CRT ISSUE

Information DISPLAY

June 1999
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SID

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Do Direct-View CRTs Make Sense for HDTV?

- New HDTV Tubes
- The "Camel" CRT
- High-Contrast CRTs
- Display Works '99 Repo
- EID '98 Report

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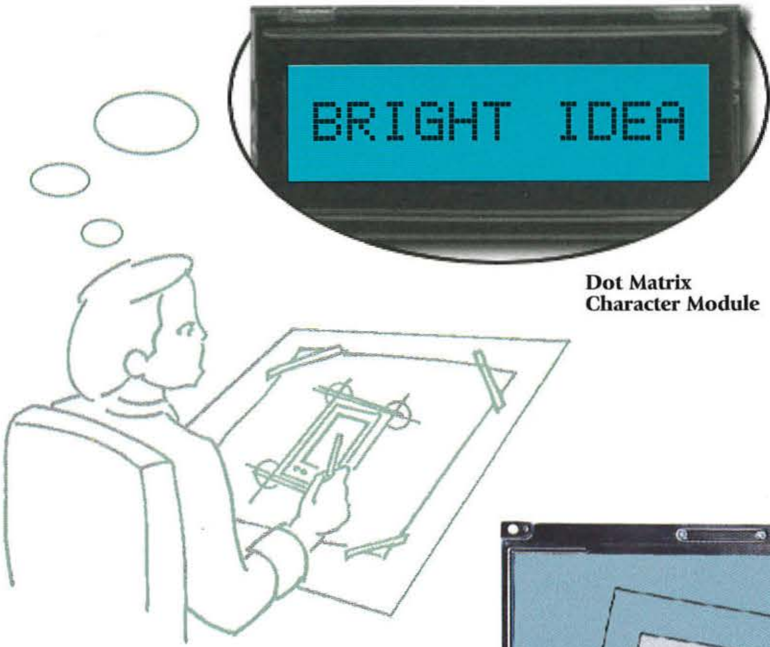
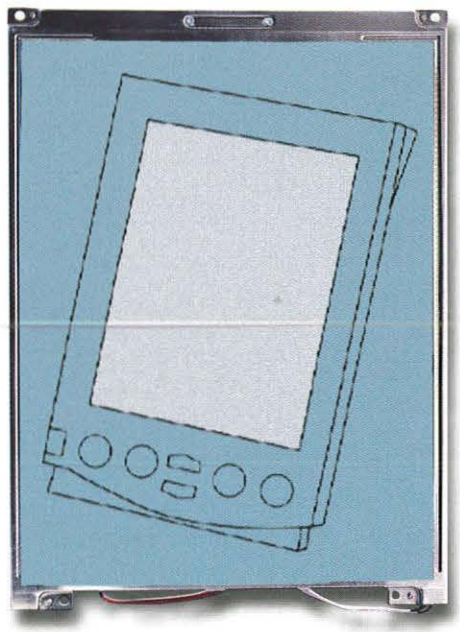
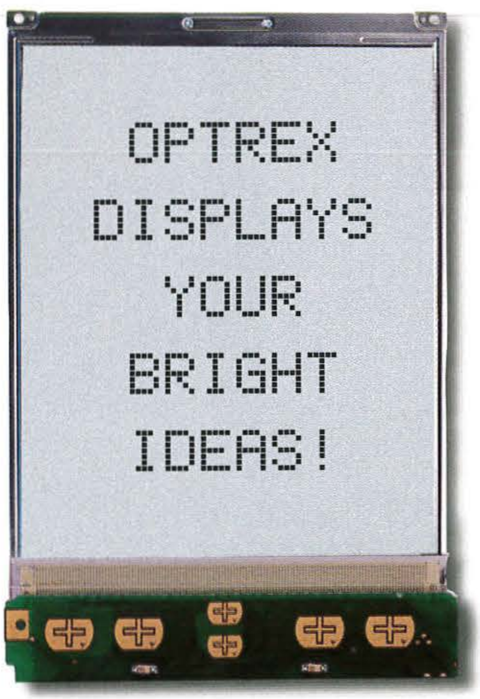


Dot Matrix Character Module

Color Graphics LCD Module



Monochrome Graphics LCD Module



Custom LCD Module

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COVER: The new generation of high-definition television (HDTV) tubes – like this one from Philips – can present impressive images, but can the difference between these HD images and standard-definition digital images be seen at normal viewing distances? Philips, Thomson, and Sony say yes. See the article by R. Donofrio beginning on page 22.

Credit: Philips Display Components

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*

Microdisplay Issue
- Microdisplay Overview
- Microdisplay Partnership
- Vehicle Displays Report
- Company Profile: S-Vision
- FID Conference Report

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Information DISPLAY

JUNE 1999
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editorial

You Mean, Displays Matter?

At the end of February, 3Com introduced two new models in their Palm™ line of palm-top computers. The new Palm V™ seems to have about the same functionality of the Palm III™, but it fits into a slimmer, anodized aluminum case that weighs only 4 ounces.

The Palm IIIx™ has double the memory of the Palm III™ or the Palm V™ and, uniquely in the Palm lineup, has an open connector slot for easier addition of pagers (when available) and memory upgrade cards.

But the most interesting thing to me is that both of the new models are advertised by one of 3Com's New York dealers as having a "new, clearer screen display." What does that mean? Some hunting around on the 3Com Web site unearths an answer: "Enhanced LCD technology, improved readability at all angles, in dim light, and in bright sunlight."

From one perspective, 3Com is simply answering a widely heard complaint about their previous models. But are we also seeing display characteristics becoming important parameters in the competition for the hearts and minds of portable-device buyers?

"Selling the display" has been an important part of the notebook-computer and high-end television games for some time, but purchasers of palm-top computers, PDAs, and cellular phones have, I think, been properly concentrating on system, feature, and usability issues, and have usually been willing to accept the display that came with the package. Now that 3Com is not alone in selling an attractive palm-top package, it's time to go back and find some competitive advantage in the areas that had previously been regarded as "costs" rather than "opportunities" - like the display.

Major display manufacturers, of course, continually work on improving the performance of their small- and medium-sized displays in each price and performance segment, and system makers are sometimes willing to pay more where enhanced display performance is needed to satisfy the customer or where product differentiation seems to be required for marketing reasons. It would be a very nice addition to this dynamic if makers of small display-centric consumer products start selling display performance to their customers as a routine strategy.

And that seems to be happening. Hewlett-Packard's Jornada 420 sports a color display, and more color competition for 3Com's Palm™ computers is reportedly coming from Compaq, Casio, Everex, and Philips. But, as we know, all color displays are not created equal, so ...

- Ken Werner

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

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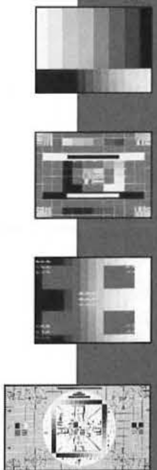

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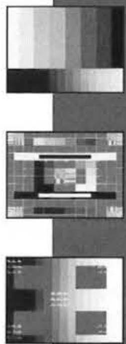

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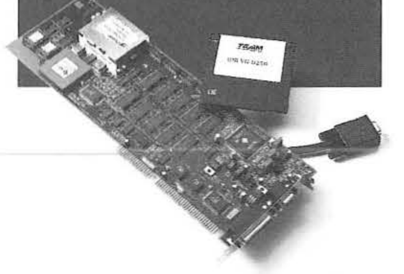

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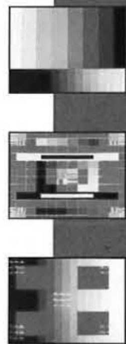

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Circle no. 2

the display continuum

So Easy to Imagine, So Difficult to Do ...

by Aris Silzars

One early morning while sitting in the waiting area of gate N10 in the North terminal, I was doing my best to pretend that I didn't need to be awake yet. Clearly, it was way too early to be even thinking about catching up on my technical reading. That would come soon enough in the six hours of airplane time still ahead of me.

Thus, while exerting minimal energy to maintain my vertical and barely awake position, my eyes were left to randomly wander among the other travellers and contemplate their various stages of wakefulness. Eventually, my attention came to rest upon a child of about ten years who seemed to have some type of unfortunate disability. He wore fairly thick glasses, but what was particularly unnerving was that his head was continually jerking and bobbing. The movements were so intense and so rapid that it seemed to me that he would, at any moment, pull a muscle, or, worse yet, break his neck. I knew that if I tried to do what he was doing, something would give way in no time at all.

However, as I continued to observe him, there seemed to be a pattern to these rapid head movements. They were similar to the movement one would make if suddenly startled - that quick turn of the head to identify the cause of the intrusion. Later, during the flight, I was able to confirm what my observations were leading me to suspect: The source of these rapid head movements was not some nervous disorder. Rather, the muscles that normally control the movement of the eyeballs were not functioning. The child had learned to accommodate for this limitation by moving his whole head instead.

Once I realized this, I naturally had to spend the next fifteen minutes analyzing my own eye movements. There was definitely the same pattern of rapid scan, followed by a few-seconds'-duration hold onto a subject of interest, with another burst of scanning and another lock onto a different point of interest.

This reminded me of something that great artists have understood and exploited for at least the last several hundred years in composing their masterworks. There is a definite scanning pattern that our eyes will follow in appreciating a painting or a scene, and this pattern can be controlled by the artist through the selection of the compositional elements and the tonal values.

It's really pretty amazing. We think we are instantly "taking in a scene" when in actuality we are doing rapid multiple scans, with numerous holds, that in total may require anywhere from ten seconds to more than a minute to process for a complete recording of a given environment.

When we read a book, most of us utilize a very orderly eye-scanning pattern that follows the sequence of the words appearing in the text. It has been suggested by some reading experts that comprehension can be enhanced by first doing a rapid and somewhat random scan of the entire text, then going back to fill in the details. What would a text look like if it were specifically designed to speed up our ability to absorb information using this approach? Pictures of course do this already, but could we optimize word patterns for easier and faster concept retention? Hmmm...

Not far into the flight, as I was skimming my way through a technical publication using the traditional sentence-by-sentence approach, I came upon an

continued on page 42

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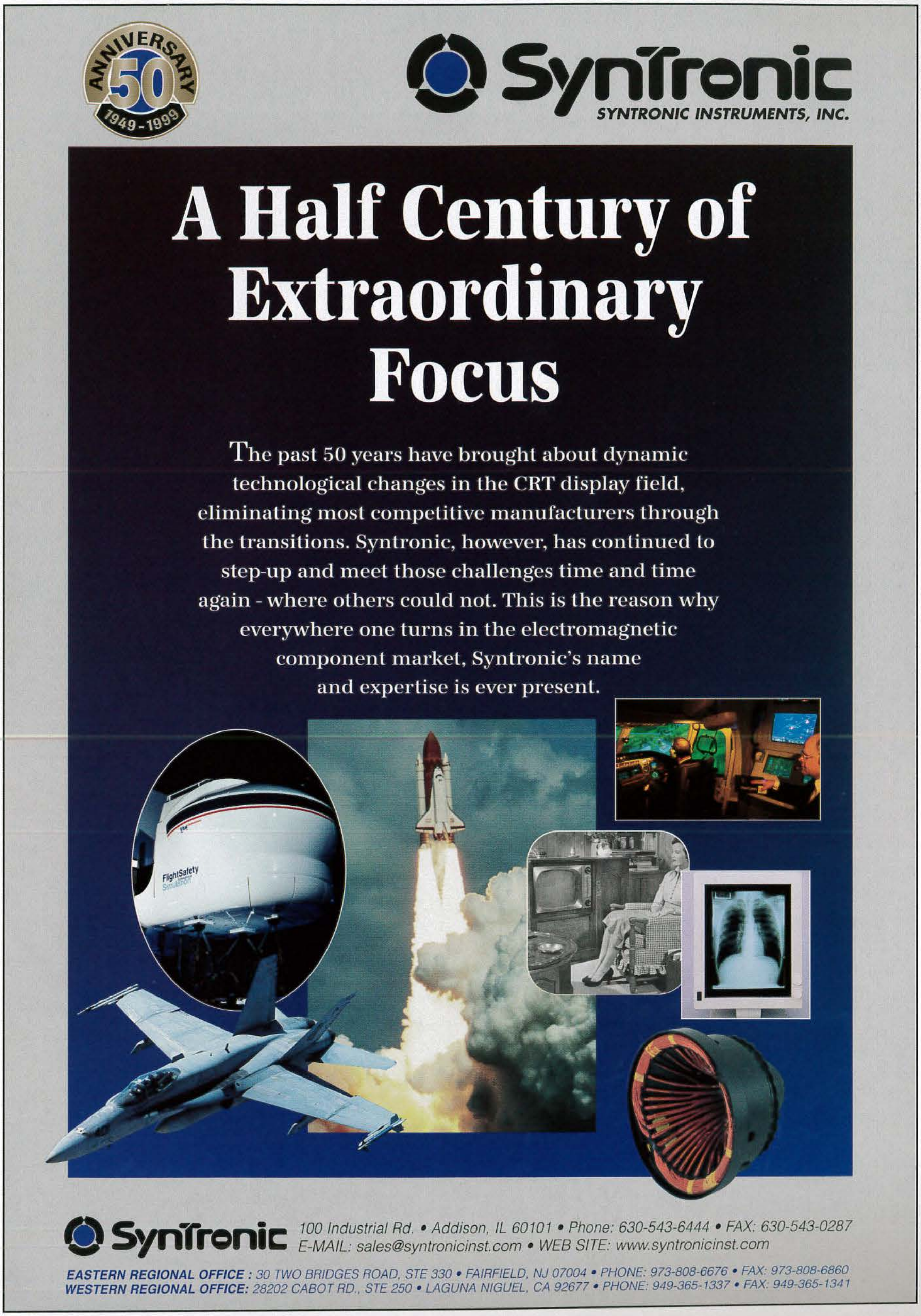
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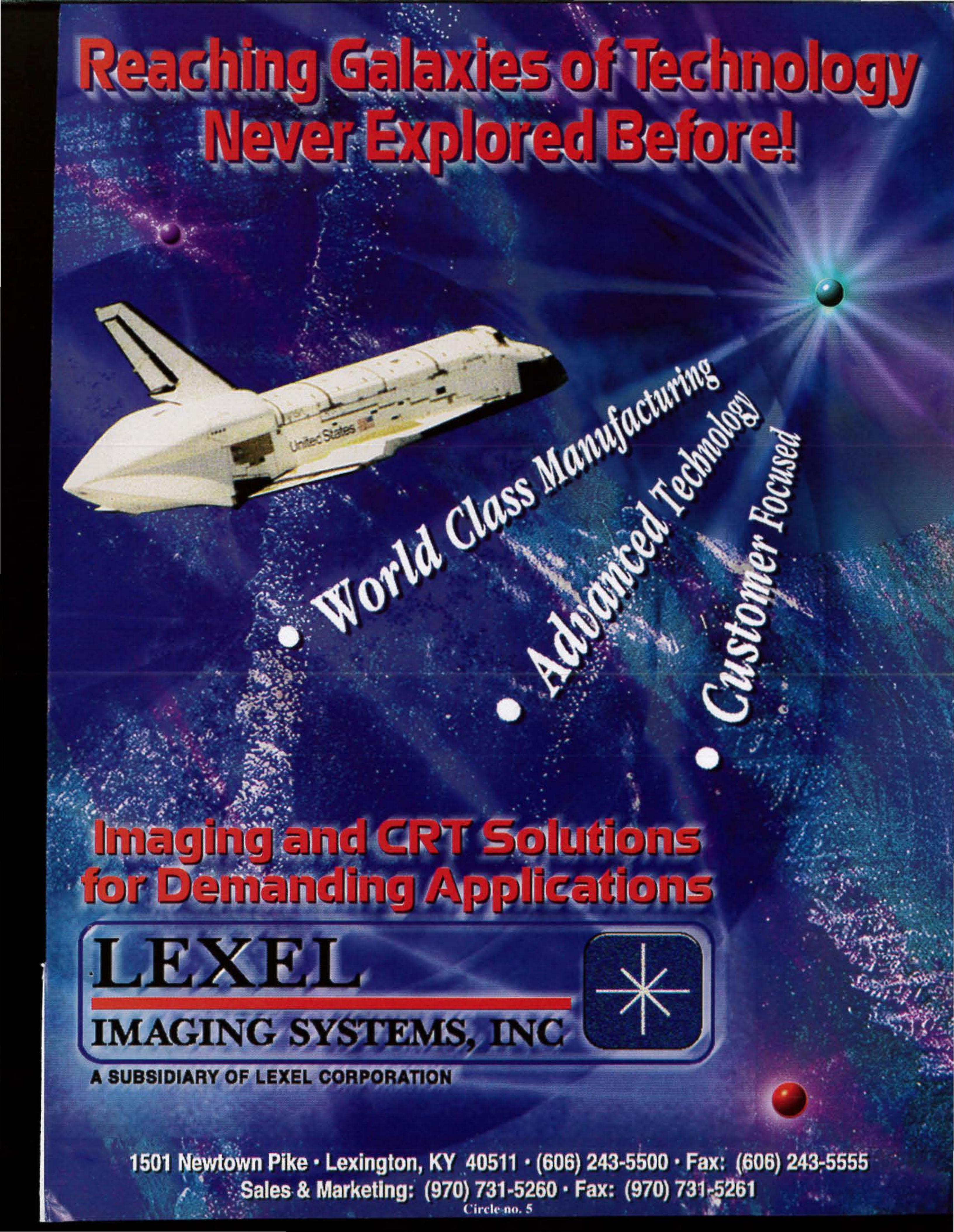
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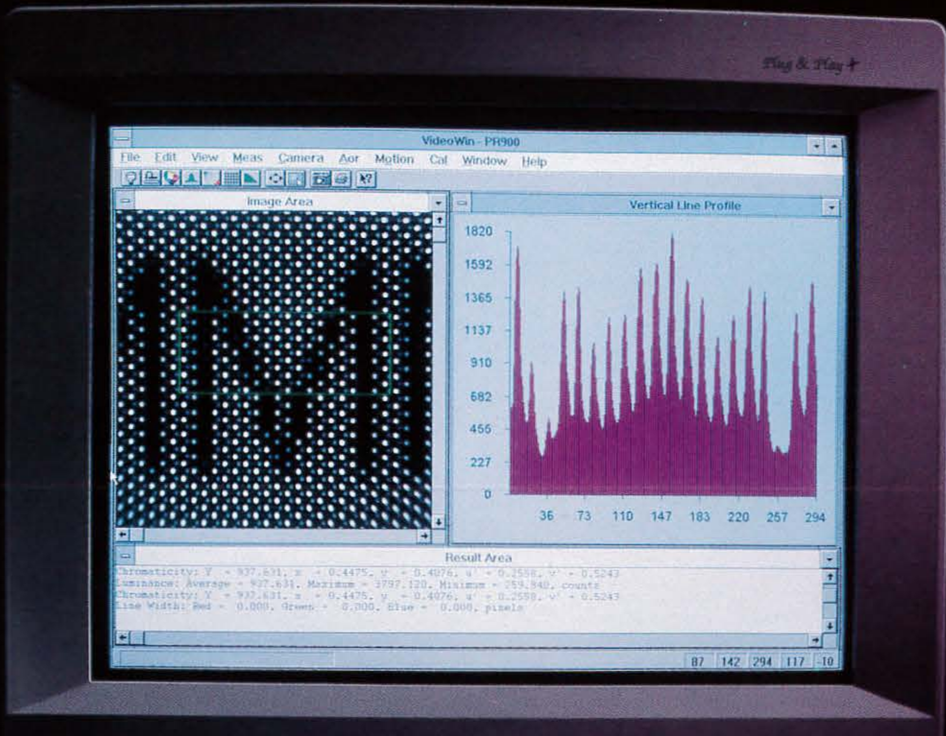

