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Information DISPLAY

APRIL/MAY 1999
Vol. 15, No. 4/5

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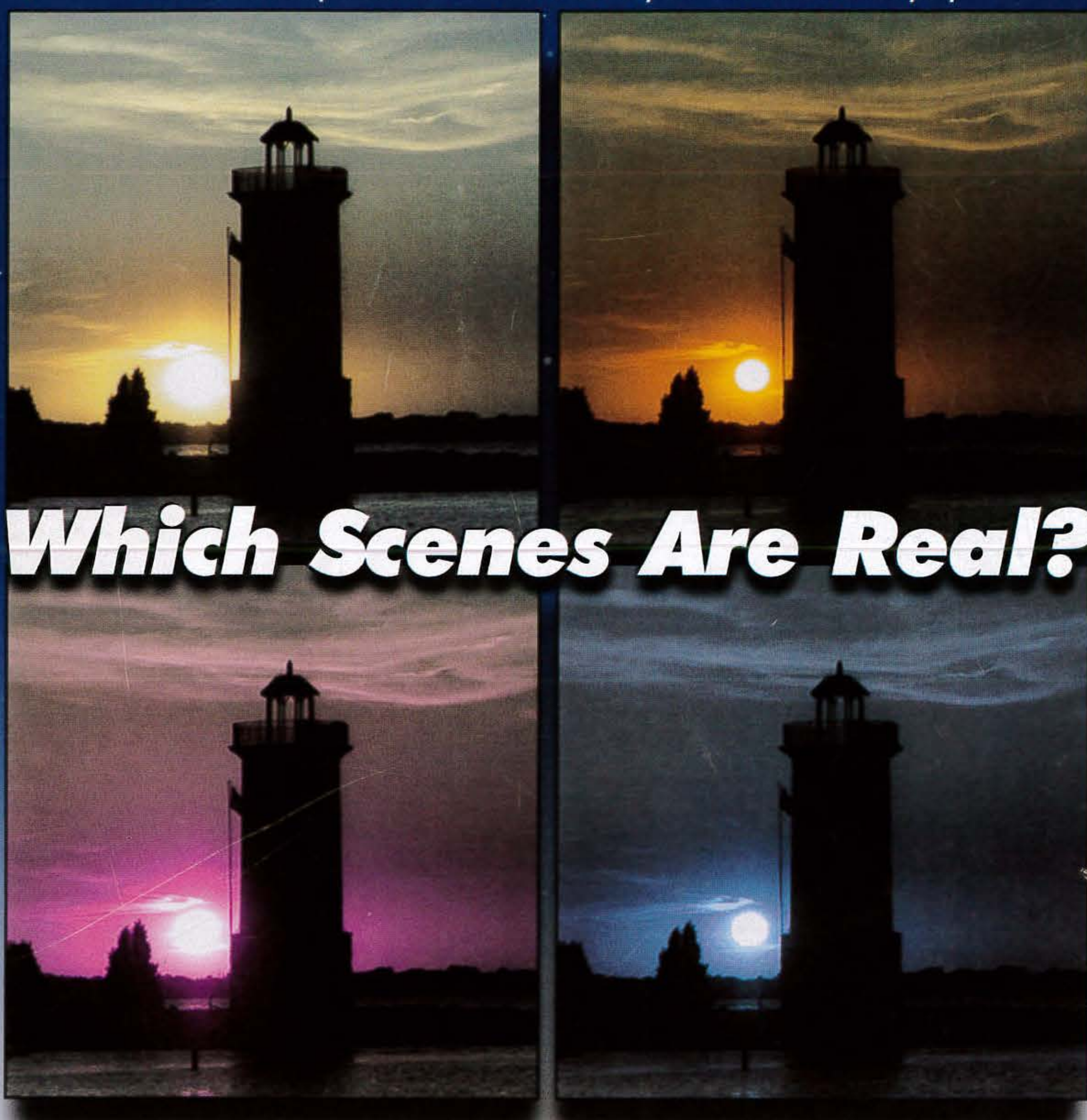

- **Products on Display at SID '99**
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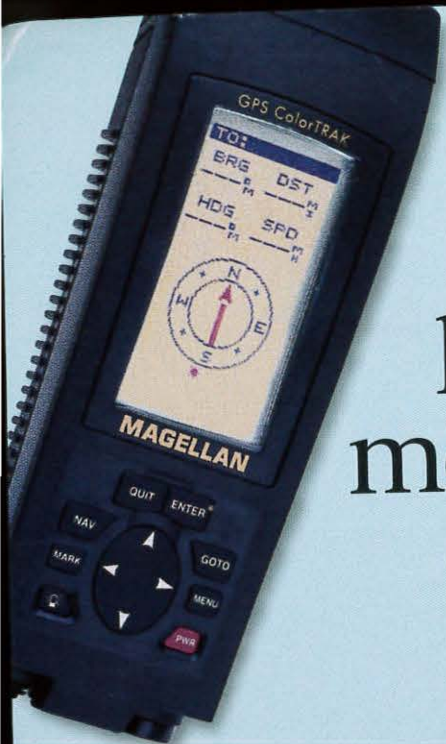
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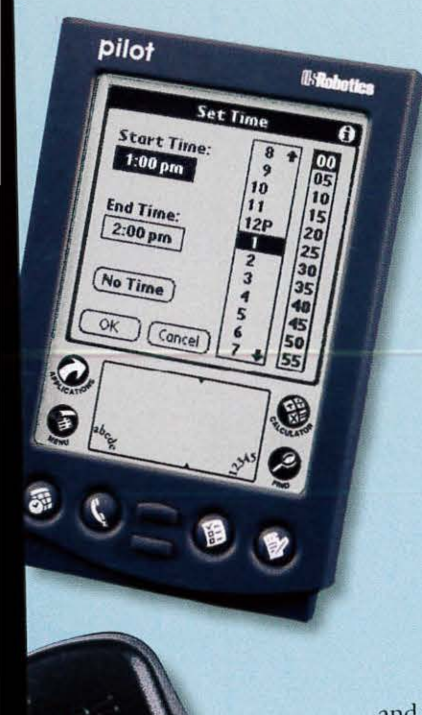
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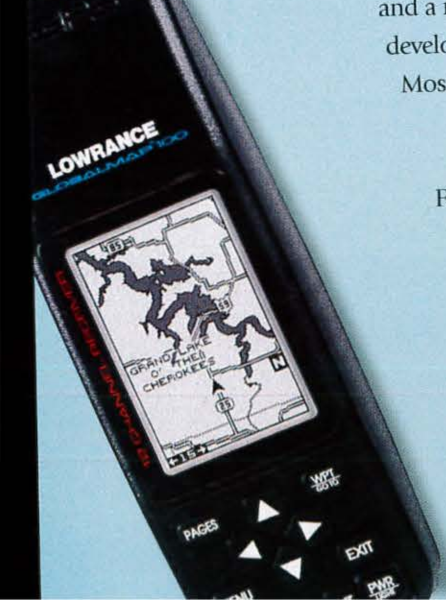
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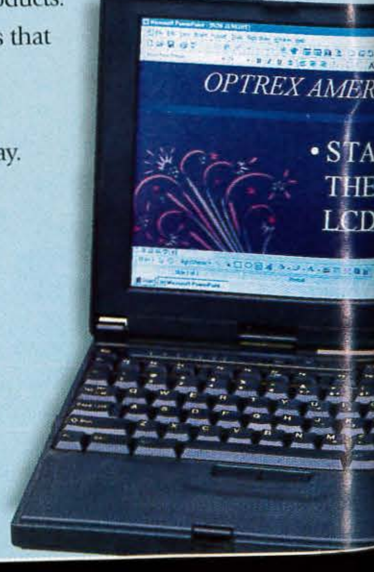
OPTREX AMER

COVER: When we can't see the original scene, how do we know what's real? Judging the naturalness of color rendition becomes much more difficult in scenes that are unfamiliar. See "Space, the Final Color Frontier," beginning on page 46.

Credit: S. Yendrikhovskij, IPO, Eindhoven

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Next Month in *Information Display*

CRT Issue

- The "Camel" CRT
- High-Contrast CRTs
- Direct-View CRTs
- EID '98 Report
- Display Works Review

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Information DISPLAY

APRIL/MAY 1999
VOL. 15, NO. 4&5

editorial

Display Education in the U.S.?

Sungkyoo Lim, Director of the Information Display Research Center at Dankook University in Cheonan, Korea, tells me that there are approximately 100 professors in Korea working on display-manufacturing issues. Just display manufacturing!

There is also (not surprisingly) generous academic support for the display industry in Japan, where the International Display Workshops - a research-oriented conference - draws more than 800 people annually, 75% of them from Japan.

Although there are pockets of display-related academic activity in the U.S. (see Bob Donofrio's piece in "SID News" in this issue), the only world-class center - in my opinion, at least - is Kent State University's Liquid Crystal Institute. The Institute has done impressive work, but one center is not enough. Now, the University of California, San Diego, wants to help fill the void.

UC San Diego is working to establish a Center for Information Displays, which would be a university-industry-government consortium. Among the entities working to develop the new center are the California Office of Strategic Technologies, Sony (which has a major presence in San Diego and neighboring Tijuana, Mexico), Intel, Motorola, Proxima, Candescent, Gemfire, and the U.S. Display Consortium (USDC).

UC San Diego is no stranger to display-related research and education. Thirteen professors and 30 graduate students and post docs are doing display-related work now, and courses are being taught at both the undergraduate and graduate levels. Jan Talbot, a professor of chemical engineering, is the Center's Acting Director.

The university also has experience in creating centers and making them work. Existing centers for wireless communications and magnetic recording have succeeded in attracting private-sector support, drawing creative students and faculty, and producing valuable results.

Talbot and her industrial and academic colleagues are now working on attracting industry partners and obtaining their requests for the research they would like to have done. In a recent telephone interview, Jeff Nagle of the School of Engineering External Relations office told me, "Industry came to us and said, 'Here's this huge market that's getting bigger, but there are so many unresolved issues, and there needs to be someplace where these issues can be brought together.'

"The industry said to us, 'Displays are the future and the U.S. needs to do more, especially in regard to emissive displays.' Our faculty members who had already been working on such issues were delighted to receive this message."

Nagle concluded our conversation by saying, "We would hope to announce the formal creation of the Center at SID '99 in San Jose during the week of May 16th."

USDC made a concentrated effort to develop the hardware for a display-manufacturing infrastructure in the U.S., but there has been no parallel effort to expand the human infrastructure. With appropriate assistance, UC San Diego's Center for Information Displays could produce much-needed knowledge about both specialized and multi-disciplinary display issues - and also train a new generation of knowledge seekers.

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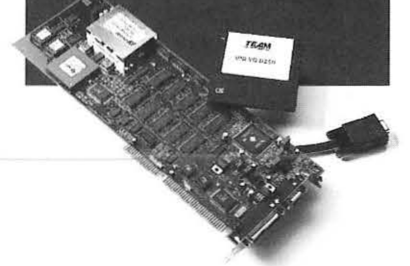

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Circle no. 60

The Great Inversion of 2029 ...

by Aris Silzars

It was 5:45 in the morning and still dark outside. Jeff was not ready to get out of bed. Another half-hour of peaceful snoozing wouldn't be so bad, would it? Unfortunately, with each passing minute the computer-programmed music increased in volume and tempo. At 5:52 Jeff's computer changed to its speaking mode and told him that he really would have to get up now. Along with the verbal prodding, the computer also increased the illumination in the room to full brightness.

By now, Jeff knew the routine. No sense putting up with more of this. He might as well get out of bed. While having his customary quick breakfast, Jeff scanned the news and had a brief discussion about his latest credit card statement with his computer. He hated these discussions. Computers just don't understand the joys of shopping for a new high-tech toy, he thought to himself.

By 6:20, he was in his car and out on the crowded highway heading east from Antioch. It was a typically clear, warm, and dry California late-spring morning. The sun was about to break over the bare East Bay hills. In spite of the traffic, Jeff didn't mind the forty-five minute drive to his work site today. In fact, the sunrise and the fresh early-morning air had so captivated him that it was some time before he was aware of a vague, uneasy feeling that he had forgotten something.

He was within five minutes of the construction site when he remembered to adjust his neural implant to lower his IQ to better suit his day's activities. Jeff's computer had reminded him to do this as he left the house that morning, as it did every morning, but this time he had almost forgotten. Oh well, the first hour on the job would be a little more frustrating while the implant slowly adjusted his intellectual-stimulation acceptability level to match his construction job demands, but then for the rest of the day he would be OK.

Every time he forgot to adjust his implant, it felt like he was stripping his gears while he worked. His mind would go all philosophical on him, which was a distracting nuisance that slowed his work rate on his job as a journeyman residential electrician. Philosophical contemplation wasn't exactly what was desired while installing electrical wiring in this multithousand-home development, with its over-pretentious name "Grand-Ridge Executive Estates" - house by house, wire by wire, and switch box by switch box.

The last ten years had been eventful in his life. Back in 2010, Jeff had graduated with an advanced computer-science degree from a well-known California university. His career had really taken off along with the rapid progress being made in software technology and computer intelligence. But during the critical ten-year period starting in 2023, as computer intelligence increased and finally surpassed what humans could do, the careers of most software engineers, computer scientists, and other knowledge workers had come to an unexpected and abrupt end. The government-sponsored retraining programs had been of some help, but still the change had been dramatic and had devastated careers, companies, and university departments.

Here he was in 2035 in the prime of his life, and the only jobs available were those involving physical activities that computers couldn't do yet. From the per-

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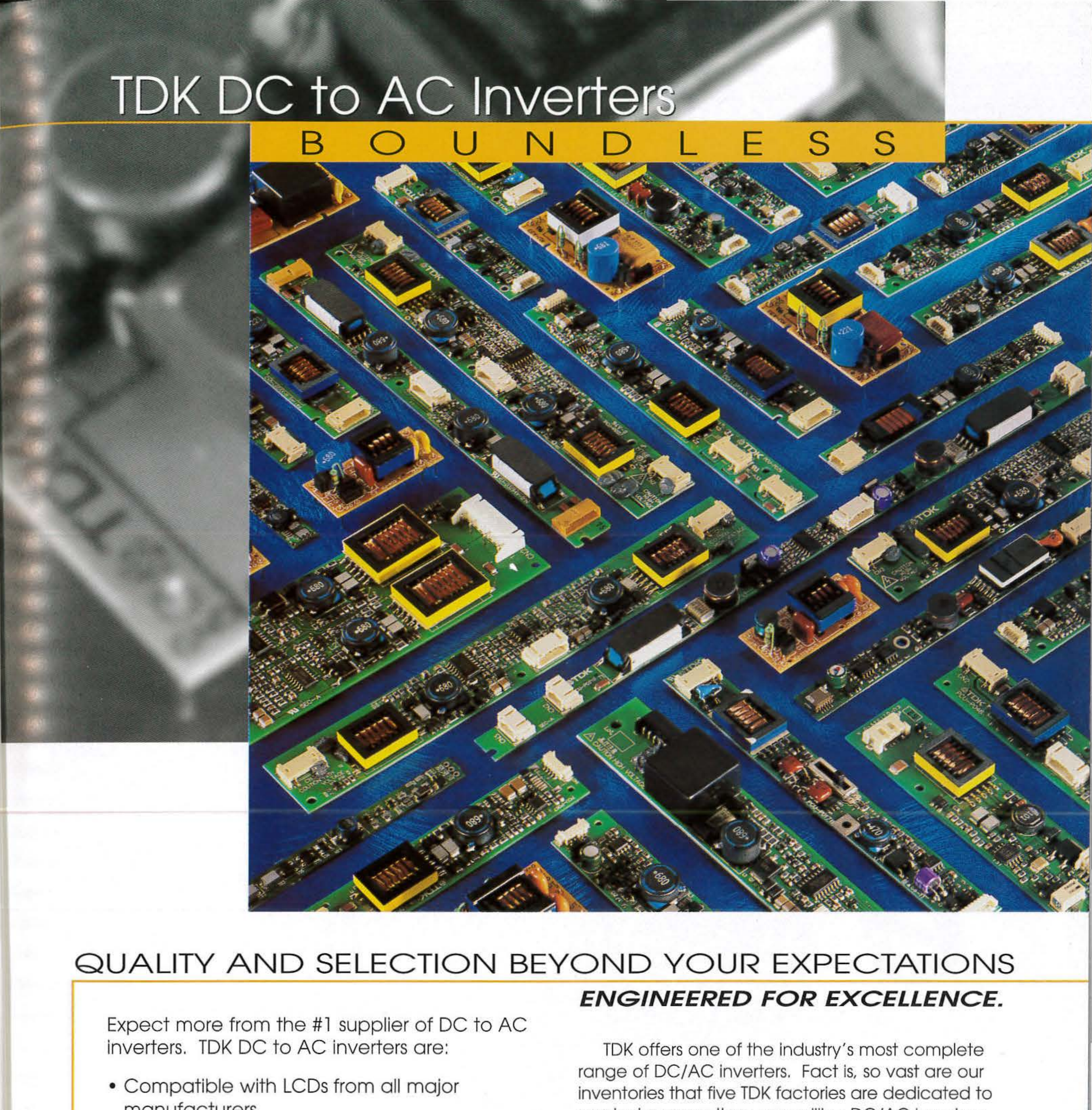

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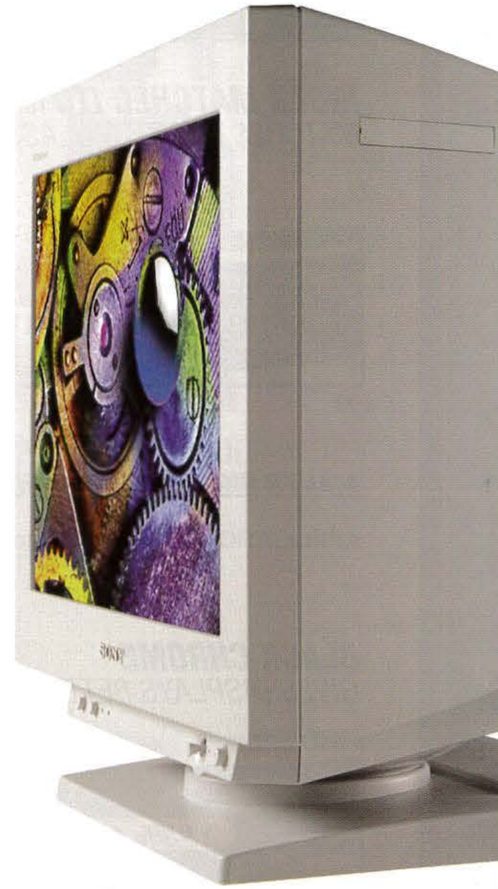

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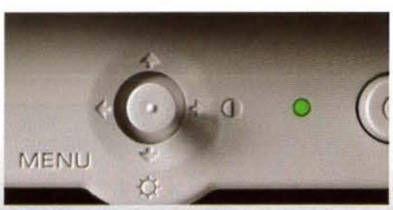

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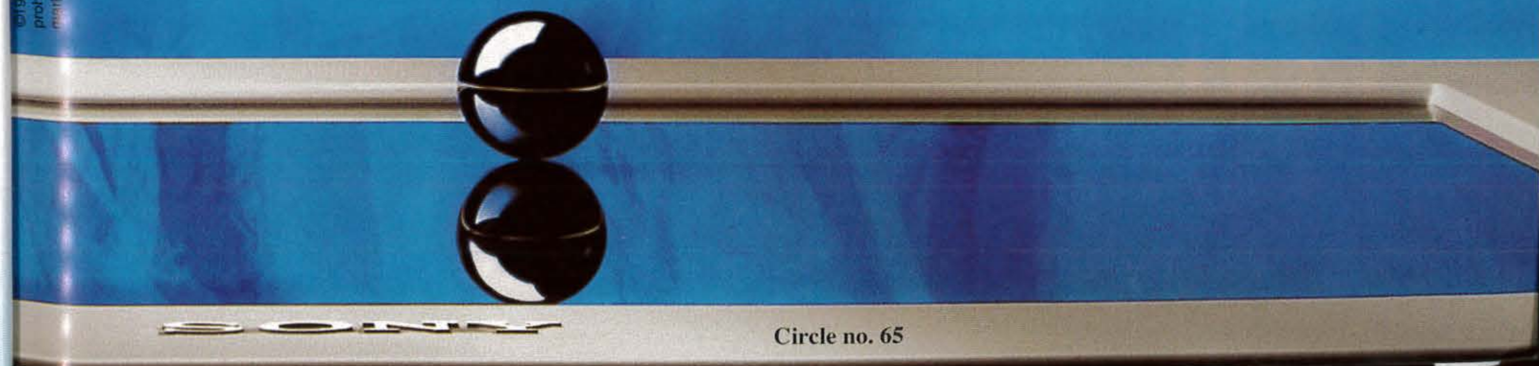

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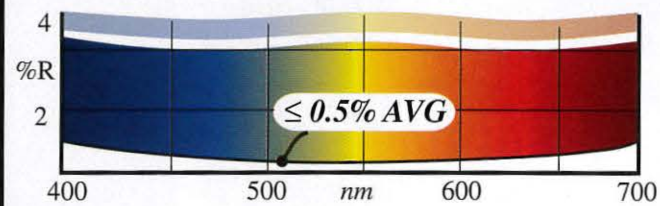

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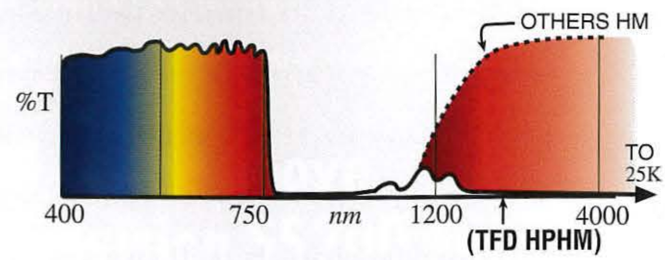

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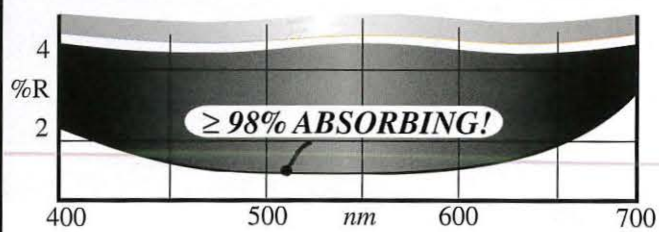

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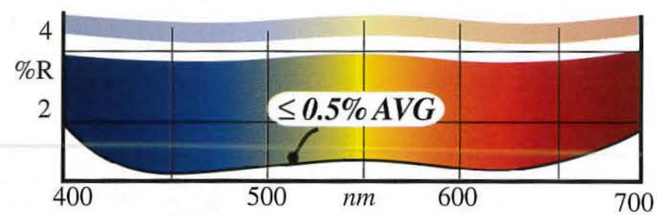

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Whither LCOS?

Liquid-crystal–on–silicon displays have a very bright future – but there are several types, and each type is best suited to particular applications.

by Alan Mosley and Lewis Banks

ONE OF THE AMAZING THINGS ABOUT the liquid-crystal-display (LCD) industry is that just when we start to think it has now matured and no major new developments can be expected, it suddenly undergoes a whole series of dramatic changes. We are now living in such a time.

Among the changes is the introduction of new technologies, such as the move to low-temperature-polysilicon (LTPS) thin-film transistors (TFTs) and away from amorphous-silicon (a-Si) TFTs in active-matrix LCDs (AMLCDs). New technologies are gaining momentum, such as liquid-crystal-on-silicon (LCOS) displays and reflective color LCDs. In addition, LCDs are beginning to compete with cathode-ray tubes (CRTs) in the desktop-monitor market. If they are to compete effectively, developers must reduce the manufacturing costs of LCD modules. Designers are investigating many ways of doing this, particularly the use of field-sequential color, which obviates the need for expensive color filters and also reduces by two-thirds the number of column drivers that are required to address the display.

Alan Mosley is Display Technology Alliance Project Manager for CRL, Dawley Road, Hayes, Middlesex, U.K. UB3 1HH; telephone +44-1-81-848-6400, fax +44-1-81-848-6653, e-mail: amosley@crl.co.uk. He is a Regional Associate Editor for Information Display. *Lewis Banks is Business Development Director for MicroPix Technologies Ltd., Dalgety Bay, U.K.; telephone +44-1383-828-333, fax +44-1383-828-345, e-mail: lewisb@micropix.com.*

Is there a realistic scenario for the development of LCOS displays in the context of lower-priced LCDs that can compete with CRTs?

