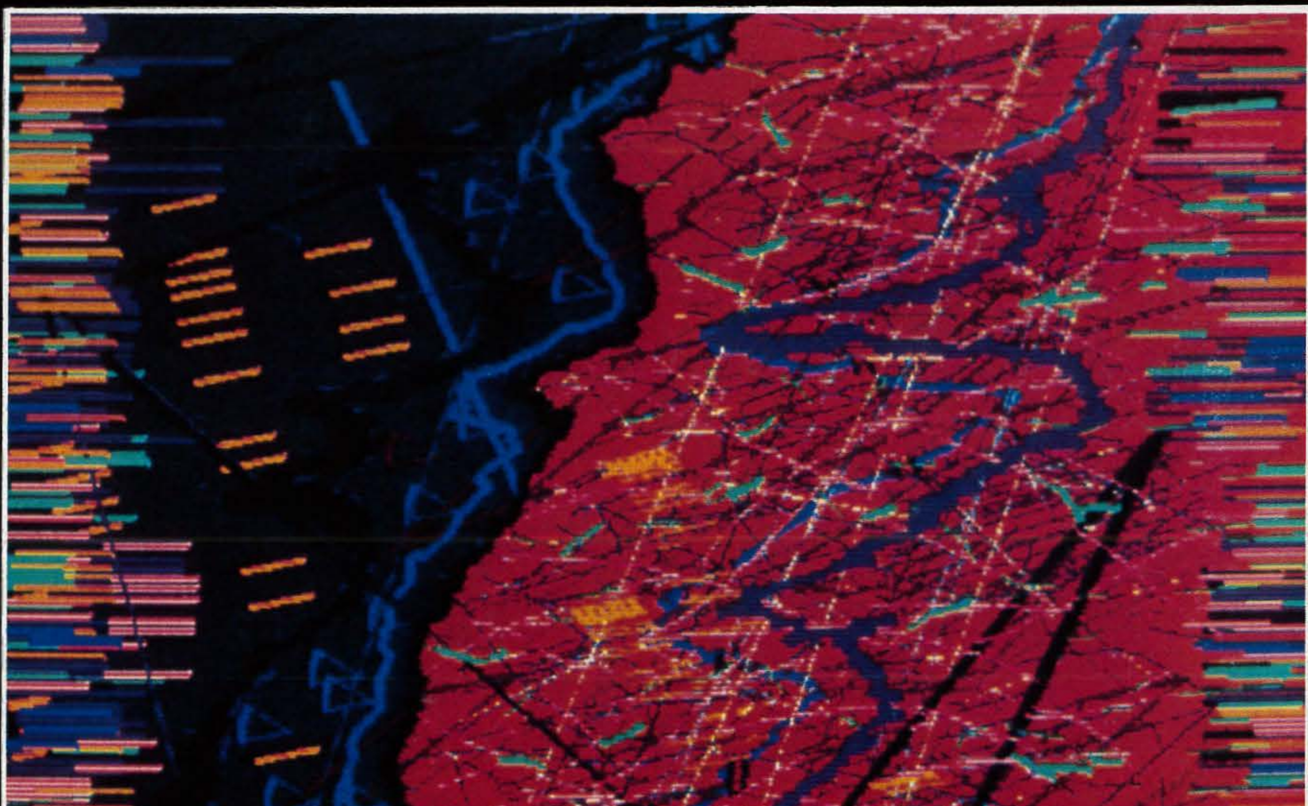
Official Monthly Publication of the Society for Information Display

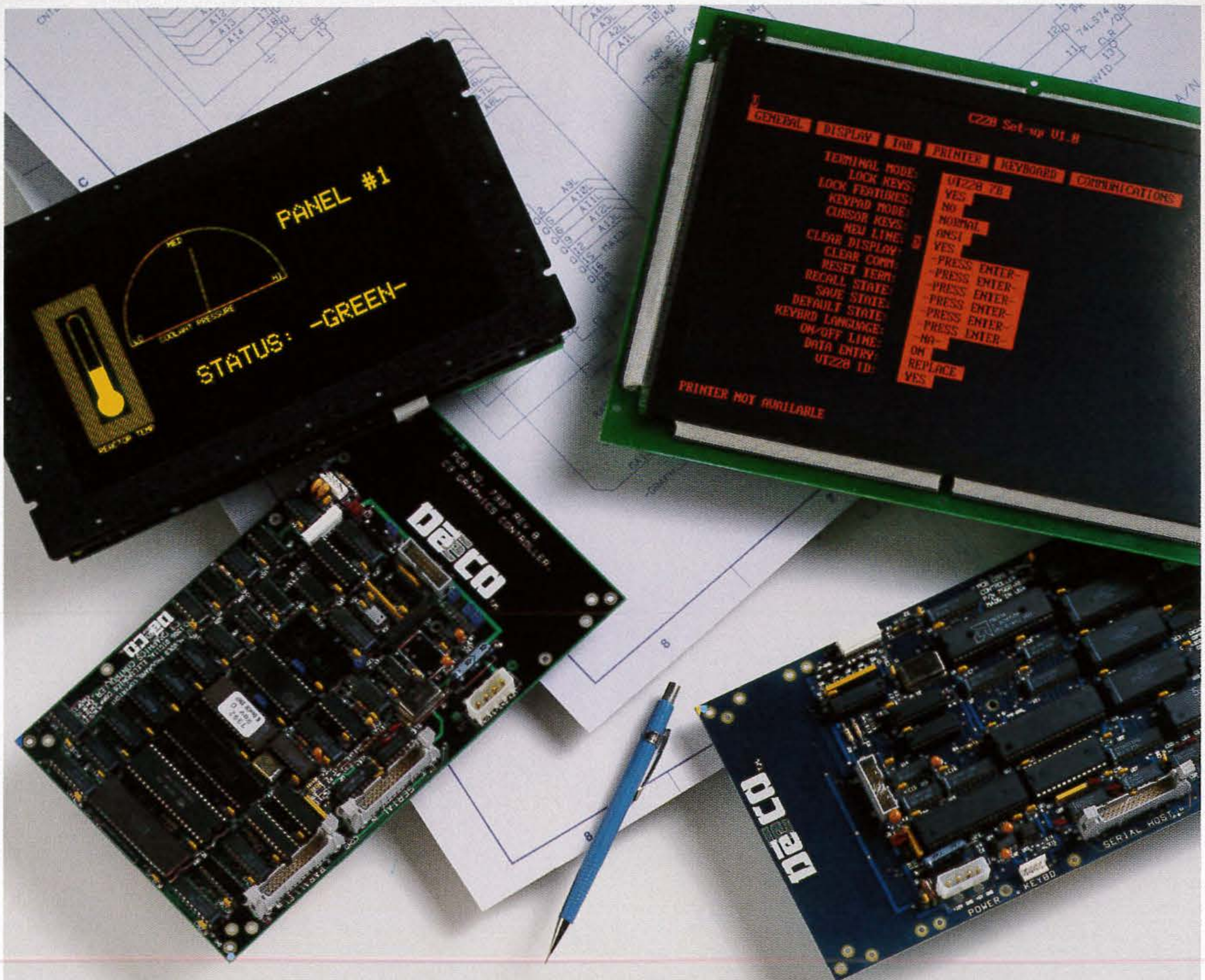
INFORMATION DISPLAY

December 1988
Vol. 4, No. 12



1988 TECHNOLOGY ROUNDUP

CRTs
Flat-panel displays
Large displays
Printers



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Cover: Artist Karen Guzak of Seattle, Washington, created this computer drawing on a 640×480 NEC MultiSync 2 monitor using the Florida Computer Graphics Beacon 610 system with a Digi-Pad 5 tablet and Ibis software. The hard copy was produced on a Xerox 420 ink-jet printer at a resolution of 120 dpi. *(page 22)*

Photo: Karen Guzak

Next Month in Information Display

CRT Technology

- TEMPEST display systems
- Flat cold-cathode CRTs
- Selecting phosphors for displays

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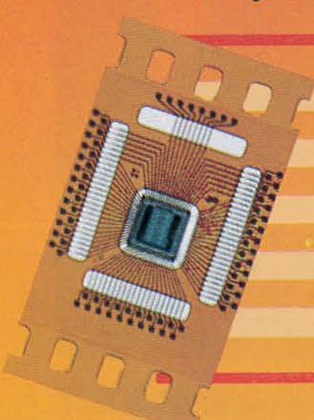

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**Available 2nd Quarter, 1988

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INFORMATION DISPLAY

INFORMATION DISPLAY (ISSN 0362-0972) is published monthly for the Society for Information Display by Palisades Institute for Research Services, Inc., 201 Varick Street, New York, NY 10014; David Slater, Chief Executive Officer; Leonard H. Klein, President; Harold R. Summer, Vice President; Hildegarde Hammond, Secretary; Laura Mangone, Treasurer.

EDITORIAL AND BUSINESS OFFICES: Palisades Institute for Research Services, Inc., 201 Varick Street, New York, NY 10014; telephone 212/620-3371. Send manuscripts to the attention of the Editor, ID.

