3D Display in Mobile Applications

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Abstract

SDI has been developing mobile 3D display for years. For mobile applications, we adapted parallax barrier method. We have developed auto stereoscopic swing 3D display in which people can 3D image in both portrait and landscape mode. Furthermore to increase 3D resolution, we have developed a high resolution 3D display using time division multiplexing parallax barrier method

1. Objectives and Background

Most of developments of display are driven by trying to realize the natural view. With this achievements, high resolution, full color, three-dimensional (3D) display will be popular and strong display in the near future.

For successful 3D display market, some conditions must be met for example, natural view, wide viewing zone, high 2D quality, amount of 3D contents, 2D/3D conversion etc Mobile display is better than TV or monitor in these conditions. So we think mobile 3D display will be available first in 3D display market. For this reason, we have developed mobile 3D display.

Among various technologies for 3D imaging the auto-stereoscopic displays using a FPD (flat panel display) and an optical plate for making binocular disparity have been intensively developed in recent years. Regardless of the disadvantages such as eye fatigue and lower image quality, auto-stereoscopic displays are very promising for mobile applications because they are capable of generating 3D images without using special glasses. There are two main methods on auto-stereoscopic approach. One is using a lenticular lens and the other is using LC panel as a parallax barrier. The method using a lenticular lens has the advantage of the high brightness of 3D image but the disadvantage of the difficult switching between 2D and 3D modes electrically. On the other hand, the method using LC barrier has the disadvantage of low brightness but the advantage of the easy switching

2D/3D modes and simple structure.[1] Also LC barrier method shows the high 2D image quality. Therefore we focus on the method using LC barrier because 2D/3D convertibility and high image quality are most important issue for setting the trend without any market resistance.

The observer can recognize 3D image depth by binocular disparity.[2] Binocular disparity means the difference between two images through left and right eyes. Figure 1 shows the side view of the structure which is a LC barrier in front of FPD.[3] The pixels on FPD are divided into two groups for displaying left and right images. LC barrier have opaque and transparent parts in 3D mode. The light emitted from left image arrives to left eye of observer through the transparent part of barrier, but are blocked up to right eye by the opaque part of by barrier. So left eye can feel only left image emitted from left pixel and right eye can see only right image. The observer can perceive 3D image depth by the disparity out of separated two images. Because LC barrier is entirely transparent in 2D mode the observer doesn't discriminate between left and right images.
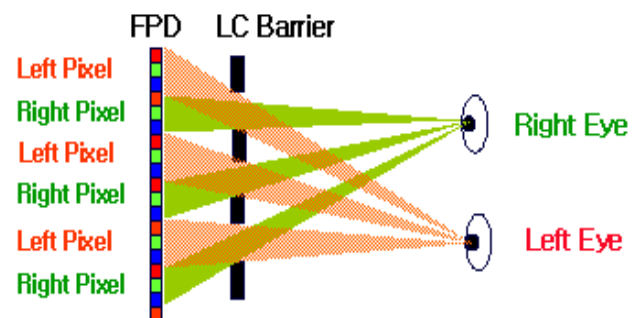

Figure. 1 Basic idea of parallax barrier method

2. Swing 3D Display

Recently many kinds of mobile phones and contents with 3D graphics are produced, and for many of them it is possible to swing the display part between portrait and landscape view. Therefore it is needed to develop the mobile 3D display that is working for portrait and landscape view simultaneously. For this purpose, we have suggested new 3D display with swing LC barrier. The shape of LC barrier in our swing 3D display is changed electrically according to the viewing mode. It is accomplished by optimum design of variable LC barrier and signal process for mode conversion. Figure 2 shows the swing 3D display.

(a) Portrait view   (b) Landscape view

Figure 2. Swing 3D display

We have used 2.2" TFT LCD as FPD imager with the resolution of QVGA (240*320*RGB). The viewing distance from the display to the observer depends on the pixel size of FPD and the gap between FPD imager and LC barrier. For proper viewing distance of 30~40 cm, left and right image parts on FPD is alternatively formed by pixel unit (3 sub-pixels unit). And the pitch of LC barrier is designed in order to converge left and right images on FPD into each eye of the observer at proper distance of 35 cm. We have aligned this LC barrier to front of 2.2" TFT LCD.

Figure 3. LC Barrier and 3D Module

The measured beam profile of left and right images is represented in Figure 4. The eye of observer must be located in the viewing zone area in the figure. The Observer can see 3D image more conveniently in landscape mode than portrait mode because color separation does not occur in landscape mode.

