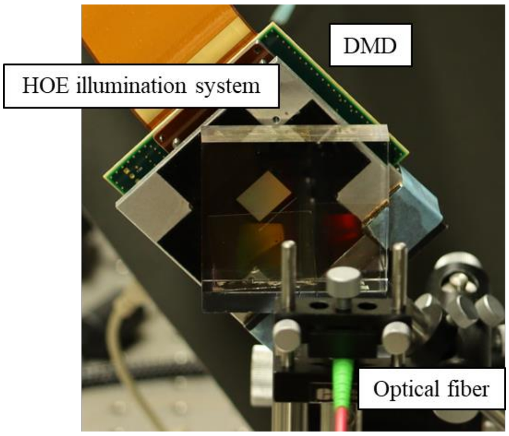

Fig. 5 Display system using pulse-modulated MEMS SLM with HOE illumination system.

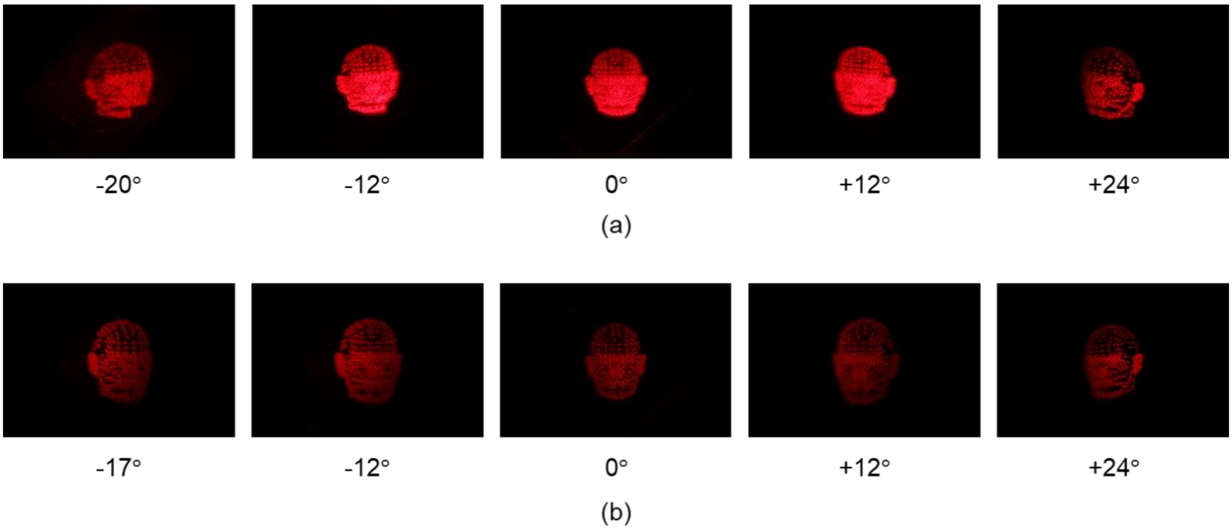

Fig. 6 Reconstructed images obtained using (a) HOE illumination system, and (b) previous illumination system using half mirror.

5 Conclusions

In this study, we proposed the HOE illumination system to improve the light intensities of holographic images produced by the pulse-modulated MEMS SLM. The display system was constructed and the increase of the brightness of the holographic images was experimentally verified. Moreover, the display system size was reduced.

Acknowledgement

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