DISTRICT SALES OFFICES: WEST—Ted Lucas, P.O. Box 852, Cedar Glen, CA 92321; telephone 714/337-6627. MIDWEST—Joe Brennan, Paul Wagner, Lisa Zurick, Pattis/3M, 4761 West Touhy Avenue, Lincolnwood, IL 60646; telephone 312/679-1100. EAST—Becky Akers, Pattis/3M, 310 Madison Avenue, Suite 1804, New York, NY 10017; telephone 212/953-2121.

SID HEADQUARTERS, for correspondence on subscriptions and membership: Society for Information Display, 8055 West Manchester Avenue, Suite 615, Playa del Rey, CA 90293; telephone 213/305-1502.

SUBSCRIPTIONS: Information Display is distributed without charge to those qualified and to SID members as a benefit of membership (annual dues $45.00 U.S. & Canada; $65.00 elsewhere). Subscriptions to others: U.S. & Canada: $36.00 one year, $64.00 two years, $90.00 three years, $3.00 single copy; elsewhere: $72.00 one year, $128.00 two years, $180.00 three years, $6.00 single copy.

PRINTED by Sheridan Printing Company, 1425 Third Avenue, Alpha, NJ 08865. Third-class postage paid at Alpha, NJ.

POSTMASTER: Send address changes to Society for Information Display, 8055 West Manchester Avenue, Suite 615, Playa del Rey, CA 90293.

editorial

The year that was

Welcome to our first annual year-end technology review, in which we attempt to remind you of everything important that happened in and to the display industry during 1988. The attempt is, of course, hopeless. But selective and idiosyncratic as it is, we hope you will obtain as much stimulation and entertainment from reading this issue as we did from compiling it. We deeply appreciate the efforts of our authors, industry experts who sacrificed weekends to produce these articles on very tight schedules and bring you their impressions of a very active and exciting year.

In addition to technical and commercial developments, 1988 saw the Society for Information Display investigate a more active role in formulating display standards. Pete Keller, chairman of SID's definitions and standards committee, has informed me of two recent Engineering Bulletins from the Electronic Industries Association that may interest *Information Display*'s readers. *Relative Display Resolution and Addressability* (PEPAC TEB 27) and *1976 CIE-UCS Chromaticity Diagram with Color Boundaries* (TEB 26) are available from the EIA Standards Sales Office. Calling 202/457-4966 should bring forth the necessary details.

It may not elicit much holiday cheer from his colleagues at IBM, but Howard Funk, *Information Display* contributor and well-known display-community activist, was elected president of the American Federation of Information Processing Societies (AFIPS) on September 12. His goal of restoring AFIPS to its former vigor assures him of an extraordinarily busy year.

The editorial, sales, and production staffs of *Information Display* would now like to wish Howard, Pete, and the rest of our readers a joyful holiday season. We are grateful to you, our advertisers, and our authors for a successful year. And our contract advertisers, at least, get a special holiday gift. In January, our circulation base rises 30% to total 13,000 creative members of the display, imaging, and graphics systems community.

—Kenneth I. Werner

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Circle no. 6

CRTs—present and future

BY CARLO INFANTE

CRTs, WHOSE DEMISE was so confidently predicted some years ago, are as healthy and as vital as ever. This is due to the characteristics of the device, beginning with the tremendous dynamic range of available performance. Sizes cover a range of 100:1; peak luminance, 10,000:1; and resolution capability, 100:1. CRTs have infinite addressability, and routinely offer color and gray scale (which other technologies are busy inventing), good lifetimes, and superior ergonomic properties. An established and very flexible manufacturing base may be the device's strongest point. The CRT is a remarkably flexible technology with an extremely broad gamut of applications [Fig. 1].

Electron guns

In a CRT, electrons are generated by a cathode, formed into a beam by an electron gun, and then deflected by either an electric or magnetic field. The electrons then strike a phosphor screen where their energy is converted to light. In color displays, several different-colored phosphors are used together with an appropriate mechanism (such as a shadow mask or grill) or an electronic method to insure purity. The luminance of the displayed picture is proportional to beam power, while the resolution depends on the diameter of the beam. Both of these properties are determined by the electron gun. The principles of generating and forming electron beams have been known for several decades, but the challenge of producing an intense, well-focused spot seems everlasting. The challenge is intensified because the gun must be kept small—power consumption increases rapidly with neck diameter—and the gun must be made to precise performance tolerances in large quantities with available equipment. This has not been a major deterrent. A number of new gun designs have been disclosed in the last few years [Table 1], another indication of the vitality of the technology. The most important factor in gun design

Carlo Infante has worked at Tektronix, Xerox, and Kaiser Electronics. He is currently a consultant based in Belmont, California. Dr. Infante is the author of several papers, including a tutorial on CRTs. His reviews of books and software appear irregularly in Information Display.

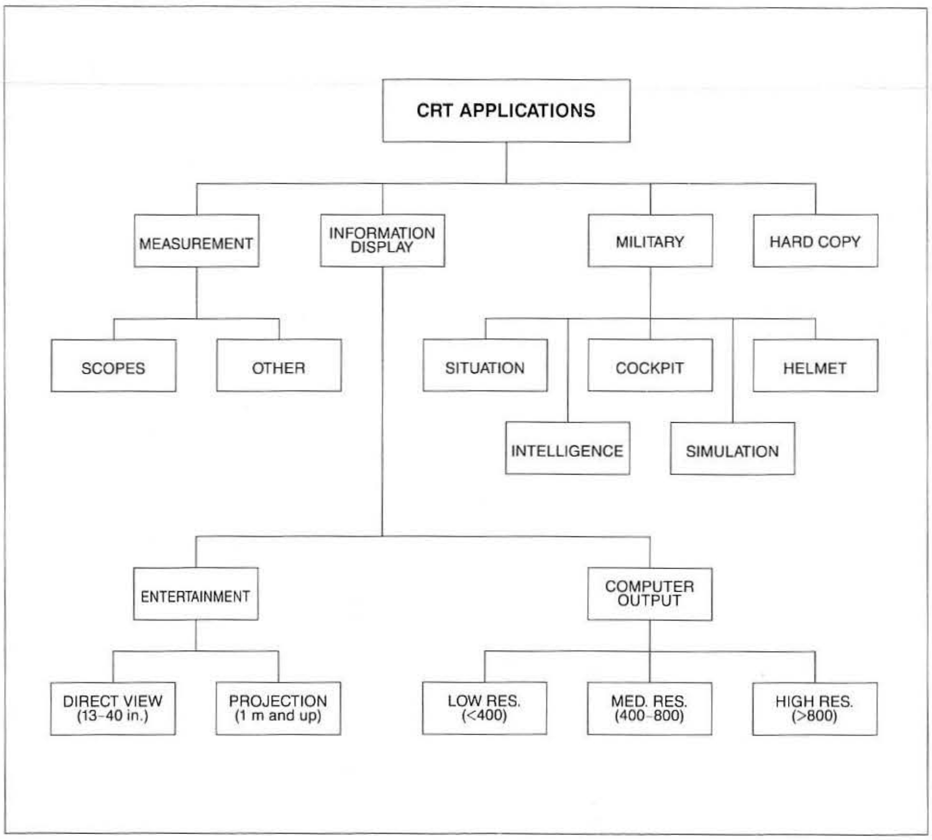

Fig. 1: *Cathode-ray tube technology is highly flexible and has an extremely broad range of applications.*

has been the increasing availability of evermore sophisticated computer-aided-design tools. As an example, researchers at the David Sarnoff Research Center recently presented some impressive advances showing the ease and precision with which complex structures can be simulated on a modern computer. Deflection defocusing, the effects of space charge, and to some extent, the notoriously difficult problem of modeling deflection yokes can all be treated straightforwardly and accurately. We have yet to see the full impact of this trend in the increased performance of modern CRTs and I expect many more developments in this area in the years to come.

Bulbs

CRTs are available in an enormous variety of shapes and sizes, from the 0.5 in. used in helmet displays to the 40 in. and up developed for the entertainment market. A significant trend is the appearance of tubes so large they exceed the dimensions once considered absolute limits. This, too, is due to CAD tools, which greatly simplify the required stress and thermal analyses. Matsushita has announced 40- and 43-in. tubes, while Sony has described a 45-in. Trinitron. These tubes are for current television standards, but HDTV versions cannot be far away. The Japanese expression for high-definition television is apparently "high-presence TV." These large bulbs certainly achieve that objective [Fig. 2].

Screens and masks

Several manufacturers of monochrome CRTs have introduced proprietary, high-contrast, "paper white" phosphors. The search for long-persistence phosphors has fortunately eased, but the hunt for the "right" projection-TV and cockpit-display phosphor continues unabated. The combined goals of high efficiency, no saturation, and long life make a long search likely. Cockpit displays also require a narrow spectrum to optimize optical-filter performance. We have also seen a resurgence of beam-index devices, with Peter Barten of Philips hinting that major developments are forthcoming. Whether the technique can overcome its limited luminance dynamic range and adapt itself to higher resolutions remains to be seen.

