A New Field Sequential Stereoscopic LCDs by use of Dual-Directional-Backlight

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Abstract

We have developed the Scan-backlight Stereoscopic LCD that is a kind of field-sequential -Stereoscopic LCD combining the Dual- Directional- Backlight and the fast-response OCB panel. The Dual-Directional-Backlight using a double-sided prism sheet can change the direction of light by switching the LED light sources. The OCB panel using Feed-Forward Drive can realize frame rate of 120 Hz. As a result, the Scan-backlight Stereoscopic display works at its original resolving power, and produces flicker-free stereoscopic images. This auto- stereoscopic display can resolved the problems of the double images and the pseudoscopic images in case of watching at oblique angles.

Keywords : LCD,Scan-backlight,Steroscopic,PseudoscopicImages,Flicker

1. Introduction

The performance of small LCDs for mobile phones and other portable electronics represents a remarkable improvement for fine definition and for improved color reproducibility. Another advances in LCD technology have created models that display stereoscopic images even to viewers who are not wearing special eyeglasses. The conventional stereoscopic LCDs adopt the lenticular method or parallax barrier method. However, the horizontal resolution of the conventional stereoscopic images drops to half that of two-dimensional images. Additionally, for viewers watching at oblique angles from the screen, these displays often present double images and pseudoscopic images, in which the concave portions appear convex, and the convex portions appear as concave sections.

We have developed a new Field Sequential Stereoscopic LCDs by combining the Dual- Directional- Backlight and the fast-response OCB panel with Feed-Forward Drive (FFD) technique.

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2. Scan-backlight Stereoscopic LCD

2.1 Concept

The depth perception depends heavily on binocular disparity that is the difference in the images arriving at the right and left eyes. The brain receives these different images, known as parallax images, and synthesizes them into a single image that gives the impression of depth.

In case of the Field Sequential Stereoscopic methods, the parallax images are displayed alternately and irradiated to the corresponding eyes. Fig. 1 shows the schematic image of the scan-backlight stereoscopic LCD combining the Dual- Directional- Backlight and the fast-response OCB panel.

The Dual- Directional- Backlight adopts two light sources on the rear portion. These light sources, which correspond to the viewer's left and right eyes, flash in

