SID '98 REVIEW ISSUE

Information DISPLAY

SID

September 1998
Vol. 14, No. 9

Official Monthly Publication of the Society for Information Display

Looking In Depth at SID '98

- **SID '98 Review:**
  Overview • Microdisplays • LCDs • CRTs • FEDs • Emissives • Projectors • Manufacturing Equipment

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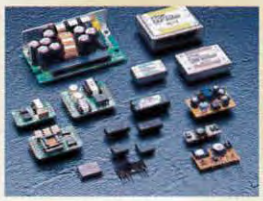

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- Isolated and non-isolated designs
- Special designs for VFD
- PCB mountable packages

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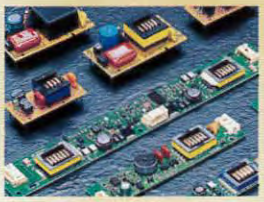

DC to AC
- 1.5 to 20 watts
- 1 to 4 lamps
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- Integrated dimming control - voltage/resistive/PWM
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- Remote on/off
- Open load protection
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COVER: The SID Symposium is the international display community's premier event, and it provides an annual overview of the state of display technology and the display business. In this, our SID Review Issue, six editors provide detailed coverage of the Symposium in eight articles.

Credit: Joe Orlando for SID

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*

Flat-Panel Issue
- LCD Technology and History
- Reflective Color LCDs
- Three Components of Reflection
- Advanced Shadow-Mask Mounting
- Computex Taipei '98 Report

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Information DISPLAY

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editorial

If It's Tuesday, This Must Be EID ...

The new conference/symposium/seminar/workshop/trade-show season is upon us. Between now and the end of the year, you can confer on display strategies in Ypsilanti, phosphors in Oregon, display research in Seoul, liquid crystals in Madrid, electronic information displays in Esher, color imaging in Scottsdale, advanced display technologies in Minsk, flat information displays in Monterey, and displays in general in Kobe. That's not counting COMDEX in Las Vegas, the Hong Kong Electronics Fair in Hong Kong, the Taipei International Electronics Show in Taipei, and local meetings everywhere. (And that only takes us up to December 9th!)

Are things getting out of hand? Well, yes, but every one of these meetings serves a purpose and all are of high quality. Furthermore, geography counts. The majority of the people who go to EID in Esher will be from the U.K. or nearby Europe, 75% of the people who go to IDW in Kobe will be from Japan.

Still, there are quite a few people who take in a pretty good sampling of these meetings, and they have a problem: getting their regular jobs done. The only solution I've come up with is to redefine your job as "conference-goer." In fact, a great many people must now be professional conference-goers. How else could they be going to all of these meetings?

I can account for six of these professional conference-goers immediately. They are the six editors who contributed to this SID Review Issue of *Information Display,* and I hope you will be as pleased with their work as I am. As I edited and organized these articles, I found myself stimulated by their different sensibilities and points of view. And as much ground as we covered, even all six of us could not exhaust the remarkably rich and varied event that the SID International Symposium, Seminar, and Exhibition has become.

– Ken Werner

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

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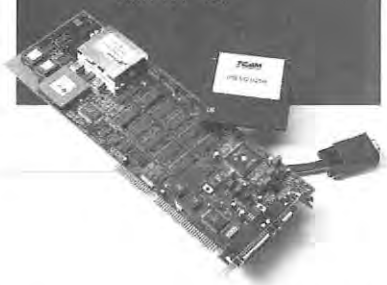

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Circle no. 6

the display continuum

And Then Things Got Really Complicated ...

by Aris Silzars

If you try really hard, can you remember any of your early at-home or school experiences with creating your first serious works of art - probably around the time of kindergarten or first grade? Weren't those first art experiences great? You were given a large piece of paper and some crayons or watercolors. Getting started was no problem. You picked whatever colors appealed to you and made interesting shapes on the paper, which then spread to whatever surfaces were surrounding the paper. Of course, your hands were soon as multi-hued as the paper, and finally even your clothes became a reflection of your colorful and artistic personality. Unfortunately, all too soon your teacher or parent would suggest that the paint was supposed to be put only on the paper. "But why?" "Just because - that is the way painting is supposed to be done. And, anyway, you're making way too big of a mess! Don't ask any more silly questions, just do it the way I showed you, or we'll have to put everything away." "WAAAAA!!!"

By grade school, we were all much more grown up. We knew that we must draw and paint only on the designated paper surface and, by the way, also must not let loose with blood-curdling screams when we didn't immediately get our way. We also graduated to more sophisticated boxes of crayons of up to 60 colors and watercolor sets with many more choices, which mysteriously were much harder to wash out of our clothes. By observation or intuition, we had also decided that to do really great art, one must use lots of these colors. With crayons, that was easy. Just pick whatever color looks good and go for it. With watercolors it was much harder because the colors would run and mix on the paper in unpredictable ways. In any case, some intentional mixing was needed because only a few of the wealthier kids in class had watercolor sets with more than about a dozen colors.

Now the teachers started saying things like, "Now, what color do you think your tree should be?" And you pointed to your gorgeous pink and purple tree. "No, that's not right - trees are green. Why don't you make another one next to it and this time make it green." And having been told by your parents that it's important to get good marks in school, and not wanting the other kids to make fun of you, you made your next tree green - even though you liked your pink and purple tree much better. And down deep inside, so that no one else could hear, you said, "WAAaaa... ."

Then came junior high, and we were all becoming quite mature - even though our parents still insisted on treating us like little kids. By now, art classes dealt with sophisticated themes like how colors mix to produce other colors. We learned that there are three primaries from which all other colors can be mixed. The primaries, we were told, are red, yellow, and blue. "If you mix blue and yellow, you get green. If you mix yellow and red, you get orange. And if you mix red and blue, you get purple. And, of course, if you vary the proportions of the primaries, you will get everything in between." It was never mentioned that this assumed that one always starts with a white sheet of paper. As students, we were also occasionally allowed to use a black pigment, because mixing all the primary colors together usually produced something approximating nice dirty

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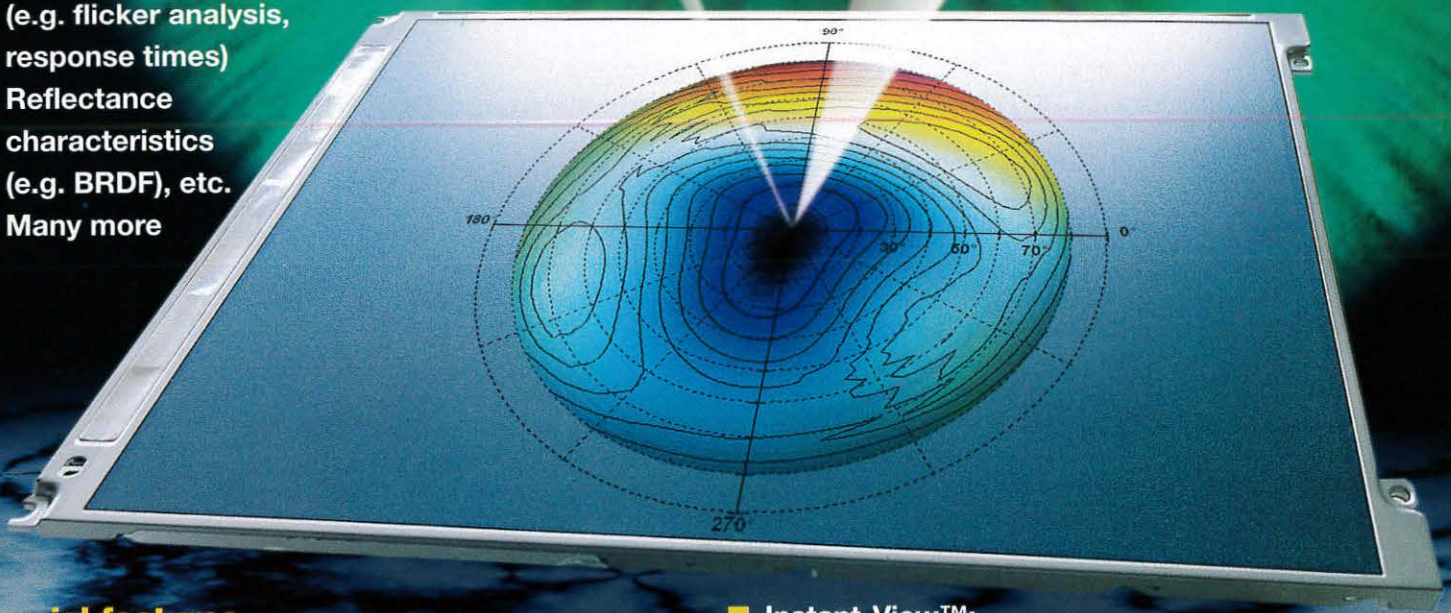

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Even the European Commission Can't Feed Two Cultures from One Bowl

by Bengt Stebler

There is an opinion among producers of IT hardware – an opinion shared, it seems, by the general public, who have perhaps been influenced by the views of journalists – that too little of the taxpayers' money going into our universities is seen coming out in the form of new products and/or workplaces. (People might not care had they a job to go to the next morning, but many Europeans do not.)

To be more precise regarding the industry's idea about what's wrong: They say there ought to be more involvement, at early stages, by industrial steering of research so that the goals set up are realistic and that demonstrator devices could lead to production prototypes for eventual inclusion in a customer-ready system. Nothing wrong with these views, or is there?

Surely most people involved in materials and device research on the European information-display scene – not to speak of industrial reviewers – would agree that there has been no lack of efforts, or funding, or scientific success, during the last thirty years. But, to sing along with the late European-American movie star Marlene Dietrich – "Where have all the flowers gone ...?" – you may turn desperate while looking for European flat-panel production chimneys resulting from all those efforts. After all, it was, to refresh the reader's memory, in European laboratories that the TN, STN, and FLC technologies – among others – were first demonstrated.

An exception to the rule is seen in Optrex Europe's plant at Babenhausen in Germany. There, with a dominating share of the LCD market among European car producers, independent (from its Japanese mother company) R&D has actually led to considerable and efficient production. But otherwise and elsewhere? Now, toward the end of a lost half-or-so century, European spending on IT-related research – through either national or European Commission programs – seems to be trying hard to improve the situation. (Yes, half a century has been lost. European industry is to a large extent living on its founders' basic ideas, many of which came up during the first half of the twentieth century or even earlier. Really new ideas seem to find a better breeding-ground across the Atlantic, or further away across the Pacific!)

By prescribing, at least in the Swedish and E.C. regulation of most official R&D support, that money be given only to consortia involving several industrial partners alongside a number of academic groups, it is hoped that production – and, of at least equal political importance – workplaces will emanate as a result of the effort.

But is this really the right thing to do? Although this approach may reflect the democratic requirements of the political bodies that possess the funds and the decision-making power, does it totally lack compatibility with the needs of the recipients? The problem is that two cultures are forced to meet under these consortia umbrellas. The first is the academic, traditionally open, society with its freedom of speech – with the exchange of ideas as its very nutrition. The second is the industrial/commercial culture, that to a great extent nourishes itself by keeping secrets to get ahead of its competitors.