At last count there were roughly 30 companies involved in the development of LCOS displays. These companies range from huge corporations like IBM, through long-established medium-sized companies such as Three-Five Systems, to new start-ups such as Colorado Microdisplay and MicroPix. (The structure of the LCOS displays fabricated by MicroPix is shown in Fig. 1.) The current market for LCOS displays is in LCD front

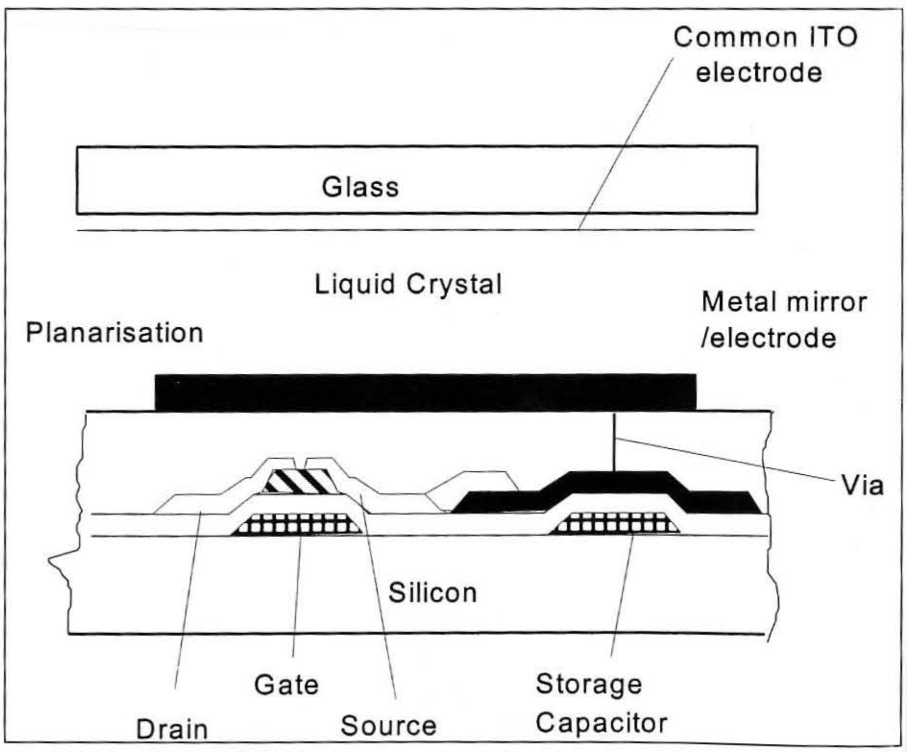

Fig. 1: The current range of LCOS displays from MicroPix use conventional DRAM-like structures.

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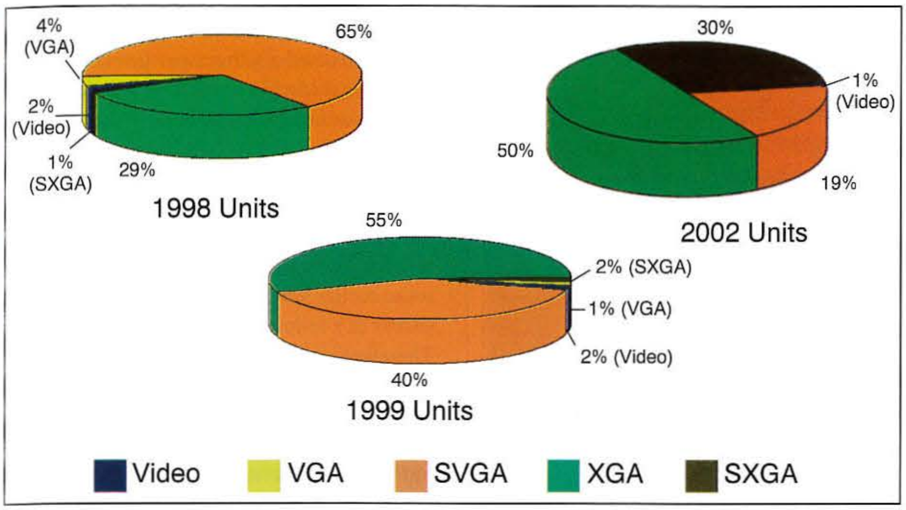

Fig. 2: Predictions for the North American front-projector market indicate that the XGA format will have at least 50% of the market until 2003. (Courtesy of Stanford Resources, Inc.)

projectors, but in this market LCOS displays must compete with high-temperature-polysilicon LCDs, which are very well established. The main market for LCOS displays in the future appears to be in viewers for e-mail, fax, and Web pages that are attached to mobile telephones. Another potential market seems to be rear-projection desktop monitors.

Somewhat surprisingly, the predicted markets for headsets are much lower than those for viewers and desktop monitors. The poor acceptance of headsets to date and unanswered questions about whether users will be inclined to use a headset with a wearable computer in public are probably the factors that are negatively affecting market predictions for these products. Having said this, MicroPix Technologies is already working in partnership with one company to produce a PC-compatible XGA headset with a predicted street price of less than $200. It is only with the emergence of this kind of high-performance, low-cost product that the true market for wearable computer headsets will be revealed.

For each of the four applications we've discussed - front projectors, viewers, desktop monitors, and headsets - there are four key factors:

1. The use of three displays *vs.* the use of two displays or one display and a field-sequential-color technique.
2. The screen resolution of the display required for each particular product. Many LCOS displays now have a pixel pitch of 12 μm, so the size of the display is determined by the screen resolution.
3. Is gray scale achieved through voltage modulation or temporal dither? (In our opinion, spatial dither is not a sustainable option in this kind of high-resolution display.)
4. The structure of the silicon backplane, *i.e.*, DRAM *vs.* SRAM.

Factors 1 and 3 are generally determined by the choice of the particular liquid-crystal technology. The general features of the more common liquid-crystal technologies are shown in Table 1.

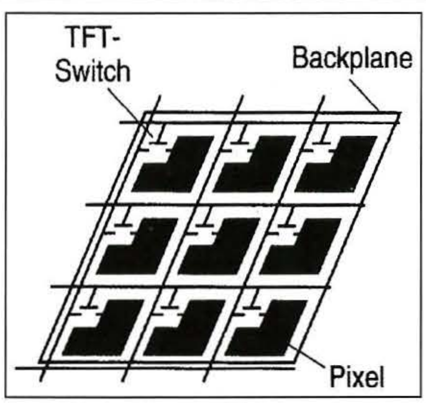

Fig. 3: Large-area AMLCDs based on a-Si TFTs have always employed a DRAM type of structure having (almost always) one transistor per pixel, as shown here. As a result, the majority of first-generation LCOS displays were based on DRAM structures. (Courtesy Society for Information Display.)

Field-Sequential Color

It seems to be generally accepted that field-sequential-color techniques will have be used in the viewers and headsets. There simply is not enough room to include three LCOS displays and their combining optics in these product categories. But for projectors there is a real choice. Using three displays will generally provide brighter images, reduce the demand for a very-fast-switching liquid crystal, and ease the rate at which data must be fed to the display. On the other hand, using a single display greatly reduces both the cost and size of the projector and simplifies the design of the optics - and it increases the reliability of the product because there is no longer any possibility of misaligning the images from three displays.

If we consider these factors together with the present dominance of the three-polysilicon-display approach in front projectors for business applications, we can draw the following conclusions:

- LCOS display manufacturers should first develop devices for viewers, headsets, and rear projection desktop monitors.
- Viewers and headsets demand the use of field-sequential color.
- In order to compete with CRT monitors, LCOS rear-projection monitors should be based on single displays employing field-sequential color.

Resolution

The ideal number of pixels required for the four identified applications is developing into an interesting issue. The general view for projectors and monitors is "the more pixels the better." But the predictions for the North American front-projector market share by format - SVGA, XGA, SXGA, *etc.* - indicate that the XGA format will have at least 50% of the market until 2003 (Fig. 2). Similarly, it is predicted that the XGA format will initially dominate the marketplace for LCD monitors. A view emerging from the Far East is that in order to compete with today's CRT-based products, the entry point for single-channel rear projectors will be pixel formats of SXGA and UXGA projected onto screens with 30-in. diagonals. Another market that has been identified for LCOS displays is for HDTV and

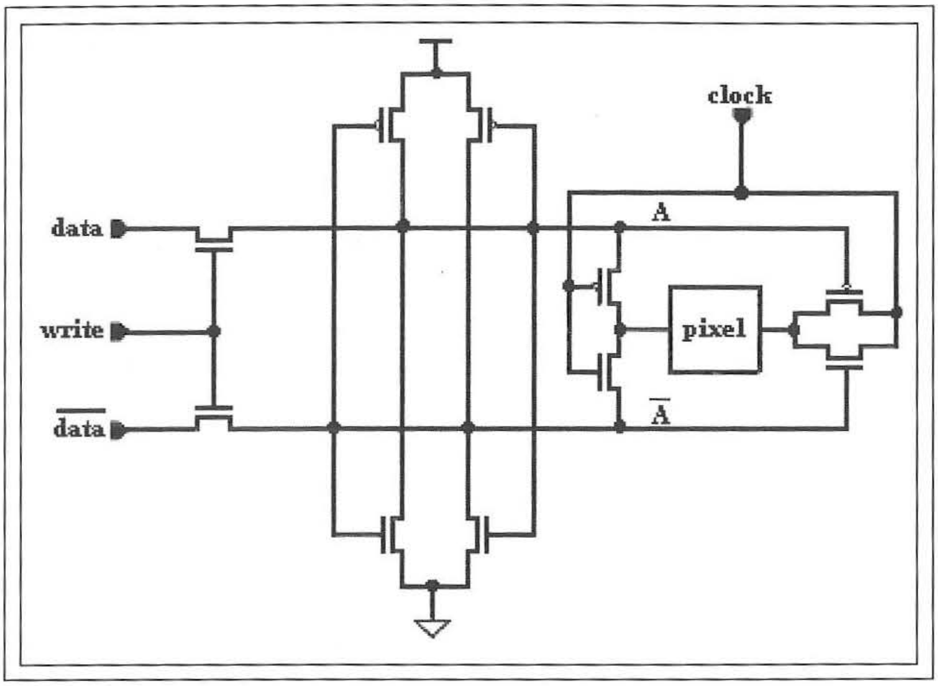

Fig. 4: A one-channel field-sequential-color LCOS display system with a DRAM-like structure has a low duty ratio of almost 1:4, which is particularly inefficient for a projector, in which every last lumen counts. This problem can be relieved with an SRAM type of structure, with several transistors per pixel allowing data to be stored at the pixel level and permitting a whole frame of data to be written in a few nanoseconds.

SDTV displays projecting onto screens of 60 in. or more.

These inputs seem to suggest that those LCOS suppliers aiming to provide low-cost rear-projection desktop monitors and TVs need to work closely with OEM companies to ensure that the displays they develop are suitable for the final products.

The situation relating to viewers is far from clear. Again, the general feeling seems to be the more pixels the better, but the CyberDisplay 320C prototype developed by Kopin has only quarter-VGA resolution. One is forced to ask, "How many pixels are necessary for a viewer?" It is very important to answer this question correctly because when field-sequential color is used, the greater the number of pixels, the higher the data rate (Table 2). In turn, data rate, as discussed below, has an impact on the choice of the silicon backplane. One way of handling this uncertainty is for the LCOS manufacturer to form a partnership/alliance with a mobile-telephone manufacturer. Fortunately, most people seem to agree that the most common resolution for LCOS displays in headsets is likely to be XGA.

Gray Scale

With the exception of ferroelectric liquid crystals (FLCs), all of the effects listed in Table 1 generate gray scale by voltage modulation. This is possible because these liquid-crystal effects exhibit a smooth, gradual, and reproducible change in contrast with increasing voltage. This means that the pixels in the display need only be addressed once per color frame in a single-channel field-sequential-color display system, or once per frame in a three-channel system.

The voltage-contrast curve for the FLC effect shows a great deal of hysteresis and consequently very poor gray-scale fidelity. Fortunately, FLCs have two very well defined ON and OFF states. It is therefore possible to obtain excellent gray-scale fidelity by repeatedly switching between these two states, *i.e.*, using temporal dithering to obtain gray scale.

The main disadvantage of this approach is that the display must be addressed several times per frame in order to generate gray levels. Consequently, the data must be loaded several times per frame, thereby increasing the data rate, which in turn will increase the power consumption. For example, generating 2^6 - *i.e.*, 64 - gray levels requires the display to be addressed six times per frame, and the data rates shown in Table 2 will be increased by a factor of 6.

Silicon Backplane

Large-area AMLCDs based on a-Si TFTs have always employed a DRAM type of structure having one transistor per pixel - ignoring some earlier structures that utilized two transistors in a redundancy scheme (Fig. 3). Therefore, it is not too surprising to find that the majority of first-generation LCOS displays were based on DRAM structures.

In a DRAM-based device, data are transferred to the display one row at a time until the whole display has been addressed. The time taken to transfer the data can be very short: on the order of 1 msec, as outlined above. But in a field-sequential-color display system, one must wait for the liquid crystal to respond after the data has been transferred, which can be 3 msec, before illuminating the display. Because only 5.5 msec are available for each color frame in the preceding example, only 1.5 msec are left to illuminate the display - a duty ratio of almost 1:4. This is clearly inefficient, particularly in a single-channel projector, the designers of which will be fighting for every last lumen.

One approach to relieving this problem is to use an SRAM type of structure. In an SRAM device, there are several transistors per pixel (Fig. 4). This increased complexity enables data to be stored at the pixel level, which permits a whole frame of data to be written in a few nanoseconds. In operation, while a frame of data is being displayed, the next frame is being written into the circuitry below each pixel. It is now possible to read in the new frame of data after sending a simple control signal.

A present limitation of the SRAM structure is that it can only provide two voltage levels. This means one can not really drive a nematic liquid crystal, particularly not a fast-switching nematic liquid crystal, using an SRAM configuration. On the other hand, the SRAM structure is ideally suited to driving a ferroelectric liquid crystal because the latter operates by switching - in about 50–100 μsec - between two stable states.

Using an SRAM structure with an FLC is an excellent approach to an LCOS display for use in single-channel display systems utilizing field-sequential color. This is particularly true of a single-channel projector, in which it is important to have a very high duty ratio. In such a system based on an SRAM ferroelectric it should be possible to achieve a duty ratio of 1:1.1, compared with 1:4 for a DRAM nematic-based system. An SRAM FLC display (FLCD) can be considered the electro-optic equivalent of the electromechanical DMD device.

The Way Forward

At this time, the future of LCOS displays appears to be very promising. There are two potentially very large markets - rear-projection desktop monitors and viewers for mobile telephones - that can be addressed by LCOS technology. There are already some signs that manufacturers have realized that the transfer of very large amounts of data, particularly for the highly cost-effective single-channel display systems, will be an issue. Consequently, SRAM silicon backplanes are being considered.

While SRAM devices are ideally suited to driving fast-switching bistable FLC materials, they are not suited to the addressing of fast-switching nematics. In order to drive the latter materials, circuitry is required that is able to store a frame of data at the pixel level and provide multiple voltage levels to obtain the required number of gray levels. ■

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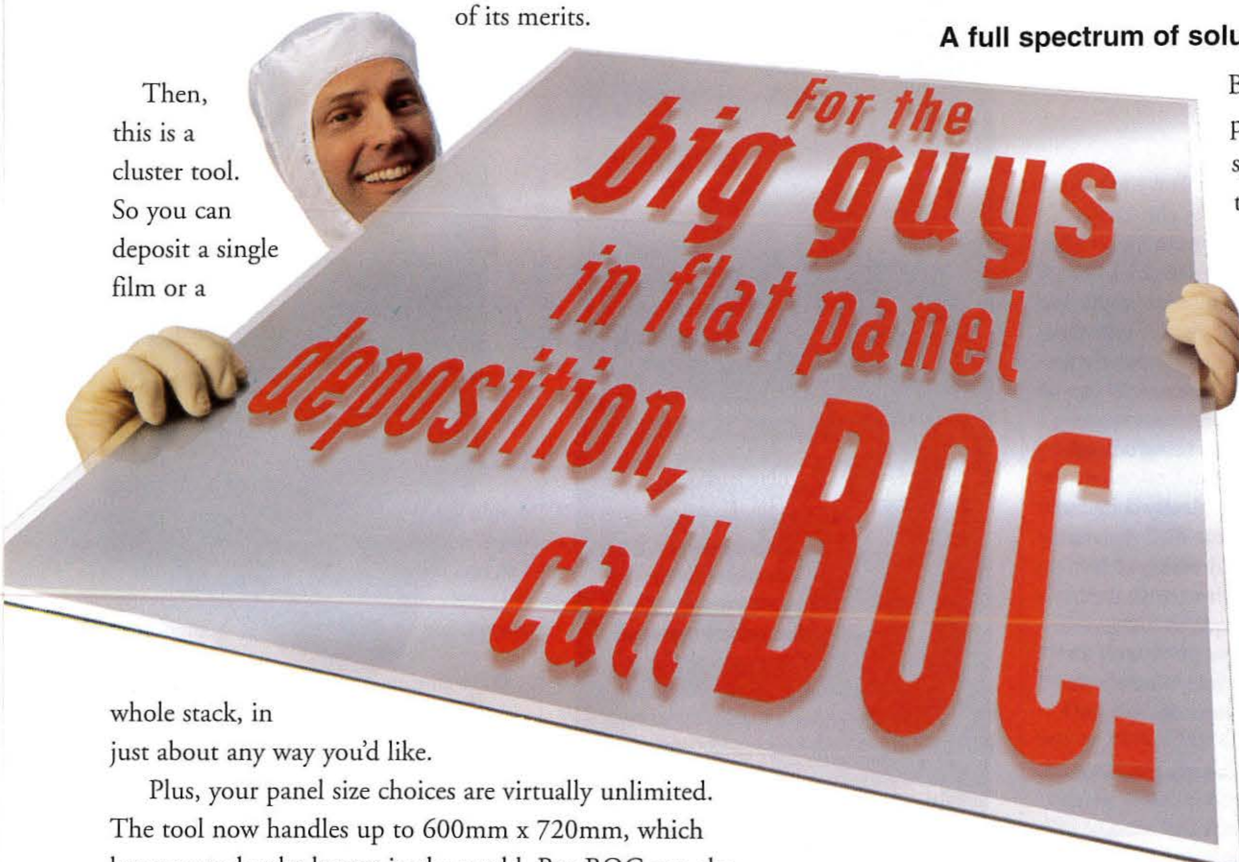

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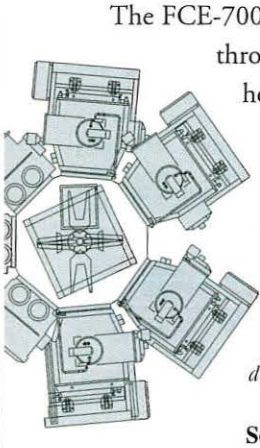

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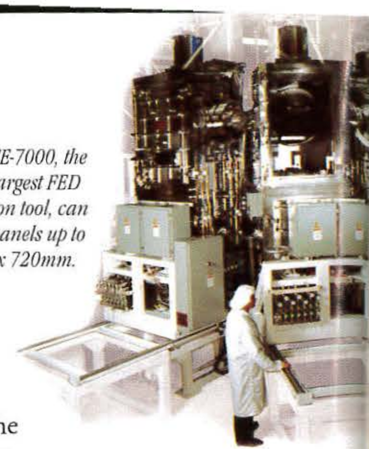

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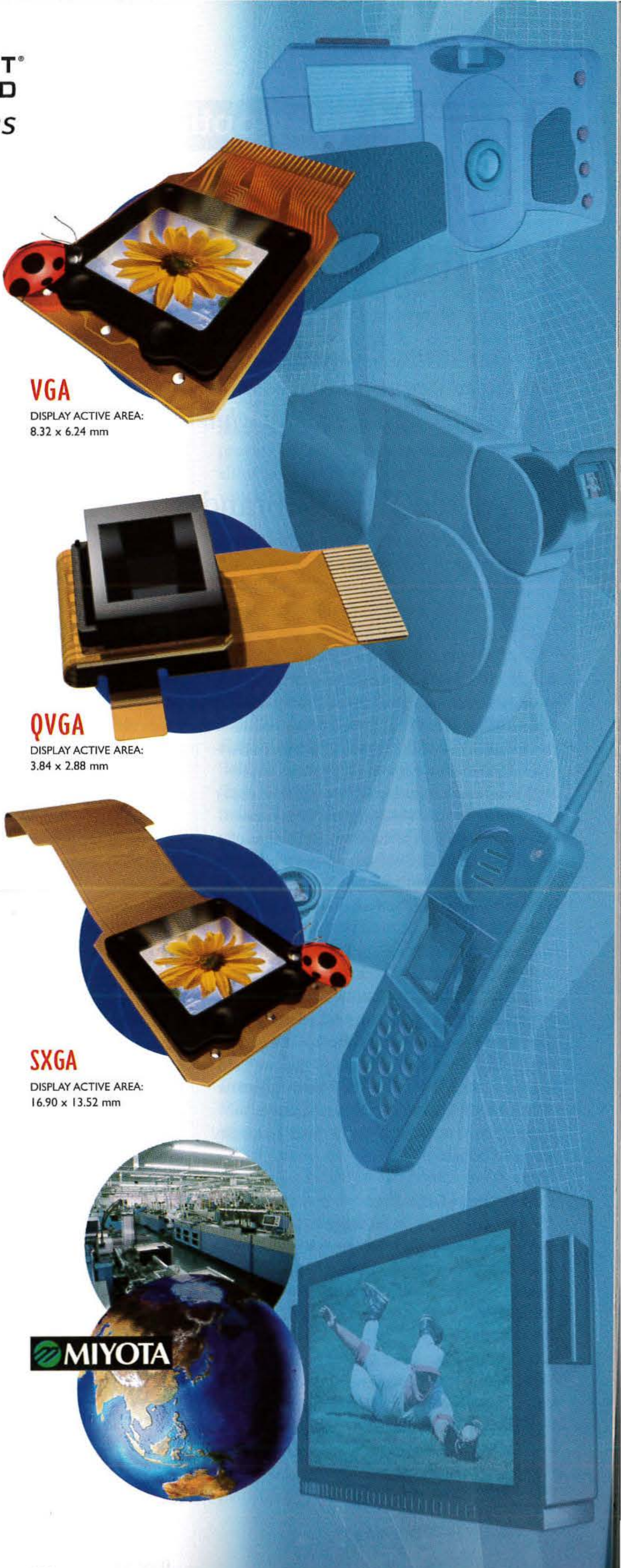

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High-Quality Optics for Microdisplays

The new generation of liquid-crystal–on-silicon microdisplays produces beautiful images, but designing optics that increase the virtual size of the display while maintaining image quality is not easy.

by Alfred P. Hildebrand

JUST AS CONSUMERS begin to express a strong interest in mobile data communications and wireless Internet access, a new class of microdisplays is emerging that allows pocket-sized (and even wearable) appliances to present images comparable to those people enjoy on their desktops. Utilizing liquid-crystal–on-silicon (LCOS) technology, this class of displays creates full-color high-resolution SVGA (or better) images on CMOS devices measuring less than half an inch on a side (Fig. 1).

Creating a highly magnified image of a high-resolution display this small is a challenging optical-design problem, especially considering the ergonomic requirements of the consumer-product marketplace. With an emphasis on monocular displays that are held to the eye for viewing, we will describe a few of the optical approaches that have been demonstrated and compare their image quality and ease of use.

Resolution of the Eye

The perceived size of an image is measured by the angle subtended by that image at the observer's eye. In a reasonable ambient, the eye is able to resolve image features as small as 1 minute of arc (1/60 of a degree), although this resolution will drop rapidly with a reduction in brightness or contrast.

For small angles, the subtended angle of a resolvable image element equals the element's dimension divided by the distance of the image from the eye. Normally, one can increase the viewability (resolvability) of fine features by bringing the image closer to the eye because this will increase the subtended angle. But doing so requires the eye to focus more closely, to which there is a limit of about 10 in. - called the "near point."

It is interesting to compare the angles subtended by a given image element when presented by several different display mechanisms - a fax on bond paper, a high-performance CRT monitor, and a digital projector - as seen by the eye at normal viewing distance (Table 1). The subtended angles range from 1.5 to 2 arc minutes. But in a typical microdisplay, where a 12-μm pixel is viewed at the near point (250 mm), the resulting subtended angle is far too small for the eye to see, and the display must be magnified to at least ten times its size for the pixel to become visible. In the field of optics, magnification is defined in just this way, through a comparison of the apparent image size with the size of the unmagnified object viewed at the eye's near point.

Magnification Primer

We are all familiar with the simple lens or magnifying glass used to magnify fine print. Jewelers and photographers utilize much more refined magnifiers called loupes, often with a magnification of 8× or 10×. As a result of the way it is defined, the magnification of a lens equals the eye's near point (250 mm) divided by the focal length of the lens. To achieve a magnification of 10×, the focal length of a magnifier must be 25 mm. It is virtually impossible to make a well-corrected lens - even a doublet (two optical elements cemented together) or triplet (three elements cemented together) - with a diameter larger than its focal length. As a result, these loupes have an aperture of less than 20 mm and must be held close to the eye.