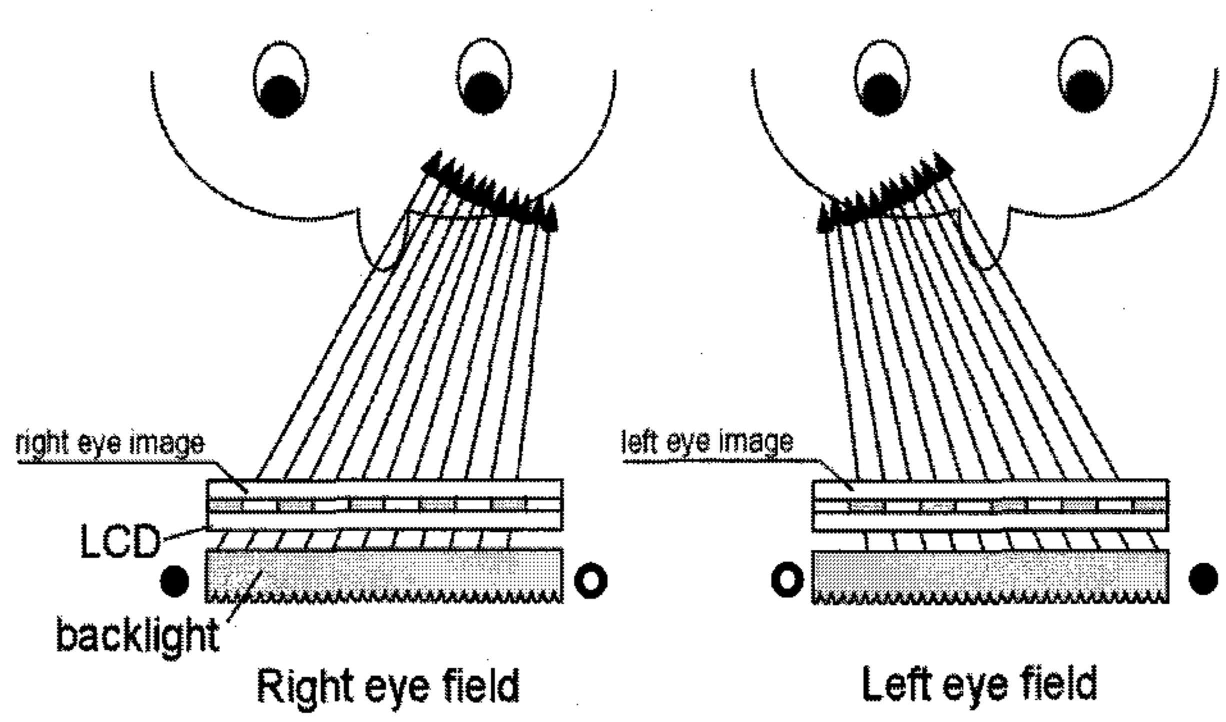

Fig. 1. Scan-backlight Stereoscopic LCD.

alternating sequence. In synchrony with their flashing, the fast-response OCB panel displays parallax images corresponding to the left and right eyes. The field rate is 120 Hz and frame rate is 60 Hz, meaning 60 flashes per second for each eye, which is same frame rate to the NTSC CRT-TV, so that it realize flicker free.

2.2 The Dual- Directional- Backlight

Fig. 2 shows schematic image of the Dual- Directional- Backlight. The backlight consists of a light-guide plate, two sets of four LEDs at both edges of light-guide plate, a reflection sheet and the double-sided prism sheet. Fig. 3 shows cross-section of the double-sided prism sheet that has TIR (totally inner surface reflection) line-prism and lenticular lens.

As shown in Fig.4, when the left-side LEDs are set on, the light ray from a light-guide plate progresses at the small angle to the front surface of the light-guide plate. The light ray incidents on surface A of the prism sheet and is reflected on the surface B. The reflected light ray incidents on the lenticular lens at point E. The focal point of the lenticular lens is set to the ridge of the TIR line-prism, so that the light progress only in the left direction. In the same manner, the light ray from right-side LEDs progress only in the right direction.