To make things even worse, academic palms are usually earned by those providing new ideas in the fundamental branches of science, while success from an industrial point of view is measured in a financial crossover within the present

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Display Technology

The 18th International Display Research Conference (Asia Display '98). Sponsored by KPS and SID. Contact: Prof. S. Lim, Secretary General; +82-417-550-3542, fax +82-417-551-9229, e-mail: limsk@ns.dankook.ac.kr, Internet: http://tftlcd.kyunghee.ac.kr/idrc98.
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Dec. 1-5, 1998 Minsk, Belarus

The 15th Annual Flat Information Displays Conference. Contact: Stanford Resources, Inc., Attn: Laura Barretto, P.O. Box 20324, San Jose, CA 95160; 408/448-4440, fax -4445, e-mail: www.stanfordresources.com.
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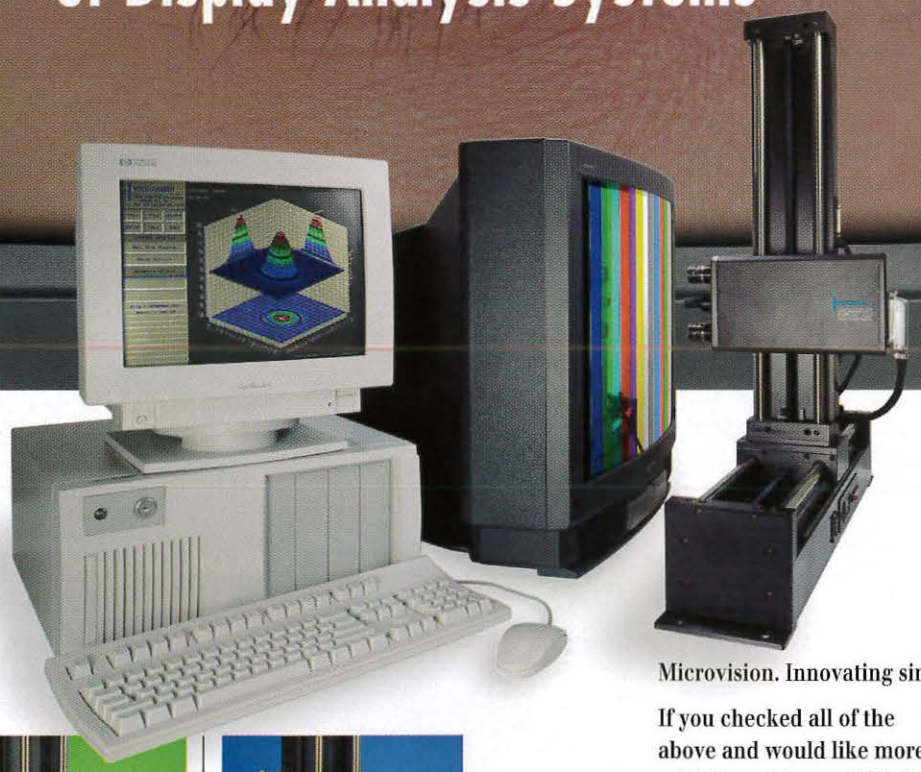

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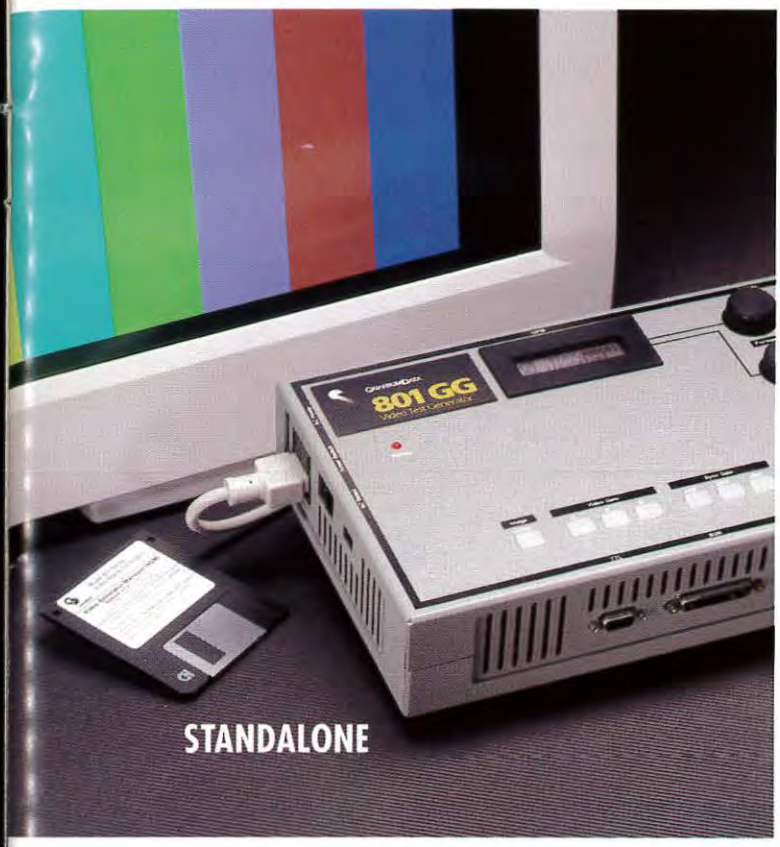

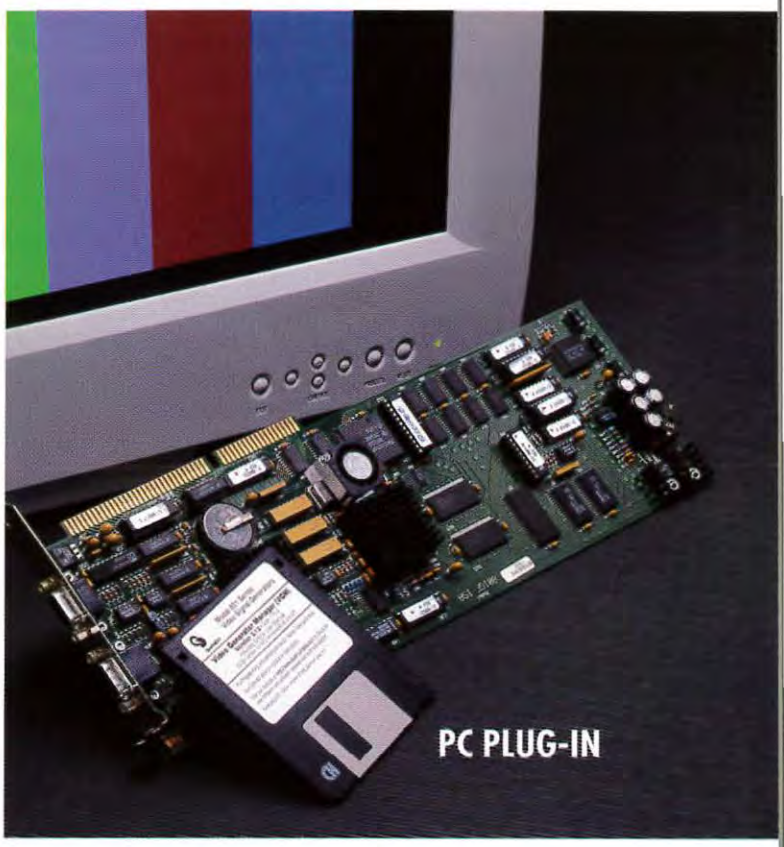

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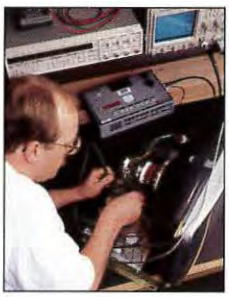

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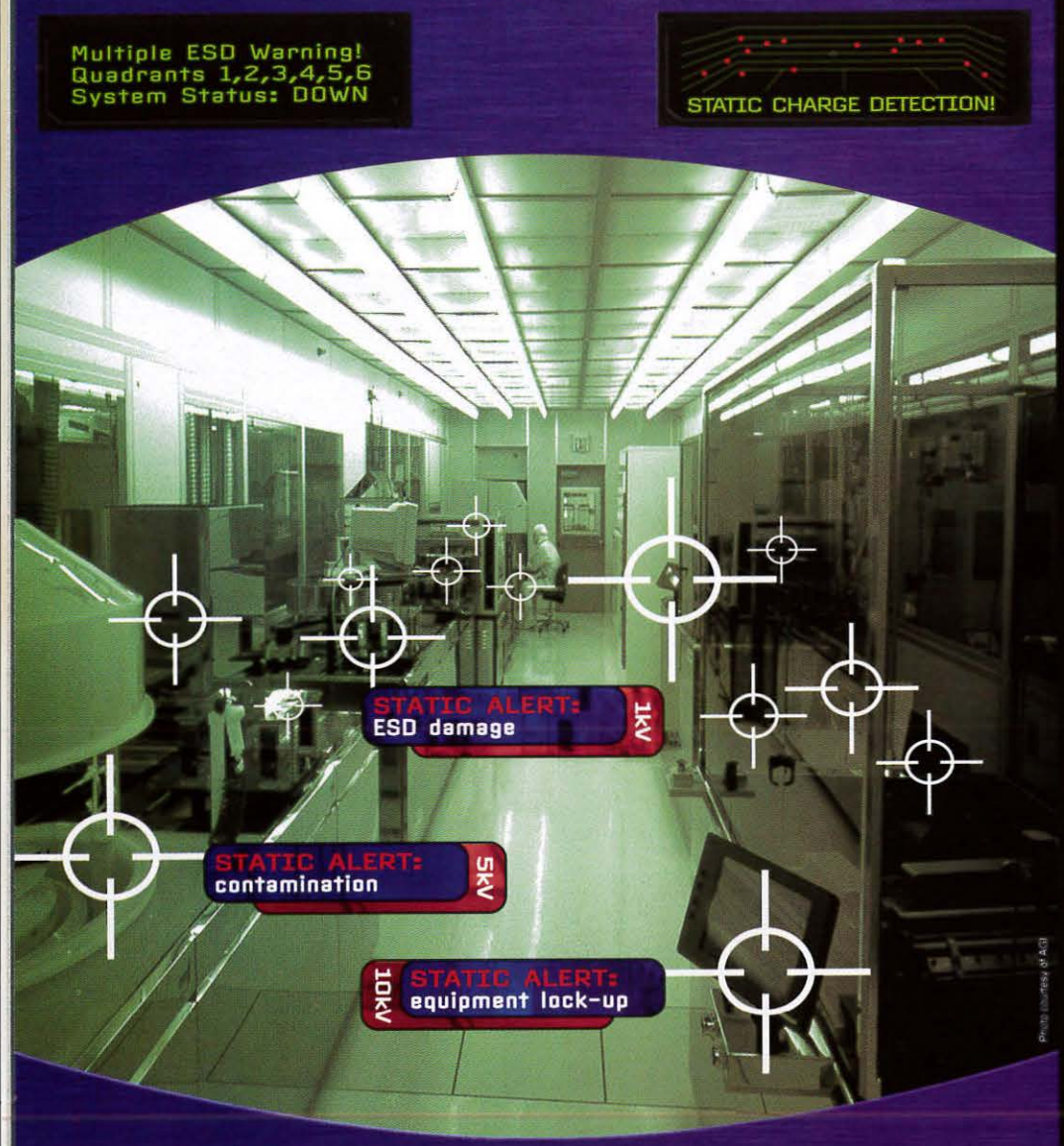

