High Optical Performance of 7" Mini-monitor Based on 2D-3D Convertible Autostereoscopic Display

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Abstract

We have developed a 2D-3D convertible 7" autostereoscopic mini-monitor with high 3D quality, in which the parallax barrier LCD is attached on the TFT-LCD. The excellent optical performance was achieved by design of the ghost free barrier and precise assembly between the barrier layer and the TFT-LCD panel. Our design principle and fabrication technology suppressed 3D cross-talk and improved viewing angle. In this paper, the design and fabrication process of the 3D mini-monitor are described. The evaluation for the 3D performance is also discussed.

1. Introduction

Autostereoscopic displays with the parallax barrier were fabricated by assembly of two liquid crystal display (LCD) panels. Figure 1 demonstrates the operational principle of the 2D-3D convertible display. By switching the barrier layer, 2D image is changed into 3D image or vice versa.

Recently, the 3D market is opened and autostereoscopic displays begin to be commercialized. Though products of the 2D-3D convertible display emerge in the market, the image quality does not satisfy the consumers' needs such as cross-talk free and good viewing angle characteristics. The application of the 2D-3D convertible display using parallax barrier for two views is limited to small size.

In this paper, we introduce our autostereoscopic display, which is suitable for sub monitor. Since the 7" mini-monitor with excellent optical performance is connected to the main monitor by USB, a separate power supply is not required.

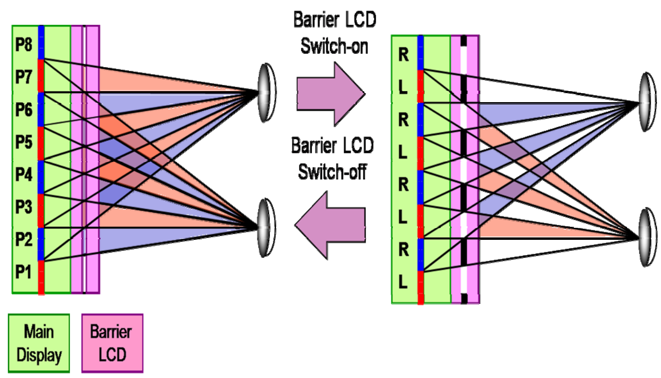


Fig. 1. Autostereoscopic 2D-3D convertible display.

2. Fabrication of 3D mini monitor

3D displays performance is significantly dependent on the design of the optical configuration. For the excellent optical performance, parallax barrier was designed by optimizing the pixel pitch and the thickness of both the TFT LCD and barrier LCD, including the thickness of the polarizer.

The design principle of the parallax barrier is represented in Fig. 2. The actual visible position is not D' but D, because the refractive index is different from the surrounding medium. The viewing distance, D is calculated by Snell's law. So the D was indicated D' divided by the refractive index.

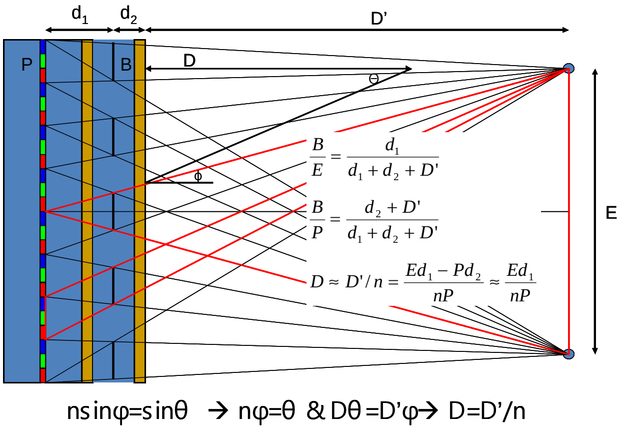


Fig. 2. Design principle of the parallax barrier.

We describe the fabrication process of the parallax barrier attached on the TFT LCD. We first start to explain the specification of each panel. In this parallax barrier, the angle between the transmission axis of the crossed polarizers and the rubbing direction of the LCD was 45 degrees. The driving voltage of 3.5 V with 120Hz for a second was applied to the parallax barrier LCD, the cell gap of which was 5um and the viewing direction was 6 o'clock.