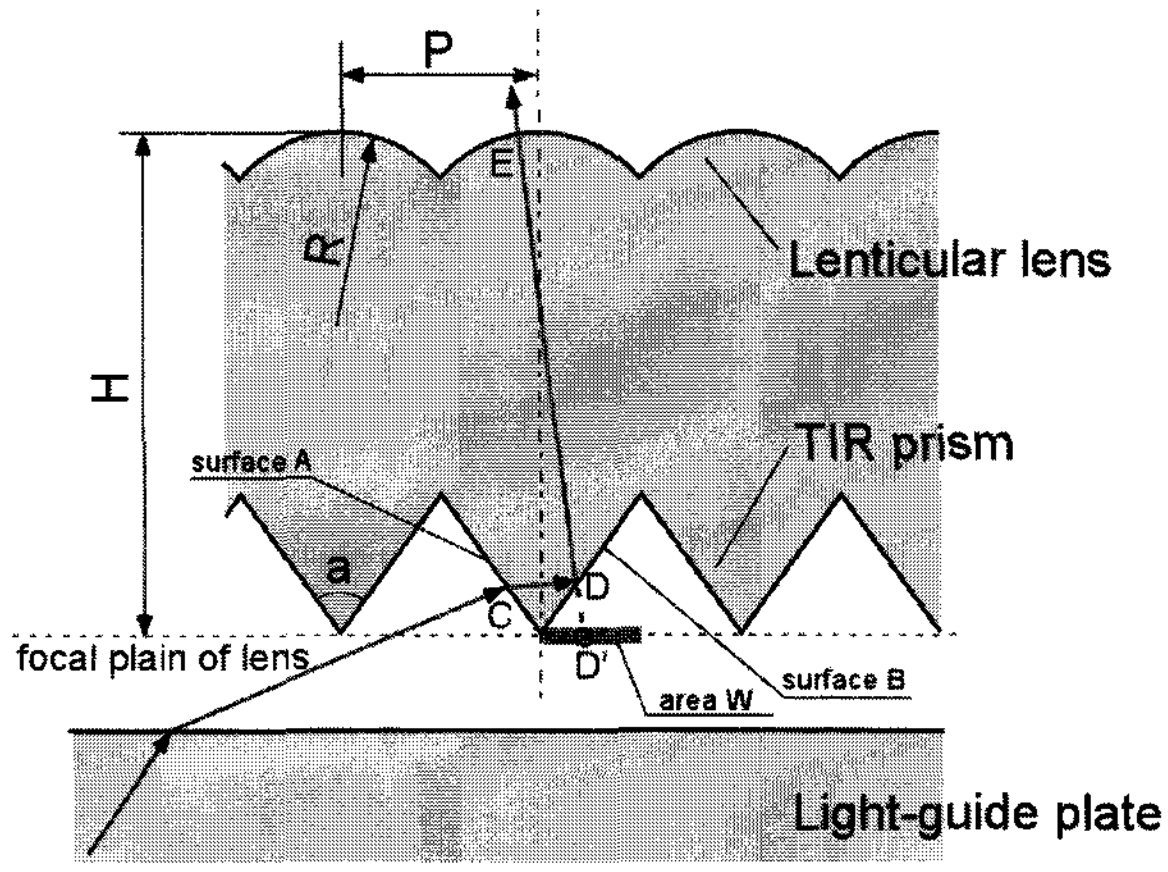

Fig. 4. Schematic concept of light directional control.

