# Electronic Holographic Display Using MEMS-SLM with 40 Degree Viewing Zone

Yoshitaka Takekawa[1], Yuki Nagahama[1], Yuzuru Takashima[2], Yasuhiro Takaki[1]

[1] Tokyo University of Agriculture and Technology, 2-4-16 Naka-cho, Koganei, Tokyo 184-8588, Japan,
[2]Univerity of Arizona 1630 E. University Blvd., Tucson, AZ 85721, USA.
Keywords: Holographic display, Computer holography, Optical microelectromechanical device.

**ABSTRACT**

*The illumination of the MEMS-SLM by short laser pulses can dramatically increase the viewing zone of holographic images without reducing the pixel pitch. We demonstrate the generation of 3D images with a viewing zone angle of 40 degrees using the DMD with a pixel pitch of 13.68 μm.*

## 1 INTRODUCTION

Although holography is an ideal three-dimensional (3D) display technique, the conventional techniques for implementing the electronic holographic displays require a one-micron pixel pitch for spatial light modulators (SLMs) to provide 3D images with a large viewing zone. Many researches have been conducted to develop SLMs with a one-micron pixel pitch [1-3]. Our research group have taken the other approach which employs the combination of a MEMS-SLM and a horizontal scanner [4-6]. As shown in Fig. 1, the pixel pitch of the MEMS-SLM is enlarged so that the screen size increases. In this case, because the pixel pitch increases, the viewing zone reduces. The reduced viewing zone is scanned by the horizontal scanner to increase the viewing zone. Because of the high framerate operation of the MEMS-SLM, the viewing zone is enlarged by the time-multiplexing technique. In this study, we remove the horizontal scanner and the illumination of short laser pulses is used to enlarge the viewing zone [8]. The MEMS-SLM is used for both displaying hologram patterns and scanning the viewing zone. The maximum viewing zone angle obtained by this technique is four times as large as the rotation angle of the MEMS mirrors consisted of the MEMS-SLM. In this study, the viewing zone angle of 40° is experimentally demonstrated.

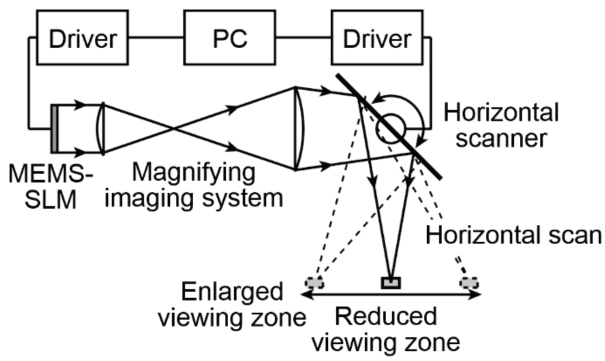


**Fig. 1 Previous viewing-zone scanning holography.**

## 2 THEORY

Figure 2(a) shows the holographic display system using the MEMS-SLM which is illuminated by short laser pulses. The MEMS-SLM consists of a 2D array of MEMS mirrors and the MEMS mirrors are rotated to modulate light two-dimensionally. Although on- and off-states of the MEMS mirrors are usually used for the light modulation, this study uses a rotating state of the MEMS mirrors. When a short laser pulse illuminates the MEMS mirrors during their rotation, the reflection direction of light is determined by the illumination timing as shown in Fig. 2(b). Therefore, the modulated light is scanned by controlling the generation timing of the short pulses.

