Electrically-Controllable Fresnel Lens Based on Liquid Crystal

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Abstract: This study proposes an electrically-controllable Fresnel lens based on liquid crystals. A special design patterned electrode type and a homogeneous alignment sample cell has been fabricated to form a liquid crystals lens. The transmission light can be focused or defocused by varying the applied voltage. The focal length in this Fresnel lens is around 300 mm.

[Chi-Ting Horng, Mu-Hsin Chen, Chung-Hsin Liao, Shuan-Yu Huang. **Electrically-Controllable Fresnel Lens Based on Liquid Crystal**. Life Science Journal. 2012;9(1):474-476] (ISSN:1097-8135). http://www.lifesciencesite.com. 71

Keywords: Fresnel lens, liquid crystals

1. Introduction

Fresnel lens is highly appreciated because of its well known properties of long distance optical communication, large collecting aperture, optical interconnection, ease of replication, and additional degrees of freedom in correcting aberrations and three dimensional display systems [1-7]

Conventional Fresnel lens, fabricated by electron beam writing, has some limitations, such as a fixed focusing efficiency and narrow fabrication tolerance. However, liquid crystals (LCs) lens is a good candidate for a variety of applications in optics due to large birefringence and electrically-controllable focal length [1–3]. Because of simple fabrication processes and tunable optical properties, switchable LC Fresnel lenses have attracted considerable attention in research [4–7].

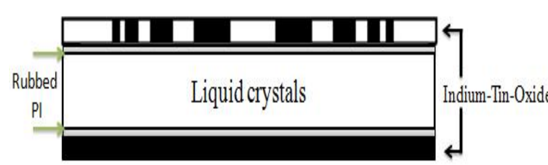
In this study, we demonstrated Fresnel lens based on liquid crystal. The diffraction efficiency of a liquid crystal Fresnel lens is electrically controllable, the focusing and defocusing states can be tuned by varying the applied voltage, and the focal length in this Fresnel lens is around 300 mm.

2. Experimental

Device Fabrication

Figure 1 schematically shows the procedure for fabricating the Fresnel zone plate in a homogenous-aligned LC cell. The zone plate photomask plays a key role in this work; it has transparent odd zones and opaque even zones. The concentric rings photomask within a diameter of 1 cm was used in this study as shown in Figure 1(a). Figure 1 (b) illustrates the schematic fabrication of the liquid crystal Fresnel lens.The radius r_m of the mth zone can be expressed as $r_m^2 = m\, r_1^2$, where r_1 is the radius of the inner zone. The primary focal length f is related to the inner radius r_1 as $f= r_1^2 / \lambda$, where λ is the wavelength of theincident beam. The LC E7 (Merck, n_o=1.5216, n_e=1.7462), are injected into the homogenous empty cell and the thickness of the cell is 12μm, forming a LC Fresnel lens.

(a)



(b)

Figure 1 (a) the concentric rings photomask (b) the schematic fabrication of the liquid crystal Fresnel lens.

Setup

Figure 2 shows the experimental setup for the focusing features of the liquid crystal Fresnel lens. The incident linearly polarized He–Ne laser beam of the wavelength 633 nm is expanded and then passes through a diaphragm and the LC Fresnel lens with an external applied voltage *V*. A photodiode is linked to a computer to measure the transmission intensity, in which another diaphragm D2 is placed in front of the photodiode.

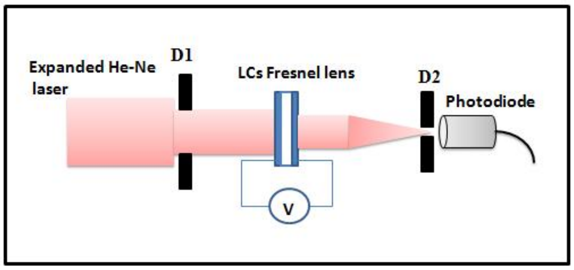


Figure 2 Experimental setup. D1, D2 are diaphragms

3. Results and Discussions

Figure 3 plots the variation of the transmission intensities at various applied voltage-controlled at 5 V , 7 V, 10 V, and 12 V. According to theoretical calculations, the theoretical focal length of approximately 300 mm, the transmission intenisity can be significant changed in the vicinity of this location as the voltage change. From Figures 3(a)-(b), the maxium transmission intensity maintains a stable level, the transmission intensity gradually decays as the applied voltage larger than ~10V as shown in Figures 3(c)-(d). The fringing effect at a higher voltage causes the bent electric field partially to reorient the LCs molecules, and degrades the Fresnel lens effect.

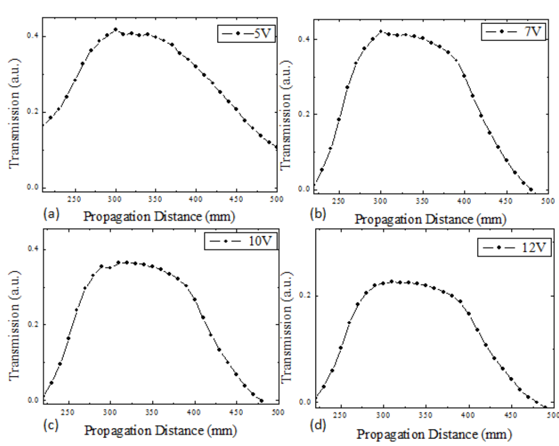


Figure 3 The variation of the transmission intensities at various applied voltage-controlled at (a) 5 V (b) 7 V(c)10 V (d) 12 V

Figure 4 plots the variation of the transmission intensities with varying the appled voltage at position 300 mm. The result shows the transmission light can be focused with a lower applied voltage, and gradually defocued as the applied voltage exceeds 7 V. In the appropriate voltage, Fresnel lens can be electrically tuned the focusing or defocusing state.

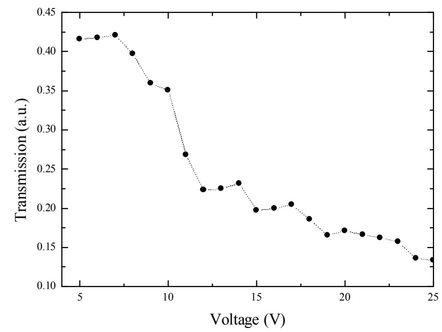


Figure 4 The variation of the transmission intensities with varying the applied voltage at position 300 mm.

4. Conclusion

In this study, we demonstrated a simple method to fabricate liquid crystals Fresnel lens. The focusing and defocusing states can be tuned by varying the applied voltage, and the focal length in this Frsenel lens is around 300 mm.

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2/2/2012