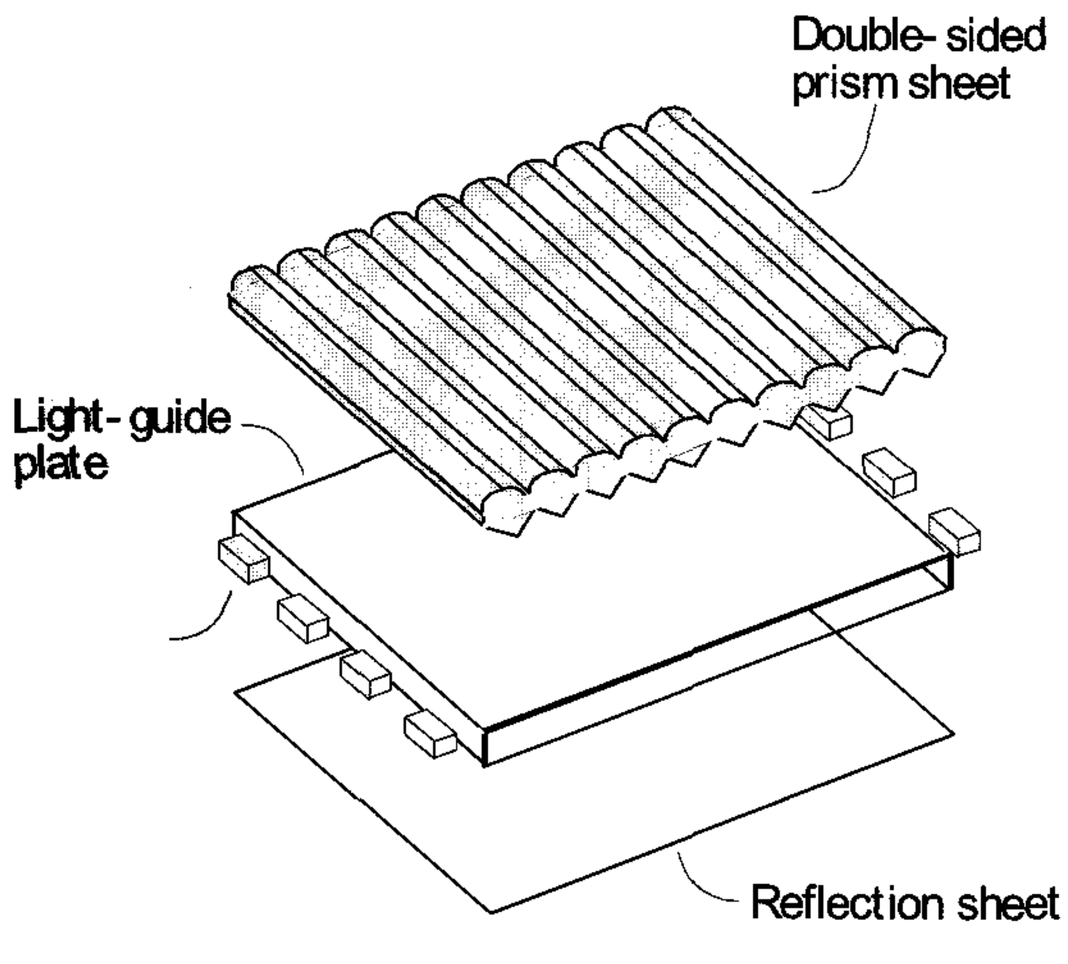

Fig. 2. Dual- Directional- Backlight

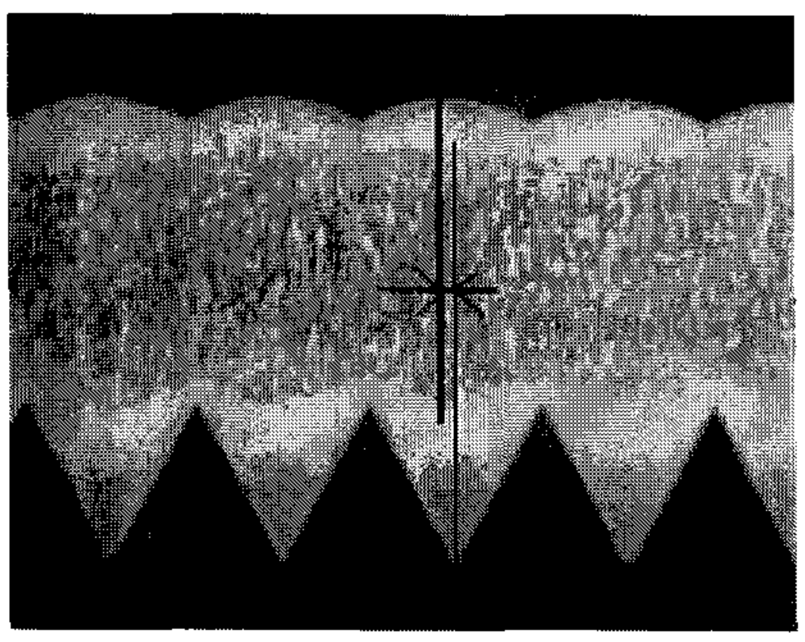

Fig. 3. Cross-section of the double-sided prism sheet.

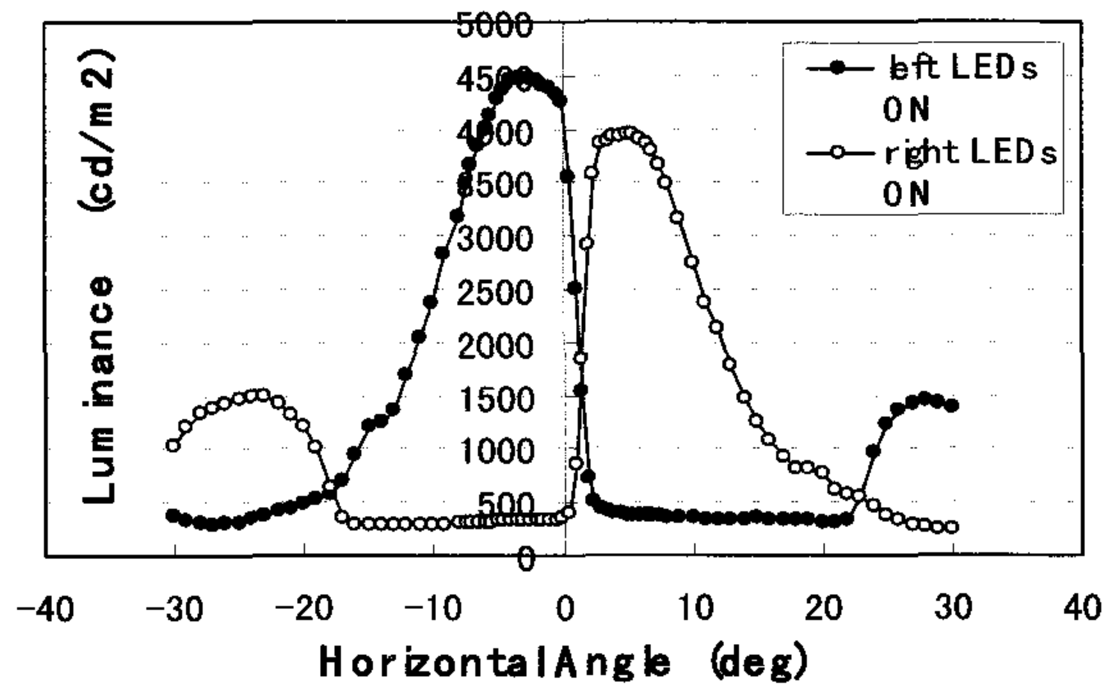

Fig. 5. Luminance angular distribution of Dual- Directional- Backlight.