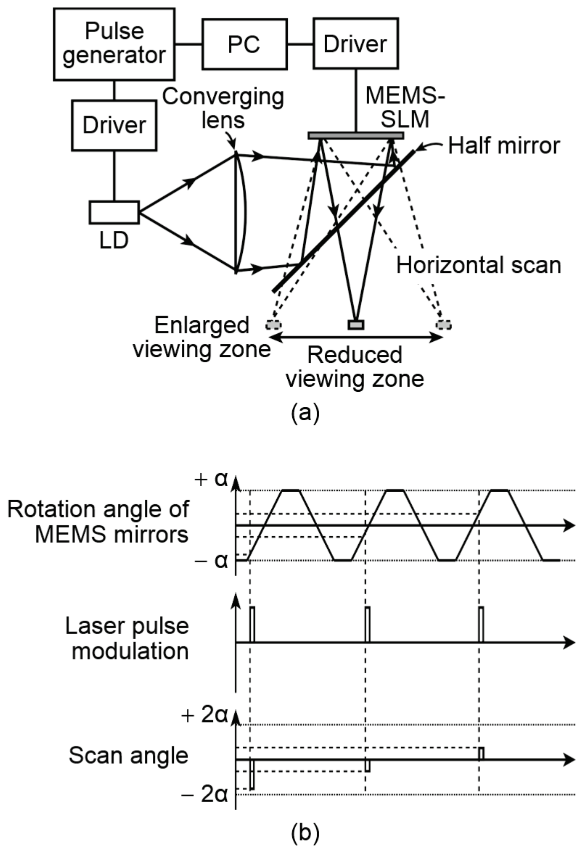


**Fig. 2 Proposed technique: (a) viewing-zone scanning holography using MEMS-SLM and pulse modulated laser, (b) scanning of light by MEMS mirrors illuminated by short pulses.**

The MEMS-SLM displays hologram patterns sequentially at a high frame rate, and the viewing zone is scanned in synchronization with the viewing zone generation. When the rotation angle of the MEMS mirrors is ± α, the viewing zone angle can be enlarged to 4α.

## 3 EXPERIMENTS AND RESULTS

In this study, a digital micromirror device (DMD) was employed as the MEMS-SLM which are used for commercial projectors. The resolution was 1,024 × 768, the pixel pitch was 13.68 μm, and the frame rate was 22.727 kHz. The rotation angle of the MEMS mirrors was ± 12° and the rotation time was 3.83 μs. A laser diode with a wavelength of 488 nm and a maximum output power of 100 mW was used. The pulse width was 20 ns, and the pulse generation was controlled by an FPGA. The maximum scan angle was ± 24° and the maximum viewing zone angle was 48°. The number of scanning points was 192 (= 3.83 μs / 20 ns). Because black images are inserted between hologram patterns to reset all MEMS mirrors, the frame rate of the holographic display was 59.2 Hz (= 22.727 kHz / 2 /192). Figure 3 shows the photograph of the experimental system.

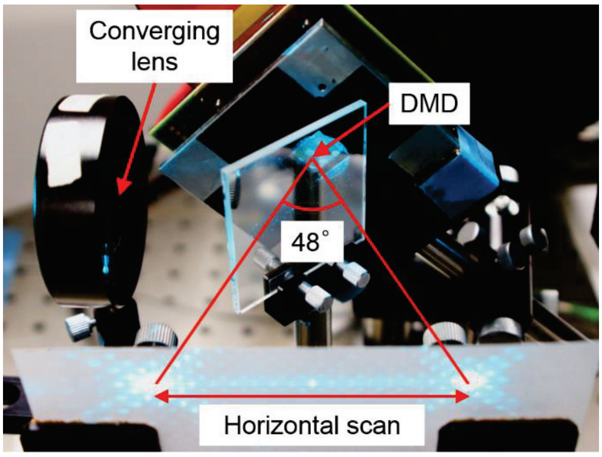


**Fig. 3 Photograph of the experimental system.**

Figure 4 shows the reconstructed images captured from the different horizontal directions. Because of the unstable movements of the MEMS mirrors at the beginning of their rotation, the effective scan angle was from −17° to +24°. Therefore, the viewing zone angle of the reconstructed images was enlarged to 41°. As shown in Fig. 4, the parallax of the reconstructed image changed depending on the viewing direction. The reconstructed image could be observed by both eyes and had enough brightness for the observation in the laboratory room.

## 4 DISCUSSION

The technique used in this study can increase the viewing zone of holographic images without reducing the pixel pitch of the SLMs. The viewing zone angle of the conventional holographic display systems is given by 2 $\sin^{-1}(\lambda / 2p)$ where $\lambda$ is a wavelength of light and $p$ is a pixel pitch. Therefore, the pixel pitch should be $p$ = 0.73 μm to obtain the viewing zone angle of 40° when $\lambda$ = 0.5 μm. The pitch of the MEMS mirrors used in this study was ~20 times larger than that required for the conventional techniques. In addition, the pixel pitch of the MEMS-SLM can be increased because the viewing zone angle depends on the mirror rotation angle and does not depend on the pixel pitch. Therefore, the screen size of the electronic holographic displays can be easily enlarged. The viewing zone angle could be further increased by using the MEMS-SLMs which are specialized for this technique.