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Table 1: Typical Images with Normal Viewing Conditions

Type of Image	Horizontal Size	Resolution Elements	Angle/Element (minutes of arc)
Faxed page at 10 in.	8 in.	200 dpi	1.71
CRT at 20 in.	12 in.	0.26-mm pitch	1.78
Projection screen at 8 ft.	4 ft.	1024 pixels	1.91
Microdisplay at 10 in.	9.6 mm	800 pixels @ 12 μm	0.162

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An alternative type of magnifier is a concave mirror, which - unlike a lens - has no chromatic aberration, *i.e.,* all colors from a point on the display are imaged to the same point by the magnifier. Many head-mounted displays have made use of a concave mirror to achieve low-cost magnification, albeit with the addition of a beam splitter to fold the axis of the display onto the mirror axis. When the eye is located at the center of curvature of the mirror, virtually no off-axis aberrations are created except field curvature. As a result, large fields of view are easier to achieve with a mirror magnifier than a single-lens element. Lens and mirror magnifiers come in many configurations, two of which are shown in Fig. 2.

Siliscape, Inc.

Fig. 1: Plans are afoot to use microdisplays based on LCOS technology in a wide variety of applications, such as embedding them in a mobile telephone.

Compound magnification - using more than one stage of magnification - can easily provide higher power than simple magnifiers, although usually with ergonomic limitations, which we'll discuss later.

Image Size and Field of View

The angle subtended by the entire image is called the field of view, and it is typically measured on the diagonal of the displayed image. The required field of view is directly determined by the eye's resolution times the number of pixels in the display (Table 2). For an SVGA display with 800 horizontal pixels subtending 2 arc minutes per pixel, the total diagonal field of view is 34°. Too small a field of view results in inadequate magnification. Too high a field of view can create eye fatigue from excessive eye movement. Movement of 24° vertically and horizontally (34° diagonally) is considered an acceptable limit in head-mounted applications.

Large fields of view are hard to achieve when imaging objects as small as microdisplays, and aberrations of the magnifier become radically more pronounced in large fields of view. Field curvature and distortion are serious aberrations, which are proportional to the square and cube of the field angle, respectively.

Image Location and Field Curvature

Most engineers are familiar with the magnifying glass used in laboratories to examine fine solder joints. Although their magnifying power may be only a factor of 2, these large lenses also help by creating an image that is farther from the eye than the object itself, well beyond the near point of the eye. In fact, the image created by any magnifier appears to be out in space. Such images are called "virtual images," in contrast to the "real images" created by direct-view displays.

Location of the image becomes much more important for older viewers because the lens of the eye becomes less flexible with age and loses its ability to accommodate the traditional near point. This is why older readers often hold finely printed documents at arm's length, particularly in dim lighting.

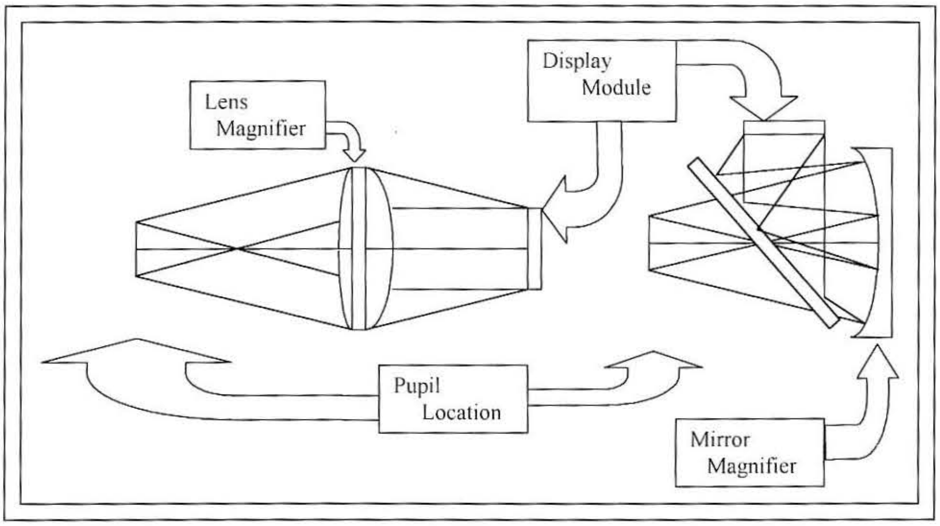


Fig. 2: Lens and mirror magnifiers have different form factors. The mirror is more compact due to the folded path, while the lens has more eye relief.

For high-resolution images such as text, a comfortable image distance is often a compromise between focal accommodation of the eye and adequate character size. Reading glasses solve that problem by adding power to that of the eye to help see close-up objects. When viewing a virtual display, the user should use the eyeglasses prescribed for normal distance viewing (as opposed to reading glasses) because the virtual image is normally located at least a meter from the eye.

Unfortunately, the magnified-image plane is rarely flat, and the focal distance will vary with angle from the center of the image to the corners. This phenomenon is called field curvature, which can be a serious problem, especially in binocular displays. For large field curvatures, the eye must constantly refocus as the image is scanned, and if the eye's range of accommodation is too small, part of the image will be out of focus. Uncorrected mirror magnifiers have negative field curvature, in which the center of the display is focused nearer to the eye than the edges, while lens magnifiers have the opposite curvature.

The Eye-Movement Box

In addition to adequate magnification and an image located at a comfortable distance from the eye, the display must provide for a large range of movement relative to the eye without disturbing or distorting the image. The distance from the display to the eye – called "eye relief" – must be large enough (at least 25 mm) so as not to interfere with prescription eyeglasses. Furthermore, the optical system must be able to tolerate side-to-side motion of the eye to accommodate rotation of the eyeball and viewer movement.

If the aperture of the magnifying optics is too small for the desired field of view, the image will be clipped. The viewing window itself may define the aperture or, in many cases, a pupil is formed within the optical system itself. Clipping – or vignetting – can be easily observed by moving the display relative to the eye, and the amount of movement that can be tolerated without diminishing the display's quality or fullness of view is often called the "eye box." A large eye box is very important to consumer acceptance of such displays (Fig. 3).

The figure shows the size of the eye box required to allow a 35-mm eye relief and 34° field of view. The pupil size is nominally 4 mm and moves 6 mm laterally as the eye scans over the 34° field of view. As a result, the eye box must have a diagonal of at least 10 mm. Furthermore, if the display is to be hand-held, we must expect display motion of another few millimeters. For these reasons, Fig. 3 shows an eye box with a 12-mm diameter at the extreme of the eye relief. This is also the location of the exit pupil of the magnifier.

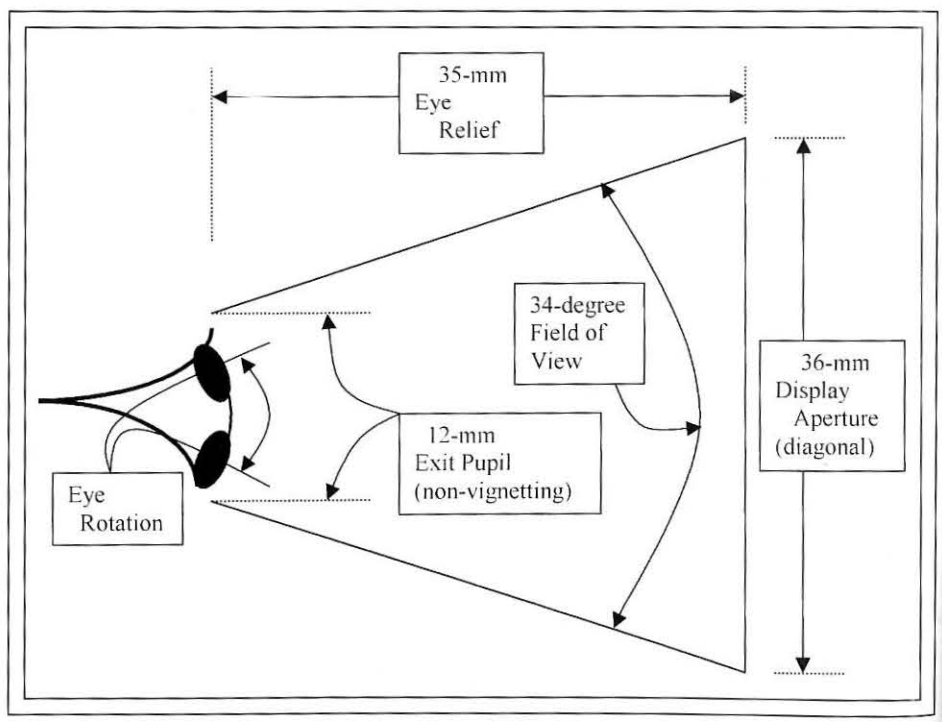


Fig. 3: A 35-mm eye relief and 34° field of view are good specifications for a virtual microdisplay, and would require an "eye box" of the size indicated here. The pupil size is nominally 4 mm and moves 6 mm laterally as the eye scans over the 34° field of view. If the display is to be hand-held and thus subjected to additional relative motion, the eye box should have a diagonal of at least a 12 mm.

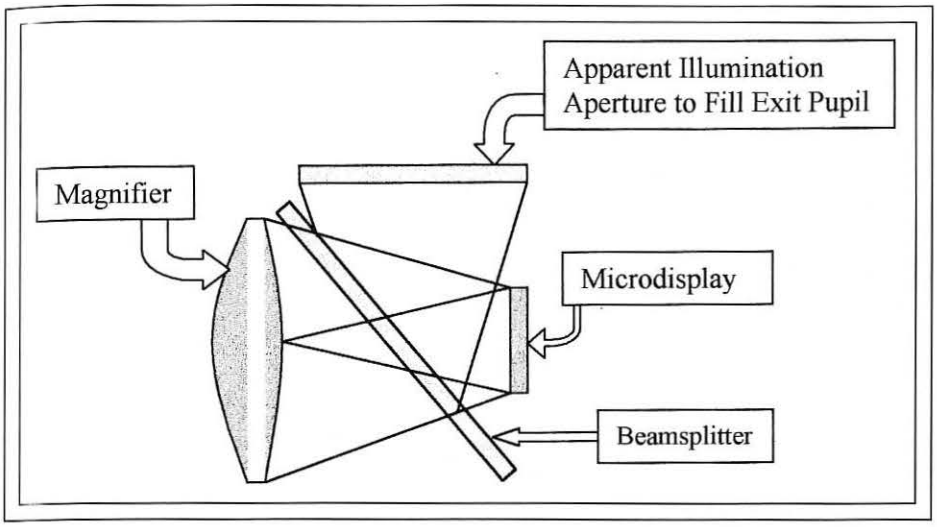


Fig. 4: Beam splitters are typically used to separate the illumination axis from the viewing axis in LCOS displays. The illumination rays must emanate from a very large apparent source aperture. If the illuminator does not fill this aperture, a restricted exit pupil will be created at the location of the eye and there will be a very limited eye box.

Although a simple magnifier does not actually form an exit pupil as a compound magnifier does, the illumination system may create the effect of an exit pupil in reflective displays such as CMOS devices.

Illumination of a Reflective Display

Reflective displays on silicon act much like mirrors unless the pixel is switched off, a fact that complicates the illumination of reflective displays as opposed to transmissive displays.

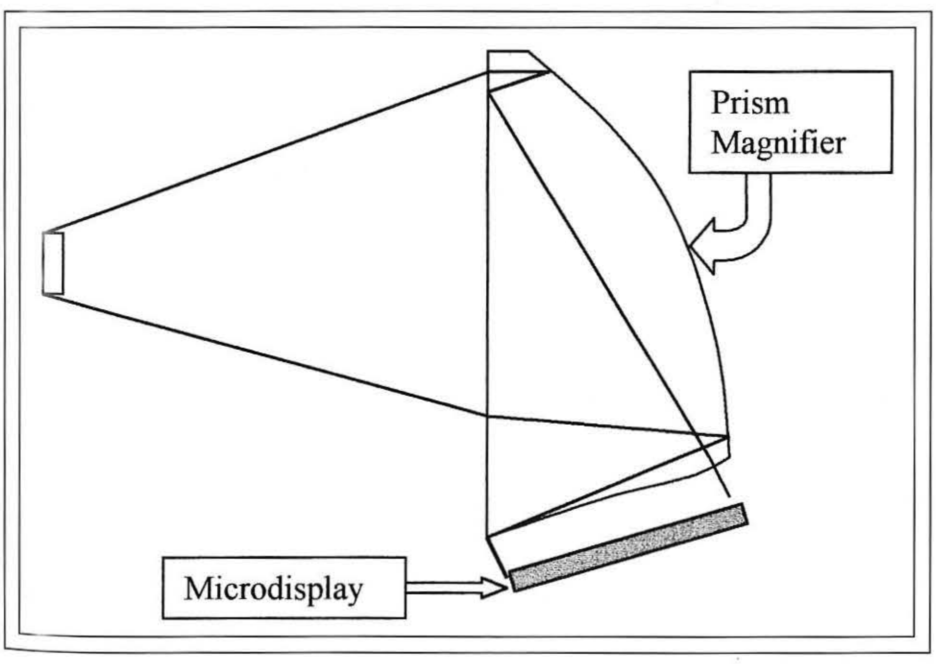


Fig. 5: A comfortable portable product will need to have a depth that is less than the effective focal length of the magnifying optics, which requires extensive folding of the optical path. This magnifier has a twice-folded beam path, which achieves an excellent form factor.

Table 2: Required Fields of View

Display	Resolution	Diagonal Field of View (deg)
QVGA	240 × 320	13.3
VGA	480 × 640	26.7
SVGA	600 × 800	33.3
XGA	1024 × 768	42.7

Typically, designers use beam splitters to separate the illumination axis from the viewing axis (Fig. 4). The illumination rays must emanate from a very large apparent source aperture. If the illuminator does not fill this aperture, a restricted exit pupil will be created at the location of the eye and there will be a very limited eye box. Generally speaking, a good display will have a brightness over the entire span of the eye box that is at least 50% of the peak brightness in the center of the display. Acceptable luminance ranges from approximately 20 to 100 fL.

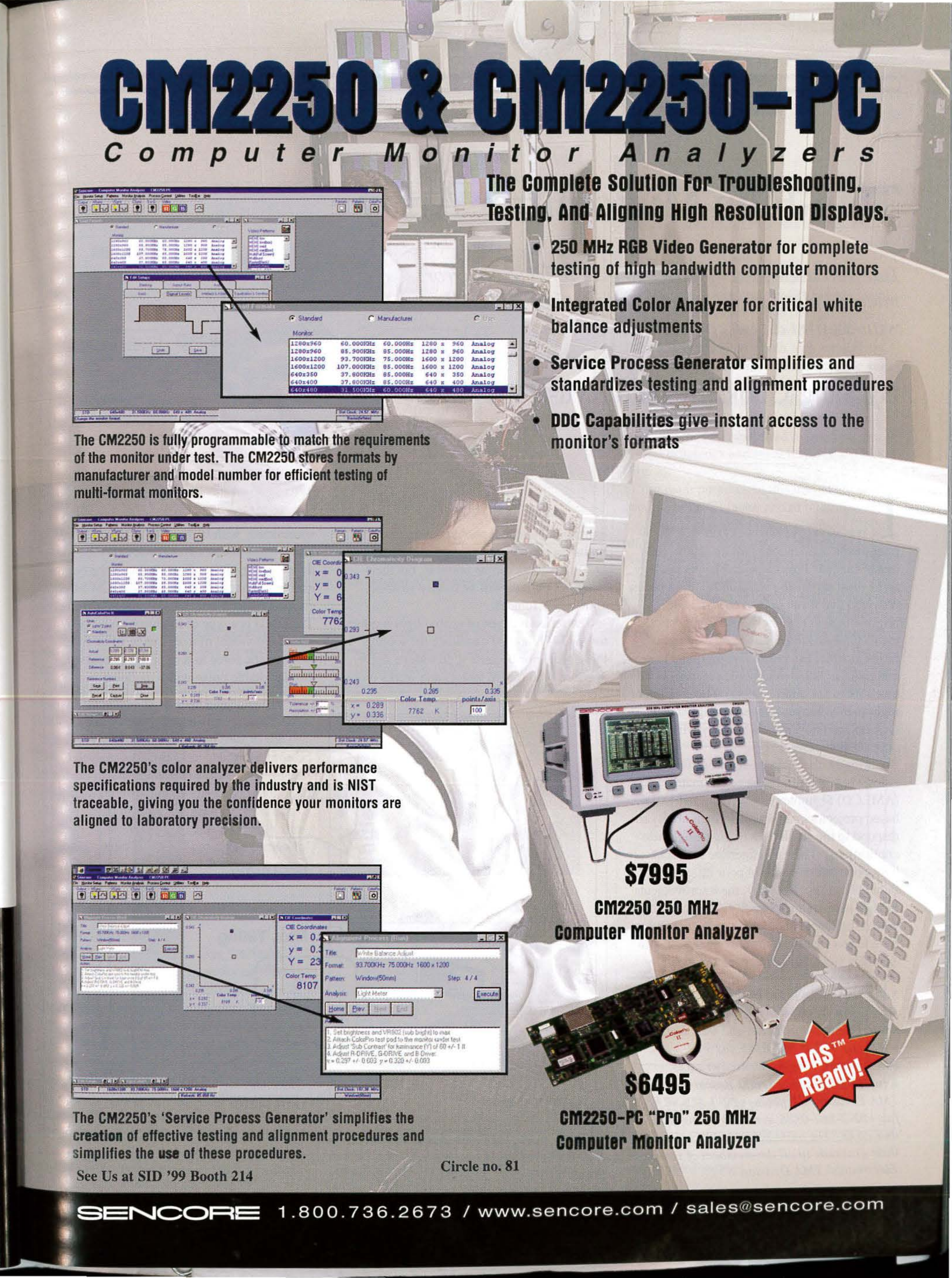
Display Size and Form Factor

It is important for a portable product to feel comfortable in the pocket, on the belt, and in the hand. At least one dimension should be very small - less than 18 mm - and since it is smaller than the desired display aperture, this dimension must be the depth of the display. For the depth of a display to be smaller than the effective focal length of the magnifier and less than either the height or width of the viewing aperture is a very strict requirement, and it requires extensive folding of the optical path (Fig. 5).

Meeting All Requirements

There is no hard and fast boundary to any specific design constraint. Optical design for microdisplays gets easier if one is willing to pay the price of a larger CMOS die size. Indeed, magnified displays utilizing the somewhat larger TFT displays with pixel sizes over 20 μm allow fields of view of well over 34° using simple magnifiers, albeit with somewhat excessive form factors. Achieving all the necessary characteristics with a single optical design requires the balancing of many variables, and there is no one answer, but some solutions make the trade-offs much easier.

Siliscape has found that a thrice-folded beam path inside a prism, a compound magnifier with both reflective and refractive power, and the integration of several functions into each optical element provide an attractive set of solutions. Although more complex optically, the functional integration combined with advanced fabrication technology allows for a highly manufacturable design. Most importantly, user testing has validated that consumers will be very pleased with the large and comfortable image provided by the compact package. ■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Thin-Film Micromirror Array

Daewoo uses piezoelectrics to give reflective-mirror microdisplays a new twist – and provide TI's DMD with its first direct competition.

By Sang-Gook Kim and Kyu-Ho Hwang

IN THE EMERGING INFORMATION ERA, many multimedia applications require brighter and larger images. Projection-display technology is the most promising solution for these needs, provided that it can deliver a sufficiently bright image to the screen. Recent developments have created commercial electronic projectors that can create images under normal room lighting conditions, yet there is still much room for improvement. The creation of high-quality images in typical display venues requires an innovative technology with high optical efficiency.

Currently, the mainstream projection technology is the transmissive active-matrix LCD (AMLCD) technology. Conventional LCD-based projectors are limited in their ability to respond to the challenges of high-brightness applications. The small aperture ratio and light polarization result in poor efficiency of light utilization. Recently, the improvements in high-temperature poly-Si LCD technology with microlenses and polarization conversion have led to significant improvements in optical efficiency. However, heat generated by light absorption and photodegradation still limits the use of high-power light sources. LCD projectors can be portable, but their luminous outputs will be limited to about 1500 ANSI lumens.

The reflective type of spatial light modulator (SLM) is a good candidate for solving these problems because it provides a higher aperture ratio (or fill factor) and works more successfully with higher-power light sources. The Digital Micromirror Device (DMD) developed by Texas Instruments is the typical example of the reflective type of SLM based on a microelectromechanical system (MEMS). The DMD is a type of micromirror array in which individual mirrors can be tilted by an electrostatic force to turn pixels on and off. The inevitable pulse-width modulation control

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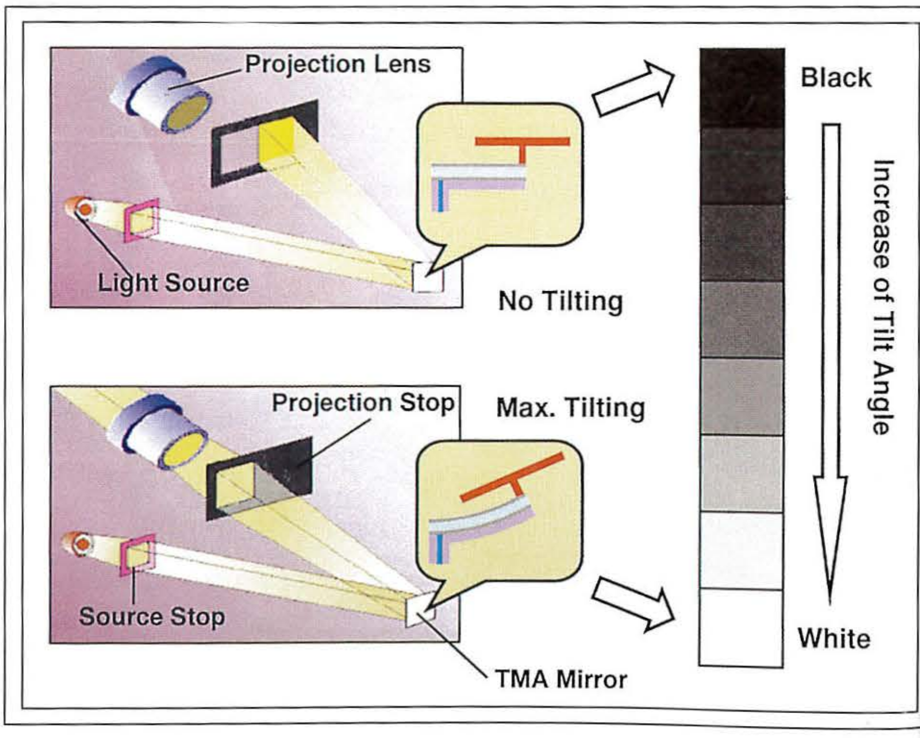

Fig. 1: A projection stop is used in the TMA design to modulate the light level of individual pixels.

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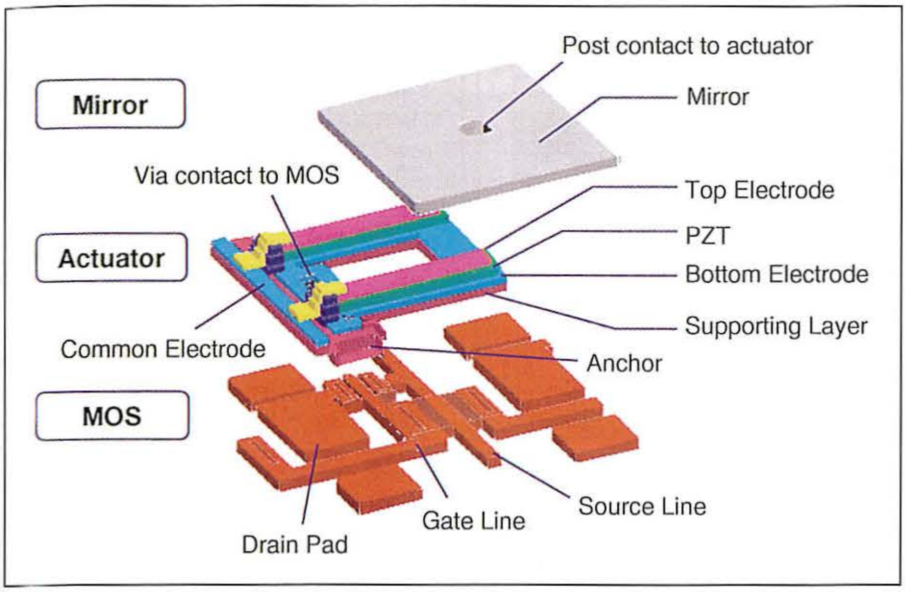


Fig. 2: The pixel structure of the TMA device has been refined to improve efficiency and reliability.

of on/off mirrors for gray-scale generation requires very sophisticated and expensive driving circuitry.

Daewoo Electronics has developed a new kind of reflective SLM based on MEMS called a Thin-Film Micromirror Array (TMA). The TMA device looks very similar to the DMD device, but TMA uses micromachined thin-film piezoelectric actuators to control the gray scale on the screen. The continuous change of the tilt angle of each micromirror controls the gray level of each pixel with simple image-processing circuitry. In addition to the simplicity of the system, TMA has a much higher optical efficiency than any other SLM at the present time.