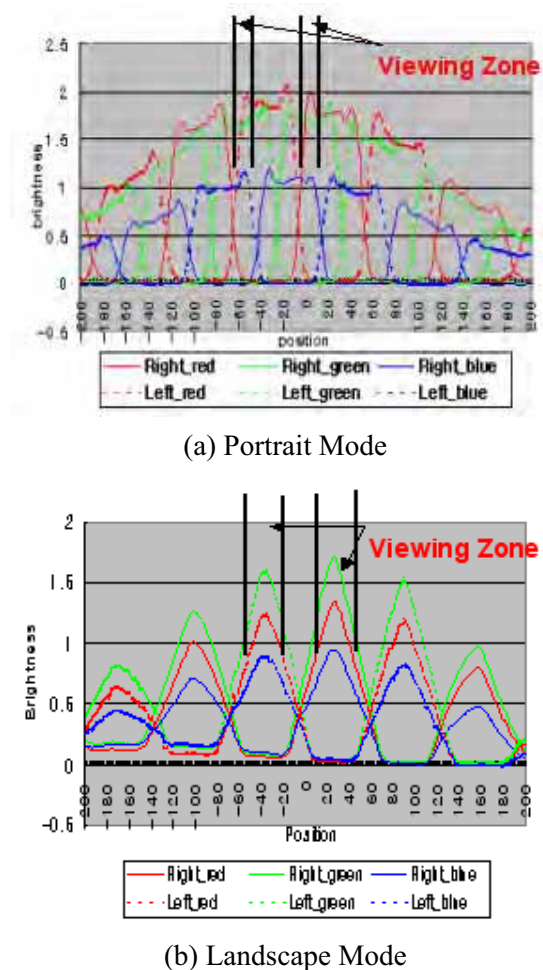(a) Portrait Mode

(b) Landscape Mode

Figure 4. Measured Beam Profile

The 3D brightness is proportional to slit ratio of barrier, but crosstalk is also proportional to slit ratio. So we cannot increase the slit ratio recklessly. To solve this low brightness problem, we controlled the current of light emitting diode (LED) in backlight. In 3D mode, we applied more current to LED than 2D mode, so we increased the 3D brightness without increasing the crosstalk. In this method we raised 3D brightness up to 80% of 2D brightness. Measured brightness in 3D mode was 150cd/m^2 and measured brightness in 2D mode was 180cd/m^2. Fig. 5 shows difference of brightness in each mode.
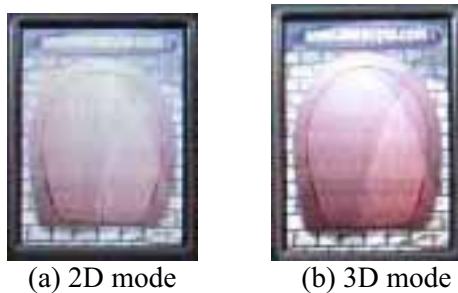
(a) 2D mode (b) 3D mode

Figure 5. Brightness characteristic

3. High resolution 3D Display

In LC parallax barrier method, however, display is divided into right and left part, and each eye can see only half pixels of display in horizontal direction, the 3D image resolution becomes half of 2D image resolution [1].

For high-resolution auto stereoscopic mobile 3-D display system. We suggest TD parallax barrier method. Fig 6 shows the principle of TD parallax barrier method.
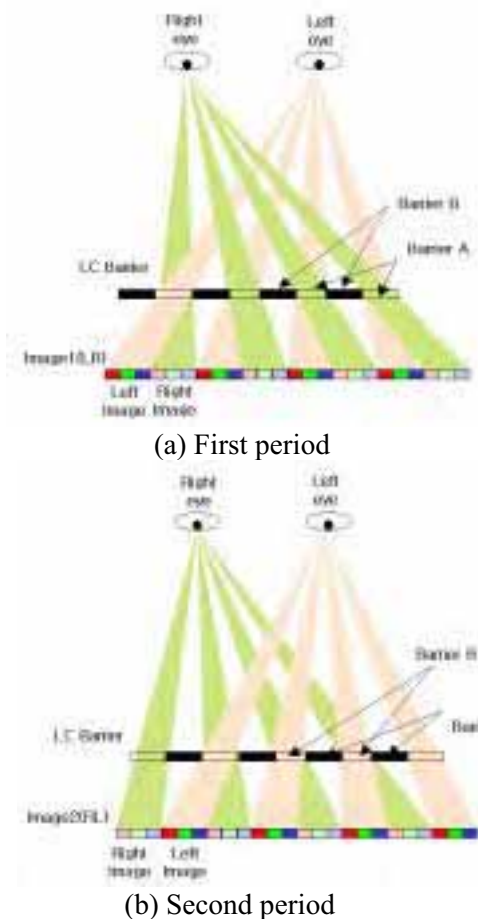

(a) First period

(b) Second period

Figure. 6. Time division parallax barrier

In this method, spatial division and time division are used simultaneously. For a first period, image1 (LR), where odd pixels have left image information and even pixels have right image information, is displayed, and LC barrier operates so that Barrier A is transparent and barrier B is opaque (barrier B On). So right eye can see right image at every even pixels and left eye can see left image at every odd pixels. Then for a second period, image2 (RL), where odd pixels have right image information and even pixels have left image information, is displayed, and LC barrier operates so that Barrier B is transparent and barrier A is opaque (barrier A On). So right eye can see right image at every odd pixels and left eye can see left image at every even pixels. These operations are repeated. As a result, each eye can see all pixels of display and 3D resolution is not degraded.