Zenith has developed the flat tension mask (FTM) to the point where impressive 14-in. displays are being built and incorporated into personal computers. Yields on this tube apparently are now less of a problem than they were, as is extending the technology to larger sizes and finer screens. FTM eases the so-called "doming" problem. Alternate solutions are masks made out of Invar, now being introduced by a number of Japanese manufacturers.

Ergonomics

Much of the most interesting work that has taken place in the CRT arena recently concerns ergonomics—or human factors—rather than CRTs proper. While this work affects all display areas, the impact has been felt most by the CRT simply because it is the leading display technology. In the area of flicker, Hewlett-Packard's Joyce Farrell recently published a set of much needed equations that predict the critical fusion frequency for a wide range of viewing conditions [Fig. 3]. This is particularly important for computer displays, which are viewed at close quarters and for extended periods.

Similarly, a number of analytical approaches are now available that quantify the subjective sensation of image sharpness. Of these, the MTFA concept popularized by Harry Snyder and others has become part of an ANSI standard. Peter Barten has shown that his SQRI algorithm correlates best with experimental data, although some human factorists continue to voice reservations.

Unfulfilled promises

If this article were to end here, it would leave the impression that all is well in CRT-land. Guns are better, bulbs are bigger, screens are brighter, and we know more about the human side of the interface. All this is true, but there have been some disappointments and unrealized opportunities along the way.

Notable among these is the color shutter, originally conceived by the Royal Signals and Radar Establishment and further developed by Tektronix. The shutter consists of an electrically addressable liquid-crystal cell that, when placed in front of an appropriately driven monochrome CRT, can extract a single primary color. Driving the cell synchronously with the CRT generates a color picture. The concept is elegantly simple, but major draw-

Table 1: Summary of New Electron Guns

Author/ Affiliation	Name	Neck Diam. (mm)	Size (center)[1]	Size (corner)[1]	@ Ib (mA)
Kobayashi/ Toshiba[2]	LAT-QPF	29, IL	0.14	0.23	0.15
Yamane/ Mitsubishi[2]	XF-DBSII	29, IL	—	—	—
Miyazaki/ Hitachi[2]	ES	22, IL	0.31		0.1
Ashizaki/ Matsushita[2]	DAF	29, IL	0.28	0.27	0.3
Shoji/ Hitachi[3]	EA-U-B	29, IL	—	—	4
Spanjer/ Philips[3]	SP-ART	?, M	0.1	—	4
Saito/ Sony[3]		?, M	0.09	—	1.5
Katsuma/ Toshiba[4]	DAC-QPF	29, IL	0.5	0.52	0.3
Nakamura/ Sony		36.5, TR	2.1	—	7
Yano/ Sony[4]		22.5, M	0.14	—	0.3

NOTES
[1]In mm @ 50%
[2]Japan Display 1986
[3]SID Symposium 1987
[4]SID Symposium 1988

IL = In-Line
M = Monochrome, Beam Index
TR = Trinitron

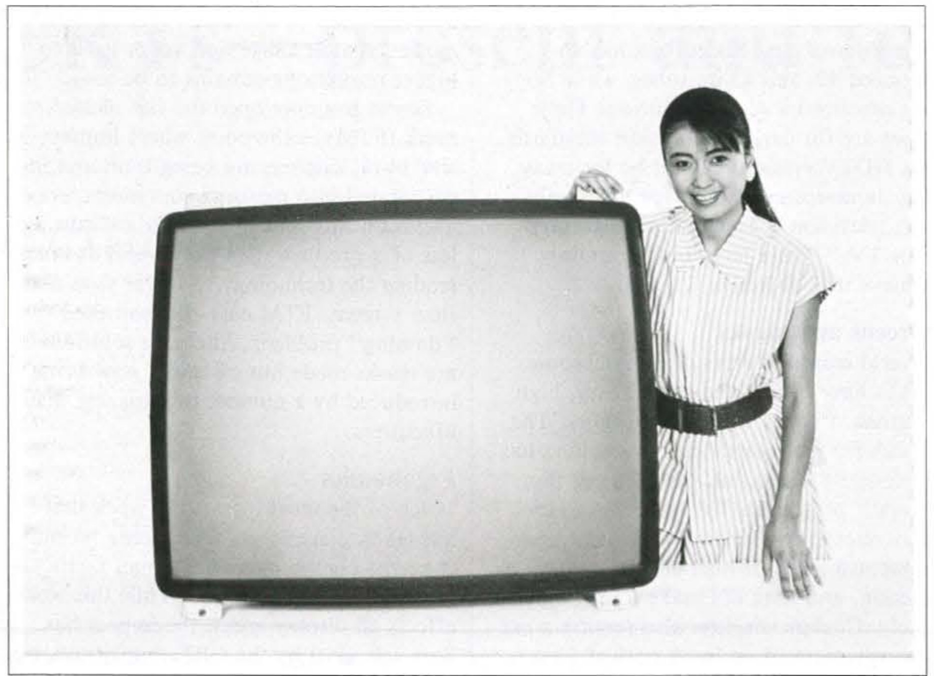

Photo: Matsushita Electric Co.

Fig. 2: Very large cathode-ray tubes were announced by Matsushita, Mitsubishi, and Sony in 1988. This 43-incher is from Matsushita.

backs have hindered its widespread adoption. First, the cell and the filters attenuate the light emitted from the CRT by a factor of about 20 for a full-color cell. Major improvements in both electron guns and phosphors are thus required.

Second, since each color is presented sequentially, the system must be refreshed at three times the normal rate to avoid flicker. This makes stringent demands on deflection and video circuitry. Finally, some major ergonomic issues persist, such as color-image breakup due to relative motion between the display and the viewer. Together with the failure to achieve a significant cost advantage at the system level, these drawbacks have relegated the color shutter to a few narrow niches.

Another once-promising concept is the multi-beam CRT. Here, a number of electron beams are swept in parallel within a single envelope. This reduces both the horizontal and video frequencies significantly. Unfortunately, keeping all the beams converged to within a fraction of their widths is tricky and expensive, so this technology has failed in the marketplace. MegaScan uses a more conventional approach to produce a monitor with a resolution of more than 3000 lines—close to the ergonomic limit of the human eye.

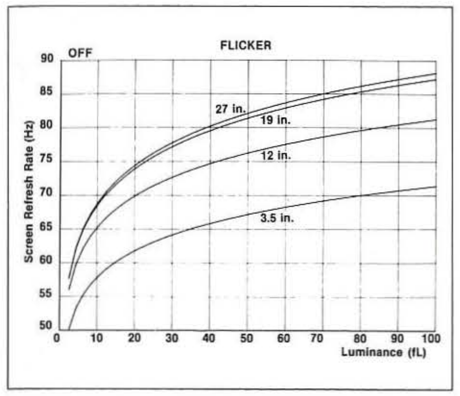

Fig. 3: Using equations devised by Joyce Farrell of Hewlett-Packard Laboratories, the minimum refresh rates to avoid flicker at a viewing distance of 20 in. were plotted for different screen sizes.

But the major disappointment from my point of view is the market's failure to demand the higher resolution that CRT technology is ready and able to provide. Two-thousand-line systems in both monochrome and color are feasible, but the primary demand currently is for 1000-line systems with higher brightness and refresh rate at lower cost. On the positive side, a number of manufacturers currently produce excellent large high-resolution monitors in both monochrome and color. These have become affordable to the point that PC users of both the Macintosh and IBM-compatible persuasions can afford them. As RAMs return to being merely expensive—as opposed to unaffordable—I expect the trend to higher resolution to reemerge.

Conclusion

Where does all this lead? As the leading display technology in the marketplace, the CRT is a natural target for other technologies, and is thus increasingly challenged by them. I see CRTs continuing to dominate a number of niches as a result of some of the work described here. HDTV is certain to have a major impact on price and performance, especially when we in the United States finally stop debating which way is best and get around to implementing the technology.

Acknowledgments

I have benefitted from conversations with many people, but special thanks are due to Chris Curtin of Tektronix for suggesting I give a paper at the 1988 International Display Research Conference, which formed the basis for this article, and for sharing his views with me. Special thanks are also due to Lou Silverstein (Honeywell) and Peter Barten (formerly of Philips) for their many useful insights. A more extensive, fully referenced presentation of this material will appear in the *Proceedings of the Society for Information Display* during 1989. ■

Plasma technology

BY JAMES L. KEHOE

THERE IS NO RED in plasma technology's bottom line. Personal computer products continued to use increasing numbers of plasma displays in 1988. Compaq, GRiD, and Toshiba, which introduced plasma technology to the high-volume PC market, offered enhanced products and experienced sustained sales. In addition, formidable new products were introduced by NEC and Hitachi, and rumors circulated of more significant product introductions to come.

Toshiba offers four basic models of its portable personal computer with plasma displays. The newest is the T-5200, with an 80386 processor and a plasma monitor that can display 16 shades of gray. Compaq, which last year reported sales of approximately 200,000 units, continues to realize good market penetration with its Portable III and Portable 386. Industry reports indicate nearly 70,000 of these machines will be sold in the United States alone by year's end.