Light Modulation

The TMA's optical system uses Schlieren optics to control the light intensity on the projection screen through continuous changes of the reflection angle of each mirror. The projection stop functions as a light valve (Fig. 1). The light reflected on a mirror surface forms an image on the projection-stop plane, and this image moves along the horizontal axis as the reflection angle changes. When a mirror does not tilt, all the light reflected by the mirror is blocked by the projection stop, and the pixel image on the screen shows the darkest state (black). When the mirror is fully tilted, all the light reflected by the mirror goes out through the projection stop and the pixel is at its brightest state (white). The amount of light that passes through the projection stop is linearly proportional to the tilt angle of each mirror. The precise control of the tilt angle can generate more than 256 levels of gray.

Pixel Architecture

The TMA pixel is a monolithically integrated MEMS device fabricated over a simple metal-oxide-semiconductor (MOS) switch. Each pixel consists of a mirror and an actuator. Each mirror must have both high reflectivity and excellent flatness, while the actuator must have linear and fast-response characteristics, as well as mechanical and electrical reliability. Several types of pixel structures have been designed and modified to improve the optical efficiency and reliability of the TMA (Fig. 2).

The main purposes of this design are to maximize the fill factor and to minimize the mechanical non-uniformity. The high fill factor produces the high optical efficiency at the pixel level and the seamless projected image. This is done by hiding the actuating mechanism under the mirror. In the early design of the TMA pixel, the mirror and the actuator were co-planar, and the mechanical structure of the actuator was directly exposed to the incident light. This resulted in less area being available for the reflection and more light

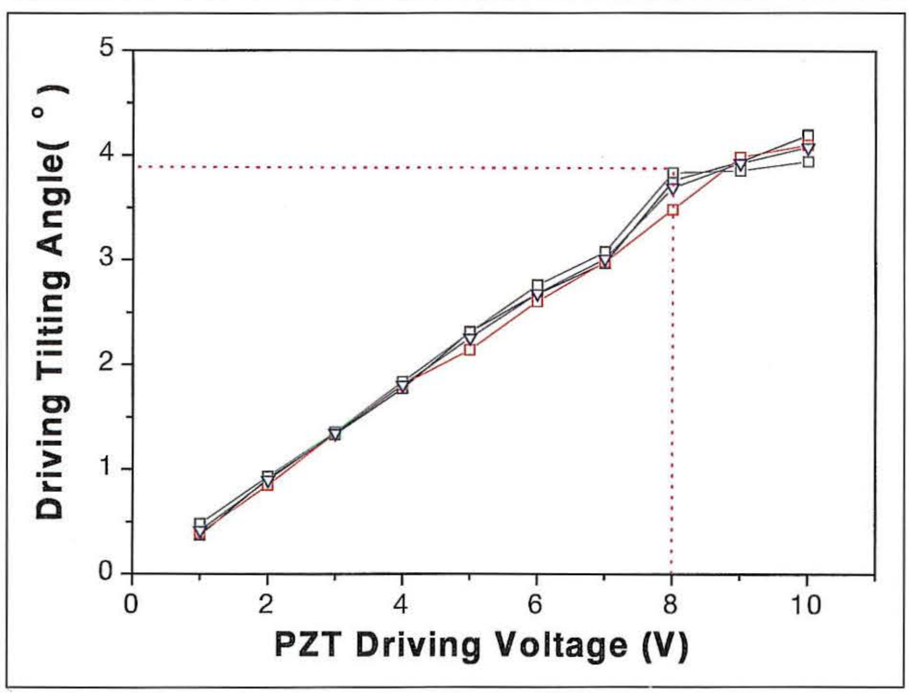


Fig. 3: The tilt angle of the TMA mirror is linear with applied voltage.

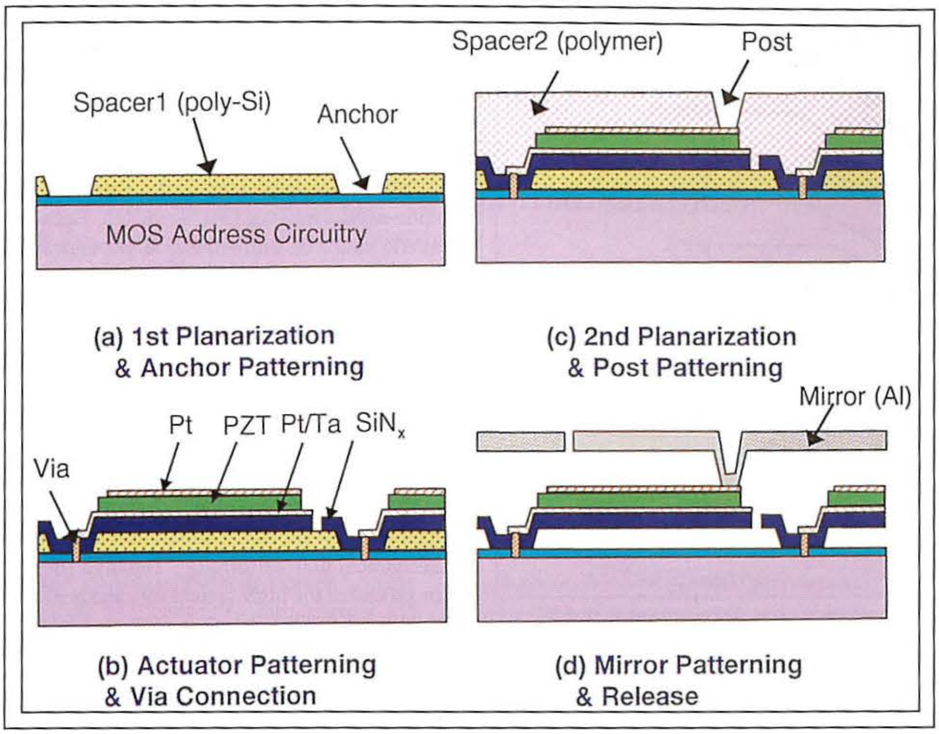


Fig. 4: A sequence of semiconductor processes are used in the fabrication of TMA modules.

being scattering by the exposed mechanical structures. The result was poor optical efficiency and a low contrast ratio. The new design increases the fill factor to as much as 94% and the contrast ratio to as much as 200:1.

The TMA uses thin-film piezoelectric actuators in the form of micro-cantilevers. A mirror is connected to the underlying cantilevers through a support post. The cantilevers themselves are anchored to the underlying substrate. A cantilever consists of the supporting layer, bottom electrode, piezoelectric layer, and top electrode. When an electric field is applied between the two electrodes, the piezoelectric layer shrinks in the horizontal direction and expands in the vertical direction. Because the neutral plane of the cantilever shifts toward the bottom electrode due to the thickness of the supporting layer, the mechanical strain of the piezoelectric layer causes vertical deflection of the cantilever - and of the mirror on top of it.

The tilt angle of the mirror (θ) is linearly proportional to the applied signal voltage within the 0–10-V operating range (Fig. 3). The maximum tilt angle of 4° at 8 V is higher than the specification required by the optical system and thus provides a margin for optimizing the system. The response time of the TMA pixel is less than 25 μsec and is fast enough even for field-sequential-color display applications.

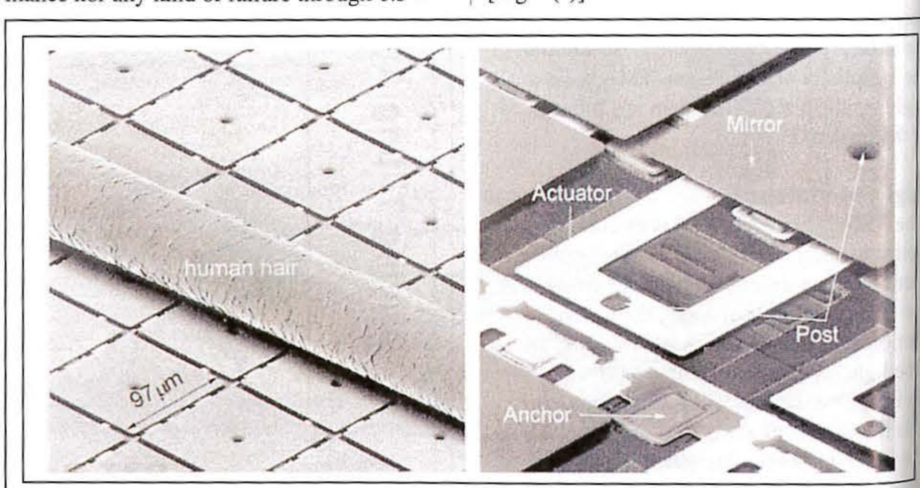
An accelerated experiment was performed to test the reliability of the TMA pixel. It showed no observable degradation in performance nor any kind of failure through 0.5 × 10^{10} cycles, which would be enough for a projector life of 10 years.

Fabrication

The TMA module is monolithically fabricated over a PMOS active matrix by surface micromachining techniques. The active matrix is a transistor array that addresses the video signal to each pixel. The size of each mirror is 97 × 97 μm for the current VGA-format prototype. For the forthcoming XGA-format modules, these dimensions will be reduced to 50 × 50 μm.

The fabrication of the TMA module begins with the completed PMOS active matrix employing a W metallization process (so it can stand the high-temperature post processes). After a circuit-protection layer is added on top of the active matrix, a poly-Si sacrificial layer (spacer 1) is deposited by a low-pressure chemical-vapor-deposition (LPCVD) process. A chemical-mechanical-polishing (CMP) process follows to provide a flat surface for the subsequent TMA fabrication processes. The degree of planarization does not seriously affect the projector's brightness uniformity and contrast ratio because there is another sacrificial layer under the final mirror layer. The measured tolerance of the sacrificial-layer thickness is less than 3% within the whole module.

The planarized sacrificial layer is removed later to produce an air gap for the vertical displacement of cantilevers. Anchor regions - where the support posts for the cantilevers are formed - are patterned on the sacrificial layer [Fig. 4(a)].



Daewoo Electroni

Fig. 5: A scanning-electron-microscope image of a TMA module shows the mirrors (left). A few of the mirrors have been removed to show the underlying structure (right).

post after mirror metal covers its sidewall [Fig. 4(c)].

The mirror layer is made of aluminum and is sputter-deposited on the second sacrificial layer. The measured reflectivity of the aluminum layer is over 90%. The aluminum layer is patterned to make mirror shapes by a dry-etching process. Finally, the sacrificial layers are removed to form air gaps. Since two different materials are used as sacrificial layers, the release process is performed in two steps. First, the second sacrificial layer is removed through the openings between mirrors by plasma etching. After completely removing spacer 2, spacer 1 is exposed to air and removed by a XeF_2 vapor-etch process [Fig. 4(d)]. Both release methods show fast lateral etch rates, leave no residues, and do not etch or damage the Al and PZT layers and thus do not need protection layers. Scanning-electron-microscope (SEM) photographs of the completed TMA module after the release process show the real array of mirrors, and, with some mirrors intentionally removed, the underlying structures can be seen (Fig. 5).

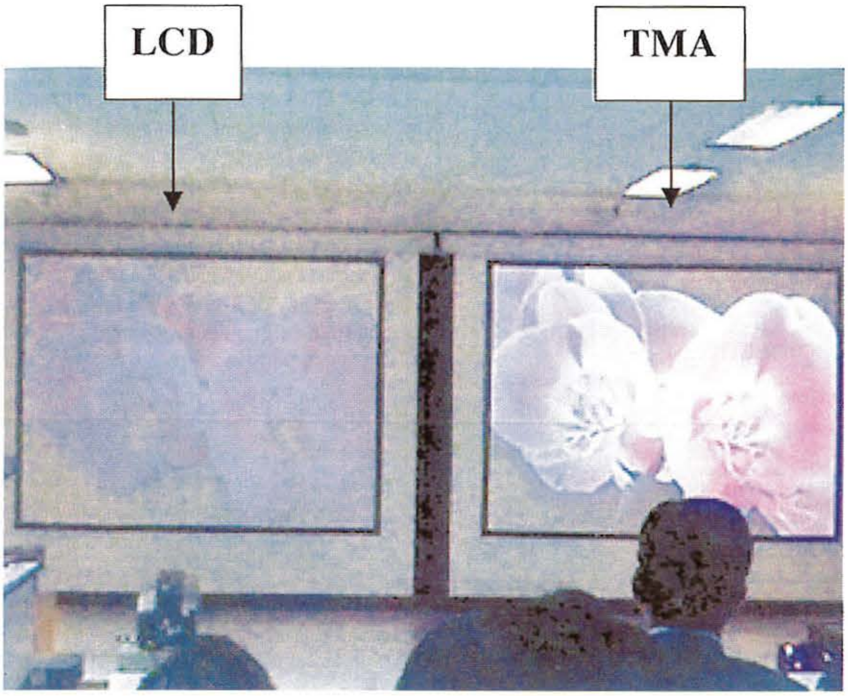


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Fig. 6: A side-by-side comparison of images projected by LCD and TMA devices with lamps of the same power demonstrates the advantage of the high optical efficiency offered by TMA projectors.

The bending moment at the anchor region is responsible for a large portion of the initial deflection of the micromachined cantilevers. This bending moment is sensitive to thickness variations and uneven residual stresses resulting from process tolerances, and causes a non-uniform distribution of the initial deflection of the cantilever actuators. A novel design for the support anchor was developed to minimize the non-uniformity in the initial deflection of the cantilevers.

The subsequent layers - the supporting layer, the bottom electrode, the lead zirconate titanate (PZT) layer, and the top electrode - that make up the cantilever are deposited on top of the first sacrificial layer. The supporting layer is made of a silicon-rich silicon nitride (SiN_x) and deposited by the LPCVD process. The function of this layer is to convert the expansion/contraction deformation of the piezoelectric layer to the vertical displacement of the cantilever. In addition, it makes the long cantilever flat by controlling the residual stress. The top and bottom electrodes are deposited by the dc magnetron sputtering of platinum. The piezoelectric layer is formed by using the sol-gel method with PZT, whose composition lies in the morphotropic phase boundary (MPB). The sol material is first spin-coated onto the bottom electrode and subsequently heat-treated. A rapid-thermal-annealing (RTA) process is used to crystallize thin-film PZT into the Perovskite structure. After the deposition of the top electrode, etching steps to shape the cantilever are performed in reverse order. The top electrode, the PZT, and the bottom electrode are etched using dry-etch processes. The via hole is formed to connect the bottom electrode to the drain pad of the active matrix. The supporting layer is etched after the via formation [Fig. 4(b)].

A second sacrificial layer (spacer 2) is needed to build a flat mirror on top of the actuator structure. The material for this layer was carefully selected by considering the process compatibility, process temperature, and ease of planarization. A fluid polymeric substance is spin-coated and hardened to form the second sacrificial layer. The hole in the second sacrificial layer forms the metal support

Optical Efficiency

The optical efficiency of the TMA projection system is the product of the efficiencies of the lamp coupling, the optical transition, and the TMA pixel.

The lamp-coupling efficiency is defined as the amount of collected light that can be used by the TMA relative to the total emitted lamp flux. For a given lamp entendue, the lamp-coupling efficiency increases as the TMA panel size increases. The current size of the TMA panel gives a high lamp-coupling efficiency of up to 72%. High lamp-coupling efficiency will be maintained even when the TMA pixel pitch is reduced to 41×41 μm for SXGA resolution.

The optical transition efficiency depends on the dichroic-mirror reflection and transmission losses and the reflection losses in the optical elements. The TMA optical system has a color-filter/projection-lens efficiency of 45%.

The optical efficiency of the TMA module depends mainly on the fill factor, the reflectivity, and the mirror flatness. Currently, the TMA module has a high fill factor of 94%, obtained by hiding the actuator structure behind the mirror. The reflectivity of an aluminum mirror is 90%. The real micromachined mirrors, however, have a surface topology resulting from the imperfect planarization of the underlying sacrificial layer and the warpage from unbalanced residual stresses after the release process.

In the TMA optical system, the mirror flatness strongly affects the shape of the beam image formed on the projection stop. In order to achieve high optical efficiency, special planarization processes have been developed. We are currently obtaining about 70% optical efficiency. Today, we are obtaining a total light efficiency of 22.7% – the highest ever among high-brightness projectors.

Prototypes

Two prototype TMA projectors were developed using lamps of different power. With a lower-power lamp, such as would be used in lower-cost applications, the highest optical efficacy of 9.2 lm/W was achieved with a 270-W metal-halide lamp. When compared with the image projected by an LCD projector using a lamp of the same power, the TMA projector is significantly brighter (Fig. 6). For high-brightness applications, 5400 ANSI lumens were produced from a 1-kW xenon lamp – the most output ever obtained from a display using a 1-kW lamp. This high-power TMA projection system was demonstrated at Asia Display '98 in Seoul, Korea.

What Now?

The highly efficient optical performance of the TMA module makes it possible to manufacture projection displays offering high brightness at competitive costs. We expect that commercial XGA projectors with an output of over 5000 ANSI lumens will be on the market within a year. The simplicity of the light-modulation principle and the high optical efficiency allows more brightness to be provided for high-end large-venue projectors. At the low end, we will be able to provide desktop projectors and HDTVs that match the luminance of current products at lower cost. ■

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company profile

Varitronix: An Engineer's Fairy Tale

This is the story of an engineer and a physicist who built a substantial LCD company that seems nearly immune to the industry's boom-and-bust cycle – and it's true.

by C. C. Chang and Ken Werner

ONCE UPON A TIME two young Ph.D.s – one from the University of Manchester Institute of Science & Technology and one from Harvard University – decided to create a company that would make displays in a fabled city famous for its entrepreneurial spirit. The year was 1978 and the entrepreneurial center was not Silicon Valley; it was Hong Kong.

The two entrepreneurs, C. C. Chang and York Liao, had become lecturers at the Chinese University of Hong Kong after receiving their doctorates. Chang gave up his position to create Varitronix, a company that initially specialized in small custom liquid-crystal displays (LCDs). Liao retained his university position until 1984, when he joined Varitronix on a full-time basis.

It may not be easy to remember the display environment in 1978. It had only been 5 years since Sharp went into volume production of the EL-805, the first LCD-based electronic calculator, and only 3 years since Sharp had begun replacing displays based on RCA's original dynamic scattering mode (DSM) with the revolutionary twisted-nematic (TN) mode. It was just in the previous year, 1977, that LCD wrist watches were first produced in volume. The making of small TN displays was an exciting and challenging new technology in 1978.

Initially, Varitronix manufactured and marketed standard watch, calculator, and instrument displays. The company's first invoice to a customer for a watch display showed a selling price of US$1.25 per piece, 5–10% below the market price at the time. By 1980–81, with a vast volume of displays coming from Japan, the price plunged to below US$0.30 per piece for the same unit. (Of course, it is much lower today.) During that period, a few U.S. and European manufacturers closed their operations.

Varitronix recognized that it couldn't compete with big players, so it took advantage of being small and flexible. The company focused on custom displays and was flexible enough to accept orders with no minimum quantities. Varitronix's strategy was then changed to emphasize R&D and to increase the company's ability to provide as many

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Varitronix

Fig. 1: Varitronix moved into its new 160,000-ft.^{2} manufacturing facility and headquarters in Hong Kong's Tseung Kwan O Industrial Estate in October 1997.

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Varitronix

Fig. 2: This wireless version of Varitronix's Telebet customer-input terminal is used by the Hong Kong Jockey Club. Over 80,000 of the older, wired terminals are currently in use. Both versions use a Varitronix touch-sensitive overlay on a Varitronix-made display.

technologies as possible. In this way, the company would be prepared to give customers (almost) anything they wanted in their custom displays.

In the succeeding 20 years, Varitronix has become extremely successful, with 1200 employees; factories in Hong Kong, Shawan (China), Heyuan (China), and Penang (Malaysia); sales offices in Hong Kong, Champlan (France), Toronto (Canada), Milan (Italy), Los Angeles (U.S.A.), Bracknell (U.K.), Penang (Malaysia), Munich (Germany), and Graben (Switzerland); and a design center for liquid-crystal modules (LCMs) in Singapore.

Varitronix does not seem to follow the usual models. It is growing rapidly, having opened its 120,000 ft.^{2} factory in Penang in September 1993, moved into its new Hong Kong factory and headquarters in late 1997 (Fig. 1), and opened its Swiss sales office and Singapore LCM design center in late 1998. These investments did not seem to distract management from operational considerations. The company's revenues grew approximately 12% (to HK$491M, or US$63M) for the first 6 months of 1998 compared to the 6-month period a year earlier, with a similar percentage increase in operating profit. The Asian flu finally affected Varitronix in the second half of 1998, and revenues were flat for the year.

Eggs in Many Baskets

The company's ability to profit during the Asian economic crisis rests in part on its geographically distributed markets. In 1997 slightly more than half of Varitronix's sales were to Europe, slightly more than a fifth to North America, and about a quarter to Asia. Both revenue and profit have increased every year since 1990 (although the increase from 1995 to 1996 was small). Revenue in 1997 was HK$843M. Market capitalization had grown to HK$4.2B (US$540M) by November 1998.

The company prides itself on being research-driven, and has succeeded in combining a mass-market LCD business with one focused on the custom design and manufacturing of sophisticated commercial, industrial, and military display modules, assemblies, and systems. Varitronix also offers the ability to take a concept all the way to a mass-producible end product, which it did, for instance, in the case of the more than 80,000 hand-held terminals currently being used as Telebet customer-input betting terminals by the Hong Kong Jockey Club. The terminals are net-

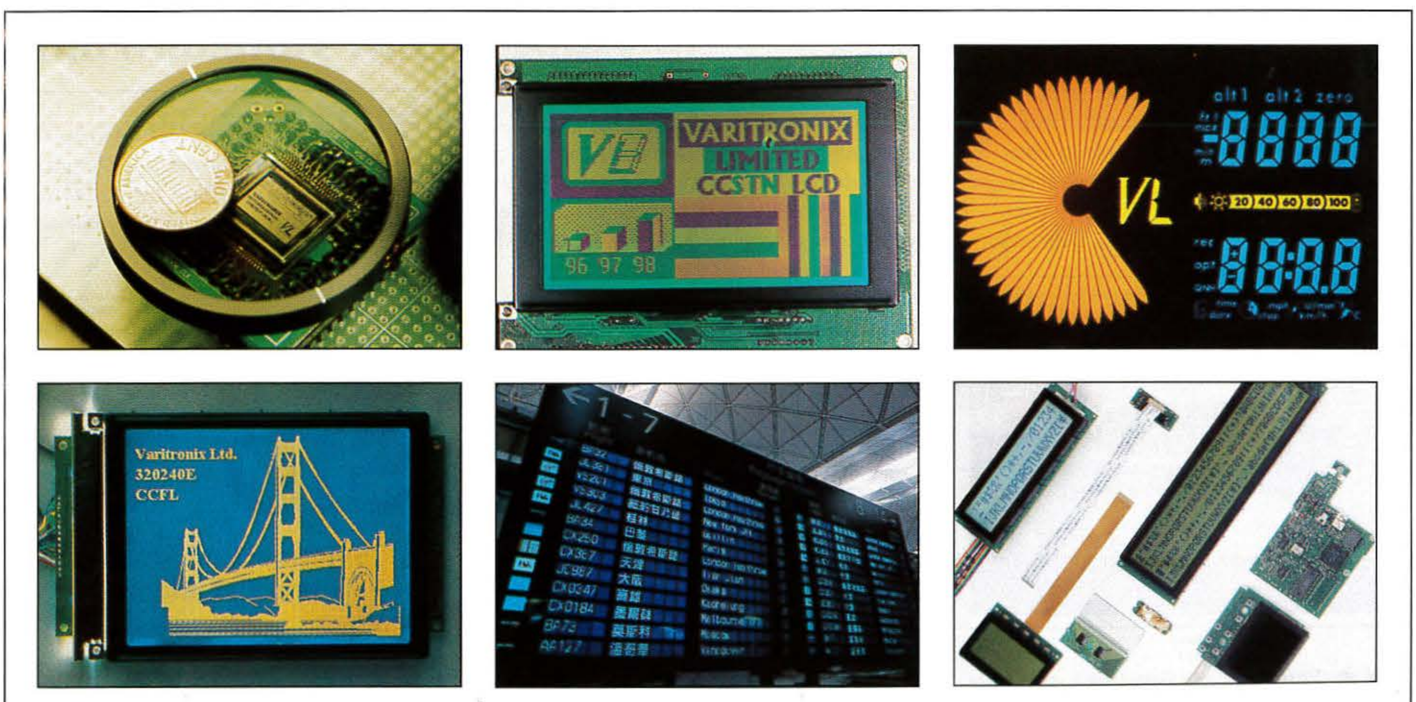

Fig. 3: Among Varitronix's products are segmented, dot-matrix, and graphics LCD modules.

worked to a central processor *via* telephone lines or serial ports, and a wireless version was introduced in 1997 (Fig. 2). Both versions use a Varitronix touch-sensitive overlay on the display for easy data entry.