The 3D LCD module was fabricated by assembling the TFT-LCD panel and the barrier layer using the align key. The 5 um spacer was spread on one side of the panel to maintain the gap between two panels. Two panels were attached by a small amount of sealant. Figure 3 shows the fabricated 7" LCD module.

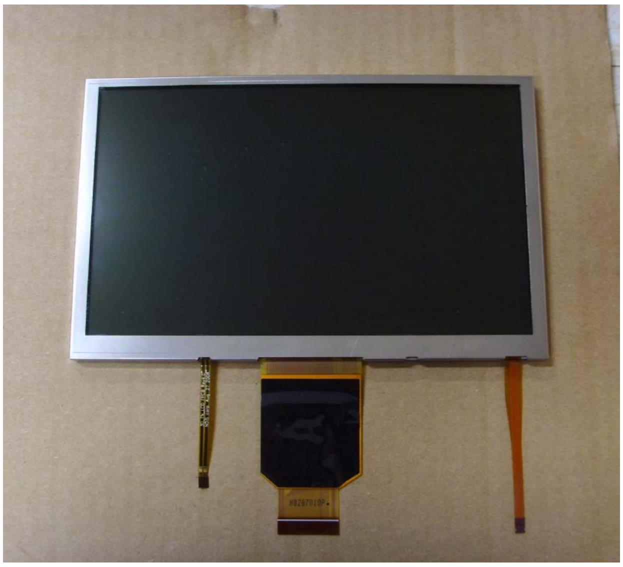


Fig. 3. Fabricated 7" 3D LCD module

3. Optical characterization of 3D displays

We measured the optical characteristics of the fabricated autostereoscopic display by the EZ contrast (ELDIM, France) based on the conoscopic method. We measured the 3D viewing angle characteristics [1-8] in which the focal length and spot size were 1 mm and 2 mm, respectively.

TABLE 1. Optical characterization items of the 3D image quality

No.	Item	Equation
1	X3D min. angle. (°)	$\chi_{3D1}(\theta) = \frac{Y_{3D2}(\theta) - Y_{3DK}(\theta)}{Y_{3D1}(\theta) - Y_{3DK}(\theta)}$
	Crosstalk (%)	
2	3D luminance (cd/㎡)	$Y_{3DW} = \frac{1}{\#of\ views}\sum_{i=1}^{\#of\ views} Y_{3DW}(\theta_i)$
3	3D contrast ratio (:1)	$CR_{3D} = \frac{1}{\#\ of\ views}\left(\sum_{i=1}^{\#\ of\ views}\frac{Y_{3DW}(\theta_i)}{Y_{3DK}(\theta_i)}\right)$
4	OVD (mm)	$OVD = \frac{IPD}{2 * \tan\frac{\theta_2 - \theta_1}{2}}$

The Optical characterization items of the 3D image quality can be represented by the crosstalk, 3D luminance, contrast ratio, and optimum viewing distance, which are shown in table 1. One of the most important aspects in the evaluation of the autostereoscopic display is the crosstalk. The 3D crosstalk represents leakage of the needless image data projected to the viewpoint [9]. The crosstalk can be recognized as blur or double images and it causes visual discomfort.

The crosstalk minimum angle (X_{3Di}) for each of the view can be derived from the crosstalk profile. The crosstalk for the view can be calculated by the first equation in table 1 [1]. The optical characteristic of 7" 3D LCD module is evaluated by the luminance profiles of each view (Y_{3D1}, Y_{3D2}), the full black state (Y_{3DK}), and the full white state (Y_{3DK}). Therefore we can easily calculate the optical characteristics by these equations, such as the luminance of horizontal viewing angle.

4. Results and discussion

From the measured results, we have obtained optical characteristics of our autostereoscopic display. Figure 4 shows the luminance profiles for each of the views (WB and BW), the full black state (BB), and the full white state (WW).

