Polarizer-free Liquid Crystal Devices

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Abstract

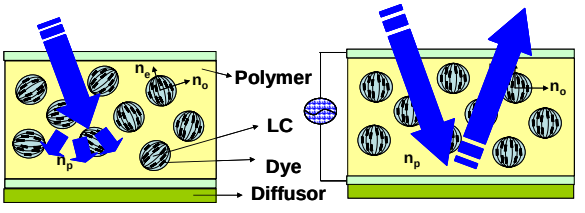
Liquid crystal (LC) devices can be operated as amplitude modulators and phase modulators. They usually require two polarizers; therefore the optical efficiency is limited. We introduce two general principles of polarization-free liquid crystal devices and also show several LC devices by applying the principles.

1. Introduction

LC amplitude modulation is commonly used in liquid crystal display (LCD) while phase-only modulation is useful for laser beam steering, tunable grating, prism, lens and other photonic devices. Most LC device usually require two polarizers, so the optical efficiency is low. Besides demonstrations of several polarization independent phase and amplitudemodulators [1-9] we introduce the general principles of polarizer-free LC devices.

2. Polarizer-free LCD (amplitude modulators)

In order to achieve good black and white state for polarizer-free LCD, principles we can use for obtaining polarizer-free LCD: dye-absorption, scattering, and mixing of absorption and scattering. Dye-doped scattering type polarizer-free LCD has been demonstrated using dye-doped polymer dispersed liquid crystals (PDLC) and dye-doped LC gels, as shown in Fig. 1 and 2.[1-3]

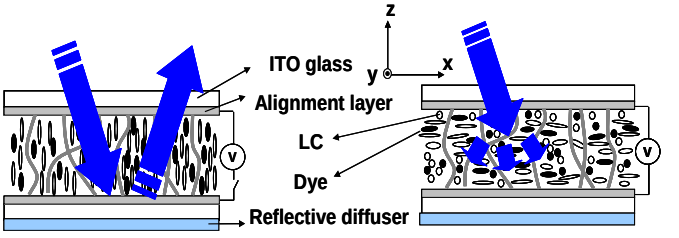


(a)

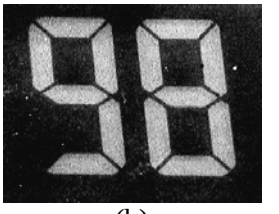
(b)

Fig. 1. (a) Dye-doped polymer dispersed liquid crystals. (b) The displayed image using dye-doped polymer dispersed liquid crystals.

In dye-doped LC gels, the LC directors and dye molecules are along x-y plane at the voltage -on state. Therefore, dye-doped LC gels have better contrast ratio~200:1 because the scattering and dye absorption can reach their maximal. Both of dye-doped PDLC and dye-doped LC gels are polarization-independent



(a)



(b)

Fig. 2. (a) Dye-doped LC gels. (b) The displayed image using dye-doped LC gels.

3. Polarizer-free LC phase modulators

Two types of polarization independent phase modulations are discussed as follows. The first example is residual phase type of LC phase modulators [4-6]. In the voltage-off state we can arrange all the LC directors to have the same tilt angle at random positions as shown in Fig. 3. When an unpolarized light propagates into the LC cell, the average refractive index depending on the tilt angles is the same for all the polarizations. Therefore, it is polarization independent. Three residual type LC phase modulators using polymer stabilized cholesteric tectures (PSCT), polymer-dispersed liquid crystal (PDLC), and LC gels are shown in Fig. 3.

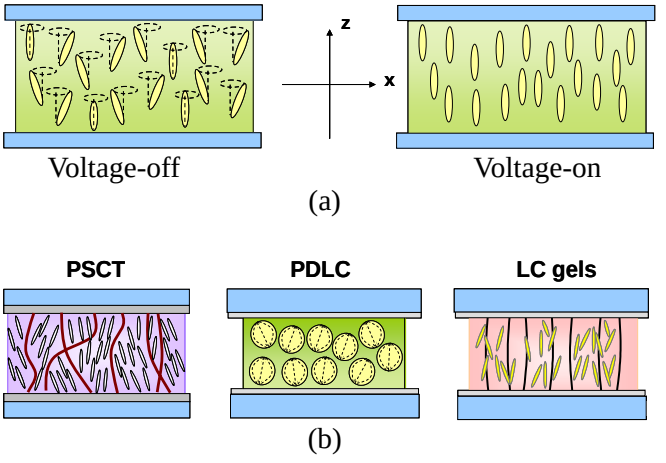


Fig. 3. (a)Residual phase type of LC phase modulators at voltage-off state and voltage-on state. (b) Residual phase type LC phase modulators by using PSCT, PDLC, and LC gels.

Another design to achieve a polarization independent phase modulator is to stack two layers together [7-9]. Two identical LC cells, such as two homogeneous cells, are stacked together in orthogonal directions. An unpolarized light can be decomposed into two orthogonally linear polarizations. After propagating through the two LC layers, both polarized lights experience the same phase change. Therefore the output polarization remains the same. Two double-layered type phase modulators using thin polymer separated structure and double LC gels are shown in Fig. 4. [7-8].

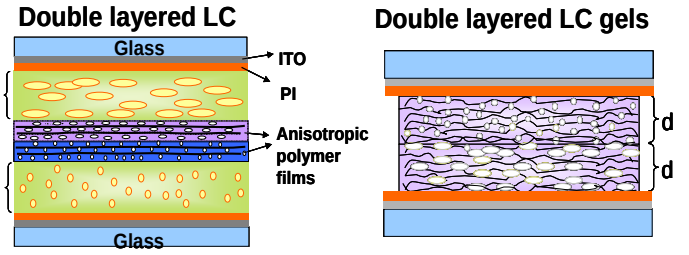


Fig. 4. Doubled-layered type LC phase modulators using double layered LC and doubled LC gels.

4. Summary

We introduce two general principles of polarization-free liquid crystal devices. We also have demonstrated two polarizer-free LCDs and the two types of polarization independent liquid crystal phase modulations: residual phase type and double-layered type. Without polarizers, the light efficiency of LCD is higher and viewing angle is wide. Polarizer-free LC phase modulators improve the light efficiency. They are also important for the tunable focus LC lenses, microlense/lens arrays.

5. Acknowledgements

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6. References

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