Among the company's products are segmented, dot-matrix, and graphics LCD modules; color-coded STN modules; direct-contact touch screens; modules with integrated touch screens; and touch-sensitive hand-held terminals (Fig. 3). Assembly technologies include chip-on-board (COB), chip-on-glass (COG), and tape automated bonding (TAB). Recent additions to the product mix are electrochromic mirrors and liquid-crystal–on–silicon (LCOS) microdisplays.

Looking Backward for Fun and Profit

In August 1997, Varitronix Malaysia entered a joint-venture agreement with Donnelly Corporation, the world's largest producer of automotive mirror systems. (Donnelly's customer list includes all of the world's major automobile manufacturers.) The newly formed company, named Varitronix EC (Malaysia), will produce interior and exterior mirrors that feature automatic dimming through the use of electrochromic technology, and mirror systems that can incorporate a variety of features such as map lights and electronic compasses (Fig. 4). Pilot production began in May 1998, and samples were submitted to automotive manufacturers for quality acceptance. Volume production started in January 1999.

Varitronix EC intends to apply its electrochromic technology to information displays. An electrochromic display is essentially a charge-retention device. Depending on the structure, the charge-retention time can be as fast as seconds to as long as hours. For electrochromic-mirror applications, designers aim for a quick response time. In an application such as shelf-edge labels for supermarkets, designers seek to maximize the duration of charge retention for a display that requires no on-board power. The long image retention and very low power consumption of electrochromic displays is a good match for applications such as the supermarket shelf-edge labels mentioned above.

Donnelly Corp.

Fig. 4: Varitronix and Donnelly have jointly created a company in Malaysia to manufacture electrochromic-mirror systems for mass-market automotive applications.

Early to Board the Micro Bandwagon

Varitronix received its first patent for an LCOS microdisplay in 1997. The company focused on mixed TN and birefringent (MTB) mode on CMOS for its microdisplays because it saw this technology as being relatively easy to bring to commercial mass production.[1] This has turned out to be the case, and an XGA microdisplay is now available that has a contrast ratio in excess of 100:1. Varitronix has recently fabricated 1.6-μm MTB cells with response times around 3 msec, which would be suitable for field-sequential color.

In microdisplay processing, the optimum method of marrying the front glass to the CMOS backplane is still an open question. The liquid-crystal material is introduced between these layers, and switching characteristics depend upon the precision and consistency of spacing between them. One is tempted to use what Varitronix calls "laminate processing," and what some other companies in the industry call "array processing." In this technique, the glass is laminated to the wafer with proper spacing in the active areas, LC material is introduced through the fill ports (which are then sealed), and the laminate is then separated with traditional glass-separation techniques.

Although some other companies are using this approach, Varitronix does not believe the process can reliably provide adequate precision and consistency of interlayer spacing in a mass-production environment. A single-piece process – in which the CMOS wafer is separated into individual display backplanes and mated with front plates one by one – provides adequate precision but is not practical for mass production.

To solve this problem, Varitronix developed its "hybrid laminate process," which mates many individual dies with a single larger piece of glass through the use of special jigs and tools. This allows LCOS microdisplays to be processed on Varitronix's existing production facilities, which provide immediate capacity to satisfy the demand for any foreseeable volume. The company has successfully controlled the cell gap to within an optical fringe in volume production, and without using spacers in the active area. Varitronix is now shipping 2000–4000 microdisplays per week.

The Varitronix story may have some of the magic of a fairy tale, but it isn't a mystery. Driven by research and committed to new technologies, the company also pays close attention to the needs of its customers and the quality and efficiency of its manufacturing. And, refusing to put all of its eggs in one basket, Varitronix supplies a worldwide market with a substantial variety of display products – which don't compete with those of Sharp, NEC, or DTI.

Notes

[1]For more information, see "Generalized mixed-mode reflective liquid-crystal displays with large cell gaps and high contrast ratios," by H. S. Kwok *et al., JSID* (to be published). ■

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Space, the Final Color Frontier

Discussion at CIC-6 returned to a basic question: How is perceived color affected by the spatial context and by parameters such as display resolution?

Michael H. Brill

THE SIXTH Color Imaging Conference (CIC-6), held November 17-20, 1998, drew 285 color scientists and engineers to the Sun-Burst Resort Hotel in Scottsdale, Arizona. The conference is jointly sponsored by the Society for Information Display (SID) and the Society for Imaging Science and Technology (IS&T). Although attendance was somewhat less than last year's 330, participants agreed that the high quality of interactions maintained the CIC's reputation as the premier forum for color imaging.

Following the theme of last year, CIC-6 continued to focus on standards for transferring color between devices - scanners, VDUs, and hardcopy devices, for example, with particular application to the Worldwide Web. However, this year also featured a return to basic vision questions. The most salient of these questions was how the perceived color of an image area is affected by that area's spatial context, and by other properties - such as display resolution - which are not usually associated with color. The spatial dependencies are not completely captured in most models of color appearance, particularly the models that have been adopted as standards. However, advances in computer technology are bringing spatio-chromatic models of color appearance closer to becoming useful tools.

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Another recurring theme was the inference and representation of the colors of extraterrestrial objects. In two senses, then, space was the "final frontier" explored at this conference.

Standards Update

"How many standards bodies does it take to change a light bulb?" asked Conference Chair Sabine Süsstrunk, to begin a panel discussion of color standards. The question was largely rhetorical, but did bring home the point that standards bodies - some comprising countries and others comprising companies - interact in very complicated ways. The panel was moderated by Prof. Robert W. G. Hunt (University of Derby, U.K.), and focused on the organization of standards bodies, their purpose in color technology, and their progress over recent years.

Representatives from four standards groups participated in the panel. The International

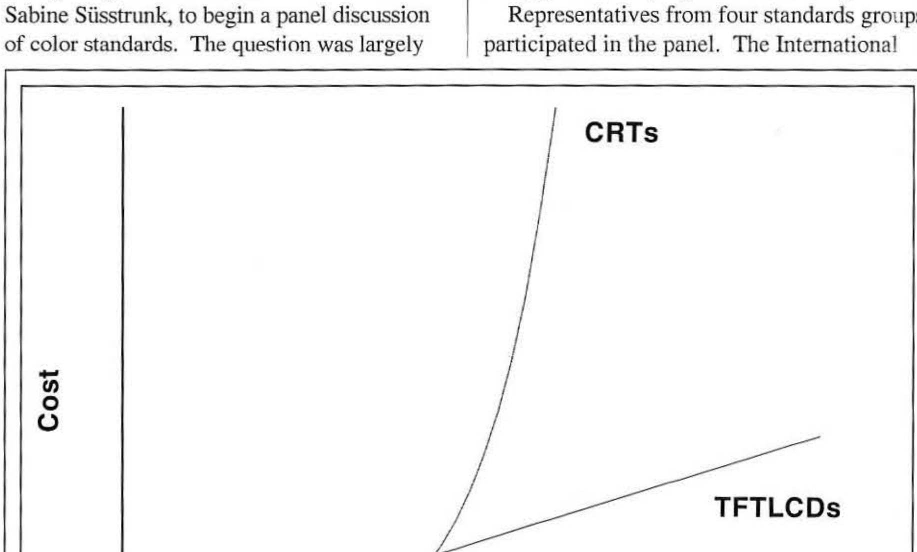

Fig. 1: As high-definition television becomes more popular, TFT-LCDs may become cheaper than CRTs of the same complexity. (Courtesy of S. Wright, IBM.)

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Color Consortium (ICC) was represented by Tim Kohler (Canon Information Systems); the International Commission on Illumination (CIE) was represented by Alan Robertson (National Research Council, Canada); the International Standards Organization (ISO) was represented by Tony Johnson; and the International Electrotechnical Commission (IEC) was represented by Mike Stokes (Hewlett-Packard).

David McDowell of Kodak provided an overview of the relationship among the various standards bodies. Although thought to be too slow moving to keep up with technology, the CIE has recently established Division 8 (Image Technology, to be chaired by Todd Newman of Canon Information Systems), and Divisions 8 and 2 are moving very fast toward color-appearance standards.

On the other hand, although the ICC was first thought to be a fast-moving organization based on consensus, it has slowed down in the last few years. One reason is financial: companies are more reluctant to devote their efforts to color-management and device-independent color. Another reason is that the focus of the group has been on interfaces and not on full technical solutions. As a result, it is possible to transport prescriptions for decoding color that are incorrect relative to what was sent, though the syntax of the interface will not detect this fact. The bookkeeping issues (due to the multiplicity of devices and color-space options) seem as daunting as the basic technical issues. It may be years before we see "plug and play" color.

Beyond this panel discussion, many individual contributions also dealt with standards. For example, several tests were reported of the color-appearance model CIECAM97s, which recently became a CIE standard. Nathan Moroney (Hewlett-Packard) presented "A comparison of CIELAB and CIECAM97s." Moroney concluded that, although CIECAM97s has closer connection to color-appearance attributes, CIELAB sometimes wins in perceptual uniformity. A poster by Shuichi Kumada *et al.* (Canon and Japan Color Research), "Performance Evaluation of Color-Appearance Model," tested CIECAM97s against four other models. Of the five models, CIECAT94 was the winner in predicting color appearance. Because the correct color-appearance standard is yet uncertain, several papers presented results in both CIECAM97s and CIELAB coordinates so as to be sure that these results were not artifacts of the color space.

Finally, in "Color-Fidelity Test Methods," Michael Stokes (Hewlett-Packard) and Tom White (Microsoft) offered three kinds of test patterns for testing color-management systems. One such pattern is a complicated image in which there are delicate high-resolution objects - such as text - as well as a multitude of colors. The authors subject this image to "simple visual assessment," which amounts to a quick qualitative check that it is rendered properly. Another test pattern uses a page of solid reference colors, with user control over a test color within the context of these reference colors.

Demands Outrun Standards

Despite much work on standards, new technology has brought little reported improvement in color quality. However, the demand of color-system users is a moving target: We demand higher and higher quality - including color - in the displays we use most of our lives. Besides the obvious fact that people get used to a good thing and want more, another factor whets the demand for better color. Finer display resolution (apparently unrelated to color) results in a more acute demand for better color reproduction.

Nowhere was this more apparent than in "Image-Quality Issues for High-Resolution TFT-LCDs," by Steven Wright of IBM (with A. N. Cazes, R. W. Nywening, and S. E. Millman of IBM; J. Larimer of NASA Ames; and J. Gille and J. Luszcz of Raytheon). The centerpiece of Wright's discussion was the new IBM Roentgen display, which has 2K × 2K full-color pixels, 200 pixels/in., 150:1 contrast (measured either with full screen or with grating), high peak luminance, and light (20-lb.) weight. Because of its capabilities, viewers see a high-quality image even at a close viewing distance. Wright made the point that, as display complexity - addressability - increases and the sales volume remains high, the expected cost increase of the TFT-LCD should be much less than that of cathode-ray-tube (CRT) technology. In fact, he predicts TFT-LCDs to be much more economical than CRTs in the near future (Fig. 1). Furthermore, Wright stated that the quality demanded by consumers increases to match the best quality that's available, and that we are nowhere near the point where further improvements are indistinguishable to consumers. Wright's contribution was not explicitly in color technology, but since color and spatial vision are inseparable, it is reasonable that color quality depends on more generic image-quality issues.

Another way in which demands outrun standards is that new display technologies are not so well understood as CRTs, so the old tried-and-true NTSC model cannot be relied upon. Consider LCDs, for example. Yoshi Ohno (with Steven W. Brown) of NIST has performed measurements of color-tracking of primaries for LCDs. Their results, reported in "Four-Color Matrix Method for Correction of Tristimulus Colorimeters - Part 2," reveal that chromaticities of the R, G, and B primaries do not stay constant with digital level. The chromaticity of each primary wanders due to unwanted light from the other primaries. By subtracting the black-point tristimulus vector from all the measurements, it may be possible to make the chromaticity of each primary invariant with drive level. Ohno had not yet tested this hypothesis, but Mark Fairchild found that it worked for one high-end LCD (not reported at this conference).

Frontier of Inner Space

In his keynote address on the first day of CIC-6, "Physiological Mechanisms of Primate Color Vision," David Hubel reminded us that awareness of the connection between spatial and color vision is not new. Hubel's neurophysiological work 30 years ago, which won him the Nobel prize in 1981, showed that in macaque monkeys - whose vision is very like our own - every level of spatial vision conveys color as well. One almost-forgotten fact found by Hubel in 1966 was that, just after retinal processing - in a peanut-sized brain structure called the lateral geniculate body - color seems to be encoded in cells that have a fairly broad and unselective spatial response (but more spatial dependence comes into play in higher brain centers).

David Hubel's son Paul, who also contributed to CIC-6, introduced him and helped stage some impressive visual demonstrations of the interaction between spatial and color vision. Certain strong spatiotemporal effects, such as the appearance of a set of moving dots as a rotating cylinder, are abolished when the dots are made the same luminance as the background.

Fig. 2: The problem of assessing naturalness in color rendition becomes more difficult for unfamiliar scenes. (Courtesy of S. Yendrikhovskij, IPO, Eindhoven, The Netherlands.)

Robert W. G. Hunt (University of Derby, U.K.) gave another keynote address on the second day of CIC-6. This one also dealt with the problems of spatial context in color perception. In "An Eye for All Seasons," Hunt observed evidence of chromatic adaptation: perceived colors depend on a certain object being seen as white, even if seen under spectrally biased illumination. This adaptation tends to ensure that all object colors stay constant under illumination change. Color constancy has its limits, and Hunt described modeling efforts to capture these limits, culminating in CIECAM97s - to which he contributed.

However, Todd Newman noted afterward that object-color perception may also depend on cognitive factors that are not in any model, *e.g.*, the adopted white for a particular scene may not be the same as the adapted white for the same scene or a simpler scene with similar color statistics. Such effects were evident in "Influence of Background Characteristics on Adapted White Points of CRTs" by Peyma Oskoui (Hewlett-Packard, Palo Alto) and Elizabeth Pirrotta (Consultant, Mountain View). They were also clear in "Visibility of Thin Lines on Coloured Backgrounds" by R. Victor Klassen (with Karen Braun, Robert Buckley, and Kalpana Janamanchi from Xerox Corp.).

Mark Fairchild of the Rochester Institute of Technology (with Jim Ferwerda of Cornell) further reinforced the color-spatial connection. Fairchild and Ferwerda described an impressive spatio-chromatic vision model ("Multiscale Model of Adaptation, Spatial Vision, and Color Appearance"). The authors acknowledged that their multi-resolution model - called a pyramid architecture - was inspired by the Sarnoff JND Vision Model reported by Michael Brill at last year's conference. In the present model, the authors explicitly ensured that perceived colors in an image do not change with viewing distance when they are part of image features that are much above detection threshold. Also, the outputs of the model are presented in color-appearance coordinates, where they are used to predict various psychophysical effects. The method is described in the conference proceedings, as well as in last summer's proceedings of SIGGRAPH.

Frontier of Outer Space

A paper by Thor Olson (Management Graphics, Inc.) on "The Colors of the Stars" not only told us about the history and measurement basis of astronomy, but also showed how to convey the most information about stars in a map without compromising spatial relationships such as constellations. Olson's pictures of stars encoded their chromaticities faithfully, but the brightness - magnitude - range was too great for direct visual presentation. Olson found it was best to encode a star's magnitude as a carefully thought-out hybrid of brightness and size. Finally, Olson displayed the stars in stereo using a 1.5-light-year stereo base. The effect was impressive when seen through a 3-D viewer.

Closer to home, Peter H. Smith (University of Arizona) gave the third keynote speech: "Is Mars Really Red? Color Imaging from Mars Pathfinder." Smith discussed how physical conditions on the surface of Mars influence the colors one would see there. First of all, Mars is not red - it is "butterscotch" in color. Reputation exaggerates the redness - it is not even observed in earthbound photographs if the color is represented correctly. Furthermore, the Martian sky is filled with wind-blown dust whose optical thickness is thinnest in the direction of the sun. Consequently, the yellowish sky surrounds a blue halo around the sun. Three distinct lighting conditions can be seen through shadows cast by large rocks: the direct sunlight, a fairly collimated light from the blue halo, and a diffuse yellowish light from the dust. Some startling, unearthly shadows appear more yellow than patches directly illuminated from the blue halo. We on earth are more used to a bluish shadow from the sky.

Other Highlights

Among the poster papers, the winner of the annual "Cactus" award was "Optimizing Color Reproduction of Natural Images" by

Sergej Yendrikhovskij [with F. J. Glommaert and H. De Ridder (IPO, Eindhoven, The Netherlands)]. Yendrikhovskij's difficult goal was to assess colors in an image by a "naturalness index" to determine automatically how well the image represents a natural scene. His inspiration was a set of four pictures of a lighthouse scene, only two of which appear natural (Fig. 2). Here is a quote from his Ph.D. dissertation: "One has a very good reason to feel uncomfortable eating something blue."

Another approach to understanding color in the natural world was "A Huge Spectral-Characteristics Database and Its Application to Color-Imaging-Device Design," presented by Johji Tajima (C&C Media Research Labs, NEC Corporation, Kawasaki, Japan). The measured spectra in the database included photographic materials, graphic prints, paints, flowers, leaves, human skin, and outdoor objects. Characterizing these data in lower-dimensional spaces helps designers of color-imaging devices. Tajima's paper summarized the work of the Spectral-Characteristics Database Construction Working Group of the Japan Standards Association.

Although constraints in the natural world might help the design of color imagers, there are *a priori* design principles that make a device intrinsically better at rendering color. A paper that discussed this issue, "Prime Colors and Color Imaging," was presented by Michael Brill (Sarnoff Corp.), with Graham Finlayson (University of Derby, U.K.), Paul Hubel (Hewlett-Packard), and William A. Thornton (Prime-Color Inc., Cranford, N.J.). In theory, TV-camera sensitivities should be linear combinations of the color-matching functions. Which linear combinations should they be? Ideally, they should be dual to the spectral primaries of the TV, *i.e.,* a color-matching experiment using the TV phosphors as primaries should yield the camera sensitivities as color-matching functions. This ideal is strictly impossible because the required camera-sensitivity functions would be negative at certain wavelengths. But the negativity is reduced by choosing the phosphor-primary chromaticities near three wavelengths called the prime-color wavelengths – approximately at 450, 540, and 605 nm, as determined by Thornton 30 years ago. These wavelengths give the greatest efficiency per primary. Also, when the illuminant spectrum changes on a scene, gain control on these TV primaries restores most accurately the tristimulus values of object colors in the scene. Because standard phosphors are near the prime-color chromaticities, current TV technology enjoys these advantages.

Together with softcopy displays, ink-on-paper technology had a large representation at CIC-6. One particular presentation was a significant theoretical breakthrough: "Spectral Colour Prediction Model for a Transparent Fluorescent Ink on Paper," presented by Patrick Emmel (with Roger Hersch, from Ecole Polytechnique Federale de Lausanne, Switzerland). Emmel showed a matrix method that generalizes Kubelka-Munk formulation to include fluorescent colorants suspended in a volume vehicle. The ultimate goal is to prescribe the colorant quantities necessary to achieve a particular tristimulus specification under a particular light. Previous theories – of which Eugene Allen's 1964 theory still holds sway – make enough assumptions so that the shape of the predicted fluorescent emission spectrum does not change shape with colorant concentration. But this cannot be true in a volume suspension, as Emmel showed in a vivid demonstration. When fluorescent-bearing plastics of various colors were overlaid, it was clear that the color depends on which is on the top and which is on the bottom. This is what has made the prediction of color for mixtures of fluorescent inks difficult. Emmel's approach – an extension of a model he presented at CIC-5 – promises to solve this difficult problem.

The poster session contained other papers dealing with hardcopy color issues including gamut mapping and device characterization. One of these, "Halftone Color: Diffusion of Light within Paper" by Geoffrey Rogers, Fashion Institute of Technology, continued the excellent physical-modeling work reported last year by J. S. Arney (CIC-5 Proceedings, pp. 62-65).

Finally, William A. Thornton gave a stand-by paper on "Basic Colorimetry" that called into question the CIE standard observers that underlie all color-imaging work. Thornton observed the following. Let light A (a full-spectrum white reference) match light B (concentrated around two complementary wavelengths) as perceived by a human observer. Thornton found a light C (a full-spectrum light reflected from a green patch) that matches light B to the CIE 1931 Standard Observer. When humans compare lights A and C, they see A as being white and C as being bright green. Although Thornton's result is not a show-stopper for current color technology, it may be important in some future color systems that have strong inherent metamerism.

Plan for 1999

The Color Imaging Conference continues to be a unique and dependable forum for color technology. In 1999, the CIC will again be held in the SunBurst Resort Hotel in Scottsdale on November 16–19, and will revisit many themes from previous years. Besides adopting the goal of reporting individual advances, the organizers of CIC-7 will encourage speakers to provide cross-references with other papers from this and previous CICs. This "coherent front" emphasis will help make progress in color technology – all the way from basic research to standards of practice – more evident. ■

Please send new product releases or news items to Information Display, c/o Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003.

See Us at SID '99 Booth 621 **Circle no. 101**

Circle no. 102

See Us at SID '99 Booth 1243

Circle no. 103


FOR CRTs,
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At Thomas Electronics, CRT solutions come in all shapes and sizes.
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See Us at SID '99 Booth 507
Circle no. 104

Products on Display at SID '99

Some of the products on display at SID's largest exhibition ever are previewed.

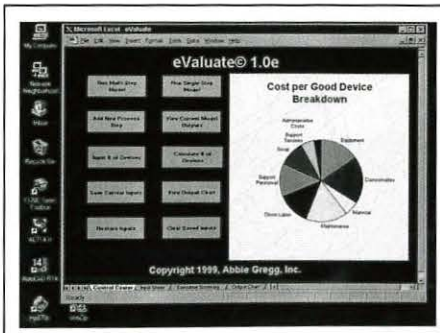
by THE EDITORIAL STAFF

THE SID '99 INTERNATIONAL SYMPOSIUM, SEMINAR & EXHIBITION *will be held at the San Jose Convention Center in San Jose, California, the week of May 16. For 3 days, May 18–20, leading manufacturers will present the latest displays, display components, and display systems. To give you a preview of the show, we invited the exhibitors to highlight their offerings. The following is based on their responses.*

ABBIE GREGG, INC. (AGI)
Tempe, AZ 602/446-8000
Booth 1234

FPD cost-of-ownership software

AGI will demonstrate eValuate© software at SID '99. This unique software program is designed to assist FPD companies in understanding the cost of ownership of tools in an FPD fab. Some of its features and benefits include providing FPD manufactures and OEMs with a systematic approach to comparing the different tool types; increasing the understanding of the role that recurring costs, process yields, and other non-fixed costs have with regard to overall tool ownership costs; information on the manpower and number of tools required to support a given production volume; and evaluation of the impact of proposed process changes.
Circle no. 1



ADHESIVES RESEARCH
Glen Rock, PA 1-800-445-6240
Booth 326

Adhesive-coated products

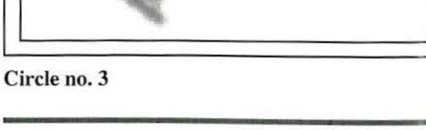
Adhesives Research will display optically clear unsupported transfer adhesive products and custom-coated optically clear pressure-sensitive adhesive-coated products for defect-free bonding of backlights, polarizers, filters, retarders, and diffusers and holographic, anti-reflective, and hardcoated films used in projection screens, touch screens, LCDs, and flat-panel displays. Also on exhibit will be electronically clean and low-outgassing pressure-sensitive adhesives for electronics assembly, and electronically conductive adhesives for static control, shielding, grounding, and interconnections.

Circle no. 2

APPIAN GRAPHICS
Redmond, MA 425/882-2020
Booth 811

Display-management software

Appian Graphics will feature Jeronimo™ Pro, a software program that provides superior speed and power to instantly access and manipulate text, complex 2-D/3-D graphics, and video. Perfect for power users, such as financial managers, design engineers, digital content creators, and multi-media developers, the Jeronimo Pro enables the user to master the power of multiple monitors. It includes HydraVision, Appian's patented display-management software that uses high-speed Permedia 2 accelerator chips.



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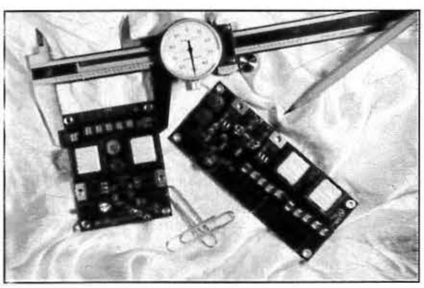
APPLIED CONCEPTS
Tully, NY 315/696-6676
Booth 1221

ac-to-dc inverters

Applied Concepts, a designer and manufacturer of ac-to-dc inverters for multiple CCFL backlights used in sunlight-readable, vehicular, military, and industrial display systems, will introduce the standard AC5 family of inverters at SID '99. The series offers a compact low-profile package capable of driving 1-10 outputs and up to 35-W output power, at average electrical efficiencies greater than 90%. AC5 inverters are factory firmware programmable for maximum control function flexibility, including ambient-light sensing/feedback, single-line serial control, and custom brightness response curves (linear or logarithmic). This flexibility also allows for very wide dynamic dimming ranges.

