Official Monthly Publication of the Society for Information Display

INFORMATION DISPLAY

December 1997
Vol. 13, No. 12

SID **DISPLAY OF THE YEAR AWARDS** SID

The Best of '97

Fujitsu's (left) and NEC's (right) 42-in. full-color plasma display share this year's top award.


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INFORMATION DISPLAY

DECEMBER 1997
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COVER: The Japanese display industry made a major commitment to develop and commercialize large, flat plasma-display panels. Fujitsu and NEC were first to market and share this year's Display of the Year Award. For the other award winners, see Ken Werner's article that begins on page 10.

Credit: Fujitsu
NEC

For more on what's coming in *Information Display,* and for other news on information-display technology, check the SID Web site on the World Wide Web: **http://www.sid.org**.

Next Month in
Information Display

Monitor Issue
- New technology for CRTs
- Liquid-crystal materials
- Touch screens
- Government display systems
- IDRC report

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editorial

The Great Tide

The forces of global integration are a great tide, inexorably wearing away the established order of things.

— William Jefferson Clinton
Addressing the United Nations General Assembly
Monday, September 22, 1997

It is a wonderful story. In 1275, according to his own account, Marco Polo of Venice began a 20-year exploration of China, opening the wonders of Chinese technology and the riches of Chinese trade to the West. The story may not be true, but it is wonderful nonetheless.

A recently discovered account by Jacob of Ancona, which itself may not be true, describes a slightly earlier and much briefer exploration. Four years before Marco ever claimed to have arrived in China, Jacob described a thriving foreign community in Zeitung and a society so licentious that it moved the Orthodox Jewish trader to write, "May God forgive me for what my eyes have seen." But on one thing Jacob, Marco, and virtually all others analysts agree: In the 13th century China had, culturally and technologically, the most advanced civilization in the world.

But China came to look inward, and global power migrated to the West. Chinese cultural and technical superiority, which had been part of the established order of things for centuries, was worn away by the great tides of the time.

Now, I would guess that most members of the display community would be inclined to agree with President Clinton that the forces of global integration are one of the great tides of our time. And I would agree that the established order of things is being worn away, but change now seems so constant - as well as so rapid - that it's sometimes hard to remember when there was an established order, much less what it was.

But some things do change more slowly than others in the display world and the world in general, and it might be useful to try to remember what some of these relatively constant features are. These are the elements that do define something of an established order, which is a platform on which to stand and plan today's tactics and tomorrow's strategies – even if we know the platform is temporary.

This, then, is the established order of things:

- Japan's dominance of advanced display-manufacturing technology is remarkably durable.
- Western technical creativity is remarkably durable.
- North America is the largest market for displays and display products.
- The decline in North American manufacturing has reversed.
- European manufacturing has trouble competing not only with Asian countries, but also with the United States.
- Korean companies are and will continue to be major players in display technology and manufacturing.
- Seven centuries after Marco Polo's journey, the Chinese mainland is a major center of display manufacturing, sometimes in plants that are owned and managed by Taiwan-based companies.
- Taiwan makes lots of monitors.

continued on page 45

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INFORMATION DISPLAY

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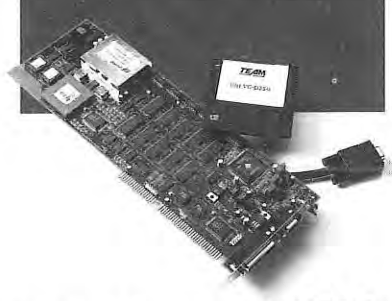

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A Million Santas, One Really Rich Kid, and a Few Others ...

by Aris Silzars

Can it already be nearly 3 months since those warm early fall days when taking the boat out on the lake seemed so pleasantly appropriate? Time sure does fly when one is having fun. Or maybe it just flies to keep me from getting done all those good things I seem to want to do.

It was one of those fall days. The late-afternoon sun was warm and the breeze was cool. Lake Washington sparkled, with the Seattle skyline on one side and Bellevue and Kirkland on the other. Since it was late in the boating season and getting toward evening, not too many other people were out. My plan was to do a run from our launch point, south of the I-90 bridge, up to Kirkland and back, a distance of about 15 miles each way. We had invited along another couple: he was a banker and she a former schoolteacher.

As we cruised along the eastern shore of this rather large lake, our guests pointed out many of the waterfront homes of the richer folks of Seattle. For a banker this is, I surmised, important information to have. There were certainly plenty of them to point out. In fact, there were darn few that didn't fit into the extremely wealthy category. This all seemed to fit in with an article I had read not too long before that said the waterfront along Lake Washington had become the highest-priced residential real estate in the U.S.

I looked and admired but somehow could not visualize myself as the owner of one of these opulent and immaculately groomed estates.

Quite suddenly, something else caught my attention. And a very important something else it was when one pilots a small boat at a good clip. I could see a giant flock of boats a few hundred yards dead ahead. Whoa! Back off on that throttle. What the heck is going on? Many of these boats seemed to be aimlessly cruising in circles, while others seemed not to be going in much of any direction at all. Then, I understood: They were all looking at Bill Gates's new "digs." The construction trailers were still there, but the place was beginning to take on a more finished look.

So what does this $50 million wonder look like? To me, like a typically northwest contemporary-style *convention center*. It surely does not look like a home or even a mansion. Perhaps it could be described as more like a village built into a hillside. I guess it's the modern equivalent of a castle, where someone started with some chambers, and then added sleeping rooms ... and then meeting rooms ... and then guest rooms ... and then support-service rooms ... and then the stables ... and then .... All this on a peaceful lake that has for many years silently accommodated less ostentatious modifications to its tree-lined shore. But did anyone, including Bill Gates, anticipate that this would become a major tourist attraction, as well as a favorite destination for locals? "Hey, you wanta go out on the boat today?" "Yeah, let's cruise over and see how Billy Gates's house is coming along."

I've always had a strong independent streak. I like the freedom to go where I want and do what I want without unwanted attention from others. I only like attention when it's by my choice, such as when I am giving a talk, teaching a seminar, or when some of you give me feedback on this column. But being a

continued on page 38

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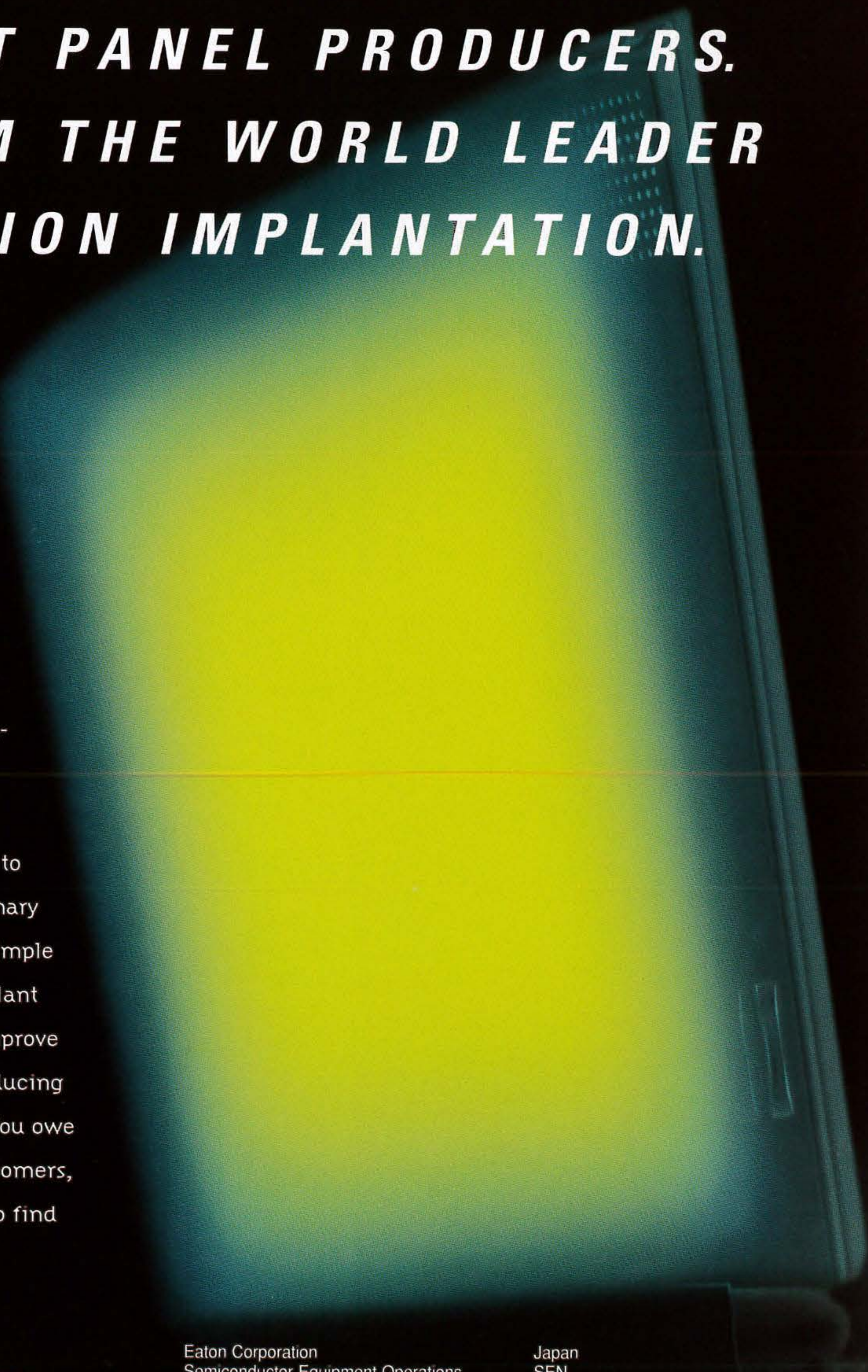
IMPORTANT NEWS FOR FLAT PANEL PRODUCERS. FROM THE WORLD LEADER IN ION IMPLANTATION.



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BEHIND EVERY GREAT MONITOR THERE'S, UM, WELL NOTHING ACTUALLY.

MultiSync LCD Series	LCD2000™	LCD400™
Viewable Size	20.1"	14.1"
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Dimensions (W, H, D)	19.7 x 19 x 8.7"	14.1 x 14.3 x 6.7"
Brightness	150 cd/m²	180 cd/m²
Viewing Angle	160° conical XtraView technology	
LCD Type	Active Matrix	

There is, however, plenty inside. For starters, both of our space-saving MultiSync® LCD monitors feature XtraView™ technology, which opens up the viewing angle to a panoramic 160°. The screen itself is flat, and presents a brighter, flicker-free image. While they consume less space than regular monitors, our LCDs also weigh in about 70% lighter. Which makes wall mounting the LCD2000 a breeze. Plus, they both boast reduced emissions and energy consumption. So really, what's behind our MultiSync LCD monitors is, as always, a continued commitment to creating outstanding products. To learn more, call 1-800-NEC-INFO. Or, if you prefer, please visit us at www.nec.com. Expect more. Experience more.

A big thumbs up to our R&D department for creating the MultiSync LCD2000, the first ever 20.1" viewable LCD monitor to be made for commercial use.

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Both models are compatible with PC, Mac, Workstation or any VESA compliant analog RGB signal, no special card required.

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Monitor Auto Alignment System

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Key Features:

- Transport streams compliant with ATSC, DVB and DAVIC specifications
- Build in standard test sequences
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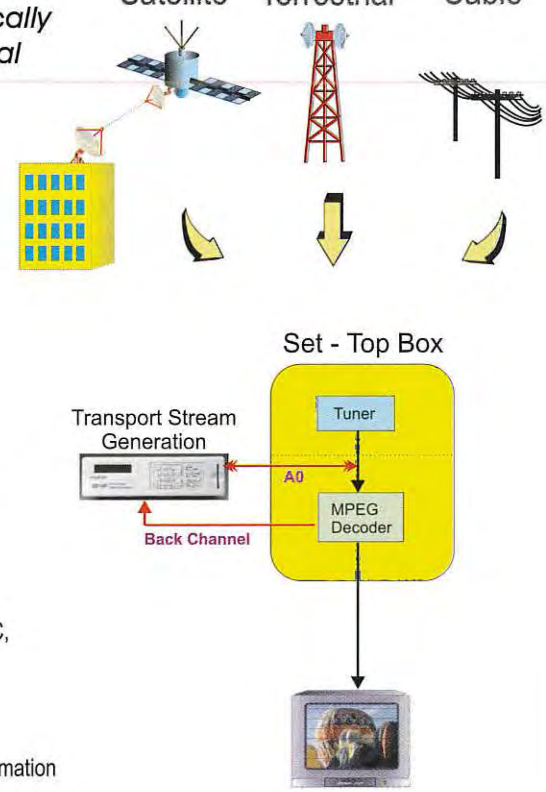
Digital Broadcasting



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Where Total Solution is a way of life

Third Annual Display of the Year Awards

This year, the display industry's leading international awards honor four different technologies from Japan and the United States.

by Ken Werner

FOR the third time in 3 years, most members of the SID/*Information Display* Display of the Year Awards Committee (DYAC) met in a secluded location on the Wednesday evening of Display Week – the Society for Information Display's International Symposium, Seminar & Exhibition – held this year in Boston during the week of May 11. At this beginning of a 4-month-long process, the members discussed the displays they had just seen and the papers they had just heard at the symposium, as well as those seen and heard elsewhere. Subsequent discussions, nominations, and voting proceeded via conversation, telephone, overnight express, fax, and e-mail.

The members selected an award winner and a recipient of an honorable mention in two categories: (1) Display of the Year and (2) Display Product of the Year. In each category, the committee members were instructed to consider many factors, including innovation, commercial significance, and likely social impact.

All of the displays and products considered for the awards were nominated either by the members of the committee or by interested parties who submitted their nominations to the DYAC secretariat. The secretariat distributed the names of all the nominees to the committee members, who then voted for the winners. The committee members pursued their responsibilities with the knowledge that upon their inception in 1995, the Display of the Year Awards were immediately accepted as major international industry awards.

***Ken Werner** is the editor of* Information Display Magazine. *The opinions expressed in this article are not necessarily those of the Publisher of* Information Display *or of the Society for Information Display.*

This year's winners are from companies in Japan and the United States, and they embrace four distinct display technologies. For the first time, the committee elected to make a joint award.

To be eligible for this year's awards, displays and products must have become commercially available – either to OEMs or end users – between July 1, 1996, and June 30, 1997.

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DISPLAY OF THE YEAR AWARD

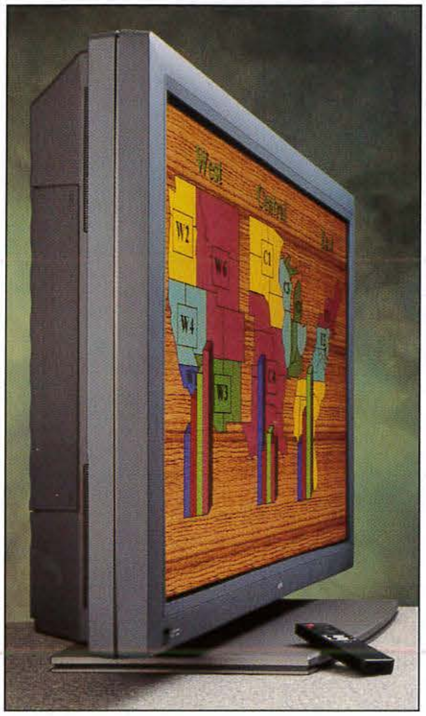
Joint Award: Fujitsu's and NEC's 42-in. Color Plasma Display Panels

The Japanese display industry has made a remarkable commitment to bringing large color plasma-display panels to market. These displays are already available in monitors for video and multimedia, and in television receivers, and they promise to offer a wide range of innovative display solutions for "hang-on-the-wall" television, video conferencing, multimedia, point-of-presence displays, conference centers, home theater, and a host of other applications.

Fujitsu, Ltd. (Kawasaki, Japan) was first with the 42-in. PDPs and dominates the still-small market. NEC Corp. (Kawasaki, Japan) has made rapid strides, and showed an impressive panel at SID '97 in Boston. Fujitsu and NEC were the only two companies to have panels commercially available before our cutoff date for the 1997 awards. The committee wished to honor both companies for their achievements and the industry as a whole for its farsighted commitment to this exciting large-screen lightweight flat-panel direct-view display technology.

As this is written, it looks as if the prices of television receivers based on these panels will begin in the $10,000 range, and some PDP receivers will be in the North American show-rooms of video dealers this fall and winter.

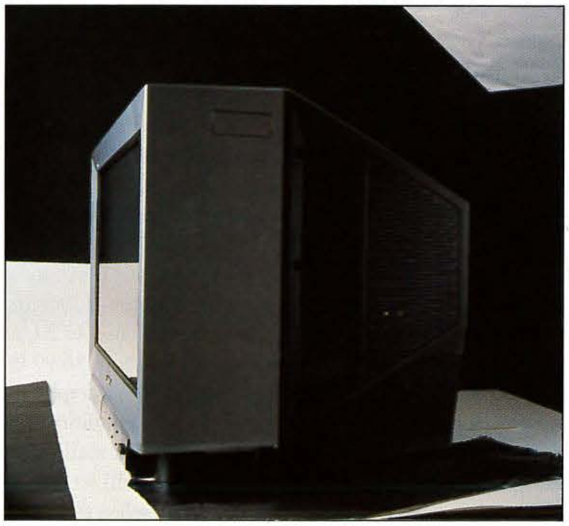
Fujitsu's 42-in. PDP



NEC's 42-in. PDP

DISPLAY OF THE YEAR AWARD

Honorable Mention: Sony's Super Flat FD Trinitron® CRT



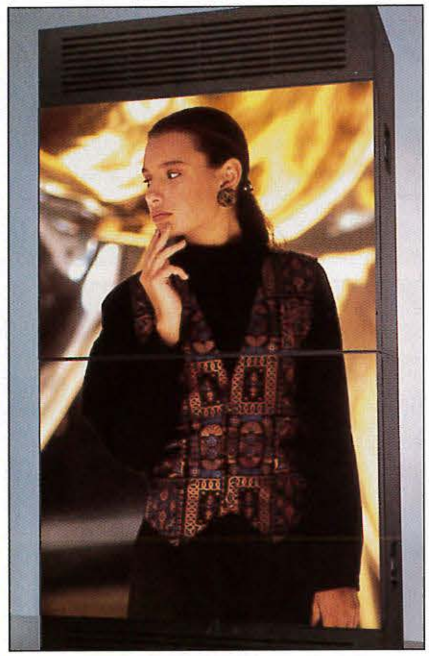
When Sony Corp. (Tokyo, Japan) exhibited a television receiver incorporating the company's new FD Trinitron® CRT at SID '97, it drew a crowd. Here was a 28-in. CRT (also available in 32-in.) with 16:9 aspect ratio, a beautiful CRT image, and a completely flat screen.

