LCD ISSUE

Information DISPLAY

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September 2010
Vol. 26, No. 9

LCD Performance Continues to Improve

3-D ACCELERATES THE NEXT WAVE OF TFT-LCDs

LOW-POWER ECO-FRIENDLY LCDs FOR TVs

EMBEDDED FUNCTIONS LEAD THE WAY TO NEW APPLICATIONS FOR LCDs

LED BACKLIGHTING ENHANCES LCD PERFORMANCE

Plus

How to Obtain a Patent Quickly

Journal of the SID September and October Contents

Information DISPLAY

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COVER: The continuing innovation of LCD technology has been a contributing factor to the implementation of new applications such as 3-D and in-cell touch.

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Next Month in
Information Display

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- OLED Requirements for Solid-State Lighting
- Phosphorescent OLED Lighting
- Manufacturing Challenges of OLED TV
- Keeping Patent Costs under Control
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Visible Progress

Stephen Atwood

Like many of you, I enjoy reading different industry periodicals because I never know where the next inspiration or clever idea may come from. One such example is the May 24th issue of *EE Times* magazine, which happened to come out right before SID's Display Week conference in Seattle. That week, *EE Times* featured an interesting article about Samsung's push into OLED TV, including a nice interview with SID President-Elect Brian Berkeley (worth a read if you have not seen it). But the reason I bring it up here is because of the cover story about Visible Light Communications (VLC), written by R. Colin Johnson. The principle is simple: If you have an LED-based visible-light source, you can modulate that source at a frequency much higher than the threshold of human flicker perception, and you can transmit digital information while the visible light appears to be solid to a human observer. Hence, you can light a room with LEDs and simultaneously transmit significant amounts of digital data such as streaming video, Internet, home automation, digital phone calls, or anything else imaginable – just by modulating those LEDs. In some cases, the light fixtures can even talk to each other along hallways and into connecting rooms, building an entire network without using any radio-frequency spectrum at all. Plus, the fact that light cannot penetrate walls makes your home network completely private from the outside. Ethernet or fiber would come into your house, go from the modem to the light controls, and then any room with a ceiling light is now Internet enabled.

The applications do not stop at the home, but can extend to almost anywhere artificial lighting is employed. One example cited is a ground-based locating system for car navigation that is updated by data sent from traffic lights in urban areas. The opportunities for commercial deployment are wide enough that the IEEE has even formed a standards effort, 802.15.7. A number of big-name companies are working on this technology, including Intel, Casio, NEC, Panasonic, Samsung, Sharp, and Toshiba. I am sure this is only a partial list. I am also sure there is a lot of backroom work going on that is not being talked about openly yet. One publically demonstrated application that was reported on earlier is the utilization of the LEDs in LCD backlights to send data from the display to another device. Samsung first showed this at Display Week 2009 in a large-area panel meant to illustrate a digital sign that could send data to your mobile phone when you approached the sign. The obvious application would be to send commercial advertising and targeted marketing to innocent bystanders through their mobile devices. This is the kind of thing that marketing people dream about in the wee hours of the morning and many consumers respond to like moths to a flame. I thought Samsung's demo was exceedingly clever and so did a lot of people who saw it.

Going beyond advertising, why not use the same mechanism to control active glasses worn by an observer to create more complex 3-D capabilities or to enhance the visual experience in other ways? You could even set up a two-way network with each pair of glasses and provide unique personalized viewing experiences for many observers of the same display. With data rates over 500 Mbits/sec already demonstrated in direct-lighting setups, there is enough bandwidth for many different applications that currently run over wired Ethernet today.

(continued on page 35)

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Executive Editor: Stephen P. Atwood
617/306-9729, satwood@azonix.com
Editor-in-Chief: Jay Morreale
212/460-9700, jmorreale@pcm411.com
Managing Editor: Jenny Donelan
603/924-9628, jdonelan@pcm411.com
Administrative Assistant: Ralph Nadell
Sales Manager: Danielle Rocco
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industry news

Do 3-D Displays Draw More Power?

Most industry observers would agree that 3-D capability and low power consumption are high on the list of new features for TVs. Even if consumers are not yet clamoring for them, these capabilities are among those that manufacturers are pushing in order to differentiate their products. Might it be possible, however, for one new feature to cancel out the other? Does the addition of 3-D make an environmentally friendly unit less so?

In many cases, yes, according to Paul Gray, Director of European TV Research for DisplaySearch. "It is very clear that with the current generation of 3-D sets, you have a significant loss of brightness," he says. (For more on this phenomenon, check out two of this month's features: "Evolving Technologies for LCD-Based 3-D Entertainment" and "Two New Technology Developments in the LCD Industry." In the case of LED-backlit units, this loss of brightness generally means that more LEDs will need to be used. And, as Gray notes, "more light costs more power."

Consequently, here is a case in which plasma has a potential edge over LCD technology because it emits. Both Samsung and Panasonic have 3-D-ready TVs based on plasma, in addition to their 3-D LCD units, and LG recently unveiled a 180-in. plasma 3-D TV prototype at the IFA show in Berlin.

To better understand just how much of a power penalty 3-D means to commercial TVs, industry observers such as CNET have started objective testing. CNET did a comparison in July (http://news.cnet.com/8301-17938_105-20009547-1.html) that included mostly plasma sets and showed that they did indeed use approximately double the wattage when in 3-D mode, as opposed to 2-D mode.

However, it would be premature and perhaps incorrect to say that 3-D TVs are going to be massive power gobblers. "If you go back a year ago," says Gray, "there was all this wailing and hand-wringing about CEC power regulations." Now, he notes, many sets are already well below the power consumption levels specified for 2013. (For more data, see Gray's blog at http://www.displaysearchblog.com/2010/07/tv-power-consumption-data-shows-how-far-set-makers-have-come/.) While 3-D does increase power usage, this is a hurdle that manufacturers will most likely clear – especially if and when new 3-D regulations are set. "Engineers still have scope to bring power-consumption improvements," says Gray.

– Jenny Donelan

guest editorial

The Current Direction of LCD Technology

by Shin-Tson Wu

During this year's annual Society for Information Display meeting in Seattle (Display Week 2010), my former colleague from Hughes Electronics Corporation, Pete Baron, and many other members of the SID Technical Program subcommittees, such as applications, active-matrix devices, LC technology, OLEDs, emissive displays, and CRTs, prepared a historical review on different display technologies over the past 50 years. What amazing achievements have been made! What seemed like small steps eventually became giant steps. For example, in the 1960s, RCA demonstrated the first flat-panel liquid-crystal displays (LCDs) based on dynamic scattering and dichroic dyes – but long-term stability was a concern. Therefore, field effects such as twisted nematic, vertical alignment, and in-plane switching were proposed in the early 1970s. Afterwards, the LCD industry grew steadily and finally took center stage. In the past two decades, we have also witnessed the rapid growth of organic LED technology, but also the dramatic shrinkage of other mature ones, such as CRTs. The display field never runs out of exciting topics. And no matter which technology is utilized, the role of displays in our daily lives keeps increasing. Nowadays, displays are indispensable in cell phones, games, computers, TVs, cameras, data projectors, and many, many more devices.

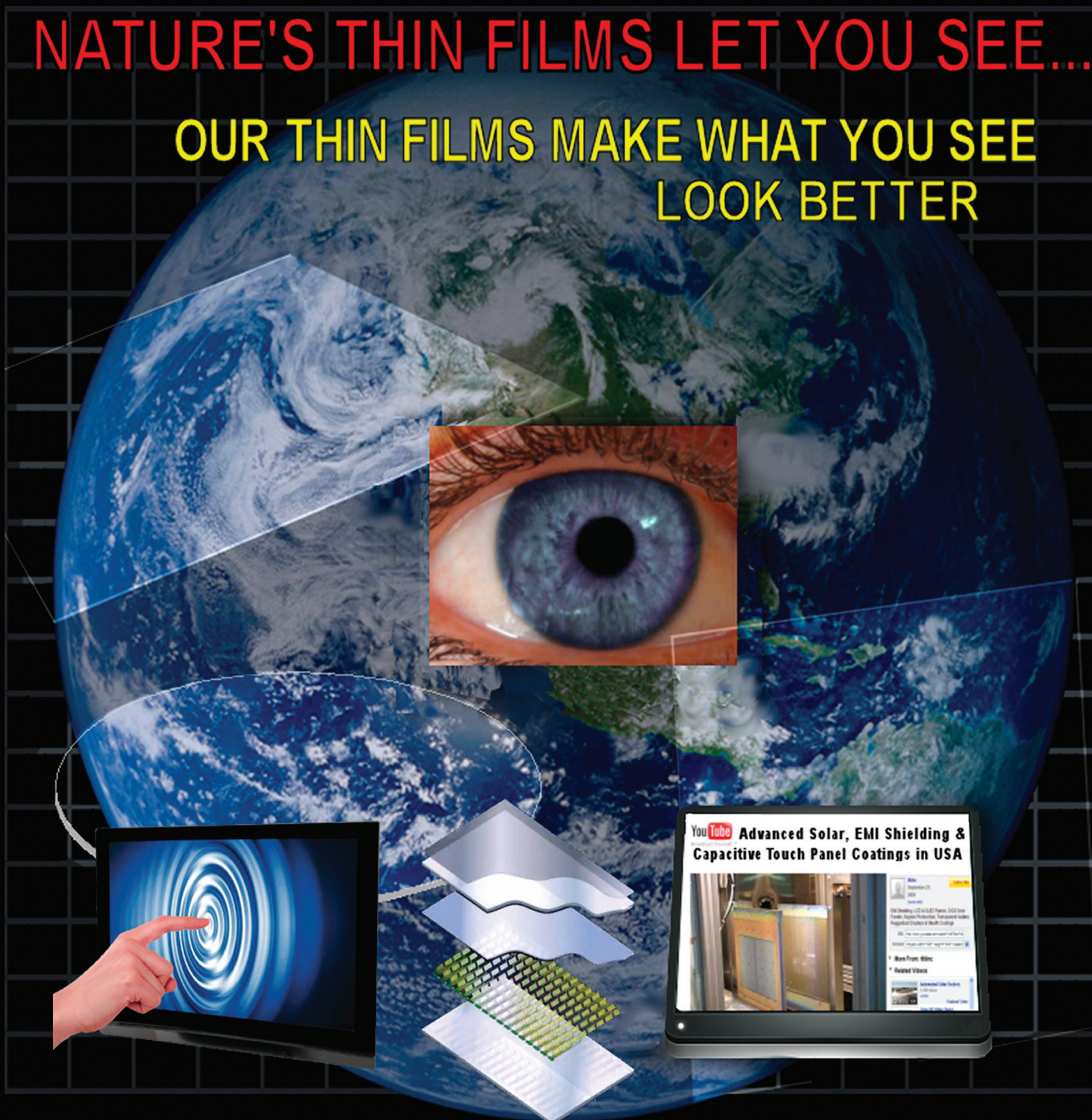
Common knowledge has it that LCD technology is fairly mature, although the pace of innovation does not appear to be slowing down much (if you saw what we saw at Display Week 2010). So what is next? Well, 3-D, touch screens, and lower power consumption are among the next technology milestones. In this special issue, I have invited researchers from LG Display, AUO, and National Chiao Tung University (Taiwan) to provide an overview of the latest advances in the above-mentioned technical areas.

In the first article, Dr. Jeong Hyun Kim of LG Display reports on advanced 3-D displays with polarized glasses. Both passive and active types of polarizer glasses are discussed. Next, Dr. Su of AUO provides us with an overview of recently developed technologies in the LCD industry: 3-D and touch screens. In the third article, Professor Shieh and Professor Huang from the Display Institute of National Chiao Tung University (Taiwan) address the critically important issue of power consumption and how it can be further reduced. By applying the stencil field-sequential-color approach, the optical efficiency of an LCD could be improved tenfold and future LCD TVs could be powered by a 9-V battery!

I hope you enjoy reading this special issue on advanced LCD technologies. Personally, I cannot wait to buy these next-generation LCD products.

Shin-Tson Wu *is Pegasus Professor with the College of Optics and Photonics at the University of Central Florida. He can be reached at swu@creol.ucf.edu.*

Society for Information Display
Office and Data Manager: Jenny Bach
1475 S. Bascom Ave., Ste. 114
Campbell, CA 95008
408/879-3901, fax -3833
e-mail: office@sid.org
http://www.sid.org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Evolving Technologies for LCD-Based 3-D Entertainment

Two technologies using polarized glasses with retarders to create home-based 3-D display imagery are presented. The leading 3-D technology on the market today is glasses-based, and the author proposes that polarizer-glasses-based technology, from a viewer-friendly point of view, will lead the premium 3-D market in the near future.

by Jeong Hyun Kim

THE PAST 2 YEARS have seen rapid growth in the 3-D industry, in both content and display technology. In terms of content, 3-D movies have made viewers comfortable with 3-D imagery. And the industry for 3-D broadcast content is also growing, with users enjoying events such as the World Cup in 3-D in their own homes. Gaming, too, has become a strong content area for 3-D.

In terms of display technology, 3-D is divided into two major categories: autostereoscopic (non-glasses-based 3-D) and stereoscopic (glasses-based 3-D). The autostereoscopic displays use lenses or barrier arrays in front of the displays, and the lenses or barriers control the paths of light from the display, projecting them to where the viewer is positioned. Viewers do not have to wear glasses, but they must be situated in the correct position with regard to the display in order to view the 3-D imagery correctly. Moreover, at this point in time, most autostereoscopic displays produce sub-optimal 3-D image quality compared to stereoscopic displays.

***Jeong Hyun Kim** is Chief Research Engineer, Head of the 3-D Technology Department, LG Display Co., Ltd. He has more than 20 years of experience in the flat-panel-display technology industry. He can be reached at kimjjhh@lgdisplay.com.*

In glasses-type 3-D displays, the light information is separated by both the display and the lenses of the glasses. Although stereoscopic displays have the disadvantage of requiring the use of glasses, they offer more freedom in terms of viewing angle and distance. Additionally, because the different left and right images are clearly separated by the 3-D glasses, they produce very clear 3-D imagery compared to that of autostereoscopic displays.

Until autostereoscopic displays improve, stereoscopic 3-D displays will continue to drive the initial 3-D market despite the inconvenience of glasses.

Polarizer and Shutter Glasses

The process of realizing stereoscopic images involves the following: Based on binocular disparity, different left and right images are transmitted to the viewer's left and right eye through the cooperation of the 3-D display and the glasses, respectively. As we combine the two different streams of information in our brains, this technology allows us to recognize the depth of given objects in or out of the display window. This is the basic concept of stereoscopic technology with glasses.