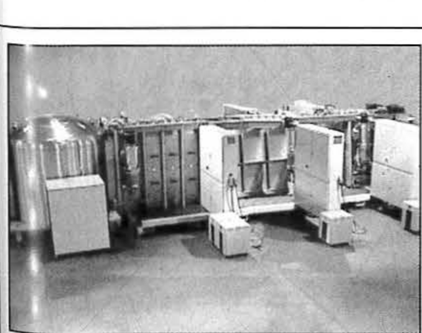


Circle no. 4

APPLIED FILMS CORP.
Longmont, CO 303/774-3200
Booth 1011

Vacuum sputtering equipment

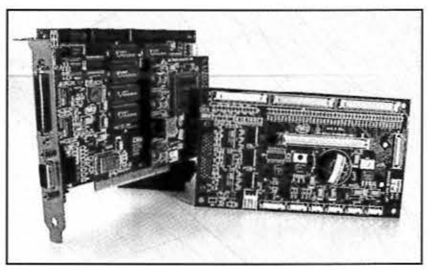
Applied Films Corp., the largest supplier of coated glass to the FPD industry, designs and builds a complete line of in-line high-throughput vacuum sputtering equipment with a focus on low cost of ownership. World-class facilities in the U.S. and China provide excellent manufacturing and training platforms. Conductive coatings and vacuum sputtering systems are presently used in the PDP, EL, electrochromic, field emission, and OEL industries.
Circle no. 5



AVED DISPLAY TECHNOLOGIES
Tustin, CA 714/573-5035
Booth 514

Controller/panel-interface control electronics

AVED Display Technologies is a supplier of key controller and panel-interface control electronics to OEMs whose end products range from industrial control and medical equipment to gaming and multimedia advertising applications. The latest board set, the AV555-LVDS, coupled with the ADT-LVDS-RCVR2 board supports 1280 × 1024 displays at 16 million colors at up to 15-m remote. Panel drive, power distribution, RS-232, and user-definable I/O are supported through a single simple cable connection. The panel interface is fully buffered and EMI filtered. The board supports large-format TFT, plasma, and DSTN panels with panel interfaces up to 48 bits wide at a 70-MHz operating frequency.

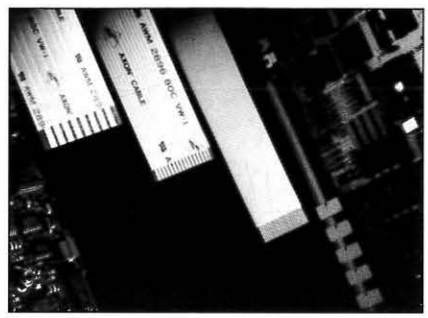


Circle no. 6

AXON CABLE
Mount Prospect, IL 847/699-8822
Booth 448

Flexible flat cables

Axon Cable will feature Axojump®, flexible flat cables used in electronic devices where space reduction is the most important criteria. Designed principally for the consumer electronics market, these flat cables are used in board-to-board interconnections in VCRs, CD players, notebook PCs, and telephones as well as TVs and radios.



Circle no. 7

BREAULT RESEARCH ORGANIZATION
Tucson, AZ 520/721-0500
Booth 437

Illumination-system modeling

Breault Research Organization will introduce at SID '99 the ASAP™ 6.5 for illumination-system modeling. The ASAP models serpentine flourescents to LEDs to polychromatic volumetric emissions from arc lamps, and handles micro-optics for backlit displays, complex dichroics for projectors, as well as polarization and scattering effects. Its non-sequential ray-trace algorithm is extremely fast, allowing system evaluation in a minimum of time. The ASAP bulb library is a growing collection of predefined industry bulbs from which a bulb model can be imported directly into the ASAP system geometry.
Circle no. 8

CENTRAL RESEARCH LABORATORIES (CRL)
Middlesex, Hayes, U.K. +44-181-848-6421
Booth 712

Miniature displays

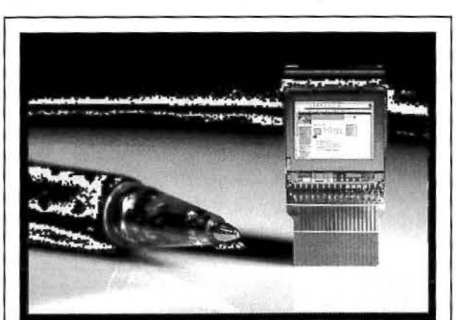
CRL will feature their Liquid Sun™ line of miniature displays that use transmissive TFT active-matrix poly-Si technology and have been designed to enable users to simply plug and play. The most recent XGAI display is a monochrome device which measures only 46 mm on the diagonal and offers XGA resolution (1024 × 768 pixels). The device is supplied with its own XGA interface to allow direct PC conversion. The miniature displays are available with and without polarizers.

Circle no. 9

COLORADO MICRODISPLAY
Boulder, CO 303/546-9700
Booth 1134

Microdisplays

Colorado MicroDisplay, Inc. (CMD) will showcase the CMD8X6P, a microdisplay that features a resolution of 800 × 600, a refresh rate of 75–90 Hz (per color), 24-bit color depth, and low power (< 45 mW). The CMD8X6P is fabricated using CMD's Dynamic Nematic Liquid Crystal on Silicon™ (DNLCOS) technology. The 8X6P supports a full range of content from text to full-motion video, enabling applications in mobile-computing, entertainment, medical, and industrial devices. Evaluation kits and microdisplays are available through CMD or one of its worldwide distribution partners. Pricing for the CMD8X6P is less than $50 in OEM quantities.

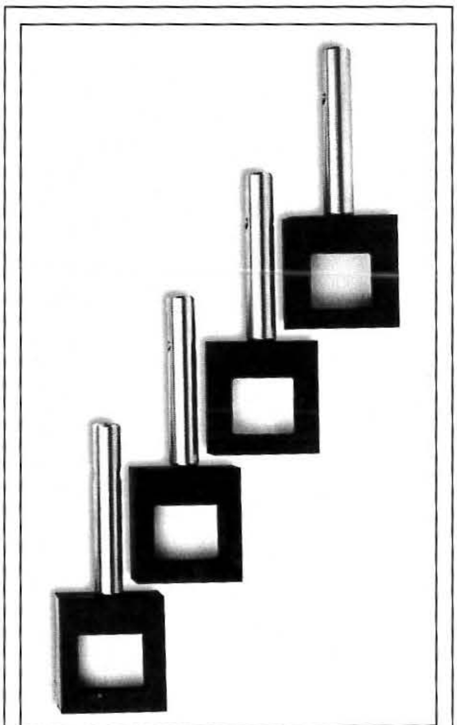


Circle no. 10

COLORLINK
Boulder, CO 303/545-5843
Booth 225

ColorSwitch

ColorLink, manufacturers of color components for projection display systems, will introduce at SID '99 the ColorSwitch™, a low-cost low-power high-throughput solid-state "color wheel." In contrast to the wheel, the ColorSwitch has no moving parts. The order, intensity, duration, and selection of red, green, blue, cyan, magenta, yellow, white, and black colors are programmable. The ColorSwitch enables each pixel to be a full-color pixel, allowing images of unprecedented sharpness and quality to be displayed with a single LCD panel. This reduces system size, cost, and complexity. Applications include rear-projection computer monitors, TVs, and multimedia systems.



Circle no. 11

COMPUTING DEVICES CANADA
Nepean, Ontario, Canada 613/596-7697
Booth 1204

Militarized AMLCD

Computing Devices Canada will feature a 12.1-in.-diagonal high-brightness militarized AMLCD with a 1024 × 768 pixel resolution. Both XGA and RS-170A composite video interfaces are supported, and RS-422 interfaces for display control and integrated switch panel status are supported. The high-performance display has already been delivered for use on the Advanced Amphibious Vehicle (AAAV) for the U.S. Marine Corps.

Circle no. 12

CRYSTALOID TECHNOLOGIES
Hudson, OH 1-888-BEST-LCD
Booth 1307

Touch-screen LCDs

Crystaloid will feature touch-screen LCD modules that use resistive sense technology, which includes superior environmental protection compared to older capacitive-sense devices. These modules can be used for operator input as well as data readout in a wide variety of applications, including handheld data I/O terminals in demanding environments. The modules contain all the LCD drive electronics and

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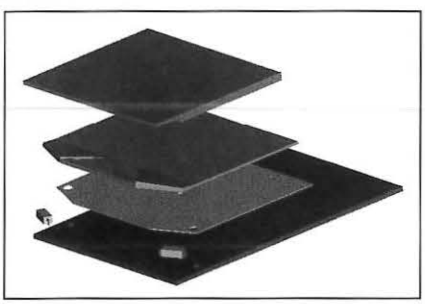
Circle no. 107

touch-panel logic required to display data, sense operator inputs, and output digital control data. The dot matrix can be programmed to display information such as alphanumerics, a QWERTY keyboard, icons, and other graphics. The touch-screen LCD is available with or without built-in backlighting.
Circle no. 13

CTP-COIL
Slough, Beprks, U.K. +44-1753-575-011
Booth 1037

Advanced LCD backlights

CTP-Coil will feature LED lightguides that demonstrate comparable performance to existing technology, with significant power savings and reduced component count. A spatially distributed scatter pattern has been optimized to provide even illumination across the viewing area, and, at just 0.5-mm thick, the lightquide is lightweight and compact. Although developed for mobile phones, the technology can be extended into other product areas such as automotive displays, portable computers, and handheld remote controls.



Circle no. 14

CTX OPTO
Sunnyvale, CA 408/541-6060
Booth 1309

Plug-and-play LCD monitor

CTX Opto will feature the PanoView 751, a completely plug-and-play LC monitor compatible with both PC and Macintosh platforms, requiring no special graphics cards or drivers. With its compact footprint, the Panoview 751 is tailored for space-constrained environments and includes an active-matrix TFT capable of displaying 16.7 million colors at a true 1024 × 768 XGA resolution. The power-efficient monitor utilizes two cold-cathode fluorescent lamp backlights with 40,000 hours of average life producing a luminance of 200 nits, yet draws only 50 W of power. The ergonomic design features dual-tilt and swivel adjustments in the base which gives viewers complete positioning control.

Circle no. 15

DARK FIELD TECHNOLOGIES
Norwalk, CT 203/853-2035
Booth 228

Laser scanners and sensors

Dark Field Technologies will introduce several new products at SID '99. These include the Telecentric Laser Scanner for on-line visual defect detection of substrates or coating defects; the Retro-Reflective Laser Scanner for on-line real-time 100% inspection of reflective and low-E coatings, as well as detection of defects in glass substrates; the compact ASC Advanced Laser Scanner for on-line/off-line 100% surface inspection for special applications; and the Flying Spot Laser Sensor for profiling, track height, and flatness measurements.
Circle no. 16

DUPONT COMPANY
Wilmington, DE 302/892-8644
Booth 115

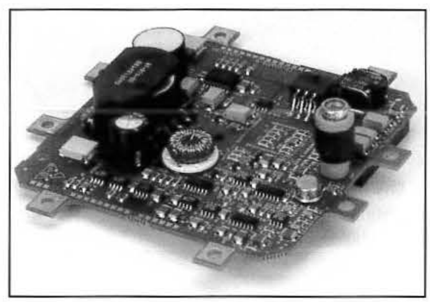
Photopolymer-based holographic reflectors

DuPont will feature photopolymer-based holographic reflectors that are currently being used in a variety of handheld devices, including cellular phones, pagers, and watches to enhance the brightness and contrast of LCDs. Current monochrome green and gold reflectors show brightness enhancement five times greater than that of the white standard and withstand rigorous environmental tests at 85°C/85% relative humidity. Next-generation white holographic-reflector prototypes will also be on display.
Circle no. 17

ELDEC CORP.
Lynwood, WA 425/743-8633
Booth 1248

Dimmable backlight drivers

ELDEC will feature new backlight drivers suited for AMLCD applications requiring high dimming. With a dimming capability of greater than 20,000:1, these backlight drivers enable readability in almost any condition from sunlight to NVIS. The drivers are compatible with both tubular and flat lamps, and cold- and hot-cathode technologies. Features include low component count for miniature size and high reliability, low power consumption for improved thermal management, and low filament stress for long lamp life. The drivers can be integrated with low-voltage power supplies to provide a total display power solution.

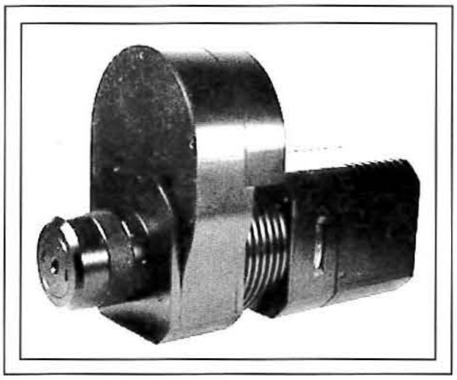


Circle no. 18

ELDIM
Herouville, France +33-2-31-94-76-00
Booth 1122

Uniformity testing equipment

ELDIM will introduce at SID '99 MURATest equipment which provides the only package for area uniformity (versus sampled uniformity). Luminance, contrast, and color coordinates as a function of the position on the display can be evaluated in less than 30 sec. The sensor is a high-grade cooled 16-bit CCD (512 × 768 or 1024 × 1536 resolution). Three optical lenses are available for standard analysis. The windows-based software allows for various analysis and remote control.



Circle no. 19

EXTRON ELECTRONICS
Anaheim, CA 714/491-1500
Booth 310

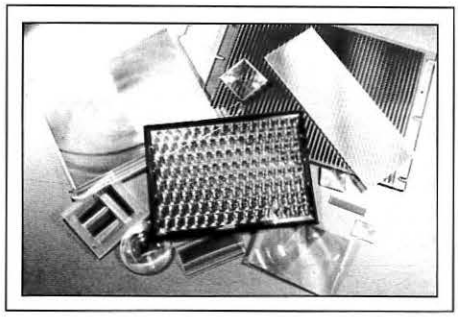
Sync processor

Extron Electronics will showcase the SS 200, a 300-MHz sync processor that accepts virtually any input sync configuration and outputs digitally reprocessed RGBHV simultaneously on five BNCs and a female VGA connector. The SS 200 restores the sync signal to its original form when sync signals have been altered through previous processing. Other applications include converting RGsB or RGBS to RGBHV since many digital displays require an RGBHV input.
Circle no. 20

FRESNEL OPTICS
Rochester, NY 716/647-1140
Booth 1318

Microstructural optical products

Fresnel Optics will exhibit large Fresnel lenses up to 67 in. on the diagonal, integrated rear-projection screen systems, micro lens arrays for projection systems, prisms used in backlighting applications, and distributed lighting applications.

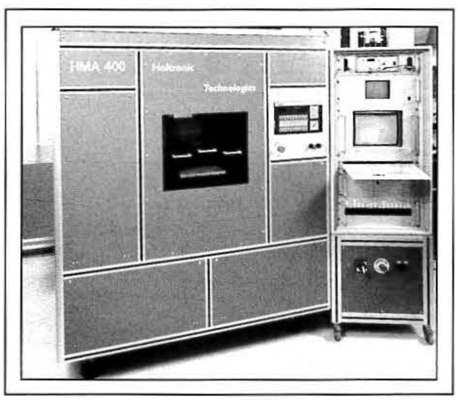


Circle no. 21

HOLTRONIC TECHNOLOGIES
Marin, Switzerland +41-32-753-6800
Booth 1302

Holographic mask aligner

Holtronic Technologies will feature the HMA400, a holographic mask aligner that uses a unique holographic exposure technique that achieves a 0.5-μm resolution without contact and has the largest exposure field in the industry – a full 10 × 12 in. The system can be configured to handle substrates of up to 400 × 500 mm, is equipped with interferometric autofocus control, and has an overlay capability of better than 0.5 μm. The HMA400 builds on the success of the HMA150 which has become the system of choice for leading developers of FEDs and poly-Si TFT-LCDs.

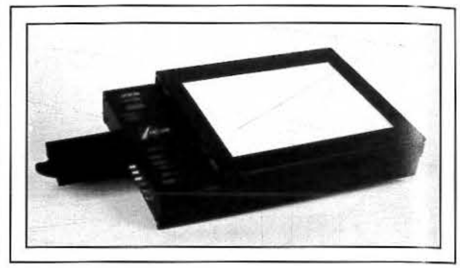


Circle no. 22

INCLINE
Newbury Park, CA 805/376-3300
Booth 1223

LCD universal test system

Incline will exhibit a universal test solution system for flat panels. The test system facilitates comprehensive testing of the individual LCD assembly as well as the whole screen assembly and electronics. Test functionality includes immediate boot-up, quick connect and disconnect, a menu-driven software interface, and a unique modular interface connector system that facilitates current and future interface technologies. The small footprint incorporates built-in illumination, a single-board computer, power adapter, and a backlight inverter. The system will support network connection, data collection, and full I/O connectivity.



Circle no. 23

INDUSTRIAL ELECTRONIC ENGINEERS (IEE)
Van Nuys, CA 818/787-3953
Booth 233

Customized plasma displays

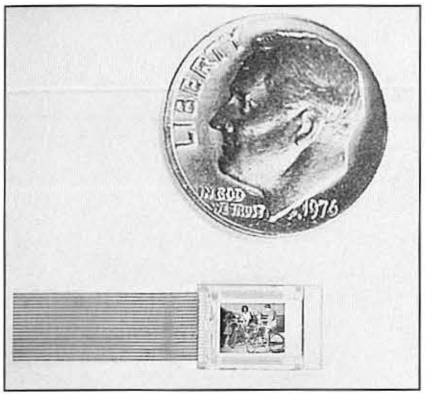
IEE will feature its large plasma displays ideal for viewing at hotels, corporate offices, fast-food outlets, as well as public-information stations at transportation centers and shopping malls. The display's high reliability makes it suitable for government applications. Available with a variety of features and analog inputs, the display can be customized to meet specific customer requirements. Only 4-in. thick, the monitor offers vibrant color reproduction in a thin and low-profile package. Its internal structure supports shock- and vibration-sensitive components in a shock-mounted compartment, reducing the transfer of externally imposed hazardous energy.

Circle no. 24

KOPIN CORP.
Taunton, MA 508/824-6696
Booth 814

Miniature displays

Kopin will exhibit a complete line of miniature low-power monochrome and color 320 × 240 and 640 × 480 AMLCDs specifically designed for ultra-portable personal-information devices. These displays can be used in camcorders, digital cameras, PDAs, GPS systems, HMDs, toys, games, smart cellular telephones, and other consumer devices.



Circle no. 25

KORRY ELECTRONICS CO.
Seattle, WA 1-800-257-8921
Booth 1114

NVIS compatible AMLCDs

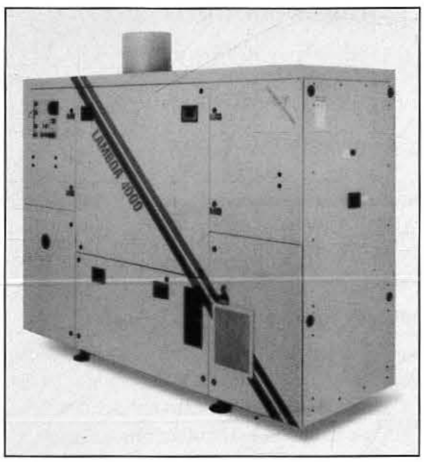
Korry Electronics will exhibit night-vision-compatible AMLCD products designed for avionics cockpit applications, offering a wide dimming range and full sunlight readability. Optional Nightshield® NVIS filtering provides high performance at reduced cost and is compliant with MIL-L-85762.

Circle no. 26

LAMBDA PHYSIK
Ft. Lauderdale, FL 954/486-1500
Booth 1222

Excimer-laser annealing

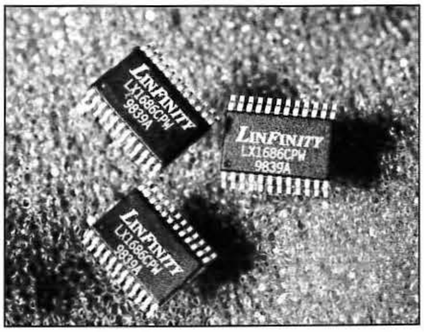
Lambda Physik will introduce the LAMBDA 4308 B, the world's most powerful industrial excimer laser. Based on award-winning NovaTube technology, the LAMBDA 4308 B is designed for high-throughput high-duty-cycle production-line environments and is optimized for high-energy stability to meet the specific requirements of TFT annealing. The excimer laser features an average power of 200 W at a repetition rate of 300 Hz. The pulse energy as well as the temporal and spatial laser beam distribution are optimally stabilized. The use of extended electrostatic and electrically driven cryogenic gas cleaning further enhances the maintenance intervals and lowers the running costs.



Circle no. 27

LINFINITY MICROELECTRONICS
Garden Grove, CA 714/898-8121
Booth 1034

CCFL controller IC

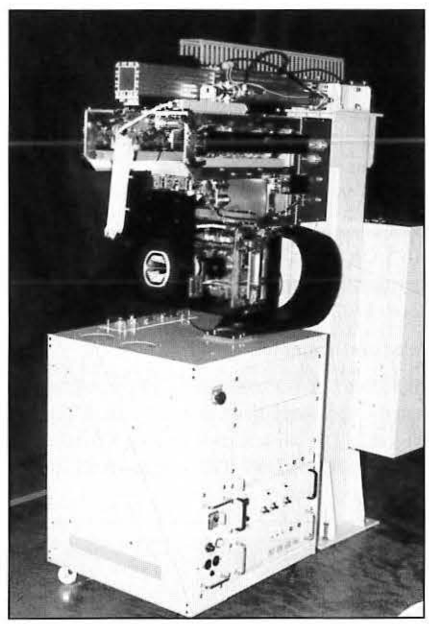


LinFinity Microelectronics will feature the LX1686 controller IC that provides direct-drive digital dimming for inverter modules that power LCD monitors and other applications lit by cold-cathode fluorescent lamps. By allowing the use of more-efficient magnetics, the IC also saves power in battery-operated applications.
Circle no. 28

MECC USA, INC.
Des Plaines, IL 847/827-4974
Booth 207

High-speed automatic CRT tester

MECC will introduce the Model HFS-01, a high-speed first-inspection system featuring very quick inspections of static characteristics in 15 sec and super-accurate socket insertions supported by sensing with a CCD camera. The PC control, isolated with fiber optics, enables more realistic operation, easy customizing of test conditions, and data collection/analysis. Also on display will be the Model YAM-21 series, a multi-frequency system which is also PC controllable and designed for screen tests.



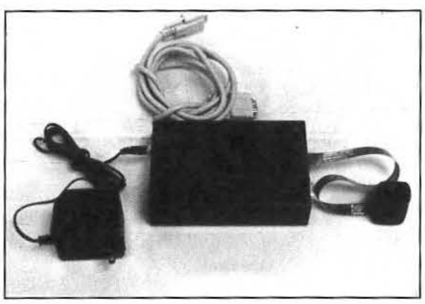
Circle no. 29

Please send new product releases or news items to Information Display, c/o Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003.

MICRODISPLAY CORP.
San Pablo, CA 510/243-9515
Booth 1245

Color-evaluation kit

The MicroDisplay Corp. will showcase the MD800G6, a thumbnail-sized SVGA full-color display now available in an evaluation system. The Color Evaluation Kit, version 2.0, features an eyepiece with all the necessary optics to comfortably view the 800 × 600 resolution display operating in field-sequential color. The kit includes an unobtrusive electronics package that may be located up to 1 m from the eyepiece on the supplied cable, and the signal input is a standard 15 pin sub D connector. The entire system can be powered indefinitely by the supplied wall transformer or for up to 3 hours using AA batteries.

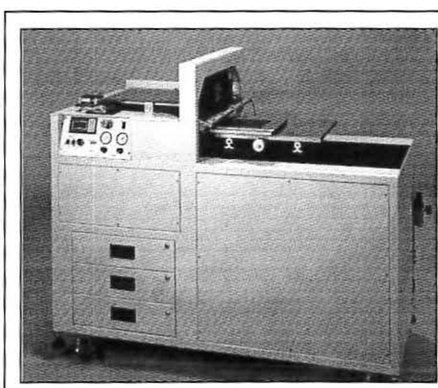


Circle no. 30

MICROJOIN
Poway, CA 619/877-2100
Booth 1102

Polarizer/laminator

MicroJoin will feature Model 6300, a polarizer/laminator with a panel-size capability of 6–21 in. on the diagonal. The lamination time for a typical 15.1-in.-diagonal panel is 6–10 sec with a total lamination process time of 39–66 sec.



