Hexa-petal Antenna for Complex Spatial Light Modulation

Jonghyun Lee, Sungjae Park, Shin-Woong Park, and Hwi Kim*
Department of Electronics and Information Engineering, Korea University, 2511 Sejong-ro, Sejong 30019, South Korea
E-mail: hwikim@korea.ac.kr

1. Introduction

Digital holography is a technology that can recognize for us hologram of three-dimensional (3D) object. If we observe a noise-free reconstructed image, it is required to modulate simultaneously amplitude and phase for single pixel of computer generated hologram (CGH). However, conventional design technique of holographic display has an issue that occurs low quality and significant noise because it can modulate only one element such as amplitude-only or phase-only. Recently, for solving this issue, meta-surface technology has been researched and developed, which is able to control complex spatial light modulation by structural specification [1-3]. In this study, we propose a new pixel design that is able to modulate simultaneously amplitude and phase. Also, we analyzed characteristics of complex modulation of unit-pixel using wave optical simulations. Based on this results, we verified increasing a quality of reconstructed image for low noise hologram.

2. General Instructions

We apply the three-phase amplitude method to the proposed design, which one complex value can be represented by a summation of three fixed phases and controllable amplitudes given by Eq. 1.

$$Ae^{j\phi} = A_1 e^{j(0)} + A_2 e^{j\left(\frac{2}{3}\pi\right)} + A_3 e^{j\left(\frac{4}{3}\pi\right)} \qquad (1)$$

In Fig. 1(a), the proposed design is constructed to three rods rotated by $2\pi/3$ for origin, and we define it to hexa-petal antenna. The amplitude of each rod can be controlled by changing width or length.

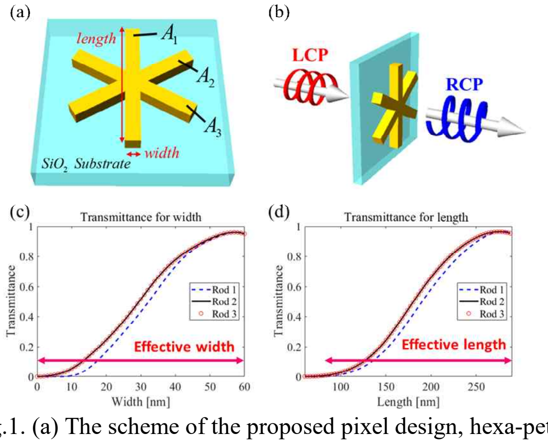

Fig.1. (a) The scheme of the proposed pixel design, hexa-petal antenna and (b) modulated component by circular polarizer, simulation results for effective range of (c) width and (d) length

As shown in Fig. 1(b), hexa-petal antenna modulates a component of cross polarization for circular polarizer. In order to verify the characteristic of complex modulation, we analyzed effective range of width or length for amplitude using Fourier Modal Method (FMM) based on rigorous coupled wave analysis (RCWA) in Fig. 1(c) and (d). For each case of width and length, effective ranges are given from 0 nm to 60 nm and from 60 nm to 290 nm. Figure 2(a) is represented to diffraction pattern designed for hexa-petal antenna, based on the above effective range. It is shown in Fig. 2(b) that the reconstructed image has low noise and high quality on the far field.

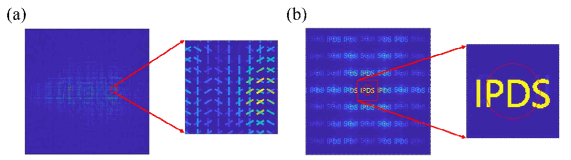

Fig.2. (a) Diffraction pattern designed for hexa-petal antenna, (b) reconstructed image for (a) of the far field

3. Conclusions

Contrary to the conventional design, the proposed pixel structure was designed by three-phase amplitude method to control simultaneously amplitude and phase. To verify the new design, we analyzed the characteristic of complex spatial light modulation for unit-pixel on the near field. Also, it is confirmed that the diffractive patterns designed for hexa-petal antenna has an advantage reconstructing a high quality image with low noise on the far field. As our new pixel design implement an ultra-low noise hologram, it can construct a compact optical system and it is our ultimate goal. The proposed pixel design can be expected to develop to various holographic displays such as augmented reality (AR) and virtual reality (VR).

Acknowledgements

This work is supported by NRF-2019R1A2C1010243.

References

[1] G. Lee, et. al., "Complete amplitude and phase control of light using broadband holographic metasurfaces", Nat. Nanotechnol., 10, 42374245 (2018).
[2] X. Ni, A. V. Kildishev and V. M. Shalaev, "Metasurface holograms for visible light," Nature communication, Vol. 4, 2807 (2013).
[3] L. Liu, et. al., "Broadband metasurfaces with simultaneous control of phase and amplitude," Advanced materials, Vol. 26, Issue 29, 5031-5036 (2014).