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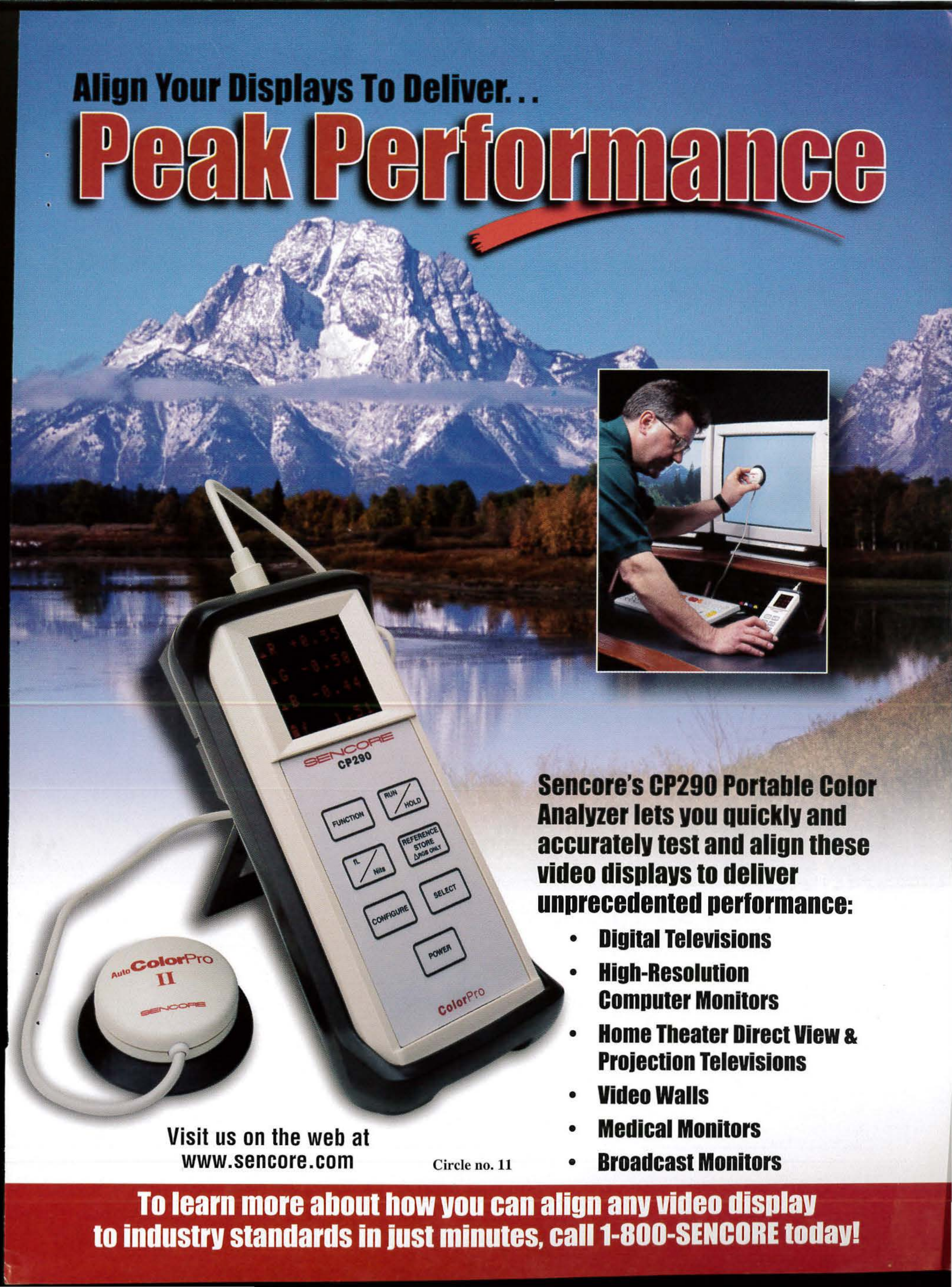
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The "Camel" CRT

In a novel CRT design, doubling the number of necks, yokes, and guns permits the depth to be cut in half. How far can we go?

by Seyno Sluyterman

When one sits in the pilot's seat of a full-motion airliner simulator, one looks out the window at a wraparound view of the world. This wide view is achieved by overlapping the images of multiple projectors on a curved screen. Why couldn't a similar approach be used to create a large cathode-ray-tube (CRT) display, using multiple sets of electron guns to paint the image across a single phosphor screen?

At Philips Components in Eindhoven, The Netherlands, we have designed just such a display. It uses two deflection yokes and two sets of guns with a single shadow mask, and the humps for the two yokes prompted the creators to give this design its name: the Camel CRT.

Why Build a Camel?

There's the old line that a camel is a horse that was designed by a committee. Why would we set out to create such a hybrid design? As it turns out, there are many advantages to this approach.

In response to competitive pressures from liquid-crystal displays (LCDs) and other new technologies, CRTs are becoming thinner and flatter. To succeed, these designs must be large enough to have an advantage over traditional CRTs, yet priced competitively. As a result, displays with a 32-in.-diagonal measurement or larger appear to be the most appropriate targets for novel CRT design.

CRTs with reduced depth can be attractive, but only if they can be made with the existing production equipment used for conventional CRTs. The cost of creating new production systems can push unit prices out of the competitive range.

Multiple gun and deflection systems provide one approach for a compact CRT. Potential drawbacks of such systems are the visual transitions between the separate areas of the screen and the lack of commonality with conventional CRTs. In the case of the Panasonic thin display,[1] success was probably limited by both the lack of commonality with CRT production and the small size of the screen. In the case of the Philips thin display,[2] there was sufficient screen size, but the chances were slim that it could ever be produced at a competitive cost.

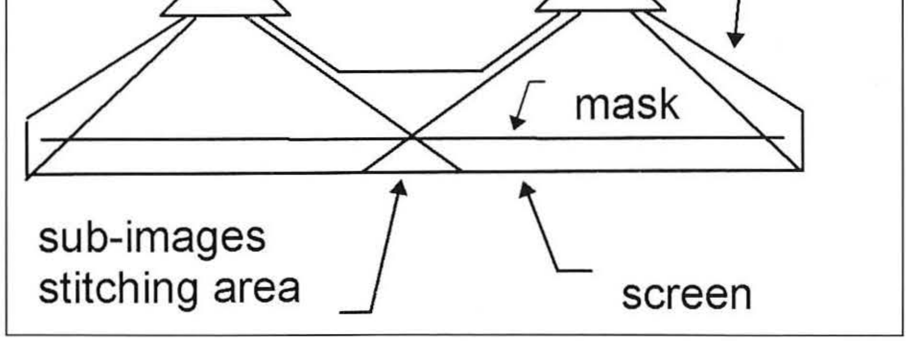


Fig. 1: *A top view of the Camel CRT shows the two wide- deflection yokes mounted on the same screen.*

Seyno Sluyterman is Senior CRT Architect with Philips Display Components, P.O. Box 218, Eindhoven, N-5600 MD, The Netherlands; telephone +31-40-278-2817; fax +31-40-278-6185; e-mail: seyno.sluyterman@comp.philips.com.

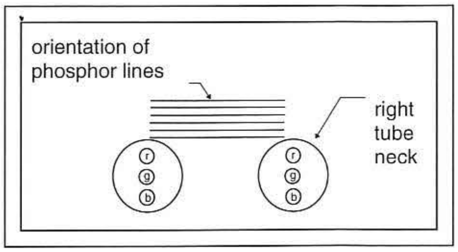


Fig. 2: In a color Camel CRT, the three electron guns are arranged vertically, at right angles to the normal striped-mask configuration.

The Camel CRT

Because we intend to apply this technology to wide-screen tubes with an aspect ratio of 16:9 and because we have set the target depth of a set at a little less than 40 cm, we concluded that it would be possible to construct a 36-in. tube using two 110° yokes side by side (Fig. 1).

One advantage of this approach over other multiple gun and deflection systems is that it produces just one transition in the screen that we have to worry about. The challenge is to stitch these two sub-images in such a way that the transition is not visible.

The purpose of our study was to see if and how these stitching problems could be solved. The experiments described here were done with a monochrome Camel CRT. Before we explore the experiments and their results, it may be helpful to first understand the layout of the proposed color Camel CRT.

Proposed Color-Tube Layout

For optimum uniformity of the CRT itself, the tube works best with just one shadow mask and with the screen processed with only one lighthouse (located between the two yokes). This can be done when we make the tube insensitive to beam landing in the horizontal direction, which can be achieved if we use a mask having horizontal slots and phosphor lines having a horizontal orientation. A further advantage of this solution is that the countermeasure (the movement of the mask towards the screen) that is normally taken to compensate for the expansion of the mask due to heating by electron bombardment is also effective for the Camel CRT.

Because color selection is now in the vertical direction, the guns have to be rotated through 90° compared with a conventional striped-mask configuration (Fig. 2). In such a tube, the problem of stitching the two sub-images can be reduced significantly by overlapping them.

When scanning this tube in a conventional manner, with horizontal scanning lines, scan moiré is likely to occur because the scan lines are parallel to the lines of the shadow mask. We therefore scan the lines vertically, which is called transposed scan (Fig. 3). This requires some conversion of the data to be displayed, but with present image-manipulation techniques this is no problem.

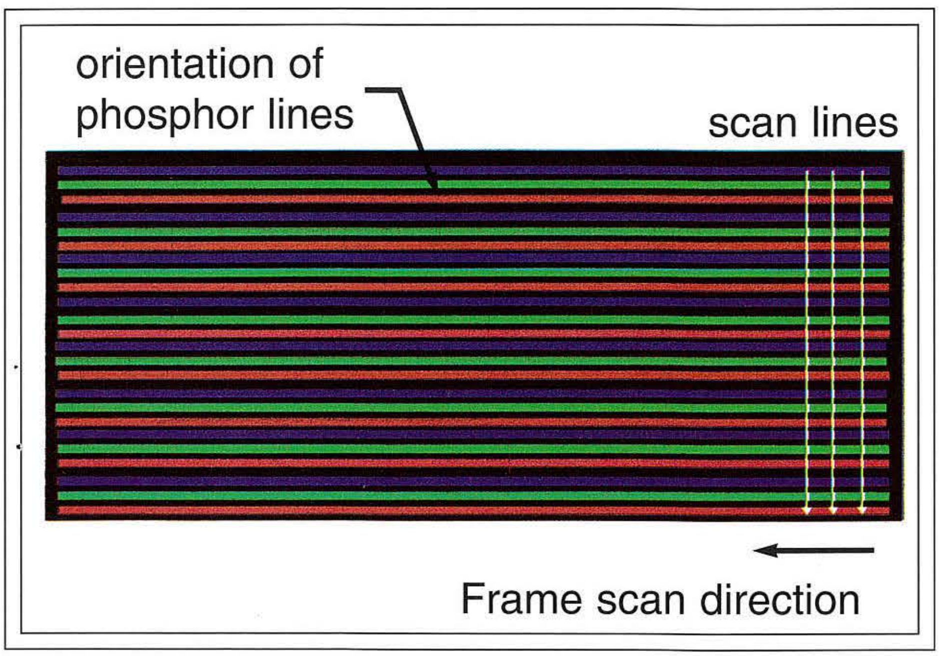


Fig. 3: The transposed orientation of the phosphor lines and electron guns requires transposed scan directions as well.

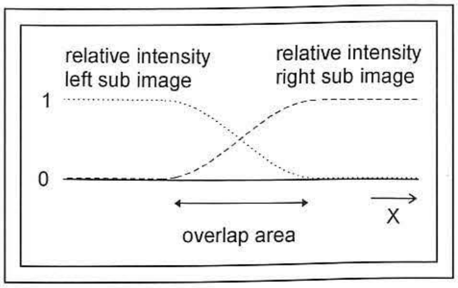


Fig. 4: The gradual relative variation of the intensities of the two sub-images helps mask stitching errors.

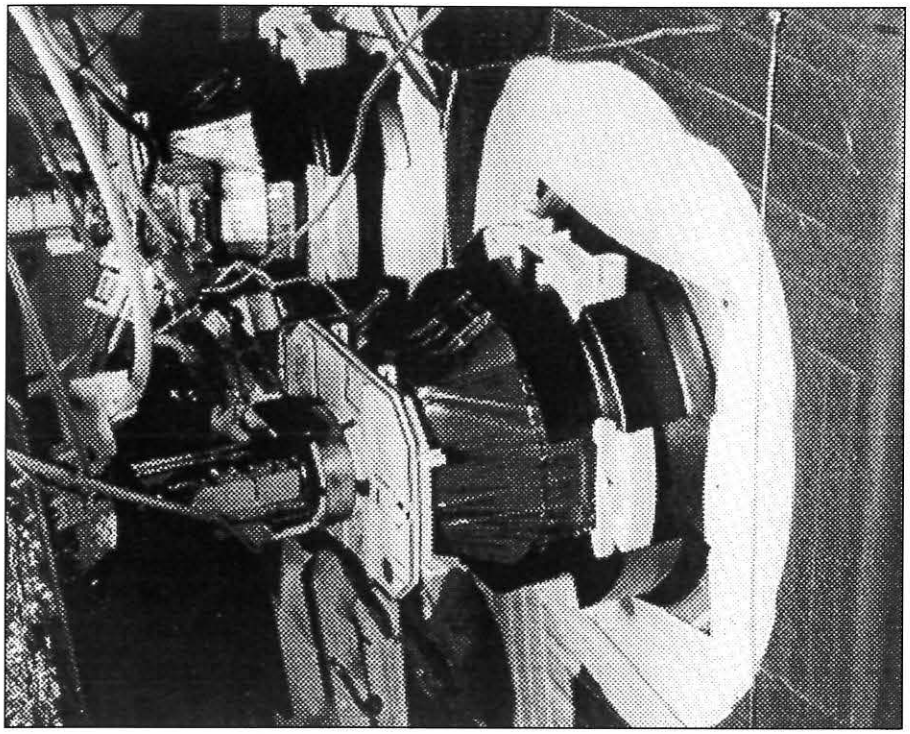
In the approach described, we have moved all the stitching problems out of the CRT and left them in the scanning area. The most critical aspect of such a design would be the required accuracy of the fit of the two sub-images.

A theoretical study was made to estimate the requirements, but we also built a monochrome Camel CRT to see the effects under various conditions.

Theoretical Expectations

It is known that in interlaced TV systems an interlace error of 10% for a 36-in. TV – corresponding to an error of less than 0.1 mm – can be seen. From that experience it was expected that the matching of the two sub-images would require an even higher accuracy – an unrealistic goal using practical techniques. We decided to examine the possibilities of reducing this accuracy requirement by creating a partial overlap of the two sub-images. The overlap of the sub-images can be optimized by making a gradual variation of the intensities of the sub-images (Fig. 4).