Flat-screen CRTs have been produced in the past in small quantities by Tektronix for military and government customers, and by Zenith in somewhat larger quantities for premium computer monitors - and one is available now from Panasonic in a computer monitor. But Sony is the first company to produce a large wide-aspect-ratio flat screen for television and the first to use Trinitron® taut-wire technology in a flat-screen CRT. The result is a striking difference in what viewers see when they watch a CRT-based television receiver.

Sony is using the designation WEGA for Japanese-market receivers based on the FD Trinitron®. The price of a 28-in. WEGA Hi-Vision model is ¥330,000. For NTSC, it's ¥220,000.

DISPLAY PRODUCT OF THE YEAR AWARD

Clarity's LCD Rear-Projection Point-of-Purchase Displays



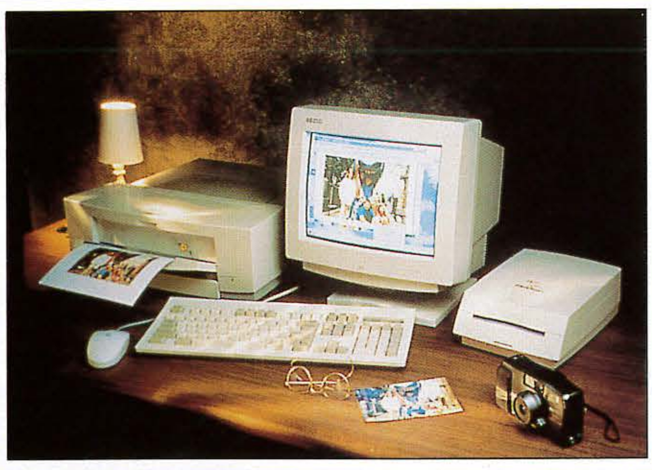
Clarity Visual Systems, Inc. (Wilsonville, Oregon) has applied rear-projection LCD technology to a specialized (but quite large) market and optimized it for videowall, kiosk, and dynamic-signage applications. Units have viewing areas ranging from 40 to 58 in. on the diagonal, depths starting at 18 in., weights beginning at 90 lbs., and an average white luminance greater than 200 fL.

Clarity's modules are designed to be used singly, arrayed horizontally in "banners," vertically in posts, and both horizontally and vertically in videowalls. Design goals included even luminosity across each screen, excellent consistency of luminance and color from unit to unit to enhance videowall-type applications, and easy accessibility and set-up.

Clarity's display modules produce a handsome image, but what the company has done especially well is to focus on a class of customers and their needs and to tailor display system integration and development efforts to specifically answer those needs. Seeing Clarity's implementation of "dynamic digital signage" makes it easy to believe that many retail environments are going to look very different in the near future.

DISPLAY PRODUCT OF THE YEAR AWARD

Honorable Mention: Hewlett-Packard's PhotoSmart Printer



Hewlett-Packard (Palo Alto, California) has advanced the cause of digital photography with its PhotoSmart Photo Printer, which is designed for Windows 95 systems. HP is clearly serious about its commitment to digital photography, and is marketing a "PhotoSmart PC Photography System" that includes a digital camera, print/transparency scanner, digital imaging software, drivers, and a full range of papers and supplies. But it is the printer that stands out.

To the naked eye, a PhotoSmart print made on HP's glossy paper in the best of the printer's three print modes is virtually indistinguishable from a photographic print. The 300-dpi ink-jet printer accomplishes this by using six different dye-based inks in two cartridges. Each color can be applied at eight different "saturation levels." HP says the inks are laid down in such a way that no dot structure is visible.

Although the printer is priced at a reasonable $499 (U.S.), its truly photorealistic results do not come cheaply in terms of time or materials costs. The average time to print a 4 × 6-in. photo is 2½ min, and an 8 × 10 takes 5 min; print drying time ranges from 3 to 20 min. Twenty sheets of 4 × 6 glossy PhotoSmart paper cost about $6.99 in the United States, and each of the two ink cartridges costs about $39.95.

So, if one thinks in terms of the chemical-photography model, in which an amateur photographer prints each photo he or she takes, PhotoSmart prints will be more expensive than traditional prints. But that would miss the point. A roll of film rarely contains more than a few shots worth printing, hanging on the wall, or mailing to relatives, although we might want to glance at the others occasionally. The high-quality output of the PhotoSmart printer will let many people do their photography digitally, enjoy the flexibility of electronic image viewing, storage, and editing, and know that when they have an image they want to print they will be able to do so without sacrificing customary photographic quality. HP has created a significant display product.

ORIGIN OF THE DISPLAY OF THE YEAR AWARDS

The idea of awards for the best displays of the year was first suggested by Professor Shunsuke Kobayashi to *Information Display Magazine* editor Ken Werner in Monterey, California, in October 1994. Following discussions with Aris Silzars, Kathy Middo, and members of the Board of Directors of the Society for Information Display, the Display of the Year Awards Committee was formally constituted in January 1995 in Santa Clara, California, with Professor Kobayashi as Chair. To ensure a broad perspective as well as in-depth technical understanding, it was agreed that the committee should include technical journalists as well as distinguished display professionals - a strategy that has proved very successful.

1997 DISPLAY OF THE YEAR AWARDS COMMITTEE

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Photo-Alignment and Patterning of Liquid-Crystal Displays

New alignment techniques promise not only economical multi-domain LCDs but also novel and exciting uses of polymeric liquid-crystal films.

by Martin Schadt

TWISTED-NEMATIC liquid-crystal displays (TN-LCDs) - or any other LCD that depends on the effect of an electric field - require that the alignment of the liquid-crystal (LC) molecules be controlled. The traditional way of achieving this control is by confining the LC layer between two mechanically rubbed surfaces. The molecules adjacent to a surface align in the rubbing direction.

In addition to the secondary drawbacks associated with rubbing polyimide-coated display substrates - such as generating dust and electrostatic charges, which is particularly detrimental for manufacturing thin-film-transistor (TFT) TN displays - there is a basic limitation: the result of mechanical alignment is primarily macroscopic. Therefore, mechanical rubbing is suitable for aligning displays uniaxially over the entire substrate area, as is now done in most commercial LCDs, but it is not adequate for generating high-resolution azimuthal aligning patterns, in which the alignment angle changes from one small area to another. This is significant because a very attractive way of circumventing the restricted

Martin Schadt, one of the inventors of the TN cell, is Chief Executive Officer and member of the board of ROLIC Ltd., a recently founded liquid-crystals research and development company, located at Grenzacherstrasse 124, 4002 Basel, Switzerland; telephone +41-61-688-1804, fax +41-61-688-1466, e-mail: martin.schadt@roche.com.

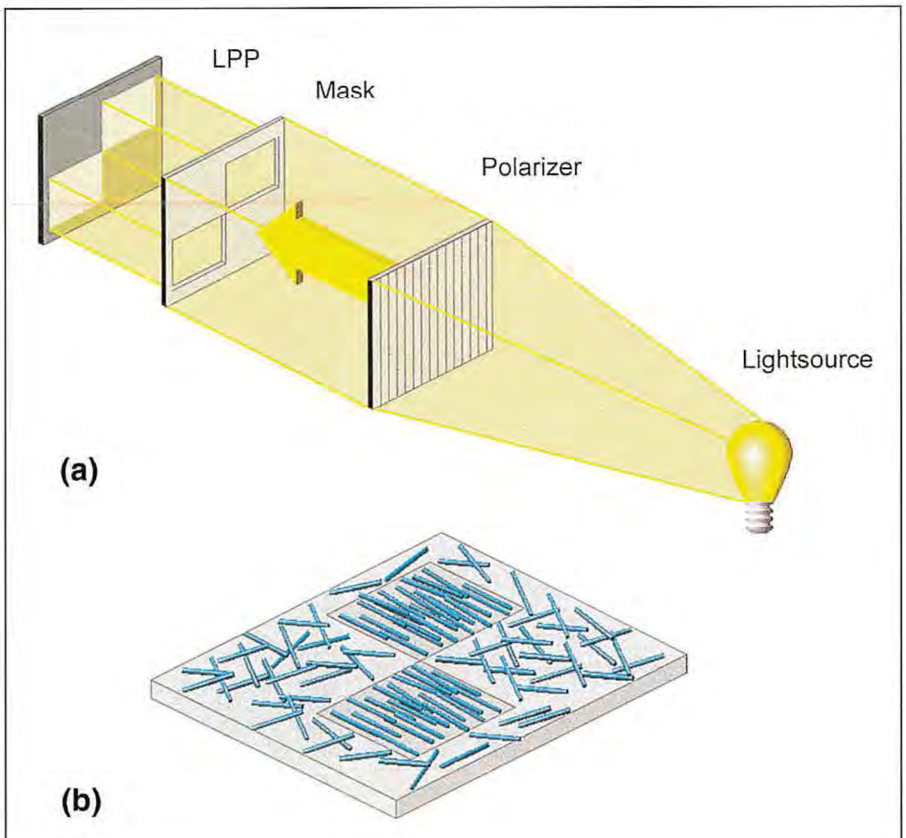

Fig. 1: *(a) Optical alignment and patterning of a substrate spin-coated with an LPP layer can readily be performed through a photomask. The polarizer orientation defines the LC-alignment direction on the substrate. (b) The openings in the mask determine the alignment pattern; the substrate areas not exposed to linearly polarized UV light exhibit random orientation.*

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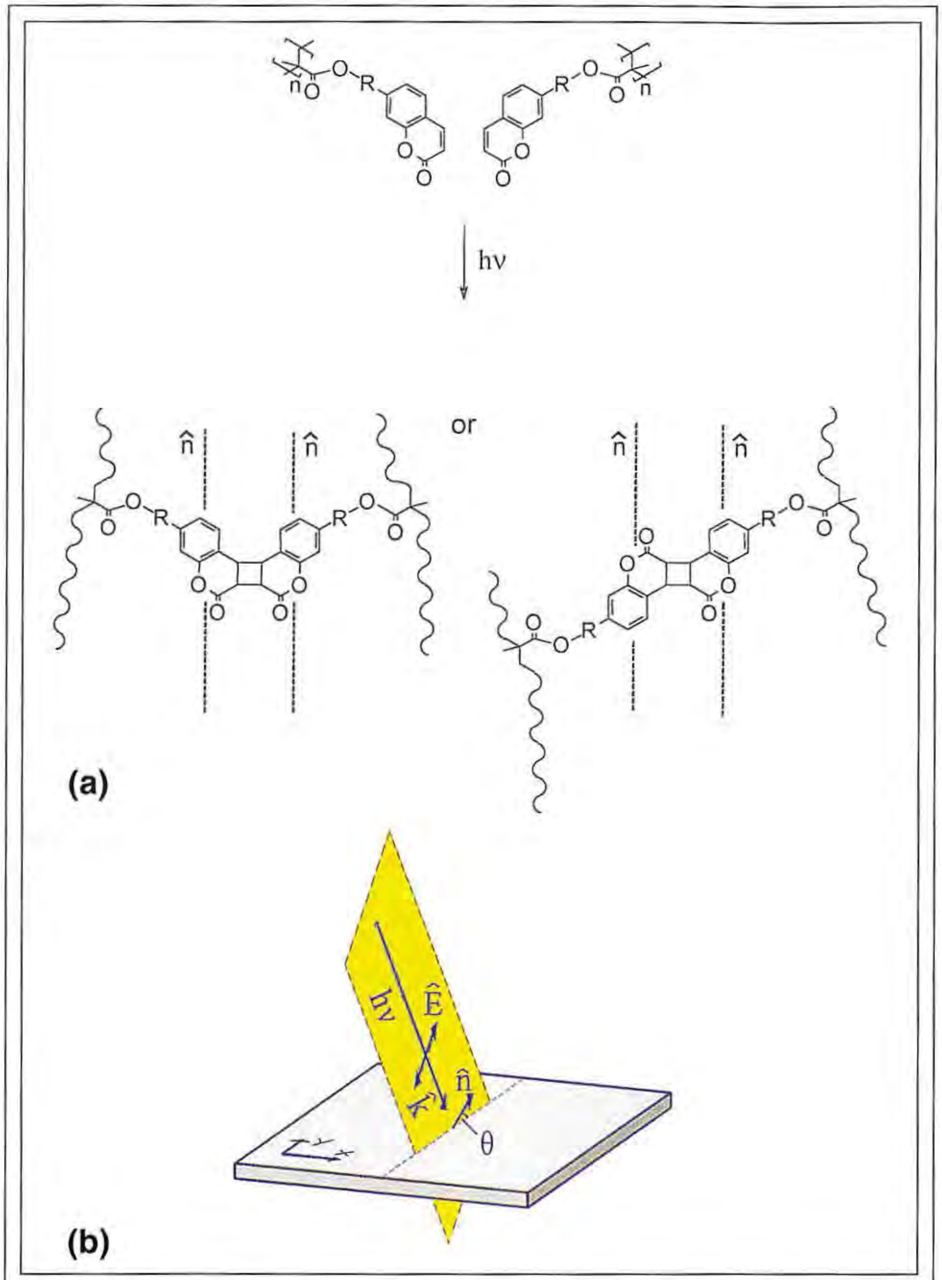


Fig. 2: *(a) LPP molecular photo-alignment and cross-linking is well understood. (b) The process allows the production of photo-induced bias tilt angles from 0 to 90° by varying material parameters and/or the angle of incidence of* ***k****.*

viewing angles of traditional TFT TN-LCDs and supertwisted-nematic LCDs (STN-LCDs) is to vary the molecular alignment in a precisely controlled manner within individual picture elements (pixels).[1] Fortunately, these high-resolution aligning patterns can be implemented with a relatively recent optical aligning process called linear photopolymerization (LPP).[2]

The polymerization process in LPP-coated substrates is distinct from the single molecular process in polyimide layers and conventional photopolymers. The *in situ* photo-cross-linking resulting from the process makes LPP photo-alignment optically stable. Because of this, and because the LPP technology makes many new optical and electro-optical devices feasible, the technology has generated strong interest since its discovery in the early 1990s.[3]

Applying LPP to Multi-Domain Displays

Stable electro-optical performance in field-effect displays requires the implementation of three boundary conditions:

- Uniaxial alignment of the LC director **n** at the respective display substrate.
- Precisely defined bias tilt angles θ between **n** and the display substrates.
- Thermally and optically stable boundary conditions.

LPP photo-alignment meets these requirements and leads to high-contrast dislocation-free TN and STN displays with wide viewing angle and without contrast inversion. The technical capabilities of LPP technology are certainly attractive, but the technology is commercially exciting because LPP coatings can easily be applied to substrates via spin-coating or other standard techniques, and optical alignment and patterning of the coating can readily be performed through a photomask [Fig. 1(a)].

As shown in the figure, the polarizer orientation defines the LC-alignment direction on the substrate, which is induced by the linearly polarized UV light; the openings in the mask determine the alignment pattern. The substrate areas not exposed to linearly polarized UV light exhibit random orientation [Fig. 1(b)].

Because the LPP process simultaneously aligns and cross-links the LPP substrate, the alignment in the exposed areas is fixed during the process and can no longer be erased by subsequent exposure to light. This LPP characteristic permits a two-directional LPP-alignment pattern to be generated from a single photomask. In Fig. 1, for example, a second alignment pattern could be generated on the initially unexposed substrate areas by removing the photomask after completion of the first alignment step and exposing the entire LPP substrate to a different polarization orientation.