GRiD Systems provides both plasma and LCD options for its newest line of laptop computers, the 1500 series. According to GRiD, plasma is chosen by the majority of its customers, even though the price is considerably higher than for LCDs. The light-emitting characteristics of the ac plasma still provide the best contrast ratio and off-angle viewing, as well as the speed needed to display rapidly moving or animated graphics images.

High-volume suppliers of plasma displays to the commercial market include Dixy, Fujitsu, Matsushita, NEC, and Oki. Their combined production capacity for "page-size" displays increased throughout the year and is now estimated at an astonishing 55,000 displays per month.

Dixy is now delivering 640 × 480-pixel panels with 16 levels of gray. It recently introduced a new screen-printed dc cathode material (LaB_6) into production, which shows significant improvements in luminance, luminous efficiency, and resistance to ion sputtering.

Matsushita continues to be one of the industry leaders in developing and shipping advanced dc plasma displays. At the 1988 SID Symposium in May, Matsushita demonstrated a 16-gray-level panel. Matsushita's high-volume dc panel offers a pleasing display and is low in cost, but its luminous background reduces contrast ratio. As this panel comes under increasing competitive pressure in 1989, will Matsushita pull a higher-contrast version out of its corporate sleeve?

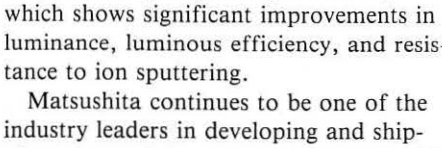

Photo: Photonics Technology, Inc.

Fig. 1: Plasma has been the only technology relied upon for very large emissive displays. This 1.0-m-diagonal workstation display is from Photonics.

NEC shipped record numbers of ac refresh plasma displays in 1988 (the flagship application being GRiD Systems). NEC plans to continue to expand its output, attaining a production level of about 5,000 dot-matrix displays per month during the second quarter of 1989. NEC is also very pleased with its successful pilot installation of 26-in.-diagonal 576 × 256-pixel plasma screens in the New York Stock Exchange. The 100 screens have operated 24 hours a day for nearly a year without failure—although one fell victim to an exuberant trader's missile! NEC plans to complete development of a 22-in.-diagonal 640 × 400-pixel display by early 1989. NEC also expects to have samples available during the first quarter of 1989 of a 4- or 8-level gray-scale panel.

Oki is also a leading high-volume supplier to the commercial market with a family of 640 × 400- and 640 × 480-pixel dc plasma displays. Fujitsu recently introduced a 1024 × 768-pixel plasma monitor that incorporates a capacitive matrix-addressing technique to reduce the number of address-driver circuits required. The drive voltage in these displays is reduced by employing an erase-cancelling technique. Fujitsu is also delivering panels with a 4-level gray scale in both 640 × 400 and 640 × 480 sizes.

Plasmaco, a new company in the plasma manufacturing arena, intends to become a high-volume producer of ac plasma displays incorporating exciting new technology. Having obtained the former IBM production equipment, patent licenses, and an exclusive license to process knowledge, Plasmaco has just introduced its 640 × 400-pixel plasma display sys-

James Kehoe is president of Plasmaco in Highland, New York.

tem, which is mechanically and electrically compatible with that of Matsushita. This system offers all the usual advantages of ac plasma technology (high contrast ratio, high brightness, and complete absence of flicker). But by incorporating the independent sustain and address (ISA) and energy-recovery sustain circuits developed at the University of Illinois, Plasmaco can produce products that carry prices lower than previously possible and that require significantly less power than dc plasma alternatives.

In the military and special purpose market, Electro Plasma has been a leading supplier for over 15 years. They supply high-quality panels as large as 1728 × 1280 pixels with an 18 × 24-in. active viewing area. Photonics Systems offers a family of ac plasma monitors ranging from a 128 × 256 display all the way to a 2048 × 2048-pixel display with a full 1.5-m diagonal [Fig. 1]. Thomson-CSF offers a 256 × 512-pixel plasma display module with an 8-level gray scale at 0.406 mm (62.5 lines/in.) resolution and a 512 × 512 module at 0.46 mm (55 lines/in.), also with 8 levels of gray.

Coloring the future

There are lots of plasma cliches. I've often been accused of seeing the world through orange-colored glasses and speaking with an orange tongue. But champions of plasma technology will not have to endure such jibes much longer, because color plasma is here! Of the six plasma papers presented at the SID Symposium this year, five were on color. NHK presented an impressive full-color 20-in.-diagonal, 640 × 448-pixel dc display with 256 gray levels that displayed a full-color television picture with quality comparable to a CRT. The other four papers on color presented new technology for achieving long life and high brightness in color ac plasma panels.

Fujitsu has developed a 320 × 240-pixel red-green-and-yellow ac plasma display. Photonics has successfully developed a full-color 4 × 8-in. ac plasma panel with 252 × 508 pixels, and is under contract to deliver a full-color 18-in. video RGB monitor this month. Photonics intends to complete a full-color meter-size display next year.

And for 1989 . . .

Advances in technology place ever-increasing computational and storage power in the hands of more and more users. And these powerhouses are compactly arranged in ever-smaller packages. Portable and laptop computers are everywhere—and the notion of the notebook computer has recently been renewed. These advances push the display industry to provide flat panels with larger pixel matrices, more gray scale, and color—and without sacrificing low weight, low power consumption, competitive price, high quality, or volume production. In this highly competitive arena, there is but a brief moment to reflect on yesterday's accomplishments. ■

Electroluminescent displays

BY ROLLAND VON STROH

THIS YEAR SAW thin-film electroluminescent (TFEL) displays become competitive with other flat panels for general applications. Rugged, reliable and eye-pleasing, TFEL displays have been known as the highest performance flat panels. However, their price premium over the cheapest alternatives meant they were only considered for military, industrial, and other high-end systems.

But that has changed. In all but long-battery-life applications, the market has rejected displays that do not measure up to the CRT standard. The early, simple LCDs costing $125 in volume have been replaced by more complex backlit supertwist or double-twist LCDs costing more than $300. The latter still have significant disadvantages in response time, contrast, and viewing angle, but have sacrificed the big LCD advantage of extremely low power consumption. Therefore, portable computer manufacturers have increasingly turned to light-emitting displays—TFEL and gas plasma—for their fast response and higher visual performance. TFEL and plasma have come rapidly down their cost curves as they've gone into high-volume manufacturing and are priced in the $400 range for high volumes. TFEL exceeds the other types of displays in many display performance characteristics and increasingly appeals to OEMs seeking a competitive edge. The existence of several manufacturers further established TFEL as a mainstream contender.

Rolland Von Stroh is vice president of marketing for Planar Systems, Inc., in Beaverton, Oregon.

Bigger, brighter, grayer (and more colorful)

TFEL matrix-addressed displays are now available in sizes from 2 × 3 in. to 12 × 14 in., with pixel counts from 320 × 25 to 1024 × 800. Most of the popular graphics and alphanumeric standards are supported, including 320 × 256, CGA, EGA, and VGA. [Fig. 1]

Already offering the brightest displays, the EL industry increased its brightness by 50% in 1988. Making use of the fact that EL-panel light output increases linearly with refresh rate, some EL customers have increased output to more than 100 fL. With good filters, customers such as Canadian Marconi, Eldec, and Computing Devices produce sunlight viewable displays.

Military displays using voltage-modulated driver ICs have displayed 16-level gray scales, and integrated-circuit driver

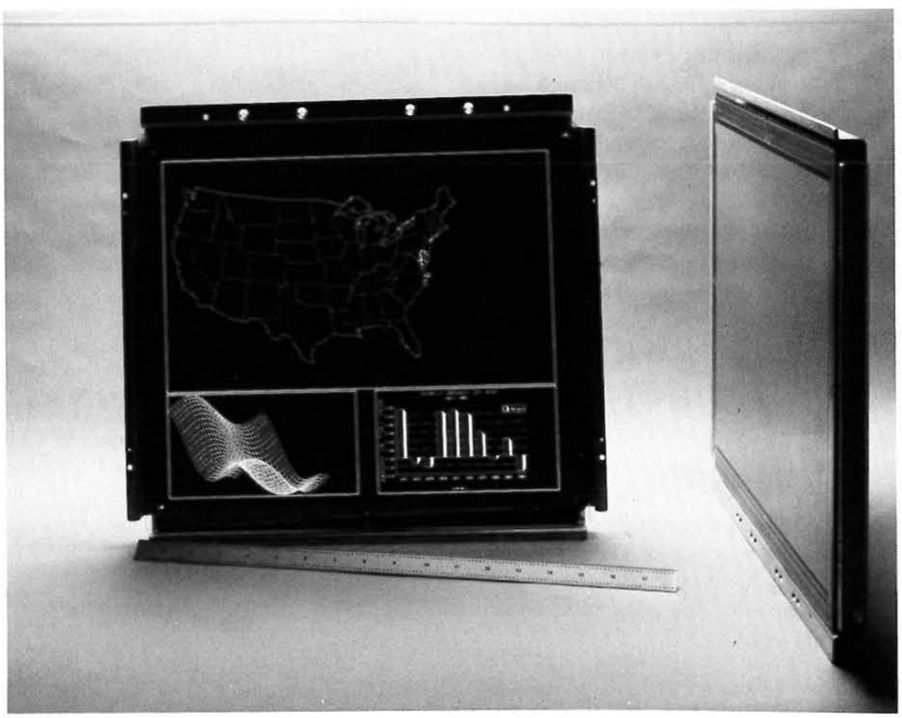

Photo: Planar Systems, Inc.