## 5 CONCLUSIONS

This study proposed the holographic display technique which combined the MEMS-SLM and the pulse laser illumination to enlarge the viewing zone of holographic images. The viewing zone angle depends on the rotation angle of the MEMS mirrors constituting the display screen of the MEMS-SLM and does not depend on the pixel pitch. This study demonstrated the

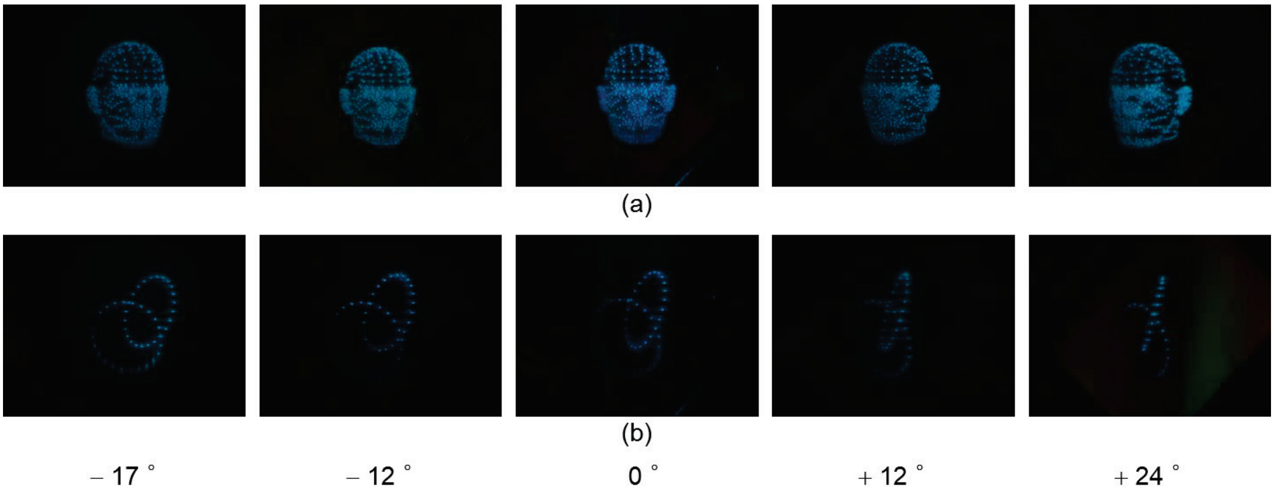


**Fig. 4 Reconstructed images captured from different horizontal directions: (a) head, (b) two circles.**

enlargement of the viewing zone angle to 40° using the DMD which are used for commercial projectors. This viewing zone angle was comparable to that of the previously developed systems which used the Galvano scanners to enlarge the viewing zone angle [4–7].

## REFERENCES


[1] Y. Isomae, T. Ishinabe, Y. Shibata, and H. Fujikake, “Alignment control of liquid crystals in a 1.0-μm-pitch spatial light modulator by lattice-shaped dielectric wall structure,” J. Soc. Inf. Disp. vol. 27, 251 (2019).

[2] K. Aoshima, H. Kinjo, K. Machida, D. Kato, K. Kuga, T. Ishibashi, and H. Kikuchi, “Active matrix magneto-optical spatial light modulator driven by spin-transfer-switching,” J. Disp. Technol. vol. 12, 1212 (2016).

[3] R. Stahl, V. Rochus, X. Rottenberg, S. Cosemans, L. Haspeslagh, S. Severi, G. Van Der Plas, G. Lafruit, and S. Donnay, “Modular sub-wavelength diffractive light modulator for high-definition holographic displays,” J. Phys. Conf. Ser. vol. 415, 2057 (2013).

[4] Y. Takaki and K. Fujii, “Viewing-zone scanning holographic display using a MEMS spatial light modulator,” Opt. Express vol. 22, 24713 (2014).

[5] Y. Takaki and M. Nakaoka, “Scalable screen-size enlargement by multi-channel viewing-zone scanning holography,” Opt. Express vol. 24, 18772 (2016).

[6] Y. Matsumoto and Y. Takaki, “Time-multiplexed color image generation by viewing-zone scanning holographic display employing MEMS-SLM,” J. Soc. Inf. Disp. vol. 25, 515 (2017).

[7] J. Li, Q. Smithwick, and D. Chu, “Full bandwidth dynamic coarse integral holographic displays with large field of view using a large resonant scanner and a galvanometer scanner,” Opt. Express vol. 26, 17459 (2018).