There are three major technologies that have been used to realize stereoscopic views with glasses: anaglyph, polarization, and active shutter. Anaglyph 3-D technology, which involves two-color glasses, with typically red on one side and cyan or green on the other, has obvious color problems, so polarizer and shutter glasses types have become the major candidates for high-image-quality 3-D.

Multiplexing Methodologies

There are two methods for displaying the left and right images to the display panel. One, generally used with polarized glasses, is the spatial-multiplexing method and the other, generally used with shutter glasses, is the time-multiplexing method. Both are depicted in Fig. 1.

For the spatial-multiplexing method, the left and right images are displayed in the same frame with different pixels or lines, while in the time-multiplexing method, the left and right images are displayed alternately in different frames. The time-multiplexing method requires a display with a high response speed. If the display is not fast enough, the two images overlap, leading to deterioration in the 3-D picture quality. This overlap is called ghosting or ghost effects. So, in order to reduce the ghosting in the time-multiplexing method, a display with a fast response and high frame rate is required. The spatial-multiplexing method, however, offers good 3-D picture quality without ghosting even with low-frame-rate displays because it does not depend on the response speed of the display.

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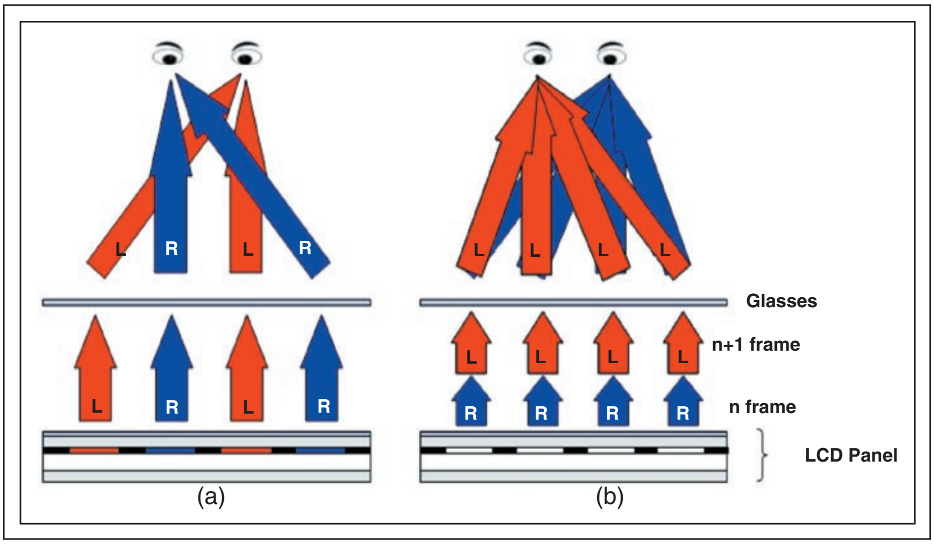

Fig. 1: The principles of (a) spatial-multiplexing and (b) time-multiplexing are shown.

With spatial multiplexing, the left and right eyes each receive only half the resolution of the total frame. However, in the author's opinion, if the images are truly 3-D and contain significant depth information, then when the images are combined, a portion of the resolution is effectively restored through the sum of the right and left resolution images.

The leading 3-D technology used along with the time-multiplexing display method incorporates shutter glasses. The glasses use left and right shutter lenses (switching liquid-crystal cell). The left and right shutters are alternately opened in each left and right frame. The shutters blink in front of each eye very quickly, but users are often aware of flicker phenomena. Because the retina corresponding to the outer part of the viewing field is very sensitive to flicker, the shutter-glasses technology used can cause eye fatigue. Moreover, because the shutter glasses contain electronics and power supplies, they are heavier and bulkier than polarizer glasses.

In this article, the current technology used for 3-D polarizer glasses and, also, a future technology that will be used for 3-D active-retarder polarizer glasses are described.

Patterned-Polarizer 3-D Displays

Patterned-polarizer 3-D, the most common technology used with polarizer-glasses-based 3-D, incorporates left and right images in the same frame. The technical concept of patterned-polarizer 3-D is shown in Fig. 2.

As shown in the figure, there is a patterned plate in front of a conventional LCD panel, which corresponds to the odd and even lines of the LCD, respectively. This patterned polarizer converts light from the LCD to either left- or right-circular polarization. The LCD interlaces left and right images; for example, a left image is displayed in each odd line and a right image is displayed in each even line. As the two different images pass through the patterned polarizer, the left image would be left-circular polarization and the right image would be right-circular polarization. The polarizer glasses are designed to transmit left-circular polarization to the left eye and right-circular polarization to the right eye. Consequently, if a viewer sees a patterned-polarizer 3-D display through the polarizer glasses, different images will be shown to the left and right eyes of the viewer, providing stereoscopic imagery.

As explained above, due to the characteristics of displaying both left and right images in one frame, patterned-polarizer 3-D technology minimizes light losses and guarantees higher brightness. Also, because the two images are clearly separated by the patterned polarizer, we experience remarkably fewer ghost phe-

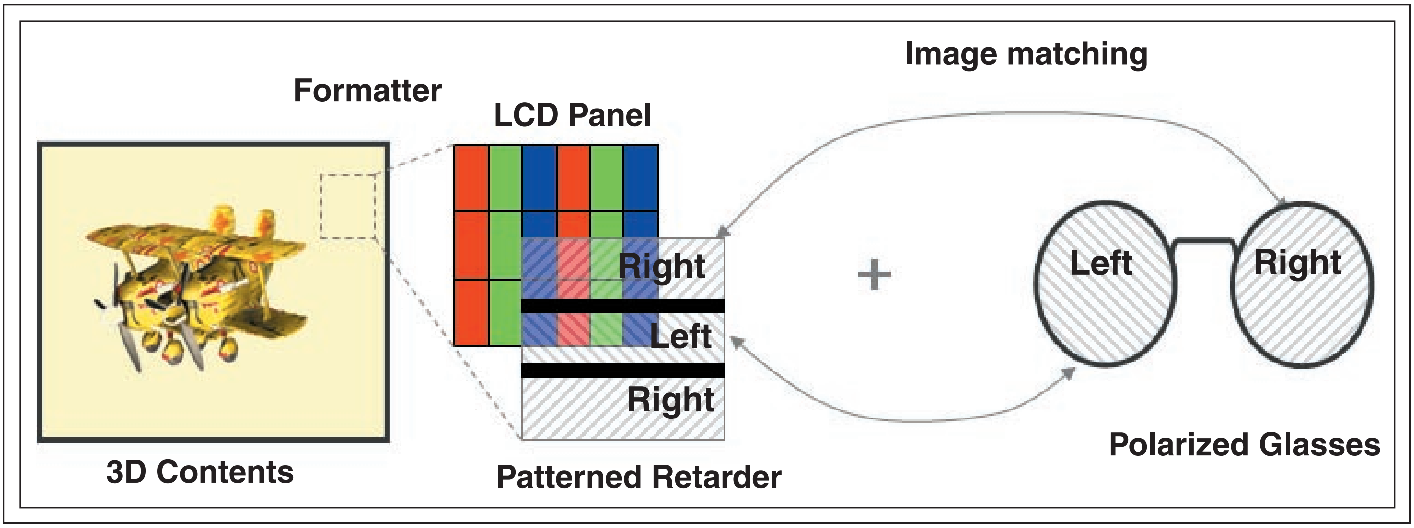

Fig. 2: The basic concept of patterned-polarizer 3-D display technology involves a patterned plate in front of an LCD that converts light to either left- or right-circular polarization in conjunction with polarized glasses.

Table 1: Polarized vs. active-shutter 3-D display systems are compared.

	Patterned-Retarder 3-D	Shutter-Glasses 3-D
Frame Rate	60~240 Hz	240 Hz
3-D W/B Cross-Talk	0.5%	2~3%
3-D Luminance	170 nits	45~60 nits
2-D Luminance	450 nits	450 nits
3-D Viewing Angle (vertical)	Narrow	Wide
3-D Glasses	Light, comfortable, inexpensive*	Heavy, bulky, expensive
Backlight	CCFL, LED	LED

**Note*: Glass-based retarder displays used in TVs have to date led to a TV product still noticeably more expensive than 2-D TVs, but LG Display is preparing a less-expensive film-based patterned retarder that may help close the gap on the 3-D price premium.

nomena; *i.e.*, 3-D cross-talk, a numerical index of this ghost effect, is very low. Therefore, the patterned polarizer can provide an outstanding stereoscopic view to the user.

Table 1 shows a comparison of 3-D TV specifications between patterned-polarizer 3-D and shutter-glasses 3-D. Patterned-polarizer technology has superiority over shutter-glasses technology in picture-quality parameters such as 3-D cross-talk and 3-D picture brightness. 3-D cross-talk is about 0.5% and 3-D luminance is three times as bright as that of shutter-glasses 3-D. Shutter-glasses 3-D greatly depends on the response time of displays in order to reduce 3-D cross-talk. But patterned-polarizer 3-D is unrelated to response time and frame rate. Moreover, since shutter glasses are electronic units with circuits and batteries, many users find them less comfortable – and less environmentally friendly. Polarizer glasses also are very light in weight – of about 10 grams.

Active-Retarder 3-D Displays

Unlike patterned-polarizer 3-D technology, which spatially separates left and right images, active-retarder 3-D technology is based on the time-multiplexing method mentioned above that separates left and right images. As shown in Fig. 3, an active-retarder 3-D display is composed of two panels.

One is a conventional LCD for 3-D images and the other is an active-retarder panel consisting of one liquid-crystal layer and two glass substrates to control polarization. As shown in Fig. 3, each even and odd frame corresponding to the left and right images is written alternately on the image panel. When two images are alternated on the image panel, the active retarder in front of the image panel converts the polarization state of the input polarization from the image panel. The LC panel switches the polarization of alternate frames between left and right circular.

This technology can provide viewers with high-resolution displays because the full resolution of one frame is projected to each eye. Also, as the scanning active retarder helps with the writing of the display panel, the result is a brightness higher than that of shutter-glasses 3-D technology. It should be noted that compared with patterned-polarizer 3-D technology, active-retarder technology requires an additional LC panel, which leads to additional cost. Thus, cost is an issue that needs to be overcome.

Table 2 shows a comparisons of 3-D performance between conventional shutter-glasses 3-D displays and active-retarder 3-D displays currently under development in sizes suitable for monitor use.

Since two of the 3-D technologies are based on the time-multiplexing method, their resolutions are full HD without resolution loss in both 2-D and 3-D modes. In the comparison of luminance under the same 2-D brightness, the 3-D luminance of the active-retarder 3-D is measured to be about 100 nits, more than twice that of shutter-glasses 3-D displays.

The white–black 3-D cross-talk of active-retarder 3-D is similar to that of the shutter-glasses 3-D, but the average gray-to-gray 3-D cross-talk is optimized to be about 2%, which is half that of shutter-glasses 3-D displays.

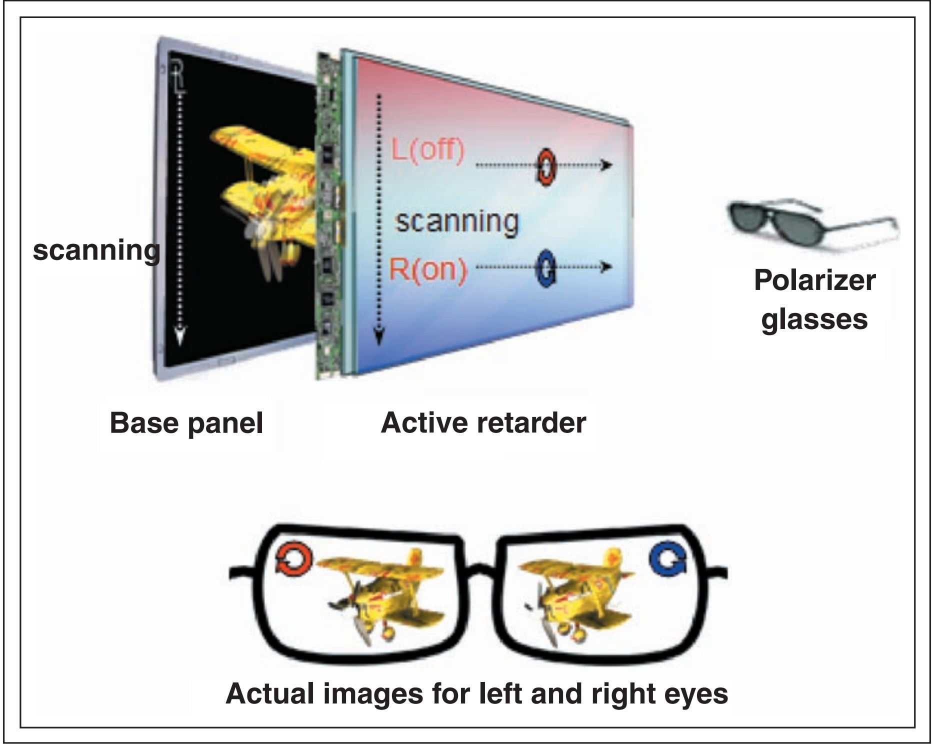

***Fig. 3:** The active-retarder concept for 3-D display technology uses two panels – a conventional LCD and a panel with one LC layer and two glass substrates.*

Table 2. Active-retarder 3-D image quality compared to shutter-glasses 3-D image quality.

Items	**Active-Retarder 3-D**	**Shutter-Glasses 3-D**
Size (in diagonal)	23 in. wide	23 in. wide
Resolution	full-HD (2-D/3-D)	full-HD (2-D/3-D)
3-D Luminance	100 nits	36 nits
2-D Luminance	450 nit	450 nit
3-D W/B Cross-Talk	1.2%	<1.0%
3-D Gray-to-Gray Cross-Talk	2.3%	4.0%
l Max – Min l of 3-D W/B Cross-Talk	<0.5%	<10%

And with the help of scanning technology, the cross-talk deviation over the entire display area is measured at 0.5% for active-retarder technology. But the cross-talk deviation for shutter-glasses 3-D is 10%, due to the difference in the data writing time of the first and last line. In this sense, the image produced in the active-retarder 3-D technology is much better than that of shutter-glasses 3-D technology due to the high-brightness. gray-to-gray 3-D cross-talk, and cross-talk deviations. Therefore, active-retarder 3-D technology is introduced as a novel technology that satisfies brightness compared to that of shutter-glasses 3-D technology in monitors. Besides, it provides wearing convenience to users because it employs polarizer glasses just like that of patterned polarizers. With such high brightness, high resolution, and user convenience, this technology should be suitable for the premium monitor or TV market.