Fig. 1: Planar introduced this 18-in.-diagonal TFEL display in November. It contains 1024 × 800 pixels and is slated for use in military, industrial, and computer workstation applications. It is the largest single EL display announced so far.

manufacturers such as Supertex are now announcing commercial versions.

Planar demonstrated a series of continually improving prototype full-color displays, developed under contracts from the U.S. Army's Electronics Technology and Devices Laboratory. The blue phosphor must be brightened and its chromaticity shifted, but TFEL will be among the first high-information displays with full color.

TFEL displays have become easier for systems manufacturers to integrate. CRT-like interfaces have encouraged accessory vendors to produce a host of compatible products ranging from filters and touch interfaces to integrated chips that drive EL displays directly.

Saving juice

EL is much more power efficient than gas-plasma technology, but has been much less efficient than LCDs. The light-producing mechanism itself uses less than 2 W in a typical display, but voltage conversions and display discharging—EL displays are essentially large capacitors that produce light as a byproduct—consumed many times that. Symmetric drive and power recovery schemes have turned this around. Three years ago, half-page EL displays consumed a peak power of 35 W. Today, full-page displays peak at 15 W. Average power consumption has gone from 25 to 10 W, putting EL on a par with backlit LC—cold-cathode backlights consume about 0.25 W/in^2 [Fig. 2].

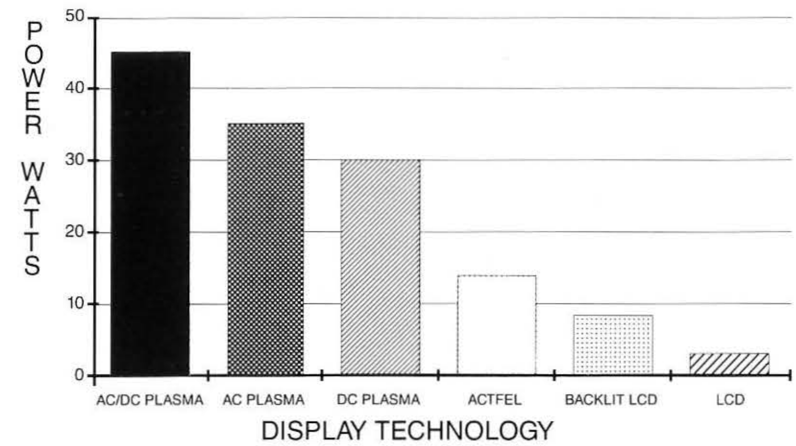

Fig. 2: Power consumption continued to differentiate display technologies in 1988. The power plotted here is the typical power consumed during mixed applications.

Made in the U.S.A., Japan, and Finland for world markets

Unlike some other display technologies, TFEL production is global. Planar (U.S.A.), Sharp (Japan), and Finlux (Finland) are the three leading manufacturers. Sigmatron Nova (U.S.A.) is focusing on the industrial indicator and control market with panels of 192 × 320 pixels and under.

Office automation demands good viewability. Many system manufacturers who cannot give up smooth scrolling, continuous cursor movements or visual performance have designed TFEL displays into their products. Among these are Data General, GRiD, Informer, V-Band, and Dynamac.

The industrial market accelerated its trend toward combining small single-variable indicators into high-information graphic displays for factory-floor automation. Tektronix, Hewlett-Packard, Cincinnati Milacron, Baxter-Travenol, Puritan-

continued on page 24

Table 1: Four Light-Emitting Display Technologies in 1988

Features	EL	DC Plasma	Backlit Supertwist LCD	Backlit Double Supertwist LCD
Brightness (average)	15 fL	6 fL	4 fL	10 fL
MTTF	50,000 hours	45,000 hours	50,000 hours	not available
Power Consumption (maximum)	14 W	35 W	5 W	8 W
Viewing Angle (≥3:1 CR)	160°	100°	50°	60°
Contrast Ratio (500 Lux with contrast filters)	25:1	10:1	4.5:1	8:1
Color	yellow on black	red on red	silver on blue	black on white
Shock	100 g's	30 g's	100 g's	3 g's
Pixel Write Speed (<16 msec for scrolling video)	<2 msec	<2 msec	>100 msec	>250 msec
Operating Temperature	−20° to +75°C	−5° to +55°C	0° to +55°C	10° to 40°

TFEL displays compare very favorably to other display technologies. Brightness, contrast, viewing angle, and display speed are particularly significant parameters, and are among those in which EL excels. (Note: average or actual perceived brightness is a product of pixel brightness and area "fill factor.")

Liquid-crystal displays

BY KENNETH WERNER

IN 1988, LIQUID-CRYSTAL DISPLAYS (LCDs) offered higher resolution, better contrast, greater variety, and monochrome in the revolutionary color scheme of black and white. The high end of laptop computer displays was decisively lost to emissive flat panels, but exciting prototype demonstrations held out the hope to LCD proponents that the battle is only temporarily lost.

So black and blue

Among passive-matrix displays, blue-mode supertwist (blue-mode STN) displays from Sharp, Toshiba, Sanyo, and Seiko-Epson proliferated and black-and-white double-layer supertwist (D-STN) displays from Sharp and Seiko-Epson started appearing. Both offer good contrast ratios—blue mode with up to 10:1 and D-STN with over 20:1—and viewing cones that are more than acceptable for single viewers. Pixel formats of 640 × 400 for EGA graphics became common, and Sharp offered STN displays with 640 × 480 pixels and 720 × 400 pixels. These displays are backlit with fluorescent lamps. Toshiba announced a lightweight black-and-white display utilizing a polymer "retardation film" (RF-STN) instead of a second layer. The display comes with a detachable fluorescent backlighting system "to maximize serviceability." Contrast ratio is advertised as 12:1.

***Kenneth Werner** is editor of* Information Display. *He wrote this review based on his own observations, on reporting from Hildegarde Hammond and Lynne Henderson, and on conversations with industry observers and participants.*

Toshiba claimed an average life for its fluorescent backlights of 20,000 hours. At the International Display Research Conference (IDRC) in October, Sanyo announced backlights featuring more uniform illumination thanks to a flat fluorescent tube.

Getting active

In January, Taliq announced its readiness for quantity production of "Varilite" nematic curvilinear aligned phase (NCAP) flexible display panels. These are low-information-content displays suitable for automotive, instrument, keyborad, and industrial applications. Colors are available through filters, and the displays really do bend.

Active-matrix color displays in commercially available pocketwatch-type television sets grew to 5 in. on the diagonal. Hitachi described their 5-in. version in detail at the Society for Information Display's International Symposium in May, and showed several complete TV sets. The company claims a brightness of 120 cd/m^2 with its U-shaped fluorescent backlight, a maximum contrast ratio of over 40, and a viewing half angle in excess of 15° vertically and 40° horizontally. All of this adds up to a good-looking display that is almost large enough to be taken seriously.

Also shown (in a laptop computer) was a prototype 6.3-in.-diagonal unit with 640 × (200 × 3) dots that drew considerable attention. (The color triads are arranged vertically, opening the possibility of an eventual 640 × 600 monochrome version.) Hitachi was delivering sample quantities by October, making this the largest color flat-panel display available for purchase.

Mitsubishi described and demonstrated a prototype 10-in.-diagonal color display with 640 × 3 dots horizontally and 450 dots vertically, 40:1 maximum contrast ratio, and a 60-Hz noninterlaced drive. "Extended applications" for this impressive display were promised "in the near future."

Where was the normally ubiquitous Sharp Corporation in the color LCD derby? Waiting for July. That's when Sharp announced a 14-in.-diagonal active-matrix color LCD—the world's largest [Fig. 1]. The unit was subsequently exhibited at SIGGRAPH and the IDRC. A maximum contrast ratio of 100:1, a 60° viewing angle, and a response time less than 17.5 msec (thanks to a new liquid-crystal material) are claimed by the company. Knowledgeable and normally gimlet-eyed observers were impressed, though one detected image smearing during fast motion. Engineering samples were promised for the first half of 1989 and products containing the display were promised by the end of 1989. Some industry observers, knowing the capabilities of the modified Nikon integrated-circuit wafer steppers used to make the prototypes, have wondered aloud whether Sharp's marketing people consulted with the factory before making these commitments.