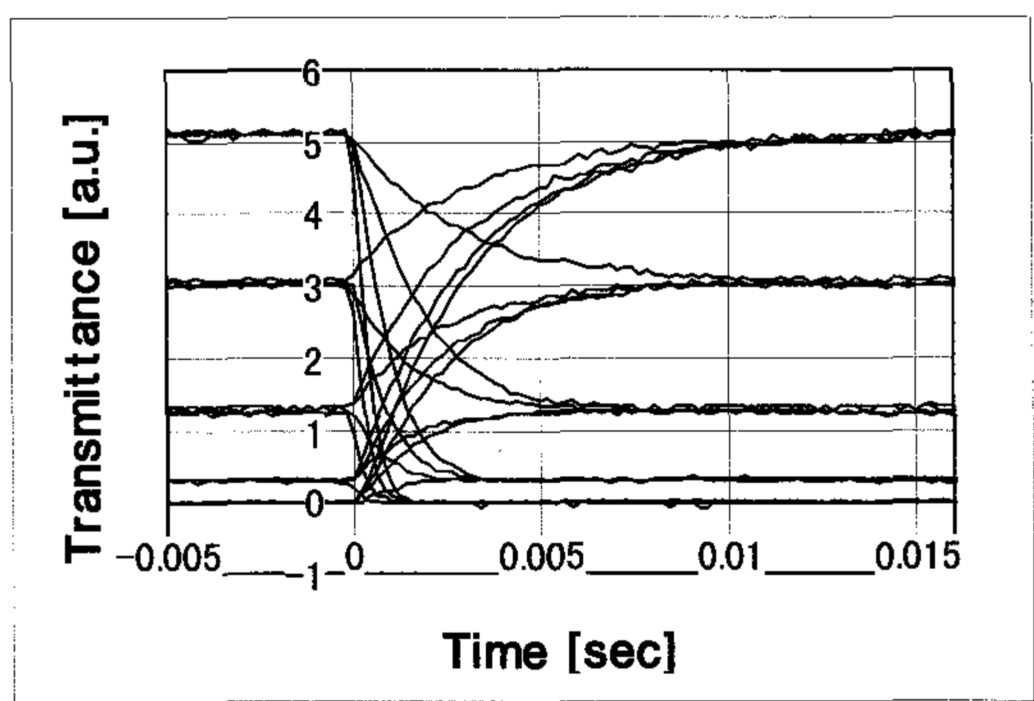

Fig. 6. Response profile of the OCB panel measure by use of a test cell.

Fig. 5 shows the angular distribution of luminance of the 2.2" Dual- Directional- Backlight. In case of the left side LEDs are set on, the luminance between −16 and 0 degree is high and the luminance between 2 and 22 degree is low. On the contrary, the luminance between −18 and 0 degree is low and the luminance between 4 and 20 degree is high in case of right side LEDs are set on. As the angle between the right and left eyes from the viewing point of 40cm is about 12degree (-6 and 6 degree), the lights for the right and left eyes are well separated. Here, the shift of the cross angle from 0 degree and the unbalance between the two peaks of the luminance profiles are due to the miss-gap between TIR-line prism and lenticular lens shown in Fig 3.

2.3 The Fast-Response OCB Panel

The fast-response liquid crystal panel is 2.2" TFT-QVGA OCB (Optically Compensated Bend) panel applied the Feed-Forward Drive (FFD) technique. The FFD technique is the over-driving technique that used feed-forward control to selects the optimum voltage for achieving the target luminance in the required time. Fig. 6. Shows the response profile of the OCB panel by use of a test cell without TFT circuits. As shown by Fig.6, it is possible to control the transmittance to be the target value from every initial value in the frame period of 8.3 m-sec for field rate of 120 Hz. However, in real TFT-LCD cells, applied voltage modification by use of FFD is necessary in order to compensate the dynamic capacitance effect of the liquid crystal cell.

