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A wavefront printer using complex-amplitude modulation by using phase-only SLM

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1. Introduction

Computer holography is being developed in recent several years and producing impressive high-definition computer-generated holograms (CGH). These high-definition CGHs are printed by high resolution printers [1-3] and the reconstructed 3D images are comparable to conventional optical holograms. However, These CGHs cannot be reconstructed by white light illumination because of its two-dimensional fringe pattern, while conventional optical holography produces volume holograms reconstructed by white light. This is because the fringes are recorded in a three-dimensional manner.

To produce synthetic volume holograms, holographic printers have been proposed [4]. This type of printers record multi-viewpoint images by optical interference of light generated by a spatial light modulator (SLM) with a reference wave. Therefore, the produced hologram is volumetric and thus reconstructed by white light illumination. However, produced images are holographic stereograms in these printers, because 2D images are recorded on the material. If wavefront, numerically synthesized by computer and generated by SLM, is recorded on the material instead of 2D images, the produced hologram dose not reconstruct stereogram but numerically calculated object fields, and thus the hologram is regarded as CGHs. In this scheme, CGH can be produced as volume hologram that reconstructs 3D images under white light illumination. We call this type of printer "wavefront printer".

Wavefront printers reported in early studies commonly use SLMs that modulate amplitude of light [5]. However, wavefront printer by amplitude SLM needs some technique to removes the conjugate image. This generally results in the narrow space-band product. Therefore, we propose a wavefront printer using phase-only SLM. However, this type of SLM has the problem of wavefront degradation because of coding noise caused by phase-only modulation. In this paper, we propose a method for reducing the degradation by using polarization modulation that is generated even in phase-only SLM.

2. Principle of wavefront printer and complex amplitude modulation

Figure 1 shows the structure of the wavefront printer. Wavefront printer record synthetic wavefronts on photo-sensitive materials by optical interfere of the wavefronts with a reference wave. Since the reference wave illuminates the material from the other side of the synthetic wavefronts, volume CGH is recorded on the material. Here, the phase-only SLM modulates not only phase but also polarization angle of the incident light according

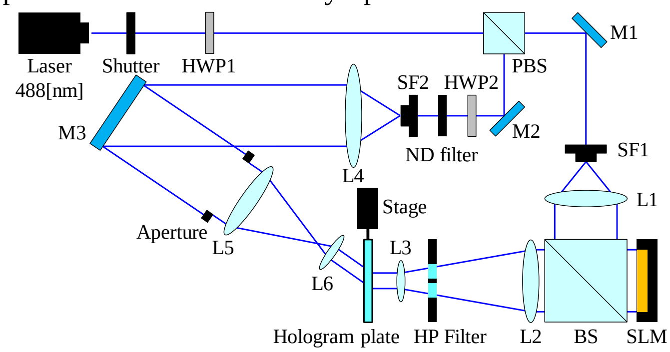

Fig.1 The structure of the wavefront printer.

Table 1 Parameter of the phase-only SLM.

Manufacturer	HOLOEYE
Model number	PLUTO
Number of pixels	1,920×1,080
Pixel pitches	8×8μm
Modulation level	256(8bit)

to the pixel level displayed on the SLM. As a result, amplitude of the recorded wavefront effectively changes dependently on the polarization angle as shown in Fig. 2(a). This allows us to modulate complex amplitude of light even in the phase-only SLM. Figure 2(b) shows the value of complex amplitude modulation for given pixel levels. This was measured in the SLM used for the printer. The parameters of the SLM is shown in Table 1.

3. Print of high-definition volume CGH and its optical reconstruction

Figure 3 and table 2 shows the 3D scene of the printed test CGH and its parameters, respectively. Figure 4 shows optical reconstruction of the test CGHs by white light illumination. Noise caused in the phase-only modulation as in (a) is slightly eased by complex amplitude modulation as in (b).

4. Conclusion

The wavefront printer using phase-only SLM is proposed for printing volume CGHs. It is verified that complex amplitude modulation is valid for reduction of coding noise caused by phase-only encoding.

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References

[1] S. Yamanaka and K. Matsushima: “A new high-resolution printer for digital synthetic holograms” in Japanese, The Institute of Image Information and Television Enginners **58**, 1665-1668 (2004).

[2] H. Yoshikawa and M. Tachinami: “Development of direct fringe printer for computer-generated holograms”, SPIE Proc. **5742**, 5742-33 (2005).

[3] K. Matsushima and S. Nakahara: “Extremely High-Definition Full-Parallax Computer-Generated Hologram Created by the Polygon-Based Method”, Appl. Opt. **48**, H54-H63 (2009).

[4] M. Yamaguchi, N. Ohyama, and T. Honda: “Holographic three-dimensional printer: new method”, Appl. Opt. **31**, 217-222 (1992).

[5] T. Yamaguchi, O. Miyamoto and H. Yoshikawa: “Volume hologram printer to record the wavefront of three-dimensional objects”, Opt. Eng, 51, 075802 (2012).

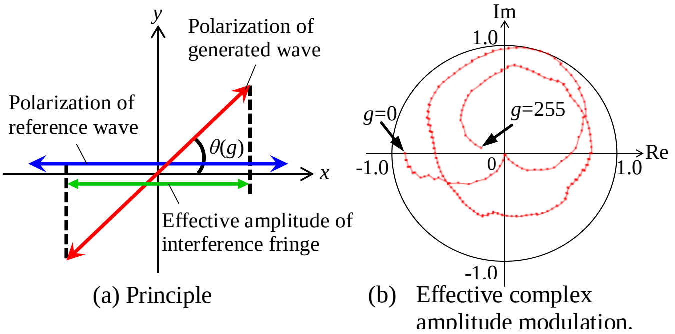

Fig. 2 Complex amplitude modulation by the phase-only SLM.

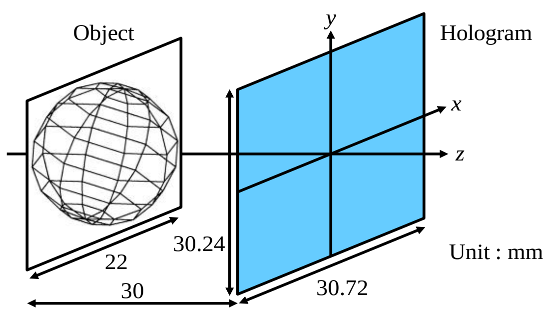

Fig. 3 The 3D scene of the test CGH.

Table 2 Parameters used for printing volume CGH.

Number of total pixels	30,720×30,240pixel
Effective pitches	1.0×1.0μm
Size of hologram	30.72×30.24mm^2
Number of pixels of a tile	1,920×1,080pixel
Number of tiles	16×28
Wavelength	488nm
Center position of the object	(0, 0, −30)mm

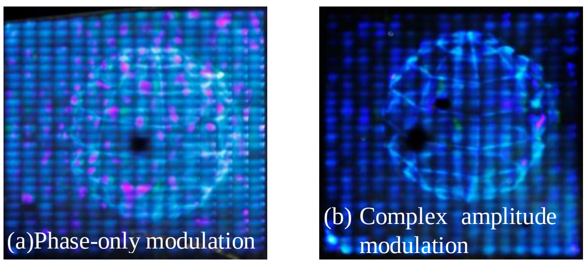

Fig. 3 Optical reconstruction of the CGHs by white light illumination.