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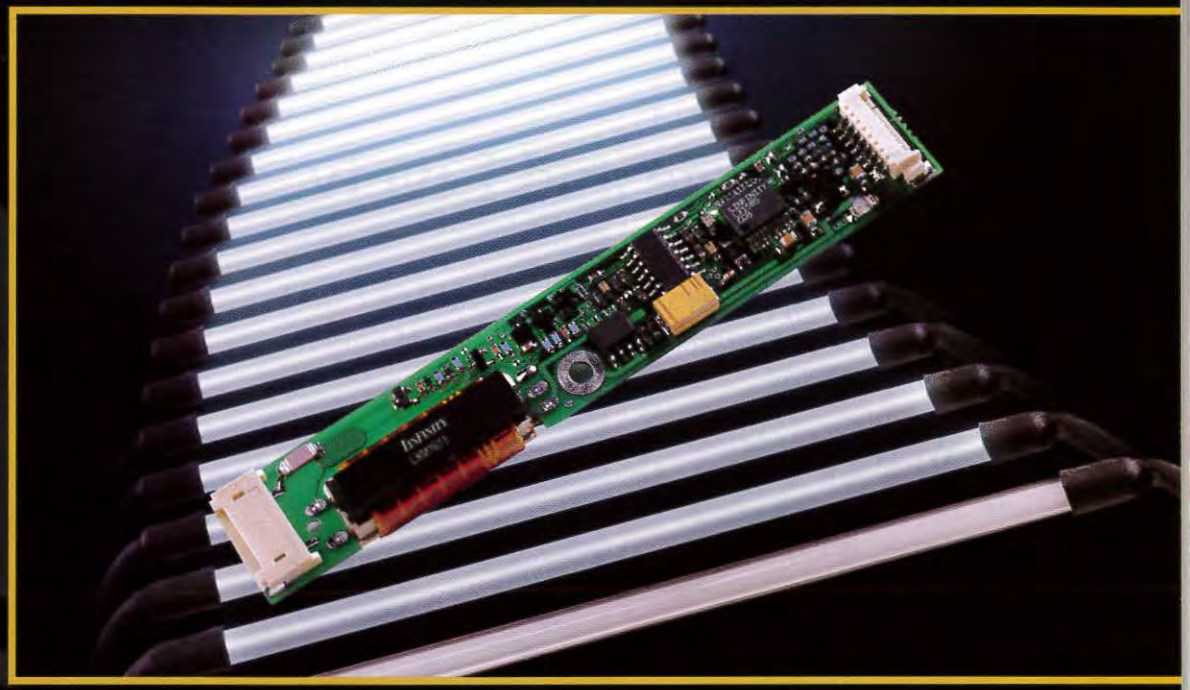

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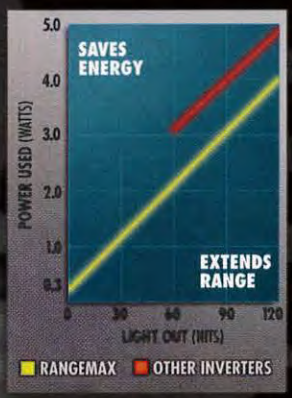

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SID '98: Large and Lively

A record number of exhibitors happily showed and sold their wares to a record number of attendees in Anaheim.

by Ken Werner

DESPITE SOME PRE-SHOW JITTERS on the part of the organizers, even the Asian flu could not seriously dampen enthusiasm for the 29th Society for Information Display (SID) International Symposium, Seminar & Exhibition, held May 17–22, 1998, in Anaheim, California. Overall attendance was a record 6200 (compared to 6000 last year in Boston and 5500 in 1995 in San Diego), the number of exhibitors was up to 252 from 240 in Boston, and the number of exhibit booths was up to 383 from 347.

It's not that the Asian flu didn't have its effects. Several Asian exhibitors reduced the number of booths they rented (compared to the number they had reserved months before), full registrations for the technical program were down slightly to 1642 from 1657 the year before, and registrations for the Monday and Friday seminars were down nearly 20%. Subjectively, it seemed that the proportion of Japanese and Korean attendees was less than usual for a SID symposium.

But new sources of exhibitors and attendees helped cushion these losses. Microdisplays, interface chips and electronics, controllers and drivers, manufacturing equipment and materials, display integrators, component suppliers, and test-equipment suppliers all helped to increase the attendance and the exhibit-floor space.

The new Display Technology Showcase (DTS), a side-by-side comparison of different display technologies and approaches, attracted 4000 of SID's 6200 attendees. The new event encouraged several companies to exhibit on the main floor who had not planned to do so. Attendees, participants, and journalists labeled DTS a great success, and SID plans to make it a regular (and larger) component of future SID symposia.

A total of six editors covered SID '98 for this issue. We believe this major effort is justified not only because the SID Symposium is the international display community's foremost annual event, but because covering it well provides a broad-based annual survey of display technology, display trends, and the display industry.

What stood out at SID '98? Here are some personal selections, most – but not all – of which are covered in more detail elsewhere in this issue:

- A well-concealed late-news poster paper (LP-B) from Semiconductor Energy Laboratory and Sharp Corp. that described a 60-in. SXGA rear projector using three

Joe Orlando for SID

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Ken Werner

2.6-in. AMLCD panels whose TFTs are fabricated from high-performance continuous-grain silicon (CGS).

- Toshiba's 13.3-in. AMLCD that uses low-temperature poly-Si TFTs. (This is very significant for low-temperature polysilicon.)
- A variety of color reflective LCDs from Sharp, Philips, and others that seem ready – or very close to being ready – for PDAs and notebook computers.
- Microdisplays using a variety of technologies for direct-view personal displays and rear-projection monitors and television receivers – and the large number of applications envisioned for these displays.
- Acceleration of the development of plastic-substrate displays.
- The remarkable image quality of the latest generation of plasma-display panels.
- The ability of manufacturers to make LCDs even thinner, lighter, and more power-efficient.
- The remarkably low price of many large LCDs – which is tough on manufacturers but a boon to OEMs and end users.
- The excellent quality of the latest generation of LCD monitors from manufacturers such as Eizo (shown at the Wyle Electronics booth) and NEC which make use of remarkably good scaling engines, such as the one from Genesis Microchip.
- The fact that some equipment manufacturers are actually ready for Generation 4 motherglass – and even Generation 5!

And that just scratches the surface. ■

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Microdisplays Grow Up

The diagonals may be small, but optimism and pixel count are high among the folks who produce big images from very small displays.

by Charles McLaughlin

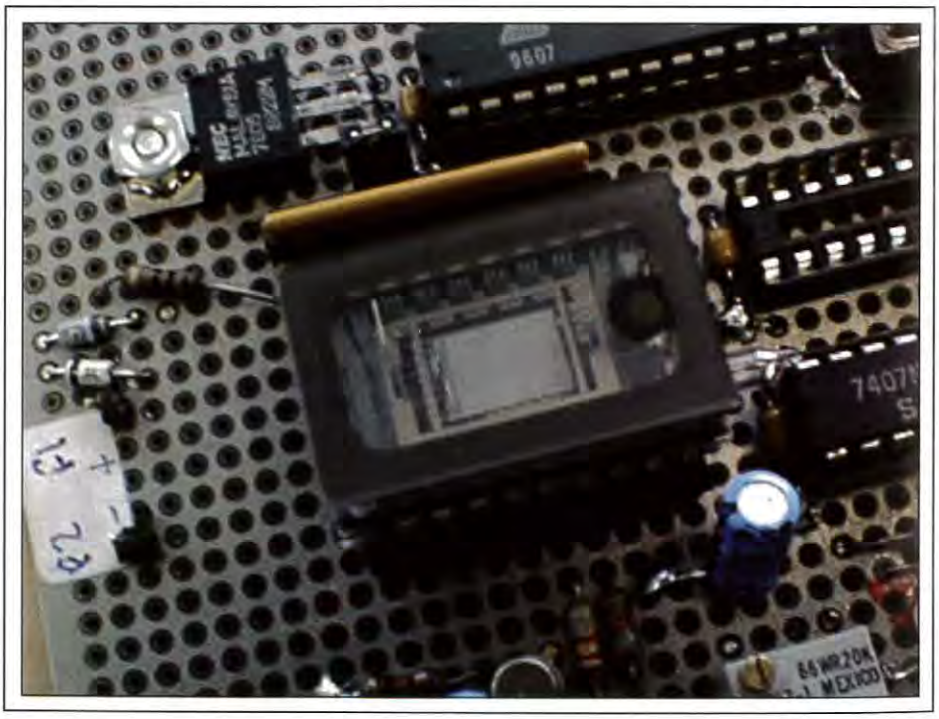
OPTIMISM was widespread among developers of microdisplays at SID '98. The sustained growth of the presentation projection market and the impending emergence of rear-projection desktop monitors and HDTV home-theater displays have enticed both Asian and Western display companies into the projection-microdisplay arena. In addition, personal-display developers were demonstrating a range of viewfinders, viewers, and headsets based on high-definition microdisplays capable of full-color video.

Microdisplay-related activities at SID '98 included several sessions of technical papers, exhibit booths featuring a variety of personal-display products, an evening panel session focused on CMOS-based devices, and an industry press conference with projection and personal-display roundtable discussions by industry executives. In combination, the progress demonstrated by exhibitors and the promise of the new developments bode well for near-term commercial prospects.

While the exact timing of new-product introductions is uncertain and picking the winners in the microdisplay derby is next to impossible, two things are clear. First, the domination in both projection and personal displays of polysilicon-on-quartz AMLCD microdisplays, manufactured principally by Epson Corp., has come to an end. Second, the commercial availability of high-definition DMD and reflective LCD-on-CMOS microdisplays from more than 10 producers promises to accelerate the introduction of several new classes of rear-projection and personal displays. And large-area low-temperature polysilicon-on-glass imagers show promise for high-brightness rear-projection HDTV projectors.

Projection

The Digital Micromirror Device™ (DMD™) is real. After more than 20 years of development, Texas Instruments has successfully gained a significant share of the front-projection presen-



Colorado Microdisplay

Colorado Microdisplay debuted the first full-color-video SVGA personal display at SID '98.

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tation-projector market, demonstrating the competitiveness of reflective CMOS-backplane microdisplays against the entrenched transmissive designs. TI has been successful in the following two market segments: lightweight mobile road-warrior projectors and high-throughput large-venue projectors. The company now claims to be the top supplier in the road-warrior class and has reached the milestone of having supplied DMDs for more than 100,000 projectors. Accepting the TI claim, DMD-related revenues for 1998 could easily approach $100 million.

The compactness and simplicity of the single-imager DMD design has enabled several projection-system companies, led by In Focus Systems, to market road-warrior SVGA units with outputs of greater than 500 lm that weigh less than 8 lbs. Even better, these projectors are at the $5000 price point and have been well received.

Three-imager XGA DMD projectors with outputs of up to several thousand lumens are now available from a variety of projector companies. While priced above $20,000, such units offer new competition in the large-venue market segment.