For this TD parallax barrier method, we need TD display system and TD LC barrier. Figure 7 shows the diagram of display system and LC barrier.

To prevent flicker, frame rate must be more than 120 frame/sec, so we set the each period to 1/120 second. But when each frame is refreshed, image is overlapped with previous image, and during that time we cannot see 3D image because two images are mixed. To solve this problem we have divided each period into two parts, overlapped image part (T1,T3) and pure image part (T2,T4), In overlapped image part(T1,T3), image1 and image2 are overlapped, so LC barrier block all light from display In pure image part(T2,T4), each pure image is displayed, and corresponding barrier become transparent. So, people can see 3D images. For this system we need faster frame rate more than 240 frame/sec.
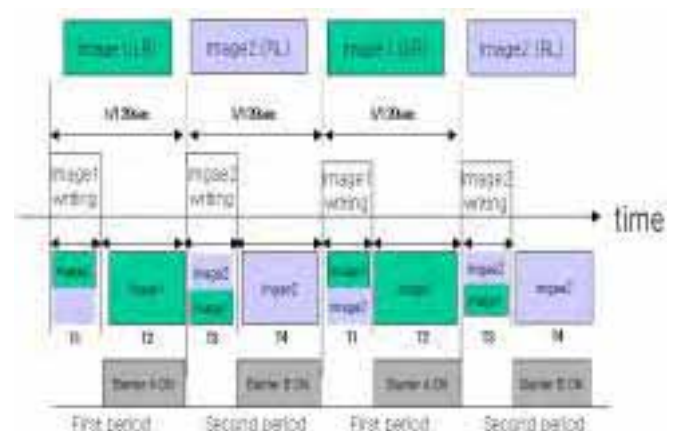

Figure. 7. Diagram for Display system and LC barrier

Another import point of TD parallax barrier method is fast LC barrier. In conventional parallax barrier method, response time of LC barrier is not important because LC barrier operates in static mode. But in TD parallax barrier method, LC barrier operates in dynamic mode so response time is very important. We turn LC barrier on or off at every 120Hz, so response time must be less than 5ms. We cannot use conventional Twisted Nematic(TN) LC barrier because response time of TN LC is usually more than tens milli-second. So we used LC barrier using Optical Controlled Birefringence (OCB) mode. The response time of manufactured OCB LC barrier is about 5ms.

To change barrier pattern with time, we adapted variable barrier pattern not static barrier pattern. Figure 8. shows design and fabricated OCB mode LC barrier and fabricated 3D display panel module.
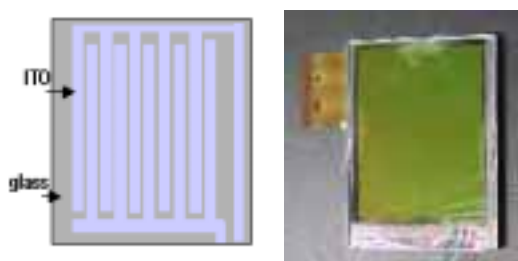
(a) ITO Pattern   (b) 3D display module
Figure. 8. ITO pattern and fabricated barrier

We applied this method to 2.2" QCIF and 4.3" WQVGA AMOLED panel. For a fast frame rate, we adapted AMOLED panel not TFT LCD panel. The maximum frame rate of QCIF panel that drive IC can support is 480 frame/sec and that of WQVGA is 360frame/sec.

Figure 9 shows the 3D images in TD parallax barrier method and conventional parallax barrier method. As you can see in figure, 3D resolution in TD parallax barrier method has been increased to 2D resolution. In contrast, 3D resolution in conventional barrier method is half of 2D resolution. Furthermore in conventional parallax barrier method, observers see moiré pattern like black stripe, but in TD parallax barrier method this moiré pattern is removed.

(a) TD Parallax Barrier

(b) Conventional LC Barrier
Fig. 9. Result of TD Parallax Barrier

4. Conclusion

We have developed 3D display for mobile applications. First, with auto-stereoscopic mobile swing 3D display system, people can see 3D images in both portrait and landscape mode. Second, observer can see 3D images with 3D resolution, which is same as 2D resolution without moiré pattern using high-resolution auto stereoscopic mobile 3D display system.

5. References

[1] I. Sexton,"Parallax barrier 3D-TV" in SPIE Proceeding Vol.1083, P84, 1989

[2] V. Grinberg, "Geometry of Binocular Imaging", Proc. Of SPIE, vol. 2177, pp56-65, February 1994

[3] G. Hamagishi, M. Sakata, "Stereoscopic LC Displays without Special Glasses", SID Digest, XXXI, pp75-78, May, 1995