It's not necessary to put a color LCD panel on the front side of an active-matrix array. In July, Alphasil announced a high-resolution black-and-white active-matrix panel for military applications. In August, Ovonic Imaging Systems announced delivery of 6 × 8-in. black-and-white active-matrix prototypes to the U. S. Air Force Human Resources Laboratory. This display is in VGA format (640 × 480 pixels), and OIS claims a 20:1 contrast ratio, a 140° viewing angle, and speed sufficient for television.

Not by monitors alone

You can look at a liquid-crystal panel or you can use it as a valve to modulate light shining through it—a distinction that blurs a little with the proliferation of backlit displays. Kodak introduced a portable, liquid-crystal light-valve video projector for the business presentations brigade. (See "Large Displays.") And Casio's liquid-crystal-shutter print engine appeared in a Qume electrophotographic printer. (See "Printers.") At the International Packaging Conference in October, Greyhawk described a liquid-crystal light-valve system suitable for printing 24 × 24-in. printed-circuit boards with 0.003-in. minimum feature size. Greyhawk has also been showing full-color 300-dpi 8½ × 11-in. images printed with a developmental light valve on Mead Cycolor photographic imaging paper. (See "Printers.")

Fig. 1: In August, Sharp demonstrated a 14-in. full-color matrix-addressed liquid-crystal display—the largest yet. Sharp is promising evaluation units during the first half of 1989.

Are ferros here?

"Near future" is always a popular time for introductions. But proponents of ferroelectric LCDs used it several times too often, and industry watchers had all but concluded that FLC's chronic problems—narrow operating temperature range, slow speed, and mechanical instability—had proved overwhelming. But, the IDRC saw Canon demonstrate a 14-in.-diagonal monochrome FLC display with 1120 × 1280 pixels—and there's no active matrix. There was no sign of smear on scrolling images and dragging cursors, and no evidence of mechanical instability. Canon claims a contrast ratio over 5 within viewing angles of ±30° and good viewability from any direction, along with an operating temperature range from below 0°C to 50°C. That should be good enough for office applications.

Waiting for '89

In 1988, passive-matrix LCDs established themselves as the displays of choice for middle-class laptop computers. These displays are clear, pleasing, and readily offer resolution up to EGA level—and sometimes beyond. Impressive prototype displays for the long-awaited color laptop

continued on page 24

Large displays

BY ALAN SOBEL

THE DEMAND FOR large electronic images with areas exceeding one square foot continued to grow in 1988. Manufacturers looked at the growing use of high-performance computer workstations and the anticipated development of high-definition TV (HDTV) and decided that this bull market is not facing any "Black Monday." The result is a quickening pace of technical research and system deployment.

CRT projection displays

CRT projectors continue to improve. Several manufacturers offered devices with claimed resolutions exceeding 1000 lines, albeit at low luminances. Evolutionary improvements to electron guns, phosphors, and lenses contribute to the enhanced performance.

At the National Computer Graphics Association meeting in March, Triuniplex Display Systems of Simi Valley, California, demonstrated a novel projection configuration using three CRTs with *convex* faces. Luminance and resolution are both excellent, image size can be readily changed, and the assembly is compact and rugged.

At the SID International Symposium, Philips described another convex-faceplate-CRT system, with antireflection coatings on the faceplates. Philips claimed significant improvements in luminance over more conventional arrangements.

High-performance flight or vehicle simulators often require several projectors to produce images with sufficient information content. A major problem is to blend adjoining image sections without disconcerting seam lines. Workers at Evans & Sutherland described a system that greatly simplifies the required alignment, although it still requires human intervention. Their technique is an excellent example of operator-system interface design.

Light-valve projectors

Liquid-crystal (LC) light valves used in conjunction with overhead projectors exhibited only minor improvements this year. Several devices now present 640 × 400 pixels—enough to project an image from the usual personal-computer display for teaching or boardroom applications. Contrast and gray scale are being improved, but color is harder to come by. Most of these devices are too sluggish for TV, but are adequate for normal computer applications.

Kodak, known in this market for its Datashow™ projector, announced a full-color LCD projector of lower resolution but higher speed. It uses three small 320 × 220-pixel active-matrix LCD panels—one for each color. The three panels share the light from a single conventional slide-projector lamp. The resulting images are

Photo: Kodak

Fig. 1: Kodak started a small trend with its 13-lb LC500, a video projection unit packaged like a slide projector. Late in the year, Sanyo, Seiko-Epson, and Toshiba announced similar products.

Alan Sobel is a consulting engineer and physicist specializing in electronic displays. He was president of Lucitron inc [sic], a company developing very large, full-color, flat-panel displays.

combined and projected through a single lens. The unit looks much like a 35-mm slide projector [Fig. 1]. It produces 65 lm—enough for a highlight luminance of 5.4 fL on a 5-ft-diagonal unity-gain screen. Kodak claims good-quality NTSC TV images and CGA graphics for this unit. Though not suitable for spreadsheets or other high-information-content imagery, its portability is likely to attract buyers where high resolution is not essential. Sanyo, Seiko-Epson, and Toshiba have announced similar products.

Work continues on other LC light valves, often with eventual HDTV applications in mind. A group at the University of Karlsruhe reported on an LC phase modulator that is a more efficient light valve than amplitude modulators like Kodak's. Another proposed LC light valve would use LCs as controllable light scatterers. Here, the liquid-crystal material is in the form of microscopic droplets encapsulated in transparent plastic. There is some resemblance to the large-area liquid-crystal films marketed by Taliq. For all of these light valves, a TFT or other switch would be required at each pixel.

A group at Fujitsu Laboratories demonstrated a multicolor (but not full-color) light valve that uses a two-layer structure and a nematic-cholesteric mixture. TFTs are not required, but the display's information content was not reported.

In the realm of laser-addressed LC light valves, the large high-resolution display marketed by Greyhawk Systems is now being challenged by Hitachi. Greyhawk describes its device as a "paperless plotter." It produces large high-resolution (2200 × 3400-pixel) images that can be viewed and edited much more rapidly than a plotter can churn out hard copy. The approach may never be fast enough for real-time TV, but there are many applications in which the size and resolution are more important than fast motion.

Big bulbs

The expanding computer workstation market requires increasing numbers of larger CRTs. The current "standard" is a 19-in. high-resolution unit in either monochrome or color, but even larger tubes are appearing.

In the consumer world, several manufacturers introduced CRTs bigger than 25 in. Mitsubishi's 35-in. unit has been improved and now has higher resolution than the first edition. Sony showed a prototype 43-in. 253-lb CRT in May. Its depth of 28 in. is probably as great as the home market will tolerate, and commercialization is probably a few years away.

Philips appears to have abandoned its flat CRT, which had the potential of becoming a medium-to-large display. The display was slim, but its costs were deemed too fat for a high-volume consumer product.

Plasma panels

NHK Laboratories, the research arm of the Japanese government broadcasting system, has improved its photoluminescent full-color panel, and has now made units 20 in. on the diagonal. This device, with 448 × 640 cells (each cell producing a single color), can generate a maximum white luminance of 17 fL but so far only at the low efficacy of 0.13 lm/W. Achievement of this size has required

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Circle no. 13

hard and elegant work on manufacturing methods. The device is constructed with thick-film and photolithographic techniques, which may eventually lead to production at reasonable cost.

Liquid-crystal panels

There is as yet no large LC panel, but sizes are creeping up and techniques are steadily improving. The work is being sparked by the sales of small "personal" TV sets and laptop computers. Both of these are sizable markets, so volumes are going up and prices are decreasing. In August, Sharp demonstrated the largest full-color LCD yet at SIGGRAPH. (See "Liquid-Crystal Displays.")

Miscellaneous

An ingenious scheme from Texas Instruments produces real 3D images in a volume determined largely by the available laser power. Although it requires expensive laser light sources and a mechanically rotating plane to form its image, the device could find use in military and large-audience entertainment applications. TI is looking for development partners.

Workers in the People's Republic of China reported a large powder electroluminescent (EL) device for displaying ideographs in a large meeting room. The display is over 79 $ft.^2$, uses a matrix of 25 modules, has a total information content of 22,400 pixels, and offers a luminance of 29 fL. The pixel pitch is 0.7 in.

Planar Systems has announced an 18-in.-diagonal 1.09-ft^2 ACEL panel with 1025 × 800 pixels.

Next year?

The key to large displays at reasonable cost is volume. At present, the only foreseeable high-volume application is higher-definition television systems, and these are several years away. However, many Japanese and some European companies are devoting substantial efforts both to HDTV systems and the large displays for them. Recent decisions on advanced television systems (ATV) by the U.S. Federal Communications Commission have energized development of a U.S. system. Both projection and flat-panel technologies are benefitting from the attention. ■

Printers

BY WILLIAM J. LLOYD

THE PAPERLESS OFFICE was not visible in 1988. In fact, printer shipments will reach an all-time record by year's end—more than 7 million printers with a value in excess of $9 billion, according to DataQuest.

At the beginning of the year, Hewlett-Packard introduced the DeskJet printer, which offers laser-printer quality at less than $1000. The DeskJet is an ink-jet printer that uses disposable thermal ink cartridges and emulates HP's popular LaserJet laser printer [Fig. 1].