The Future for 3-D Polarizer-Glasses Technology

In this author's experience, in certain cases the shutter-glasses-type 3-D display can cause dizziness due to flicker, cross-talk, and low overall luminance. The relatively expensive shutter glasses appear to be an inconvenient burden to consumers that could limit adoption. The polarizer-glasses-type 3-D display with simple and inexpensive glasses is more user-friendly. In terms of 3-D display quality, the patterned-retarder-type 3-D display offers high brightness and is flicker and cross-talk-free, reducing visual fatigue. Thus, at some point in the future, the patterned-retarder type may emerge as a good candidate for mainstream 3-D technology in the home. ■

Two New Technology Developments in the LCD Industry

Flat-panel-display manufacturers are looking for ways to extend the display market. Besides increasing the size and improving the image quality of displays, new functions can provide additional applications for the product. Among the new technologies currently being implemented and investigated are 3-D and in-cell touch.

by Jenn Jia Su, Hsiang-lin Lin, and Alan Lien

FLAT-PANEL-DISPLAY (FPD) technology has seen many exciting developments over the past decade, and among these liquid-crystal-display (LCD) technology has risen to the top. Today, countless electronic devices use LCDs to display vital information and to provide entertainment. LCD manufacturers are continuously investing in larger-generation factories to increase the average size of displays. And at the same time, many revolutionary technologies such as new LC modes, pixel structures, and manufacturing processes have been developed to further improve image quality.

New demands from consumer are helping to drive the development of the next generation of displays. For example, film directors have immersed their audiences in the scenes of movies by using 3-D technology. The consumer enjoys the 3-D experience and wants to watch 3-D TV at home (or 3-D TV manufacturers hope so). With regard to touch, the iPhone provides a very convenient and reliable user interface, and displays embedded with touch functionality will be a standard in the future.

Jenn Jia Su *is Senior Manager of the LC Technology Department at AU Optronics Corp., located in Hsinchu Science Park, Taiwan; e-mail: potato.su@auo.com.* ***Hsiang-lin Lin*** *is the Manager of the Flexible Technology Department at AU Optronics Corp.; e-mail: Stan.HL.Lin@auo.com.* ***Alan Lien*** *is currently a Senior Associate Vice President in charge of the Display Development Center of AU Optronics Corp.; e-mail: alan.lien@auo.com.*

1. 3-D LCD Technology

To enable 3-D viewing on a flat-panel display, the basic concept is to allow the right eye to see the right image and the left eye to see the left image. Several technologies have been developed to achieve this, as shown in Fig. 1.

The 3-D technologies are classified into two categories based on whether or not users need to wear glasses.

1.1. Glasses-Based 3-D Technology

There are two types of 3-D technology that require users to wear glasses, as shown in Fig. 1(a). The first involves a patterned retarder; the other, shutter glasses. Patterned-retarder technology is based on the spatial-domain concept.[1] The content of the left and right views are rearranged in an interlaced pattern that loses 50% of the information of each view. On the display side, an additional retardation film with a striped pattern is placed in front of the base of the panel. The retardation film is used to change the polarization of the light coming from the base of the panel. The striped pattern is designed to have a phase difference of $\lambda/2$ between the odd and even rows. Lastly, a pair of unpowered passive glasses composed of polarizer film is used to filter the corresponding image for each eye.

Shutter-glasses technology uses the time-domain concept.[2] The content of the left and right views vary with time. The content must be synchronized with the shutter glasses in order for the corresponding images to be seen by each eye. On the display side, the display must be designed to support a higher-frame-rate driving capability. Furthermore, the response time of both the display and the glasses must be as fast as possible in order to obtain acceptable 3-D performance.

The merits and drawbacks of these two technologies are as follows:

- ***Glasses:*** The patterned-retarder method utilizes passive glasses, composed of polarizer films. They are lightweight (<10 g), cheap (<US$10), and easy to clean. The shutter-glasses method uses active glasses that are composed of two LC cells that are driven by batteries. They are heavy (~50 g) and more uncomfortable to wear. They are also expensive (~US$100) and difficult to clean with water.
- ***3-D luminance:*** Both current 3-D approaches represent a significant sacrifice in total luminance available to the observer. For the patterned-retarder method, the combined effect of the

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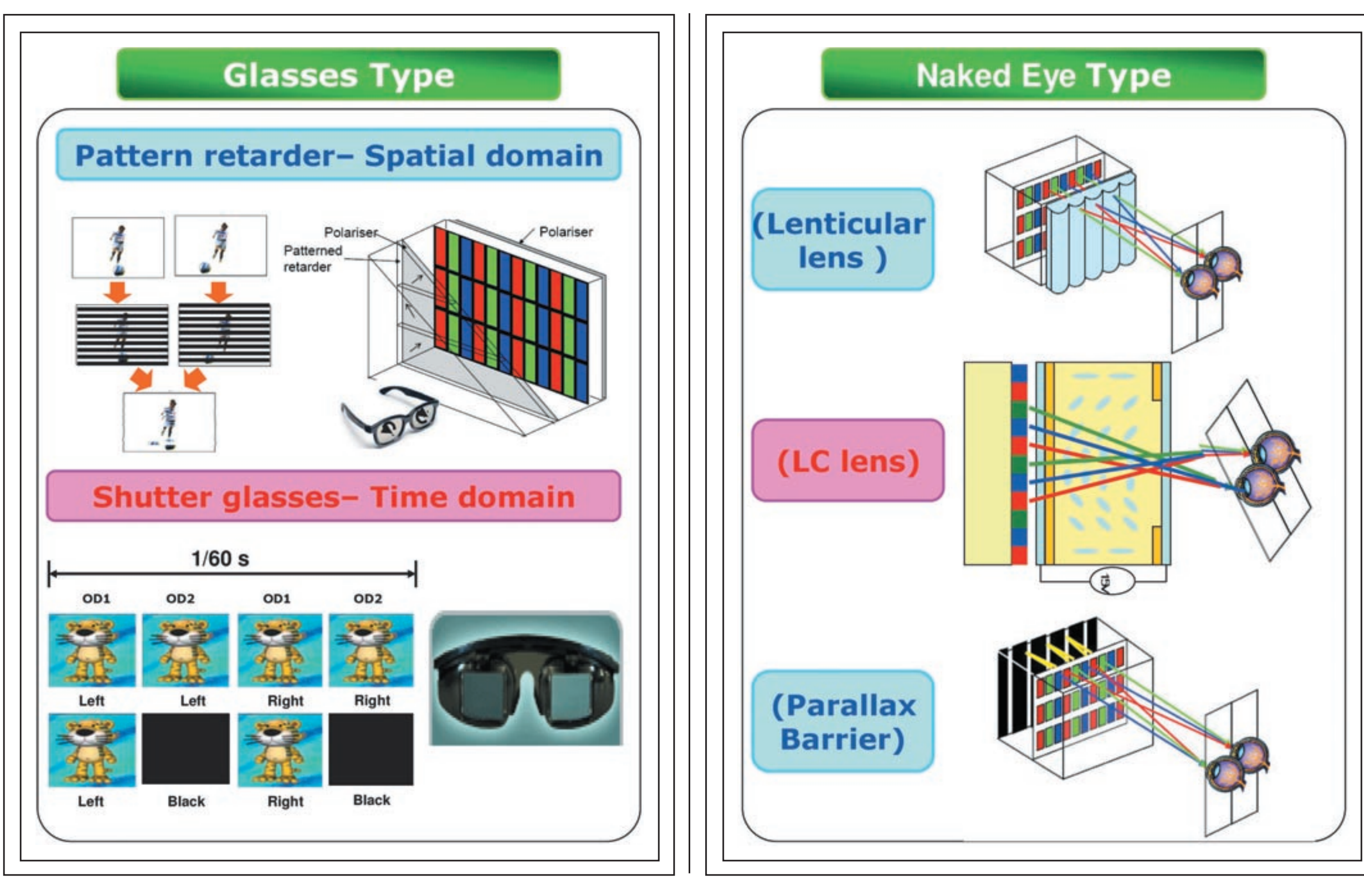
retarder on the display and the polarizer film on the passive glasses results in a net loss in luminance of about 58%. Approximately 50% is due to the inherent separation of the 2-D image into separate left and right fields. The polarizer film on the glasses, which is made with a polyvinyl alcohol (PVA) plastic layer, absorbs another 16% of the light that tries to pass through it, resulting in a net transmission of 50% times 84%. Therefore, the maximum 3-D luminance for the patterned-retarder method is 42% of that for the 2-D mode. However, higher 3-D cross-talk can be perceived at large vertical viewing angles in current patterned-retarder structures. To solve this problem, an additional black-matrix (BM) layer or equivalent pixel structure is used, which leads to a further loss in luminance of 40%. As a result, the final transmittance of the 3-D imagery is about 25% of that of 2-D imagery [based on an AU Optronics Corp. 65-in. full-high-definition (FHD) unit]. For the shutter-glasses method, the technology is based on time domain, and the blinking (shutter-open) ratio of each eye is only 25% at a 240-Hz frame rate. The glasses, which are composed of two polarizer films and one LC layer, have a transmittance of about 60%. The final transmittance of the shutter-glasses method in 3-D mode is about 15% of that of the 2-D imagery. Taking a 65-in. FHD TV with a 2-D-mode luminance of 500 nits as an example, the patterned- retarder method provides 125 nits in 3-D mode while the shutter-glasses method provides only 75 nits. (Typically 300–500 nits are preferred for an enjoyable viewing experience. However, since the 3-D mode always offers lower luminance, a luminance of 125 nits definitely provides better viewing performance than 75 nits.)

- ***3-D cross-talk:*** Cross-talk is an index that defines the percentage of light leakage from one eye's image into the other eye's image. It identifies what percentage of the left view is perceived though the right eye, for example. The display with lower 3-D cross-talk provides a sharper image for each eye and increases viewer comfort when viewing 3-D content. For the patterned-retarder method, the cross-talk can be less than 1% by using an optimized design for both the retardation film and the glasses. For the shutter-glasses method, the response time of the display and glasses is a key parameter for cross-talk. In general, the shutter-glasses method results in more cross-talk than the pattern-retarder method.



(a) (b)

Fig. 1: *Hardware configurations used for 3-D technologies, both (a) with and (b) without the use of glasses, are depicted above.*

- ***3-D resolution:*** The shutter-glasses method has a major advantage in resolution because it is operated by the time domain, using all available display pixels for each eye image. The patterned-retarder embodiment loses one-half of the resolution in the vertical direction when operated in 3-D mode because the available pixels on the display are physically sorted into left or right eye images only. This should barely be detected by a user who is viewing imagery from a distance. However, if the contents have fine patterns such as text, a user can detect the loss of information very easily. The resulting user experience is therefore more content and viewing-position dependent.

1.2: "Naked-Eye" 3-D Technology

The 3-D technologies that work with the "naked eye" (no glasses) are based on the spatial domain and are also generally referred to as autostereoscopic. There are three types of autostereoscopic 3-D technology, as shown in Fig. 1(b). For the lenticular-lens type, a lenticular-lens film is placed in front of a flat-panel display to refract the image signal of each set of subpixels to specific positions in space. The best 3-D viewing distance is related to the design of the lens curvature and lens pitch. The LC-lens type is based on the same theory as the lenticular-lens type. The major difference is that the lens structure is composed of a liquid-crystal layer. A special electrode pattern is designed to align the liquid crystal that forms the effective refractive-index profile to have the same effect as a lenticular lens. For the parallax-barrier type, a black-matrix layer or another liquid-crystal layer is stacked with the FPD to block a portion of the output light and direct the image of the subpixel set to specific positions in space.

The image content of autostereoscopic 3-D technology requires simultaneous multi-views. In Fig. 2, the process flow from five different images into a single 3-D image is illustrated.

These five images are captured by a charge-coupled device (CCD) at a slightly different viewing angle. The length of the tiger's tail in each view is therefore slightly different. The combination of the five images into a single

Fig. 2: *For the signal arrangement of multi-view 3-D displays, the output image is the combination of the five images with special pixel arrangements.*

one is processed through a special subpixel-arrangement method. The subpixel arrangement in each view must correspond to the structure of the lenticular lens or parallax barrier. As a result, the final 3-D content includes all five images, and thus 80% of the information of each view is lost.

By using a combination of multi-view content and an autostereoscopic display, viewers can see the combined 3-D image from a specific position in front of the display. They will also see some dead zones from other positions. To reduce the number of dead zones, 9 or 12 views are required. However, 89% or an even higher percentage of the resolution will be lost, which degrades the image quality dramatically. To improve the 3-D image quality, an FPD with a higher resolution (4K × 2K or 8K × 4K) is required, which is challenging for LCD designers and manufacturers.

1.3. The Future of 3-D Technology

Consumers are looking for high-quality 3-D technology and hoping to enjoy the 3-D experience more comfortably. In the short term, glasses-type 3-D displays will dominate the market because it currently provides the best image quality. In terms of 3-D cross-talk, the shutter-glasses type needs to be improved by using a faster-response-time FPD or a higher-frame-rate LCD. The synchronization between the content and the blinking time of the glasses can also reduce the cross-talk. The shutter glasses should be designed to be lighter in weight and will get less expensive in the future. For the patterned-retarder type, the LCD makers are eager to reduce the cost of the retardation film. A 50% lose in resolution and a limited vertical viewing angle are still the challenging issues that need to be addressed. In the long term, the naked-eye-type 3-D technology is undoubtedly the best 3-D solution. Large-sized displays with resolutions higher than FHD is now quite challenging because of low cell transmittance. However, 3-D capability will be a key force driving the development of higher-resolution displays in the future.

2. In-cell-Touch LCD Technology

Displays with touch functionality are in great demand (as explained in other recent articles in *Information Display*, and especially in our March 2010 issue). At the current time, touch sensors are mostly integrated outside of the display, and we call this an "out-cell touch display." These technologies include projection-capacitance, resistor, motion sensor, IR sensor, *etc.* However, it is an industry goal that the touch sensors be integrated into the LCD cells, which we call "in-cell touch displays." This technology provides the merits of (a) reducing the total thickness of the module, (b) reducing the light-interference effect due to the additional touch-screen glass, (c) not requiring calibration between the LCD and the touch sensors, and (d) providing the possibility of lower overall system cost.