Under this arrangement, the right image has no intensity at the left side of the overlap and full intensity at the right end of the overlap. Conversely, the left image has zero intensity at the right end of the overlap and full intensity at the left end of the overlap. The intensity of the image is controlled by the intensity of the beams. The non-linear behavior of the phosphors plays no role as long as we make sure that the electron density is uniform. The



Philips Display Components

***Fig. 5:** The rear end of the monochrome Camel CRT shows the two deflection yokes mounted side by side.*

voltage driving the gun was derived from these considerations, taking the non-linear relation between driving voltage and beam current into account.

One criterion for calculating the stitching accuracy is the luminance variation that results from a stitching error. When we set a 5% limit for the luminance variation, we are allowed a stitching error of ±1 mm for a 30-mm overlap.[3] This is a more realistic requirement than the requirement of less than 0.1 mm expected from experience with interlace errors.

Another criterion for calculating the stitching accuracy is the maximum spatial frequency to be displayed in the center of the overlap area. The loss in modulation depth due to a stitching error is maximum in the center of the overlap area because at the center of the overlap both sub-images have an equal contribution to the image. When we add two waves with an equal wavelength but a different phase, caused by a stitching error, a new wave arises with equal wavelength but deviating amplitude. For a 50% loss in modulation depth, we can allow a stitching error of ±1/3 of the shortest wavelength to be displayed. So, if we want to display a wave with a length of 1.5 mm, which is a realistic value for the shortest wave in a practical 36-in. HDTV display, a stitching error of ±0.5 mm would be allowed. Note that this resolution loss occurs only in a small part of the image, and that this requirement is not influenced by the size of the overlap.

Next, we wanted to know how these theoretical requirements would hold for real TV-like images. For this we did some experimental work.

Experimental Work

We built a monochrome Camel CRT in which we used a glass cone. As a result, we could process this tube in the same way as we normally do with a color CRT (Fig. 5). The only difference was in the sealing of the guns, where we could not use gun-sealing machines in which the tube rotates.

We used a conventional TV chassis to drive the tube. The line coils were connected in parallel with a balance coil to control the distribution of the currents between the two yokes. The yokes were rotated around the yoke axis to rotate the scan such that the lines of the two sub-images were, at least in the overlap area, parallel to each other.

The frame coils were also driven in parallel. We used the amplitude of the vertical deflection coils for controlling the overlap of the two sub-images. At a certain stage of the investigation, we used the frame coils in anti-phase - scanning the beams in opposing directions. As a result, both sub-images were simultaneously writing in the overlap area. One advantage of this was that we could also use the dc offset of the frame deflection for controlling the overlap of the sub-images. Another advantage of scanning the frame coils in anti-phase is that we could use the trapezium correction built into the chassis - normally used for correction of east/west trapezium distortions - to eliminate the trapezium distortions arising from the curvature of the screen (Fig. 6).

The guns were driven by conventional video amplifiers, with the video signals created by a computer system. Static images were loaded into the computer system, and these images were cut into two sub-images so that both included the image part that belongs to the overlap area. The gradual-overlap functions were applied, and compensation was made for the non-linearity of the guns. The final images were stored in a memory, and the memory of the computer system was large enough to contain a sequence of images for the simulation of motion.

One of the images we used contained a set of horizontal bars with constant luminance within each bar, but with a different lumi-

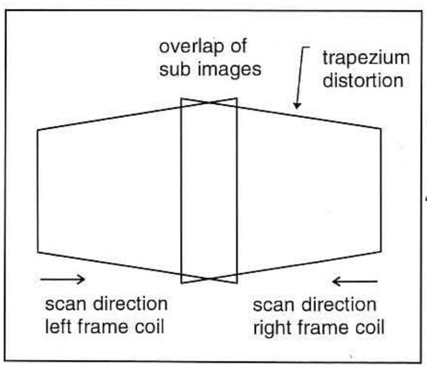


***Fig. 6:** Electronic trapezium corrections were used to align the sub-images in the overlap area.*

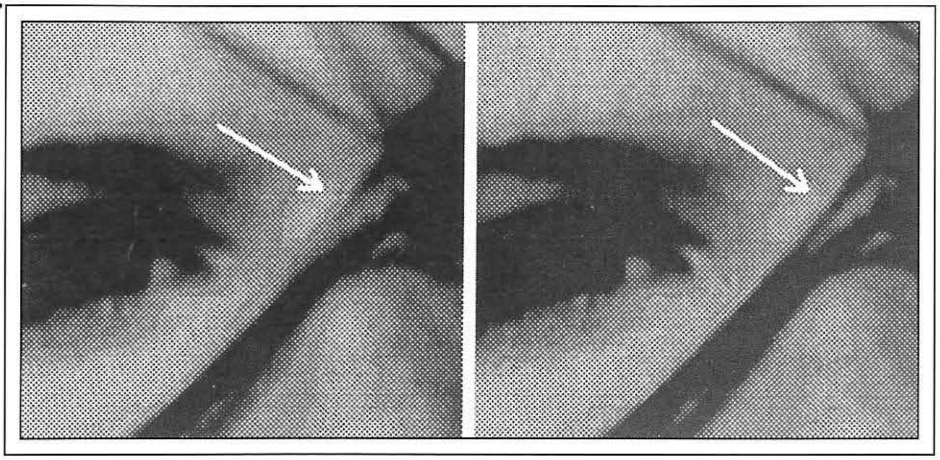


Fig. 7: The discontinuity of a hair in the left image is the result of a stitching error. The right image shows no stitching error – the hair is continuous.

nance value for each individual bar. With the aid of this image we made the gray levels of the two sub-images equal by adjusting the black level and the gain for each gun. These two parameters were enough, although the black level must be set accurately. We foresee that black-level stabilization will be needed in a practical display.

When we came to checking the required stitching accuracy, we found that we had established a luminance criterion that is unnecessarily severe whenever there are images on the screen. It turns out that one line of information is enough to distract the attention from a luminance gap or overshoot in the center of the screen. When real images were displayed on the screen we could allow stitching errors of several millimeters before they were observed. We also found that the wavelength criterion is also too severe because the original information is not known. Only when the original image is known to the viewer - and only then by thoroughly studying the result on the screen - could stitching errors be detected (Fig. 7). At a glance, these errors are not noticed at all.

In another experiment, moving objects were displayed. We noticed that the frame coils had to be scanned in anti-phase because that was the only way in which the overlap area of the two sub-images could be written by the two deflection yokes at the same time, and then no motion artifacts were visible. When the frame coils are scanned in phase, a clear discontinuity of the two sub-images was visible, especially in the case of vertical movements.

We also displayed text that moved over the screen, thus simulating scrolling subtitles. These images turned out to be the most critical because when text is scrolled horizontally a viewer can see the characters crossing the overlap one by one. The viewer can then see deformation of the characters at the center of the overlap when a significant stitching error occurs. For instance, in the middle of the overlap the horizontal width of a character can be too small or too large, depending on the horizontal stitching error (Fig. 8). These defects were not significantly different, however, from the artifacts normally seen on a display with raster linearity or geometry errors.

Comparison with an Alternative

An alternative to the Camel CRT could be a CRT with a dramatically enlarged deflection angle. Compared with that, the Camel CRT has the following advantages:

- Deflection energy and dissipation is distributed over two deflection yokes.
- The number of scan lines is already doubled, which is convenient for HDTV.
- The brightness is twice as high for a given beam current per gun. This higher brightness could be used for reducing the anode voltage of the CRT, thereby reducing the deflection energy.
- Spot deformation as a result of deflection is smaller.

A disadvantage of the Camel CRT is the required video-image manipulation, but this disadvantage will become less significant in time. The Camel CRT will certainly cost more to make than a conventional CRT because of the additional deflection yoke and electron gun. But these costs are only a fraction of the total cost of a large CRT.

Philips Display Components

Fig. 8: Horizontally scrolling text was the most susceptible to stitching errors. The stitching area is a vertical bar in the middle of the image.

Will We Ride a Camel?

The Camel CRT may be the ideal solution for large wide-screen tubes with a depth of less than 40 cm. We made a Camel-like monochrome CRT with two guns and two yokes. It showed that with a sufficient overlap of the two sub-images, the total image was amazingly insensitive to alignment errors. It also showed that motion artifacts could easily be avoided. The required real-time video manipulation is expected to be available in the near future without a significant increase in cost.

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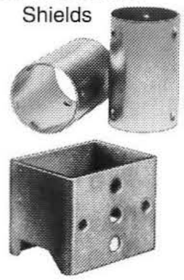

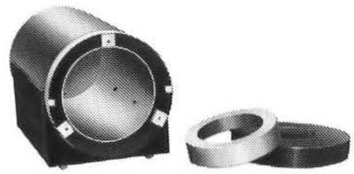
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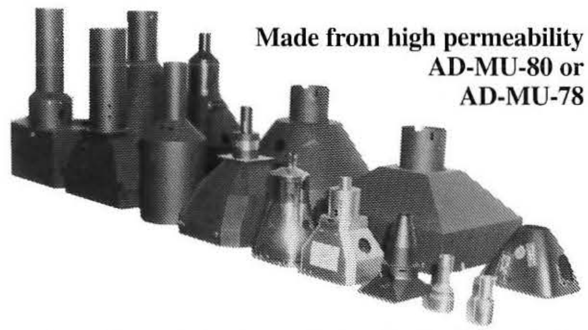

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Thermal Expansion Coefficient/°F(68°-212°F)	$7.0x10^{-6}$	$7.5x10^{-6}$	$4.6x10^{-6}$	$7.6x10^{-6}$
Thermal Conductivity ($BTU/in/ft^2/hr/°F$)	136	115	90	–
Electrical Resistivity (ohm-cir mil/ft)	349	331	290	–
Curie Temperature (F)	845	761	932	–

Typical Mechanical Properties of AD-MU Alloys

(Forming Temper – Not Annealed)

	AD-MU-80	AD-MU-78	AD-MU-48	AD-MU-00
Tensile Strength ($lbs/in^2 \cdot 10^3$)	90	85	85	45
Yield Strength ($lbs/in^2 \cdot 10^3$)	35	30	40	30
Modulus of Elasticity ($lbs/in^2 \cdot 10^3$)	32.0	30.0	24.0	29.5
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Hardness (rockwell B)	62/75	64/74	59/68	65

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High-Contrast Extended-Color-Gamut CRTs

New phosphor production methods provide increased contrast while maintaining luminance and expanding color gamut.

by Y. Han, C. W. Park, and H. G. Yang

As COMPETITION in the display industry grows more fierce, there is a growing need for much-improved image quality in Braun tubes. Current market trends demand higher contrast, larger screen sizes, and higher resolution. In order to meet these challenges, we have developed a new Braun tube which has high luminance contrast, a semi-dark-tinted appearance, and superior color gamut.

In a conventional color CRT, highly tinted glass is used to increase contrast; this does decrease the reflection of ambient light, but the luminance of the phosphor screen is severely compromised. Samsung's new high-contrast CRT uses glass with higher transmittance (Fig. 1). Heavily pigmented red, green, and blue phosphors are coated with pigments of corresponding colors; the resulting phosphor screen selectively absorbs certain wavelength ranges. This arrangement affords a low screen reflectance without reducing screen luminance significantly.

Luminance and Contrast Ratio

The contrast ratio of a CRT depends on the luminance and on the intensity of the ambient light reflected by the glass surface and the phosphor screen:

$$CR = 1 + L_t/L_a(R_s + R_p)$$

where L_t is the luminance of the CRT, L_a is the intensity of the ambient light, R_s is the phosphor-screen reflectance, and R_p is the glass-surface reflectance. The actual equation is more complicated and depends on the incident angle of the ambient light, but this simplified version will suffice for the purposes of this article.

For typical panel glass, the surface reflectance is 4.4% at a 30° incident angle of ambient light. Reflectance by the phosphor screen varies with panel transmittance and with the ratio between the areas of the black matrix and the phosphor dots. For a semi-tinted panel with 53% transmittance and 40%

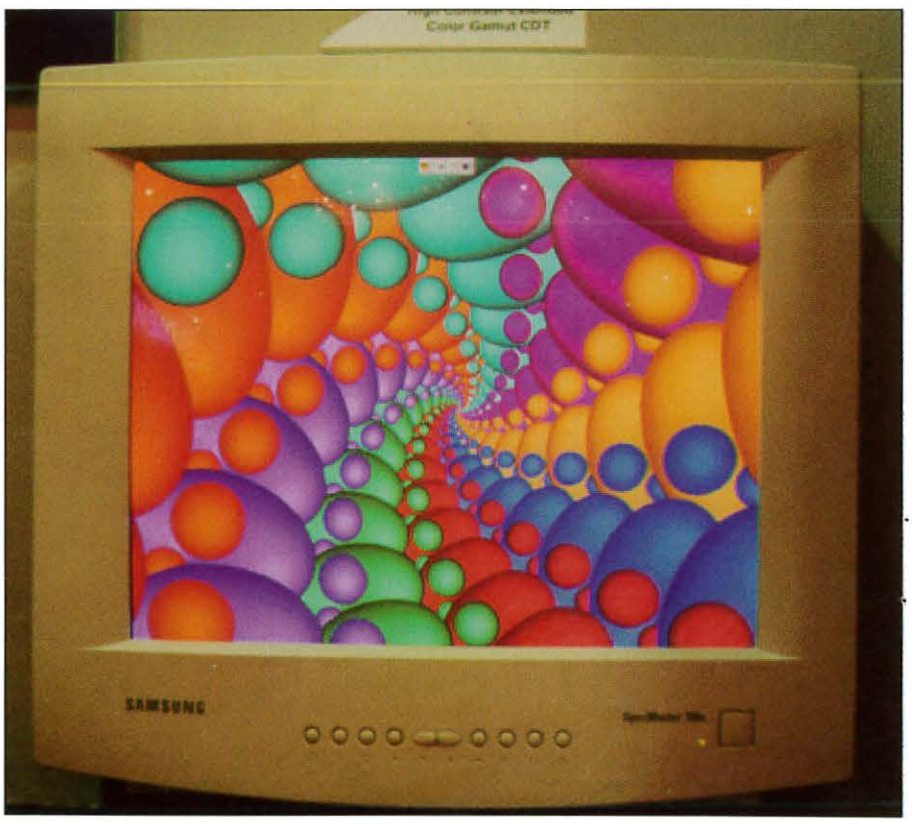

Fig. 1: *Samsung's new CRT has high contrast and an extended color gamut.*

The authors are with Samsung Display Devices, Fundamental Materials Technology Lab, 575, Shin-Dong, Paldal-Gu, Suwon City, Kyungki-Do 442-391, Korea; telephone +82-331-210-7959; fax +82-331-210-7799; e-mail: hanyong@sdd.samsung.co.kr.

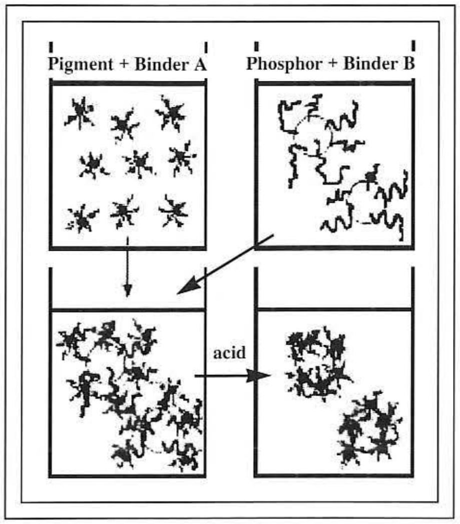

Fig. 2: The binder-adsorption method developed for the high-contrast-phosphor CRT allows more pigment to be applied to phosphors than conventional methods.

phosphor dot area, the average surface reflectance of the conventional and the high-contrast phosphor screens are 4.8 and 3.8%, respectively.

Pigmentation by Binder-Adsorption Method

Phosphor screens are formed by spin-coating a phosphor slurry containing appreciable amounts of surfactants and dispersants. Because the phosphor slurry is stirred for several hours prior to screening, pigment peel-off is quite a common phenomenon. This turns out to be much more problematic for high-contrast phosphors because of their higher pigment content (4–6 times higher than conventional phosphors).

This problem made it necessary to develop a new pigmentation method. Simply increasing the amount of binder did not work because this caused agglomeration among pigment and phosphor particles. Two kinds of binders were used. Binder A acts as a dispersant for the pigment, while Binder B acts as a dispersant for the phosphor. Furthermore, the two binders can cross-link with each other in the presence of an acid. Our solution was to adsorb Binders A and B onto the pigment- and phosphor-particle surfaces, respectively, by separate aging processes. The two suspensions were then mixed together, followed by the addition of an acid (Fig. 2).

Scanning electron micrographs (Fig. 3) of conventional and high-contrast blue phosphors reveals the additional pigment on the surface of the high-contrast phosphors. These images also show the uniform distribution of the nano-sized pigment - particles are less than or equal to 0.1 μm - on the high-contrast phosphor.

The degree of pigment peel-off was assessed by a semi-quantitative comparison. After 24 hours of stirring, the phosphor slurry was centrifuged for 5 minutes at 2500 rpm, and the supernatant was diluted by a factor of 20. This solution was analyzed with a UV-visible spectrophotometer. The degree of pigment peel-off can be determined with a series of solutions having predetermined concentration.