But it is also here in the large-venue and high-performance desktop segments that the first projectors incorporating reflective liquid-crystal CMOS microdisplays are appearing. Product announcements, technical papers, and product demonstrations included:

- ***JVC*** – JVC presented a paper on their SXGA D-ILA™ projector using reflective VAN on CMOS. Aperture, reflectivity, and performance are impressive. The projector itself was shown at both the NAB and INFOCOMM exhibitions, and it lives up to expectations.
- ***IBM*** – IBM is now supplying its SXGA reflective nematic/CMOS projection components and engine to several integrators. The IBM imager is distinguished from the competition by its size (33-mm diagonal) and resulting output.
- ***National Semiconductor and Three-Five Systems*** – Earlier this year these two companies announced a cooperative agreement. They offer SXGA projection microdisplays and report working closely with an unnamed system integrator.
- ***S-Vision*** – The company's initial XGA product is now available in a 1000-lm projector from Chisholm, as demonstrated at INFOCOMM.
- ***Displaytech*** – Displaytech added credibility to its projection-microdisplay initiative with the announcement of a tie-up with Samsung targeted at several products, including rear-projection television.
- ***Colorado Microdisplay (CMD)*** – CMD also threw its hat into the projection ring, and announced a deal with In Focus Systems shortly after SID.
- ***Silicon Light Machines (SLM)*** – SLM returned to the stage, presenting a paper on its laser-scanned linear diffractive grating array. A contrast ratio of more than 200:1 was reported for a 1920 × 1080 HDTV system using a white-light laser source.

The developers of reflective LCD (RLCD) CMOS-backplane microdisplays have clearly established the lead in the high-definition market segments, getting a leg up on both the polysilicon-on-quartz and DMD designs. IBM presented a paper and clearly stated in discussions that the migration to high definition has only just begun. Most of the developers of RLCD/CMOS devices already have demonstrated SXGA imagers and predict UXGA devices will be commonplace before year's end. Next year, even higher-definition offerings are promised for both desktop-computer monitor and HDTV applications.

While not even beginning to approach the definition limitations of the RLCD/CMOS technology, such new designs are constrained in light throughput by the economics of chip fabrication. Most companies are designing devices with approximately a 25-mm diagonal, although IBM, for one, is now selling a 33-mm-diagonal device. Given the output limitations of long-lifetime projection lamps, system output for the projectors can easily be 500 lm, but 1000 lm is a stretch without reverting to high-wattage lamps. Such microdisplays can easily light up a 20–30-in. high-definition rear-projection monitor, but are stretched to the limit for a 60-in. rear-projection HDTV.

The projection panel discussion at the press conference was very bullish. Microdisplay makers predicted the continuing high growth of front-projection presentation markets with the development of a mass-market projector. Given reliable operation and foolproof interconnectivity, why would anyone buy an overhead projector and pay for transparencies? Bruce McWilliams of S-Vision predicted a future of "five million presentation projectors

Kopin Corp.

Kopin's microdisplay with transparent single-crystal-silicon TFTs is used as the viewfinder in this digital camera, and was shown in many possible applications.

JVC

JVC presented a paper on its SXGA D-ILA™ projector that uses reflective VAN on CMOS. The reported aperture, reflectivity, and performance were impressive.

selling at a $2000 price point." There is similar optimism for the large-venue segment of the market.

And the killer ap will be ... what?

While there was also optimism about prospects for rear-projection monitors, there was little consensus on product configuration, pricing, and timing. While McWilliams and Dan Schott of Three-Five Systems predicted that 24-in. SXGA and UXGA monitors would be successfully introduced next year, Robert Melcher of IBM was more reserved. He felt that "a very-high-definition rear-projection monitor with a diagonal of 30 in. is required to differentiate the technology from AMLCD flat-panel monitors." There was also a significant difference of perception on price points. The supporters of the UXGA model are predicting prices well under $2000 and potentially under $1000, while Melcher envisions a high-performance premium-priced offering.

The various views of microdisplay-based rear-projection big-screen TV makers were even more divergent. Larry Hornbeck, the father of the DMD, said, "It will take a miracle to achieve an HDTV rear-projection television that can sell for under $2000." In contrast, Mark Handschy, Displaytech's leading technologist, who was buoyed by his company's agreement with Samsung, predicted, "We will see microdisplay-based rear-projection HDTVs next year priced well under $5000, and high-volume pricing at $2000 is within sight."

Absent from the panel discussions were representatives of Sharp and the other Asian developers of low-temperature polysilicon-on-glass projection imagers. Sharp presented a paper on a 1920 × 1080 device with a 65-mm diagonal aimed squarely at HDTV and offering a much larger area than the RLCD/CMOS devices. There will clearly be more than one way to make big-screen TVs.

Personal Displays

Despite the lack of substantial markets, a variety of developers continue to support the development of microdisplays for personal displays: bring-to-the-eye viewers and viewfinders, as well as head-mounted displays. Most of the activity centers around transmissive and RLCD/CMOS single-microdisplay designs in the VGA/SVGA class. Full-color-video capability is achieved with a field-sequential-color (FSC) LED illumination system. Activities of interest included:

- ***Kopin*** – As a pioneering firm in the field, Kopin seems to lead the pack toward commercial applications, despite lagging in the introduction of VGA color devices. The Kopin booth at SID '98 was loaded with engineering models and prototypes produced in cooperation with partners and customers. The cellular telephones and digital cameras were particularly impressive.
- ***Colorado Microdisplay (CMD)*** – CMD's debut at SID featured the first full-color-video SVGA personal display. Based on Dynamic Nematic Liquid Crystal on Silicon™ technology, CMD claims to have developed a way to get video performance out of a nematic liquid crystal using an FSC scheme. No details have been published, but a low-voltage drive and conventional cell-gap spacing is claimed. CMD exhibited a monocular headset that approaches an eyeglass form factor. The prototype caused more than a few head-mounted skeptics to reevaluate their opinions.
- ***Displaytech*** – The company showed more configurations of the full-color VGA personal display introduced last year, with improved field of view and optics.
- ***Siliscape*** – Back for its second year, Siliscape has maintained its focus on the cellular-telephone market. The wide field of view of the company's folded compound magnifier is as impressive as ever. Prior to SID, the company announced a partnership with Three-Five Systems that should further strengthen its push into cellular telephones.
- ***Planar Systems*** – Planar continues to advance their AMEL microdisplays, targeting both military and industrial applications.

The panel discussion for representatives of the personal-display industry centered around the timing of the development of markets. The theme was "Show me the money." Clearly, the suppliers can now offer excellent displays, capable of laptop-quality imaging, at prices and power levels nearly an order of magnitude less than conventional direct-view LCDs. Given this enormous potential for cost and power savings, when will we see this new class of displays in real products? Opinions varied widely.

Viewfinders for camcorders and digital cameras should offer the most immediate market acceptance. Consumers are accustomed to

Siliscape

Siliscape has a microdisplay, but the company's impressive folded compound magnifier is what really sets it apart – along with its just-announced partnership with Three-Five Systems.

peeking into a viewfinder, and the better definition of the new microdisplays can match that of the camera CCD. In addition, their power consumption is less than conventional polysilicon-on-quartz viewfinders and direct-view AMLCD viewer panels.

Glenn Kephart, V.P. of marketing for Kopin, and Mark Willner, president of CMD, were both bullish. Kephart predicted, "We will see the first CMOS-based microdisplays in camera viewfinders before the end of this year." Willner noted that "several companies are piloting the new designs now." Other developers were not as optimistic.

Opinions on implementing personal viewers into cellular telephones and other wireless network appliances were both more strident and varied. Kephart, Anthony Artiglierre, V.P. of marketing of Displaytech, and Al Hildebrand, founder of Siliscape, all expressed the opinion that units will be introduced next year. Others felt that market forces ranging from the lack of a killer application to insufficient processor capacity and transmission bandwidth would delay the development of the market for a few years. Several members of the audience suggested that e-mail is already the killer application, and that processor and transmission technology will not hold back implementation.

Potential markets for head-mounted displays range from small vertical markets for military and industrial displays to general-purpose computer and game peripherals. Willner was the most optimistic of the industry leaders on the emergence of such markets. At the exhibition, his company demonstrated very lightweight SVGA monocular headsets that set a new benchmark for performance. Willner sees the peripheral market taking off in 1999. But his peers are more reserved in their enthusiasm, feeling it will be 2000 or beyond before much happens.

Al Becker of Reflection Technology reviewed the history of the Nintendo Virtual Boy program, which was cancelled despite sales of more than 1 million systems. Becker told the press conference, "For success in the consumer market, a killer application that attracts millions of consumers is a must."

A few personal-display companies were focusing on vertical markets. Bill Sproul of Planar said, "We look to the vertical markets for the early adopters and are pursuing both military and industrial applications." Others worried that such markets could not justify the investment and that applications were very slow in developing.

Summary: Play Ball!

Markets and applications for microdisplays in projection and personal displays are expanding rapidly and moving toward higher definition. New technologies, including the DMD and RLCD/CMOS devices, are rapidly penetrating existing and new markets, especially those requiring high definition. Prospects for the continued expansion of the presentation market are excellent as prices fall and as rear-projection microdisplay-based monitors and HDTVs are introduced in 1999. Market prospects for personal displays are more uncertain, but all of the developers seem confident that their chosen segment will soon mature into volume production.

But as they say in baseball, let's wait till next year. ■

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LCDs Galore at SID '98

LCD innovation seemed to be accelerating at SID '98 – with no slowdown in sight.

by Chris Chinnock

THE SID '98 SYMPOSIUM lived up to its advance billing. It was truly a cornucopia of flat-panel technology. There were innovations such as a whole crop of microdisplays, the triumph of manufacturing engineering [in relation to products such as plasma-display panels (PDPs)], and the continuing evolution of ever better liquid-crystal displays (LCDs). Let's take a look at what was new and exciting at SID '98 in the area of LCDs.

Reflectives Get Closer

Reflective displays so far have been mostly monochrome STN-LCDs because reflective color displays have suffered from poor contrast, limited colors, and low brightness. But that is changing, with a number of companies now close to commercial introduction of color reflective displays. Such devices will greatly improve the visual appearance of many products.

Some designs incorporate improved back-surface electrodes, which increase reflectance, with active matrices of TFTs or diodes also boosting performance. On supertwisted-nematic (STN) displays, new drive techniques, such as multi-line addressing, are improving contrast and speed. Most incorporate only one polarizer/compensator layer and eliminate the backlight. Many manufacturers are also working on new frontlight illuminator concepts.

Sharp, for example, showed their new line of Super Mobile Highly Reflective (HR) TFTs. A micro-reflective structure has been utilized to achieve 30% reflectance from the back electrode. When combined with their manufacturing approach for improving the aperture ratio, Sharp's 8.4-in. model is two-thirds the thickness, half the weight, and uses one-seventh the power of a comparable transmissive TFT.

The HR-TFTs looked good in the Sharp booth. Joel Pollack, V.P. for display-product marketing, says that production has now started on the 2.5-in. model, which is targeted for audio/visual applications, and will be followed by a 3.9-in. model for portable information tools and an 8.4-in. model for mobile PCs. All of the HR-TFT products exhibit a

Toshiba America

The image quality of low-power reflective LCDs has improved dramatically, and impressive units were shown by Philips, Sharp, and Toshiba. Shown is Toshiba's 8.4-in. unit, which uses polysilicon TFTs and integrated drivers.