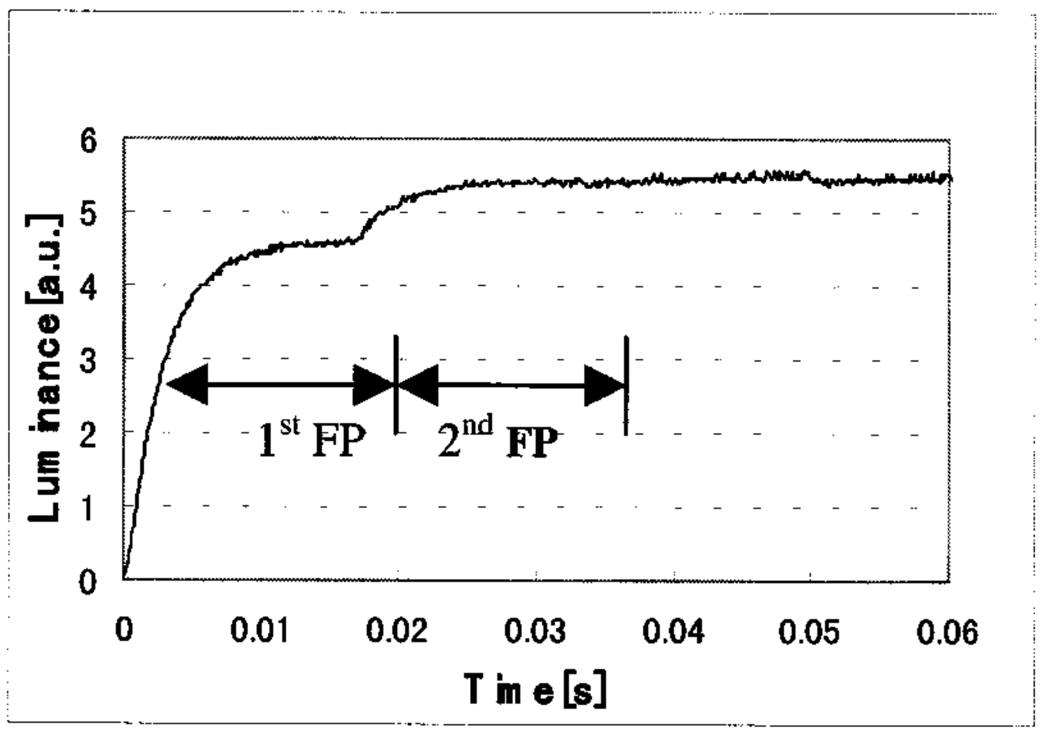

Fig. 7. Response profile of the TFT-OCB panel in case of gray-level transition from 0 to 255.

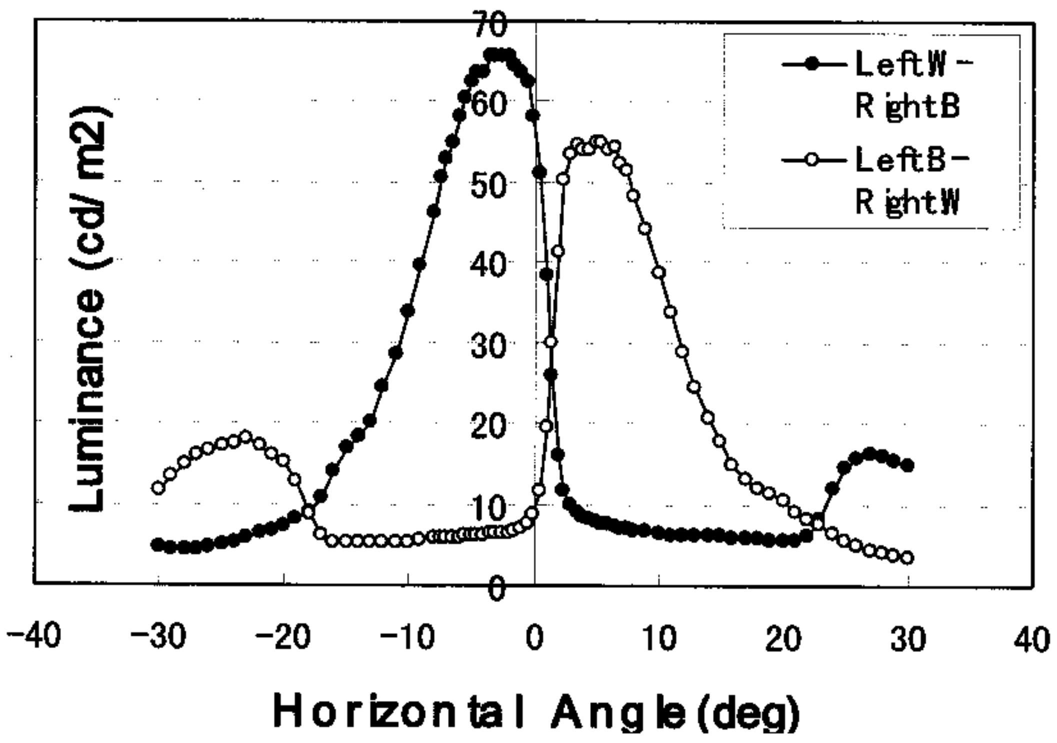

Fig.8. Measured luminance angular distribution of the Scan-backlight Stereoscopic LCD,
Black: white panel for left eye and black panel for right eye,
White: black panel for left eye and white panel for right eye.