For green and red phosphors, the degree of departing pigment was insignificant for both conventional and high-contrast phosphors. For blue phosphors, however, there was a dramatic difference between conventional pigmentation and the binder-adsorption method (Table 1). In the case of high-contrast phosphor using the binder-adsorption method, no significant peel-off was observed, with a pigment content of 4.0% even after 36 hours of vigorous stirring.

High-Contrast Phosphor Reduces Reflectance

Phosphor screens with various pigment contents were characterized to determine the optimum pigment concentration required to reduce reflectance (Fig. 4). The luminance of the phosphor powder was measured with a demountable CRT and was found to be approximately linear with respect to pigment content. The optimum pigment concentration was determined on the basis of white luminance, current-density ratios of the RGB electron guns, and the contrast ratio of the CRT.

High-Contrast-Phosphor Screen

The surface properties of high-contrast phosphor are quite different from those of conventional phosphors because of the high degree of pigmentation. The heavily pigmented phosphor particles tend to have weaker adhesion to the glass panel. This was overcome by overcoating the pigmented surface with trace amounts of colloidal silica particles. In the

Table 2: Comparison of Various 17-in. CRTs

Panel type	Dark-tint	Semi-tint	Semi-tint
Transmittance	43%	53%	53%
Phosphor type	Conventional	High contrast	Conventional
Luminance	100%	113%	118%
Reflectance (relative)	7.5% (100%)	8.2% (109%)	9.6% (128%)
Contrast-ratio enhancement	100%	104%	92%

Table 1: Percentage of Pigment Peel-Off in Phosphor Slurry

Duration of stirring	Conventional pigmentation (1.0%)	Conventional pigmentation (4.0%)	High-contrast phosphor*
12 hours	11.5%	34.8%	1.3%
24 hours	14.5%	38.3%	1.0%
36 hours	24.5%	49.8%	1.8%

*Pigmentation of 4.0% by binder-adsorption method.

Table 3: Comparison of the Primary-Color Coordinates and Color Gamut of Conventional and High-Contrast CRTs

	Conventional		High-Contrast	
	x	y	x	y
Red	0.631	0.325	0.660	0.310
Green	0.292	0.596	0.264	0.614
Blue	0.143	0.068	0.142	0.056
Color Gamut (relative)	100%		118%	

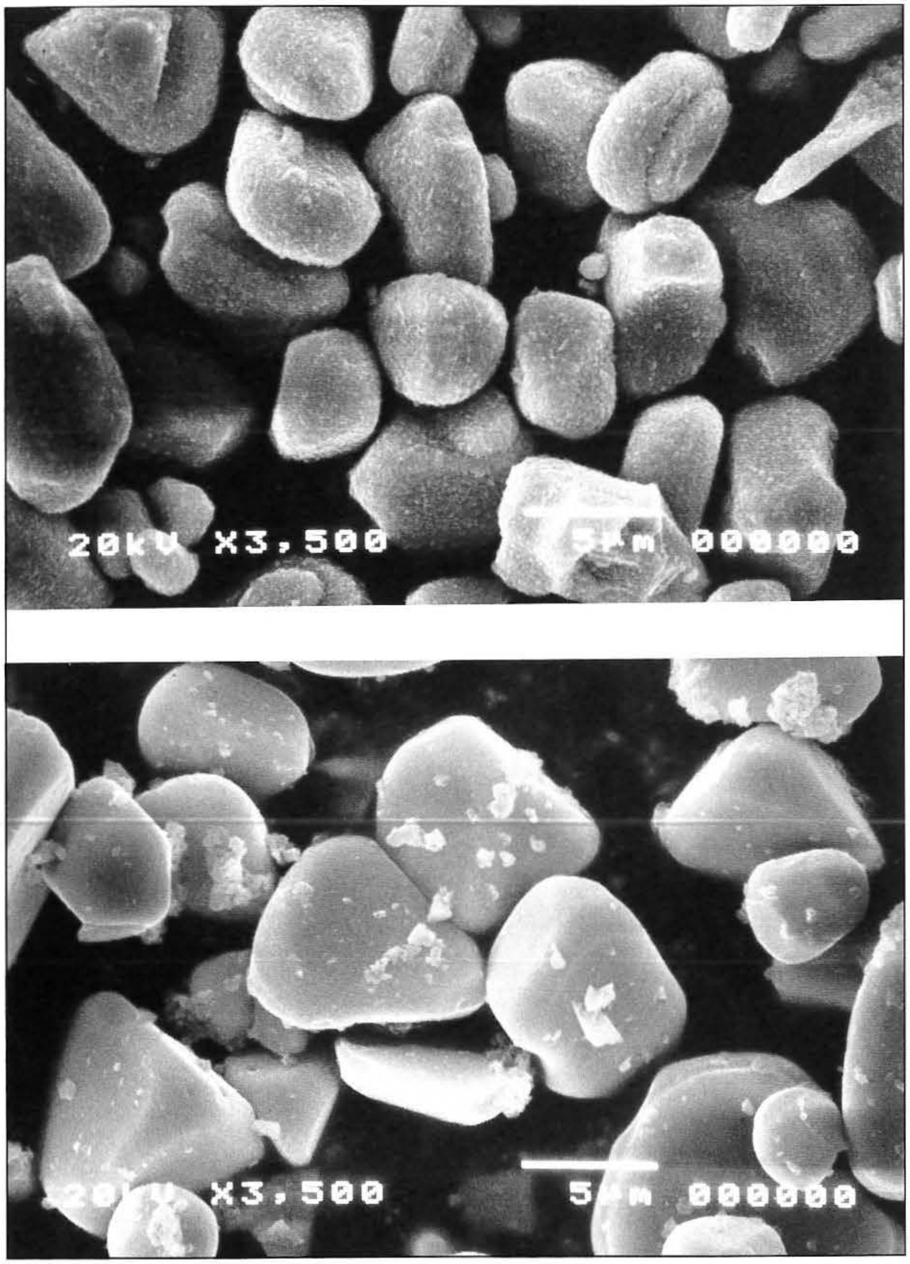

Fig. 3: Scanning electron micrographs of high-contrast (top) and conventional (bottom) blue phosphors show about 4% pigmentation for the high-contrast phosphors compared with 1% for the conventional phosphors.

case of the red phosphor, however, this proved to be insufficient, primarily because red pigment (Fe_2O_3) is a fairly efficient UV absorber. Since UV is used to harden the photoresist to form the desired phosphor-screen pattern, the presence of a UV absorber inhibits the pattern formation. We found that the photosensitivity of the photoresist has to be doubled to compensate for the iron oxide, which we accomplished by adding an adequate sensitizer to the slurry.

The surface treatment and the sensitizer made it possible to create the enhanced phosphor screens (Fig. 5). Fewer pinhole defects

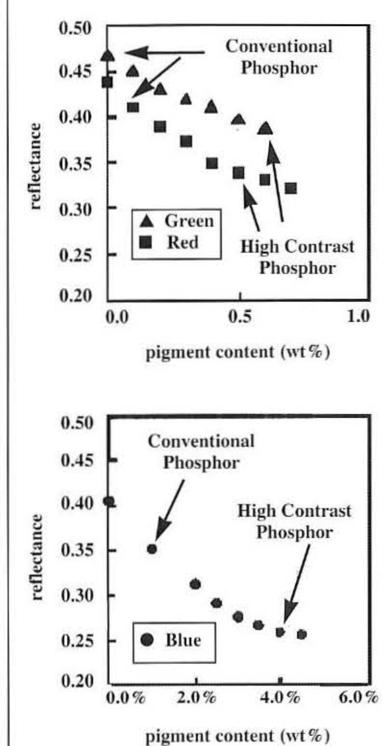

Fig. 4: The reflectance of the screen depends in part on the pigment content of the phosphors.

are observed in the high-contrast-phosphor screen than in the conventional phosphor screen.

Our new CRT delivers contrast equivalent to a darkly tinted glass screen while maintaining a luminance equivalent to a semi-tinted glass screen (Table 2).

Extended Color Gamut

One additional benefit of this new high-contrast-phosphor design is an increase in the color gamut. When the three primary-color coordinates of the conventional and high-contrast-phosphor CRTs are compared, the color gamut of the latter is 18% higher (Table 3). The color gamut was calculated from the primary-color coordinates. Since luminance usually decreases with increasing gamut, this is a significant improvement.

For CRTs to maintain their dominance in the display industry, CRT technology must continue to advance. The utilization of high-contrast phosphors prepared by the binder-

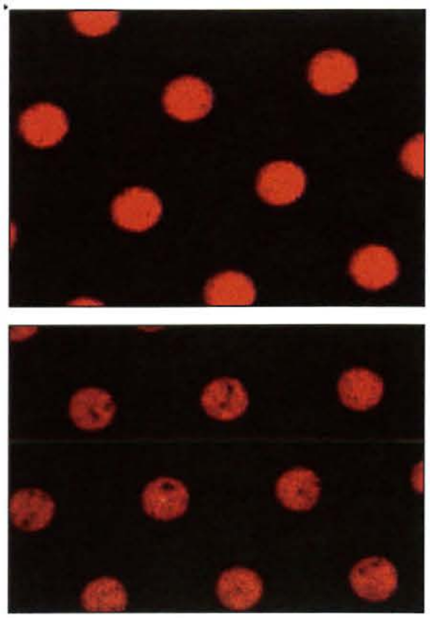

Fig. 5: Comparison of the high-contrast-phosphor screen (top) and a conventional phosphor screen (bottom) shows fewer pin-hole defects in the high-contrast phosphors.

adsorption method not only provides a brighter display image with greater contrast than conventional phosphor technology, but also an extended color gamut and a reduction in pinhole defects in the screen. ■

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Do Direct-View CRTs Make Sense for HDTV?

A simple analysis from the perspective of the eye's visual acuity indicates we can't see the difference between SDTV and HDTV on a 34-in. screen at typical viewing distances – but we can.

by Robert Donofrio

THE DIRECT-VIEW CATHODE-RAY TUBE (CRT) is experiencing a dramatic transformation from today's NTSC TV device to a device that displays the Advanced Television Study Committee (ATSC) Digital Television (DTV) formats - otherwise known as Standard Definition Television (SDTV) - and then to High Definition Television (HDTV).

As this transformation progresses, the CRT is (conceptually) being stretched from its present 4:3 aspect ratio to DTV's and HDTV's 16:9 aspect ratio. In addition, the yoke deflection angle must change as the tube size increases, from the 90° used in 19V (19-in. viewable diagonal) 4:3 tubes to about 110° for 27V (4:3) and 38V (16:9). In some cases, manufacturers are making two tubes with the same screen size, but with one having a finer triad line pitch for improved resolution.

Robert L. Donofrio is the President of Display Device Consultants, 6170 Plymouth Rd., Ann Arbor, MI 48105; telephone 734/665-4266; fax 734/665-4211; e-mail: rldonofrio@aol.com.
Part of the work described in this article was done for the McLaughlin Consulting Group's (MCG's) HDTV Project. The author thanks Chuck McLaughlin for allowing him to use this material. The author also thanks Frederick Fayolle, Mark Dorogi, and Dave Elder of Philips Display Components; and Sterling Owens, Kevin Trompak, and Patrick Dunn of Thomson Consumer Electronics for the development, product, and viewing-demonstration information they provided. Notwithstanding this generous assistance, the author's opinions are his own and not those of MCG, Philips Electronics, or Thomson Consumer Electronics.

For HDTV, the largest 16:9 CRT is currently 38V. Being digital, the signal to the receiver will generally provide a lower-noise video signal and a sharper picture. In addition, the CRT will be capable of displaying a higher-resolution image by increasing the scan from 480i (480 scan lines, interlaced) to 480p (480 lines, progressive scan), 720p, and 1080i. These higher-resolution tubes require better electron guns and deflection yokes.

If HDTV images were to be shown on CRTs in today's most popular sizes (25V and 27V), they would not look significantly better than pictures shown in SDTV at the typical viewing distance (in the U.S. and Europe) of about 9 ft. The eye's ability to appreciate the higher-resolution image that is being displayed depends on how close the eye is to the screen. (Display engineers are well known for moving closer and closer to a CRT until they can discern the raster lines, but that is not typical behavior for viewers in general.)

When we think about displaying and viewing HDTV images on direct-view CRTs, several questions arise.

Can HDTV Tubes Be Made?

HDTV tubes are clearly manufacturable (Fig. 1). Tubes with a 16:9 aspect ratio have been made in Japan since 1990. In 1994 Matsushita manufactured a range of HDTVs, the largest being 36 in. (Model W86KYP895X). Both Philips and Thomson are making 16:9 tubes in Europe, and, according to John van Raalte (formerly of Thomson, and now with Philips), Thomson in France made a 16:9 HDTV tube prior to 1992.

Currently, Thomson is completing a line in their Marion, Indiana, plant to fabricate 38V

Table 1: Comparison of the Diagonals of 4:3 and 16:9 CRTs with Similar Image Heights

	Approximate Image Height (in.)				
Aspect Ratio	**19**	**16.5**	**15**	**12.5**	**11**
4:3	31V	27V	25V	20V	19V
16:9	38W 38V (W97)	34W 34V (W86)	30W 30V (W76)	26W 26V (W66)	22W 22V (W56)

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Fig. 1: Philips' 16 × 9 HDTV tube shows what the new generation of direct-view television tubes can do.

tubes - the industry's largest HDTV 16:9 tubes - at a cost of $20 million. Thomson expects to ship these tubes late in 1999. The company will also manufacture 34V tubes in the Marion plant. Thomson's 38V tube has been reported to have a 0.78-mm pixel pitch and to be capable of 1280 × 1080i resolution. Philips manufactures 16:9 CRTs in Aachen, Germany, and Sony manufactures its 34W ("W" for wide) 16:9 tube in California.

Thomson has a version of its 38V 16:9 tube for SDTV with 0.9-mm pitch (instead of 0.78 mm) and an aluminum-killed iron mask instead of an Invar mask. This tube will allow Thomson to sell 38V television receivers at a more affordable price than present large-screen CRT HDTV sets.

How Do 16:9 Tubes Look?

The picture on the new 16:9-aspect-ratio sets are not as tall for a given tube diagonal as the image to which viewers have become accustomed on the standard 4:3 sets. The height of a 34V 16:9 tube is close to that of a 27V 4:3 tube (Table 1). This reduction in expected height was readily observed at Display Works 99, where Sony presented a side-by-side comparison of their 34W 16:9 tube and their 36V 4:3 tube.

Tube designations get a bit complicated, primarily because manufacturers have not yet agreed on a common way of describing them. For instance, Thomson calls its new 16:9 tube a 38V (W97), while Philips calls it a 38W. The worldwide designation for wide tubes is "WXX," where XX is the diagonal screen size in centimeters. Thus, Thomson's 38V is a W97, and has a screen diagonal of 97 cm, or 38 in. Not confused yet? We'll try harder. A final complication is that in Europe a W97 tube is considered a 40-in. tube, since Europeans measure the diagonal of the entire tube face, not just the viewable screen.

Digital-TV Options

HDTV operates under the new ATSC standards rather than the old NTSC standards, which has major consequences for the CRT (Table 2).

The analysts at Stanford Resources believe that the last two formats in the table - which are suitable for the average viewer with a digital conversion box - will be around for a long time.[1] Based on our calculations, they will be adequate for the direct-view CRT's normal viewing distances of 3-5 times the screen diagonal.

The Limit of Visual Resolution

It is often said that a visual element must subtend an angle of at least 1 minute of arc at the eye for reliable detection, but Sol Sherr states that, for optical reasons, the actual limit is closer to 2 minutes of arc.[2] ISO Standard 9241-3 puts the minimum at 1.7 minutes for concentrated viewing. A value of 2.2-2.4 minutes is preferred, and this permits relaxed viewing. Using the 2-minute resolution criterion for a CRT viewed at 6 ft., we would just be able to observe a screen pitch (the distance between the centers of the green phosphor lines) of 1.06 mm. Today's 27V 4:3 television-grade CRT, with a screen pitch of 0.70 mm, falls well within this limit.

This analysis can also be applied to raster-line resolution. Using the 2-minute criterion, it would not be possible to resolve any pixel array finer than 625 × 352 on a 30-in. (16:9) screen viewed at 6 ft. This means that a viewer would not see any benefit from the HDTV 1920 × 1080 and 1280 × 720 formats.

The resolution data clearly indicate that, because the majority of TV sets presently used have 25V and 27V tubes, the 704 × 480 SDTV digital-TV format will be more useful for the majority of viewers than HDTV. This issue generates a lot of controversy in the broadcasting world because the use of this

Table 2: Options for Transmitting under the New ATSC Digital Television Standard

Aspect Ratio	Horizontal Pixels	Vertical Lines
16:9	1920	1080
16:9	1280	720
16:9 or 4:3	704	480
4:3	640	480

lower format would allow the broadcasting of more "channels" of programming for each 1920 × 1080-spectrum channel.

Calculating Observable Resolution

We can calculate the observable pitch (P_O) and, therefore, the resolution (pixels) observable for various tubes with 16:9 aspect ratios. The data was obtained by simply dividing the horizontal and/or vertical picture size by the observable pitch for the various viewing distances.