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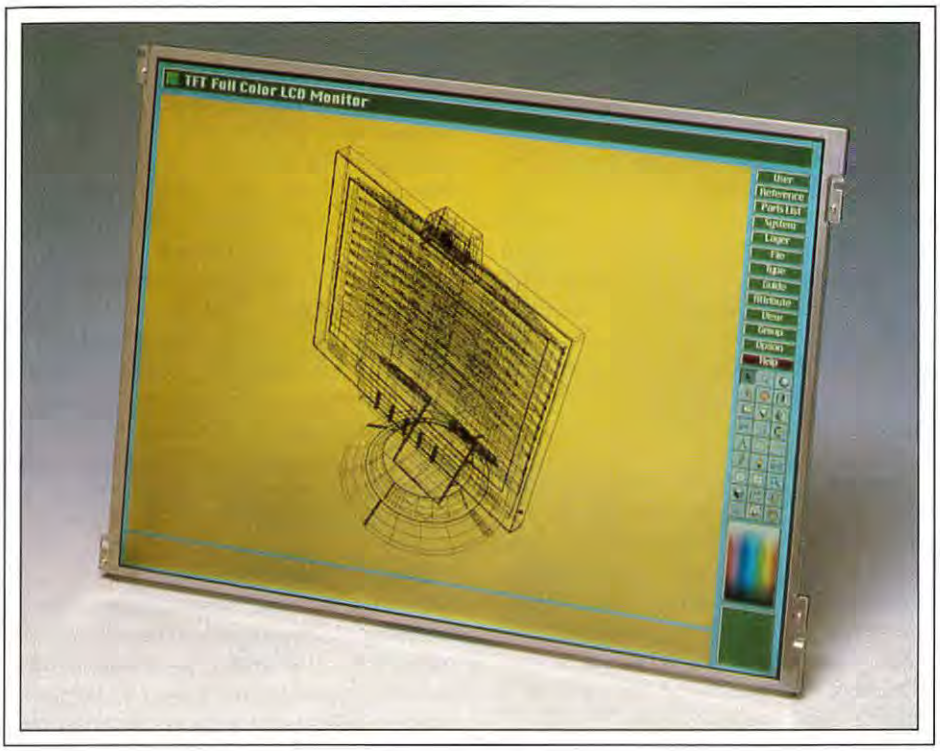


NEC Electronics

Trimming grams off the weight and millimeters off the thickness was another trend at SID '98. NEC's 13.3-in. Ultra-Slim notebook panel was a prime example.

100° viewing cone, 50-ms response time, and a 260k color palette. Sharp also showed a prototype of an HR-TFT display with an integrated frontlight so thin that it was almost unnoticeable.

Also opting for a TFT matrix in its reflective displays is ***Philips.*** On display was an 8.4-in. SVGA reflective panel with a 10:1 contrast ratio (CR), ±50° horizontal viewing angle (VA), and ±75° vertical VA. They report an amazing 60% reflectance for these structures. Philips expects to begin sampling both 8.4-and 12.1-in. SVGA panels this fall.

One of the most impressive demonstrations was the debut of ***Toshiba***'s 8.4-in. SVGA reflective color TFT display fabricated with low-temperature poly-Si (LTPS) processing. The prototype's specifications list a 12:1 CR, 30% reflectance, and 256k colors. Production is planned for Q1 '99.

Epson America showed two 312 × 230-pixel reflective LCDs, with 2.5- and 2.0-in. diagonals, that offered 256 colors. The company has developed new low-power driver circuits and an improved back-surface electrode that boosts reflectance to 30%.

Hitachi's Tim Patton says his company has a reflective color STN design that will be 8–10 in. and feature 256 colors. Hitachi is showing prototypes to key customers now, but products won't be available until next year. A smaller device was actually shown in the poster session, and several knowledgeable observers considered it to be quite good.

Cholesteric displays were also evident. ***Advanced Display Systems*** showed a prototype of a 5-in. reflective QVGA STN display that showed eight colors. While the display was clearly in need of improvement, the potential for cholesterics is huge. The displays are bistable, so once the image is set, no power is required to maintain the image. ***Kent Displays*** showed shipping products based on cholesteric technology – technology that is the subject of legal action between the two companies.

Matsushita representatives presented two papers on reflective color LCDs. They described a prototype 7.8-in. VGA reflective color STN panel with 4096 colors and a 14:1 CR. The authors also described a 3-in. reflective color TFT panel with a "full" range of colors and a 15:1 CR, with the pixels arranged in a 480 × 234 triad arrangement.

The second paper described a reflective color TFT panel that includes integrated LTPS drivers. The authors fabricated a 4-in. 320 × 234 analog display with 15% reflectance and 15:1 contrast that consumes only 45 mW.

Notebook LCDs

Notebook displays were in abundance, featuring lower profile, power, and weight, with improved brightness. Representative of this trend were ***NEC***'s latest offerings of an ultra-slim line of TFTs. They are all 6.4 mm thick and come in 12.1-, 13.3-, and 14.1-in. diagonals. The 13.3-in. XGA version cuts 75 grams, 2 mm, and 0.4 W from its predecessor, yet boosts the brightness by 20 cd/m^2. All of the panels produce 262k colors and are sampling now.

Toshiba showed a 13.3-in. LTPS display in an XGA format! The display will be produced in limited quantities, but plans for mass production are not yet set. The benefits of poly-Si are impressive. On a typical XGA 12.1-in. notebook module, poly-Si processing allows Toshiba to reduce the component count from 280 to 200 and internal connections from over 4000 to just 200.

Mitsubishi's Dale Maunu said that they are now standardizing on a luminance of 150 cd/m^2. The company introduced a 14.1-in. XGA panel that is 7.5 mm thick and weighs 610 grams, and a 12.1-in. SVGA panel that is 5.5 mm thick and weighs in at 395 grams. Both are currently available.

Samsung also showed an ultra-slim 12.1-in. TFT panel that was even slimmer than ***NEC***'s at 5.2 mm. ***Hitachi*** showed a nice-looking 14.1-in. TFT panel that uses in-plane switching (IPS) to achieve a 160° VA and 200 cd/m^2. ***Philips*** showcased their 12.1- and 14.1-in. XGA panels, which feature side-mount technology to reduce border area. The units are available with optional low-voltage differential signaling (LVDS) or PaneLink™ interfaces. NEC uses edge-mounted studs on its new 14.1-in. panels.

Several vendors confirmed that they think notebook displays will soon leave the 13.x sizes behind and settle on a 14-in. size. Hitachi's Tim Patton noted that the 11.3-in. was quickly displaced by 12.1-in. displays.

On the STN front, ***Hitachi*** took the wraps off their latest Super-Clear color STN (CSTN) panel. This is a multi-line-addressing (MLA)

technology that has reduced the response to 150 ms. Hitachi has a 13.0-in. XGA panel with a 40:1 CR, and is thinking about a 16.8-in. product.

Sharp's improved CSTN technology looked very impressive too. They have incorporated a number of technology upgrades that reduce ghosting and crosstalk, improve contrast, expand viewing angles, and bump up response speed by the use of an MLA technology. A 12.1-in. SVGA model is available now with all of these upgrades. It sports a 40:1 CR, 150-ms response time, and 140° VA (H) and 90° VA (V). Sharp has even integrated gray-scale circuitry right into the panel to produce 262k colors.

LCD Monitors

LCDs for flat-panel monitors (FPMs) generally start around 13 in. on the diagonal and move up to about 21 in. For monitors, LCDs need to be brighter and have a wider viewing angle than comparable laptop displays. Product designs can often use more power to accomplish these goals.

According to ***DisplaySearch***, the best-selling FPMs today are from NEC, Viewsonic, Compaq, IBM, and HP. Interestingly, NEC's 20.1-in. monitor was the top seller of them all, says DisplaySearch's Ross Young. SID '98 was the opportunity for many LCD-panel manufacturers to offer new desktop-monitor products and panels. These introductions are now helping to fill out product lines with many new sizes and configurations.

For example, ***Samsung*** showed both 21.3-in. UXGA and 17.0-in. SXGA analog-interface monitors. They put out 200 cd/m^2, offer replaceable backlights, and produce clear and crisp images. Samples will be available in Q4 '98, with mass production in Q1 '99. The new units will be added to Samsung's current line of 13.3-, 14.0-, and 15.0-in. monitors.

Samsung also showed a technology demonstrator of their 30-in. UXGA (1600 × 1200) panel. It is fabricated with a single 550 × 650-mm substrate and features 16.7M colors and a 50-ms response time. Although it's impressive, there are no plans to mass-produce it at this time.

Philips exhibited their 18.1-in. SXGA monitor for the first time in the U.S. It offers viewing angles of ±60° (H) and +45°/-40° (V), a luminance of 200 cd/m^2, 16.7M colors, and consumes 30 W. Production was slated for August. Philips also showed a technology demonstrator of a 20.1-in. SXGA monitor that uses IPS to achieve an 80° viewing cone. Production is possible in early 1999, but Philips is still evaluating other technologies for this size range.

Sharp has extended their improved CSTN technology to larger displays for FPMs. Sharp's Joel Pollack believes the performance afforded by these displays is good enough for many applications and is cheaper than TFTs. Since price is critical to expanding the FPM market, he thinks CSTN will gain a big share of desktops. Sharp now offers 13.8-, 15.0-, and 17.7-in. CSTN panels, and also offers a line of TFT panels, the newest being an 18.1-in. SXGA.

Hitachi is developing their 15.0-in. XGA TFT panels for desktop monitors that output 200 cd/m^2. This, and an 18.0-in. SXGA panel, are expected by Q4 '98. They fill out the IPS product family by joining the 14.1-in. XGA panel that is just moving into production.

NEC filled out their line of TFT panels by announcing an 18.1-in. SXGA that has either an analog or digital interface. A new 15.4-in. SXGA model was also introduced, and both are sampling now. They join the 20.1-in. IPS panel.

Fujitsu was showing its new 15-in. XGA multi-domain vertical-alignment (MVA) TFTs that offer a 160° viewing cone, 300:1 CR, and a sizzling 25-ms response time. The MVA process eliminates conventional rubbing and instead incorporates a new "protrusion" structure that aligns the liquid-crystal molecules in a vertical orientation relative to the glass substrate, thus improving light extinction. The panel offers 262k colors and 200 cd/m^2 of luminance, and marketing manager Joe Virginia thinks they can reach the $1000 price point with this panel very soon.

dpiX unveiled improved versions of its wide-angle displays. With the new ViewSpan technology, TFT viewing cones extend to ±80° in all directions without compromising video performance, brightness, or saturation, says the company – in a reference to the reduced response time of IPS techniques. The technology should become standard on all dpiX TFT displays by the end of the year.

LCDs for Every Occasion

As new markets and product categories that incorporate LCDs continue to expand, specialized displays are emerging to fit target needs. Automotive navigation displays, for instance, must typically offer a wider operating-temperature range and higher luminance than laptop displays.

For this application, ***Epson*** showed a new 5.6-in. diode-matrix device with a 150:1 CR and a luminance of 300 cd/m^2 from a 960 × 238-pixel format. Philips has a 5.8-in. model

Sharp Electronics

Improvements in response time and viewing angle are making CSTN panels suitable for FPD monitors, which will help make them more competitive with CRT-based monitors. These displays are from Sharp.

that operates from –30 to +85°C and comes in either a 4:3 or 16:9 aspect ratio. ***Sharp*** showed prototypes of their latest double-metal (diode-matrix) TN devices in 5.5- and 4.7-in. sizes. They feature high speed and high contrast with a monochrome LED backlight.