We now have a good understanding of the molecular aligning and cross-linking symmetries of the LPP photo process [Fig. 2(a)]. LC alignment occurs parallel to the electric-field

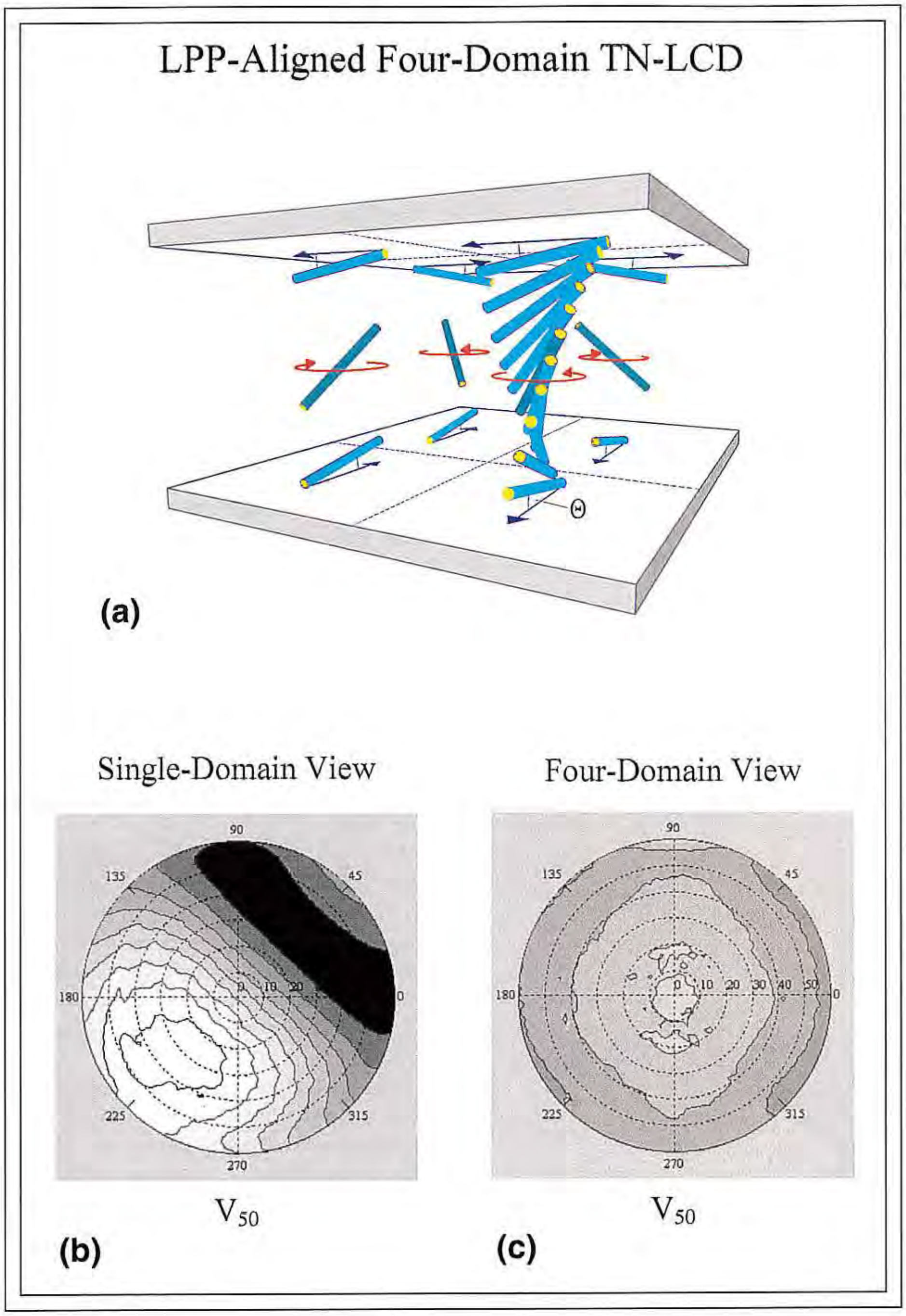


Fig. 3: (a) A single photomask was used to generate the tilted LPP-alignment pattern in this four-domain LCD pixel. The different bias tilt directions determine the twist sense of each of the four subpixels, and the different tilt angles are produced by different angles of incidence of the wave vector ***k****. The angular dependence of the four-domain display's luminance (c) is much less than that of a single-domain TN-LCD (b).*

vector **E** of the incident linearly polarized UV radiation within the plane defined by **E** and wave vector **k**. Because of this symmetry, we can produce stable photo-induced bias tilt angles that are adjustable over the entire range of θ from 0 to 90° by varying LPP-material parameters and/or the angle of incidence of k [Fig. 2(b)].

The technology has been developed to be practical in a manufacturing environment. The latest LPP materials require a processing time of less than 5 sec at a light intensity of only 2 mW/cm^2.

Multi-Domain TN-LCDs

The director configuration of a single, partially switched pixel of an LPP-aligned four-domain TN-LCD is considerably more complex than a single pixel in a conventional single-domain display [Fig. 3(a)]. A single photomask was used to generate the tilted LPP-alignment pattern, as described in the previous section. The different bias tilt angles θ on each substrate determine the twist sense of each of the four subpixels. The different tilt angles are achieved by changing the angle of incidence of the wave vector **k**.

On a macroscopic scale, the optical anisotropies – changes of optical characteristics with viewing angle – of the differently aligned central directors **n** of the helices in the four subpixels in the figure compensate each other. Therefore, the angular dependence of the four-domain display is much less than that of a single-domain TN-LCD. This is illustrated by the uniform brightness of the four-domain viewing-angle graph [Fig. 3(c)] compared with the corresponding single-domain graph [Fig. 3(b)]. These graphs were generated by measuring the angularly dependent brightness of the partially switched-on displays in all four quadrants with light incident at all angles between the vertical and 60° off-axis. The gray levels at vertical light incidence are identical for the single- and four-domain displays and correspond to 50% transmission. As can be seen in Fig. 3(b), the intensity of the single-domain display changes by nine out of ten gray levels within its first and third quadrants instead of remaining constant. The brightness of the LPP-aligned photo-patterned four-domain display changes by only three gray levels within any of the four quadrants. At SID '96 in San Diego, a team from LG Electronics demonstrated the first LPP-aligned 10-in. color TFT TN-LCD. The display consisted of one LPP-aligned four-domain TFT substrate and one conventionally brushed polyimide counter-substrate.

As demonstrated by ROLIC at SID '97 in Boston, LPP alignment also makes it feasible to render dual-domain STN-LCDs with considerably improved fields of view (Fig. 4).

LPP-Aligned Optical Retarders

Photo-aligned LPP substrates can align not only monomeric LCs sandwiched between two aligned substrates but also LC-polymer (LCP) films that are coated in pre-polymer form on a *single* LPP-aligned substrate. The possibility of stacking and photo-structuring LPP and LCP films opens exciting synergies between the different film functions: alignment (LPP), photo-patterning (LPP), and optical retardation (LCP).

ROLIC has shown that these synergies produce a wide range of new optical solid-state devices, such as non-absorbing polarization interference color filters, photo-patterned polarizers for direct-view stereo displays, complex optically patterned retarders for displays, and novel optical security elements that are visible only in polarized light.

One possibility is a solid-state LPP-photo-patterned polarization interference color filter whose non-absorbing pixels are blue and yellow when placed between crossed polarizers (Fig. 5). The two colors result from stacking two differently aligned LCP films (LCP_1 and LCP_2) on top of each other, each of which is individually photo-patterned and aligned by the LPP-alignment layers LPP_1 and LPP_2 along the two directions a_1 and a_2. The interference colors occur when the LPP-LCP optical retarder is placed between crossed polarizers with the slow optical axes $\mathbf{n}_{ex}$ aligned under 45° with respect to the polarizer directions, where n_e is the extraordinary index of refraction. The left pixel in Fig. 5 acts as a subtractive retarder with respect to LCP_1; *i.e.*, $\delta_{yellow} = \delta(LCP_1) - \delta(LCP_2)$.[4] The right pixel retardation is additive: $\delta_{blue} = \delta(LCP_1) + \delta(LCP_2)$. Because the hybrid LPP-LCP configuration shown in Fig. 5 is non-absorbing in the visible spectrum, the LPP-LCP color filter is fully transparent and optimally bright.

Figure 6 shows a high-resolution LPP-LCP phase-retarder image on a single glass substrate. The retarder image was made by photo-aligning a 2-μm-thick LCP film on an LPP-photo-patterned substrate whose aligning pattern consists of two pixelated directions that were generated with a single digital photomask.

To visualize the phase-retarder image, part of the substrate was placed between crossed polarizers. The non-structured white area in Fig. 6, where the phase image is invisible, is outside the crossed polarizers. The black-and-white image in the figure results from the optical retardation δ = 230 nm ≅ $\lambda/2$ induced by these LPP-LCP pixels, whose slow optical axes are aligned at under 45° with respect to the polarization direction (white pixels). The pixels whose slow optical axes are parallel to the polarizers appear black.

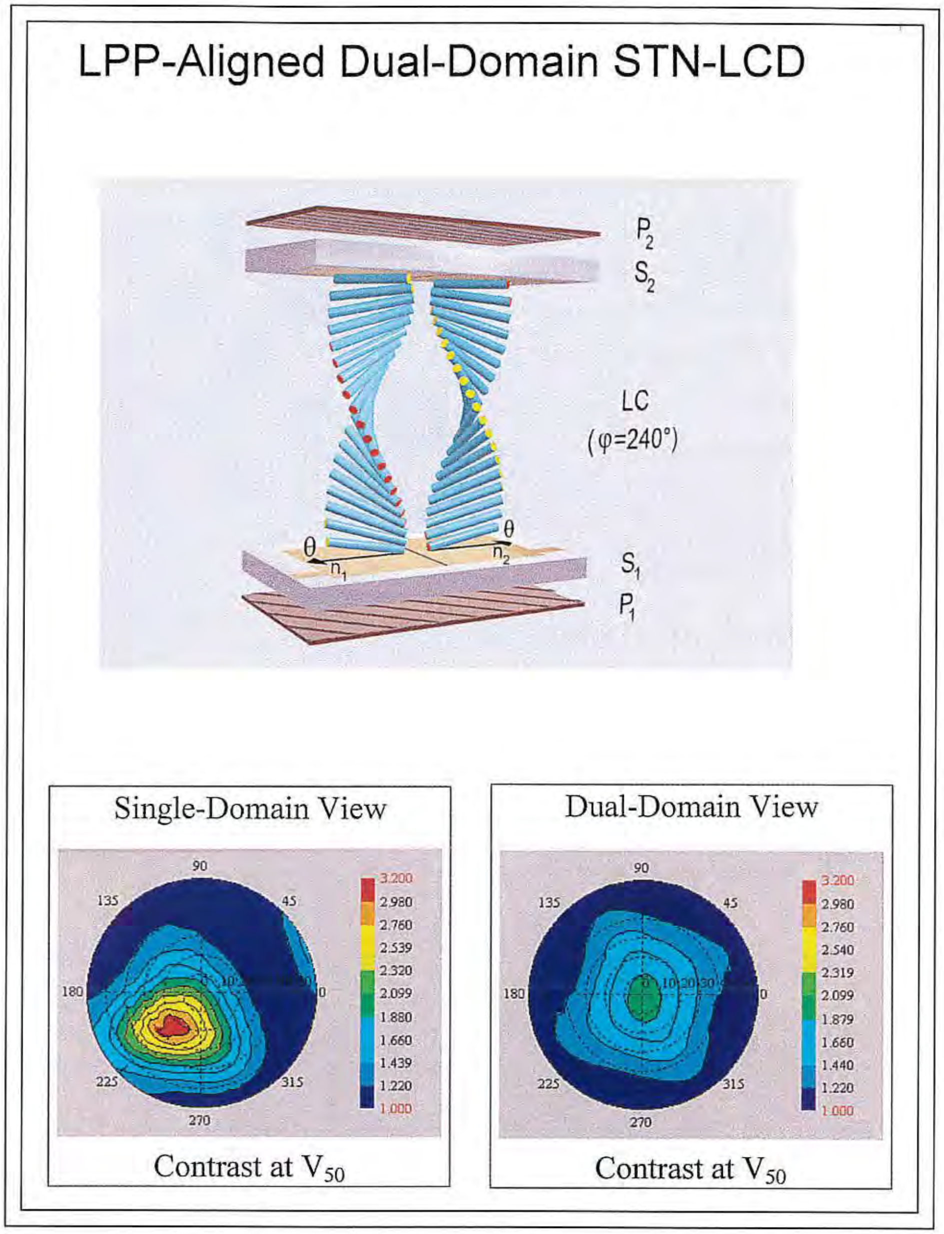


Fig. 4: *LPP alignment also makes it feasible to render dual-domain as well as four-domain STN-LCDs with considerably improved fields of view.*

Looking Ahead

Linear-photopolymerization technology has made feasible high-resolution LC-alignment patterns with defined and broadly adjustable bias tilt angles. The process renders mechanical alignment - with its detrimental generation of dust particles and electrostatic charges - obsolete. LPP alignment of monomeric and polymeric LCs improves the performance of existing displays, and also opens up interest

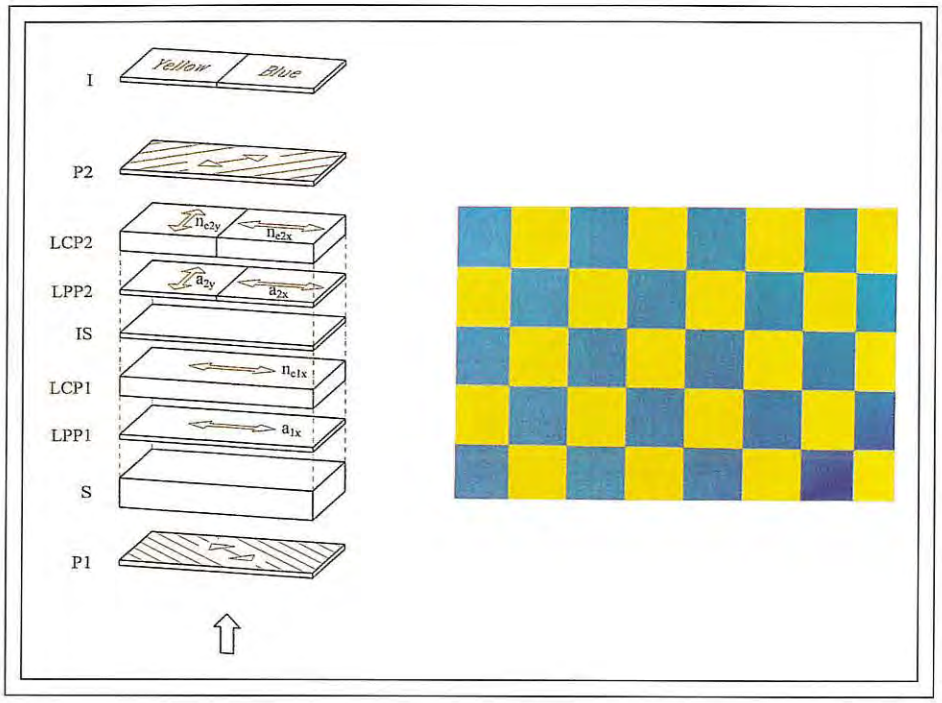
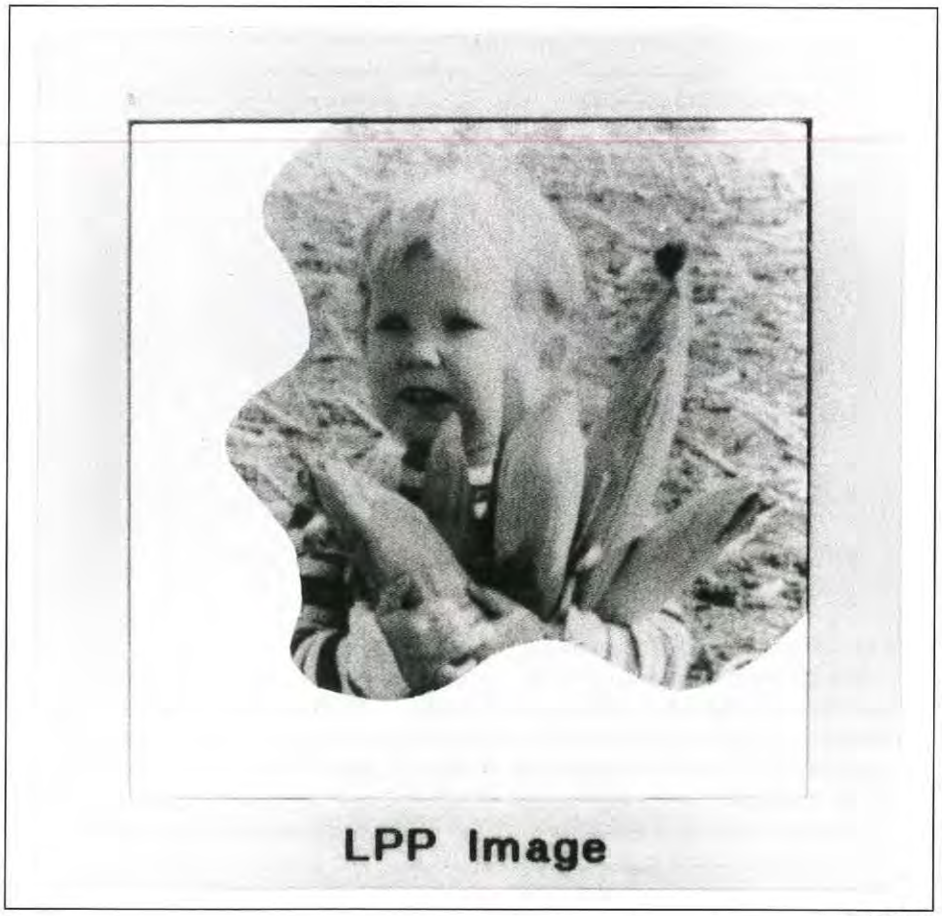


Fig. 5: *Photo-alignment and patterning permits a variety of novel solid-state optical devices, including this polarization interference color filter (a) whose non-absorbing pixels are blue and yellow when placed between crossed polarizers (b).*

ing new display configurations and non-display solid-state optical devices that can operate transmissively as well as reflectively.

Notes

[1]M. Schadt, H. Seiberle, and A. Schuster, *Nature* **381,** 212 (1996).
[2]M. Schadt, "Liquid Crystal Materials and Liquid Crystal Displays," in *Ann. Rev. Mat. Sciences,* Vol. 27, ed. by E. N. Kaufmann, guest ed. C. J. Summers (1997), pp. 305-375.
[3]ROLIC Ltd., U.S. Patent No. 5389698.
[4]$\delta = (n_e - n_o)d$, where n_e and n_o are the extraordinary and ordinary refractive indices; d = LCP film thickness. ■



ROLIC Ltd.

Fig. 6: *This single-substrate solid-state display produces a high-resolution image when the substrate is placed between crossed polarizers. The white area, where the phase image is invisible, is outside the crossed polarizers.*

Circle no. 15

Circle no. 16

LC-Modulated Photoluminescent Displays

Putting the visible light source on the viewer's side of an LCD instead of behind it looks more complicated – but it pays off.

by William A. Crossland, Ian D. Springle, and Anthony B. Davey

EMISSIVE DISPLAYS such as plasma-display panels (PDPs) and cathode-ray tubes (CRTs) (which produce their own light) and liquid-crystal displays (LCDs) (which do not) each have their weaknesses. Combining the strategies of the two display types can produce dramatic performance benefits.