Table 3, which assumes the 2-minute resolution criterion, indicates that even with a 38W tube, a vertical resolution beyond 480 lines is not needed for a 6 ft. or greater viewing distance. Putting it another way, SDTV at 480 lines, either progressive or interlaced, is adequate for direct-view TV at normal viewing distances. HDTV is more appropriate for projection systems than for direct-view systems.

These conclusions are not revolutionary. In early 1992, John van Raalte wrote, "NTSC resolution is as good as human beings can appreciate on a 25V receiver at 8–9 ft."[3]

So, we've demonstrated that there is no reason to think about better-than-SDTV resolution for direct-view TV receivers under 38V, right? Not exactly. We haven't considered MTF yet.

Personal Observations and MTF

Observations at the Thomson Consumer Electronics booth at the Consumer Electronics Show in Las Vegas in January provided some very interesting results. Thomson showed moving pictures in the 1920 × 1080 and 1280 × 1080 HDTV formats and the SDTV 704 × 480-format 38V, 34V, and 30V sets. The image improvement was visible on all sets at normal viewing distances when going to the higher scan frequencies. Thomson personnel reported that the image sharpness could be seen to improve substantially from 704 × 480 to 1280 × 1080, and to improve a bit more when going from 1280 × 1080 to 1920 × 1080. As criteria for image sharpness, they reported sharper edges and crisper borders. Doesn't this contradict the careful analysis we just made in the previous section? Not really.

In image sharpness, we know that resolution is not the main factor, but a quantity called the modulation transfer function (MTF). MTF was first used in optics and photography, and then applied to TV in the 1970s by a number of people, including the author of this article.[4]

Briefly, it is the shape of the MTF response curve that's important for image sharpness and not the high-frequency limit (which is usually called "resolution"). The MTF of a CRT can be determined by taking the Fourier transform of the electron beam's intensity distribution where it impinges on the phosphor screen.[5] So the electron beam's shape is an important parameter of MTF image sharpness. (As a system-response parameter, the MTF is a function of the receiver electronics, yoke, and CRT.) The maximum response of the human eye occurs at a spatial frequency well below the resolution limit. So both the spot size and the electron beam's generated-luminance intensity distribution are important factors in image sharpness.

Table 3: Calculation of Observable Pitch (P_O) and the Number of Raster Lines (or Pixels) for Various 16:9 Tube Sizes and Viewing Distances

			Calculated Minimum Observable Pitch				
			3 ft.	5 ft.	6 ft.	9 ft.	12 ft.
		P_O (in.)	0.0209	0.0349	0.0419	0.0628	0.0838
		P_O (mm)	0.53	0.89	1.06	1.59	2.13
Viewable tube size	**Picture dimensions (mm)**		**Observable Resolution at Viewing Distance**				
38W	841 (H)		1587	945	794	529	395
	473 (V)		892	531	446	297	222
34W	750 (H)		1415	843	708	472	352
	422 (V)		796	474	398	265	198
30W	662 (H)		1249	744	625	416	311
	373 (V)		704	419	352	235	175
26W	575 (H)		1085	646	542	362	270
	324 (V)		611	364	306	204	152
22W	488 (H)		921	548	460	307	229
	275 (V)		519	309	259	173	129

Challenges for 16:9 Tubes

The technology is in hand to make the current generation of 16:9 tubes, but there are some technological challenges to face in building tubes of greater performance.

Screen pitch. This is an important parameter because it determines the ultimate pixel size that may be addressed on a CRT. The screen pitch is directly related to the mask pitch. Not surprisingly, finer-pitch screens are generally more difficult to produce. The Thomson 38V tube comes in two screen pitches. The 0.78-mm screen pitch is for the 1080i or 720p, and the 0.9-mm pitch is for the 480p and 480i. Thomson's 34V also comes in two pitches: 0.70 and 0.89 mm.

Deflection yoke. Thomson Consumer Electronics uses a saddle/saddle yoke designed for 2.14H and 3H scan operation (where H is the scan frequency of 15,750 Hz used in NTSC) for the 38V 16:9 tube (108° deflection). These yokes can run at high frequency without excessive heat. In addition, convergence error is reduced, which is particularly important in the corners of the screen.

Philips Display Electronics uses its patented double-mussel deflection yoke on its 110° DTV tubes. The double mussel comes into its own because of the excellent fit between its performance attributes and the demanding requirements of HDTV. Dave Elder of Philips in Ann Arbor, Michigan, has stated that the popular saddle/toroid yokes are hampered by their simple but inexpensive winding technology, which does not permit a high degree of vertical field modulation along the path of the electron beams.

It is the magnetic-field modulation, which is a function of the yoke geometry, that makes it possible to correct convergence errors over the entire tube screen. The mussel-shaped coils, which do not have the rear flare seen in saddle/saddle designs, can be moved along the axis of the tube. This allows the designer to fix the relative position of the horizontal and vertical coils where the best convergence and raster geometry performance is achieved. The double-mussel yoke also has a high degree of deflection sensitivity, which translates into lower energy losses in the yoke - an important factor for systems with high scan rates.

Electron gun. The electron gun consists of a heater cathode assembly and a series of grids to electrostatically - and in some cases magnetically (with stunts) - shape the electron beam. The higher-resolution 38V Thomson product uses the COTY-MDF dynamic-focus electron gun and "Beam Scan Velocity Modulation." In this system, a separate coil driven by a separate current is used to reduce horizontal spot size.

Cathodes. Philips has developed the avalanche cold cathode (ACC), a silicon-based technology that provides (1) instant on/off emission, (2) reduced power consumption, and (3) small electron spot with high current. This technology may contribute to HDTV when commercialized.

Flat screen. Philips has developed a new "Real Flat" wide-screen tube with a design that optimizes the inner-screen contour to eliminate the "hollow appearance" seen with other flat tubes. This design also reduces panel-glass weight. In January 1999, Philips showed 32-in. WSRF "light-and-play" samples in Europe.

Gun-pitch modulation (GPM) for flat HDTV. Another Philips development is GPM, which permits a very flat inner-panel contour. In this technology, the pitch of the electron gun (the distance between the center electron beam and the outboard beams) is varied as a function of deflection. The gun pitch is changed by means of a dynamic quadrupole that is placed over the gun, and the convergence is restored by means of a second quadrupole that is wound toroidally around the core of the deflection unit. GPM is compatible with the double-mussel yoke.

Conclusion: Direct-View HDTV Will Fly!

The HDTV tubes now being made (and in development) will bring 16:9 wide-screen digital viewing to average viewers. If tubes with the picture heights of current 25V and 27V tubes continue to be the highest-volume types, then viewers will probably not need the image resolution of the 1920 × 1080 or 1280 × 720 formats, and SDTV's 704 × 480 will be adequate. But actual viewing results reported by Thomson indicate that MTF is determining image sharpness, and that improved image sharpness has been observed for sizes of 30V and up. There are a number of new technological advances, such as "Real Flat" wide screens, high-sensitivity beam-scan velocity modulation, gun-pitch modulation, and the avalanche cold cathode, which give a flatter tube geometry and improved picture quality. Some of these advances are being used now and some may be used in HDTV CRTs of the future.

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conference report

EID '98 Celebrates Display Integration and Commerce

What Great Britain and Europe lack in display manufacturing, they make up for in clever integration and vigorous merchandising.

by Bryan Norris

The Society for Information Display held its annual Electronic Information Displays (EID) show at Sandown, U.K., November 17–19, 1998.

EID consists of a single-track technical conference coupled with an exposition that gives manufacturers the chance to show their latest LCD monitors - especially those intended for use in industrial environments. The product highlights of the show will be discussed below, and will be followed by a brief review of the technical conference's keynote addresses.

LCDs for Industrial Applications

Calibre, a small company based in Bradford, U.K., and previously specializing in CRT products for niche industrial markets, launched a series of open-frame LCD monitors featuring 12–15-in. XGA-resolution TFT panels with on-screen displays and integral analog video interfaces. The monitors support a range of standards, including XGA, VGA, SVGA, NTSC, PAL, and SECAM. RGB, YC, and composite inputs are supplied, as is automatic input-signal detection. They also feature optical-quality scaling methods to present a 1024 × 768-pixel image regardless of the input resolution. Calibre had also launched an upgraded universal interface card for TFT-LCDs, featuring an auto-scanning input that accepts standard and non-standard signals. All signals are shown full-screen at maximum panel resolution.

Living up to its company name, ***Elo TouchSystems*** introduced the TrimLine range of three touch-screen active-matrix LCDs (AMLCDs). The range comprises a 640 × 480 12.1-in. model, an 800 × 600 14.1-in. model, and a 1024 × 768 15-in. model, all of which offer a horizontal viewing angle of 140° and use IntelliTouch touch-screen technology. Elo is also partnering Philips in the development of touch-screen products, so Elo offered an IntelliTouch surface-acoustic-wave version of the Philips Brilliance 151 AX LCD, a 15.1-in. TFT from Philips/Hosiden. This version will be aimed at point-of-information and retail markets, while an AccuTouch five-wire resistive version will be aimed at the medical, finance, banking, and point-of-sale markets.

This year ***CTX Opto Europe*** had a stand on which it promoted its extensive 10.4–15-in. range of Panaview LCD models. And ***Anders***

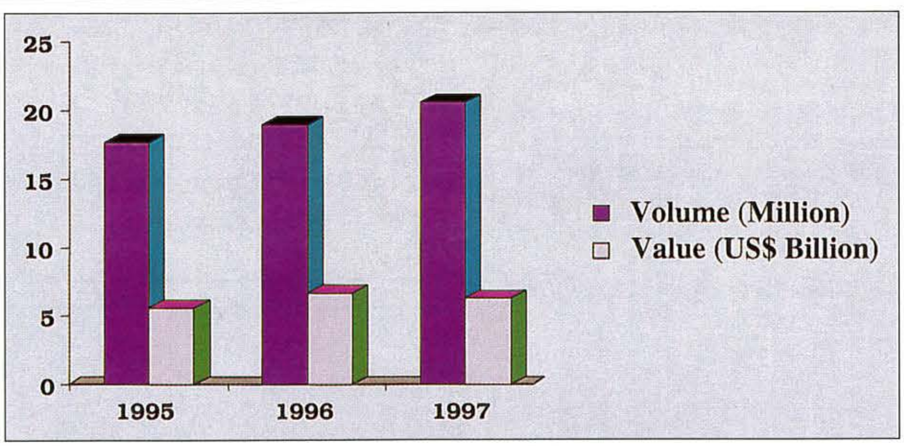

Fig. 1: *A steady growth of 7–8% in the number of color CRT monitors sold in Western Europe each year resulted in 1997 sales of 20.6 million units. (Source: Bryan Norris Associates)*

Bryan Norris *is the Senior Partner and founder of Bryan Norris Associates, Consultants in Electronics, 7 Biddenham Turn, Biddenham, Bedford MK40 4AT, U.K.; telephone +44-(0)-1234-26-7988; fax +44-(0)-1234-26-2345; e-mail bnorris@kbnet.co.uk. They specialize in all aspects of VDU markets in Europe and provide the highly respected VDU Vision market-analysis service. Mr. Norris is a contributing editor to* Information Display Magazine.

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	Germany	UK
14 in.	4%	31%
15 in.	37%	39%
17 in.	50%	26%
19 in.	3%	1%
21 in.	4%	2%
Others	2%	1%

Fig. 2: The two largest European national markets for color monitors are very different, as indicated by their contrasting profiles of unit sales as a function of screen diagonal. (Source: Bryan Norris Associates)

Displays, a unit of ***Anders Electronics*** (London, U.K.), was offering the LM151X1 15.1-in. XGA display panel from ***LG Semicon*** which is suitable for kiosks, EpoS, and CRT replacement in office environments. The device offers a 250-cd/m^2 brightness; a viewing angle of 120° (H), 90° (V); and a replaceable twin-CCFL backlight assembly. Buyers have a choice of built-in LVDS or PaneLink™ interface.

Displaze introduced the Z range of color flat-screen display modules, which can be housed as desktop monitors or integrated into OEM systems. Each module comprises an enclosure, an interface card, and an LCD panel. They use the ***NEC*** range of TFT-AMLCD panels from ***Sunrise Electronics,*** providing a choice of sizes ranging from 10 to 18 in.

As well as promoting its range of low-cost fast-response STN panels, ***SEI Macro*** launched the new ***Sharp*** 18.1 TFT-LCD panel, intended for use in computer monitors, which has SXGA resolution, 250-cd/m^2 luminance, wide viewing angle, and a high contrast ratio of 300:1.

Sanyo was concentrating less on luminance and more on expansion. The brochure for the company's LMU-TF191A1 18.1-in. LCD monitor boasted that the model offers automatic image-size adjustment with edge-smoothing technology to ensure high-quality full-screen images. VGA, SVGA, XGA, and SXGA images are all displayed full-screen automatically, and are crisp and clear even after expansion.

Craft Data showed a stylish 12.1-in. LCD monitor from the Korean ***GTT*** (an offshoot of LG) and reported that 14.1- and 15.1-in. models would soon be available, followed by an 18.1-in. model during the first quarter of 1999.

Plasma Rising

Craft Data was also promoting the world's first touch screen for a 42-in. plasma display. This infrared product from ***Carroll Touch*** is initially intended for the Fujitsu plasma monitor.

Another plasma first was found on the ***Delphi*** stand, where the Direct Digital Plasma display was being shown. This is a modified digital version of ***Fujitsu's*** Plasmavision 42-in. display, and the monitor is the first to allow broadcast-quality video to be shown directly onto the screen. The image is a true digital image, not converted to analog. Delphi proclaimed it had installed "over 1000 plasma monitors to date," principally in the U.K.

A new U.K. company, ***Plasma Screen Company,*** was displaying a 50-in. plasma monitor from ***Pioneer*** – the PDP-501MX,

Cost conscious	Technology conscious	In-betweens
UK	Switzerland	Austria
France	Germany	Netherlands
Greece	Sweden	Belgium
Italy	Norway	
Portugal	Finland	
Spain	Denmark	
Ireland		

Fig. 3: When national purchasing characteristics are illustrated on a map of Europe, the geographical pattern is absurdly apparent. The technology-conscious countries are dark blue; the cost-conscious countries are light blue; and the "in-betweens" are, indeed, in between. (Source: Bryan Norris Associates)

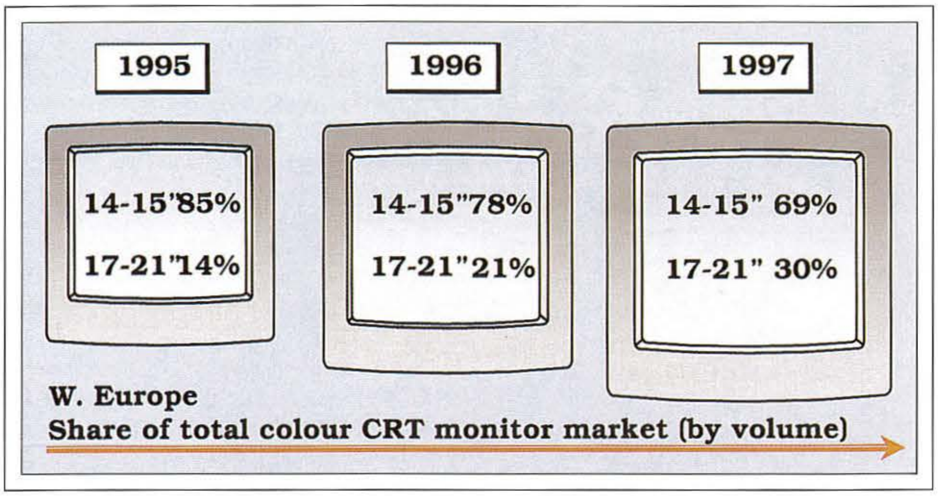

Fig. 4: The second major trend has been for monitor purchasers to buy larger, more sophisticated models. (Source: Bryan Norris Associates)

Because of rapidly falling LCD prices, the worldwide market for FPDs was projected to be only $14 billion in 1998, $17 billion in 2000, and $26 billion in 2004 - substantially less than the most optimistic estimates of $40 billion in 2000 that were being made by some analysts in 1994. By contrast, said Castellano, the CRT market is projected to be $24 billion in 2000 and $26 billion in 2004. So 2004 is now projected as the historic cross-over year when the FPD market finally equals the CRT market. But this is a milestone that has been 5 years away in each of the last 5 years.

Edward Stupp of Stupp Associates spoke on "Projection Displays: What Next?" and examined consumer, presentation, large-venue, electronic-cinema, and desktop products.

And the writer of this article spoke about changes in the Western European monitor scene, about which we will now say much more.

with XGA resolution, an aspect ratio of 16:9, and a depth of only 6 in. - for £11,995/ US$19,800 (twice the price of the 40-in. V-401E). The accessories include an SXGA graphics card, a tilting wall or ceiling bracket, desk stand, and 12-W stereo speakers.

Even ***PD Systems International,*** known for its large-screen CRT products, reported it was working together with ***NEC*** to introduce a 42-in. plasma model to the market. The company was again showing its range of large-screen CRT Colourmaster intelligent display monitors, in both standard and wide-screen formats, which are primarily intended for airport information units.

