Teaching organic LED displays to deliver sharper high-definition stereo images

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A segmented parallax barrier capable of line-by-line switching reduces ghosting in a full-resolution 2D/3D organic LED.

In 1902, Frederic E. Ives pioneered the use of an opaque mask with evenly spaced vertical slits (parallax barrier) for viewing in stereo without special eyeglasses. Applied to the modern image panel, the barrier provides selective vision of odd and even image columns to the left and right eyes. The main advantages of the device are simple manufacturing and the absence of optical aberrations. The disadvantages are light loss and diminished horizontal resolution, which have been an obstacle to the widespread use of parallax barriers for years.

Recently, the technology has begun to enjoy renewed popularity among 3D display engineers and researchers for the simple fact that the barrier can be rendered on a liquid crystal (LC) panel. This makes it possible for a user to switch it on and off depending on whether 3D or 2D images are being viewed. The first commercial 2D/3D displays to use a no-glasses (autostereoscopic) LC parallax barrier were marketed by Sharp in 2004. They offered half-resolution 3D imaging with reduced brightness or full-resolution 2D imaging with maximum brightness. In 2006 Samsung SDI introduced the time-division parallax barrier technique, which improved resolution of 3D images by displaying two interlaced half-resolution fields to each eye in series. To do this, the time-division LC parallax barrier toggled between two complementary barrier modes at a high frame rate. Consequently, 3D imaging has improved, but the crosstalk between left and right images, which causes undesirable ghosting, has markedly increased.

We have developed a parallax barrier technique that enables low-crosstalk operation with minimum light loss and is suitable for high-definition organic LEDs (OLEDs) with polarized light output. Crosstalk occurs when there is a time mismatch between switching of the parallax barrier and image updating. The challenge is that updating an image line by line takes almost the entire frame period, but the time-division parallax barrier is switched all at once. In other words, exact synchrony with the image update process is provided for only one line of the image (e.g., the central line). For the remainder, the temporal mismatch between line-by-line updating and barrier switching increases toward the top and to the bottom of screen. Our technique is based on segmenting the barrier structure vertically, thus making it possible to switch segment by segment. Figure 1 shows the main principle of the technique in schematic form.

The parallax barrier switching method applied is similar to the line-by-line method of updating images in OLEDs. Exact synchrony in scanning can be achieved if the barrier panel has at least the same number of segments as the vertical resolution of the image panel. We found that a smaller number of the wider segments is also acceptable. A few comparatively wide

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Figure 2. Structure of the parallax barrier electrodes.

Figure 3. Parallax switching between barriers A and B.

Figure 4. Light distribution in a viewing zone.

segments, switching quasi-synchronously, can be applied if the ‘time mismatch crosstalk’ does not exceed acceptable levels of the order of 1%. With optimal phasing, the maximum time mismatch does not exceed $1/(2N)$th part of the frame period, where $N$ is the number of segments, which corresponds to the average crosstalk $C = 1/(4N)$. For instance, the number of segments in the prototype is 19, thus $C = 0.013$.

Figure 2 illustrates the transparent electrode structure of the segmented parallax barrier. Two individually addressable barrier electrodes, A and B, are formed on the front substrate of the barrier panel. A common electrode on the rear substrate is divided into 19 individually addressable segments to provide vertical scanning. The front substrate is covered with a polarizer, which is not shown in the picture for simplicity. Barrier electrodes A and B are connected to a controller, generating two square waves with a mutual phase shift at half-period. Segments are driven by similar square waves. A phase shift of each square wave is proportional to the index number of the segment. When the square waves applied to the barrier electrode and the segment are in phase, the corresponding barrier is switched to the slit mode. Applying the square waves in counterphase enables switching between barrier A and barrier B modes. When all the square waves are applied in phase, both barriers are off and 2D images can be displayed without light loss.

The pitch of the barrier’s electrodes is about $75.9 \mu m$ with $15 \mu m$ gaps in between. Though the gaps occupy as much as 20% of the active area, the additional inserted crosstalk is as low as 1%. This can be explained by the ‘fringing field’ effect (i.e., leaking of electric field from the electrode edge to the gap). Another source of the additional crosstalk is residual leakage through the barrier electrodes in the on state and slow switching of the barrier from on to off. One percent of leakage has been measured in the opaque state. To eliminate the problem of slow switching, we apply the so-called ‘normally white mode’ to enable switching on of the barrier by activating the LC cell. The resulting switching-on time is as brief as 100$\mu s$. Also, the relaxation time (switching off) of the barrier is as short as 2.1 ms. Summarizing the crosstalk caused by all these phenomena, we would expect $1.3 + 1 + 1 = 3.3\%$ of crosstalk at the ‘sweet’ spot, the point in front of the screen where the 3D image is perceived.

The parallax barrier has been applied to a Samsung 14.1 in high-definition active matrix LED panel with a resolution of $1366 \times 768$. Figure 3 shows barriers A and B as seen using a microscope: A on and B off (top), and B on and A off (bottom).

Figure 4 shows the light distribution in a viewing zone under the black-white stereoscopic test. Bright and dark stripes in the photo correspond to the optimal positions of the left and the right eyes of the viewer. The intensity profile has the triangular shape typical of parallax barrier displays. To evaluate the
crosstalk, $C_m$, in the vicinity of the sweet spot, the luminance of the OLED screen was measured by placing a photometer in a dark stripe ($I_0$) and in a bright one ($I_1$). The crosstalk was calculated as the ratio $C_m = \frac{I_0}{I_1 + I_0}$ and found to be below 5%, which is noticeably lower than previously reported. Switching between 2D and 3D modes is followed by a reduction in brightness by a factor of two (in 3D mode) and does not affect image resolution.

We have proved the feasibility and good performance of a high-definition 2D/3D OLED display using a quasi-synchronous scanning segmented parallax barrier. This new method provides low crosstalk and obviates the use of the barrier black mode, thus providing a brighter and sharper 3D image. Increasing the number of segments and reducing the gaps between the barrier’s electrodes could lower crosstalk even further. Further research will also focus on lessening the restrictions on the position of the viewer.

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Sergey Shestak graduated from Moscow State University in 1972. He received his PhD in radio physics in 1983. He worked on lasers, electro-optics, and acousto-optics at the Vega Corporation, Moscow (1972–1998), on optical data processing, holographic display, and 3D display at the Institute of Neural Optical Processing, Russian Academy of Sciences (1999–2003), and at the Korean Institute of Science and Technology as a visiting researcher (1993–1998). He has been with Samsung Electronics since 2003.

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Seon-Deok Hwang received his undergraduate degree in 2004 and his MS in 2006 from Chung-Ang University in Korea as a member of the Optical Signal and Laser Application Lab. His master’s thesis was a study of prominence and depression measurement for road surfaces using laser displacement sensors and global positioning systems. Currently he is working on 3D-display testing for Samsung Electronics.

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