Circle no. 31

MITSUBISHI ELECTRONICS AMERICA
Sunnyvale, CA 408/730-5900
Booth 534

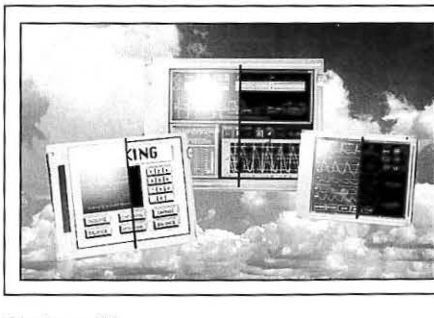
Non-PC TFT flat-panel displays

Mitsubishi Electronics America will display 8.4-, 10.4-, and 12.1-in. color ANGLEVIEW™ TFT flat-panel displays for the non-PC marketplace. The 8.4- and 10.4-in. VGA and 12.1-in. SVGA High-Bright displays offer luminances of 350, 300, and 300 nits, respectively, for the industrial and instrumentation markets. All High-Bright displays have two fault-tolerant field-replaceable cold-cathode fluorescent tubes that make the display useable even if one of the tubes should fail. The displays feature a 120° viewing angle, 18-bit color depth, and Mitsubishi's CMOS/TTL standard digital interface for crisp image quality and easy implementation.
Circle no. 32

PANELVIEW
Beaverton, OR 503/643-9311
Booth 1124

Optically enhanced TFT-LCDs

Panelview will feature the ENH series of optically enhanced VGA TFT-LCDs with diagonals of 6.4, 8.4, and 10.4 in., ideally suited for high-ambient lighting conditions and outdoor sunlight readable applications. Applications include industrial control, portable medical devices, gas pumps, point-of-sales terminals, or any other application that requires viewability in bright ambient lighting conditions. The ENH standard is a TFT display with a complete optical-enhancement system. The ENH*plus* has the addition of a bright backlighting system, while the ENH*brite* adds a bright 1500-nit backlight for maximum viewability.



Circle no. 33

PHILIPS FLAT DISPLAY SYSTEMS
San Jose, CA 408/570-5600
Booth 1008

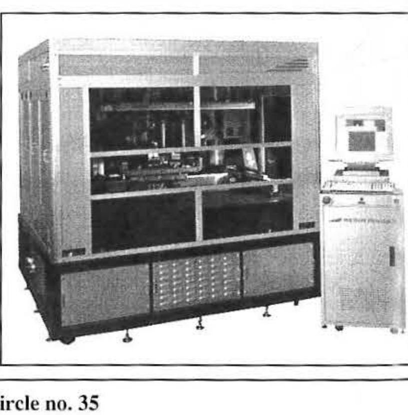
Flat displays

Philips Flat Display Systems will showcase a variety of flat-display products, including LCD modules ranging from 5.8 to 18 in. for monitor, notebook, handheld, and automotive applications. Its 8.4-in. reflective panel offers SVGA resolution that delivers clear images and low-power consumption for extended battery life. In addition, a 5.8-in. AMLCD panel for extreme temperature applications in automotive and industrial markets will also be on display.
Circle no. 34

PHOTON DYNAMICS
San Jose, CA 408/226-9900
Booth 826

FPD array test system

Photon Dynamics will showcase the ArrayChecker, an FPD array test system that integrates with robots and CIM systems, detects the broadest range of defects, produces gate-data defect maps, and handles 650 × 830-mm plates. The system provides color images of substrate films with selective magnification, and images can be printed or stored for subsequent analysis. The ArrayChecker reduces test fixture and panel production costs by using checking arrays before adding expensive color filters to the panel.



Circle no. 35

PHYSICAL OPTICS CORP.
Torrance, CA 310/320-3088
Booth 433

Holographic light-shaping diffusers

Physical Optics Corp. will feature Holographic Light Shaping Diffusers® (LSD®) that are used as randomized surface-relief diffusers, homogenizers, and beam shapers. LSDs allow the controlled distribution of

Circle no. 113

light while achieving transmission efficiencies up to 92%. A variety of circular and elliptical angles from 0.2° to over 100° FWHM, suitable for many light sources such as homogenizing, machine vision, LEDs, automotive lights, and LCD backlights, are available. The high-resolution and micron structures are excellent for digital rear- and front-projection screens.

Circle no. 36

PIXTECH
Santa Clara, CA 408/986-8868
Booth 834

World's largest FED

PixTech will unveil 15-in.-diagonal FEDs at SID '99. These high-voltage (5–6 kV) FED prototypes clearly demonstrate their wide equal-brightness viewing angles and, in particular, their true video speed, making them the only flat-panel video displays with no motion artifacts.

Circle no. 37

PLANAR SYSTEMS
Beaverton, OR 503/690-1100
Booth 407

EL displays

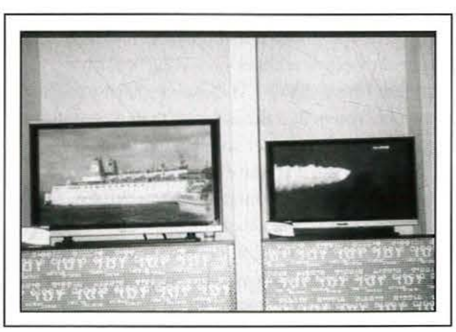
Planar Systems will feature the EL160.120.39, a new electroluminescent display module that delivers excellent viewing quality in a compact package. The display is designed for instrument applications requiring at-a-glance readability. The rugged design, with a broad temperature range, makes this new display equally well-suited for indoor and outdoor applications, as well as portable equipment. The 160 × 120 matrix has a 4-bit LCD-type video interface, built-in analog dimming, and a wide voltage input range, making it suitable for battery-powered systems.

Circle no. 38

PLASMACO
Highland, NY 914/883-6800
Booth 707

ac plasma displays

Plasmaco has developed large-area ac plasma displays that incorporate state-of-the-art color plasma technology. Features include 16.7 million colors with a bright high-contrast image and a 160° viewing angle – the widest of any flat-panel technology. Both 42- and 50-in.-diagonal displays will be on exhibit at SID '99.

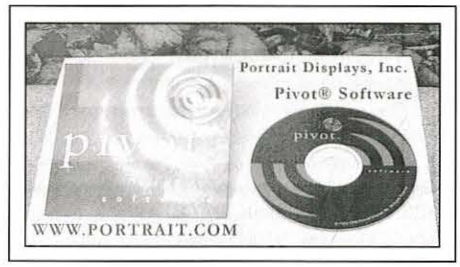


Circle no. 39

PORTRAIT DISPLAYS
Pleasanton, CA 925/227-2700
Booth 1304

Pivot software

Portrait Displays will feature Pivot® Software, a software program that allows the rotation of an image 90° clockwise for portrait as well as traditional landscape modes on rotating LCD, plasma, and CRT monitors as well as for handheld, all-in-one, and pen-based tablet computers. Pivot® Software works as a "plug-in" to the native graphics driver and is compatible with over 90% of the most popular graphics cards and chipsets, both analog and digital. It is currently available on CD-ROM and for licensing with support in many languages.

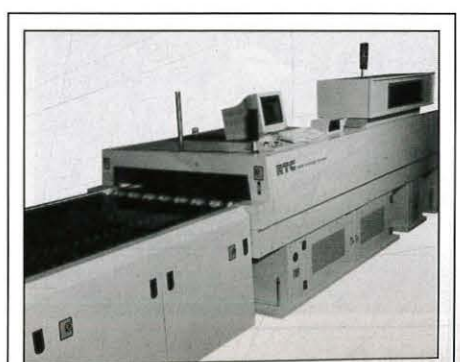


Circle no. 40

RADIANT TECHNOLOGY CORP.
Fullerton, CA 714/991-0200
Booth 1137

Infrared furnaces

Radiant Technology Corp. designs and manufactures infrared furnaces ideally suited for the thermal-processing demands and cleanliness requirements for manufacturing flat-panel displays. Patented heating technology delivers extremely tight temperature control even under demanding thermal load associated with large glass panels. These systems can be equipped with indexed or continuous-motion belt conveyance or powered rollers up to 60 in. wide. The furnaces can be



equipped with an automated loading and unloading capability. A very low particulate level is maintained throughout the process area of the furnace. The control system is based on standard off-the-shelf electronic components and provides robust capability through a graphical user interface.
Circle no. 41

SAGE
San Jose, CA 408/383-5300
Booth 647

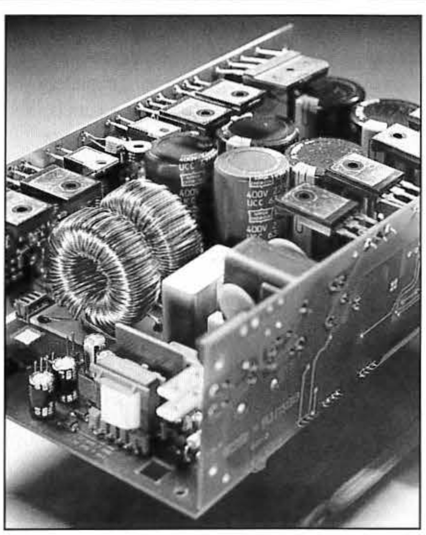
Display drivers and controllers

Sage will demonstrate the highly integrated Cheetah ASIC solution for driving XGA/SXGA TFTs. Also featured will be various LCD-monitor OEM products powered by the Cheetah ASIC.
Circle no. 42

SCHIEDERWERK GmbH & CO.
Nurnberg, Germany 310/459-3441
Booth 237

Arc-lamp power supplies

Schiederwerk GmbH & Co. will introduce its new line of compact electronic arc-lamp power supplies at SID '99. Power supplies are available for ac and dc lamps, and range in power from 35 W (for the D2 lamp) to 1200 W. All power supplies feature power-factor correction, line-voltage auto-select, and adjustable power output. Power supplies for halogen lamps are available as well.

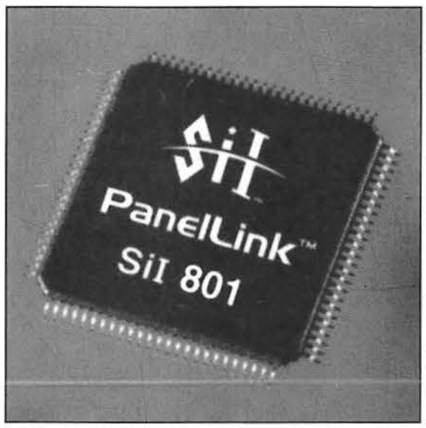


Circle no. 43

SILICON IMAGE
Cupertino, CA 408/873-3111
Booth 414

Monitor-on-a-chip

Silicon Image will launch at SID '99 the Sil 801, the world's first pure-digital monitor-on-a-chip that provides a total digital monitor solution in a cost effective 100-pin TQFP package. Features include an integrated PanelLink™ receiver, a high-quality PixelPrecision™ scaling engine, a built-in OSD, and auto-resolution detect circuitry. The Sil 801 accepts input resolutions up to SXGA (25–112-MHz dot clock). Starter kits and samples are now available.

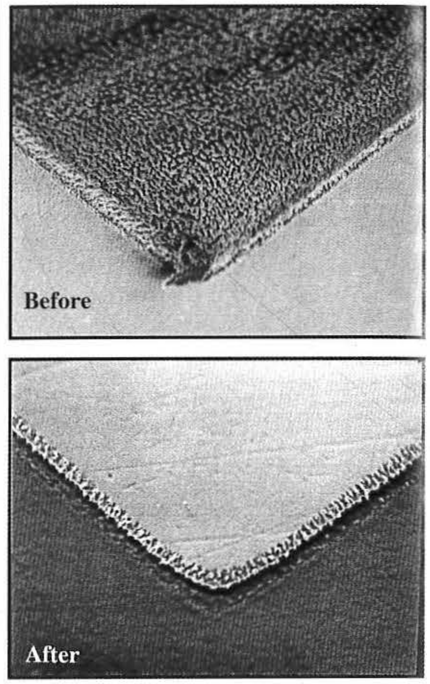


Circle no. 44

SILICON VALLEY CHEMLABS
Sunnyvale, CA 408/732-4700
Booth 1138

Positive photoresist stripper

Silicon Valley Chemlabs will feature the SVC-175™, an advanced positive photoresist stripper that safely cleans photoresist and polymer residue from flat-panel displays without corroding sensitive metal thin films. SVC-175 dissolves hard-to-remove polymers 2–3 times faster than conventional strip methods. It is water soluble and biodegradable, and because it is non-flammable, non-toxic, and non-corrosive, soft metals such as Al, Co, Cr, Cu, Fe, Ni, Al_2O_3, and other sensitive alloys are not affected. The product eliminates the need for post-strip-rinse solvents such as isopropyl alcohol or NMP, and the stripped parts can be rinsed directly with de-ionized water, minimizing costs and process sequence.

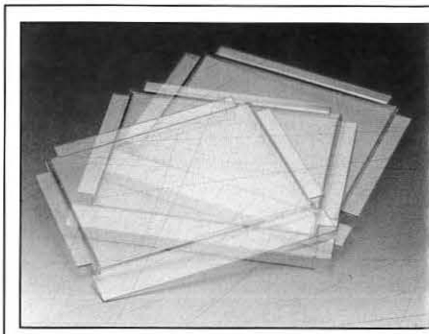


Circle no. 45

SILVER CLOUD MANUFACTURING
Millville, NJ 609/825-8900
Booth 234

Screen protectors

Silver Cloud Manufacturing will feature thin hard-coated screen protectors for LCDs and other types of displays. The protectors are especially effective where pens or other instruments are touched against the screen to initiate actuation. The thin sheets are adhesive backed and can be installed easily. The hardness of the thin film protects the display against scratches or other types of damage to the display. These thin hard-coated protectors can be die cut into housings that already exist. The screen protectors are available in a variety of thicknesses and surface finishes and can be produced in custom sizes and shapes.

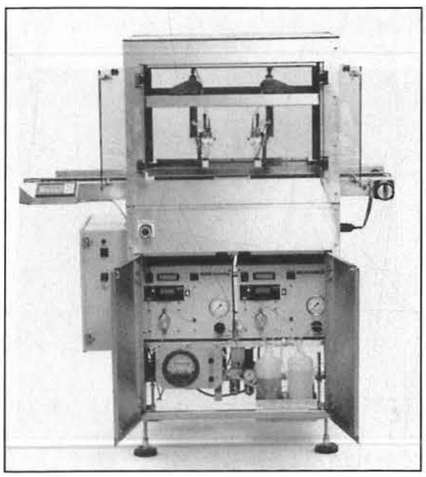


Circle no. 46

SONO-TEK CORP.
Milton, NY 914/795-2020
Booth 748

Spray-coating system

Sono-Tek will demonstrate the MCS-Infinity spray coating system that delivers a soft, uniform, and highly controllable spray pattern over virtually any width. The MCS-Infinity system can be used to apply micro-sphere spacers and rods up to 8 m in diameter. In addition, the low-velocity uniform spray is ideal for anti-scratch and anti-reflective coatings.



Circle no. 47

STANFORD RESOURCES
San Jose, CA 408/448-4440
Booth 626

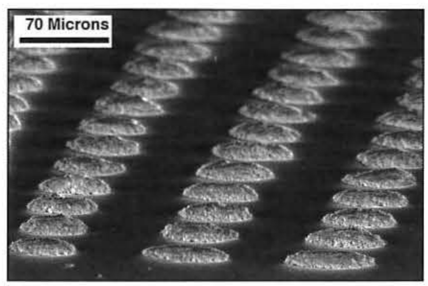
FPD monitor report

Stanford Resources will feature their most comprehensive report on the FPD monitor market, *Flat Panel Monitor Market Trends in 1999.* This report defines the complete FPD monitor market through an examination of the current supply and demand for all desktop computer displays, an analysis of the global display environment, and identification and discussion of the companies involved in supplying FPD monitors worldwide. The report features a database that covers extensive FPD monitor information segmented into TFT-LCD and STN-LCD screen size, pixel format, and region as well as compound annual growth data through the year 2004. Each region's forecast provides separate tables for units, average selling price, and market value.
Circle no. 48

SUPERIOR MICROPOWDERS
Albuquerque, NM 505/342-1492
Booth 1308

Phosphor powders

Superior Micropowders will feature phosphor powders that have advanced powder characteristics not found in traditional phosphors, making them ideally suited for ink-jet printing pixels and features. The phosphor powders are micron-sized with a narrow particle-size distribution, spherical morphology, and are non-agglomerated. These attributes allow for the formation of controlled rheology phosphor dispersions suitable for ink-jet printing without comprising brightness.

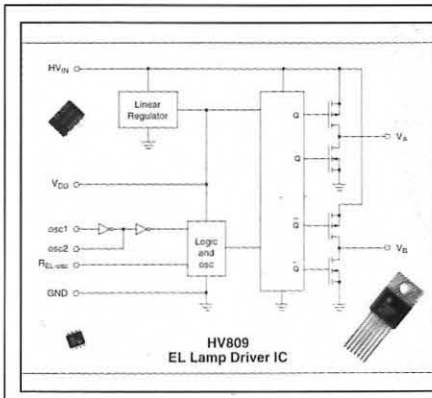


Circle no. 49

SUPERTEX
Sunnyvale, CA 408/744-0100
Booth 627

EL backlighting lamp driver IC

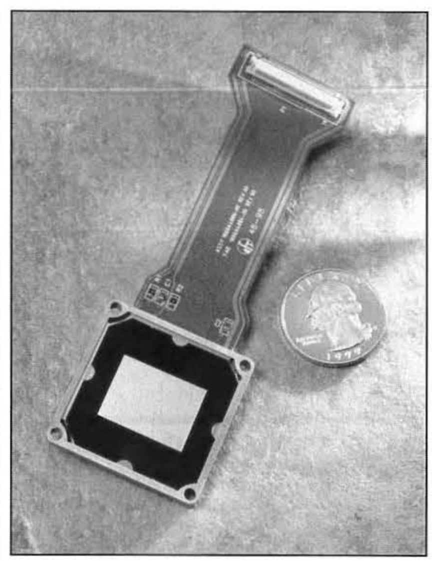
Supertex will feature the HV809, the only high-voltage EL backlighting lamp driver IC suitable for illuminating backlighting panels up to 100 in.^{2}. The HV809 features power efficiency, brightness, space, and cost savings. Applications include backlighting large control panels in industrial equipment, appliances, data acquisition terminals, advertising signs, point-of-sale terminals, remote-control terminals, and GPS systems. The HV809 is the first IC in the industry to address these applications which currently are handled by discrete components and bulky components.
Circle no. 50



S-VISION
Santa Clara, CA 408/987-5000
Booth 936

Silicon imaging products

S-Vision designs and assembles silicon imaging products, which enable OEMs to produce a new generation of large-screen high-resolution computer monitors, multimedia projectors, and digital TVs. The MicroLCD imager combines two proven and mature technologies, liquid-crystal materials and silicon ICs, resulting in a new display device which offers a superior combination of resolution and brightness. By providing comprehensive solutions, S-Vision is able to demonstrate implementations of its technology and enable its customers to reduce their design cycles and bring products to market more rapidly and inexpensively.



Circle no. 51

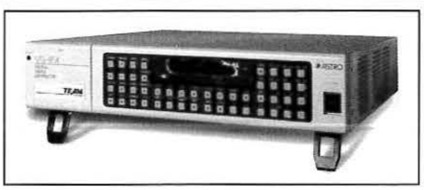
Please send new product releases or news items to Information Display, c/o Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003.

trade-show preview

TEAM SYSTEMS
Santa Clara, CA 408/720-8877
Booth 622

New HDTV and digital video generators

TEAM Systems will feature the ASTRO VG-854 HDTV video generator that combines HDTV capabilities with high-end computer display testing. The VG-854 offers Monosope and Zoneplate patterns for all the preset SDTV and HDTV timings and is capable of simulating all the ATSC formats. Its maximum pixel frequency is 400 MHz and the maximum horizontal scanning range is 300 kHz. The ASTRO VG-854 is priced at $18,550 and will be available in the second quarter of 1999. The UNI VG-DD080pc, the first PC-based digital video generator, will also be featured. Its interfacing to FPDs will be tested through "Personality Modules," which makes any of the present or future interfaces such as parallel digital, LVDS, PanelLink (TMDS), etc., easy to use. The maximum pixel frequency is 80 MHz with either up to 24 or 48 bits of parallel outputs per clock edge. The list price for this new unit starts at $6100 with delivery scheduled for the third quarter of this year

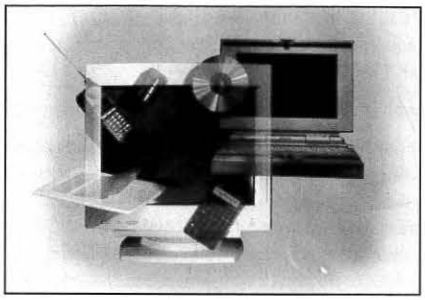


Circle no. 52

TEKRA ADVANCED TECHNOLOGIES
2New Berlin, WI 414/784-5533
Booth 144

Hardcoated films

Tekra Advanced Technologies Group will feature Terrapin™ hardcoated films, developed to meet the demands of the optoelectronics, photonics, and emerging avionics markets. High-optics, smooth-surface, and anti-glare properties combined with highly defined resolution make these films ideal for applications such as touch screens, digitizers, flat-panel displays, CRT monitors, and global positioning devices. Terrapin films are receptive to vacuum deposition, A/R coatings, and ITO sputtering and exhibit excellent clarity, resistance to chemicals and abrasions, and pass the 3H pencil hardness test.

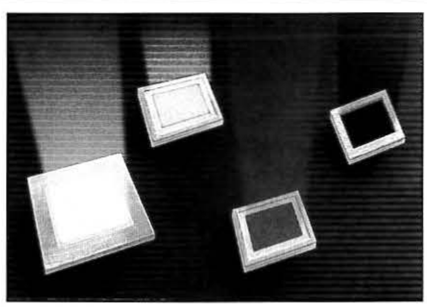


Circle no. 53

TELEDYNE LIGHTING & DISPLAY PRODUCTS
Hawthorne, CA 323/242-1900
Booth 822

Alphalight™ illumination

Teledyne Lighting & Display Products will offer ALPHALIGHT™ diffuse illumination products ideal for back, edge, and front lighting of LCDs and spatial light modulators. These products provide the highest optical efficiency along with superior uniformity for applications requiring field-sequential-color lighting, white light that economically replaces CCFLs, and monochromatic lighting for specialty applications that includes NVIS. The ALPHALIGHT™ products are five times brighter than equivalent electroluminescent products.



Circle no. 54

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THREE-FIVE SYSTEMS
Tempe, AZ 602/389-8600
Booth 343

LCOS displays

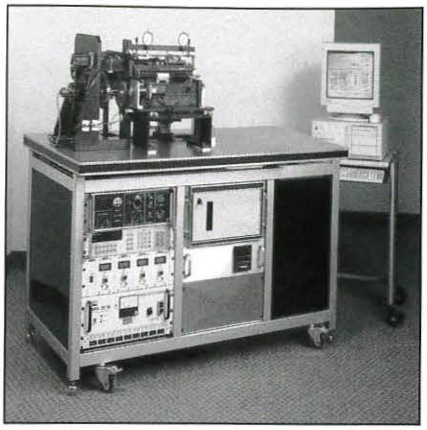
Three-Five Systems will feature the LCaD™ 1/4-VGA display system that is a fully integrated "system on the display," with a capability of displaying 16 shades of gray. An advanced multi-line addressing technique is utilized with a 5-in. passive-matrix panel to achieve the 16 shades of gray. The built-in controller allows hardware engineers to architect the display as an I/O device, with no specialized display circuitry or components required. The display is available with CCFL, LED, or EL backlighting.

Circle no. 55

TORREY PINES RESEARCH
Carlsbad, CA 760/292-4800
Booth 215

Breadboard test fixture

Torrey Pines Research will feature the PDLab Breadboard, a standardized laboratory-grade test fixture with a flexible architecture that supports feasibility testing and data acquisition for critical experiments. It is also an excellent platform for complex manufacturing. The breadboard comes with an optical benchtop, an expandable 19-in. rack structure for housing standard electrical components. It also includes an embedded industrial PC with analog and digital I/O boards that control individual components via VXWORKS - a real-time operating system - and an ac/dc power distribution system. The PDLab Breadboard can be used for a variety of tasks including electrostatic coating and ink-jet micro-dispensing systems.