Traditional backlit LCDs modulate the white light, usually from a fluorescent lamp, that impinges on the LC panel from the rear – the side away from the viewer. PDPs, CRTs, and field-emission displays (FEDs) all produce light by exciting phosphors that emit light toward the viewer. In CRTs and FEDs, the phosphors are all cathodoluminescent: they are excited by the energy of electrons impinging upon them. In color PDPs, a vacuum ultraviolet (VUV) plasma is generated electrically and used to excite visible light from a phosphor using photoluminescence. Only recently have researchers begun to investigate displays in which an LC panel modulates near-UV light, which is then used to excite photoluminescent phosphors – phosphors that are excited by light rather than electrons.

Such displays – which we call photoluminescent liquid-crystal displays (PL-LCDs) –

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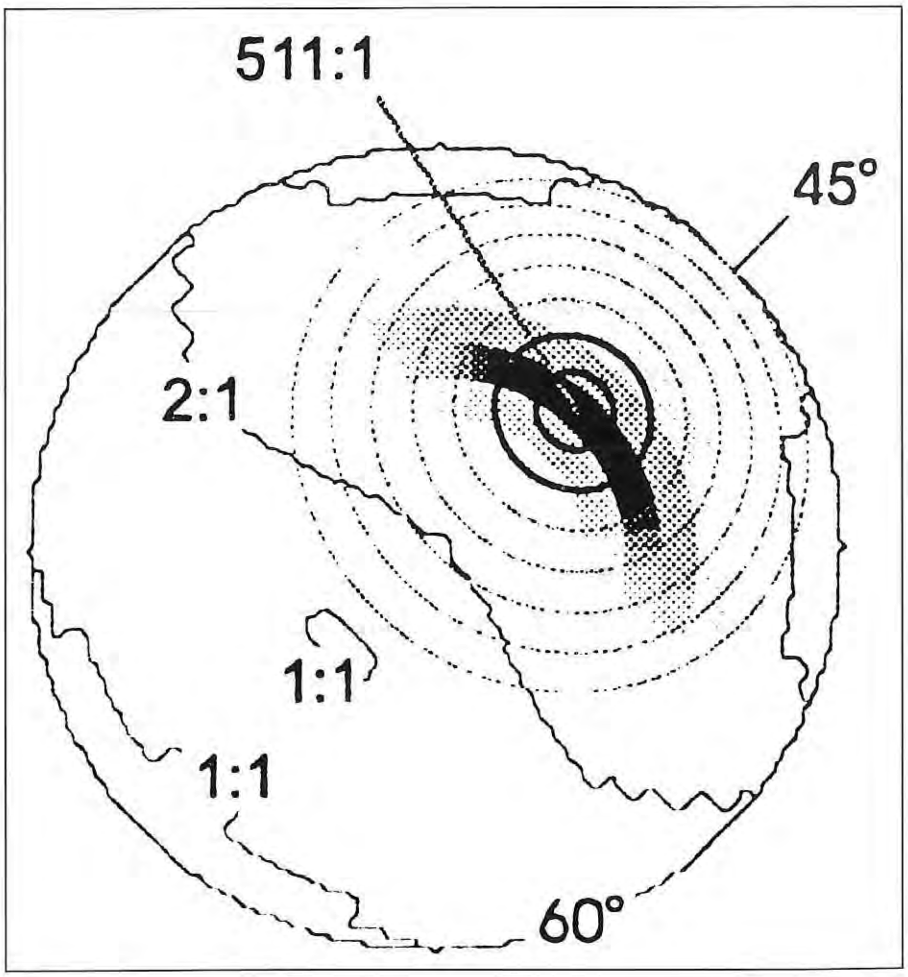

***Fig. 1:** Contrast ratio varies with viewing angle, as indicated here for a simulated second-minimum TN display. The PL-LCD architecture allows a designer to direct low-divergence illumination through the high-contrast regions of the TN response.*

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allow the internal modulated light to be de-coupled from the emitted light seen by the viewer. This de-coupling, and the additional degrees of design freedom it provides, can be used to substantially improve display performance. Specifically, the de-coupling allows the internal illumination, LC modulators, and drive scheme to be optimized for maximum performance without affecting the viewing angle or color of the display. Let's take a closer look at how this works.

Phosphor Decoupling

Phosphor decoupling manifests itself in three forms: spatial, spectral, and temporal. Spatially, the luminous flux emitted from a flat phosphor pixel is proportional to the total amount of activating light falling upon it from any internal direction (even a very narrow range of angles), and the emitted light has a Lambertian spatial distribution.

The spectral distribution of the emitted flux is independent of the spectral distribution of the activating illumination, so the observed color of the display is not affected by the internal illumination spectrum or by chromatic effects in either the LC modulation or the optical elements of the display. Temporally, if the activating illumination fluctuates on a time scale which is comparable to or shorter than the phosphor decay time, the temporal characteristics of the emitted flux become a time average of the illuminating signal.

Whereas the electro-optic characteristics of a conventional LCD vary with viewing direc-

Table 1: Efficiency of PL-LCD *vs.* Traditional LCD Structure

Change to the Display Structure	Efficiency Gain
Backlight (× 0.92)	
• Wasting visible Hg lines	× 0.92
Architecture (× 1.66)	
• Removal of color filters	× 4.3
• Additional phosphor conversion	
• Quantum efficiency	× 0.90
• Utilization factor	× 0.86
• Loss of backward-emitted light	× 0.50
Total	× 1.53

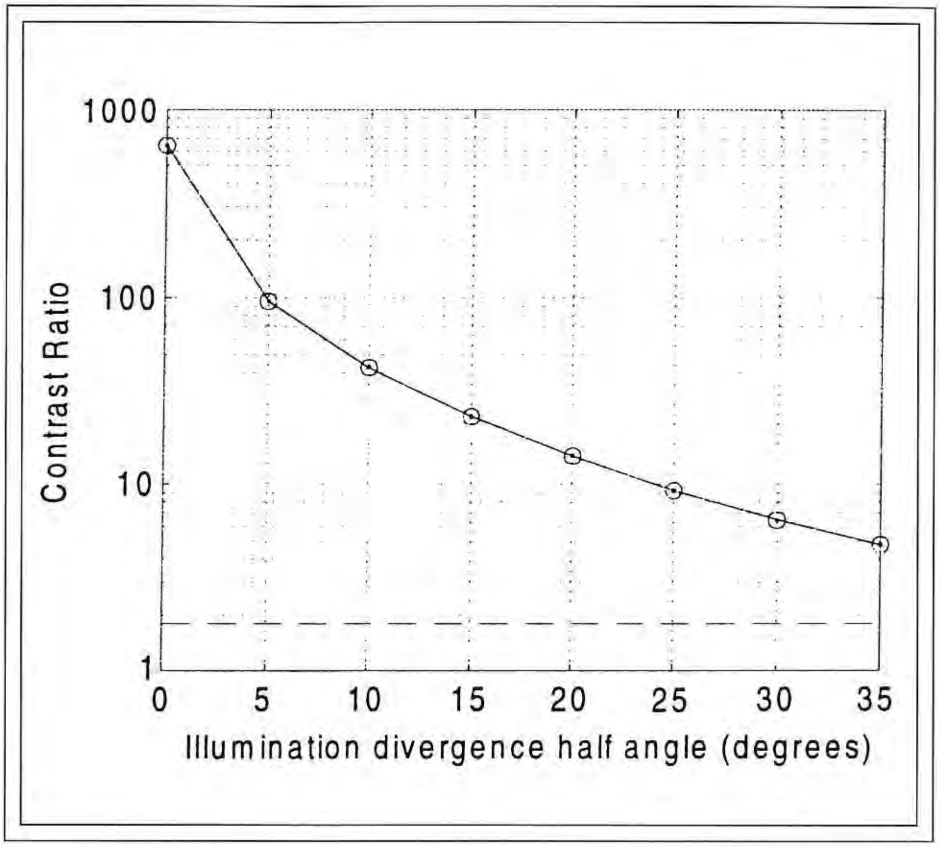


Fig. 2: The contrast ratio of this simulated PL-LCD can range from over 600:1 to 4.8:1, depending on the level of illumination divergence. The dashed line represents Kahn and Birecki's minimum visibility criterion of 1.8:1 contrast ratio.

tion and subpixel color, the electro-optic characteristics of a PL-LCD is the same in all directions and for each subpixel color. This single characteristic is a combination of the characteristics of the LCD panel in all internally illuminated directions and at all wavelengths within the UV backlight distribution. Similarly, the switching response of a PL-LCD is the combination of the dynamic response of the LC with the dynamic response of the phosphor.

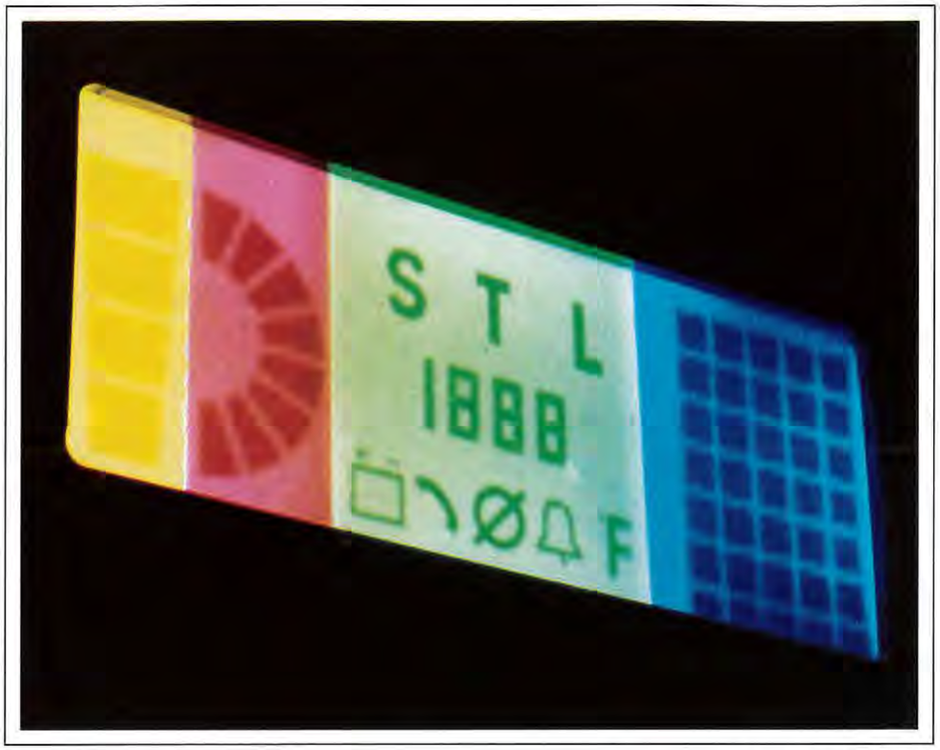
A Fundamental Advantage

The fundamental advantage of PL-LCDs is that the picture brightness, color, and contrast seen from any forward direction will be the same. This immediately solves the viewing-angle and color-shift problems that have been virtually synonymous with LCDs. Because the color of a pixel in a PL-LCD is entirely a characteristic of the front-face phosphor material, the color filters used in conventional LCD architectures become redundant.

In addition to these intrinsic advantages, PL-LCD architectures provide three degrees of freedom not usually available to LCD designers:

- The freedom to collimate the internal illumination to an arbitrarily high degree and choose the direction of this illumination without compromising the display's angular viewing characteristics.
- The freedom to use narrow-bandwidth activating illumination without affecting the emitted color.
- The freedom to use phosphor persistence to remove flicker and other unwanted temporal artifacts.

The use of perfectly collimated, single-wavelength illumination greatly increases the optical performance and multiplexability attained with LC electro-optic effects. This technique could substantially improve the performance of both passive-matrix (*e.g.,* STN)



Screen Technology Limited

Fig. 3: Screen Technology Limited has fabricated the first PL-LCD proof-of-principle display.

and direct-drive (active matrix or simple numerics/alphanumerics) displays. It also permits designers to use narrow-band electro-optic effects and effects sensitive to the direction of incidence, which have, until now, been unsuitable for direct-view color displays (*e.g.*, structures using waveplates or Bragg reflectors). With single-wavelength illumination, polarizing components based on selective reflection from single-pitch cholesteric films become possible, and the retardations of waveplates become precisely defined. In reality, perfect collimation in a flat-panel format is not practicable and neither is "single-wavelength" excitation - at least for the moment - but narrow-bandwidth low-divergence illumination can be readily achieved.

Efficiency

We can compare the power efficiency of PL-LCDs to conventional architectures if we assume the PL-LCD is illuminated by a low-pressure Hg discharge lamp (CCFL) identical to that used in the conventional display except for the phosphor coating, which would emit UVA in the case of the PL-LCD instead of visible radiation (Table 1). A fundamental efficiency gain of 1.53 is estimated. Only those factors which differ from conventional color-filter LCDs are included. The difference in efficiency is due primarily to the replacement of the traditional display's color filters by the PL-LCD's phosphor conversion.

There are three architectural modifications that could further increase the efficiency differential between conventional displays and PL-LCDs:

- Techniques to recover the backward-emitted light.
- Polarization recovery using cholesteric polarizers.
- The development of new lamp technologies.

Initial investigations suggest it will be possible to improve efficiency by a factor in the range of 1.3–2.0 using a dielectric reflector designed to transmit activating illumination but reflect visible wavelengths, and placing it directly behind the phosphor screen.

At the 1996 SID Symposium Applications Seminars, D. Coates and his colleagues reported on the performance of a wideband cholesteric reflector and quarter-wave foil combination used to implement polarization recovery in conventional white-light LCDs. Although the brightness gain of the system was high at low viewing angles, the gain diminished at angles over ±20°. Using a similar technology in a PL-LCD structure, with illumination collimated to within ±20°, should allow a total efficiency gain approaching the on-axis gain of the white-light system.

It has been estimated that an efficiency gain of 1.6 relative to the conventional display *with* polarization recovery could be achieved in this way. But by combining narrow-band - rather than wideband - cholesteric reflectors with narrow-band illumination, we believe higher efficiency gains are possible. The fundamental efficiency gain (1.53) combined with the recovery of backward emitted light (1.3–2.0) and improvements in polarization recovery (1.6) would produce a threefold efficiency increase.

In the longer term, the ability to use narrow-band light would make it attractive to develop a light source that emits light directly at the wavelengths needed to excite the display phosphors, rather than relying on a phosphor to convert UV radiation to these wavelengths, as is done in today's fluorescent tubes. If all the flux generated by an Hg discharge were emitted at 365 nm and the internal phosphor coating were removed, the efficiency of the PL-LCD illuminated by the discharge would roughly double.

How a TN PL-LCD Works

When used in a PL-LCD, the spectral bandwidth of the light modulated by the LC can be made arbitrarily small. This is a great advantage because reducing the bandwidth of a spectrally flat light source improves the modulation of normally incident light through an

Table 2: Effect of Light-Source Bandwidth on the Modulation of Light through an Unpowered TN Device

	Transmission (%)		Contrast
$\Delta\lambda$ (nm)	NW mode	NB mode	NB Mode
1	91.4	0.018	5072:1
10	91.3	0.108	845:1
199	88.3	3.16	29:1

Note. The light source is assumed to be spectrally flat, and its light is assumed to be normally incident on the LC panel.

unpowered TN device (Table 2). In normally white (NW) mode, the reduction in bandwidth from 330 to 1 nm produced a 5% increase in transmission efficiency.

The corresponding effect in normally black (NB) mode is a dramatic increase in contrast. At a bandwidth of 330 nm, 4.6% of the illumination was transmitted, producing a contrast ratio of 20:1 (based on a 90% bright-state transmission). At a bandwidth of 1 nm, almost none of the illumination is transmitted. Thus, use of narrow-band illumination can be used to maximize the transmission efficiency of a TN PL-LCD when operated in NW mode, or to maximize contrast when operated in NB mode.

Figure 1 shows the angular variation of contrast ratio for a simulated second-transmission-minimum conventional TN display, illuminated with a tri-band backlight and operated at the limiting Kahn and Birecki maximum of five multiplexed lines (±40° field of view).[1]

The PL-LCD architecture allows a designer to direct low-divergence illumination through the high-contrast regions of this TN response. The resulting PL-LCD performance is dependent upon the chosen illumination direction, divergence, and bandwidth. The benefits of PL-LCD operation can be demonstrated using simulations of a second-minimum TN device operated conventionally and within a PL-LCD architecture. One way to express these benefits is in terms of increased contrast at a fixed number of multiplexed lines.

The rings on the diagram indicate the angular extent of seven different levels of divergence (from ±5° to ±35°) when illumination is directed through the point of highest contrast on the conventional display. Figure 2 shows the variation of PL-LCD contrast ratio with illumination divergence when multiplexed at the limiting five-line multiplex of the conventional display (dashed line). Contrast varied from over 600:1 to 4.8:1 (bright-state transmission varied between 90 and 81%, while that of the conventional display was 75%). In fact, the optimum illumination direction for maximum PL-LCD contrast using the five-line multiplex did not coincide with the direction of highest contrast through the conventional display. Contrast in excess of 1500:1 was generated with optimally directed illumination.

When used in conventional architectures, the TN panel must modulate the entire visible spectrum. In a TN PL-LCD, the bandwidth of the illumination can be made arbitrarily small in order to reduce this demand, and thereby increase performance. Because the TN electro-optic effect is relatively achromatic these benefits are modest, but they illustrate an important point for more chromatic effects such as STN. Table 2 shows the advantage gained from reducing the illumination bandwidth in the simulated PL-LCD when normally illuminated with collimated light. In normally white (NW) mode, the reduction in bandwidth from 199 to 1 nm produced a 3.1% increase in transmission efficiency. The corresponding effect in normally black (NB) mode was a dramatic increase in contrast. At a bandwidth of 199 nm, 3.2% of the illumination was transmitted, producing a contrast of 29:1. At a bandwidth of 1 nm, dark-state transmission was 0.02% and contrast was 5072:1. Thus, use of narrow-band illumination can be used to maximize the transmission efficiency of a TN PL-LCD when operated in NW mode, or to increase the contrast when operated in NB mode.