Figure 3 summarizes the four types of in-cell touch technology that have been recently developed. The first type is a photosensor[3] using ambient light. Compared to a conventional TFT-LCD, a matrix of additional TFTs is designed on the array side of the display. On the color-filter side, the black-matrix layer of these additional TFTs is removed. As a result, these TFTs have leakage currents if they are placed in a bright environment. The leakage currents from these TFTs are conducted to the integrated-circuit chips by the

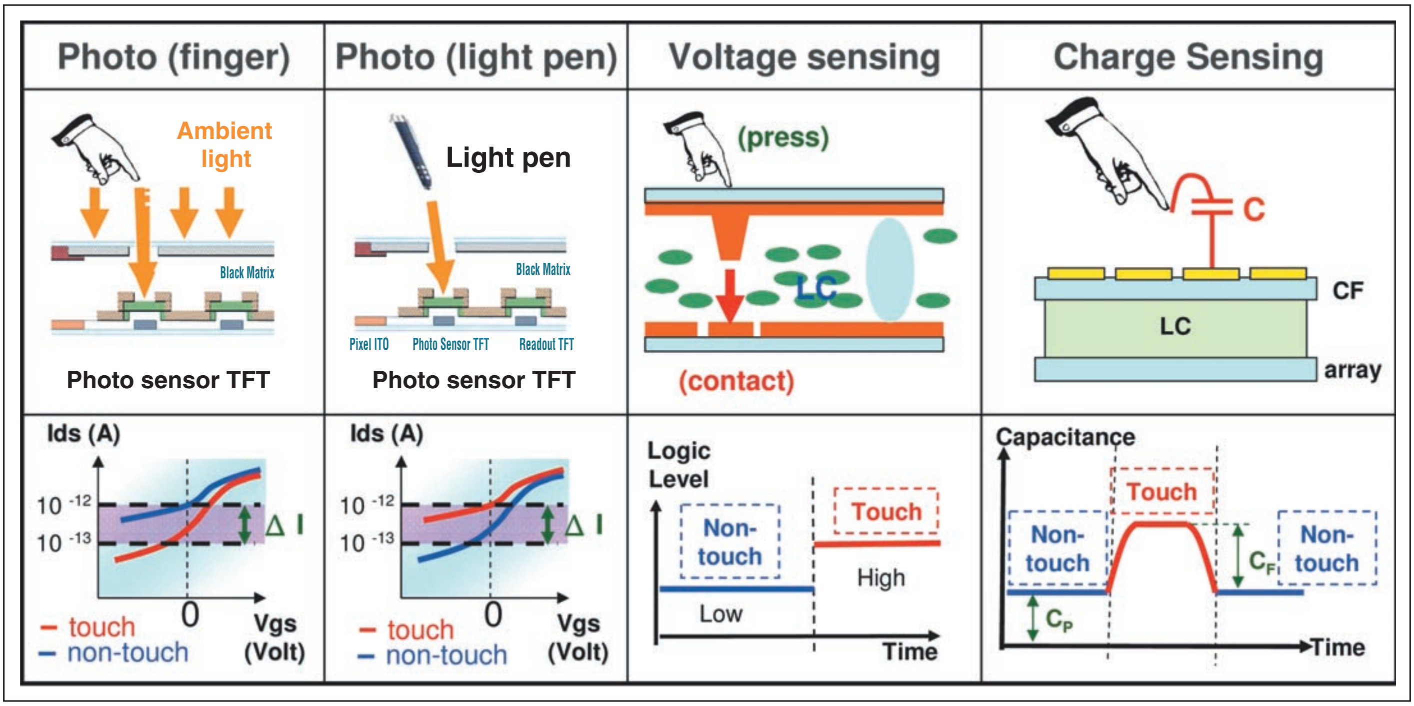


Fig. 3: Summary of in-cell touch technologies, with both the structure profile and the signal transition with and without touch are described above. Note: The fourth technology, charge sensing, is sometimes referred to as "on-cell" technology, depending on the configuration. For more on this distinction, see the article "LCD In-Cell Touch" in the March 2010 issue of Information Display.

readout lines, which are also designed on the array side. If the user places a finger in front of the display, it will obstruct the environmental light radiating to these TFTs, and the TFTs will stop leaking currents to the readout lines. The integrated-circuit chips will compare the voltage differences of each readout line and judge the position of the finger. Obviously, the environmental light will affect the operation of the touch function. To increase environmental flexibility and allow the technology to work in a dark-ambient environment, additional illumination such as infrared light can be added to the system, provided either by the backlight or from a front-light enhancement.

The second technology is also based on the photosensor method described for the first case. The only difference is that the user points at the display by using a light pen. As a result, the TFTs leak more current when the TFTs are exposed to the light. The position pointed to by the user can be detected by the readout lines and integrated-circuit chips.

The third technology is the voltage-sensing type.[4] It involves a matrix of sensor pads that are designed in the array substrate. The sensor pads are made with metal electrodes or transparent electrodes such as ITO and are located on the top layer of the array electrode, which will be used to make contact with the color-filter layer directly. To prevent the sensor pads from covering polyimide, a special sensor-pad design is used. On the color-filter side, two photo-spacer processes are required. The first photo-spacer layer is processed after the color-filter resin layers. The common electrode layer is then deposited on the surface of the color-filter resin and the first photo-spacer layer. The second photo-spacer layer is then processed, which will be used to maintain the cell gap of the LCD. The height of the first photo-spacer layer is slightly smaller than the second photo-spacer layer. When there has been no touch force applied to the display, the cell gaps are maintained based on the second photo-space layer. However, if the panel is pressed with a certain force, the cell gap is reduced and there will be direct contact between the common electrode in the color-filter layer and the sensor pads in the array substrate. The voltage of the common electrode is then transmitted to the integrated-circuit chips by the readout lines that are linked to the sensor pads. The integrated-circuit chips calculate the logic level between touch and non-touch; therefore, the position in which the user applies force on the display can be detected. Unlike the photo-sensing method, this technology is independent of the brightness of the environment. It has the potential to detect pressure through a special sensor-pad design. There are many good features for this kind of technology, such as low cost and high cell transmittance. However, the biggest challenge is that the user needs to apply significant pressure to trigger the sensors. The force is called activation force, which is an index of the sensitivity of the touch function. To reduce the activation force, the thickness of the color-filter substrate should be polished to less than 0.2 mm; however, that will cause low yield in the LCD process. (Although touch-panel durability is not covered in this article, it is worth noting that for touch-display applications, the panels will be tested for durability with more than 500,000–1,000,000 repeat contacts. Suitable photo-spacer materials and designs can help touch-panel products meet durability requirements.)

The fourth technology is charge-sensing touch-display technology. The design of the pixel on the array and color-filter sides is the same as that for conventional LCDs. On the outside of the color-filter substrate, there is a matrix of sensor pads made by transparent electrodes such as ITO. All of the sensor pads are linked to the integrated-circuit chips. If a finger is placed on the surface of the display, there is additional capacitance between the sensor pads and the finger. The integrated-circuit chips detect the change in the capacitance of the sensor pads and then determine the position of the finger. This technology has the features of high sensitivity, high transmittance, and low cost. The major concern is the dual-side color-filter process, which may suffer scratches in the electrode layer.

2.1. Future Perspective of In-Cell Touch Technology

More and more operating systems will support displays with touch functionality as an input interface. There are also numerous technologies that can provide touch functionality. In-cell touch technology has many good features, such as thinner modules, low cost, and good image quality. It should be very suitable for small-sized LCD or portable applications. All the technologies described above support multi-touch features (at least two points), which are useful for practical applications. In the short term, there are some aspects that need to be improved for in-cell touch technology: (a) the frame rate of the sampling touch sensors should be faster (>180 Hz) in order to catch up with the high speed of handwriting, (b) the yield must be improved, and (c) the sensitivity of the touch function should be as good as the projection-capacitance type. But there should be no limitation in terms of input devices. And in the long term, a touch display should be able to detect the depth information based on the activation force of the user.

3. Summary

Nowadays, most technologies need to combine both software and hardware in order to meet consumer requirements. For 3-D technology, the display needs to provide good-quality 3-D imagery without sacrificing 2-D imagery. Despite the inconveniences, glasses-type technology seems to be the best solution thus far. Besides, the availability of high-image-quality 3-D content is also a key factor in the success 3-D displays in the future. For touch technologies, there are a variety of solutions, but in-cell technology provides many good features for which LCD manufacturers are keen on developing it for mass production. Because the FPD industry is a consumer-oriented industry, these technologies along with other technologies are being developed to meet consumer requirements.

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Advanced Methods for Field-Sequential-Color LCDs with Associated Power Reduction Advantages

*Using stencil-field-sequential-color methods with field rates as low as 120 Hz in conjunction with local color backlight dimming can effectively suppress color break-up. With the addition of a color-filterless LCD with an intelligent LED backlight and a non-polarized LC cell, optical throughput can be increased by a factor of 10, while at the same time requiring a lower material cost/count, resulting in an environmentally friendly display.**

by Han-Ping D. Shieh and Yi-Pai Huang

HIGH IMAGE QUALITY, low power consumption, and low material costs are all important factors for display devices if they are to thrive in the mainstream of the future. However, conventional red-green-blue color-filter LCDs are still low in optical throughput and have an imperfect "dark" state. For a typical 32-in. LCD panel, the use of polarizers and color filters produces a net optical throughput of about 5–10% to yield a front-of-screen image (Fig. 1), while the polarizer

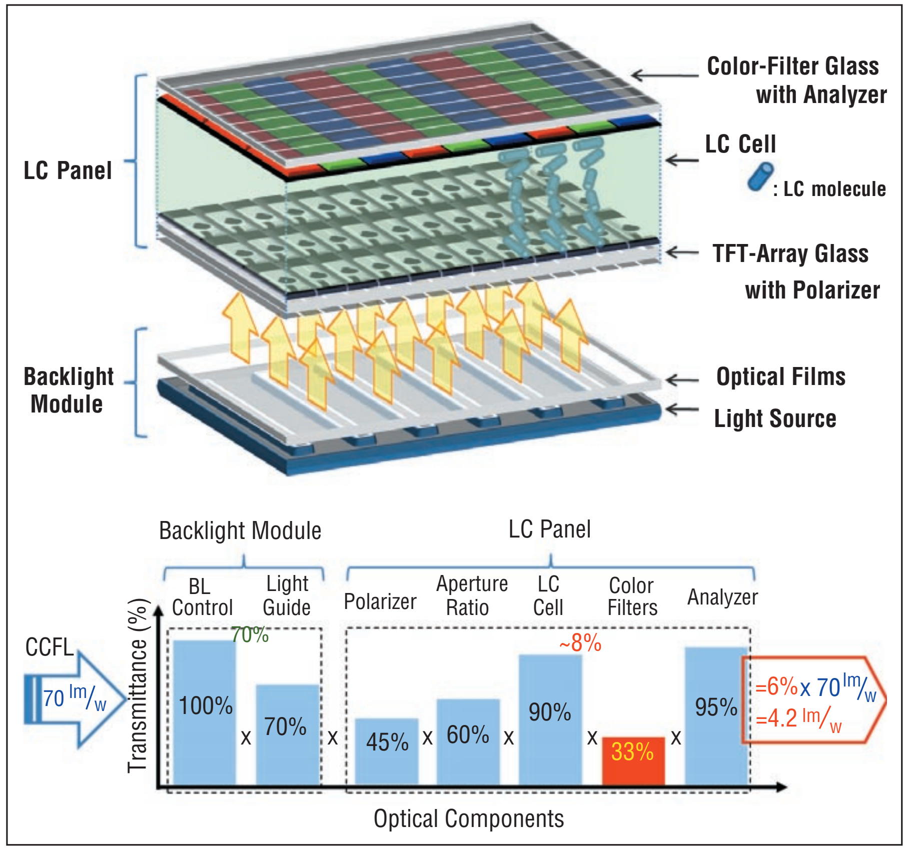

Fig. 1: Low light efficiency in a CCFL-backlit LCD can be attributed to the low efficiency of the optical components.

***Han-Ping D. Shieh** is a Chair Professor with the Department of Photonics and Display Institute, National Chiao Tung University, Hsinchu, Taiwan, and a Changjang Chair Professor at Shanghai Tang University, Shanghai, China. **Chang Jiang** is Chair Professor at Shanghai Jiao Tong University, Shanghai, China. He can be reached at hpshieh@mail.nctu.edu.tw. **Yi-Pai Huang** is an Associate Professor with the Department of Photonics and Display Institute, National Chiao Tung University, Hsinchu, Taiwan. He can be reached at boundshuang@mail.nctu.edu.tw.*

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and color filter represent 10% and 19% of the material cost, respectively. If the next generation of LCDs is to meet market expectations and ever-stricter government regulations with regard to environmental friendliness, lowering power consumption is essential.

The Beginnings of an "Eco-Friendly" Display Using FSC

As far back as 1985, a high-light-efficiency field-sequential-color (FSC) LCD without the use of a color filter has been demonstrated to reduce power consumption.[1] In this demonstration, the authors, by rapidly displaying red (R), green (G), and blue (B) field images time sequentially, created a full-color image by temporal color synthesis, as illustrated in Fig. 2. Consequently, fast-response RGB light-emitting diodes (RGB-LEDs) were applied to an LCD backlight system to replace conventional CCFLs. Without a color filter, FSC-LCDs are capable of high light efficiency, wide color gamut, low material cost, and a screen resolution that is possibly three times higher than that of RGB-LCDs.

However, in order to commercialize the FSC-LCD, a serious visual artifact must be overcome: color breakup (CBU), which occurs when relative velocities exist between the screen objects and the human eye, as shown in Fig. 2.[2] During eye movements, the separated R, G, and B frames of an image degrade image quality and cause viewer discomfort. CBU suppression has been implemented in digital light-processing (DLP) projectors by increasing the field rate to 540 Hz or higher. Although LED backlights can be switched very rapidly, a slow LC response time of several milliseconds still limits the implementation of FSC in large-sized FSC-LCDs.