The EID exhibition is useful and has its own orientation. If you are interested in the latest FPD technologies, particularly in industrial environments, a trip to Sandown Racecourse in November is well worthwhile. It's certainly easier to pick out product winners at the EID show than it is winning horses on the track!

The Technical Program

As always at EID, a conference was held each day at the show to review the worldwide display industry.

Three keynote addresses were given on the first day of the conference. Joe Castellano of Stanford Resources presented a talk entitled "Display Markets: Facts & Fantasies," which exploded the myth that LCDs would dominate the displays market in the very near future.

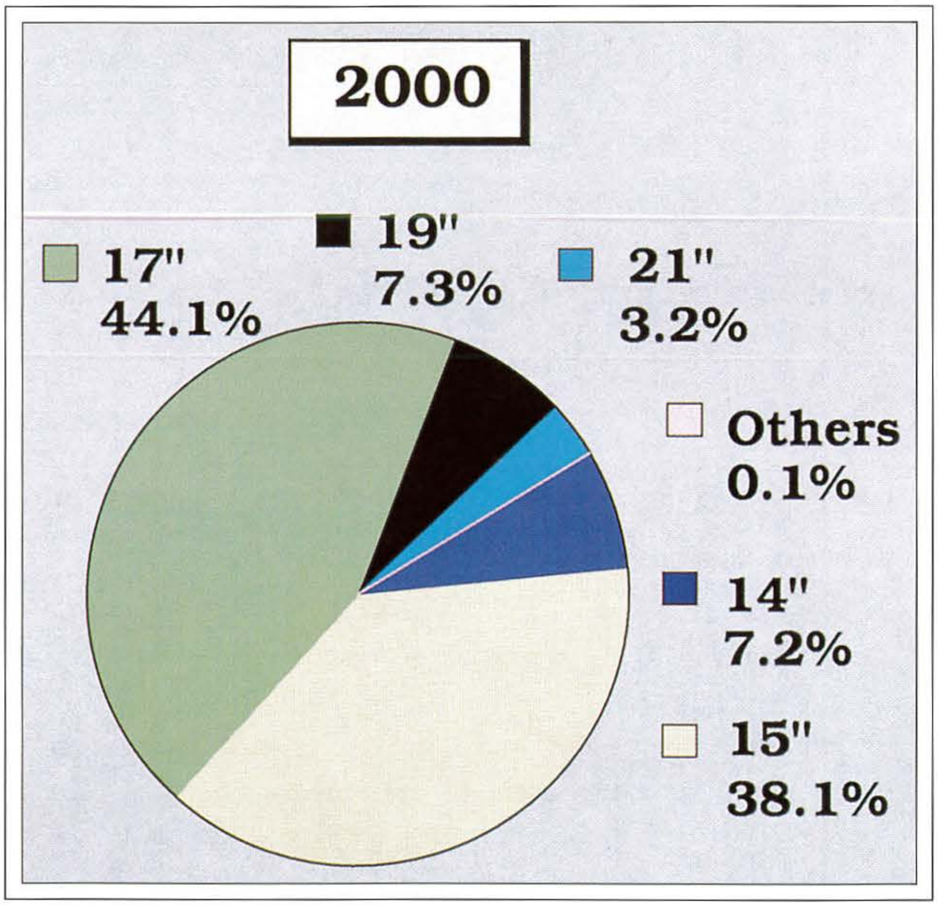

Fig. 5: By the end of the year 2000, 17–21-in. color CRT monitors will account for 55% of the volume market in Western Europe, overtaking the smaller-size categories. (Source: Bryan Norris Associates)

Monitor Trends in Western Europe

Over the last few years, Western Europe has witnessed various trends in the monitor industry, the most obvious being the growth of the market. There has been a steady growth of 7-8% in the number of monitors sold each year, so that by 1997 Western Europe saw sales of 20.6 million monitors (Fig. 1). But in terms of value, the market saw a 6% decline between 1996 and 1997 as a result of falling monitor prices and the strength of the U.S. dollar. During the period 1995-1997, the U.K. was the only country whose currency kept pace with the dollar in terms of exchange rate, which obviously affects any estimates that use the dollar to value the overall European market. Using the dollar as an international common denominator as been an almost inevitable tactic in the past, but European valuations may soon be based on the new Euro, which should lessen the effect of exchange-rate fluctuations.

About 80% of the monitor market is accounted for by the top six of Western Europe's 16 countries - Germany (25%), the U.K. (20%), France (13%), Italy (9%), Netherlands (7%), and Spain (5%) - with Germany and the U.K. representing nearly half the total market. Therefore, it's no surprise that many new or emerging monitor players begin by concentrating their efforts on these two countries.

There's No "United States" of Europe

Monitor companies entering the two largest markets in Europe have to be wary of adopting the same approach in each country. The two markets are, in fact, very different, which is starkly illustrated by comparing how the volume sales of color CRT monitors broke down by screen size in Germany and the U.K. during the first half of 1998 (Fig. 2).

In the U.K., the smaller screen sizes accounts for a much greater proportion of the market; and there is also a noticeable difference in the number of 17-in. monitors sold in each country. Seventeen-inch units accounted for half of monitor sales in Germany, but for only one-quarter in the U.K.

Indeed, every country in Europe has a unique screen-size "profile" because buyers in each country have a different set of priorities when it comes to choosing a monitor. But in carrying out comparisons, one can discern purchasing similarities that allow the countries of Europe to be grouped into three broad categories: the technology-conscious (Switzerland, Germany, Sweden, Norway, Finland, and Denmark), the cost-conscious countries (the U.K., France, Greece, Italy, Portugal, and Spain), and the "in-betweens" (Austria, The Netherlands, and Belgium).

Buyers in the technology-conscious countries tend to be concerned primarily with the display's technical and environmental specifications. So, for example, in the second half of 1997 the favorite type of monitor in Switzerland was a high-end 17-in. model with TCO '95 ecology/energy/ergonomic/emission certification. Buyers in the cost-conscious countries tend to be interested in the price first and foremost, and then consider what specifications come with the price tag. A TCO rating, for example, may tilt the purchase decision - but only if there's no extra charge. Not surprisingly, consumers in the in-between countries tend to balance specifications and price.

When the three country categories are illustrated on a map of Europe (Fig. 3), the geographical pattern is absurdly apparent.

Larger Markets, Larger Screens

Apart from market growth, the other major trend has been the move by monitor purchasers to buy larger, more sophisticated models (although to varying degrees in the different markets) (Fig. 4). Units with 14-in. screens declined dramatically in their share of the overall color CRT market (by volume) from 60% in 1995 to 29% in 1997. In technology-conscious countries, the 14-in.-screens share is now down to just a few percent. But in countries where the end-user is still most concerned about price, sales of 14-in. models are still appreciable.

Seventeen-inch models make up most of the sales in the larger-screen-size category. Their volume share of the overall Western European color CRT-monitor market has increased from 12% in 1995 to 27% in 1997. The 19-in. model was successfully launched in the second half of 1997, though supplies were restricted until the last few months of that year.

Not surprisingly, the trend towards increasing sales of larger screen sizes is expected to continue. By the end of the year 2000, 17-21-in. monitors will account for 55% of the volume market, overtaking the smaller-size categories (Fig. 5).

Monitoring Some Other Monitor Trends

Of course, monitor manufacturers haven't been concerned only with increasing screen sizes. They've also been trying to improve technical capabilities and decrease the overall size of their CRT monitors. So, new tube technologies are continuously being introduced, the most significant in the last 3 years probably being the Hitachi 19-in. FST, new aperture grilles from Sony and Mitsubishi, and the Matsushita ZenTan 100° "short neck" (but really shorter length) tube.

Manufacturers are also adding features or approval specifications to their products. A survey of CRT models available in Western Europe taken in July 1998, compared with a similar survey in July 1997, shows an increase in the incidence of models with TCO '95 and

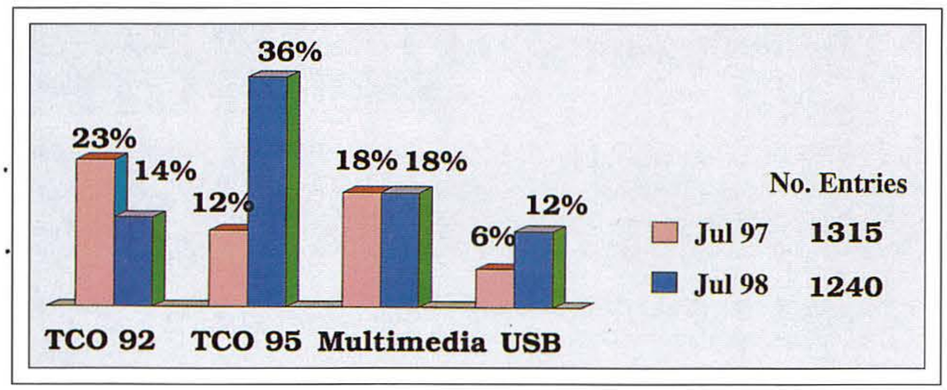

Fig. 6: Manufacturers are adding features or approval specifications to their products. Surveys of CRT models available in Western Europe taken in July 1997 and July 1998 show an increase in the incidence of models with TCO '95 and a USB option. (Source: Bryan Norris Associates)

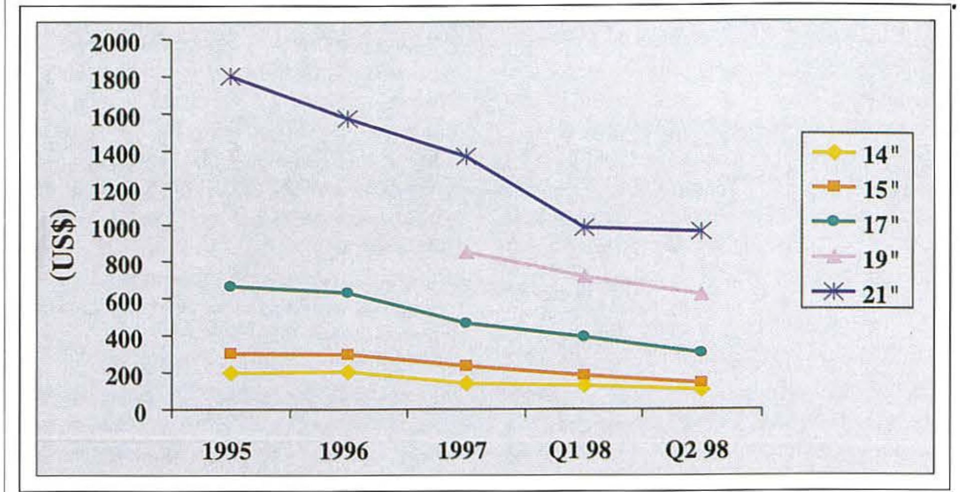

Fig. 7: Price drops have been steep even for high-end large-screen models. (Source: Bryan Norris Associates)

a USB option (Fig. 6). (TCO '95 will be succeeded by TCO '99, which has now been introduced. The first batch of TCO '99-approved monitors was announced prior to EID). Manufacturers, particularly in the "technology-conscious" countries, are also having to keep abreast of other standards, such as ISO 9241-7, which sets maximum levels for reflections.

In addition, environmental laws are increasingly important. Recycling targets, for example, have already been set in Germany and Switzerland for the disposal of old monitors.

All of these improvements are having to be introduced at a time of growing competition and falling prices. Price drops have been steep even for high-end large-screen models (Fig. 7). There was a sharp drop in selling prices of 17-in. models during 1997 and 1998 as new 19-in. models were being introduced.

The Latest Monitor Development – LCDs

In 1995 and 1996, LCD-monitor sales represented a tiny proportion of the total VDU market. But 1997 saw LCD-monitor sales increase significantly, although their overall share of the market remained small. In 1997, sales of LCD monitors were concentrated in the markets of Germany (taking 31% of European LCD sales), the U.K. (27%), Sweden (18%), and Switzerland (12%). The most popular LCD screen sizes are likely to be 14/14.1, 14.5, and 15/15.1, and the new 18/18.1-in. models also promise to become popular.

Over the next few years, LCD-monitor sales are expected to increase dramatically, so that in 1998 they should make up around 1% of the total European VDU market, and by 2000 they may account for around 7%. So, just as Joe Castellano pointed out in his talk, there's definitely some way to go before LCDs dominate the displays market! ■

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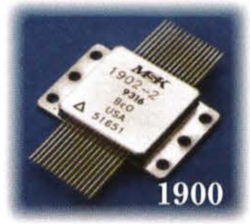

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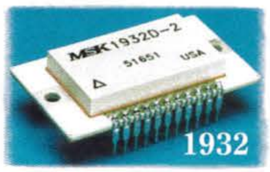

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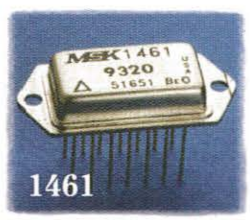

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"TVs for Nothin', Pixels for Free"

The promise of lots of cheap pixels continued to fuel excitement about microdisplays at Display Works 99, but manufacturing and integration of direct-view displays still defined the mainstream.

by Ken Werner

DISPLAY WORKS 99 was held February 1-5 in San Jose, California, but the main activities started on Tuesday, February 2, with the Display Works Business Conference sponsored by the U.S. Display Consortium. [Display Works 99 was jointly sponsored by three leading display organizations: the Society for Information Display (SID), Semiconductor Equipment and Materials International (SEMI), and the U.S. Display Consortium (USDC).]

A highlight of the morning session was a panel discussion moderated by Chuck McLaughlin (McLaughlin Consulting Group) entitled "Applications for Miniature Displays in Personal Displays." McLaughlin led off the discussion with a self-running slide show of microdisplay applications set to music by Dire Straits, but with McLaughlin's recorded voice singing his own lyrics: "TVs for nothin', pixels for free."

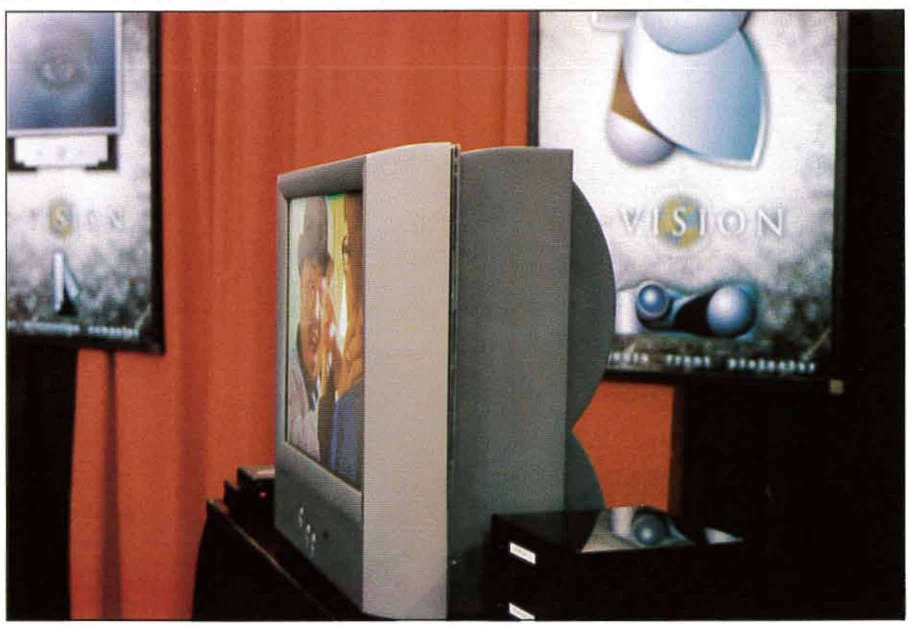
That rollicking opening set the tone for much of what followed, with McLaughlin declaring, "Microdisplays are a potentially disruptive technology," with an SVGA display costing only a few tens of dollars and consuming less than 100 mW.

Frank Canova (Director of Hardware Engineering, Palm Computing) stimulated the rest of the panelists by saying that microdisplays don't work for Palm. "We need to simulate what people see on a laptop with a stylus interface. So how can we do that with a microdisplay?"

Joy Weiss (President and CEO, Siliscape) saw opportunities for microdisplays and a reply to Canova in a *Fortune* article predicting that PC-free computing and high-bandwidth portable devices are two of the big growth areas in the coming years. "Palm is strong in the first of these categories. We'll see a variety of different form factors and appliances. People will not want a 3-in. black-and-white display as their only display," she said.

Mark Wilner (President and CEO, Colorado Microdisplay) agreed that microdisplays really don't fit the Palm paradigm, and added, "The viewer/headset issue has not been fully sorted out yet."

Following the panel discussion, John Medica (VP, Worldwide Procurement, Dell Computer) pushed the benefits of standardization of supplies and cooperation between systems houses in his presentation, "The Power of Vir-



Ken Werner

S-Vision showed a 24-in.-diagonal 12-in.-deep 25-lb. rear-projection television demonstrator using three of the company's XGA microdisplays.