Seiko Instruments debuted their new Vitrium display: a 1/8-VGA device that features chip-on-glass (COG) drivers. Targeted at the telecom, PDA, and GPS markets, the black-and-white film STN device operates over a –10 to +60°C range and includes an LED backlight.

Korry Electronics, a provider of backlight technology, is now offering display subsystem integration as well. Their booth generated a lot of interest because of the cockpit mock-up they filled with all kinds of displays, including a 6.25 × 6.25-in. and a 4 × 4-in. display featuring glass from ***OIS***. These displays, with Korry's very bright backlights, are targeted at military and commercial avionics applications. (OIS seems to be past its manufacturing troubles and is now offering displays up to 8 × 8 in.)

Computer Dynamics cranked up the volume and showed their high-brightness line of LCDs. They now have six sizes between 6.4 and 15.0 in. that offer up to 1600 cd/m^2 and dimming inverters.

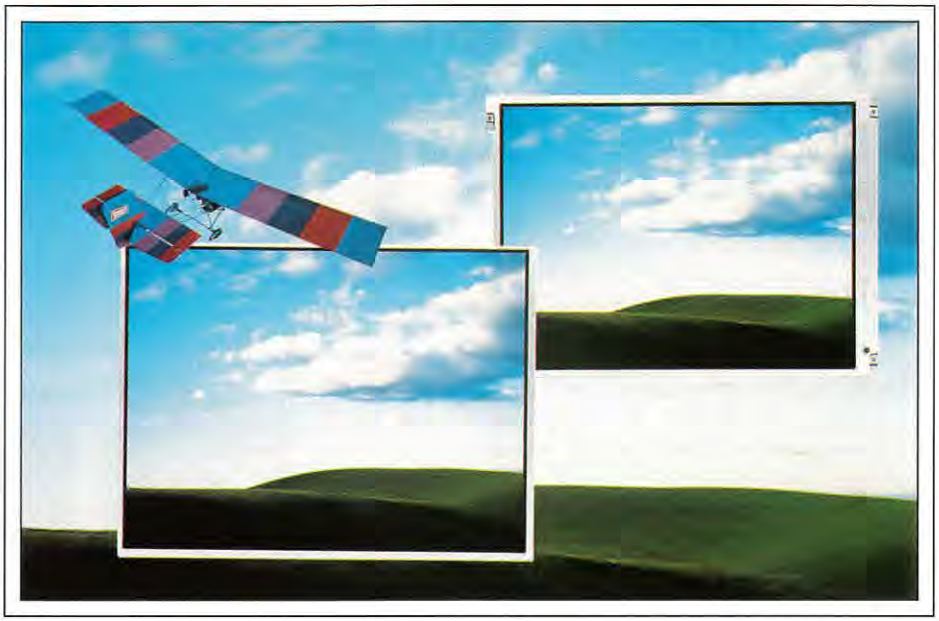
EMCO Electronics checked in with an ATM display that was sunlight-readable and pumps out 1700 cd/m^2. EMCO's innovation here is a cleverly designed high-output backlight that mates with standard Sharp 10.4-in. glass. That should help the next time sunlight tries to wash out the ATM screen.

Three-Five Systems has added 16 levels of gray to their new QVGA panel by means of what they call Liquid Crystal active Drive (LCaD). The new display has ten times the screen resolution of previous models and is now sampling to customers for outdoor, recreational, and office-automation applications. Devices come in reflective, transflective, and transmissive configurations. Thirty-two gray levels and video response are promised by Q4 '98.

Electronic Designs, Inc. (EDI), which has a cozy relationship with Sharp, exhibited several displays in the 4.0–5.6-in. range. EDI has had success in the military/aerospace market and is now moving into commercial and industrial applications. For example, they plan to use an 8.4-in. Sharp HR-TFT for a new marine-navigation display system.

Interfaces Take the Spotlight

SID '98 highlighted the growing importance of interface electronics in building an FPM or integrating a flat panel into a myriad of other applications. Generally, the job of interface electronics is to allow video or computer signals to be conditioned for presentation on an FPD. This may require image resizing, frame-rate conversion, video de-interlacing, automatic image optimization, and color (gamma) correction. The interface electronics are recognized as a major cost component – especially in FPMs.



Mitsubishi Electronics America

Mitsubishi's new 12.1-in. SVGA and 14.1-in. XGA AngleView™ AMLCDs are lighter and thinner than their predecessors. The 14.1-in. model is 50% brighter at 150 nits, consistent with the trend for new notebook displays to deliver substantially more luminance than the traditional 70 cd/m^2 or even the more recent 100 cd/m^2.

Perhaps the most exciting announcement at SID '98 came from start-up ***PixelWorks***, a spin-off from In Focus Systems. The company announced a single-chip ASIC solution that provides almost everything but the kitchen sink. For example, inputs can be analog video sources, such as laser discs, DVDs, satellite, cable, and VCRs; digital HDTV; or digital PC signals – as well as analog PC signals in resolutions from VGA to UXGA. Any of these signals can be converted and scaled to fit 4:3 output formats from VGA to SXGA, or to fit the 16:9 formats at 852 × 480 and 1280 × 720. Output signals drive LC, plasma, or DMD displays.

PixelWorks demonstrated such capabilities in their booth with impressive results. The new chip will be available in Q1 '99 for less than $150, and will allow interface-electronics boards to shrink considerably. For example, the company suggests that only four chips will be needed to configure a multipurpose interface board: the PixelWorks ImageProcessor, analog input, LVDS, and ROM.

Sage's new Cheetah ASIC and controller-board solutions are available today. The Cheetah chip combines the functionality of several chips into a single ASIC solution and accepts analog PC input signals to drive either TFT or CSTN panels from VGA to XGA resolution.

Newly announced by ***James Grunder & Associates*** is the PV-5000, a controller board that accepts multiple PC and video inputs, including all 18 HDTV formats. Images can be resized or rotated to fit 16:9 plasma panels or LCD monitors. Also exhibiting interface-electronics solutions were ***Arithmos***, ***Genesis Microchip***, and ***ViewTek***.

Advances from these and other companies are going a long way toward lowering the cost of FPMs – a key requirement if they are to displace CRT monitors. The developments at SID '98 show that innovation is continuing at a remarkable pace. New displays and product solutions promise to amaze us for years to come. ■

The Old Dog Still Barks

The glamour may be in flat panels, but CRT makers were busy – and busy is good!

by Joe Hallett

IT SOUNDS LIKE last year at SID: CRTs will be around for a long time; some players are dropping out while others are growing through acquisition; and some manufacturers chose to skip the SID exhibition in favor of more specialized vertical-market shows.

"We're as busy as we've ever been," said Ken Compton of ***Clinton Electronics***, makers of display monitors and monochrome tubes. He commented that the CRT side of the business has been flat, but the company still makes lots of low-end monochrome CRTs. Compton believes the CRT still has a dramatic performance advantage in some markets, such as medical, where sales are stable to growing, with good margins.

But alternative technologies are making inroads in some applications. For example, makers of CRT monitors are starting to see competition on the desktop from flat displays, but higher cost still prevents wide replacement of CRT products.

Field-emission displays (FEDs) continue their gradual emergence into the marketplace. Quarter-VGA products were shown by several firms, including ***Futaba***, ***PixTech***, and ***Motorola***.

This year's SID show provided a new venue for display makers to show their wares, thanks to the addition of the Display Technology Showcase (DTS). But not all new technologies were comfortable in this environment. "We wanted to be in the Showcase but we couldn't get the right signal," said PixTech's Tom Holzel, whose guest editorial in

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Motorola FPD

FEDs continued their deliberate progress at SID. Motorola showed its 5.1-in. quarter-VGA FED in a "mocked-up" global-positioning-system device.

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Thomson Tubes Electroniques

Thomson was showing its line of monochrome CRTs, ranging from 15 to 21 in., for medical monitors.

Information Display helped to trigger interest in creating the DTS event.

CRTs

Clinton's medical market is growing, according to Ken Compton. The company is being completely re-directed to medical products, as demonstrated by its acquisition of Orwin last January, he said. He sees substantial high-end medical growth at the five-million-pixel level, requiring lots of gray scale.

"Also, our business has changed dramatically in the way we interface with the customer. Once we couldn't handle an order of one, but now in medical we have to talk directly to the customer: 'Do you sell monitors? Do you take credit cards?'" MIS-equivalent hospital personnel aren't there any more. Hospitals want to optimize productivity and facilities. They have a development laboratory for information systems, and are receiving and sending images and x-rays over phone lines. This is a big change in the way key hospitals and radiologists work, Compton said.

Brimar Ltd., which completed a management buyout last year, sees expansion in its miniature and commercial display markets, according to spokesman Robert Hoffman. Brimar continues to supply display components to the military for helmet-mounted and portable display systems. It also manufactures high-resolution medical-imaging CRTs and digital-imaging CRTs for faster film recorders and direct-to-paper applications.

Hitachi showed a new high-resolution 19-in. color CRT with 100° deflection that supports up to 1600 × 1200 pixels in a short-neck design.

CRT maker ***SGB Enterprises*** of Valencia, California, exhibited for the first time at SID '98. "I'm relatively new to displays," said president William Flowers, "but the more I work with CRTs the more I realize how incredibly versatile they are. I believe the CRT will fill a lot of niche applications." The company manufactures displays for simulation and training, medical, and film printers. "We do a lot of miniature CRT work, including a proprietary high-resolution color CRT. Since a spinning color wheel or liquid-crystal shutter is not applicable to some environments, we use a monochrome CRT with a proprietary method to select RGB phosphors," Flowers said. Although the CRT was shown, few details were available at the show. "We are waiting for patents to clear," he told *ID*.

The CRT continues to support related product areas. "Most of our applications are for CRTs and projection," said Frank Roschow of German photometric instrument maker ***LMT***. John Constantine, president of yoke-maker ***CELCO***, seemed satisfied with the way business is going. "We are happy with the takeover of Discom's business. We're seeing action in areas where new technologies can't do the job yet," said Constantine. "New areas for the CRT seem to be in very large and very small sizes. But we don't seem to get as many inquiries for new programs," he added.

"Business has been OK for us: we've grown in sales," said Gardner Marcy, president of yoke-maker ***Syntronic Instruments***. "We have tried to focus on medical displays. It's still an industry that hasn't figured out what its end customers want to do. Our customers get mixed signals regarding aspect ratio and quality. Almost weekly we see a new requirement for a different neck size or gun design."

Marcy commented that photo imaging is another part of the business that's active, with development going on at both old and new firms. "We can use 20-year-old yoke designs!" he laughed. "Flight simulation is another pretty active area, and there's some projection. We're finally seeing some maturation in the area of helmet-mounted displays, where after 12 years of engineering we have penetrated the military market."

Marcy believes that although newer color avionics that might once have been CRT may go to flat panel, older aircraft will never move to flat-panel displays, so there is at least decent business in replacements.

Commenting on changes in the display industry, Marcy noted that there has been considerable consolidation over the past few years. Discom has been absorbed by CELCO, WinTron has been acquired by Video Display Corp., and there are only about five CRT firms left, he said. Marcy also observed that "People building displays aren't as familiar with what they are doing as 20 years ago. We spend half our time educating people. It's hard to tell a customer that what he's doing is wrong!"