Stencil-FSC Methods

For practical applications, the field rate of FSC systems is limited to 240 Hz or lower. Stencil-field-sequential-color (stencil-FSC) methods using commercial OCB (optically compensated bend) (for 4- and 3-field), or even MVA (multi-domain vertical alignment), IPS (in-plane switching), and TN (twisted-nematic) (2-field) LC modes to effectively suppress CBU have been demonstrated for large-sized TFT-LCDs, as shown in Fig. 3(a). The stencil-FSC method incorporates local color-backlight-dimming technology at a low field rate of 240 Hz, which significantly reduces CBU effects. (For more on this methodology, see the article "2009 JSID Outstanding Student Paper Award" in the May/June 2010 issue of *Information Display*.)

Conventional FSC-LCDs compose a full-color image by using three high-luminance primary-color (R, G, and B) field images. When the eyes perceive the three high-luminance images sporadically, CBU is easily seen and reduces image clarity. Therefore, it is better for the major luminance to be in a single field, with much lower luminance in residual

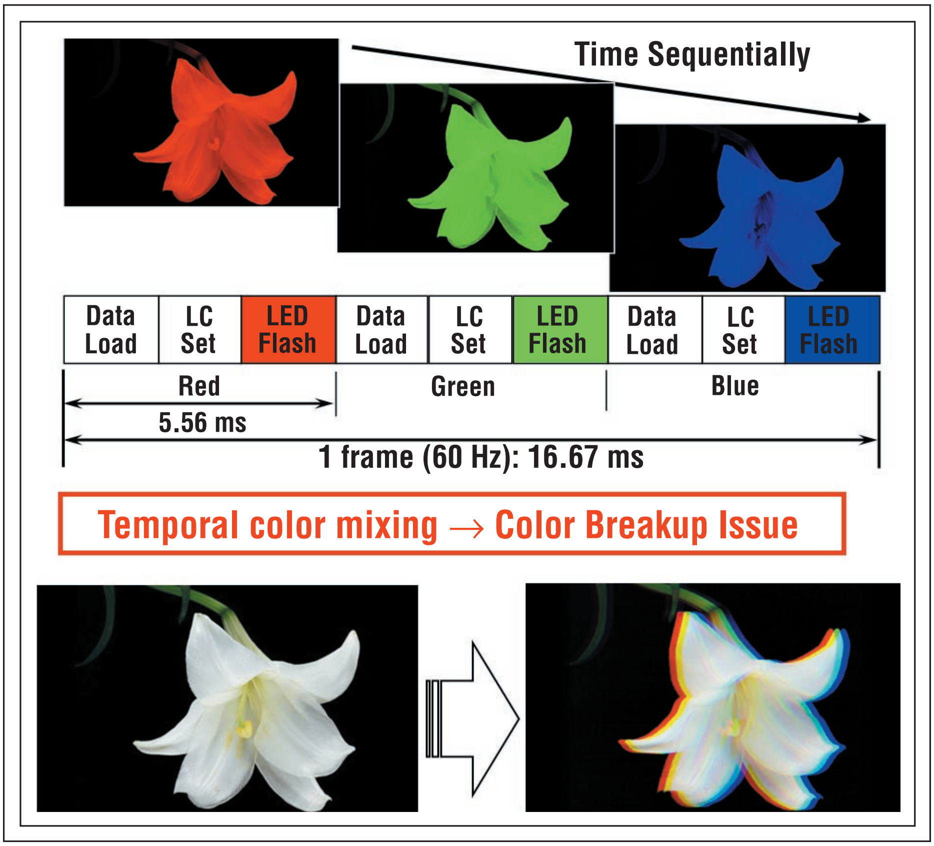

***Fig. 2:** In the FSC-LCD mechanism, color images are created by rapidly and time sequentially flashing the display primaries (top). Below, FSC display color breakup during eye movement is shown at right.*

Table 1: Conventional RGB-FSC and stencil-FSC methods are compared.

	Conventional RGB-FSC	Stencil-FSC 240 Hz	Stencil-FSC 180 Hz	Stencil-FSC 120 Hz
Field Rate (Hz)	180	240	180	120
BL Divisions	Global	24 × 24	32 × 24	45 × 80
*Color Difference (Avg ΔE_{00})	—	0.07	0.8	4.1
*CBU (%)	100	58.6	59.1	37.8
**Relative Optical Power of Backlight with RGBW LED (%)	100	62.6	51.3	24.6

*: With 70 test images
**: Based on the same brightness; with 110 lm/W white-light LED

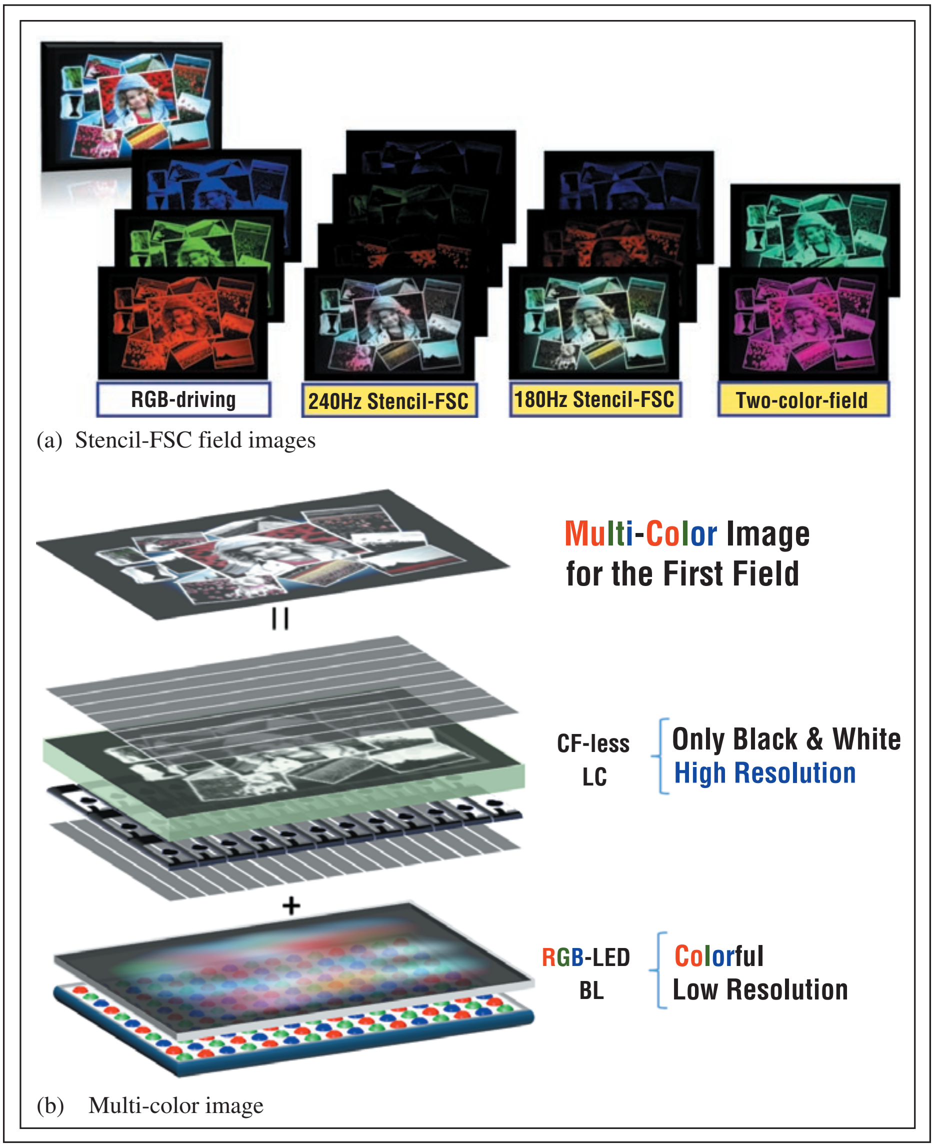

Fig. 3: *(a) Shown are a target image of girl (©Microsoft), along with field images using the 240-, 180-, and 120-Hz stencil-FSC methods,respectively, and (b) a multi-color image yielded by a low-resolution RGB-LED backlight and a high-resolution color-filterless LC cell.*

images. A multi-color field therefore can be used to show the most image luminance instead of a conventional mono-primary image. As a result, the low-luminance residual field images are only used to modify the color details.

4-Field Stencil-FSC Method

By using 4-field stencil-FSC, each primary color has two fields to display information, including the first field and the residual primary fields. Therefore, 4-field stencil-FSC could easily maintain image fidelity and suppress CBU by more than 50% and be made almost imperceptible with 24 × 24 backlight divisions. This method was implemented by researchers in 2009 on a 32-in. FSC-LCD TV to yield a high dynamic contrast of 26,000:1, a power consumption of less than 35 W, and a wide color gamut of 114% NTSC.[3-5]

To yield a multi-color image in a color-filterless LCD, local color backlight dimming [also referred to as high dynamic range (HDR) technology] was utilized in 2008, as described in the paper, "Dynamic Backlight Gamma on High-Dynamic-Range LCD TVs".[6] An LC panel using the RGB-LED backlight was studied as a dual-panel display with different spatial resolutions: a low-resolution backlight module and a high-resolution LC panel. The backlight displayed a low-resolution color image and the color-filterless LC cell preserved high-resolution monochrome-image details. By combining these two panels, a multi-color image was generated, as shown in Fig. 3(b).

3-Field Stencil-FSC Method

For further hardware implementations, researchers reduced the number of field images from four to three, as described in the referenced 2010 article. The green-field content was moved to the first field because the human eye is most sensitive to green color. Using 32 × 24 backlight divisions, CBU could be suppressed by more than 40%, making CBU almost imperceptible and yielding high image fidelity.[7]

2-Field Stencil-FSC Method

The 2-field sequential method utilizing a high-resolution LC panel and a low-resolution RGB-LED backlight system to generate two field images – a red-blue and a green-blue field – is illustrated in Fig. 4. By sequentially displaying these two field images at 120 Hz, a full-color image can be generated without visible CBU. 40 × 40 backlight divisions can render pleasing imagery with less color difference ($\Delta E_{00} < 3$) due to the human eye being less sensitive to the blue image.[8, 9] Therefore, current commercial LC modes, such as TN, MVA, or IPS, can be used for 2-field stencil FSC.

Further Perspective on an Eco-Display

To reduce the power consumption even more, the optical throughput of the LC cell and backlight system needs to be further improved. For example, a pair of polarizers absorbs around 55% of the total light throughput. However, in order to eliminate the polarizers, new LC modes would be needed. If such an LC mode were available, it could be combined with the inherent high dynamic range of an LED backlight to produce a very efficient display system. A 4-in-1 style R-G-B-W backlight system such as that shown in Fig. 5(a) could take advantage of white LEDs that have efficiencies of more than 100 lm/W.

Considering practical viewing situations, backlighting luminance can be reduced in a dark environment, and the emitting angle of the backlight can be directed at a smaller angle for a single viewer, as illustrated in Fig. 5(b). Using all the above-mentioned factors with the stencil-FSC color-filterless LCD, the optical throughput of the LCD can be increased by a factor of 10, and the power consumption can be reduced to only 25% of a current FSC-LCD (as shown in Table 1). For a 42-in. LCD-TV, the power may be reduced from 200 W to less than 30 W.

Conclusion

Stencil-FSC methods with field rates as low as 120 Hz can effectively suppress CBU. The stencil-FSC method yields a high image contrast of 26,000:1, an average power consumption of less than 35 W, and a wide color gamut of 114% NTSC for a 32-in. RGB-backlight LCD. A low-field-rate stencil-FSC could be achieved by using commercial LC materials and MVA, IPS, or TN modes. To further reduce the power consumption and material counts, the authors are actively working on an FSC-LCD without a polarizer that is powered by an intelligent backlight system. A factor-of-10 increase in optical throughput and lower material counts/costs indicate that a stencil-FSC LCD with an intelligent backlight system is a potent possibility for an eco display – perhaps even one running on a simple battery.

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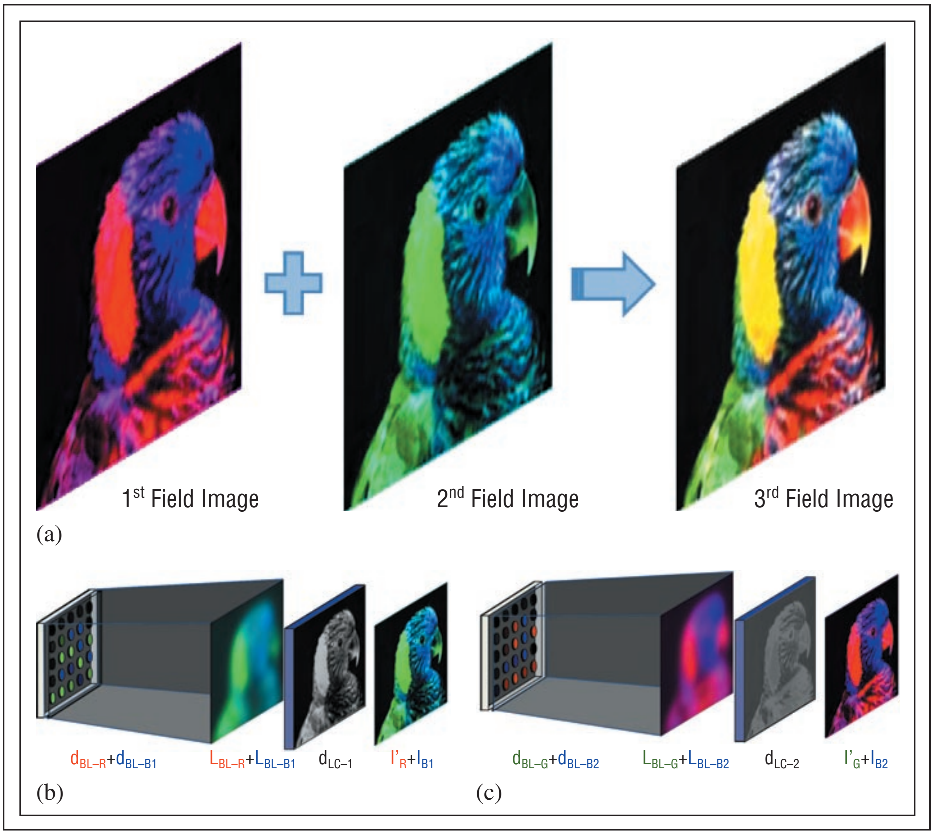

Fig. 4: *(a) A two-field driving scheme is used to display two field images sequentially, which are integrated by the human visual system to form a frame image. This process is decomposed into (b) the first field and (c) the second field on an LCD with a spatially modulated color backlight.*

