

# A Volumetric 3D Display System Based on Coded-Multiplane PDLC

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## Abstract

In this paper, we present an optically transparent multi-planar 3D display device based on multi-passive matrixed coded pixelated polymer-dispersed liquid crystals (PDLC). The PDLC film used in this experiment has high transparency transmission (97.1%) and fast switching time characteristics within 20ms. We provide a method to display different depth-of-field images by layering them on a multi-layer screen, by which it is possible to render near and far views in different planes, thus bringing 3-dimensional visual information to the observer, ultimately A proof-of-concept prototype of a dual-plane 3D display has been realized.

**Keywords:** Volumetric Display; Multi-plane display; Pixelated PDLC

## 1. Instruction

In recent years, display systems for augmented reality (AR) have developed rapidly in recent years and their applications are becoming increasingly widespread [1, 2]. Among many three-dimensional display technologies, multi-plane volumetric three-dimensional display is a candidate technology. By using the advantages of mature two-dimensional display technology, three-dimensional images can be displayed with an acceptable computational load. Multi-plane volumetric 3D display is considered to be a true 3D display because it can construct a 3D scene with correct depth information. In order to achieve multi-plane 3D display, many methods have been proposed [3-7]. For example, Hua et al. designed a multi-focal plane HMD using a liquid lens [7]. The same research team later implemented a six-sided HMD running at 60 Hz using fast DMMD [4]. Lin et al. proposed a zoom surface using a liquid crystal lens [6]. Wu et al. proposed a polarization converter based on fast switching and a polymer-based stabilized cholesteric scattering film [8].

In this design, we can realize 3D display on a 2-dimensional plane by programmable pixelated PDLC plane. We use pixelated PDLC and projector to test the feasibility of the theory. In order to achieve a fast switching projection on the pixelated PDLC, it is first necessary to achieve a precise control of each unit of the PDLC.

## 2. Simulation model

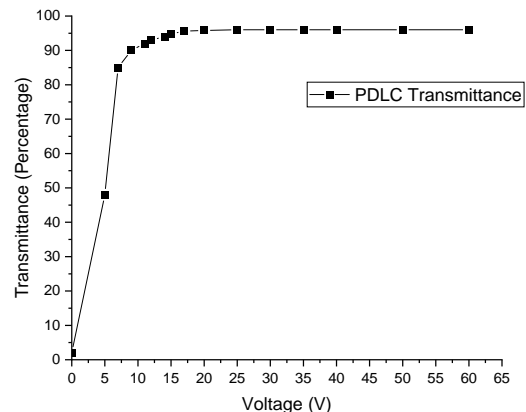
By coding and controlling the passive matrix PDLC on different planes, it is possible for the human eye to see patterns with different depths of field on different planes, as shown in Fig. 1., thus achieving the effect of naked eye 3D. Firstly, to achieve collimated and homogenized light, we build model, simulate and optimize a uniform lighting

system. Then we use pixelated PDLC and projector to test the feasibility of the theory. As shown in Figure 1, our system is divided into two main components: projector and multi-planar Pixelated PDLC.



**Fig. 1.** System scheme of the multi-plane optical see-through volumetric 3D display system.

Two pixelated PDLC screen are introduced in the design in this paper. The two different surfaces can be used to display objects with different depths of field, thus achieving a naked eye 3D effect. The specific properties of the PDLC used here are as follows. The correlation between transmittance and voltage is shown in the Fig. 2.. The transmittance is able to reach over 90% after exciting voltage of 10V and to reach a haze of 98% when no external voltage is applied.



**Fig. 2.** Voltage-Transmittance curve of pixelated PDLC

To control two passive matrix based PDLC, FPGA based aligned-system is introduced here. Each PDLC unit has high resistance and high capacitance, so the FPGA cannot directly drive it. To solve this problem, we design an amplifier circuit

and test its capability as shown in Fig. 3(a).

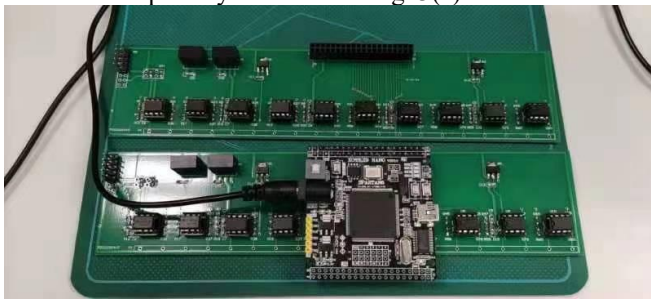
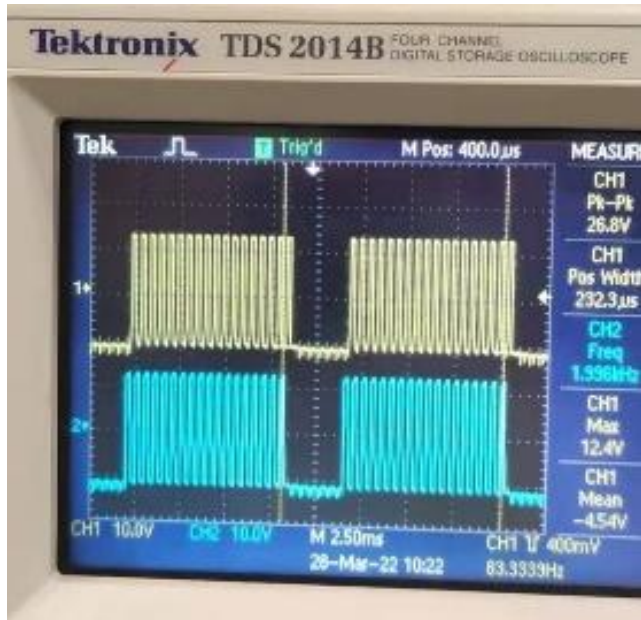


Fig. 3. (a)FPGA based amplifier system



(b) Modulated signals

In order to make sure each unit is individually adjustable, modulated signals is designed as in Fig. 3(b).On this basis, each PDLC unit will have three states, positive voltage, negative voltage, and a high impedance state.

### 3. Experimental results

To test the ability of the FPGA code to control the pixelated PDLC screen, different patterns were selected for testing, as shown in Figure 4.



Fig. 4. Three FPGA based patterns of PDLC screen

The results in Figure 4 show that the FPGA designed in this paper is able to drive the PDLC's screen very well and enables precise control of each unit. The same control is loaded on both PDLC screens and the clocks are synchronized aft

er several simulations. As shown in Fig. 5, the two screens successfully passed the alignment-coupling test and were able to achieve a depth of field on a flat surface at a certain angle.



Fig. 5. Coupling of two Pixelated PDLC screens

In order to achieve a contrast between the two depth-of-field effects, two identical patterns are projected onto this Pixelated PDLC display plane, as shown in Fig. 6. Under the control of two different programs, the one in Fig. 6a achieves the effect of the left-hand pattern in front of the right-hand one, while Fig. 6b achieves the effect of the right-hand pattern in front of the left-hand one.



Fig. 5. (a) Left pattern in front of right



Fig. 5. (b) right pattern in front of left

#### 4. Conclusion

In this paper, we have designed an optically transparent multi-planar 3D display device based on coded pixelated PDLC plane. The PDLC film used in this experiment has a high transparency transmission (97.1%) and fast switching time characteristics within 20ms. On this basis we propose a method for displaying images with different depths of field in layers on a multi-layer screen, by which near and far views can be presented on different planes, thus giving the observer three-dimensional visual information and finally realizing a proof-of-concept prototype for a two-plane 3D display.

#### 5. Acknowledgements

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