Slow growth for color

Color printers continue to gain market share—slowly. But now that color copiers are beginning to produce copies that satisfy their users, this market segment should get a boost. High-quality digital color printers for the graphic arts are now available, with dye-diffusion thermal-transfer technology becoming dominant.

Products and technology from Kodak, Dainippon, Hitachi, Sony, ICI, and others are capable of producing high-quality color images on special substrates. 3M formally introduced its color dry-silver medium with a resolution of 100 line-pairs/mm. Printers for exploiting this medium are to be announced next year.

Mead Corporation formed a joint venture with Seiko to commercialize Mead's proprietary Cycolor silverless pressure-developed imaging paper. The first order of Cycolor was shipped to Noritsu America in October for the Noritsu QPS-101 Cycolor slide printer, which was unveiled earlier in the year.

Laser still tops . . .

Electrophotographic printers still captured most of the spotlight in 1988, with over 70 new products introduced in the under-$6000 range. Most of these printers produce between 6 and 10 pages/min. While these printers account for only 20% of the units shipped, they represent over 50% of the revenue.

In February, Apple introduced three new products based on the Canon SX print engine. The $2799 LaserWriter II is Apple's first laser printer that does not support PostScript. Instead, Apple chose the QuickDraw protocol operating over a Small Computer System Interface (SCSI). The top-of-the-line LaserWriter II NTX offers PostScript and an emulation of HP's LaserJet II PCL. This $6599 printer uses an Apple-built controller based on

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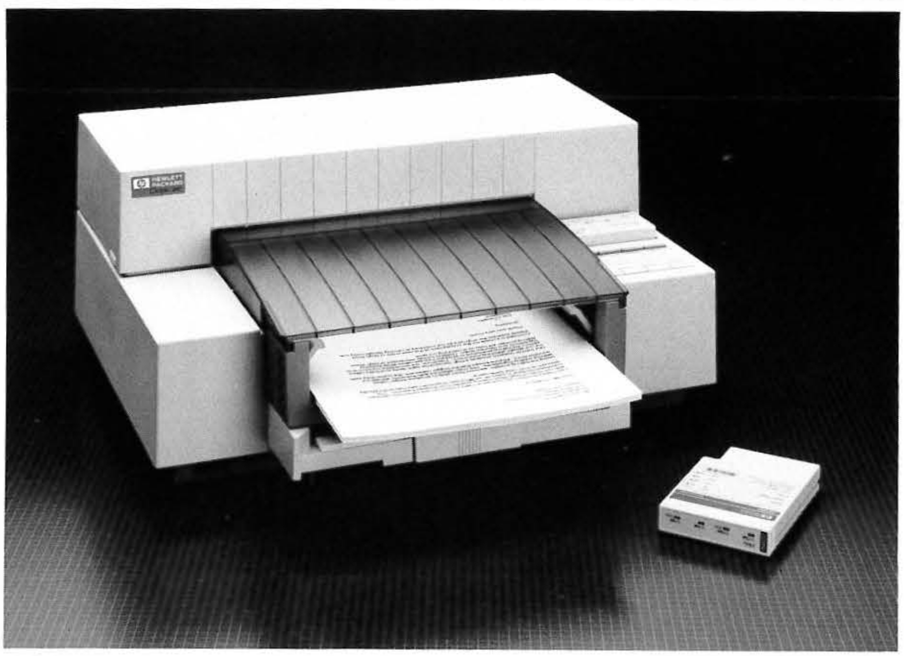

Fig. 1: *At its Boston Fall Print Quality Conference during the last week of October, DATEK gave its Printer-of-the-Year Award to the Hewlett-Packard DeskJet—the plain-paper drop-on-demand ink-jet printer that produces laser-quality output.*

William J. Lloyd *is manager of printing technology at Hewlett-Packard Laboratories in Palo Alto, California.*

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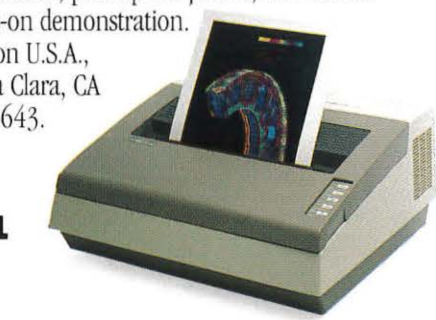

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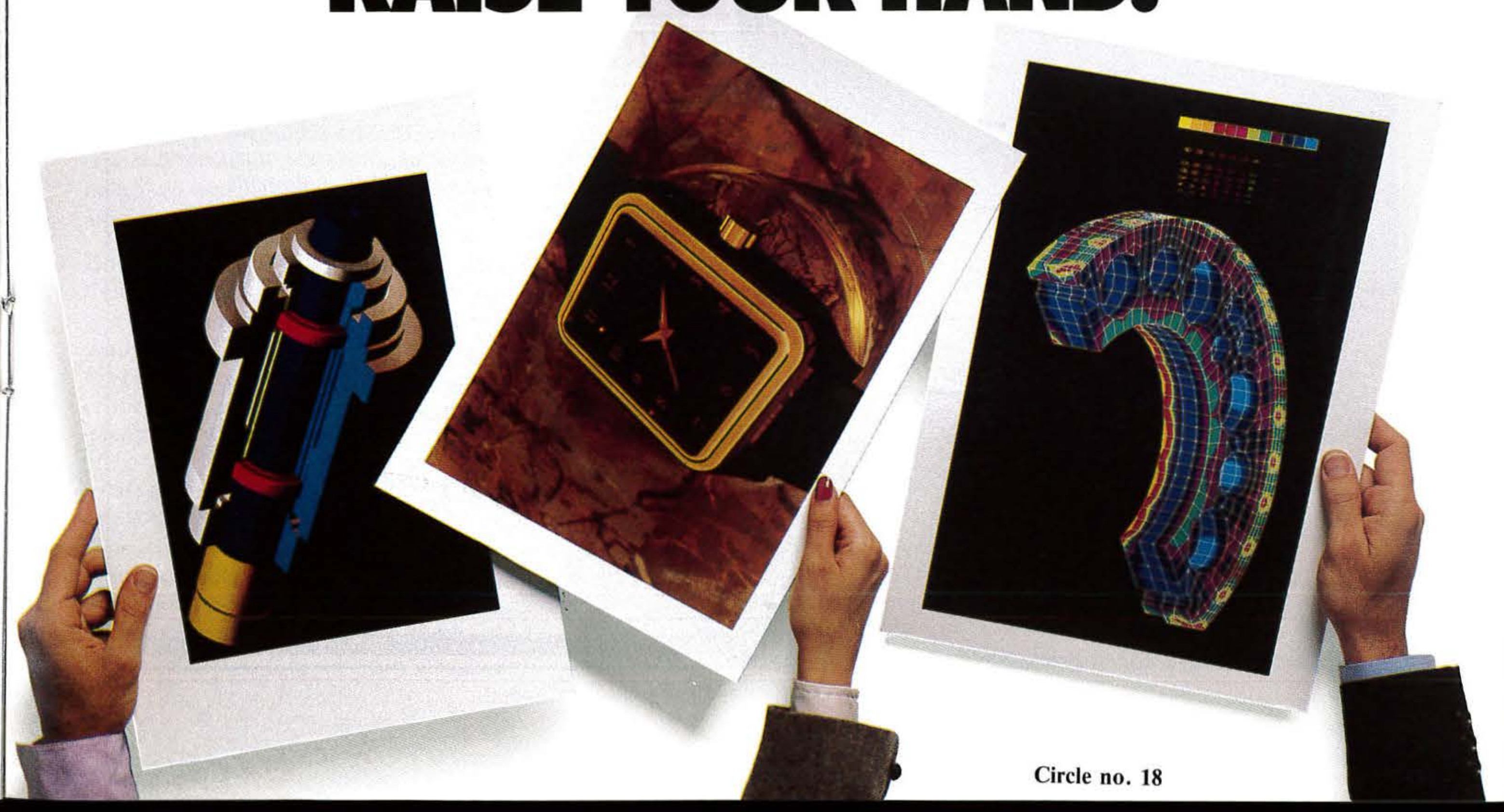

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Correction

In the September Industry Directory, an incorrect fax number was printed for Sigmatron Nova's East Coast office in Eatontown, New Jersey. The correct fax number is 201/542-4317.

EL

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Bennet, and Ampex, among others, have adopted EL for this application.

EL continued to find favor among military users for its visual performance, ruggedness, and tolerance of harsh environmental conditions. Customers for these displays include Honeywell, Magnavox, IBM, Canadian Marconi, Norden Systems, SAIT, Eldec, and Computing Devices.

And . . .

Color capability, excellent visual performance, rapidly declining cost, and further reductions in power consumption point to a successful future for EL as flat panels continue to make inroads on the CRT's market share. ■

LCDs

continued from page 17

were shown by several manufacturers, and even more presented technical papers at display conferences demonstrating solid advances. And ferroelectric technology finally seemed ready to deliver on its promise of very high monochrome resolution without active matrices. The unanswered questions concern availability, quantity, price, and power consumption—and reliability for ferroelectrics. Some of those questions will be answered in 1989.