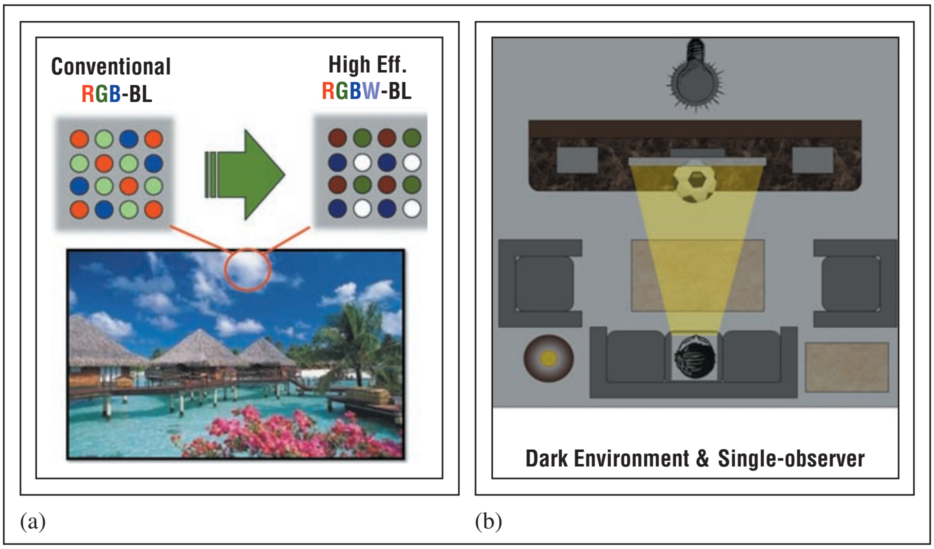

Fig. 5: *(a) At left is an RGBW 4-in-1 LED and (b) at right, a single-viewer and environment-controlled backlight.*

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Improvements in TFT-LCD Performance: Better Picture, Thinner, and Lower Power

Large-area TFT-LCDs have made great strides in terms of improved image quality and form factors, and developments in LED backlights will lead to additional improvements. The next wave of TFT-LCD development will focus on 3-D capability and advanced formats.

by Paul Semenza

MANUFACTURERS of large-area TFT-LCD panels face an ongoing dilemma – they need to continuously invest in advanced-generation manufacturing facilities, or fabs – which are increasingly expensive, but at the same time, they face strong competition, which drives down prices. Given the need to quickly amortize the high up-front costs of building a fab, and given the high material costs of making each panel, panel makers are focused on developing features that will support prices. Over the past several years, TFT-LCD manufacturers have focused on several areas of improvement. Primarily, these have involved better image quality, particularly for TVs, and thinner, more power-efficient panels.

Image Quality

Perhaps the most important improvement has been image quality. It is difficult to characterize image quality in a simple specification, but it was clear to consumers that, in many cases, LCDs lagged behind that of the CRTs they were replacing, and often behind competing technologies such as plasma, particularly in video performance. The differences became much more noticeable as panel sizes above 40 in. became widely available. Many of the challenges were related to the unique nature of LCDs – the speed depends on the liquid-crystal materials as well as the manner in which they are driven, and the color and contrast ratio depend on optimizing the liquid-crystal material, color filters, optical films, and backlight. Key metrics in this regard include response time, frame rate, color gamut, and contrast ratio. These metrics are often subjects of debate, in terms of their relationship to perceived performance, and also in that they can be subject to overuse or misuse when being used to market these products.

Paul Semenza is Senior Vice-President, Analyst Services, with DisplaySearch. He can be reached at paul.semenza@npd.com.

Response time has been a key enabler for improved video performance; current panel performance is in the range of 2–6 msec. This is significantly faster than a decade ago and is related to new formulations of liquid-crystal material, as well as to the use of "over-driving," which involves temporarily driving the liquid-crystal mixture with a voltage higher than needed to maintain the desired optical state in order to reach that state more quickly.

However, this metric only measures the time to switch the liquid crystal from one gray level to another, typically from full white to full black and/or back again. Because LCDs typically produce images by holding information for each frame, as opposed to the "impulse" method of CRTs, viewers can perceive blurring of images even with fast switching.

Panel makers have addressed this issue through several techniques. One approach is to increase the frame rate from 60 to 120 Hz or higher and insert interpolated frames (created by analyzing two adjacent frames and estimating what an intervening frame would look like), which results in a smoother motion appearance. This approach is called ME/MC (motion estimation/motion compensation).

A simpler approach is to insert black frames, or frames with partial data, which simulates the impulse method in terms of leading to sharper images, but results in lowered brightness and flicker. Another approach is to scan the backlight in a synchronized fashion with the row scan of the display. This was first achieved with CCFL backlights and is now accomplished through scanning LED backlights. Combined with 120- or 240-Hz refresh rates and ME/MC, very high-quality motion reproduction has been achieved. In order to describe the effect of these moving-picture improvements, MPRT (moving picture response time) is used instead of refresh rate.

Color performance is generally measured in two ways. One describes the percentage of the color space that the display can show, as defined by the NTSC standard. (This standard, created in the early days of color-TV broadcasts, is considered obsolete by many, but is still widely used as a specification.) The other is the number of colors, which is typically indicated by the term "bits," which defines the number of realizable gray levels in the red, green, and blue primaries. The standard reference for "full color" is 8 bits, which translates into 256 levels of gray per color and 16.7 million total colors. Recent displays can

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address 10 bits, which results in over 1 billion colors, and even 12 bits or more, but it is not clear that there is a perceptible difference at such high numbers of colors. Additional bit depth can be achieved through dynamic backlight control.

Another attribute of image quality is contrast ratio, which in its simplest form is the ratio of the brightness of a "white" pixel to that of a "black" pixel. This is another area in which the method of an LCD is at a disadvantage; in emissive displays, individual pixels can be turned completely off – no light is emitted. In a typical LCD, all pixels are constantly illuminated by the backlight, so turning off a pixel relies on the combination of polarization rotation in the liquid-crystal material and the extinction of crossed polarizers, neither of which is complete. One way to improve the contrast ratio is to actively control the backlight, through the scanning mentioned above or through local dimming, which provides varying levels of control over the backlight. In 0-D local dimming, the entire backlight is dimmed, or turned off, during dark image sequences. In 1-D local dimming, a horizontal band or bands can be dimmed separately. 2-D dimming breaks up the backlight into blocks of multiple pixels, giving a very high level of control. So-called 3-D dimming adds color control, using RGB LEDs.

Local dimming of the backlight, combined with the ability to analyze the content of each frame to determine the optimal backlight brightness level, has enabled much higher contrast ratios in LCDs. Similar to the situation with MPRT, a new metric has been developed to try to capture this improvement; "dynamic contrast ratio" (DCR) is a term that has been used to describe the presence of local dimming and also to differentiate the specification from "static" contrast ratio, the typical metric. Figures for DCR specifications are arrived at by comparing the brightest pixels in any given sequence of frames to the darkest one in the sequence, as opposed to static contrast ratio, which compares bright to dark in a given image. The DCR values can thus be very high, in excess of 10,000:1. Again, it is not clear how perceptible such high levels of DCR are, though the fact that TV is often viewed under low ambient light levels means that there is a greater degree of sensitivity than for other types of display viewing.

Physical Attributes

Another aspect of the rapid growth in panel size has been increasing concern about the size and power consumption of LCD panels. When LCDs first began competing with CRTs, the benefit in size was obvious – no longer was the display roughly as deep as the screen diagonal. However, there have been increasingly significant declines in the thickness of panels, driven by weight and form-factor considerations in notebooks and design considerations in TVs. These two applications have also demanded reductions in power consumption – in notebooks to extend battery life and in TVs to comply with environmental regulations.

The reduction in thickness has been achieved through a combination of techniques: thinner glass and components such as light-guide plates, reduction in optical components, use of edge-lit backlights, and reduced thickness of LED packages. Even large screen sizes are now available that are thinner than 10 mm: Samsung's 55-in. C9000 model uses a panel that is 7.98 mm thick. Given the weight and volume savings from thinner panels, there is perhaps even greater benefit to using them in mobile PC applications. Since these displays are made on smaller substrates, thinner glass can be used – 0.5 mm instead of 0.7 mm; for smaller displays (less than 15 in.), 0.4-mm substrates can be used, and for ultra-portable notebooks, the display cell can be thinned even more through the use of mechanical or chemical treatments. These techniques have enabled the production of displays as thin as 3 mm or less.

Given the increasing level of concern over global energy usage, regions around the world

Table 1: Typical Specifications for Large TFT-LCD Panels.
(CCFL – cold-cathode fluorescent lamp; EEFL – external-electrode fluorescent lamp.)
Source: *DisplaySearch Quarterly Production Roadmap Report*

	Notebook		Monitor		TV	
	Mainstream	**High End**	**Mainstream**	**High End**	**Mainstream**	**High End**
Brightness (nits, cd/m^2)	200–300	300–400	250–300	300–500	400	500
Response Time (msec)	8+	6 or less	6	2–3 (TN)	3	2
Color (%NTSC)	45–60	up to 100	72	100+	72	up to 100
Color (bits)	6	8	—	—	10–12	12+
Contrast Ratio	500–700:1	800:1	700–2500:1	5000:1 (LED)	3000–6000:1	10,000:1 (dynamic CR)
Backlight Type	LED edge	LED edge	2 CCFL	LED edge	U-shaped CCFL; EEFL	LED edge-direct LED
Frame Rate (Hz)			60	120–180	60–120	240–480
Thickness (mm)	5–7	3	10–15	<10	>20	10
Power (W)	3–5	2			32 in.: 100 42 in.: >100	32 in.: 50 42 in.: <100

are implementing power-consumption regulations that cover flat-panel TV. While less power hungry than the CRTs they have replaced and many of the plasma TVs they compete against, the sheer number and growing screen sizes of LCD TVs have put their power consumption in the spotlight. Since nearly all of the power consumption is due to the backlight in the LC module, LCD makers have been working on reducing power consumption through a variety of means. One avenue is to improve the optical transmission of the LCD cell, for which there are multiple approaches.[1] The other way is to improve the efficiency of the backlight through the use of more-efficient LED chips, as well as better backlight optical design.

Where to Next?

With higher-quality, thinner, and lower-power-consuming panels becoming mainstream, what are the next steps in LCD technology development?

The rapid improvements in image quality, display thickness, and power consumption described earlier owe a great deal to developments in LED backlighting. The first LED TV backlights were direct configurations – the LEDs were placed in an array directly behind the panel. But the high cost of the LEDs and the desire to create very thin form factors caused a quick shift to edge-lit configurations. Such backlights couple the light from arrays of LEDs into light-guide plates, which distribute the light across the display and extract the light through optical structures that use reflection or refraction to turn the light 90º. By addressing individual "bars" of LEDs, edge-lit LED backlights have been able to implement both 1-D and 2-D local dimming; the latter originally thought to require direct backlighting. However, with the large declines in LED prices and the desire for ever-higher performance, a new crop of direct-lit LED backlit panels is emerging. The emphasis will likely be on large (40 in. and larger) high-end panels that can command premiums.

Continued improvement in LED brightness, efficiency, and package designs are likely, and this will enable continued display improvements. Most LED backlights use white LEDs, and there are ongoing improvements in phosphor design as well as developments such as quantum dots that could enable greater efficiencies. It is also possible that RGB LEDs could be utilized, which could eventually enable implementation of field-sequential color.

The year 2010 marked the beginning of mass-production of large 3-D LCD panels for TV. Most of these panels are for "active," or frame-sequential-type 3-D sets, which can use standard 120/240 Hz or higher panels – the set maker adds an additional video channel and a transmitter/receiver circuit to communicate with the shutter glasses. However, panel makers are developing "passive," or polarization-based 3-D panels, in which the left and right frames are presented simultaneously and presented to the left and right eyes through the use of polarizing glasses. (See, "Evolving Technologies for LCD-Based 3-D Entertainment" in this issue.) This involves the integration of a polarizing retardation layer or other type of film that is built into the panel. This could mean lower costs for the consumer because the polarizing glasses are much cheaper; more importantly, it could enable panel makers to capture a greater share of any 3-D premium. However, the performance of passive 3-D displays has not yet reached the level of the active systems. Autostereoscopic 3-D displays, for which no glasses are required, are farther behind in development for large panels, though mass production is now starting in small sizes for mobile games, cameras, and mobile phones.

In 2009, panel makers started promoting what is being called cinema displays – 21:9-aspect-ratio panels, with pixel formats of 2560 × 1080. As with most transitions to widescreen panels, part of the rationale for this format is "panelization" – the ability to use a greater fraction of the substrate, particularly in Gen 8 and higher fabs, which lowers manufacturing cost. Some argue that an aspect ratio of 21:9 more closely simulates the feeling of cinema and that Blu-ray DVD supports Cinemascope HDTV, a 2.35:1 format, without the letter-box effect. Finally, with the growth in connected TV, some sort of tool bar is often required, and a 21:9 widescreen allows space for this along with a full-HD image. It is not clear if this format will succeed because there is little to no content available and the format means that consumers will have to purchase even larger displays to maintain the same screen height. Most likely, this format will be most effective in very large (greater than 60-in. diagonal) screen sizes used in home theaters. Other formats have been proposed, most notably quad-HD (3840 × 2160 pixels), but given the gradual transition to full-HD (1920 × 1080) it is not clear when the demand for such panels will become significant.

TFT-LCD Development in Perspective

With improvements in performance, particularly in video image quality, TFT-LCDs have come a long way toward matching CRT performance across the board, and surpassing it in several aspects. At the same time, available screen sizes have expanded tremendously and the physical extent of these devices has been reduced significantly. With the exception of power consumption, the rate of improvement in these areas is likely to slow, and the emphasis is shifting to advanced capabilities such as 3-D, higher resolution, and new formats. (See the article, "Two New Technology Developments for the LC Display Industry" in this issue.)

In the future, it is likely that developments in large-area TFT-LCDs will shift toward embedding more intelligence on the panel. This could include increased integration of existing functions (for example, communications or memory), as well as the development of panels that can sense and react to their environments. Integration of touch, ambient light sensing, imaging, and other functions could enable TFT-LCDs to serve as communication portals (for example, videoconferencing) and increase the capability for interactivity (for example, gesture recognition). These types of functions will provide added value and enable revenue streams that are needed to justify ongoing investments in research and manufacturing.