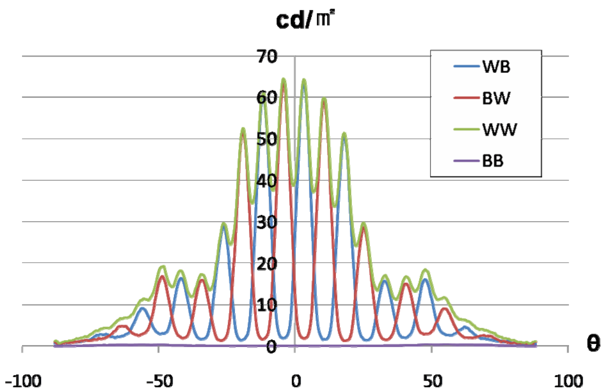


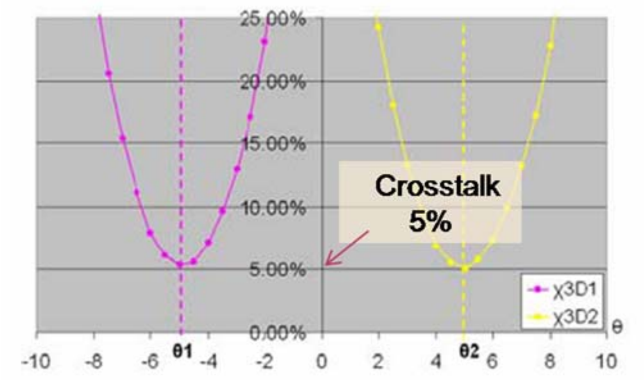
Fig. 4. Luminance profile of 7" mini-monitor

Firstly, we focus on the analysis of the crosstalk profiles of our fabricated 3D LCD module. The measured crosstalk was compared with that of conventional 3D mobile display shown in Fig. 5.

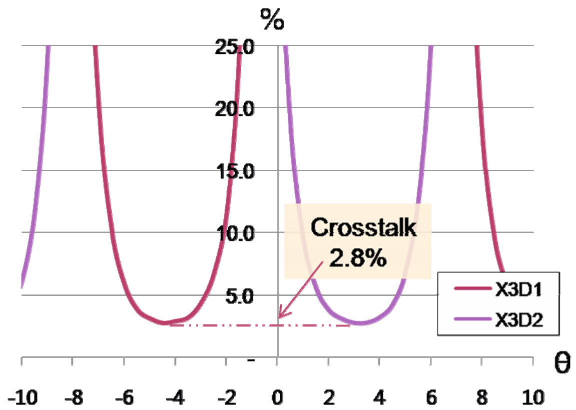
The crosstalk of the mini-monitor was about 2.8% while the crosstalk of the conventional display was about 5% as shown in Fig. 5. Our novel design principle and fabrication technology dramatically suppressed the crosstalk and remarkably improved the 3D image quality.

TABLE 2. Specification of 7" mini-monitor

3D specifications		
Views		2 view
Distance		505 mm
2D specifications		
Display	Screen size	7" wide
	Resolution	WVGA(800 X 480)
	Brightness	350 cd
	Contrast	400:1
	Color	16.7M
Signal Input	Video	USB2.0 high speed
	Connector	USB mini type
Power Input		USB DC 5V 500mA
Dimension (W x L x H)		197 X 97.5 X 180 ~ 209mm



(a)



(b)

Fig. 5. 3D Crosstalk profile of (a) 2.4" typical 3D display, and (b) 7" 3D mini-monitor.

Each specification for 2D and 3D performance of the 7" mini-monitor was represented in table 2. The 3D display specification includes the optimum viewing distance or viewing zone, which are unique characteristics of the 3D display comparing to the 2D display. They are the most important factors in the 3D display that determine the optimized location of the observer.

We designed the optimum viewing distance as 505mm, which is appropriate distance for the sub-monitor. The measured distance was 480 mm, because of the uncertainty of the measurement system. The deviation value of the viewing distance caused by the accuracy of the equipment resolution is not so large [10].

5. Summary

We have optimized the optical configuration of the barrier layer to reduce the ghost and 3D LCD module was fabricated by assembling the TFT-LCD panel and the barrier layer. Our novel design principle and fabrication technology suppressed the crosstalk and remarkably improved the 3D image quality. Since the 7" mini-monitor can be connected to the main monitor by USB, a separate power supply is not required. Our results indicate that it is natural to expect application area of the 3D mini-monitor would extend to multimedia, photograph, movie, game, medical, advertisement applications and so on.

6. References

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