PL-LCD designs incorporating both narrow-bandwidth and low-divergence illumination are expected to enable a dramatic increase in the multiplexability of twist cells. Such twist-cell designs will need to be specifically optimized for PL-LCD operation.

Practical Considerations

There are some practical problems which must be confronted before PL-LCDs can be commercialized. First, because the phosphor image and the modulated area are spatially separated for out-of-cell phosphors, pixel size is limited by illumination divergence if crosstalk is to be avoided. In addition, a high level of collimation is required to fully utilize the potential of some electro-optic effects.

Polarizers and other optical components designed for visible displays are not generally suitable for use at shorter wavelengths. Also, requirements for LC stability limit the range of existing LC mixtures that can be used.

Screen Technology Limited, a company established to solve these practical problems and to commercialize PL-LCD technology, has fabricated the first PL-LCD proof-of-principle demonstrator[2] (Fig. 3). It uses 365-nm illumination with limited collimation, modulated by a TN electro-optic effect to excite red, green, and blue external phosphors. Using an excitation wavelength as close as possible to the visible will minimize the increased absorption and decreased lifetimes experienced when illuminating at 365 nm.

The Promise of PL-LCDs

PL-LCDs promise to transform the viewing characteristics, multiplexability, and power efficiency of existing types of LCDs, as well as make possible a number of new display concepts. Current work focuses on developing an optimized nematic structure using sub-blue excitation for a wide range of applications, including video.

Acknowledgments

The authors wish to thank Merck Poole, in particular Dr. Coates, for the development of cholesteric polarizers and quarter-wave foils suitable for use at 365 nm; Dr. Jacob of Merck Darmstadt for his advice on cell materials suitable for UV operation; and the Defence Research Agency for their test cells and refractive-index measurements. This work was funded by the EPSRC, the Leverhulme Trust, and Screen Technology Limited. We would also like to thank Barbara Needham of Screen Technology Limited for her help in the preparation of this article.

Notes

[1]In 1979, Kahn and Birecki reported their studies of the angular variation of the TN electro-optic transfer characteristic and proposed an empirical rule for determining the smallest discrimination ratio at which an NW TN display can be operated while still producing a discernible picture. Their criterion was based upon 90% transmission in the unselected state (relative to zero-voltage transmission) and 50% transmission in the selected state. This guarantees a good level of brightness and a contrast not falling below 1.8:1 over the specified (but limited) viewing cone.

[2]Details of the demonstrator were reported at EID '97 in Esher, Surrey, U.K. (I.D. Springle *et al.*). ■

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Circle no. 17

The Perils of Plasmaco

As in the old-time movie serial "The Perils of Pauline," Plasmaco has had many brushes with disaster on its way to success.

by Jane D. Birk

PLASMACO is familiar to many readers of this magazine, as is its President and co-founder, Larry Weber (Fig. 1). Those who have attended SID shows have seen the company exhibit new developments almost every year (Table 1). But what is the rest of the story? Most people don't know how Plasmaco came into being, how it faced and overcame many obstacles, and how, more than once, it nearly perished on the rocks of disaster. Plasmaco's story is one of survival based not only on technical innovation but also on the loyalty, trust, and painful self-sacrifice of its dedicated people.

Plasmaco began at the end of an era. By the late 1980s, IBM was the last of the major U.S. plasma-display manufacturers, persevering after companies such as Owens-Illinois, AT&T, Texas Instruments, Sperry, Burroughs, and NCR had dropped their plasma programs. In 1987 Larry Weber, then a professor at the University of Illinois, attempted to revive IBM's development program with new technologies invented at the university. With the help of Jim Greeson, a longtime SID member, a meeting was scheduled at IBM in Raleigh, North Carolina, to discuss Weber's proposal. The February 1987 meeting had to be canceled when a freak ice storm struck Raleigh, essentially shutting down the city for a week. Before the meeting could be rescheduled, IBM's management had made its final decision to close its plasma-display manufacturing operation in Kingston, New York.

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With the closing of IBM's plasma program, there seemed to be no markets left for Weber's innovations. After "being depressed for about a month," Weber again contacted Jim Greeson for help in locating someone from IBM who might be interested in starting a new plasma company. Greeson put Weber in touch with Jim Kehoe, the manager of IBM's Kingston, New York, plasma-display operation. Weber's interest excited Kehoe because he and Everton Henriques, Kehoe's second-in-command at IBM, had been thinking along the same lines.

The partnership seemed perfect since Kehoe and Henriques had extensive plasma-panel manufacturing know-how and Weber was an expert in electronics. Mike Marentic, a former graduate student of Weber's who had plasma-display experience from NCR, AT&T, and Interstate Electronics, was recruited to the venture. Together the four formed Plasmaco, an independent company that would utilize IBM's plasma manufacturing line and Weber's new developments from the university.

Apple Juice

Initial financing, enough to last just 6 months, was secured, and Plasmaco acquired the exclusive rights to IBM's manufacturing equipment, patents, and technology. The first task was to find a location to store the equipment. Weber searched the area from his small airplane, looking for large buildings with empty parking lots. Many promising sites turned out to be IBM storage facilities, but his search finally yielded a vacant apple-juice processing plant 20 miles from IBM's Kingston facility. In the fall of 1987, more than 80 tractor-trailer loads of equipment were moved into the building. While initially intended only for temporary storage, later construction began to convert the 64,000-ft.^{2} building into a manufacturing facility. (The huge below-grade concrete structure into which trucks originally dumped apples, and which guided the apples to the juice-processing equipment along a water-filled moat, is too massive to remove and has no obvious application to display manufacturing. Conversion schemes are a topic for lunchtime conversation at Plasmaco.)

Table 1: Chronology of Plasmaco's Plasma-Panel Development

1988	First display
1989	640 × 400 monochrome prototype
1990	640 × 400 production model
1991	1280 × 1024 monochrome prototype
1992	1280 × 1024 production model
1994	First color display
1995	21-in. high-brightness color display
1996	21-in. color display with 100% digital video
1997	42-in. color display

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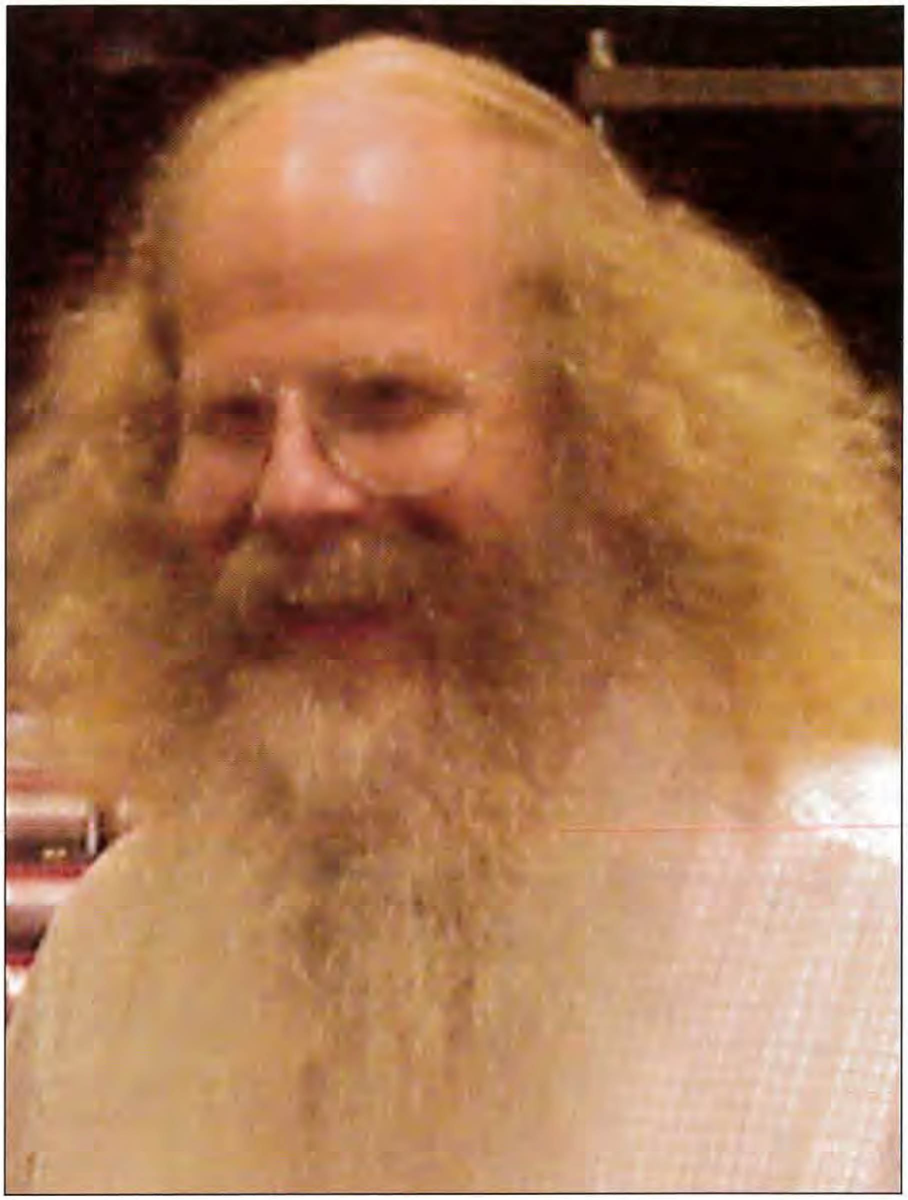


Fig. 1: Plasmaco's Larry Weber has a lot to smile about.

Development work began in earnest in order to make a big splash at the SID Symposium and Exhibition in May 1988 in California. The schedule was extremely aggressive. Because of a lack of funds, the first cleanroom - a tiny 1000 $ft.^2$ - was not constructed until April 1988. On the Friday before SID, work began on the first Plasmaco panel, and processing continued around the clock over the weekend. On Monday morning, the final panel-processing steps were completed as a courier waited, and the panel was sent by air express to California. Final assembly of the panel with electronics began on Monday evening in Mike Marentic's living room. Of course, all did not go smoothly, and Weber and Marentic worked throughout the night and the next day to complete the display. (This would be the first of many "all-nighters" recalled by the company's employees.) The hard work paid off, and Plasmaco's first display prototype made its public debut at SID '88 (Fig. 2).

Money Comes in - and Runs Out

The stock-market crash of October 1987 severely hurt the company's fund-raising efforts. Despite financial hardship, the company began developing displays utilizing Weber's energy-recovery sustain circuitry, chip-on-glass, and independent sustain and address (ISA) technologies. A 10-in. prototype display incorporating these features was shown at SID in 1989.

After having stretched its initial 6-month financing to last 2 years, Plasmaco finally secured major financing in August 1989, enabling the company to begin manufacturing. An additional 10,000 $ft.^2$ of cleanroom was constructed, and manufacture of 10-in.-diagonal displays began in December 1990. Just as production was getting fully under way, hardship struck once again. Most of Plasmaco's 10-in. displays were sold in Europe, and a mid-1991 European recession constrained the market. A 21-in. high-resolution display was introduced in 1991 but it, along with the 10-in. model, met with limited acceptance in the U.S. because of the increasing availability of color LCDs.

By 1993 the company was in serious financial trouble, and in late June drastic action was taken by Plasmaco's board. At the end of the day, three of the company's four founders were dismissed, and only Weber, as chief technology officer, remained from the original management team. A renowned turn-around expert was brought in to bring the company to solvency. Unfortunately, according to Weber, 6 weeks later the turn-around expert "turned around and left," deeming Plasmaco's situation hopeless.

The board called upon Weber to take the lead, and he reluctantly took on the role of Plasmaco's Acting CEO. The board's first directive to Weber was that he lay off half of the company's dedicated work force. An audit revealed that it cost $1750 to make one of Plasmaco's 10-in. panels, which sold for $500, so production was terminated. The audit also indicated that the company only had funds sufficient for 3-4 months of operation, but again the money was stretched - and lasted for a year.

Inspired by an idea drawn from the first SID Manufacturing Technology Conference in January 1994, Weber devised a way to manufacture 21-in. color plasma displays using the company's existing monochrome equipment. Incredibly, Weber maintained that not only was this proposal feasible but a display based on it could be shown at the next SID show only 5 months away! Even the optimistic Weber acknowledged that there was a serious obstacle: the company didn't have the $80,000 needed to purchase components for the development effort.

Although this was the smallest amount the company would ever need to raise, it was the hardest to acquire. One of the company's original investors agreed to invest half the money, but no one else wanted to invest in what appeared to be a failing venture. Since Plasmaco's bank was threatening foreclosure on existing loans, Weber approached it with a proposition. He told the bankers that if they foreclosed they would get next to nothing for the company's aging equipment, but if they allowed the continuation of his color-display development, their rewards would be much greater. Weber's argument was convincing, and 15 minutes before the foreclosure deadline the remaining investment money was found. As a condition of forestalling foreclosure, Weber agreed that a color panel would indeed be shown at SID. If no panel was shown, foreclosure proceedings would be reinstated immediately.

The pressure was on, and Plasmaco's employees rose to the occasion, working literally around the clock. By the start of SID week, the panel and electronics were fabricated but the display was not yet working. Knowing that exhibition of the display at SID was vital, Weber shipped it with a dozen boxes of spare parts and laboratory equipment to San Jose. In a friend's garage, Weber and Jim Noecker, one of the company's design engineers, worked day and night to debug the display. At noon on the final day of SID, only 2 hours before the close of the exhibition, they achieved their goal, and the display made its debut at SID (Fig. 3). *Information Display* editor Ken Werner recalls Weber's saying, only half jokingly, as he turned on the power supply, "The solder joints are still warm." The 21-in. display showed only a simple color-bar pattern, but it caused considerable excitement not only in the exhibit hall but also back at Plasmaco.

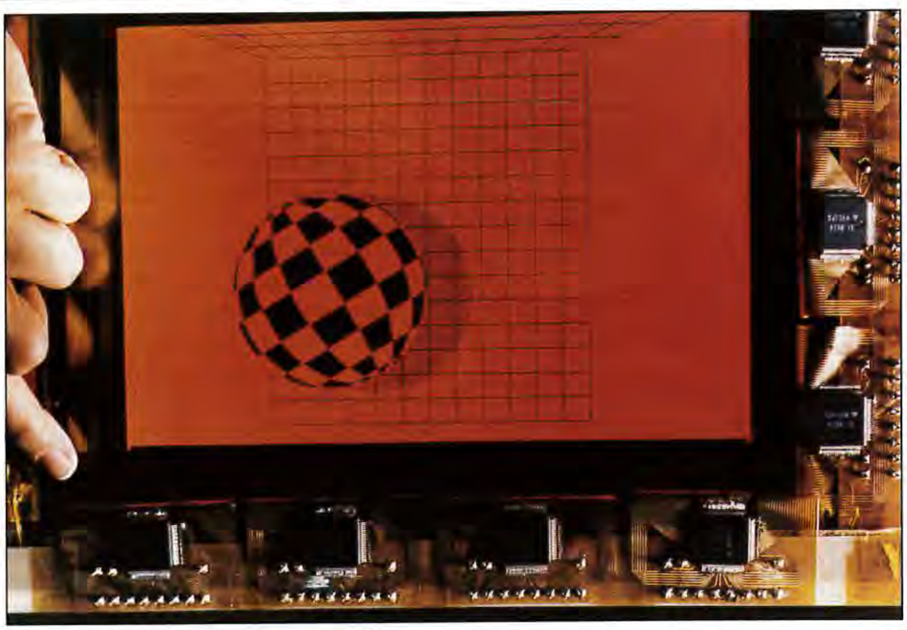
The following months were the darkest for Plasmaco. Although the successful showing at SID prevented foreclosure, the company was practically out of money. Weber couldn't even answer the telephone because bill collectors called constantly. The sheriff was literally at the door. Plasmaco owed everyone; even the company's lawyers, says Weber, "headed for the hills." The electric and telephone companies threatened to cut off service, and most of the company's employees were put on a 2-day work week to reduce expenses. Even through these hard times, Plasmaco's design team continued their development efforts. The 21-in. display was first exhibited publicly showing a 24-bit-color full-motion-video image at the Flat Information Displays Conference in December 1994.

Enticed by the potential of the color technology, a group of venture capitalists provided the company with an infusion of capital in September 1994. This funding came in the nick of time; foreclosure was again imminent. But to achieve large-scale success, additional funding was needed. The venture capitalists took on a vital role in Plasmaco's fund-raising efforts, aggressively pursuing every potential source of financing.

Happy Resolution – with No End in Sight

In May 1995, Plasmaco entered into a joint development agreement with Matsushita Electric Industrial Co. of Osaka, Japan. The company's staff returned to full-time status, and at SID '95 a display was shown with double the brightness and four times the contrast ratio of competing displays. Negotiations during the next several months resulted in Matsushita's purchase of Plasmaco. The deal was closed in January 1996, with Weber remaining in place as President.

With the backing of an electronics giant, funding was now available to pursue development of larger displays. Almost immediately, a new challenge was raised: construct a 42-in. display to be shown at the Japan Electronics Show in October. Suddenly, the existing equipment that had enabled Plasmaco to produce 21-in. displays was inadequate. The staff rallied to acquire new equipment in record time and construct additional clean-room space to house it. After much hard work – and many hours of overtime – contributed by all of the company's employees under Weber's leadership, Plasmaco's first 42-in. display was unveiled at the 1996 Japan Electronics Show (Fig. 4). Although under development for a very short time, Plasmaco's display bested the performance of many of its competitors. Incidentally, the display shown



Globus Brothers Studio

***Fig. 2:** Plasmaco's first display was exhibited at SID '88 with a bouncing-ball demo. Because the monochrome display was transparent, Weber boasted of its "360° viewing angle," and asked for suggestions concerning what to do with the extra 180°.*

Plasmaco

Fig. 3: *Plasmaco surprised SID '94 attendees with its first color display. Completed just a couple of hours before the end of the show, the panel displayed a hard-wired pattern of color bars.*

Plasmaco

Fig. 4: *The 42-in. color display was shown at SID '97. Plasmaco brought a busload of its employees to Boston to see the show.*

at JES was completed less than an hour before it was shipped to Japan for the show.