References

[1]C. Annis and P. Semenza, "Better Transmission: TFT-LCD Manufacturing Advances Reduce Cost and Energy Consumption," *Information Display* **17**, No. 12 (December 2009). ■

How to Get A Patent Quickly

With the U.S. patent office deluged with patents, and the pace of display technology innovation ever increasing, display pioneers with new inventions may want to consider the Accelerated Examination process.

by Steve Murray

DISPLAY TECHNOLOGY is a fast-moving industry. For example, large-screen television technology has exploded over the last decade as companies introduced thinner and thinner sets with larger and larger screen areas. Now, just as high-definition television is becoming the norm, a new generation of 3-D televisions has hit the market.

As a result of such fast-paced development, display pioneers need to protect their inventions as quickly as possible. Unfortunately, the United States Patent & Trademark Office (PTO) is inundated with hundreds of thousands of patent applications each year, and the applications are examined in each relevant field on a first-come, first-served basis. A well-publicized backlog of applications has led to a delay in patent issuance.

In 2009, according to the PTO, a patent application sat in a queue for 25.8 months, on average, before being initially reviewed by a patent examiner. The total average pendency (*i.e.*, the time period from filing to issuance of a patent or abandonment by the applicant) of an application in 2009 was estimated to be 34.6 months, or just under 3 years. This number has grown from an average of 29.1 months in 2005. These numbers do not even begin to tell the whole story. Some art fields, particularly those involving complex technology, have longer pendency periods. For example, the technology center for Computer Architecture, Software & Information Security has a total average pendency of 40.7 months.

Although provisions exist to compensate a patent owner for PTO delays during prosecution of the patent, the result is only an extension of the patent term at the back end. This is of little value to a patent owner if the technology claimed is already obsolete by the time the patent issues.

Special Petitions

Fortunately, the PTO allows for a "Petition to Make Special," wherein an applicant can have the application examined out of turn. An application may be taken out of turn if (i) the applicant is over 65 or is in a state of health such that the applicant might be unable to assist in prosecution if the application should proceed to run its normal course, (ii) the application was first filed in a particular foreign country and received a ruling favorable to patentability in the foreign country; or (iii) the application complies with the requirements for "Accelerated Examination."

Options (i) and (ii) are not available to the vast majority of patent applicants. Thus, the most promising method for speeding up patent prosecution in the U.S. is to take advantage of the "Accelerated Examination" program. The goal of this program is to complete examination within 1 year of the filing date of the application, which is a much more welcome

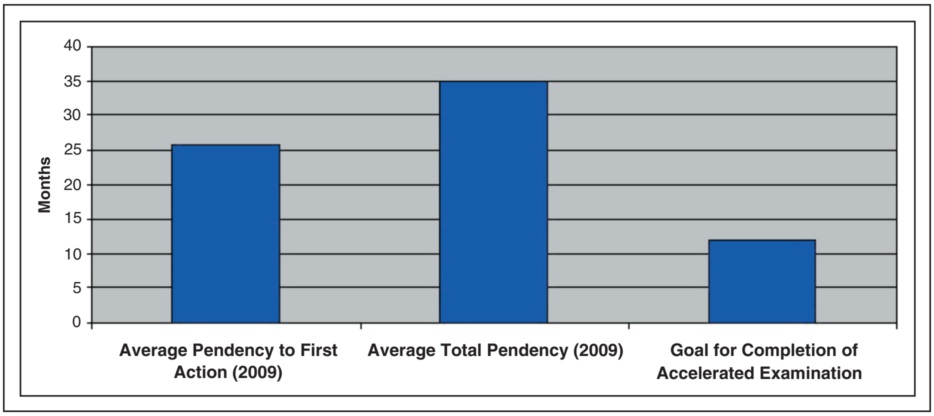

Fig. 1: *The average pendency time frame for a non-accelerated patent application is about 3 years.*

Stephen Murray *is a Registered Patent Attorney at Panitch Schwarze Belisario & Nadel LLP in Philadelphia, Pennsylvania. His practice involves the preparation and prosecution of patent applications, enforcement and litigation of patents, and opinion work on patent validity, infringement, and patentability. He has a B.S. degree in physics from Temple University. He can be reached at smurray@panitchlaw.com.*

time frame than the nearly 3-year average pendency (see Fig. 1). A petition must be filed and granted by the PTO in order to receive an accelerated examination.

Accelerated Examination Requirements and Procedures

Of course, there is a catch to the Accelerated Examination program, which is that the applicant must meet several stringent requirements in order to have the petition granted by the PTO. Among the most important requirements is that the applicant must conduct a detailed search of U.S. patent and published applications, foreign patent documents, and non-patent literature for the claimed invention. Once the references most closely related to the subject matter of the invention are located, the applicant must provide a detailed explanation as to why the claims (the portion of the patent that delineates the scope and boundaries of the invention) are patentable over each reference. Essentially, the applicant is performing one of the examiner's tasks; namely, locating the closest and most relevant "prior art," which helps to streamline the examination process down the road.

If the petition is granted, prosecution of the patent application proceeds as it would normally, but on a much faster schedule. The examiner will review the claims and the cited references, do some further searching, and then either allow or reject the claims. Often the examiner will request an interview with the applicant to discuss any issues the examiner has identified, in an effort to either get the claims in condition for allowance or to focus or narrow down the issues that will be addressed in a formal rejection. If any claims are rejected, the applicant has 1 month to file a response, which may include amendments to the claims. The examiner reviews the response, and then, if all goes well, allows the claims, although other rejections may issue. If the examiner issues a final rejection, the applicant can request further examination, but the further examination will not necessarily be on the accelerated timetable. However, this may not always be objectionable since the bulk of the pendency of an application is awaiting the first action by the PTO.

There are pros and cons associated with an Accelerated Examination. Perhaps one of the largest negatives is the up-front cost. The cost for filing a patent application includes PTO fees and fees incurred by a patent attorney or agent. Preparation of the petition piles on more costs. For example, to meet the demands of the PTO in terms of searching the prior art, a professional search firm is typically employed. A search performed by a reputable patent searching firm for purposes of an Accelerated Examination petition will often cost several thousand dollars. Once the results are received, the patent attorney or agent needs to review each reference to determine how the claimed invention differs from each of the references. The attorney or agent then must prepare the documents in support of the petition, which can be extensive depending on the nature and complexity of the invention. The up-front cost can sometimes total as much as the cost of preparing the patent application.

Patent applications in the Accelerated Examination program are also limited in the number of claims that may be presented. The applicant can file no more than three independent claims and 20 or fewer total claims. While this number of claims should be sufficient in most instances, certain features may have to be omitted from the set of claims in order to meet these limits.

The applicant is also limited in the amendments that can be made to the claims during examination. If the applicant wishes to amend the claims during prosecution by introducing a new feature, then the search must be updated, which can be difficult given the time constraints imposed for responding to rejections. An applicant normally has a period of 3 months to file a response with the PTO and can obtain three more months of extension upon payment of a fee, but in the Accelerated Examination process, the applicant has only 1 month (non-extendable) to file a response.

Lastly, petitions are meticulously inspected by the PTO, and therefore require careful preparation by the applicant. Petitions can be denied for any number of formalistic reasons, such as inadequacy of search, failure to recite certain phrases, or the like. Once a petition is denied, an applicant has only a limited number of opportunities to correct the deficiencies before the application is placed back on the regular schedule.

Accelerated Examination Has High Success Rate

On the positive side, however, patents are issuing at a much faster rate under Accelerated Examination. The PTO is meeting or exceeding the expected 12-month goal for concluding prosecution. Even better, of the applications that have completed prosecution under the Accelerated Examination program, 71% have issued as patents. Compare this with the 44% allowance rate of all applications in 2009 (see Fig. 2). By filing under the Accelerated Examination program, an applicant's patent is much more likely to be allowed.

One reason for the higher allowance rate is that the applicant has a better idea of the state of the prior art and the most closely related references before filing the application. For a regular (non-accelerated) application, an applicant is not required to search the prior art. While many applicants commission patentability searches, such searches are typi-

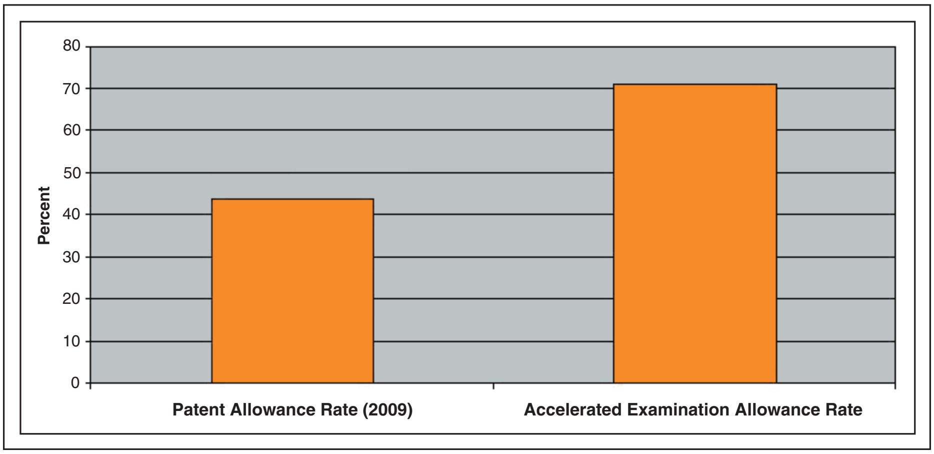

Fig. 2: *Percentage-wise, accelerated patent examinations fare better in terms of allowance rates than their non-accelerated counterparts.*

cally not exhaustive, and the applicant is often surprised by references located by the examiner. By performing a much more intensive search up front, the applicant is in a better position to know where the boundaries of the patent protection should be set, rather than taking wild stabs in the dark.

A further benefit derived from Accelerated Examination is that the overall cost of obtaining the patent may be less. As described earlier, the cost for taking an application out of turn is very front-loaded. However, as a prosecution drags on for several years, the cost can climb substantially, particularly where the examiner issues several rejections. Under the Accelerated Examination program, with the PTO and the applicant working toward concluding prosecution within 12 months, and with the most relevant references already known, the rejections and responses are much more focused and succinct. In the long run, filing for Accelerated Examination may actually save money.

New Application Tracks Proposed

Very recently, the PTO has proposed a new scheme in which an application can be placed into one of three tracks: (i) prioritized examination; (ii) conventional examination; and (iii) delayed examination. Entrance into the prioritized examination track would require only the payment of a fee to the PTO. Unlike the Accelerated Examination program, no search would be required, so the examination process itself would not necessarily be quicker; it would just start sooner.

It is unclear at this point if or when the PTO will implement this proposed three-track procedure. Hopefully, the PTO will retain the Accelerated Examination process as an option for applicants because it not only reduces the pendency prior to initial review by the examiner, but also speeds the examination process itself.

The option for obtaining a patent quickly is definitely available. The questions to consider are whether getting a patent issued as soon as possible is worth front-loading the cost and putting in the extra effort required to make it happen. If the technology will be obsolete in 3 or 4 years, or if a competitor is expected to copy the invention immediately, this option should definitely be investigated. ■

Journal of the

SOCIETY FOR INFORMATION DISPLAY

The following papers appear in the October 2010 (Vol. 18/10) issue of *JSID*.
For a preview of the papers go to sid.org/jsid.html.

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SID 2011 honors and awards nominations

On behalf of the SID Honors and Awards Committee (H&AC), I am appealing for your active participation in the nomination of deserving individuals for the various SID honors and awards. The SID Board of Directors, based on recommendations made by the H&AC, grants all the awards. These awards include five major prizes awarded to individuals, not necessarily members of SID, based upon their outstanding achievements. The **Karl Ferdinand Braun prize** is awarded for ***"Outstanding Technical Achievement in, or contribution to, Display Technology."*** The prize is named in honor of the German physicist and Nobel Laureate Karl Ferdinand Braun who, in 1897, invented the cathode-ray tube (CRT). Scientific and technical achievements that cover either a wide range of display technologies or the fundamental principles of a specific technology are the prime reasons for awarding this prize to a nominee. The **Jan Rajchman prize** is awarded for ***"Outstanding Scientific and Technical Achievement or Research in the Field of Flat-Panel Displays."*** This prize is specifically dedicated to those individuals who have made major contributions to one of the flat-panel-display technologies or, through their research activities, have advanced the state of understanding of one of those technologies. The **Otto Schade prize** is awarded for ***"Outstanding Scientific or Technical Achievement in the Advancement of Functional Performance and/or Image Quality of Information Displays."*** This prize is named in honor of the pioneering RCA engineer Otto Schade, who invented the concept of the Modulation Transfer Function (MTF) and who used it to characterize the entire display system, including the human observer. The advancement for this prize may be achieved in any display technology or display system or may be of a more general or theoretical nature. The scope of eligible advancement is broadly envisioned to encompass the areas of display systems, display electronics, applied vision and display human factors, image processing, and display metrology. The nature of eligible advancements may be in the form of theoretical or mathematical models, algorithms, software, hardware, or innovative methods of display-performance measurement, and image-quality characterization. Each of these above-mentioned prizes carries a $2000

SID honors and awards nominations

Nominations are now being solicited from SID members for candidates who qualify for SID Honors and Awards.

- KARL FERDINAND BRAUN PRIZE. Awarded for an outstanding *technical* achievement in, or contribution to, display technology.
- JAN RAJCHMAN PRIZE. Awarded for an outstanding *scientific* or *technical* achievement in, or contribution to, research on flat-panel displays.
- OTTO SCHADE PRIZE. Awarded for an outstanding *scientific* or *technical* achievement in, or contribution to, the advancement of functional performance and/or image quality of information displays.
- SLOTTOW–OWAKI PRIZE. Awarded for outstanding contributions to the education and training of students and professionals in the field of information display.
- LEWIS & BEATRICE WINNER AWARD. Awarded for exceptional and sustained service to SID.
- FELLOW. The membership grade of Fellow is one of unusual professional distinction and is conferred annually upon a SID member of outstanding qualifications and experience as a scientist or engineer in the field of information display who has made widely recognized and significant contribution to the advancement of the display field.
- SPECIAL RECOGNITION AWARDS. Presented to members of the technical, scientific, and business community (not necessarily SID members) for distinguished and valued contributions to the information-display field. These awards may be made for contributions in one or more of the following categories: (a) outstanding technical accomplishments; (b) outstanding contributions to the literature; (c) outstanding service to the Society; (d) outstanding entrepreneurial accomplishments; and (e) outstanding achievements in education.