But all the interesting cards are not yet in play. The Japanese Ministry of International Trade and Industry (MITI) has funded its multi-million-dollar "display-on-a-wall" program. A long-held dream of the flat-panel community is about to assume a new measure of reality. ■

printers

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the Macintosh II instead of the Adobe Atlas controller.

Printing and page-description technologies have brought higher quality and greater capabilities to printers, but paper handling has until recently taken a back seat. In November, Hewlett-Packard introduced the $4295 LaserJet II D, which offers double-sided printing, two input trays, and an optional envelope feeder.

. . . But competition mounts

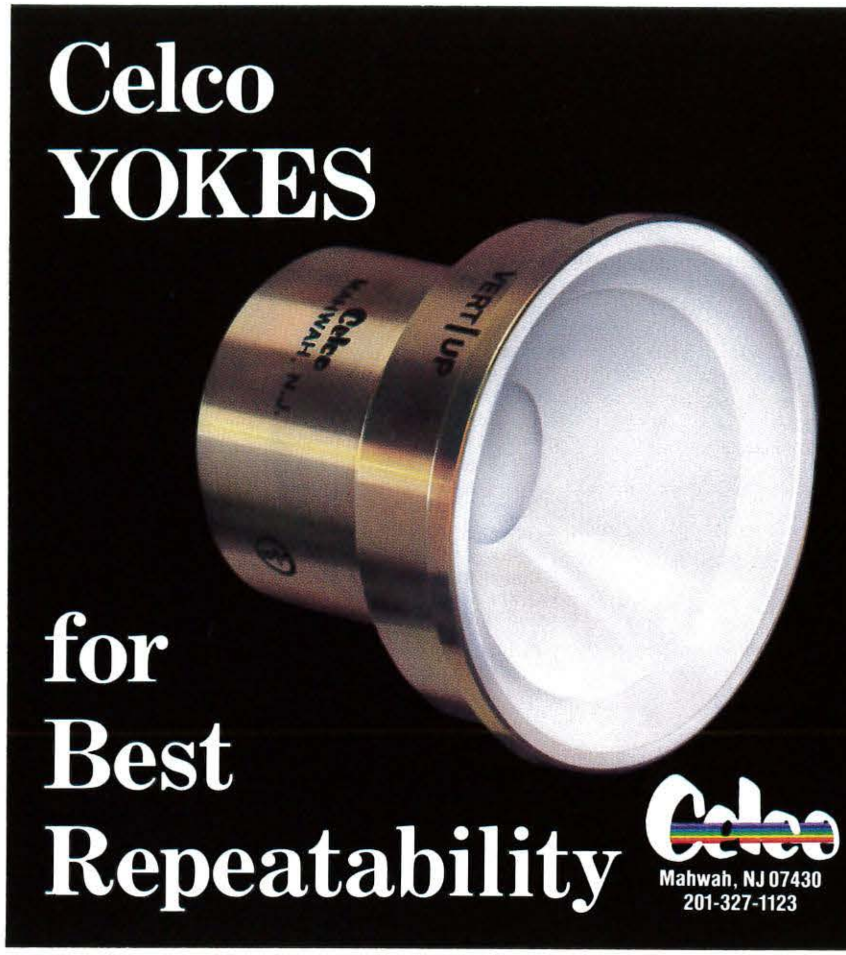
Alternative imaging technologies for electrophotographic printers are gaining popularity. Qume introduced the CrystalPrint Wp at a list price of $1299. Using Casio's liquid-crystal-shutter print engine, this unit establishes a new price point for electrophotographic printers. Continued development of liquid-crystal-shutter technology will clearly put pressure on laser-printer dominance.

LED printers are also establishing their presence in this crowded market. Page-width LED arrays offer much higher speed than do liquid-crystal shutters, and LED printers delivering more than 20 pages/min cost less than equivalent laser-scanned systems. Elimination of the rotating polygon mirror in mid-range and high-speed laser printers should improve reliability.

Many of the new electrophotographic page printers support Adobe's PostScript page description language. The price leader in this category is a $4000 liquid-crystal-shutter printer from Jasmine Technologies, which is likely to attract a lot of attention.

Dot matrix still makes impact

Even with the interesting and varied printer technology now available, dot-matrix impact printers continue to account for the most units shipped. The low price of these units ($200 and up) makes them the printer of choice for personal computer users. The 9-pin printer is still dominant, but most new products introduced this year have 18 or 24 pins, and one of these is selling for as little as $300. At least one 48-pin unit, offering 360 dpi addressability, has been introduced. Many of the new products offer color as an option. ■



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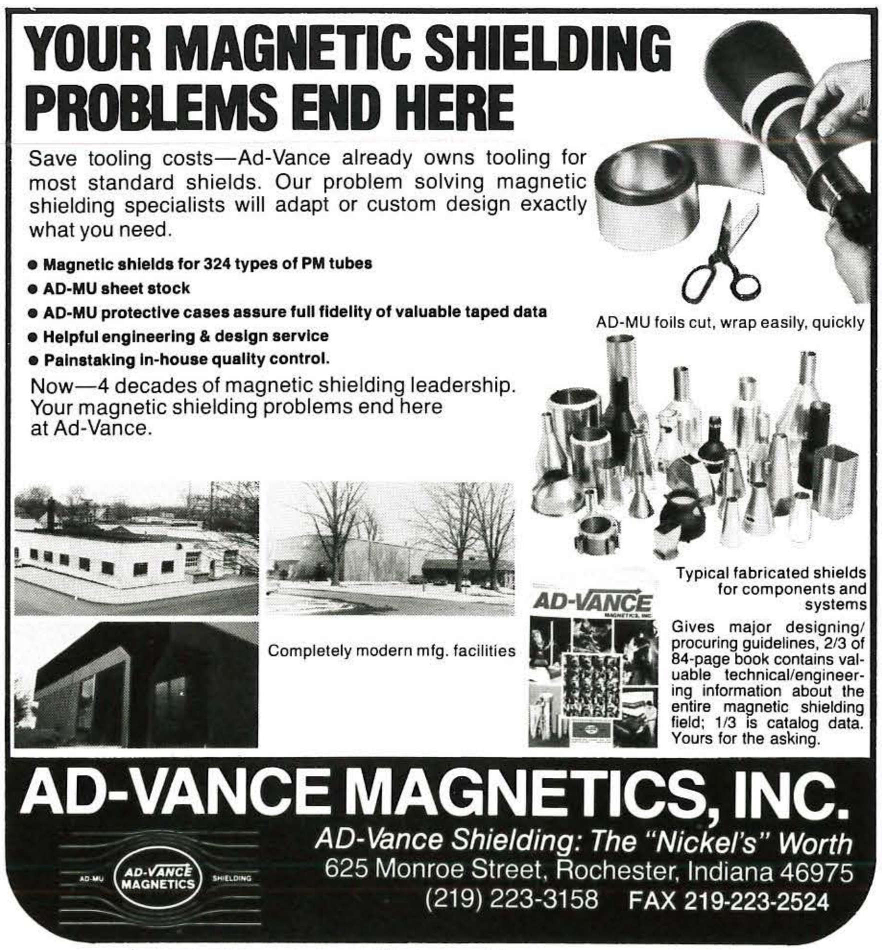

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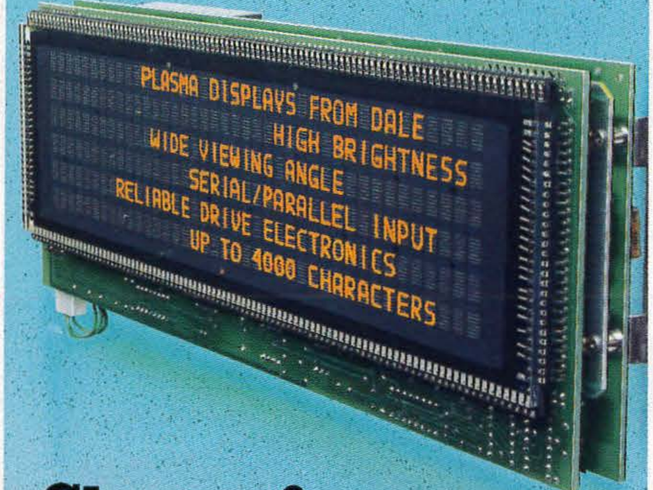

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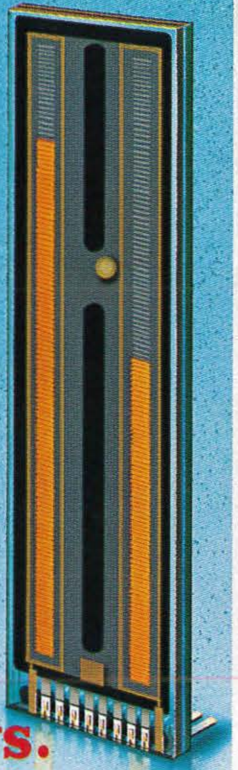

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