Over the past year, advancements have continually been made to improve image quality, and Plasmaco's 42-in. displays have been on a road show of sorts, making stops at COMDEX, Display Works, the Consumer Electronics Show, and various Panasonic events, leaving onlookers visibly impressed. At SID '97 the company's booth boasted two of its 42-in. 4:3-format displays showing digital video, as well as a 16:9-format display made by Matsushita Electronics Corp. using Plasmaco's core technology. In June 1997, Plasmaco hosted a tour of its facility by a busload of members of SID's Mid-Atlantic chapter. Weber's well-received talk during this visit was the inspiration for this article.

The cliff-hanging "perils of Plasmaco" seem to be over, but what's ahead? Plasmaco now has a secure position as an arm of Matsushita that is tasked with developing innovative plasma display and manufacturing technology and doing prototype and small-volume manufacturing. That Plasmaco's people have sacrificed, succeeded, and prospered in the face of repeated disasters has led them to believe that almost anything is possible.

The "team-building" of rope courses and guided, blindfolded walks is already becoming something of a corporate joke. But at Plasmaco there *is* a team of people who have learned they can trust each other even when their livelihoods are at stake.

These are people whose experiences have given them ample reason to like and trust each other, and to feel certain that under Larry Weber's leadership Plasmaco will continue to be an innovative force in plasma-display technology.

Postscript

On September 5th, Plasmaco's employees celebrated the company's tenth anniversary with a surprise luncheon honoring Larry Weber. Also attending were co-founders Jim Kehoe and Everton Henriques, as well as Steve Globus, one of the original investors. Weber was presented with a memory book highlighting major events in the company's history (including SID shows) as well as a giant "telegram" signed by the employees. ■

Making a Projector Lighter

Giving road warriors a smaller, lighter multimedia projector without sacrificing brightness and image quality is an engineering challenge.

by Chris Demers

LIKE EVERYONE in high-tech industries, LCD manufacturers are constantly driven to perfect and deliver the *Next Big Thing.* What is frequently forgotten, however, is that many existing products do their jobs well and are greatly appreciated by their users. Ultraportable LCD projectors are such a product.

Since their introduction, datagraphic projectors have had solid employment as business tools. A traveling salesman in those early years of the electronic-projection era was considered well equipped if he could supplement handouts with projected evidence of his products and services. The projector suggested he was well financed and successful - and therefore more credible. That old projector, however, may have weighed well over 50 lbs. and been capable of projecting only a very dim image. And those images were often less than exciting.

Today's ultraportable LCD projectors weigh less than 10 lbs. and still convey success and preparedness to the audience. But the mobile presenter can now deliver information using multimedia and interactivity. Even with video, audio, PC connectivity, and greater brightness, the ultraportable has only a fifth of its predecessor's weight and uses less power.

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Making multimedia projectors very light and compact has required great sophistication not only in display technology but also in optical and mechanical design, materials, molding, and packaging. In designing its EzPro line of affordable ultraportables, CTX Opto, Inc., has fully participated in this revolution and has made some of the lightest projectors available (Fig. 1). The specific developments that have made these lightweight units possible are advances in single- and triple-panel technologies, single and triple

CTX Opto, Inc.

***Fig. 1:** The CTX EzPro 580 LCD projector is in many ways representative of the leading lightweight single-panel projectors.*

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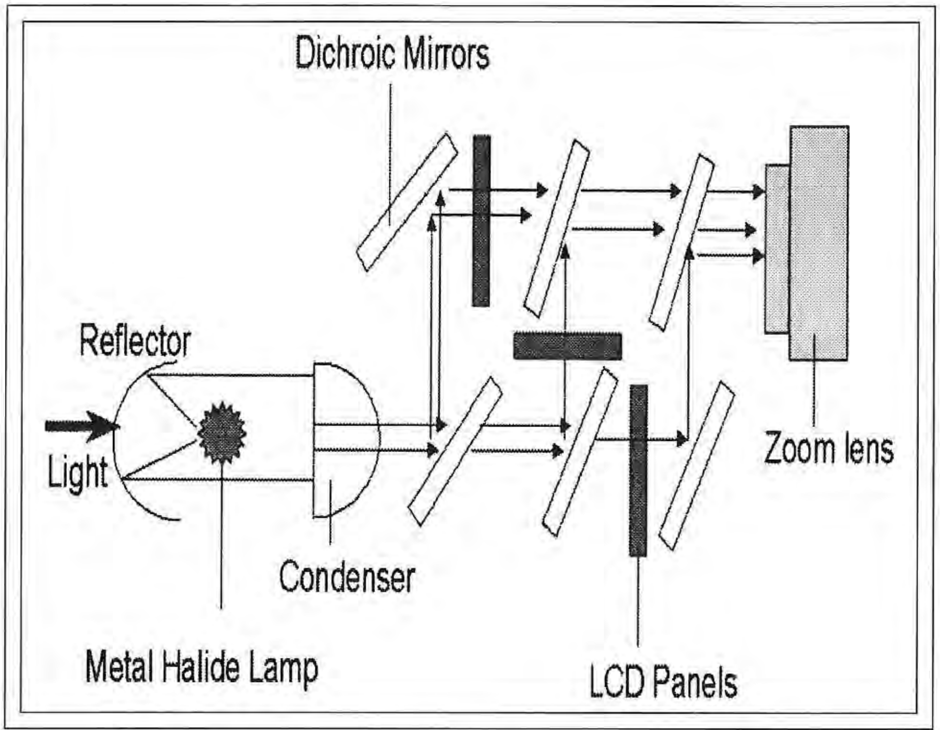


CTX Opto, Inc.

Fig. 2: Inside the EzPro 580, a spherical reflector collects light emitted backward by a lamp or light source. This light is then directed through a condenser lens and folded toward a Fresnel lens by a cold mirror. The Fresnel lens distributes the light through a hot mirror that filters out infrared light. The infrared-free light is then passed through the LCD panel to another Fresnel lens that makes the light parallel to a front-surface mirror, which folds the light and directs it through the projection lens to the screen.

optical light paths, and halogen and metal-halide light sources.

LCD projectors naturally separate into two different product categories: single and triple panels. The number of panels in an LCD projector determines the general form of its optical light path and how information from the computer source is processed in the projector and projected onto a screen.

Single-panel projectors use one LCD panel (typically 6.4 in. on the diagonal in the current generation of amorphous-TFT projection panels) to process the computerized information. Such panels provide excellent image quality and eliminate design issues regarding convergence - the proper superposition of images that must occur in three-panel units. Single-panel projectors require only one optical light path through the LCD panel and on through the projection lens. These projectors are generally lighter and more economical than triple-panel units because they use fewer components and less space.

Triple-panel projectors use three LCD panels, each of which contains one of the red, green, and blue color-information inputs from a computer. Individually, these panels are smaller (usually 1.3 in. on the diagonal) than those used in single-panel projectors and contain poly-Si TFTs in the higher-resolution models. However, triple-panel projectors must be larger in order to accommodate the longer light path and the additional components needed to direct the light through all the panels, converge the red, green, and blue images, and project them onto the screen. Using CTX Opto projectors as examples, we will examine the optical light paths associated with both technologies.

The single optical light path of a single-panel projector makes possible the compact and lightweight design of the EzPro 580 LCD projector (Fig. 2). Although this model is in many ways representative of the leading projectors in its class, it has some unusual design features which will be mentioned along the way.

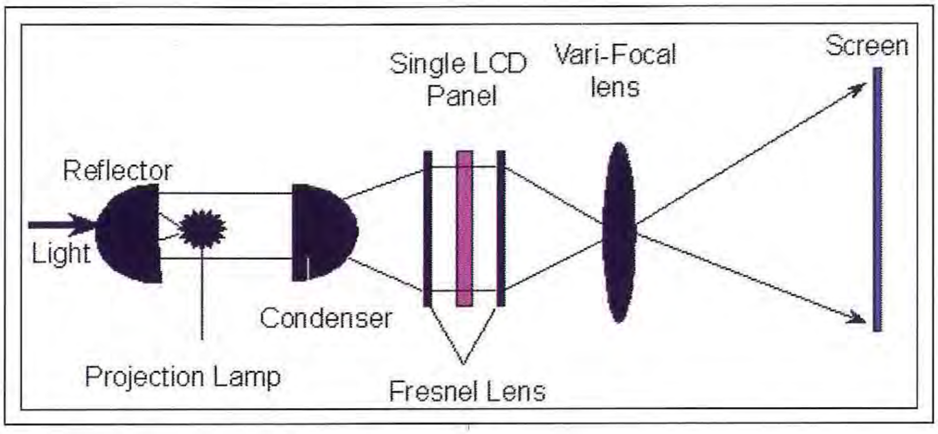
Inside the unit, a spherical reflector collects light emitted backward by a lamp or light source. This light is then directed through a condenser lens and folded toward a Fresnel lens by a cold mirror. A Fresnel lens is a flat glass lens made up of concentric rings of glass which act like prisms to bend and then magnify light into a concentrated beam. A cold mirror has a special coating which reflects visible (cold) light and transmits infrared or "hot" light. The Fresnel lens distributes the light through a hot mirror which has a special coating that reflects heat and transmits visible light. The resulting visible light with infrared removed is then passed through the LCD panel, where the computerized information is input. The light, now carrying the input information, is beamed to an output Fresnel lens that makes the light *parallel* to a front-surface mirror. This mirror folds the light, directing it through the projection lens onto the screen. Of course, good optical quality is required in such a projector, but as optical systems go, this one is not particularly complicated.

The optical light path for a triple-panel projector is far more complex than the single-panel path design (Fig. 3). It requires a longer light path, which usually requires a larger housing. In triple-panel design, light is directed from the lamp box to a dichroic mirror. A dichroic mirror is a reflective filter that yields very strong colors with high efficiency.

The blue beam is passed through the 1.3-in. LCD panel dedicated to the blue video signal. The main light beam is divided again into red and green beams, each of which also passes through the corresponding LCD panel. Using several dichroic mirrors and cold mirrors to filter and direct the light paths, the red, green, and blue beams are converged and recombined.

The image is sent through the prism (which breaks the light down into its component RGB colors), then through the projection lens, and onto the screen. The placement of the mirrors in triple-panel units is very delicate because the optical system must direct the light precisely through the small LCD panels and recombine the light information perfectly.

The last element in the design of an LCD projector is the choice between a halogen or metal-halide lamp for the light source. Halogen bulbs are the most common choice for single-panel projectors. Because halogen bulbs draw less power, designers can use smaller power supplies to drive them, which



CTX Opto, Inc.

Fig. 3: *In a typical triple-panel design, light is directed from the lamp box to dichroic mirrors that separate the white light into red, green, and blue beams, each of which passes through the corresponding 1.3-in. LCD panel. Dichroic and cold mirrors filter, converge, and recombine the red, green, and blue beams. The image is sent through the prism and the projection lens, and onto the screen.*

saves weight. Halogen structures are fairly compact. This makes it relatively easy to keep them out of the way of the optical light path, which saves space. The light output is consistently good during the bulb's life span, and the bulb can be easily replaced by the user. In addition, halogen lamps are readily available at audio/visual dealers and most lamp specialty stores, and, at no more than $30, replacement is inexpensive.

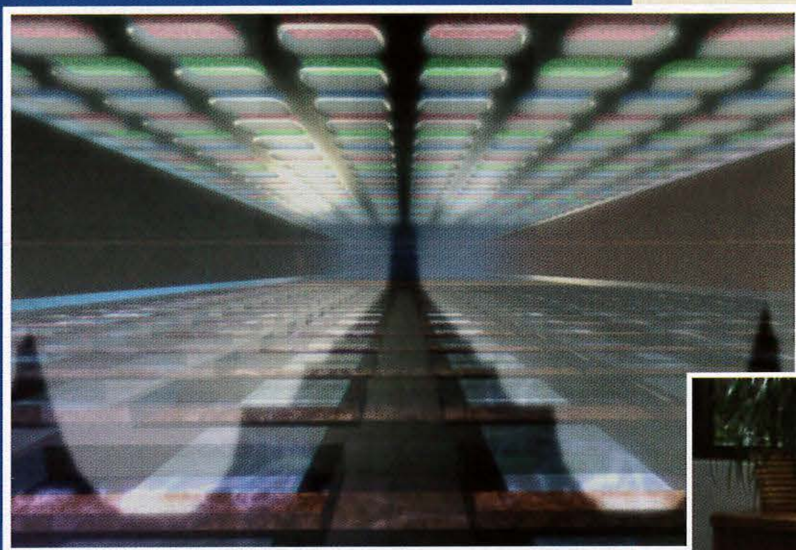
CTX Opto created an exception to this single-panel design tradition with its recently introduced EzPro 580, which has a metal-halide light source. Metal-halide lamps are often used in three-panel projectors, where their bright white light illuminates all three panels. In the EzPro 580, CTX Opto designed a metal-halide mechanism into the same compact package used for the other EzPro ultra-portables. The trick was the development of a smaller, high-voltage power supply for metal-halide lamps that would fit into the same space occupied by the halogen power supply and weigh about the same.

The specific advantages of metal-halide lamps in LCD projectors are found in the quality of the projected image. Metal-halide lamps appear "whiter" to the eye, thus brighter to the audience. Because of this whiteness, they are the better choice for accurate color reproduction and comparison. They last far longer than halogen - up to 5000 hours in some cases - but generally cost far more as well. During operation, their maximum temperature is far lower than that found with halogen bulbs.

Conclusion

Cost, application, image quality, and amount of travel are all factors which must be considered when selecting a combination of ultra-portable LCD-projector features. Each technology has different uses and each presenter has different preferences. ■

Where Opportunity and Preparation Meet.



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FPD MANUFACTURING PROGRAM STATUS
(Autumn 1997)

To date, USDC's Technical Council has selected 45 priority programs covering various areas of process technology used in manufacturing FPDs. These include programs for establishing a U.S.-based supply of equipment, materials, or process technology, using existing technical know-how, as well as both evolutionary and revolutionary technology advancements. Thirty of these programs have been brought under contract and development has begun. The others are in various stages as summarized below.

Topic/Contractor	Program Cost ($M)	USDC ß-site	Status	Current Milestone
Color filters *Rohm & Haas, Shipley Co., Clarkson University*	1.8	Several	Contract completed; 12/96	Final report issued
Color filter fabrication			Canceled	
Pre-assembly test & inspection *Photon Dynamics*	2.4	dpiX	Development under way; 3/23/94 start	ß-site testing completed 11/97; commercial offering
Treated substrates *Applied Films Corp.*	2.5	Several	Contract completed 7/96	Commercial supply in place
Polymer coating *Candescent, FAS Technologies*	3.5	FAS	Development under way; 7/12/94 start	Implement material rheology follow-on phase 10/97
Coating materials rheology optimization *FAS Technologies*	0.75	FAS	Contract negotiation	Contract signing 10/97
Dry etching *Lam Research, Lawrence Livermore National Labs, University of Wisconsin*	15.1	dpiX	Development under way; 6/20/94 start	ß-site testing completed 9/97; commercial offering
Glass supply *TBA*			On hold	
Glass inspection *Display Inspection Systems*	1.5	OIS	Development under way; 6/11/94 start	β-site testing completed; commercial offering
Automated interconnect *Anorad*	4.4	Planar	Development under way; 10/28/95 start	Module software tested and debugged 12/97
Spacer application & cleaning *Accudyne*	1.9	Accudyne, Photonics, Candescent	Development under way; 6/13/94 start	β-site testing at PDP facility in progress; spacer tool testing at Accudyne; commercial offering
Handling (benchmarking) *Competitive Strategies*	0.2	N/A	Study completed 10/1/94	Final report issued 3/95
Handling (cassette design) *Progressive System Technologies, H-Square*	0.7	Several	Development under way; 7/10/95 start	Gen. 3.5 (600 × 720) cassette completed 12/97; commercial offering
Handling (tracking) *PRI Automation*	3.3	Candescent	Development under way; 7/7/95 start	Marathon testing completed 12/97
Factory modeling *IDC*	1.3	Several	Contract completed 8/97	Modeling software package commercially available
Handling (storage & retrieval) *PRI Automation*	1.6	Candescent	Development under way; 5/13/96 start	Reset development schedule 9/97
Handling (manually guided transporer/loader) *PST*	0.35	Candescent	Development under way; 6/1/96 start	Iron man testing of phase I tool 10/97
CIM benchmarking study *CPS Research*	0.05	Several	Development under way; 8/14/97 start	Final report 1/98
Large-area lithography *Tamarack Scientific*	2.2	Photonics Imaging	Development under way; 3/1/95 start	β-site testing at PDP facility in progress; commercial offering
Large-area mask fabrication and blanks	3.8	Several	Development under way; 12/7/96 start	Install plate cleaning system 7/97
Direct laser imaging			Cancelled	

Topic/Contractor	Program Cost ($M)	USDC ß-site	Status	Current Milestone
Wet processing (etching) *CFM Technologies*	4.1	dpiX	Development under way; 2/12/96 start	β-site testing at AMLCD facility in progress
Polarizers, UV & retardation films *Polaroid*	10.9	Several	Development under way; 3/1/95 start	Evaluation of full production samples 10/97
Optical films finishing facility *Polaroid*	0.45	Several	Development under way; 9/25/97 start	Forming and packaging facility operational 1/98
Literature translation & database management *InterLingua*	0.6	N/A	Development under way; 2/15/96	Initiate monthly translation of LCD intelligence 10/97
Backlighting				
Litton Data Systems S.D./BHK	4.5	Several	Development under way; 10/25/95 start	Final program review 10/97; commercial offering
Flat Candle	0.2	Several	Development under way; 12/15/95 start	Delivery of prototype lamps 12/97
Hughes Power Products	2.0	Several	Development under way; 4/1/96 start	Demonstration of first operational backlight 10/97
Glass cutting *Accudyne*	4.6	Several	Development under way; 7/11/94 start	Prototype tool scribing and breaking head test results
Driver infrastructure				
Driver chips *Supertex*	1.25	Kent Displays, Planar	Development under way; 9/5/96 start	Design verification engineering runs 12/97
High-voltage TAB *Supertex*	0.5	CDC	Development under way; 9/5/96 start	Initial 100 TCP prototype produced 11/97
Dielectric isolation wafers *Supertex, Bondtronix*	0.9	Planar	Development under way; 9/5/96 start	Install test equipment 10/97
ac/dc converters/inverters			Project canceled	
Plastic substrates *Dow Chemical*	1.1	Several	Project terminated 5/97	Stopped at Phase I checkpoint 5/97
Reactive ion etching *Plasma-Therm*	3.8	FED	Contract completed 4/97	Commercial offering
High-resolution pattern lithography			Contract negotiation	Contract signing 12/97
LC materials, processing, and alignment *Elsicon*	3.3	Several	Development under way; 4/10/97 start	Develop new pre-tilt materials 10/97
Large-area vacuum sealing *Display Technology Systems*	3.6	FED	Development under way; 4/3/97 start	Detailed equipment drawings 9/97
Inorganic planarization layers			RFP development	RFP scheduled for re-issue 10/97
Patterned glass plate inspection & repair			Contract negotiation	Contract signing 10/97
Thin-film vacuum coating			RFP issued 9/4/97	Proposal due date 11/14/97
Cleaning technology			Proposal evaluation	Contractor selection 11/97
Glass sealing materials			RFP development	
FED getters and activation			RFP development	
Step and repeat lithography *MRS Technology*	9.5		Development under way; 6/16/97 start	Optical design of lens complete 12/97
Projection illumination technology			RFP issued 9/4/97	Proposal due date 11/14/97

Source: USDC News, Vol. IV, No. 7, Autumn 1997

continued from page 4

celebrity or a tourist attraction would, for me, seem like a dumb way to go through life.

