P-150: Tunable Liquid Crystal Lens by Spatially Controlling of Pretilt Angle

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Abstract:

Stacked alignment layer (SAL) with both vertical and horizontal alignment materials are used to control the liquid crystal (LC) pretilt angle. When one alignment material in SAL is photoalignable, the pretilt angle can be controlled by UV exposure dosage. A tunable LC lens is achieved by exposing the SAL under UV laser.

1 Objective and background

Currently there is increasing interest on liquid crystal lens with electrically tunable focal length [1-5]. Compared with the conventional mechanical lens system, which consists of group of lenses with focal length adjusted by mechanical changing of distance between lenses, the LC lenses are low weight, low cost and efficient. There are many different ways of fabricating LC lens, such as using non-uniform thickness of electrode to induce non-uniform electric field [1][2], using patterned electrode to induce non-uniform electric field [3], controlling pretilt angle spatially by rubbing density [4], and printing UV curable glue on top of alignment layer [5] etc.

In this paper, we reported a way of fabricating LC lens by using stacked alignment layer to induce spatially variable pretilt angle. Comparing with the previous methods, our method is simply in experiment process and can fabricate different size of both cylindrical and circular LC lens.

2 Methods

Stacked alignment layer is used to obtain spatially variable pretilt angle. The surface of SAL is discontinuous with two different domains which generate horizontal and vertical alignment respectively. The model for the inhomogenous alignment surface is shown in figure 1. An intermediate pretilt angle will be generated by this inhomogenous structure and it is decided by the domain ratio: $p = \lambda_V / (\lambda_V + \lambda_H)$. The average pretilt angle θ_{AV} induced by the inhomogeneous alignment surface can be approximated by [6]:

$$\theta_{AV} = p\theta_1 + (1 - p)\theta_2 \tag{1}$$

That means the average pretilt angle is almost linear relating with the domain ratio. This is the principle we use to control the pretilt angle by changing the domain ratio. To form the inhomogeneous structure, stacked alignment layer is used, with discontinuous photoalignable homogeneous polyimide ROP-103 on top of the continuous vertical polyimide JALS2021. The UV variable light dosage is used to control the domain ratio.

The experiment process for fabricating LC lens is shown in Fig. 2. In step 1, a vertical alignment polyimide JALS2021 from JSR Corporation was spin-coated on both top and bottom of the ITO glass substrates. Then it was baked and rubbed. In step 2, a photo-alignment material ROP-103 was spin-coated on top of the polyimide layer for preparing the bottom substrate. Then it was exposed under UV laser (325nm). The polymerization level of the ROP-103 material is related to light intensity and exposure time. Since the UV laser spot have spatially distributed Gaussian profile, the center of the light spot have the largest light intensity. So in the center of the laser spot, the material was polymerized more. In step 3, the solvent cycle-hexagon was used to rinse the un-polymerized material. Then a discontinuous ROP-103 layer was formed. In step 4, the top and bottom substrates were placed in an anti-parallel rubbing direction of the vertical alignment layer and then filled with liquid crystal (E7).