Longtime yoke maker ***WinTron*** (formerly PennTran) did not exhibit this year. A pre-show announcement reported that WinTron had been acquired by ***Video Display Corporation (VDC)***, and an ad in the Show Issue of *Information Display* emphasized the point: "Reports of our death have been greatly exaggerated!" – WinTron.

Carl Beechler, CEO of ***Z-Axis*** (Phelps, New York), a manufacturer of CRT monitors that is also part of VDC, is optimistic about

CRTs & FEDs

CRTs. The company is constructing a new 30,000-ft.^{2} facility. Beechler said, "We are enlightened and encouraged by CRT improvements at this show, respecting corner spot, neck length, and power. Although the basics don't change much from year to year, customers are becoming more demanding. They probably are driven by comparisons to LCDs, which are flat and free from roll-off, concern for brightness, and long-term reliability. Also, people have been burned by LCD panel sizes going away."

FEDs

FEDs appear to be gaining in acceptance, but slowly; and quarter-VGA still seems to be the size of choice. Confidence remains high in some quarters, as indicated by the latest round of financing for Candescent. Although FED pioneer ***PixTech*** did not participate in the Display Technology Showcase, the firm's exhibit offered a telling comparison of FEDs with AMLCDs: two identical test instruments were set up to display noisy waveforms. As expected, noise was clearly visible on the CRT-like FED screen, while it could not be seen on the LCD screen, which responded too slowly to react.

Futaba showed sample FED panels for OEM use in VGA (640 × 480) and quarter-VGA (320 × 240) sizes.

Candescent was celebrating its latest financing, "a milestone in the U.S. flat-panel industry," said Stewart Hough, marketing manager for Candescent. The company did not exhibit, but – as in previous years – showed developmental displays off the show floor. Hough said that Candescent is looking at the premium notebook-computer market, where the FED offers video response, wide viewing angle, saturated colors, and a savings in cost and power. ■

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Big, Bright, and Beautiful

Emissive displays come in many types and sizes, but at SID '98 it was the new generation of large plasma displays that made jaws drop.

by Alan Sobel

FOR MANY ATTENDEES at SID '98 in Anaheim, the hit of the show was clearly the big, bright, beautiful plasma panels. Ranging from 25 to 50 in. on the diagonal, the big ones – especially the big ones – were dazzling, with full-motion video, excellent color, bright images, and wide viewing angle. In fact, they have all the things we've been waiting for – except low cost.

Fujitsu, Mitsubishi, NEC, Pioneer, Plasmaco, and ***Thomson-CSF*** were all on the show floor, with panels in both 4:3 and 16:9 aspect ratios. ***Thomson*** has concentrated on smaller, ruggedized, high-resolution displays; the other companies are all aiming, eventually, for the consumer market.

There seemed to be a consensus that ***NEC*** and ***Plasmaco*** were the two standouts, with 42- and 50-in. panels. NEC is using a new construction technique that should improve contrast, but it's expensive, requiring color filters and black stripes on the front substrate that must be closely aligned with the vertically oriented phosphor stripes on the rear substrate.

The other companies all carry only the sustain electrodes on the front substrate – and perhaps a uniform neutral filter to improve contrast – so that no alignment with the rear substrate is needed. Despite the promise of NEC's technique, the big Plasmaco panel looked brighter and punchier, even though it was not shielded from ambient light as were the NEC 42- and 50-in. units. All of these panels looked excellent, with few or none of the motion artifacts (extra contour lines on moving images) that have been bothersome in previous plasma displays. Each manufacturer is coy about its solutions to this problem.

So far only ***Fujitsu*** is in serious production, claiming to produce 1000 units/month. At a nominal price of $11,000, one wonders where they are going other than to trade-show equipment renters and some other very well-heeled users. The other companies are all in various stages of pilot production. There is a good deal of informed opinion that these won't be high-volume consumer items until the price gets down to $2000 or less. All of the plasma companies have announced major production-plant investments, which should eventually drive prices down.

According to Shigeo Mikoshiba, who gave the seminar on gas-discharge displays on Monday, the drive circuitry still represents 80% of the cost of a plasma display. High-

Uniax Corp.

Despite intense research activity on organic light-emitting diodes (OLEDs), the only company on the floor was Uniax. The company claimed 150 cd/m² for this device.

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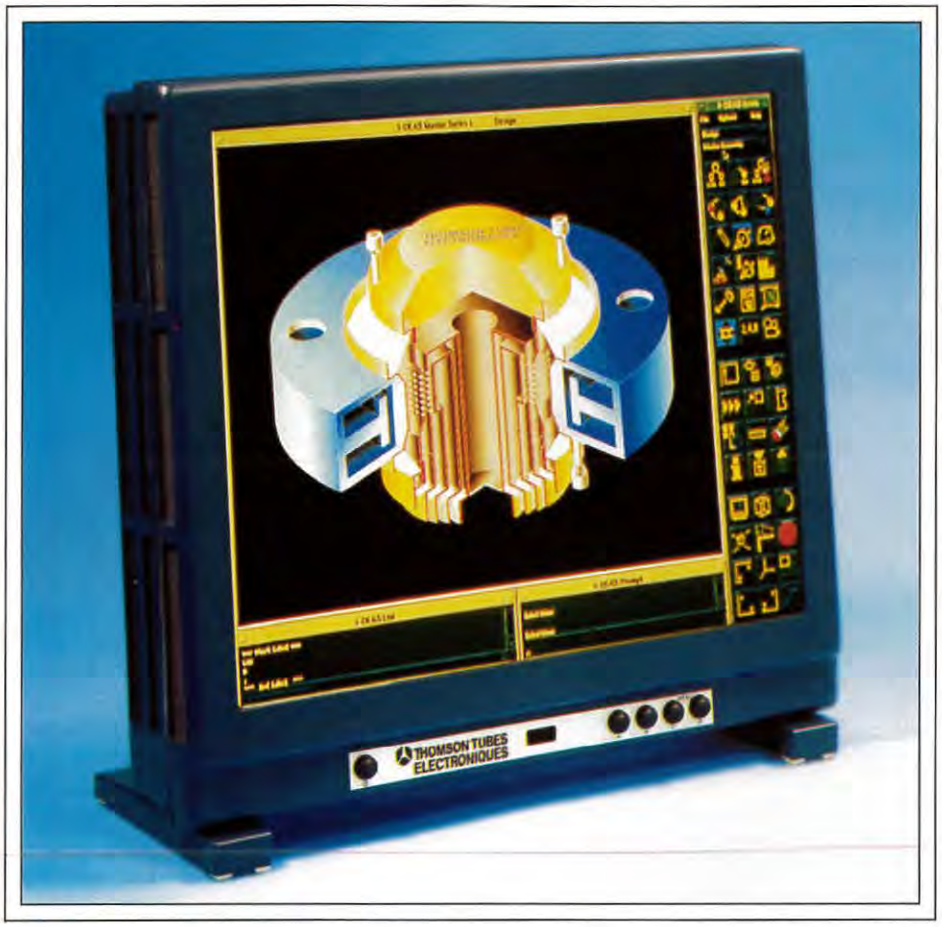

Thomson Tubes Electroniques

Standing out among the many consumer-oriented plasma displays at SID was Thomson's newly introduced 24-in. SXGA PDP with 0.38-mm pixel pitch, which is intended for professional and military applications.

voltage silicon transistors are the principal culprits; plasma-panel drivers must swing in excess of 100 V and deliver substantial peak currents to charge the shunt capacitances. Peter Brody was making 400-V TFTs in the 1970s, but no one has picked up this potentially low-cost technology for PDPs. It's also surprising that more attention has not been paid to using gas-discharge logic to reduce the number of drivers; only one technical paper this year addressed the possibility.

A related technology is the plasma-addressed liquid-crystal (PALC) display, invented at Tektronix and now being pursued by ***Philips, Sharp,*** and ***Sony.*** In these devices, a plasma discharge is used as the row-select switch for a TN-LCD. Each year these displays have improved; now they have excellent viewing angle and handle video motion well. Two of the 42-in. 16:9 panels were at the show, one in the Display Technology Showcase and one at the Philips booth. Evidently this is still a laboratory device, but it's one with a great deal of potential.

The CRT is still the display to beat. CRTs continue to improve, with higher resolution, better contrast, higher luminance, flatter faceplates, and shorter tubes. ***Sony***, in particular, was showing big flat-faced Trinitrons, but detailed specifications and prices were hard to come by. ***Toshiba***'s microfilter tubes use color filters on the faceplate aligned with the phosphor stripes. Like the NEC plasma panels, this must be a more expensive approach than uniform neutral filters. Toshiba claims increased contrast, luminance, and color fidelity.

Hitachi is using dot-patterned phosphor rather than stripe-patterned; their short (373 mm) 19-in.-diagonal tube, with a claimed resolution of 1600 × 1200 pixels, displays an excellent image.

One result of the economic problems in Asia is that CRT prices – like those of most other displays from the Pacific Rim – are coming down even faster than we might have anticipated. That's good for consumers, but manufacturers are hurting.

Field-emission displays (FEDs) were in evidence at only three booths. ***Motorola*** is spending a lot of money on plant and promotion; their displays are small (2.9- and 5.6-in. diagonals, the latter at 320 × 240 pixels) and aimed at automotive and other portable applications. The displays have full color and good motion rendition, but they are impressive primarily as evidence that the technology is moving, rather than as the kind of display one wants to take home right now.

PixTech was showing green monochrome quarter-VGA displays, including one built into a portable Tektronix oscilloscope that put the "standard" LCD to shame. PixTech's single-color unit, about the same size as Motorola's, looked less grainy, but the two displays were not side by side for careful comparison. ***Futaba*** also had a single monochrome FED that looked good, but this is not yet a production item. ***Candescent*** was not on the show floor; they had displays running in their hospitality suite and showed one at an author-interview session.

There isn't much new about thin-film electroluminescent (TFEL) displays (but see Microdisplays below). There are now four companies in the field: ***Sharp*** and ***Planar*** plus two Canadian companies, ***Westaim*** and ***Luxell.*** The displays are rugged and have excellent viewing angles, but they are still struggling to achieve full color and they are still expensive.

Not by Direct-View Alone

Projectors keep getting better; they are brighter, more compact, and have higher resolution. Both front and rear projectors were in evidence at SID '98, in a variety of resolutions, formats, and light-output capabilities. LCD light valves were used in a number of these projectors, but the U.S. consumer market is still dominated by CRT projectors.

The ***Texas Instruments*** digital micromirror device (DMD™) is now being incorporated into projectors from 20 OEMs, TI says. Small, light portable projectors using either a TI DMD or an LCD panel can be toted by

NEC Technologies

The latest version of NEC's 42-in. PDP could be seen both on the show floor and in the Display Technology Showcase.

road warriors and other peripatetics and can produce excellent images. For non-video presentation applications, field-sequential color – which uses a single light valve and three pulsed color light sources or a mechanical color wheel – have major advantages in cost and portability. Their performance is fine for most computer imagery and can be adequate for much moving video.

Raytheon showed a good-looking rear-projection cube using a DMD that's intended for the Air Force's Common Large-Area Display System (CLADS) program. Six of the displays were flight-tested by an AWACS crew in March, said Raytheon's Al Hudson.