Cruising along, letting my gaze wander along the distant Seattle skyline and the even more distant Olympic mountains, listening to the swish of the bow cutting through the water, making low sparkly arcs of white spray, watching the wake forming behind, blue sky overhead, breeze blowing in my face - if that doesn't cause one to contemplate and appreciate the meaning of life, what would?

My contemplation took me down a path approximately like this. Hmmm … A $50 million house and $40 billion to his name and still counting. Why do we make such a fuss over someone who is way out there on the fringes of the income-distribution curve? And where the heck did that $40 billion come from, anyway? Most of it, of course, still sits in Microsoft stock and cannot be quickly converted to anything else without causing bad things to happen. However, on quite a regular basis, Mr. Gates does convert a $100 million here and a $100 million there to some other forms of investment.

Then my contemplation began to take a direction that was a bit more worrisome. First, I thought back to earlier times, say to when a company such as Hewlett-Packard got started. H-P began by developing a new product (a really great signal generator), which was put on the market and which generated sales and profits. For a number of years, these profits were used to fund the growth of the company. Then, after some years of moderate - and profitable - growth, came a time when the company wanted to grow faster than it could fund from its own resources. It then reluctantly decided to sell stock and become a public company, with all the disclosures and other obligations that that entails. The stock market valued the company based on its sales and profits, and the investment world was a relatively orderly, although not necessarily completely predictable, place.

Then, sometime later (in the early 80s, as I recall), along came some aggressive biotech start-ups that decided to sell stock even before they had products to sell - just on the promise of fortunes to be made. It worked. Investors rushed to jump in as fast as some of these stocks could be issued. The concept then spread to high-tech companies in general. The idea was to try to convince investors that someday - real soon - they too would own stock in a great company and would be rich. "Buy now, and - trust us - we're about to make this great new technology work." A company no longer needed sales or profits to get into the game, just great promises of the technological wonders hiding just around the next corner.

Now, please don't misunderstand me: Microsoft is no fly-by-night outfit. It has shown great sales growth and fabulous profits.

Circle no. 21

Its growth continues because it is still on that upward part of the S-curve we talked about a few months ago. Nevertheless, it lives in today's investment climate that encourages a gambling mentality and a search for quick and spectacular returns rather than the more conservative and slower-growth approach based on solid business and financial performance.

But how does all this explain where Bill's $40 billion came from? In its entire 33-year existence (with the last 11 as a public company), Microsoft has earned a cumulative profit of roughly $11 billion. That's not a bad number, mind you, it's just not anywhere close to explaining the current valuation of the company. The $40 billion that Bill Gates holds has all come from investors buying stock in his company. It's a "donation" from every investor to Bill. What I mean by this is that $40 billion in profits from *other* business enterprises, public and private, have been shifted to the personal wealth of Bill Gates. Some of these profits no doubt came from businesses having nothing to do with high tech.

What's scary is that this process can only continue as long as there are investors who believe that the stock is going to keep going up and up. Long ago, the stock value lost any realistic connection to the sales and profits of the company. It's now riding on a wave of enthusiasm that could break any day on the rocky shores of disappointment. Paradoxically, this won't affect Bill Gates nearly as much as some of Microsoft's smaller investors. For lifestyle purposes, whether one has $40 billion or only a few billion doesn't really matter. Bill Gates has already converted enough of his stock to other investments that he will be wealthier than just about anyone no matter what happens. (Do most of us really care if he keeps or loses his "wealthiest-person" status?)

But what about all those other less-fortunate investors? What happens if Microsoft has one bad quarter and a significant number of folks lose confidence and decide to sell? Because the stock is so far beyond any reasonable sales or profit-based valuation, the downside is really a long ways down there.

All those investors. They bought and sold, and bought and sold, and bought some more. And with each transaction they paid a tribute to Mr. Gates and, in somewhat smaller amounts, to other chosen ones with names such as Allen, Ballmer, and Myrvold. A king

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San Jose Convention Center
January 20–22, 1998

couldn't be more pleased with such subjects – so willing to donate a goodly part of their wealth to him and his most favored ones. Is this perhaps why Mr. Gates's residence bears such a remarkable resemblance to a feudal lakeside castle?

Finally, I wondered, when one has $40 billion and a castle, what does one do for Christmas? Toys under a Christmas tree wouldn't seem to hold much interest. They've all already been acquired, anyway. Does one then take a day off and acquire nothing? Sort of an anti-matter Christmas? Does one perhaps take a breather from all the material acquisitions and think about something novel like the real meaning of Christmas? Wouldn't that be appropriate for one who never again needs to worry about paying bills or basic survival?

Nah, probably not. No time for that. Got to get into the office and come up with the latest strategy for destroying Sun and Netscape. Or maybe, not ... just maybe, not.

My sincerest of Merry Christmas wishes to you, Bill G., and to all of your hard-working colleagues. May the spirit of the season instill in you the wisdom to make the best use of the financial gifts that have been so richly bestowed on you.

To the many of you who have responded to my ponderings and meanderings in this column during 1997 and who have encouraged me to continue to share them with you, you have already given me a greater Christmas gift than money can buy. For this I thank you and encourage you to do the same in 1998. Actually, you can do it even more and I will like it even better. You see, I'm really no different from all those spoiled rich kids. The more presents I get, the more my expectations rise for the next year. So please send your thought-presents to me via e-mail at silzars@ibm.net, by fax at 425/557-8983, or by phone at 425/557-8850. The Post Office is busy helping Santa during this time of year, but if you still would like to practice the nearly obsolete art of handwriting – by the way, does Santa accept e-mails or faxes? – you may contact me at 22513 S.E. 47th Place, Issaquah, WA 98029.

Wishing all of you the most joyous of Holiday Seasons, and may 1998 be a really great year for us all. ■

Circle no. 25

Circle no. 26

To the Editor:

The NEC article "There's Still Room for a New High-Volume CRT" (*Information Display,* June '97) is not of the quality I expect from SID's official publication. It gives the impression that the combination of a striped phosphor screen and a slotted shadow mask is something new, when in fact this technology has been used in every TV tube except Sony's Trinitron for many years. At the same time, the article shortchanges what appears to be NEC's real achievement - stretching this old technology to achieve a 0.25 mm pitch, which requires the slots in the aperture mask to be only 0.0016 in. wide. With a mask which must be much thicker than this to support its own weight, etching such fine slots is quite a feat. This is only briefly mentioned (top of middle column, p. 20).

There are a number of errors in the article. For example, the two sentences in the top paragraph of column 3, p. 19 contradict each other: The first sentence states that for equal pitch, the maximum number of horizontal pixels for the striped type is 1.22 times that of the dotted type. One would conclude that the striped type is better. But the next sentence states that to achieve the same horizontal resolution as the dotted type, the pitch of the striped type must be finer than that of the dot-trio CRT. Which one is right?

The last paragraph of col. 2, p. 20 says that the phosphor screen is made of continuous stripes (as in all consumer tubes); but Fig. 3, same page, shows interrupted stripes.

End of p. 20: In the equation at the end of p. 20, m and n represent the orders of space harmonics of the scan line and aperture patterns, respectively; the words used to define m and n (first column, p. 21) "the dimensions of each pitch" are pure nonsense.

Figure 4 is quite unrealistic. If the spot size were so small as to cover only two adjacent color stripes, no vertical line could ever be white. The spot must cover at least one trio, and in practice it is substantially larger. But even if Fig. 4 were drawn correctly, it would prove nothing regarding legibility, because green stripes appear much brighter to the eye than red or blue stripes. To judge legibility, one would at least have to use colored dots and stripes of appropriate brightness; a better simulation should take the electron density distribution in the beam into account.

In Fig. 6, S-VGA should be 800 × 600, not 800 × 800. The curves, however, are correct for 800 × 600. The caption of Fig. 6 is misleading: The vertical axis indicates the pitch λ of the moire; it conveys no information on when the moire becomes visible. To find that information one has to look in the text (the last column states that λ should be less than 1.5 mm). That information could have been included in Fig. 6 by adding a horizontal line, but that was not done.

– Robert Adler
Consultant

The author responds:

I'd like to thank Robert Adler for his comments regarding NEC Technologies' new CromaClear CRT, as described in the June 1997 issue of *Information Display.* I appreciate his pointing out that we may have understated the significance of our finely patterned slot mask.

I would also like to offer an apology if the article did not clearly identify those elements of the CromaClear's design that were developed from prior art. However, we are proud that much of the CromaClear CRT's excellent performance is the result of innovative new design.

– Richard Atanus
Director, Product Development
Personal Display Division
NEC Technologies, Inc.

To the Editor:

This letter is in response to the published article, "Scanning Laser Projectors," by William K. Bohannon, which appeared in your August 1997 *Information Display* magazine. As a reader and product manager of Minolta, I am concerned about the irresponsible mention of a Minolta product in (pardon the pun) a "negative light." Apart from the non-necessity of mentioning a brand-name product in the article, the experiment appears to be a flawed experiment. The author is attempting to make light measurements of a scanning source which will not fill the diffuser area of a light meter. Common sense should prevail and one would immediately expect to receive incorrect data. However, the inaccuracies appear to continue when the author compares the readings of a single projected line and reports 800 fC and compares this to multiple scanning lines (which should fill the light meter's receptor area) and reports values of less than 6 fC. Is this possible? Furthermore, it should be noted that Minolta incorporates a condenser-type capacitor which stores the incident light energy during the 1-ms integration time. This enables the user to measure light-source output (Bt) faster than 1 ms by weighting the measurement over 1 ms.

– Dan Schinasi
Product Manager
Minolta Corporation
Ramsey, New Jersey

The author responds:

First of all, I really like Minolta instruments and in no way did I attempt to cast them in a negative light. I trust Minolta instruments for a wide variety of measurements, use them regularly, and write up the results of my analysis on a monthly basis in other publications. However, I respectively feel that you do not understand the basis of the measurement difficulties I described in my article for *Information Display.* The problem is not that the light from a scanning laser doesn't fill the diffuser area on the light master - the problem is that the light pulses are very, very short in time duration, on the order of a hundred nanoseconds! And then after that 100-ns pulse, the scan line moves on - rapidly. I felt that to accurately measure the display (even if the meter is capable of integrating the pulses), a meter with a sensor the size of the screen was needed, a mechanism that could move the meter to track the scan had to be developed, or I should just stop the scanning mirror on the laser projector - which I did.

Regarding your comment on the Minolta meter's ability to integrate a flickering light signal, I called everyone I could at Minolta to gather the necessary information. As you stated, the Minolta meter can integrate over a 1-ms integration time - incorporating a capacitor. This means that some kind of *RC*-type time constant is followed to charge and discharge that capacitor - I desperately needed to get the detector response data and that *RC* curve because I wasn't sure how accurately the meter would track or *hold* individual pulses of light 100 nm in duration. No one at Minolta that I spoke to had the data - just the information that a 1-ms integration time was available. However, as I stated above, after 1 ms the scan line was moving on - rapidly! Therefore, I felt that the best approach was to hold the scanning mirror in check and let the light meter reach some kind of stable reading. The results that I described in my article show that the light meter's readings eventually matched that expected from the laser's power measurements.

– William K. Bohannon
Manx Research
2060 Ridgecrest Pl.
Escondido, CA 92025
760/735-9678

To the Editor:

I was interested in the short item in the September issue entitled "The Beginning of Color" about the first RCA commercial colour TV and the first colour CRTs.

In the early 1960s, during my apprenticeship and first employment, I worked for Thorn-AEI Radio Valves and Tubes in Brimsdown, near Enfield in Middlesex, who claimed to be the first company in the UK to manufacture colour CRTs. There was a small pilot plant at Brimsdown which made 20-in. round tubes, and production later switched to their large factory in the Northeast. During this time I worked in the CRT Development Laboratory and the Applications Laboratory at Brimsdown.

I remember seeing some samples of the early RCA CRTs which, although they had a flat glass face, as mentioned in your article, they had a *metal* cone which formed the bulk of the tube. I presume that this was because, with these first tubes, the glass stress problems inherent in CRT manufacture had not all been solved. However, this technique must have raised other problems relating to glass-to-metal seals.

Another problem was the fact that this large metal cone was connected directly to the final anode and, in operation, would be up at 15 kV or so which, even within the wooden receiver cabinet, was still pretty dangerous (especially to service technicians!). This problem was solved by having a large cone-shaped plastic "shield" which fitted over the whole thing and insulated it from the outside world.

Sadly, the remaining samples we had of these historic tubes and their shields were destroyed (by throwing large stones at them!). I wonder if the CRT in the set shown in your picture is of this type?

Does anybody have any more details of these tubes? My memory is rather hazy after all these years?

– Ray Wilkinson
Microvitec PLC
Bolling Road
Bradford
W. Yorkshire
BD4 7TU, UK

At the request of the Editor, Mr. Peter Keller, curator of the SID '97 CRT Centennial Exhibition, kindly agreed to respond to Mr. Wilkinson's questions.

Dear Mr. Wilkinson:

In reply to your letter of September 29, there were five important evolutionary shadow-mask picture tubes in the early days of all-electronic color television. The first was an all-glass 9-in. prototype with a 4 × 5-in. viewing area demonstrated by H. B. Law of RCA in late 1949 or early 1950. See Fig. 6.10 in my book, *The Cathode-Ray Tube,* for this and other photographs. In March of 1950, an improved prototype (Fig. 6.12) of 16-in. diameter and using a metal envelope was shown in public and FCC demonstrations. This was at the same time that RCA was promoting metal-envelope monochrome picture tubes for size and weight savings. A metal flange facilitated sealing the shadow mask and

letters

screen to the funnel. Next, the glass 15-in.-diameter 15GP22 (Fig. 6.13) was RCA's first commercial picture tube and was used in the RCA CT-100 color-television receiver in 1954. These were the tube and receiver that were shown in the 100th Anniversary of the Cathode-Ray Tube exhibit at the 1997 SID International Symposium in Boston in May. The 15GP22 utilized metal flanges with glass-to-metal seals on both the faceplate and funnel. After fabrication of the screen, the two flanges were welded to join the two parts. A few months later, RCA reverted to a metal-envelope tube of 21-in. diameter - type 21 in. in diameter, type 21AXP22 (Fig. 6.16). Volume production began with the 21AXP22, which was probably the CRT that you remember. Finally, in 1957, RCA went permanently back to all-glass construction with the 21-in.-diameter 21CYP22 (similar in appearance to Fig. 6.17), which employed the now-common frit seal in place of metal flanges and glass-to-metal seals.

Many other interesting color CRTs using the shadow mask and other principles were developed during the 1950s by RCA, CBS, Philco, and others but, in my opinion, the five devices described above mark the major milestones until the long-awaited successful introduction of the 90°-deflection, rectangular, shadow-mask picture tube in 1965. This was 15 years after the widespread adoption of the rectangular monochrome picture tube and 11 years after the introduction of all-electronic color television.