3. Performance

First of all, by Subjective evaluation, it was confirmed that the Scan-backlight Stereoscopic display works at its original resolving power, and produces flicker-free stereoscopic images without special eye grasses by use of parallax images. Furthermore it has been found that this auto-stereoscopic display can resolved the problems of the doubled images and the pseudo-scopic images in case of watching at oblique angles. Viewers can watch a normal 2D image at oblique angles on the Scan-backlight Stereoscopic LCD.

Fig. 8 shows the angular distribution of luminance of the 2.2"Scan-backlight stereoscopic LCD. Here, The set-on duty-ratio of LEDs in the Dual-Directional-Backlight is 20 %. *Ll* is the luminance angular distribution of the parallax images those are white plane for the left eye and

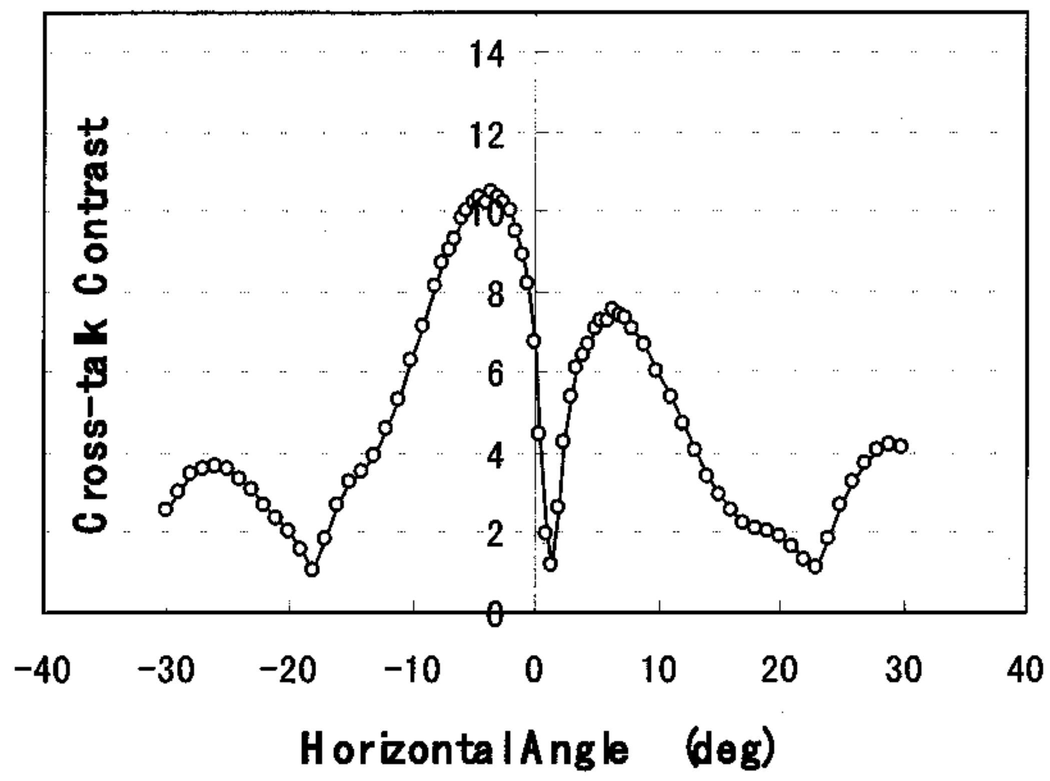

Fig. 9. Angular distribution of cross-talk contrast.