Ken Werner is the Editor of Information Display Magazine; *telephone 203/853-7069, fax 203/855-9769, e-mail: kwerner@netaxis.com.*

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Ken Werner

Sony's 34-in. 16:9 flat-screen Trinitron™ HDTV was producing a beautiful image at 1080 lines interlaced. (The dark horizontal band on the screen is a photographic artifact and was not actually present on the screen.)

tual Integration." When asked if this approach wouldn't lead to even more commoditization of monitors, he replied that Dell has gotten out of 14- and 15-in. CRTs, and that Dell wants to lead the technology transition to flat-panel monitors (FPMs). But the component cost projections they've been depending on are "now out the window." High prices will make FPMs a niche product, Medica continued. Keeping prices up on panels can be a "suicide position." He concluded by observing that CRT and FPM cost curves do not cross in an interesting way, and that the 2X premium for FPMs will not happen this year.

Projections, Players, and Cycles

Following the lunch break, Ross Young (President, DisplaySearch) predicted that FPD sales will match those of CRTs for the first time in 2005. (At the press-only Press Breakfast on Wednesday morning, David Mentley of Stanford Resources demurred, saying the curves would cross in 2004.)

The "crystal cycle" - the sort of periodic mismatch between the sizes of LCDs the industry can make efficiently and what its customers (primarily notebook-computer makers until now) will buy - will have its next minimum in 2001, said Young, but it will not be as extreme as in 1995 and 1998. "The cycle will lengthen in the future due to the reluctance of notebook makers to go larger than 12.1 in. in large quantity and the falling out of STN-LCDs as a viable alternative. And it will moderate due to FPM volume."

Young predicted an LCD shortage from mid-99 through 2000, but FPM growth will slow in 1999 because of price strengthening. He noted that notebook penetration paused in 1998 because of price stabilization and the introduction of sub-$1000 desktop PCs. But he predicts the trend of increasing penetration will resume. "The outlook for TFTs is now becoming promising, while the STN-LCD business no longer looks attractive," Young said.

As a result, 1999 and 2000 look like good years for makers of manufacturing equipment. IBM, for instance, wants to buy fourth-generation equipment in Q4 '99.

But for the recent past and present, equipment makers have been living through dark days. Their one bright spot has been Taiwan, which is in the process of creating a substantial AMLCD industry (in addition to its already substantial small TN/STN business). Julie Mei-Ling Chen (VP, Marketing and Sales, Prime View International) outlined the rationale for building this industry, and provided details about the plans of the leading players: Prime View, Unipac, Chi Mei, Acer Display, HannStar, and Chunghwa. The bottom line: by Q1 2000 Taiwanese manufacturers will be able to produce 166,000 substrates per month, with sizes ranging from 370 × 470 mm (Prime View) to 600 × 720 (Unipac and Acer) and even 620 × 750 (Chi Mei). The new players alone (that is, excluding "old-timers" Prime View and Unipac) have invested US$3 billion as initial capital - and paid bargain rates for equipment and technology alliances.

Stephen Cohen (Co-Director, Berkeley Roundtable for International Economics) went out of his way to convince the audience that at least one practitioner of the "dismal science" has a mordant sense of humor. Among the observations he made in his presentation "Asia One Year Later":

- The nature of a crisis is that things don't return to where they were.
- The large capital inflow to Asia fueled excessive expansion. The folks in Asia thought they had permanently stable currencies. When it turned out they didn't, arbitrage deals fell apart.
- Korea's approach was a big-stick restructuring. Korea seems to be recovering, but with difficulties. The Chaebols don't seem to have really changed their ways.
- The IMF-U.S. formula for Korea is good in the abstract, but the timing is wrong. Korea has a liquidity crisis. They need to pump money in.
- There are now two currencies in the world, the dollar and the Eurodollar. The Asian strategy has been to export their way out of trouble, and the U.S. is not only the biggest buyer, it's the only buyer. The U.S. has been able to buy because it has been able to run an unlimited trade deficit because people all over the world were happy to hold dollars.

Ken Werner

Samsung's beautiful 30-in. UXGA (1600 × 1200) TFT-LCD frequently drew a crowd at Display Works 99, but you can't buy one.

Now that we have a Euromarket, people may diversify. Lots of dollars could be loosened up and we could be in trouble.

- Japan needs to start importing, but they are still piling up huge trade surpluses to the benefit of no one. Although the economy is limping, people are not really suffering so there is no political imperative for change.

A Display Industry Roundtable entitled "The Game Is On ... Who Will Be the Players?" followed Cohen's talk. In introducing it, Malcolm Thompson (formerly CEO, dpiX), picked up on Cohen's theme of crisis by saying, "I don't think things will calm down as much as some others do, and that's okay. I think that chaos is good because small companies can find opportunities in chaotic times."

In answering the question "What will we need from displays in five years?" Rick Knox (Compaq Computer) answered: more resolution, more area in wide formats, and wider color gamut, all leading to appliance displays that will supply windows to many functions (computing, Internet, entertainment). Knox called such displays, which would have 4–48 Mpixels of picture content, ultra-high information content (UHIC) displays. These displays can't be built yet, but the new technologies that will be used to build UHIC displays and the new companies that will commercialize them will make display manufacturing more global, said Knox.

Harry Marshall (CEO, Candescent) predicted there would be no major infrastructural changes over the next 5 years. "PDPs will fade as CRT replacements and projector systems come on a bit," he predicted - perhaps a bit wishfully. When asked where Candescent's first large commercial FEDs would go, Marshall said, "We're likely to follow Sony's lead and go to the desktop first, and then go back to the laptop." (But as this article was being written in late February, there were rumors afoot of major changes at Candescent and in the Sony-Candescent partnership.)

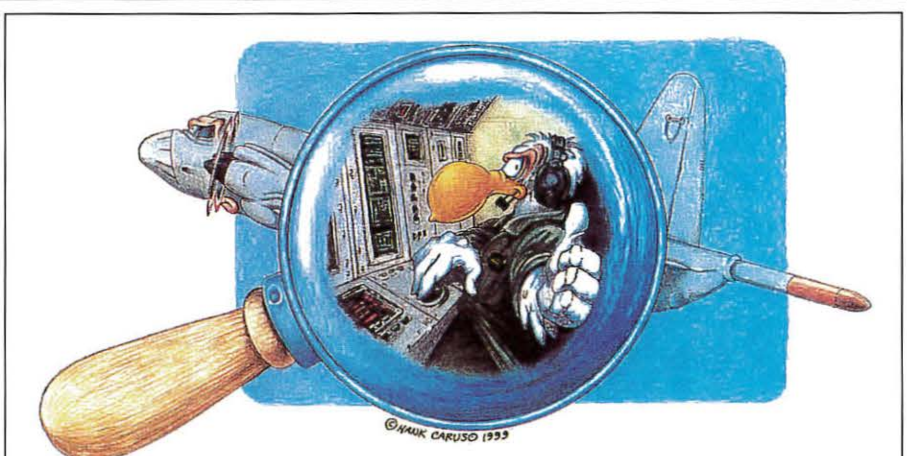
Shinji Morozumi (General Manager of Technology Operation, Hosiden & Philips Display Corp.) said, "We need new markets to support AMLCD growth. Now it is flat-panel monitors, then 25–30-in. TFT-LCDs for digital TV after 2000."

Rugged Displays Roundtable

No matter what this evening roundtable is supposed to be about - the title this year was "The Added Value of Flat-Panel Displays" - what it's really about is the making of custom rugged displays and the ruggedization of commercial-off-the-shelf (COTS) displays for military and industrial applications, then inserting those displays into their final application, and the (usually) government acquisition policies that enable - or impede - the process.

Gretchen Espo (dpiX) talked about streamlining the AMLCD insertion process and both the advantages and downside of commonality. Rick Kaiser said, "Everything is brinksmanship when you're working with obsolete parts. The high cost of cockpit re-engineering works against COTS solutions."

He went on to say that FPD technology has gotten so much better that it isn't an issue. What is an issue is the supply stability of AMLCDs. Although there are solutions, most of them come with problems. Alternative-



Ken Werner

Effective acquisition of flat-panel displays for military applications was the main topic at Display Works 99's Rugged Displays Roundtable. (Courtesy of Hank Caruso, © 1999.)

source re-engineering is costly, and, although lifetime buys are an option, money is an issue there too.

The year-by-year funding process by which the Government funds display (and other) acquisitions suppresses valid cost-reduction initiatives.

Comment from the audience: Israeli firms are getting lots of business because they are willing to re-engineer the cockpit at their cost.

Ken Sola (Naval Air Warfare Center Aircraft Division) has become a philosopher-warrior in the battle for a dramatically different and, many believe, more effective approach to DoD display acquisition. Calling himself a "purple curmudgeon," the white-bearded Sola quoted Commander Ted Klapka (USN): "The only thing more difficult than getting a new idea into the military ... is getting an old one out." He said that 1998 had been a great year for LCDs because performance had improved to the point that they were suitable for many new military applications. Sola then outlined what DoD and the industry must do to usher in a more rational acquisitions program.

DoD, he said, must

- Be less arrogant. We are a tiny tail which wags no display-industry dogs.
- Accept COTS, even though it puts some of us out of business.
- Be more role conscious. DoD states needs; display industry offers products.
- Identify its enemies better. The bad guys don't wear U.S. military uniforms.
- Change and adapt, or utterly fail in our mission.

The display industry must

- Be less political. Plus-ups are pure pork, painful for our warriors to follow.
- Accept COTS. Stop adding outrageous NRE/First Article Testing to DoD bills.
- Be more role conscious. We buy, you sell ... but are we adequately serving our warriors?
- Identify its enemies better. Ignorance and over-specification are enemies to us all.
- Change and adapt. Defense-spending increases should buy our warriors more.

As part of the change (and as evidence that things are really changing), Sola advised the industry to look for

- New contract language:
  - Consignment-spares clause.
  - Technology-upgrade clause.
  - Prior-knowledge clause.
  - Best commercial/industry practices.
  - Significantly reduced "requirements."
  - Visual-performance requirements.
  - Elimination of "how-to" language.
- Increased delivery rates.
- Assured funding.
- Multi-display workstations.
- Integrated Product Team (IPT) - not adversarial - relationships.
- A refreshing DoD humility.

Sola concluded with an advertisement for the display labs at NAWCAD (Patuxent River, Maryland), which are available for commercial testing of a wide range of photometric, environmental, and usability testing. The audience applauded.

Joe Miselli (Sun Microsystems) said, "I agree with Ken that 1998 was a great year, but for a different reason. Nineteen ninety-eight was the year that real FPD monitors became available. They are really beautiful at best, and make it hard to return to a CRT." He said that Sun had been known for resisting flat panels, and it was his job to convince the audience that Sun is changing its view.

Miselli spoke warmly of the VESA FPM mechanical mounting interface standard. He said that Sun

- Needed a single digital-interface standard.
- May need to go to a 10- or 12-bit color depth.
- Feels that in-plane switching (IPS) is an interim solution with lots of negatives.
- And sees the dpiX 19-in. monitor as a good match for Sun workstations.

Ken Werner

TEAM Systems showed its new VG-827 video generator directly driving a Compaq Presario 15-in. digital AMLCD monitor with the generator's PanelLink™ output.

DTV Workshop

Unfortunately scheduled opposite the Rugged Displays Roundtable, the SID-sponsored evening panel session, "The Impact of Digital TV on the Display Industry," was equally lively.

Moderator Chuck McLaughlin said that, eventually, a digital monitor will get plugged into a home network server, which could be a PC, a Web TV, or a Cisco home server. The potential market is huge, and the battle lines are forming. There are many kinds of displays that could plug into this home server, including PCTV, direct-view HDTV, projection HDTV, HD headset, and Internet wireless tablet.

Panelist Elliott Broadwin (CEO, S-Vision) said that the rear-projection (RP) market has the program material to drive it now. He expects the market will go over a million a year very soon. Bill Rowe (recently retired from Zenith) called the sluggish take-off of HDTV a classic chicken-and-egg situation, but he expects critical mass to be reached by

Ken Werner

Genmark was exhibiting members of its Gencobot family of "Global Positioning Robots," which compensate for cassette misalignment and arm deflection during transport.

the end of this year. PBS (the U.S. Public Broadcasting System) is an important player as a supplier of HD programming other than sports and movies.

One commentator said, "Better quality [of DTV] is a value added, but enhancement services are another important plus. Gary Feather (Sharp) replied, "Those services depend on developing infrastructure that supports profitable services. What are they? The next 2 years will be difficult."

An unidentified panelist: "The slow takeoff of HD is the fault of the cable industry, which couldn't get its standards act together."

Dave Eccles (VP Engineering, Sony): "Normal consumers want a TV model that just works. So most people won't want to see TV through a PC or network. One family member may want data services on a PCTV while the rest of the family watches 'real TV' in the living room."

Elliott Broadwin (S-Vision): "Things are changing. Old rules won't apply. We're going to partition systems differently for lower overall cost."

Manufacturing Technology Conference

The Display Works Manufacturing Technology Conference, sponsored by SID, kicked off with a keynote address prepared by Sang Wan Lee (Senior Executive Managing Director, Samsung Electronics) and delivered by Jun H. Souk (VP, Samsung Electronics). The keynote discussed Samsung's "Cut Down 40" Program for enhancing AMLCD-manufacturing efficiency. A key portion of the program is a methodology for designing, constructing, and equipping new manufacturing facilities, and bringing them to productive status, far more quickly than has been normal industry practice. Doing this well can spell the difference between profitability and loss in the cost-competitive LCD market. In a private conversation following his talk, Souk answered a question from *ID* by saying, "Taiwanese companies won't be a competitive concern [for Korean companies] for 2 years or so. Then they'll be doing small sizes (12–13 in.), and Samsung will be doing larger high-resolution displays (17–18 in.)."

In the second keynote, Dieter Mezger (President & CEO, PixTech Corp.) described his company's careful, technology-based approach to manufacturing and selling field-emission displays (FEDs). PixTech is, thus far, the only company that is selling commercial FEDs. In PixTech's suite, Mezger's colleagues were proudly showing the company's 15-in. FED-technology demonstration. There were only 278 × 368 pixels, plenty of line and column defects, and visible wall effects from the spacers, but at this stage of development the important thing is not whether the bear dances well, but that it dances at all. With full video speed, well-saturated colors, and 300-nits luminance (without a neutral density filter), this bear dances.

PixTech has long been associated with low-voltage FEDs, but the company recognizes that high voltage is needed at sizes over 8 in. on the diagonal. The 15-in. unit was running at about 5000 V. "The key to a high-voltage display is the focus technology," said George Proulx, PixTech's Director of Technology for high-voltage FEDs. Tom Holzel (Marketing and Sales Manager): "The 15-in. is a technology demonstrator intended to interest possible partners, especially CRT makers interested in a direct path to a desktop flat panel."

In the adjacent suite, Westaim was talking about - but not showing - its 17-in. color thick-dielectric EL prototype. In a larger size, the company sees its technology as a low-cost competitor for plasma in the hang-on-the-wall large-screen-TV market. The company plans to be showing the prototype around the time of SID '99 in May.

In addition to the specialized manufacturing-technology papers in the conference, there was a more general session, "Impact of Flat-Panel Displays." In "Management Strategies and Government Policies in the Global FPD Industry," Jeff Hart (University of Indiana) and Stefanie Lenway (University of Minnesota) discussed conclusions from their study of FPD manufacturers. Among those conclusions is that TFT-LCD manufacturing is much more difficult than semiconductor manufacturing.

Timing the transition from one generation of manufacturing facilities to the next was a major issue, and the timing has been pioneered in the past by a single major manufacturer - Sharp for Gen 1 to Gen 2, and DTI for Gen 2 to Gen 3. Hart indicated that it is unclear whether the shift to Gen 4 will be like previous generational shifts. Will the existence of the monitor market, the greater range of marketable sizes, market growth, and the increased number of equipment suppliers change the game?

Two other conclusions:

- "Displays, not being terribly heavy, can be shipped by 747s" for JIT delivery to a laptop assembly location. So it's a global supply strategy.
- "TFTs are vulnerable to new technologies because they are expensive to make." In this context, microdisplays are a very exciting technology.

Joe Miselli (Sun Microsystems) discussed "Hidden Cost Savings of Flat-Panel Monitors over CRTs." By doing a cost analysis taking into account the lighter weight and power dissipation of LCDs (which produce savings in shipping, power consumption, and air-conditioning), the fact that EMI shielding is virtually never needed with FPDs, and making strong assumptions about a longer lifetime for FPMs, Miselli predicted a 5-year cost savings of more than $1000 per flat-panel monitor.

In "The Simplicity of Performance-Based Display Specification," Ken Sola expanded on the direction of his Rugged Displays Roundtable presentation. Using the TV game "Jeopardy" as a model for the contracting process, Sola used overheads designed by the noted aviation caricaturist Hank Caruso illustrating the "Contract Jeopardy" players: a spec-writer, a product engineer, and user, and the "contract monster." Only the contract monster, which feeds voraciously, wins. By basing the military contract on performance rather than non-performance-based "criteria," the monster can be tamed and all parties can work together productively in "integrated product teams" instead of in a relationship typified by hostility and suspicion, which is often the case today.

Sampling the Show Floor

The number of exhibitors at the Display Works show was down a bit from last year and traffic seemed somewhat light, but, as always, there were centers of activity. Among them were the following.

Sony was showing its completely flat-faced Trinitron® FD CRT products: 19- and 21-in. computer monitors, a 36-in. XBR NTSC TV receiver with 4:3 aspect ratio and internal enhancement to 800 × 600 ($2495), and a gorgeous 34-in. 16:9 set running HDTV at 1080i ($8999). The 36-in. 4:3 set looked surprisingly huge next to the 34-in. 16:9 set.