– Peter A. Keller
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Beaverton, OR 97077
e-mail: peter.keller@tek.com

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Display Technology

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Nov. 19-21, 1997 Nagoya, Japan

Display Works 98: Display Manufacturing Technology Conference. Co-sponsored by SID, SEMI, and USDC. Contact: Mark Goldfarb, Palisades Institute for Research Services, Inc., 201 Varick St., Suite 1006, New York, NY 10014; 212/620-3380, fax 212/620-3379.
January 20-22, 1998 San Jose, CA

EUROMONITOR '98: The Second International Exhibition-Fair of Information Display Devices and Projection Equipment. Organizers: Russian National Association of Display Manufacturers, Distributors, and Consumers. Contact: E. G. Goushchin, President, SPS Concept Engineering, Office 902, 41 Vernadskogo av., Moscow, 117981, Russia; (095) 430-8650, 338-9582, 339-5726, e-mail: concept@aha.ru; Internet: http://www.aha.ru/~concept.
March 10-13, 1998 Moscow, Russia

The 1998 SID International Symposium, Seminar & Exhibition (SID '98). Sponsored by SID. Contact: Jay Morreale, Palisades Institute for Research Services, Inc., 201 Varick St., Suite 1006, New York, NY 10014; 212/620-3371, fax 212/620-3379, e-mail: jmorreal@newyork. palisades.org.
May 17-22, 1998 Anaheim, CA

9th International Workshop on Inorganic and Organic Electroluminescence (EL 98) and The Fourth International Conference on the Science and Technology of Display Phosphors. Sponsored by SID, PTCOE, DARPA, and the Oregon Center for Advanced Technology Education. Contact: Mark Goldfarb, Palisades Institute for Research Services, Inc., 201 Varick St., Suite 1006, New York, NY 10014; 212/620-3380, fax 212/620-3379.
Sept. 14-17, 1998 Bend, OR

The 18th International Display Research Conference (Asia Display '98). Sponsored by KPS and SID. Contact Prof. S. Lim, Secretary General; +82-417-550-3542, fax +82-417-551-9229, e-mail: limsk@ns.dankook.ac.kr, Internet: http://tftlcd.kyunghee.ac.kr/idrc98.
Sept. 28-Oct. 1, 1988 Seoul, Korea

editorial

continued from page 2

- There is great value in making large, fragile things close to where they will be used, especially when the production volume is high.
- Not everybody believes that the system should be integrated on the display.
- The forces of global integration are a great tide, inexorably wearing away the established order of things.

- Ken Werner

We welcome your comments and suggestions. You can reach me by e-mail at kwerner@netaxis.com, 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).

Edited by JOAN GORMAN

FPD performance measurement system

Westar Corp., St. Louis, Missouri, has announced it is now shipping the FPM-510, a flat-panel performance measurement system that provides fast, accurate, and repeatable flat-panel-display and display-module testing. The system performs automatic viewing-angle, photometric, and colorimetric measurements on flat-panel monitors in accordance with the Video Electronics Standards Association (VESA) flat-panel-display measurement standard. The FPM-510 completely characterizes the performance of any laptop display, or flat-panel monitors up to 21 in., saving hours of manual configuration and calculation time.

Information: Michael T. Madden, Westar Corp., 11520 St. Charles Rock Rd., St. Louis, MO 63044. 314/298-8748 x286, fax 314/298-8067.

Circle no. 1

Multimedia flat-panel computer

Computer Dynamics, Greenville, South Carolina, has introduced the DisplayPac-MMX-14, a highly integrated multimedia flat-panel computer featuring a 14.5-in. XGA color TFT-LCD and a 200-MHz MMX Pentium processor. Multimedia computing, the viewing equivalent of a 17-in. CRT, and an optional resistive touch screen are integrated into a rugged OEM/industrial package measuring only 18 × 13.5 × 4.5 in. The LCD features 1024 × 768 resolution, 256k colors, and 200-nit brightness; the long-life backlight is rated at 15,000 hours. In addition to its video capabilities, the system features 16-bit full-duplex integrated 3-D audio. Also integrated are an optional resistive touch screen, a 1G hard-disk drive, and the power supply. The complete DisplayPac-MMX-14, housed in a sturdy, easily mounted metal frame, draws less than 40 W and is rated at 45°C. The 200-MHz unit, with display and touch screen, is priced at $5945 in quantities of 10. The display is also available in an FP-Kit flat-panel CRT-replacement configuration, which includes a PCI flat-panel driver card.

Information: Sales Department, Computer Dynamics, 7640 Pelham Rd., Greenville, SC 29615. 864/627-8800, fax 864/675-0106.

Circle no. 2

Hand-held CCD spectrophotometer

CVI Spectral Instruments, Putnam, Connecticut, has introduced the SM-210, a hand-held, compact, low-cost spectrophotometer designed to obtain color, color-difference, and spectral data from the reflectance, transmission, absorbance, and emission of PCs. The SM-210 consists of an entrance mechanism with a built-in slit, a fiber-coupling adapter, and an order sorting filter; a spectrograph of a crossed Czerny-Turner arrangement using high-quality optics; a linear CCD sensor array and driving circuitry; and a computer-interface card. All the optical components and driving electronics are enclosed in an aluminum housing for stable operation. Applications include the relative measurement of color-monitor spectral data and the measurement of light sources including LEDs. Measuring probes, sample holders, fiber-optic cables, and light sources are available to customize the system. Prices for the SM-210 start at $1749.

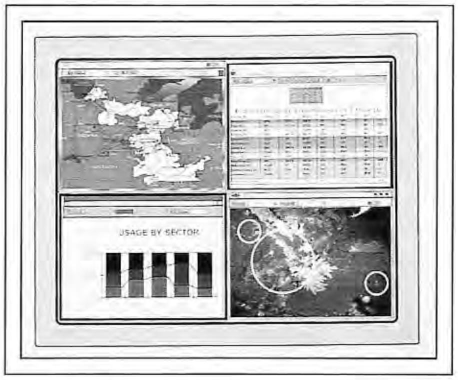
Information: John McCasland, CVI Spectral Instruments, 111 Highland Dr., Putnam, CT 06260. 914/344-4543.

Circle no. 3

Multi-computer windowing system

RGB Spectrum, Alameda, California, has announced the SuperView™ VGA*plus*, an advanced display-input system that combines multiple computer screens on a single monitor or projector. The system was developed for applications in which multiple computer sources must be displayed simultaneously, such as operations centers, control rooms, and presentation and training facilities. The unit accepts up to six computer inputs (each up to 1280 × 1024 pixels) to be displayed in windows or in the background. As an option, composite NTSC/PAL and S-Video inputs can also be displayed. The SuperView VGA*plus* combines the images for display on a 1280 × 1024-pixel-resolution monitor or projector. Each image can be independently positioned and scaled from icon size to full screen. Display alternatives include side-by-side, picture-in-picture, and overlapping windows. In addition, each input can be panned and zoomed to emphasize areas of particular interest.

Information: RGB Spectrum, 950 Marina Village Pkwy., Alameda, CA 94501. 510/814-7000, fax 510/814-7026.



Circle no. 4

1800 × 1440 @ 80-Hz monitor

Nokia Display Products, Sausalito, California, has announced the 445Xpro, the first monitor to offer support for resolution up to 1800 × 1440 @ 80 Hz, providing an 85% increase in information delivery when upgrading from standard 1280 × 1024 resolution. Operating at a scan frequency of 121 kHz with a 0.21-mm horizontal mask pitch, clear and crisp images are delivered while maintaining a flicker-free environment. The 445Xpro offers a full 20 in. of viewable screen with a 0.21-mm horizontal mask pitch. The Nokia 445Xpro's MTBF has been rated at 100,000 hours with a 90% confidence rating.

Information: John Grundy or Holly Wells, Nokia Display Products, Inc., Sausalito, CA. 415/331-4244. Nokia displays are available through authorized resellers and distributors.

Circle no. 5

Clip-on notebook video camera

Panasonic Computer Peripheral Company, Secaucus, New Jersey, has introduced the PM-S122, a color video camera that clips on to a notebook's display, allowing laptop owners to create and send video e-mail and to engage in videoconferencing. The clip-on camera employs full-duplex sound for telephone-like audioconferencing. Both camera and headset connect to an included conference card that plugs directly into any PCMCIA type-II slot through a single plug. Producing images with a resolution of 542 × 497 and 300 TV lines, the camera can swivel up to 40° and tilt up to 120°, making it easy to frame a subject's face. The PM-S122 clip-on notebook camera has an estimated street price of $549. The full package includes clip-on camera, headset, conference card, and CU-SeeMe and VideoLink mail software.

Information: Panasonic Computer Peripheral Company, 1-800-742-8086 or 201/348-7000.

Circle no. 6

Hi-res reflective microdisplay

Varitronix Ltd., Tseung Kwan, Hong Kong, has announced the availability of a microdisplay capable of producing high-resolution images in reflective mode. Silicon-wafer and liquid-crystal technologies are combined in a low-cost device that provides bright high-resolution images for projector systems and direct viewers. A full-digital driving circuit is incorporated in the silicon. The microdisplay accepts 4-bit digital data up to 100 MHz for HDTV applications, analog RGB inputs, digital data inputs, and decoded video data.

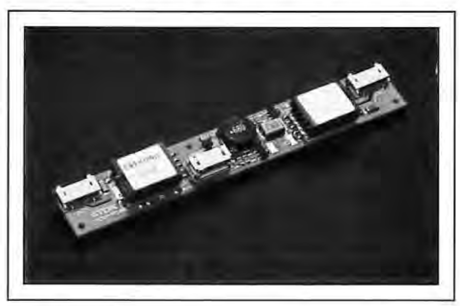
Information: Varitronix, Ltd., 22 Chun Cheong Street, TKO Industrial Estate (W), Tseung Kwan O, Hong Kong. +852-2197-6000, fax +852-2343-9555.

Circle no. 7

dc/ac inverter for 15-in. LCDs

TDK Corporation of America, Mt. Prospect, Illinois, has introduced the CXA-P1012-NJL, a low-cost high-power inverter designed to power 15-in.-LCD backlight systems utilizing dual cold-cathode fluorescent (CCFL) lamps and requiring 7 W of power. The inverter features dual isolated outputs with a single control circuit, a design which synchronizes the outputs and eliminates the flicker problems associated with dual-feedback control systems. A high-efficiency low-EMI circuit design delivers an open-circuit start-up voltage of 1500 V and an output current of 5.5 mA into each CCFL. The standard CXA-P1012-NJL sells for under $9.00 in quantities of 1000.

Information: TDK Corp. of America, Power Conversion Group, 1600 Feehanville Dr., Mt. Prospect, IL 60056. 847/390-4478.



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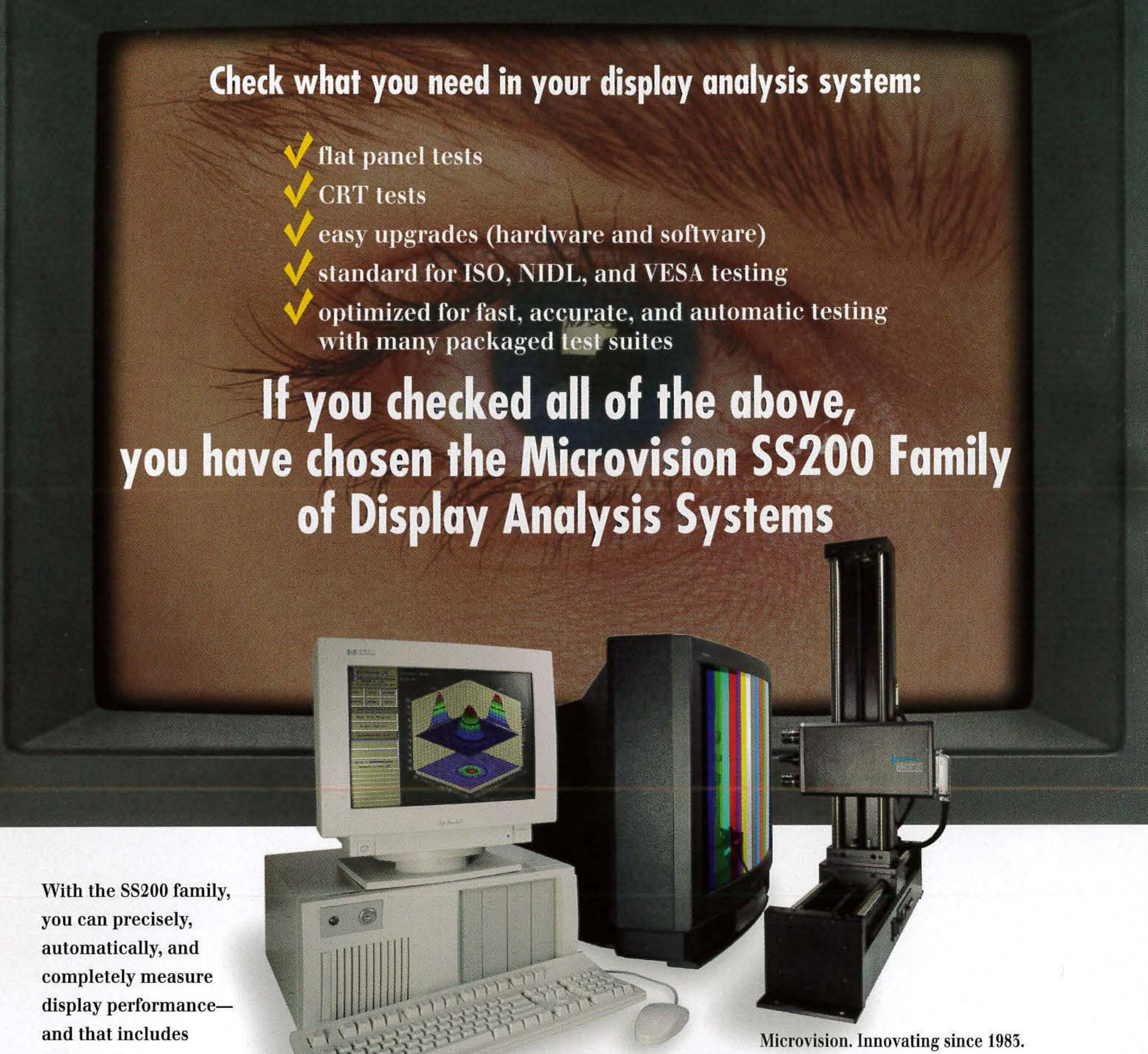

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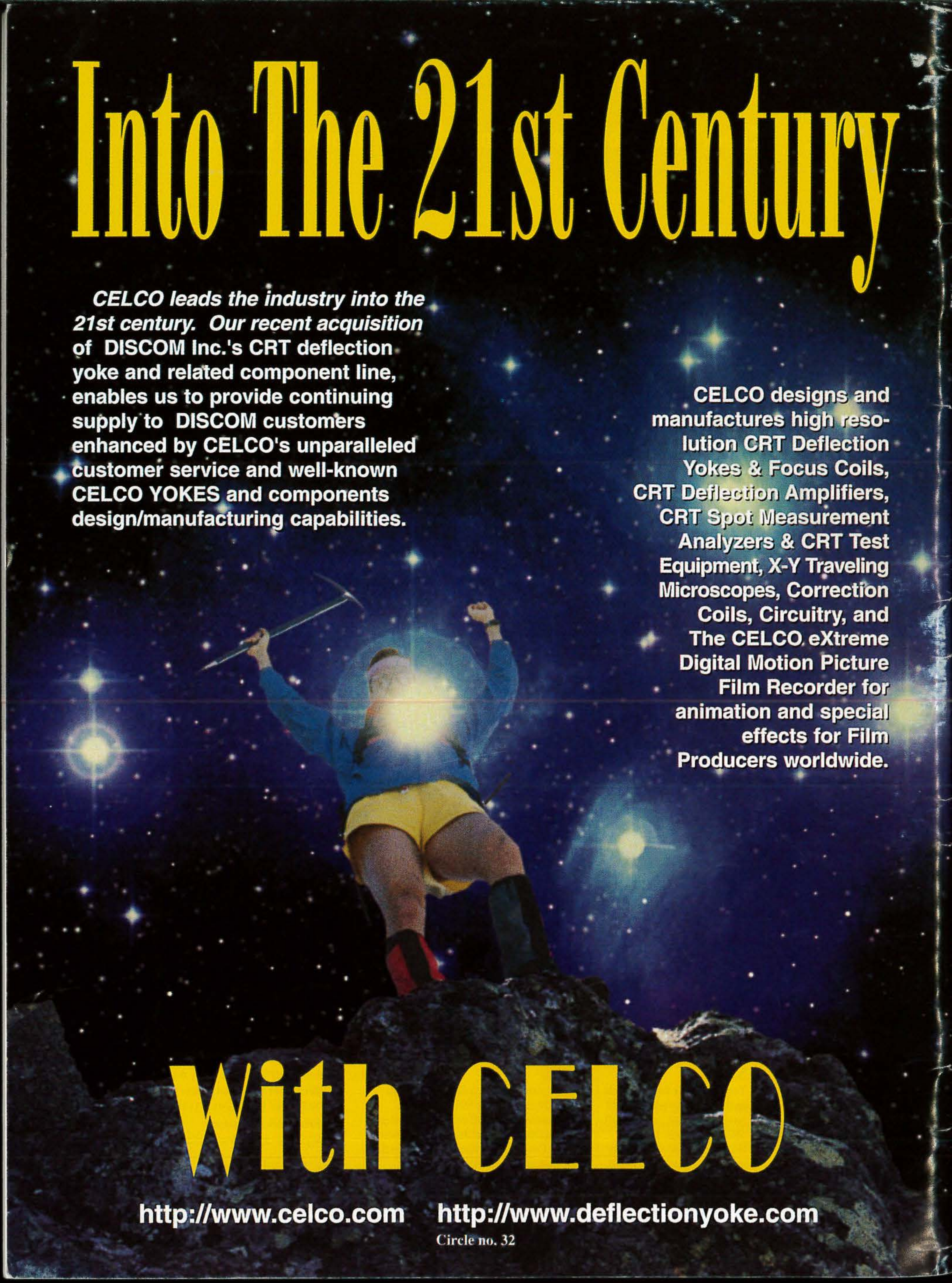
Circle no. 31


Into The 21st Century
CELCO leads the industry into the 21st century. Our recent acquisition of DISCOM Inc.'s CRT deflection yoke and related component line, enables us to provide continuing supply to DISCOM customers enhanced by CELCO's unparalleled customer service and well-known CELCO YOKES and components design/manufacturing capabilities.
CELCO designs and manufactures high resolution CRT Deflection Yokes & Focus Coils, CRT Deflection Amplifiers, CRT Spot Measurement Analyzers & CRT Test Equipment, X-Y Traveling Microscopes, Correction Coils, Circuitry, and The CELCO eXtreme Digital Motion Picture Film Recorder for animation and special effects for Film Producers worldwide.
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