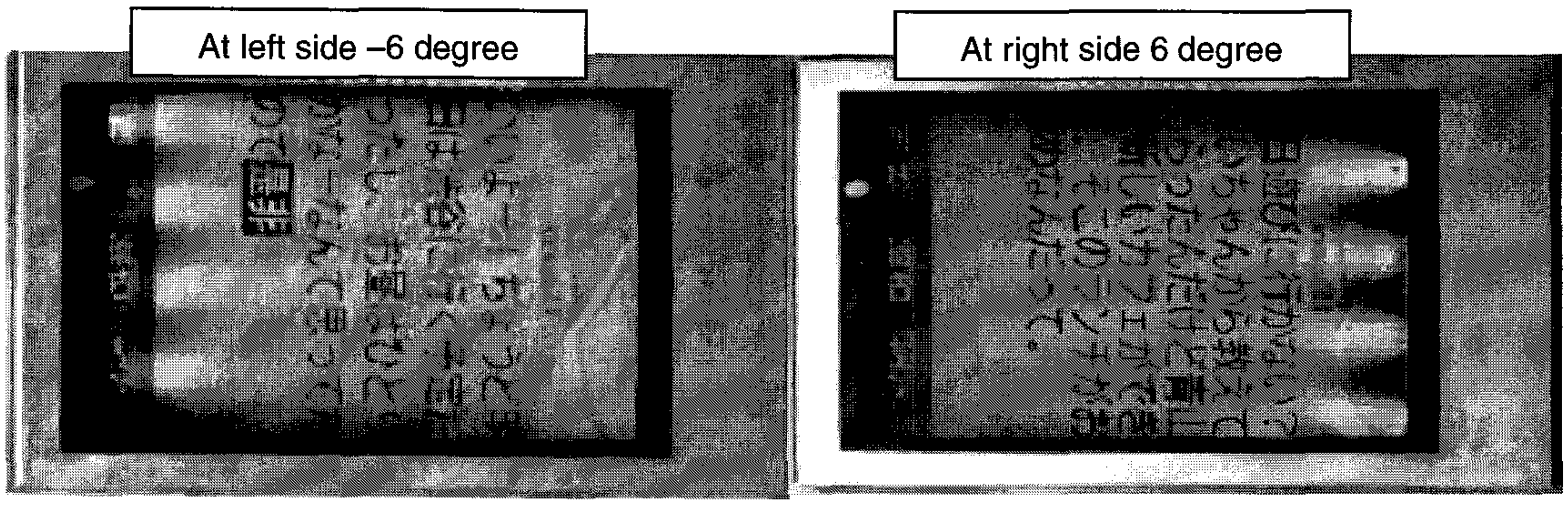

Fig.10. Photographic pictures of the images on the 2.2" QVGA Scan-backlight stereoscopic LCD taken at the horizontal angle of –6 and 6 degree, respectively.

black plane for right eye, and *Lr* is one of the parallax images those black plane for the left eye and white plane for right eye. The white and black plane are alternately displayed with field rate of 120 Hz in synchrony with the flashing of both side LEDs of the dual directional backlight. Thus, *Ll* and *Lr* represent the intensity angular distribution of the light ray, which should go to the left and right eye, respectively. In Fig. 8, *Lr* between –18 to 0 degree are significantly low in comparison with *Ll*. It shows that the light ray is well controlled by OCB panel in field rate of 120 Hz.

Here, we propose the new evaluation parameter cross-talk Contrast *XCr*,

$$XCr = 10^{|log\,(Lr/Ll)|}$$

Fig. 9 shows the cross-talk contrast *XCr* angular distribution. *XCr* is not sufficiently high, but more than 3 in wide angular region between –16 and 14 degree except for 0 degree. At the viewing angle of XCr ~1, double images occur.

Normally, the combined viewing angle for left and right eyes is about 12 degree from the panel surface of viewing distance of 40 cm. When a Viewer watches an object at viewing angle of -10 degree, the both of right and left eyes receive the same parallax image for left eye. The brain can then process the data into a recognizable 2-D image, instead of doubled and pseudoscopic images. At around –20 and 20 degrees the pseudo-scopic images occur, but those images are very dark as shown in Fig. 7.

Figs 10 show the photographic pictures of the static two images on the 2.2"QVGA Scan-backlight stereoscopic LCD instead of parallax images. These pictures were taken from the angle of 6 and –6 degree, respectively. Those angles are corresponding to left and right eye of the viewer. The shutter speed is 1/30 s that is twice of the present frame rate of 60 Hz. Though XCr is not sufficiently high, The FFD technique can successfully clear the ghost images coursed by the cross-talk.

4. Conclusion

We have developed a new Field Sequential Stereoscopic LCD combining the Dual- Directional- Backlight and the fast-response OCB panel. The Dual-Directional-Backlight using a double-sided prism sheet can change the direction of light by switching the light sources. The fast-response OCB panel using Feed-Forward Drive can realize field rate of 120 Hz. As a result, the Stereoscopic display works at its original resolving power, and produces flicker-free stereoscopic images. Also the display can resolved the problems of the double images and the pseudoscopic images at oblique viewing angles.

This characteristic makes it also possible to display the two images such as a text of an electronic mail (e-mail) message and an image attachment simultaneously. Users can switch between views of the text and of the image merely by tilting the display panel.

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