Samsung often had a small crowd around its 30-in. UXGA (1600 × 1200) TFT-LCD, apparently the same one shown in Seoul at Asia Display, delivering a response time of less than 40 ms at 25°C, a luminance of 200 nits, and a contrast ratio of 250:1. Certainly a crowd-pleaser, but we can't buy one.

For UXGA screen resolution we *can* buy, try Samsung's 21.3- in. TFT-LCD with 200 nits, 250:1 CR, under 40-ms response time, and viewing angle of ±80°. Intended for CAD monitors and similar applications, this panel produces very saturated, photograph-like images. The panel is sampling now for about $5000, with mass production in July or August for, perhaps, $3500.

Also on show was a very nice 17-in. SXGA unit in a Digitron monitor. Samples are due in Q4 '99. Samsung's Carl Steindle was happy with the show. "The non-notebook market is growing," he said.

Plasmaco/Panasonic was showing its familiar 640 × 480 42-in. plasma display, and an 852 × 480 16:9 display nicely showing programming from a MUSE laser disk. A 720p HDTV display will be shown at SID '99, said Plasmaco's Jane Birk.

Jack Bernstein, president of Japanese translation and information firm ***InterLingua***, said he was seeing lots of activity from people interested in finding partners in Japan. InterLingua will be putting its translation of the annual Nikkei Industry Directory on its Web site.

dpiX was showing its Gradient 500 AMLCD, the 5.2-Mpixel monochrome version of its Eagle 19 military display that is intended for medical diagnostic imaging. The very-good-looking direct-digital panel on display was being driven by a Dome Imaging FP5 controller card. Other cards approved for use with the panel for medical applications are made by Metheus, ATI, and Matrox. Also on display were the Eagle 19 and Eagle SR 19-in. AMLCDs, and the Eagle 5 and 6 square avionics displays, which now have digital interfaces and a response time of less than 12 ms. A monochrome Eagle 5 designed for targeting applications was impressively displaying nearly 200 dpi.

The folks at ***S-Vision*** were glowing just after "Silicon Valley Business This Week" (Channel 36) had taped an interview in their booth about microdisplay-based rear-projection (RP). S-Vision had a 12-in.-deep, 25-lb. RP television with a 24-in. screen running off a DVD player. The TV was a quickly assembled demonstrator, said S-Vision's Al Davis, and nothing was optimized. The screen was a gain 1.0 diffusing screen supplied by Draper, running with no lenticular lens and no contrast enhancement. The company's "Nova" RP engine – a reference design available to customers – had a 120-W lamp and was working through a 3× folded optical path. The flip side of having a screen with no gain is that you also have a screen that's omnidirectional, and the set produced a bright image at virtually all forward angles. For the home market, S-Vision would recommend a 50- or 70-W lamp. S-Vision's XGA LCOS chips produced an image without visible structure on the 24-in. screen. This, said Davis, is a benefit of reflective technology.

S-Vision displays should be in a commercial desktop monitor by the beginning of summer, and in a data/graphics projector around INFOCOMM. With luck, a 50-in. demonstrator could be ready in time for SID '99.

An interesting new exhibitor was ***Chip Supply, Inc.,*** which buys row and column drivers as wafers from Asia and packages them in the U.S. in tape-carrier (or other) packages to its customer's design. The company also distributes bare dies from over 20 companies, including Vivid Semiconductor, TI, and Supertex, said Chip Supply's Mark Hartung.

Accudyne's Brian Hoekstra said the company had developed a laser-scribe-and-thermal-break method for the singulation (separation) of FPDs that fully separates the displays in a single pass with no kerf or particulates. The process produces a polished edge for improved edge strength – and possible better yields in downstream processes. The scribing can be done at speeds of 1000 mm/sec, with full separation done at 70–200 mm/sec. A beta unit was being shown. The first commercial delivery was scheduled for May '99.

Genmark was showing its global-positioning robot that compensates for the misalignment of flat panels based on non-contact measurement of the misplacement of the panel with respect to the end effector. A new feature is on-the-fly misalignment compensation, said Zlatko Sotirov.

conference report

TEAM Systems was showing its new VG-827 video generator driving a Compaq Presario FP700 15-in. digital AMLCD monitor directly with its PanelLink™ output. The VG-827 has PanelLink and LVDS digital outputs, as well as analog.

A Digital Farewell

The USDC-sponsored Industry Banquet at the Hyatt Sainte Claire Hotel featured surprisingly good chicken and a presentation by Barry Armour, Computer Graphics Supervisor at George Lucas's Industrial Light & Magic. Armour said, "George [Lucas] feels that HDTV will kill film as a production medium," perhaps in 5–7 years.

Effects were optical until the beginning of the digital era with *Terminator 2.* Interestingly, a good frame takes an hour to render. That is true today and it was true in 1984, but our definition of "good frame" has changed radically.

Photorealistic digital work is of two kinds. The first is a "virtual back lot," where sets are created digitally. A variation of that is the set extension, where an actual set does not fill the entire frame and is extended digitally. The second kind of photorealistic digital work is the "virtual actor." This includes stunt doubles and extras (but far enough away so the viewer can't tell they're digital) and creatures of various sorts. In addition, mistakes made by the first unit are now often repaired digitally in post-production. And, of course, computer graphics are used for fantasy – the creation of fantastic beings and worlds.

The expansion of computer graphics in cinema is making the contract terms of directors and directors of photography longer because their responsibilities now extend into post-production. "Computer graphics," said Armour, "makes everything harder, but it also makes everything possible." When asked what pixel content he'd like to see in electronic cinema, Armour said, "We'd be happy when electronic cinema gets to 2K pixels wide."

The presentation was accompanied by clips of ILM special effects (including the trailer for the new *Star Wars* episodes) shown on an Electrohome front projector. (Electrohome provided projectors for all of the major sessions at Display Works.) The effect was spectacular.

Prior to Display Works, the United States Display Consortium announced it would sponsor a new Display Applications Conference (DAPPCON), to run concurrently with Display Works 2000. Following this year's Display Works, the Society for Information Display announced that it would not participate in Display Works next year, devoting its energies instead to expanding the already substantial manufacturing and applications content of the SID Symposium. So, it is inevitable that Display Works 2000 will look very different from Display Works 99. ■

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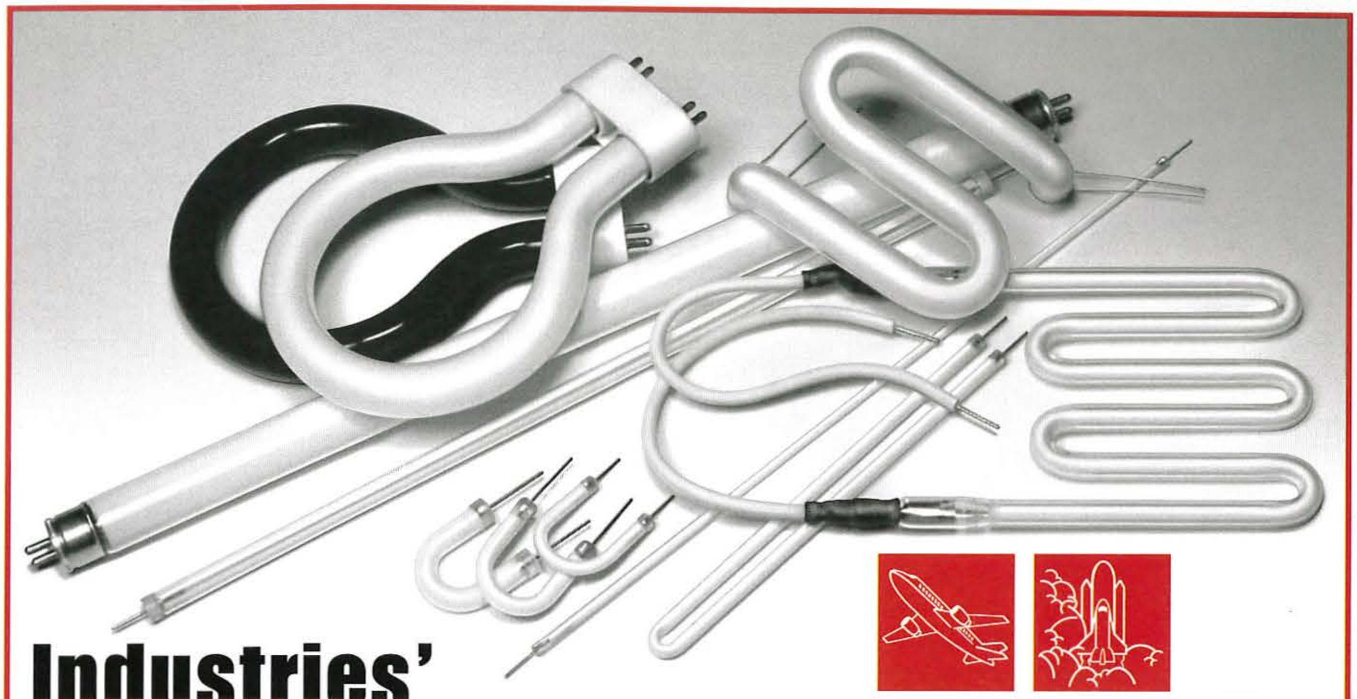

SID Conference Calendar

Next Show!

The 1999 International Display Research Conference (EuroDisplay '99)

The 19th edition of the International Display Research Conference will be held at the Maritim ProArte Hotel in Berlin, Germany, September 1–6, 1999. This year's conference is comprised of 49 papers from Asia, 46 from Europe, and 18 from the U.S. and Canada. The presentations reflect the current thrust of flat-panel research on organic LEDs, virtual displays, and light valves on Si for projection, printing replacing vacuum processes, and reflective displays with color or multiline addressing. A highlight promises to be the performance of the Berlin Philharmonic.

6 SEPTEMBER 99

19th International Display Research Conference (Euro Display '99)

BERLIN, GERMANY
SEPTEMBER 6–9, 1999

- An international conference on display research and development aspects of:
  - Display Fundamentals, Display Devices,
  - Hard Copy & Storage, Input Systems,
  - Integrated Devices and Applications,
  - Image and Signal Processing,
  - Color Perception, Human Factors

8 NOVEMBER 99

Fifth International Conference on the Science and Technology of Display Phosphors

SAN DIEGO, CALIFORNIA
NOVEMBER 8–10, 1999

- An international conference on the future prospects of phosphors for:
  - OLEDs – ELDs – FEDs
  - CRTs – Plasma Displays
  - PL Devices – LC Backlights

16 NOVEMBER 99

7th Color Imaging Conference: Color Science, Engineering, Systems & Applications

SCOTTSDALE, ARIZONA
NOVEMBER 16–19, 1999

- An international multidisciplinary forum for dialogue on:
  - Creation and capture of Color Images
  - Color Image reproduction and interchange
  - Co-sponsored with IS&T

14 MAY 00

SID '00

LONG BEACH, CALIFORNIA
MAY 14–19, 2000

- SID's MAJOR ANNUAL EVENT
- An International Symposium, Seminar, and Exhibition – Featuring:
  - Technical Sessions – Poster Session
  - Author Interviews – Evening Panels
  - Short Courses – Applications Seminars
  - Technical Seminars – Applications Sessions
  - Product Exhibits – Display Technology Showcase

For additional information:
Dee Dumont
Society for Information Display
31 East Julian Street
San Jose, CA 95112
408/977-1013, fax - 1531
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continued from page 4

announcement for a new autostereoscopic display system. To my disappointment, it turned out that the idea was not new and the only new development I could find was a design improvement in the multiple images that are presented to each eye through venetian-blind-like slats. However, what did catch my attention were the claims being made for this "new" system. The authors (or at least their press agents) were claiming that this autostereoscopic system would be the key development to the imminent implementation of virtual reality. They described the creation of visual environments where people would be "immersed" in computer-created scenes. My carefully considered and scientific response to this was, "Sure, when cows fly!"

I wished that I could have these folks right there with me on the plane so that I could introduce them to the boy with the glasses and the super-developed neck muscles. I wanted to "right then and there" show them how much more there is to creating the perception of reality than even the most perfect stereoscopic system can provide.

Even when we create near-perfect stereoscopic images, with or without glasses, we are less than one-third of the way to creating believable virtual reality. The other two-thirds comes from what else our eyes and brains are doing to acquire information about our environment while we are taking in the stereoscopically generated data. That rapid sample-and-hold scanning behavior of our eyes is not accidental. Our eyes only have a few degrees of high-resolution and full-color capability. The rest we fill in by scanning and continually re-focusing. We don't really "look" at a scene. Our behavior is more like sending out numerous and rapid "information probes" and then integrating all that we pick up. Each information probe not only looks at the image, but also evaluates the focal plane and compares it to the other peripheral information to put it all into context.

For example, as I type this line, my eye is focusing on each word, but in addition what I "see" around me is a blurry vision of a table and some of the contents of the room. If I look up, the bookshelf across the room pops into focus, but the computer screen now becomes a blur. I can no longer read what is on the screen – all I see is a white and blue out-of-focus rectangle. Given this, can you now see what's wrong with even the most perfectly created stereo images? They are in a two-dimensional plane and everything is uniformly in focus, or not. And that is why stereo images always look like they are "dollhouse" representations of reality. To our visual system, all elements of the world are not supposed to appear in focus at the same time. When presented with visual information that is, we reject it as phony.

To provide a virtual-reality experience that approaches real reality, we will need to first develop sensors that continually monitor an observer's eye position and eye focus. Then this information must be processed in real time to provide the proper combination of in-focus and out-of-focus images, and to vary them faster than the typical scanning speed of the human eye. The only good news in all this is that only a small portion of the two images needs to be at high resolution at any given moment. And while this high-resolution segment needs to track eye movement and eye focal plane accurately, the rest of the peripheral image can be of lower resolution and only needs to track head movement. However, the head movement must be tracked to positional accuracies of better than a few millimeters or the experience is more likely to induce feelings of motion sickness instead of realism. The human system is a marvelous "machine" in its complexity and sensitivity. Apparently, we humans don't like being fooled and so have developed multiple, sophisticated, and sometimes redundant sensors to prevent that from happening.

Given this complexity of human visual information processing, what is the likelihood of creating a reasonably believable virtual-reality experience? I believe that the technical feasibility of a system for one viewer at a time (head mounted) may be demonstrated in the next decade. Here's why. The compute power currently available is close to what we need. The image-processing needs are also within our capabilities. The eye-movement and focus-position sensors are also available. The head-movement sensor is not a fundamental technical barrier. However, to my knowledge, no one has yet put all this together into an effective system. The biggest missing link is a full-surround display of adequate resolution. Perhaps we can begin with something as modest as an attempt at a realistic view through a "window," the boundaries of which are defined by the size of the display. This would allow for the various system components to be developed and for the whole ensemble to be tested to see just how effective an "immersion" experience we can create. I would enthusiastically sign up as one of the early test subjects.

For multiple viewers (and large audiences), unfortunately, the likelihood of a simultaneous virtual-reality experience may need to be put into the same category as the Star Trek warp drive, teletransport, and controlled fusion. "Beam us up, Scotty, so we can all go play on the holo-deck before blasting into the next galaxy."

Not everything we can imagine – or even everything that seems like an obvious next step – can be made to happen. Well over one hundred years after the first stereo viewers appeared, we are only now beginning to understand the challenges of creating images with meaningful depth information. It's really amazing that it has taken us so long and that there are still so few who appreciate the complexity of the problem.

High-resolution images such as IMAX movies, and HDTV in the coming decade, provide the "right" level of 3-D perception just by moving the camera through a scene. These scenes, filmed while flying through canyons or over mountains, or while on roller coasters, can be thrilling and provide all the depth information that our visual systems can appreciate. ***The addition of stereo images without the corresponding depth-of-focus, head-movement, and eye-scanning information create vision-system conflicts that end up distracting us from the feel of virtual-reality experiences instead of enhancing them.***

The moving high-resolution 2-D images we have today are already very good at giving us the "feel" of a place. These multiple time-sequenced images give us much of what we need in the way of depth information. To get to the next level will take significantly more than the simple addition of a second set of simultaneous 2-D images. In the world of virtual reality, it turns out that 2-D + 2-D does not equal 3-D.

Should you wish to explore this topic a bit further, my August '97 column provides another perspective. And if you would like to add some deep thoughts of your own to my two-dimensional world, I would very much enjoy hearing from you. Please contact me by e- mail at silzars@ibm.net, by voice at 425/557-8850, by fax at 425/557-8983, or by the sequentially generated written word at 22513 S.E. 47th Place, Issaquah, WA 98029. ■

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calendar

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

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

The 6th Annual Flat Panel Strategic and Technical Symposium, *"Vehicular Applications of Displays and Microsensors."* Sponsored by The University of Michigan Center for Integrated Microsystems and the Metropolitan Detroit Chapter of SID. Contact: R. Donofrio, Display Device Consultants, 6170 Plymouth Rd., Ann Arbor, MI 48105; 734/665-4266, fax -4211, e-mail: rldonofrio@aol. com.
Sept. 22–23, 1999 Ypsilanti, MI

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

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