Circle no. 56

TOSHIBA AMERICA ELECTRONIC COMPONENTS
Deerfield, Il 1-800-879-4963
Booth 1123

4-in. LTPS TFT-LCDs

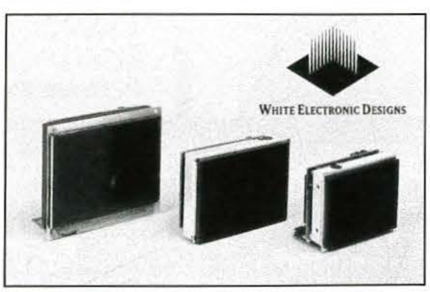
Toshiba America Electronics Components will showcase the LTM04C380S, the World' first 4-in. low-temperature poly-Si TFT-LCD with VGA resolution, a 0.126 × 0.126-mm pixel pitch, a 200-ppi pixel density, 6 bits/color, and a contrast ratio (typical) of 250:1. The new display is ideal for palm-top and hand-held portable applications, including digital cameras, personal digital assistants, telecommunication devices as well as other information equipment. The new 4-in. LTPS TFT-LCD will be available at SID '99. Sample pricing for the LTM04C380S is $500.
Circle no. 57

WHITE ELECTRONIC DEVICES
Westborough, MA 508/366-5151
Booth 411

AMLCD head modules

White Electronics will showcase sunlight-readable color AMLCD head modules designed for use in commercial and military cockpits as a multifunctional color-display assembly. These modules utilize proven ruggedization techniques and high-performance commercial-off-the-shelf AMLCD technology to provide a cost-effective solution for harsh-environment applications. The backlight is a closed-loop luminance-sensed system. A luminance sensor monitors the luminance output of the bulb and compares its output with the input voltage setting, and regulates the luminance output.

See Us at SID '99 Booth 608 **Circle no. 114**



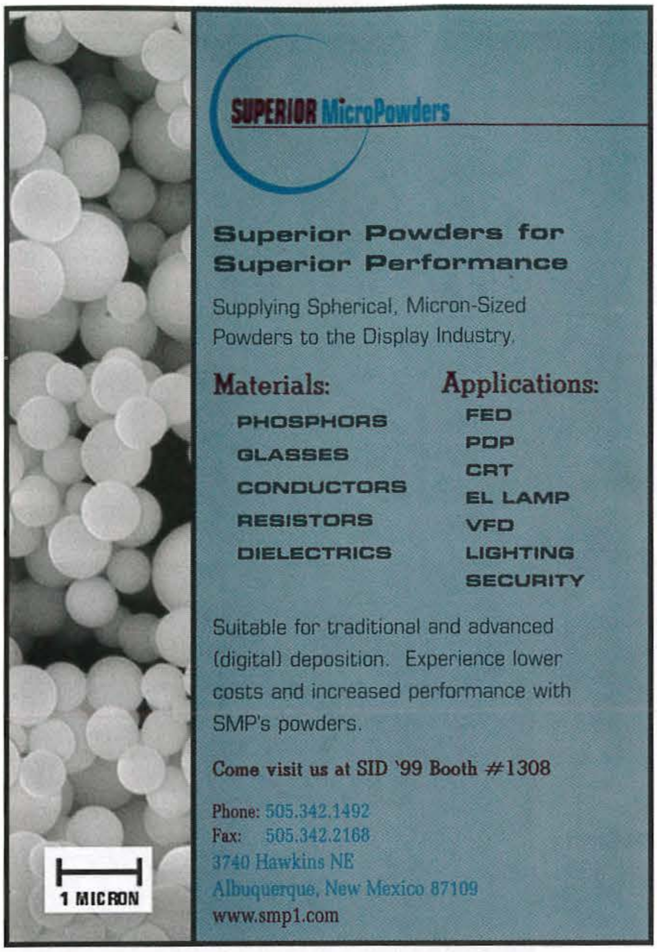
Circle no. 58 ■

SID '00

Long Beach, California

Long Beach Convention Center

May 14–19, 2000

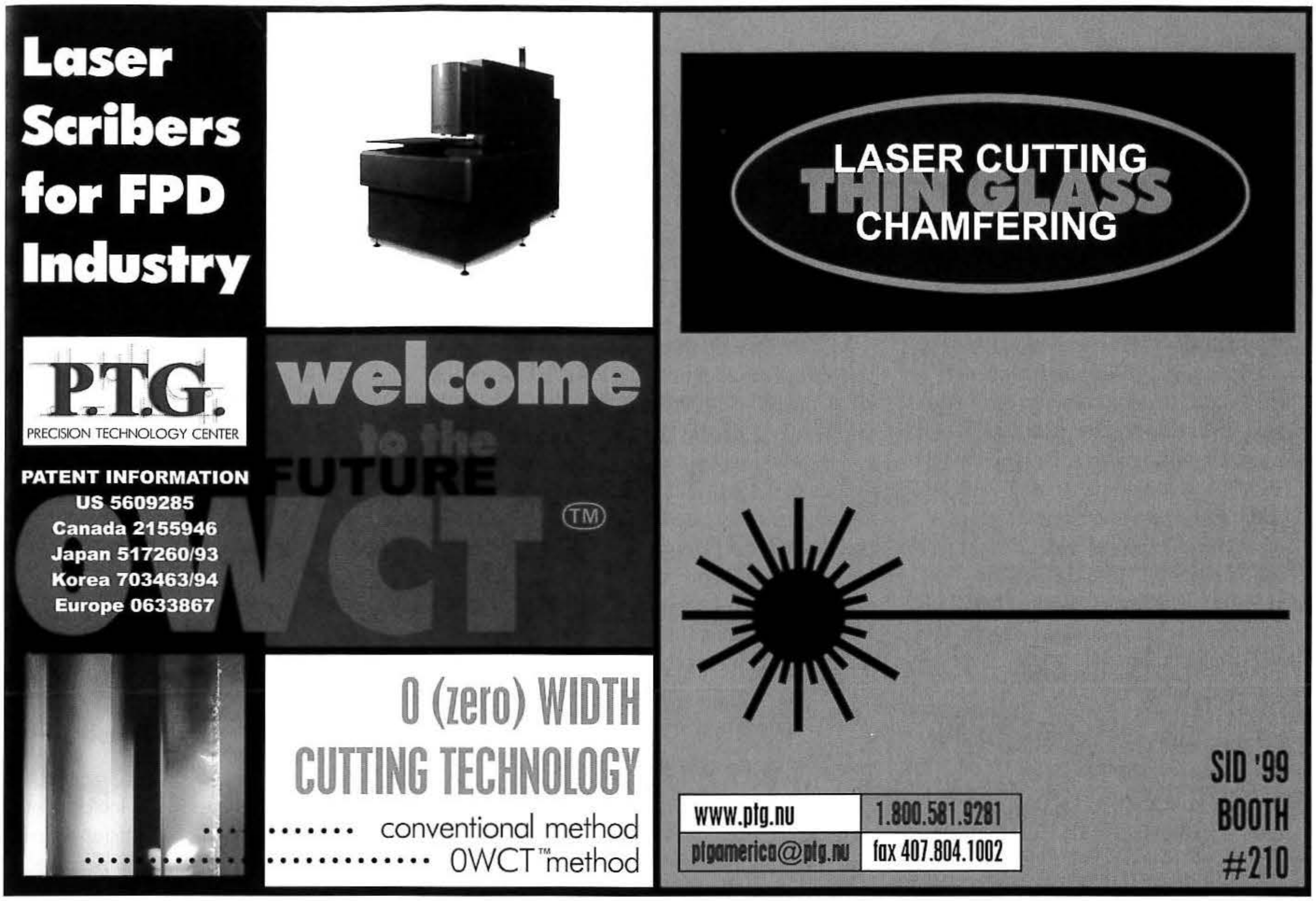


See Us at SID '99 Booth 1308 Circle no. 116

Circle no. 118

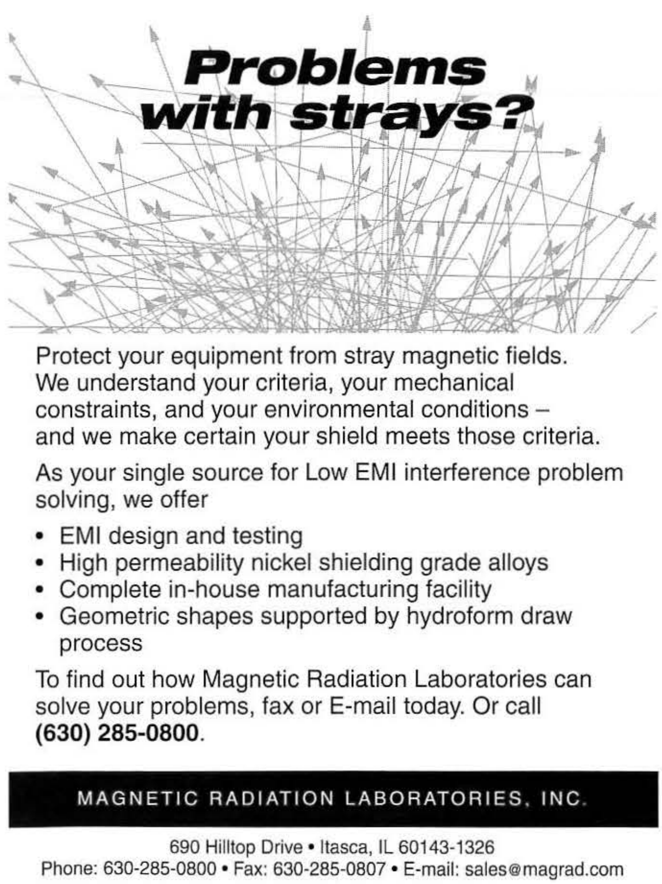
Circle no. 117

See Us at SID '99 Booth 314 Circle no. 119



See Us at SID '99 Booth 210

Circle no. 126



Circle no. 127

Circle no. 128

SID Scholarships

by Robert L. Donofrio

The Americas Region chapters have developed activities to foster SID's purpose "To encourage scientific, literary, and educational advancement of information displays."

In 1997, the Metropolitan Detroit Chapter and Optical Imaging Systems (OIS) got together to award a student with a $3000 matching scholarship. The chapter contributed $1500, which was matched by OIS. The award went to ***Steve Shannon*** of the University of Michigan for his work on plasma etching with application to display fabrication.

Two chapters in the Americas region developed and supported grant and scholarship award programs in 1998. The Los Angeles Chapter awarded a grant to ***Dr. Yang*** at UCLA for research in organic LED displays. Their grant was co-sponsored by the Industrial Electronic Engineers, Inc., with a matching sum of $2500. Dr. Yang's research focused on a novel approach for making organic LED displays. He uses a conjugated polymer solution to apply the organic EL material with the aid of ink-jet printing (IJP) technology. Potentially, this is a very low-cost and material-efficient technique for making complex 2-D patterns of monochrome or multicolor EL light emitters. The technique has been successfully demonstrated, and this has attracted considerable attention. Novel electronic devices based on IJP are expected to be reported by Dr. Yang's group in the near future.

In 1998, the top five candidates for scholarships from the Metropolitan Detroit Chapter were ranked so closely that it was virtually impossible to decide on an objective differentiation. The chapter thus gave five scholarship awards of $750 to each graduate. These awards were presented at the 1998 Strategic and Technical Symposium, sponsored by the Metropolitan Chapter and the Center for Integrated Microsystems of the University of Michigan. The award winners represented three Michigan universities - Wayne State University, The University of Michigan, and Michigan State University - and are listed below (see photo):

Aldo Badano, University of Michigan, Department of Nuclear Engineering and Radiological Sciences. Topic: High-fidelity displays for application to medical imaging.

Shaoqiu Gong, University of Michigan, Department of Electrical Engineering and Computer Science. Topic: Multi-domain LCD cells using UV photoalignment of polyimide.

Ungsik Kim, Michigan State University, Department of Electrical Engineering. Topic: Field emission from low-temperature polycrystalline diamond.

Lihua Li, Wayne State University, Department of Material Science and Engineering. Topic: Boron nitride cold-cathode materials for use as electron emitters in FEDs.

Brooke Stutzman, University of Michigan, Department of Nuclear Engineering and Radiological Sciences. Topic: Application of spatially resolved optical emission spectroscopy and quadrupole mass spectroscopy to plasma etch and deposition processes for display-related thin films.

In 1999, the $5000 SID/IEE grant for Dr. Yang's OLED research has been continued by the LA Chapter of SID. For 1999, the Metropolitan Detroit Chapter continues to offer a scholarship award of up to $3000 to qualified graduate students for study (or research) in fields that advance display technology in Michigan. The areas of interest include display-related technology in the fields of electronic engineering, physics, process and manufacturing engineering, human factors, and other related disciplines. The Southwest Chapter in 1999 is looking into supporting students via "Internships" and suggesting to students what companies may have internships. Their concept is that by interfacing the academic sector with the business sector they will see how each can be better served. This activity will improve the visibility of the SID Southwest Chapter to students and industry.

The author would like to thank Vin Cannella, Director of the Metropolitan Detroit Chapter; Peter Baron, Director of the LA Chapter; and John O'Donnell, Chair of the SW Chapter, for input on their chapter activities.

Four of the five winners of 1998 scholarships from the Metropolitan Detroit Chapter of SID, (from left to right) are Aldo Badano (University of Michigan), Ungsik Kim (Michigan State University), Shaoqiu Gong (University of Michigan), and Brooke Stutzman (University of Michigan). Lihua Li (Wayne State University) is not in the picture.

Final Call for Papers

The 6th annual Flat Panel Strategic and Technical Symposium, on Vehicular Applications of Displays and Microsensors, is soliciting papers for its September 22–23, 1999, meeting in Ypsilanti, Michigan. This two-day event will be jointly sponsored by the University of Michigan Center for Integrated Microsystems and the Metropolitan Detroit Chapter of the Society for Information Display. Topics include strategic/business issues (both government and industry), vehicular applications (status and prospects in autos, trucks, large ground vehicles, and avionics), emerging flat-panel technologies (organic EL, FEDs, silicon-based display technologies, microdisplays, *etc.*), and microsensor and MEMS technology (inertial devices, mechanical devices, chemical sensors and systems, and physical sensors). The deadline for submission of abstracts is June 11, 1999. All abstracts should be mailed to Robert Donofrio, Display Device Consultant, 6170 Plymouth Rd., Ann Arbor, MI 48105; 734/665-4266, fax 734/665-4211, e-mail: rldonofrio@aol.com. Acceptance notifications will be mailed July 2, 1999, with manuscripts due August 20, 1999.

The program will consist of four oral sessions including one strategic issues session and three technical sessions. A poster session will feature papers and demonstrations, allowing for detailed discussions with the authors. The Metrology Standards for Vehicular Flat Panel Displays meeting sponsored by SAE-ITS and SID will be held on September 24, 1999. ■

Letters

To the Editor:

In the January issue of *Information Display Magazine,* my article, "Seeing Through Screen Reflection" (pages 28-31), lacked an appropriate attribution. I wrote that article entirely under the sponsorship of the National Information Display Laboratory (NIDL), and that should be duly noted.

The NIDL, hosted by the Sarnoff Corporation, was commissioned by the U.S. Government in 1990. Its key programs focus on advanced display systems, tools for processing softcopy information, visualization, distributed collaboration, communications and compression techniques, and multimedia database design. NIDL actively promotes the development of industry standards to ensure interoperability and user understanding of commercial and consumer products.

– Michael H. Brill
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Princeton, NJ 08543-8619
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8 NOVEMBER 99

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San Diego, California

- 5th annual international conference on display phosphors

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spective of his now rapidly fading philosophical mood, he found it ironic that, while incredible growth in compute power had resulted in the replacement of essentially all knowledge workers, people still built and lived in houses very much like those at the turn of the century and the century before that. The latest generation of automobiles were also not all that different from those of thirty-five years ago – a little lighter, cleaner, and more energy-efficient. Apparently, hardware changes were on a different time-line than progress in artificial intelligence. Also, it seemed that no matter what happened with computer intelligence, people still wanted to live much like they have lived for hundreds of years – in single-family homes, driving cars to work, doing shopping, visiting friends, and periodically transporting themselves to various events and locations for pleasure and entertainment. And since building materials and construction methods hadn't changed much more in the last 35 years than in the previous 50, the work that had to be done was also much the same.

In a final spark of brilliance, before his neural implant kicked in with his lower IQ, Jeff had this thought: ***Computers can now outthink us humans, do all the knowledge work, and continue to improve upon themselves, but we humans still get to take out the trash.***

Whoa, Aris, what have you been imbibing to come up with this story? Well, let me tell you how this little vignette came about. Last Sunday evening, I was taking a break after having spent the afternoon constructing an attic space to provide some extra storage. After a few weekends of adding extra floor joists, rerouting the wiring, and putting up drywall, I had spent several hours taping the joints and covering the nail holes. So, afterwards, while relaxing on the family-room sofa for what I thought was a well-deserved break, I took a look at a recent *EE Times* issue. This particular issue featured people that *EE Times* considered particularly noteworthy in 1998. One article that caught my eye, and subsequently led me to construct this worrisome vision of the future, was a commentary about Raymond Kurzweil. From his credentials, Mr. Kurzweil is clearly one "smart cookie," with nine honorary doctorates, White House connections, a major award-winning book, three start-up companies, MIT background, and countless other honors to his credit.

When a person with such prestigious credentials asserts that we will all be wearing neural implants in something like 40 years and that computers will all be smarter than we humans, that is not something to be taken lightly. According to Mr. Kurzweil, "By the middle of the next century, machine intelligence will be so superior to human intelligence as we know it today, that in order to be intellectually relevant we will have to enhance our brains with neural implants. Of course, ultimately we won't bother with neural implants because by the middle of the next century we will be able to scan a human brain and instantiate it into a neural computer. Our old carbon-based bodies are going to be obsolete. Even the concept of a body will become unclear, since you could run your virtual personality on a network of computers or you could have multiple neural personalities all running on a single neural computer."

Now, can you begin to see the source of my confusion? Here I had just spent the day immersed in some very basic construction activities, such as hammering nails and spreading sheetrock mud, and in the next moments I read about how a computer is going to replace all my intellectual abilities. Not only that, I may even live to experience this event.

In the last 50 years, the materials and methods of building homes have changed very little. In fact, we have gone back to building homes that look more like 18th- and 19th-century French chateaux than anything remotely resembling the predicted futuristic designs. To further emphasize our apparent wish to return to the past, recent trends in automobile styling are taking their inspiration from the 1950s, and even from the 1930s. At the same time, in many parts of the world, economies continue to be too weak to provide even the basics of adequate food and shelter for a good fraction of the world's population.

Are we human beings really doomed to perform mundane chores while our computers have all the fun doing the thinking for us? Not one to take anyone's predictions at face value, no matter how famous or how prestigious his credentials, I decided to do a little more probing. Could I perhaps turn up something either to validate, refute, or perhaps modify Mr. Kurzweil's ominous-sounding future?

The first hint of suspicion about Mr. Kurzweil's abilities as a seer came while reviewing his selection for the five most significant technology developments of 1998. Among these Mr. Kurzweil included retinal displays. According to him, the retinal display heralds an era of non-invasive interface technologies that allow people to directly access information, and the retinal display achieves that by writing its images directly onto the retina of the eye, transferring pixel data to the brain without any physical connection.

Am I missing something here? Doesn't any display show up as an image on a retina? My TV or computer displays are created pixel by pixel and show up on my retina. Optical systems present me with real or virtual images. I can create these all at once or in rapid sequence. I can make them with lasers or electron beams. What is so special or fundamentally revolutionary about a scanning laser display? In fact, the more likely reaction to being told that a laser is being used to project an image onto the inside of one's eyeball is going to be, "You aren't going to blast my eyeball with that laser thing!!! I don't care how safe you tell me it is."

Not wanting to make too much of one possible discrepancy, I decided to take a look at Mr. Kurzweil's award-winning book, *The Age of Intelligent Machines.* In the conclusion of this book, written in the late 80s and published in 1990, Mr. Kurzweil makes a number of predictions of what will happen during the 1990s and into the 2000s. Many of the compute-power predictions are in keeping with Moore's law and are, therefore, pretty much on track. His prediction that in 2000 the world chess champion will be a computer is nicely on target. However, a number of technology developments that Mr. Kurzweil thought would dominate the 90s (from his perspective of the late 80s) didn't. ASIC technology didn't become nearly as pervasive as he thought it would, with systems on a chip happening instead. Artificial intelligence (AI) and expert systems also didn't take off as predicted. Apparently, we humans are better at protecting our turf from computers than Mr. Kurzweil realized. Pattern recognition for personal identification has been evolving, but much more slowly than predicted. Mr. Kurzweil also expected that many documents would never exist on paper because they would incorporate audio and video clips. (The wish for a paperless office just won't die.) He expected that by now we would have computer-generated personalities and image systems with some human characteristics. On the hardware front, he predicted three-dimensional chips as the way to implement more compute power. This may happen to a small degree in the next decade if, for example, a concept proposed by Ball Semiconductor succeeds, but certainly not in this century.

So perhaps we can temper Mr. Kurzweil's view of the future – just a little. Reading his commentary, I get the sense of a person disconnected from the day-to-day struggles of the rest of us. Given the average income of people the world over, and any reasonable scenario for what is likely to happen over the next 50 years as more and more of us populate this earth, why could he possibly think that we need or want neural implants? Maybe for the few who wish to be computer-enhanced chess champions this steroid-like existence may be appealing, but that isn't what the great majority of the world's citizens need or want. For instance, think of the millions of people living in small communities the world over leading modest but comfortable lives. What would they do with a neural implant or a computer-controlled virtual personality?

Computer processing power will continue to grow exponentially and perhaps someday surpass us all, but hardware-based robotics will come along at a much slower pace. Hardware design is clearly on a different time-line than software. Even now there is a growing realization that the interface of the computer and the human depends more on good hardware than on ever-more-complicated software offerings. We need good displays, better input and output devices, and fast and reliable communications networks. As display engineers, we couldn't be better positioned to serve the growing demands of people being assisted by intelligent machines.

However, for additional security in this rapidly changing world you may want some extra "insurance." In that case, I would recommend that you develop or maintain some practical skills. Learn how to build things. Learn home construction, explore metalworking, try building an eight-pixel plasma panel in your spare time, build a telescope, or explore the art of making jewelry by the lost-wax method. Windows 98 has come and soon will go. Our current generations of software are just that - current generations. Their complexity and difficulty of use are symbols of their immaturity. That will soon pass. Who wants or needs to learn a new "language" that's only good for one or two years? But hardware skills, with minor updates, are good for a lifetime.

The world in which we live is based on hardware - and something else. The hardware part we are beginning to understand fairly well. However, our understanding of nature's "software" is at the most rudimentary of levels. The quest for this understanding and appreciation will lead us to far greater benefits than steroid-like neural implants to turbocharge our brains' computational processes. However, tonight, before you turn in - especially if your spouse or significant other reminds you - don't forget to take out the trash.

The energy source on my neural implant is nearing depletion, so now the time has come for me to request your response to my futuristic philosophical excursion. I would enjoy hearing from you because, for me, compute power will never be able to replace the pleasure of human interactions. So please interact - by e-mail at silzars@ibm.net, via the fax at 425/557-8983, by voice communications at 425/557-8850, or by the written word at 22513 S.E. 47th Place, Issaquah, WA 98029. ■

calendar

The 7th International Conference on Ferroelectric Liquid Crystals (FLC '99). Contact: Prof. Wolfgang Haase, Condensed Matter Research Group, Institute of Physical Chemistry, Darmstadt University of Technology, Petersenstraβe 20, D-64287 Darmstadt, Germany; +49-61-51-16-33-98, fax -49-24, e-mail: flc99@tu-darmstadt.de, http://flc99.tu.darmstadt.de.
Aug. 29-Sept. 3, 1999 Darmstadt, Germany

The 19th International Display Research Conference (EuroDisplay '99). Sponsored by SID and in cooperation with ITG. Contact: Dipl.-Ing. Rupert Rompel, VDE Verband Deutscher Elektrotechniker e.V., Stresemannallee 15, D-60596 Frankfurt am Main; +49-69-6308-381, fax +49-69-9631-5213, e-mail: 100145-67@compuserve.com.
Sept. 6-9, 1999 Berlin, Germany

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Sept. 22–23, 1999 Ypsilanti, MI

The Fifth International Conference on the Science and Technology of Display Phosphors. Sponsored by SID, PTCOE, and DARPA. Contact: Mark Goldfarb, Palisades Institute for Research Services, Inc., 411 Lafayette St., New York, NY 10003; 212/460-8090 x203, fax -5460, e-mail: mgoldfar@newyork.palisades.org.
Nov. 8–10, 1999 San Diego, CA

Electronic Information Displays (EID '99). Sponsored by the SID UK/Ireland Chapter. Contact: Trident Exhibitions, Jon Jones, West Devon Business Park, Brook Lane, Tavjstock, Devon, PL19 9DP, U.K.; +44-1822-614-671, fax -818.
Nov. 16–18, 1999 Surrey, U.K.

The Seventh International Color Imaging Conference. Sponsored by IS&T and SID. Contact: IS&T, 7003 Kilworth Lane, Springfield, VA 22151; 703/642-9090, fax -9094, e-mail: info@imaging.org.
Nov. 16–19, 1999 Scottsdale, AZ

editorial

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A successful UC San Diego effort will benefit the global display community. It deserves our support.

– Ken Werner

We welcome your comments and suggestions. You can reach me by e-mail at kwerner@sid.org, by fax at 203/855-9769, or by phone at 203/853-7069. The contents of upcoming issues of *ID* are available on the *ID* page at the SID Web site (http://www.sid.org).

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