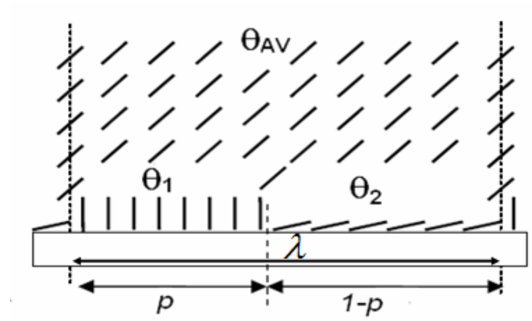

Figure 1. Model for In-homogenous alignment surface

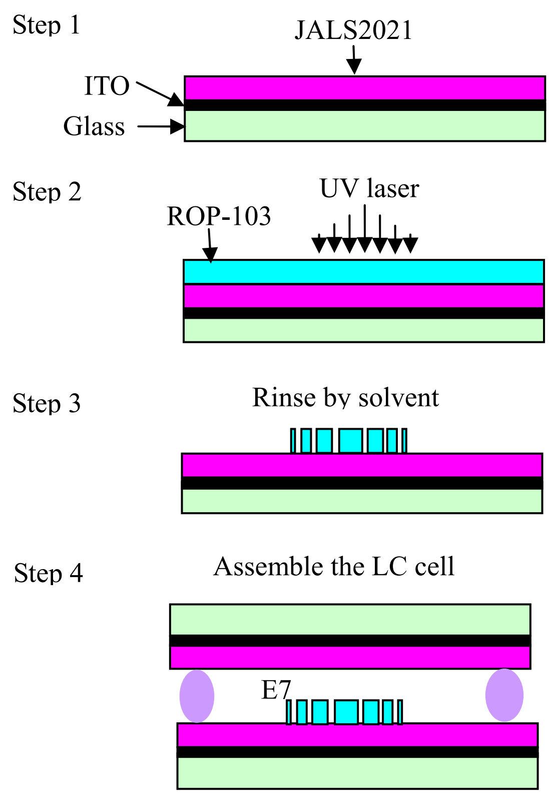

Figure 2. Experiment process to fabricate LC lens

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3 Results

To test the LC lens, the sample cell was put between two crossed polarizers. The rubbing direction of the bottom substrate is at 45° to both polarizers. Green light of 530nm was incident from one side of the polarizer and passed through the LC cell and imaged by a microscope camera. A 1 kHz AC voltage source was used to drive the LC lens. The transmittance of the LC cell is given by

$$\mathrm{T} = \sin^2\left(\frac{\pi d \Delta n}{\lambda}\right) \tag{2}$$

Fig. 3 shows photographs of the cell at different voltages. The brightness of the photo represents the transmittance, which can be used to calculate the phase profile of the LC lens. The 2D phase profile is shown in fig. 4 and 3D phase profile is shown in fig. 5. A parabolic approximation was used to fit the retardation profile. It was found that within the radius range of 0.45mm, which was the diameter of the light beam, the retardation profile could be fitted very well. Then according to the retardation profile, focal length in different voltage could be calculated out, as shown in fig. 6. It can be seen that when there is no voltage applied, the focal length is 19cm. The focal length is tunable from 19cm to infinite by applying a voltage to the lens.

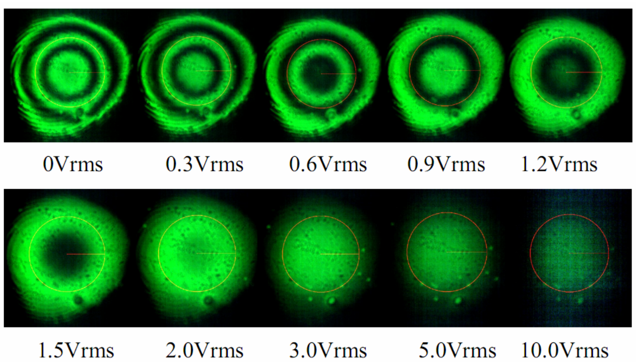

Fig. 3. LC lens with different voltage

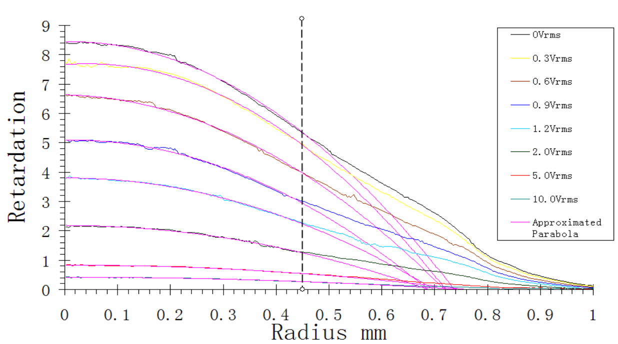

Fig. 4. 2D phase profile in different voltage

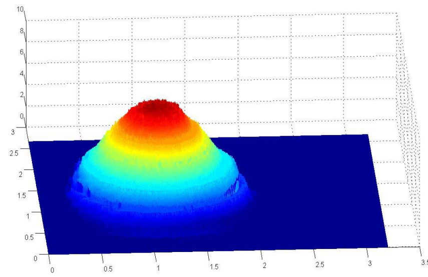

Fig. 5. 3D phase profile without voltage

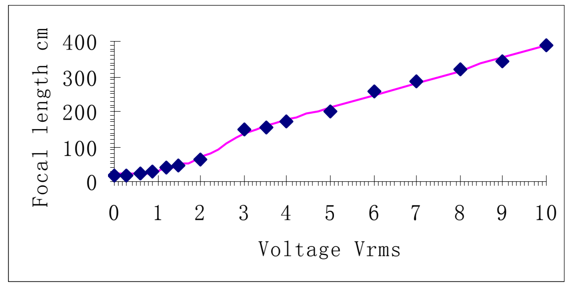

Fig. 6. Relation between voltage and focal length

4 Acknowledgments

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5 Reference

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