Nominations for SID Honors and Awards must include the following information, preferably in the order given below. Nomination Templates and Samples are provided at *www.sid.org/awards/nomination.html.*

1. Name, Present Occupation, Business and Home Address, Phone and Fax Numbers, and SID Grade (Member or Fellow) of Nominee.

2. Award being recommended:
   Jan Rajchman Prize
   Karl Ferdinand Braun Prize
   Otto Schade Prize
   Slottow–Owaki Prize
   Lewis & Beatrice Winner Award
   Fellow*
   Special Recognition Award

*Nominations for election to the Grade of Fellow must be supported in writing by at least five SID members.

3. Proposed Citation. This should not exceed 30 words.

4. Name, Address, Telephone Number, and SID Membership Grade of Nominator.

5. Education and Professional History of Candidate. Include college and/or university degrees, positions and responsibilities of each professional employment.

6. Professional Awards and Other Professional Society Affiliations and Grades of Membership.

7. Specific statement by the nominator concerning the most significant achievement or achievements or outstanding technical leadership that qualifies the candidate for the award. This is the most important consideration for the Honors and Awards committee, and it should be specific (citing references when necessary) and concise.

8. Supportive material. Cite evidence of technical achievements and creativity, such as patents and publications, or other evidence of success and peer recognition. Cite material that specifically supports the citation and statement in (7) above. (Note: the nominee may be asked by the nominator to supply information for his candidacy where this may be useful to establish or complete the list of qualifications).

9. Endorsements. Fellow nominations must be supported by the endorsements indicated in (2) above. Supportive letters of endorser will strengthen the nominations for any award.

E-mail the complete nomination – including all the above material by **October 8, 2010** – to fan.luo@auo.com or sidawards@sid.org or by regular mail to:
Fan Luo, Honors and Awards Chair, Society for Information Display,
1475 S. Bascom Ave., Ste. 114, Campbell, CA 95008, U.S.A.

stipend sponsored by AU Optronics Corp., Sharp Corporation, and Samsung Mobile Display, respectively.

The **Slottow–Owaki prize** is awarded for ***"Outstanding Contributions to the Education and Training of Students and Professionals in the Field of Information Display."*** This prize is named in honor of Professor H. Gene Slottow, University of Illinois, an inventor of the plasma display and Professor Kenichi Owaki from the Hiroshima Institute of Technology and an early leader of the pioneering Fujitsu Plasma Display program. The oustanding education and training contributions recognized by this prize is not limited to those of a professor in a formal university, but may also include training given by researchers, engineers, and managers in industry who have done an outstanding job developing information-display professionals. The Slottow–Owaki prize carries a $2000 stipend made possible by a generous gift from Fujitsu, Ltd., and Professor Tsutae Shinoda.

The fifth major SID award, the **Lewis and Beatrice Winner Award,** is awarded for ***"Exceptional and Sustained Service to the Society."*** This award is granted exclusively to those who have worked hard over many years to further the goals of the Society.

The membership grade of **SID Fellow Award** is one of unusual professional distinction. Each year the SID Board of Directors elects a limited number (up to 0.1% of the membership in that year) of **SID members** in good standing to the grade of **Fellow.** To be eligible, candidates must have been members at the time of nomination for at least 5 years, with the last 3 years consecutive. A candidate for election to Fellow is a member with ***"Outstanding Qualifications and Experience as a Scientist or Engineer in the Field of Information Display who has made Widely Recognized and Significant Contributions to the Advancement of the Display Field"*** over a sustained period of time. SID members practicing in the field recognize the nominee's work as providing significant technical contributors to knowledge in their area(s) of expertise. For this reason, five endorsements from SID members are required to accompany each Fellow nomination. Each Fellow nomination is evaluated by the H&AC, based on a weighted set of five criteria. These criteria and their assigned weights are creativity and patents, 30%; technical accomplishments and publications, 30%; technical leadership, 20%; service to SID, 15%; and other accomplishments, 5%. When submitting a Fellow award nomination, please keep these criteria with their weights in mind.

The **Special Recognition Award** is given annually to a number of individuals (membership in the SID is not required) of the scientific and business community for distinguished and valued contribution in the information-display field. These awards are given for contributions in one or more of the following categories: (a) ***Outstanding Technical Accomplishments,*** (b) ***Outstanding Contributions to the Literature,*** (c) ***Outstanding Service to the Society,*** (d) ***Outstanding Entrepreneurial Accomplishments,*** and (e) ***Outstanding Achievements in Education.*** When evaluating the Special Recognition Award nominations, the H&AC uses a five-level rating scale in each of the above-listed five categories, and these categories have equal weight. Nominators should indicate the category in which a Special Recognition Award nomination is to be considered by the H&AC. More than one category may be indicated. The nomination should, of course, stress accomplishments in the category or categories selected by the nominator.

While an individual nominated for an award or election to Fellow may not submit his/her own nomination, nominators may, if necessary, ask a nominee for information that will be useful in preparing the nomination. The nomination process is relatively simple, but requires that the nominator and perhaps some colleagues devote a little time to preparation of the supporting material that the H&AC needs in order to evaluate each nomination for its merit. It is not necessary to submit a complete publication record with a nomination. Just list the titles of the most significant half a dozen or less papers and patents authored by the nominee, and list the total number of papers and patents he/she has authored.

Determination of the winners for SID honors and awards is a highly selective process. Last year less than 30% of the nominations were selected to receive awards. Some of the major prizes are not awarded every year due to the lack of sufficiently qualified nominees or, in some cases, because no nominations were submitted. On the other hand, once a nomination is submitted, it will stay active for three consecutive years and will be considered three times by the H&AC. The nominator of such a nomination may improve the chances of the nomination by submitting additional material for the second or third year that it is considered, but such changes are not required.

Descriptions of each award and the lists of previous award winners can be found at *www.sid.org/awards/indawards.html*. Nomination forms are available at *www.sid.org/awards/nomination.html* where you will find Nomination Templates in both MS Word (preferred) and Text formats. Please use the links to find the Sample Nominations, which are useful for composing your nomination since these are the actual successful nominations for some previous SID awards. Nominations should preferably be submitted by e-mail. However, you can also submit nominations by ordinary mail if necessary.

Please note that with each Fellow nomination, only five written endorsements by five SID members are required. These brief endorsements – *a minimum of 2–3 sentences* to a maximum of one-half page in length – *must state why clearly and succinctly, in the opinion of the endorser, the nominee deserves to be elected to a Fellow of the Society. Identical endorsements by two or more endorsers will be automatically rejected* (no form letters, please). Please send these endorsements to me either by e-mail (preferred) or by hardcopy to the address stated in the accompanying text box. Only the Fellow nominations are required to have these endorsements. However, I encourage you to submit at least a few endorsements for all nominations since they will frequently add further support to your nomination.

All 2011 award nominations are to be submitted by October 8, 2010. E-mail your nominations directly to fan.luo@auo.com or sidawards@sid.org. If that is not possible, then please send your hardcopy nomination by regular mail.

As I state each year: "In our professional lives, there are few greater rewards than recognition by our peers. For an individual in the field of displays, an award or prize from the SID, which represents his or her peers worldwide, is a most significant, happy, and satisfying experience. In addition, the overall reputation of the society depends on the individuals who are in its 'Hall of Fame.'

When you nominate someone for an award or prize, you are bringing happiness to an individual and his or her family and friends, and you are also benefiting the society as a whole."

Thank you for your nomination in advance.

– Fan Luo
Chair, SID Honors & Awards Committee

Chair Holder Sought for the Carol and Lawrence E. Tannas, Jr., Endowed Chair in Engineering

The next great innovation in display technology could be coming soon from the University of California Los Angeles, thanks to a generous gift from SID Fellow and past-president of the Society for Information Display Larry Tannas and his wife, Carol. The Carol and Lawrence E. Tannas, Jr., Chair in the Materials Science and Engineering Department at University of California Los Angeles was established with a gift of $1 million. Now officials at UCLA are seeking an appropriate individual to conduct research in electronic information displays and associated areas.

Tannas notes that the Society for Information Display was founded at UCLA on September 29, 1962, by the unanimous vote of the 39 attendees, who consisted mostly, though not exclusively, of the Information Displays Class conducted by Dr. Harold Luxenberg at UCLA Extension. This class was later led, for over 20 years, by Tannas.

The UCLA Selection Committee, headed by Professor Bruce Dunn, will begin the selection process in September 2010. The holder of the chair is expected to be named in a formal presentation at the SID Symposium in Los Angeles in May 2011. "To the best of my knowledge, this chair is the first of its kind in the field of display research in the U.S.," says Munisamy Anandan, current SID President. "This fits the mission of SID very well, and I congratulate Larry on his vision."

Tannas is a consultant in the electronic-information-display industry, whose recent work has focused on the development and application of resized LCDs for the aerospace and signage industries. He began his career in the aerospace industry, working at several large engineering corporations and specializing in advanced concepts in guidance navigation and control, as well as electronic information displays. Tannas holds both a B.S. and an M.S. degree in electrical engineering.

"It is this kind of generosity and dedication to the original vision of SID that ensures that future opportunities for display technology innovation will continue to include the academic community. This in turn helps nurture the next generation of college students who may choose to focus on displays in their careers," says Stephen Atwood, *Information Display*'s Executive Editor. ■

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Partial list of invited speakers: Dr. Ana Arias, Xerox PARC, Dr. Marie O'Regan, DuPont Display, Dr. Vishal Shrotriya, Solarmer Energy, Inc., Ken Werner, Nutmeg Consulting, Prof. Mark Thompson, USC

For the complete program and registration information: http://organicdisplayslighting.com or http://sidla.org

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I think this is one of those paradigm-shifting technologies that will basically just appear one day and be everywhere the next. Traffic signals and all manner of outdoor advertising will be "data enabled" overnight. Just picture Times Square in New York City with all those lights and signs offering streaming content and personalized information to your handheld device. New buildings will be automatically designed with this technology in mind. The market for digital-data-capable LED light fixtures for homes could burst open before our eyes. The opportunity for widespread adoption at low cost with a clear value to consumers is so compelling that it could reinvigorate the entire home-automation industry. Imagine an almost endless array of wireless devices in one space with no radio-frequency conflicts or complicated setup issues. Full and unequalled privacy can be achieved within the walls of your home without you needing a master's degree in data-encryption technology. It will not be tomorrow, but I'm betting this will become one of those ubiquitous technologies such as mobile phones and microwaves. At some point, the thought of not being able to open your laptop under your desk lamp or point your iPhone at a billboard to get data will seem like being back in the dark ages.

Coming up in October will be our OLED technology issue, with a focus on architectural lighting. I am fairly sure the fast response time and wide range of power levels will enable OLED lighting to also support VLC and maybe create an interesting fabric of competition between discrete inorganic LEDs and OLED arrays in this marketplace.

Meanwhile, in our current issue, with help from our guest editor Dr. Shin-Tson Wu, Pegasus Professor at the College of Optics & Photonics, University of Central Florida, we celebrate the continuing innovation of LCD technology by looking at ongoing developments, including the state of the art for 3-D visual entertainment in the home. Now that flat-panel TVs, primarily LCD-based ones, are the standard for home entertainment, and with the clear success of 3-D cinema and its growing array of available content, it is more than obvious that 3-D television should be in strong demand as products become affordable. However, as author Jeong Hyun Kim points out in his Frontline Technology article "Evolving Technologies for LCD-Based 3-D Entertainment," there are still some meaningful shortcomings with regard to polarizing glasses and the resolution/cost tradeoffs associated with current approaches. Kim suggests a possible significant improvement over the status quo that clearly warrants further investigation.

Our next Frontline Technology feature also addresses 3-D, both glasses-based and autostereoscopic, as well as touch integration and other ongoing developments with LCDs. Authors Jenn Jia Su, Hsiang-lin Lin, and Alan Lien in their article, "Two New Technology Developments in the LCD Industry," provide a promising glimpse of the challenges and new developments in autostereoscopic LCDs, expressing their belief that the use of glasses is a short-term solution and that the final embodiment will be as natural as watching TV today, only three dimensional.

Earlier this year, we briefly described a JSID student paper on the development of the stencil method for field-sequential-color LCDs. This work was performed at the National Chiao Tung University (NCTU) in Hsinchu, Taiwan, by Assistant Professor Yi-Pai Huang and Professor Han-Ping D. Shieh, along with their very talented and innovative students. That paper was voted JSID's Best Student Paper for 2009. This month, Huang and Shieh return to share with us their broader views on the future possibilities of producing very low-power, full-color LCDs in their article "Eco-Display: An LCD-TV Powered by a Battery?"

Our fourth LCD feature this month is a look at the Display Marketplace for LCDs by frequent contributor and longtime industry colleague Paul Semenza of DisplaySearch. Paul examines the dilemma that LCD manufacturers face with continuing downward pressure on prices and the simultaneous need to fund never-ending expansions of their fabs. The answer of course is adding new technology, improving performance, and finding new ways to differentiate themselves to help sustain prices and margins. I think you will find his analysis, "Improvements in TFT-LCD Performance: Better Picture, Thinner, and Lower Power," very insightful and informative.

I really hope you enjoy this issue of *Information Display*. ■

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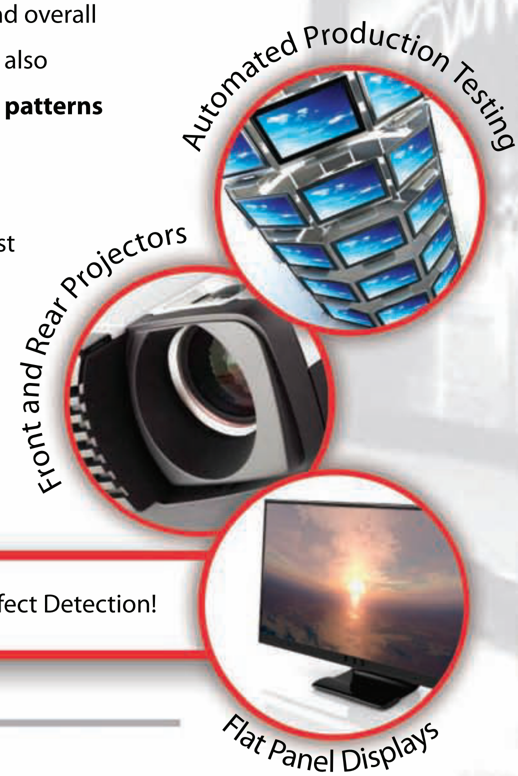

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