The new kid on the block is the microdisplay. These small displays are built on 0.5–1-in.-diagonal silicon chips. Because the substrate is single-crystal silicon, the performance of the individual pixel-control transistors is excellent, and all of the peripheral drive circuitry can readily be accommodated on the chip. Design rules are relaxed compared to such high-performance silicon as microprocessors and DSPs, so the light-valve cost should be low. The approach has been applied to various forms of LCs, TFEL, and, of course, the TI moving-mirror light valve.

Microdisplays can be used as head-mounted displays with appropriate magnifying optics, as camera or camcorder viewfinders, or as the image source for small projectors, including desktop monitors to challenge LCDs and CRTs. In LC microdisplays, ***Kopin*** has been building transmissive LCDs, using tricky technology to make the silicon substrate thin enough to transmit adequate light.

Several companies are making – or at least announcing – reflective displays, with nematic or ferroelectric LC material carried on the surface. These devices have the advantage of much better utilization of the display area than transmissive devices, but the overall package is usually thicker than transmissive types because light must be introduced from the front.

Planar is showing active-matrix EL displays, using EL phosphors deposited on silicon chips. The company is shipping VGA displays and has demonstrated 1280 × 960-pixel units.

Much of the microdisplay activity was in hospitality suites, rather than on the show floor, by startups such as ***Colorado Microdisplay*** and ***Display Research Laboratories (DRL),*** the latter proposing a revitalized form of vacuum fluorescent technology. ***Displaytech*** has been developing its ferroelectric technology for several years; it has some major advantages in speed. ***Reflection Technology*** uses a small vibrating mirror to scan a column of LEDs across the field of view of a head-mounted display. ***Silicon Light Machines*** scans grating light modulators, but is aiming at larger projectors.

Although there is talk about wearable displays for such applications as cellular phones, which would make it possible to read one's e-mail on the go (preferably not while driving), the consensus is that this and other similar applications are still in the future. If the displays were sufficiently inexpensive, they could make excellent virtual-reality game interfaces. This is probably the application that will drive prices down, but it hasn't happened yet. Still, most of these displays look far better than the 3-in. LCDs we have been seeing on tiny TV receivers up to now.

The other very new kid on the block is the organic light-emitting diode (OLED). There is intense research activity in this area and devices are improving. The only company on the floor was ***Uniax***; other workers are keeping a lower profile. Uniax claims a 10,000–20,000-hour lifetime and a 150-cd/m^2 luminance. Lifetime, cost, and drive arrangements are still problems, but this could be a major competitor in both large and small displays. One company, ***Pioneer,*** is planning to use OLEDs in automobile-radio indicators this year, which will be the first application on the market. ■

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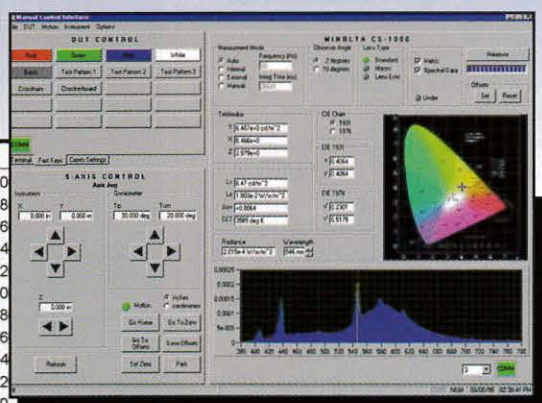

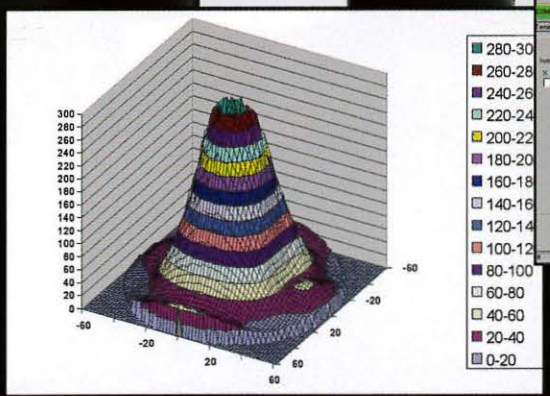

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Manufacturing Equipment

Low-temp poly was one mantra at SID '98. Greater throughput, reduced usage of materials, and large-substrate capability were others.

by Stephen Atwood and Ken Werner

THIS YEAR'S SID International Symposium, Seminar & Exhibition continued the tradition of showcasing leading-edge technology for the display community. The field of manufacturing equipment and materials was no exception. Improvements were being shown in a number of processes and capabilities, including LC displays made with low-temperature processing on plastic substrates, more precise characterization of transparent films, and, of course, a number of new processes for low-temperature polysilicon (LTPS).

In fact, LTPS was the objective of several equipment makers trying to capitalize on the potential for this new process. "Will it work?" was my favorite question. "We don't know, but we want to be around if it does," was the most frequent answer.

Intevac (www.intevac.com) was showing two new machine capabilities for 1998. The company's cluster tool, nicknamed "RIGEL," is capable of sputtering and processing FPD substrates up to 1200 × 1600 mm. Intevac claimed this to be the world's largest cluster capability. The company's other machine performs rapid thermal processing (RTP) in-line, and was designed specifically for LTPS applications. The machine performs the rapid-thermal-annealing step required for polysilicon transistors.

Eaton (www.eaton.com/product/semispec/) was also advertising their support for LTPS with their new line of ion implanters specifically designed for this approach. The first machine in this line is the NV6072, which is available now. Eaton claims that their solution is unique in its combination of relatively

Villa Precision

Villa Precision introduced its FAST-50 line of multi-head glass scribers – the only ones designed for Gen 4 LCD panels.

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ORC Electronic Products

ORC Electronic Products introduced the ProForm 9000 UV exposure system, which can process PDP substrates with diagonals up to 78 in.

small footprint, high throughput (greater than 60 panels/hour), and very precise ion-dose and H^+ control. The throughput specification is based on doses of up to 2×10^{15} ions/cm^2. The machine supports panel sizes up to 600 × 720 mm.

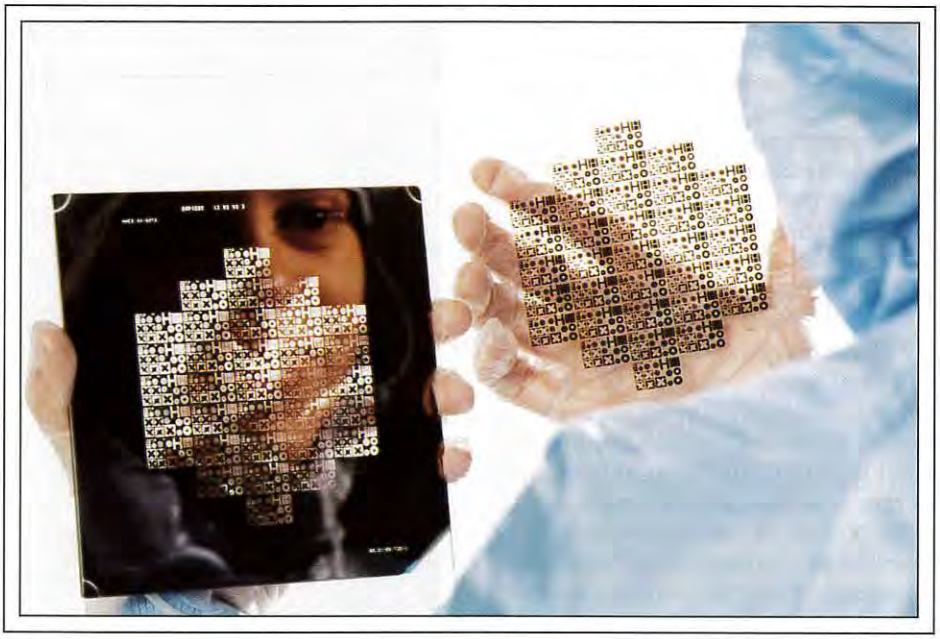
Also interesting is how Eaton has structured itself to sell and service these machines. A separate group called the Flat Panel Equipment group, located in Massachusetts, has been formed to design and build the machines. However, the marketing and servicing is done through a joint venture called Sumitomo-Eaton Nova (SEN) based in Japan. Eaton believes this approach is absolutely essential to gain access to the Japanese equipment market. Other equipment makers expressed similar beliefs.

ULVAC (www.avem.org/Ulvac.html) was also at the LTPS party. ULVAC was discussing their pilot cluster processing tool nicknamed "Satella." This machine handles all the significant steps, including ion implantation, sputtering, heating, and annealing, and supports from seven to nine separate chambers. One of the company's advantages appears to be the sheer variety of supported processes and systems. In the U.S., ULVAC claims to be leading the way in sputtering and CVD systems. In Asia, the company claims to hold about 85% of the display-manufacturing market for sputter coaters and a 93% market share in cluster tools. ULVAC's large sputtering and etching systems can support substrates up to 1 × 1 m.

Another very interesting capability, laser cutting of glass substrates, was being shown by ***Accudyne Corp.*** (www.accudyne.com). In this process, a specially controlled CO_2 laser on a precision linear drive is used to separate glass substrates between 0.05 and 30 mm thick. Below about 1 mm, the glass is literally cut. In thicker substrates, the laser scores the glass and weakens the underlying material so that it separates with minimal mechanical effort. The LC650 machine shown on the exhibit floor was using about 135 W of laser power, while the model LC4040 is claimed to do a comparable job with a 50-W laser.

The advantages of this approach are accuracy (±25 μm), the elimination of loose particles and consequent cleaning steps, and an edge strength after cutting that is claimed to be much stronger than that left behind by other mechanical methods.

Depending on laser power and substrate thickness, cutting speeds can be upwards of 500 mm/sec. A disadvantage is that the process works much better on uncoated glass. The dazzle factor for these reporters was that pieces of glass cut by this process had beautifully smooth dull edges that would not need



Schott Corp.

Schott's Foturan® photo-etchable glass can be used to fabricate FED and ink-jet-printer components, as well as many other microstructures.

The Unkindest Cut

The display world is highly competitive but remarkably civil – at least most of the time. So some of the editors and reporters covering SID were intrigued by the aggrieved tone of a last-minute faxed notice of a press conference to be held at SID by PTG Precision Technology Center (Lake Mary, Florida). The notice stated that PTG had revoked its license to the well-known equipment company Accudyne to use PTG's laser-cutting technology, and that without this license Accudyne would be unable to fulfill its contract with USDC.

The press conference itself, however, focused on the company's technology and new U.S. base of operations, not mentioning Accudyne at all until Hassaun Jones-Bey of *Laser Focus World* asked why the license had been revoked. Ric Schildwachter, PTG director of sales and marketing, said that because Accudyne had not paid its licensing fee PTG decided to revoke the license and open their own plant.

But there's another side to this story. Richard Crowson, engineering manager for Accudyne, told *Information Display* that Accudyne had paid for the license with stock, and that the company's position had been upheld by a circuit court in Florida – and Crowson offered to supply the information needed for *ID* to obtain a copy of the ruling. However, said Crowson, Accudyne had found PTG's technology unsatisfactory and was now building equipment using its own laser-cutting technology, so PTG's position could have no practical impact on Accudyne in any case.

Schildwachter, though, had seemed sincerely aggrieved when he made his comments. Could this be a case of miscommunication gone wild?

any polishing for safe handling. The machine is currently in beta test with three USDC team members.

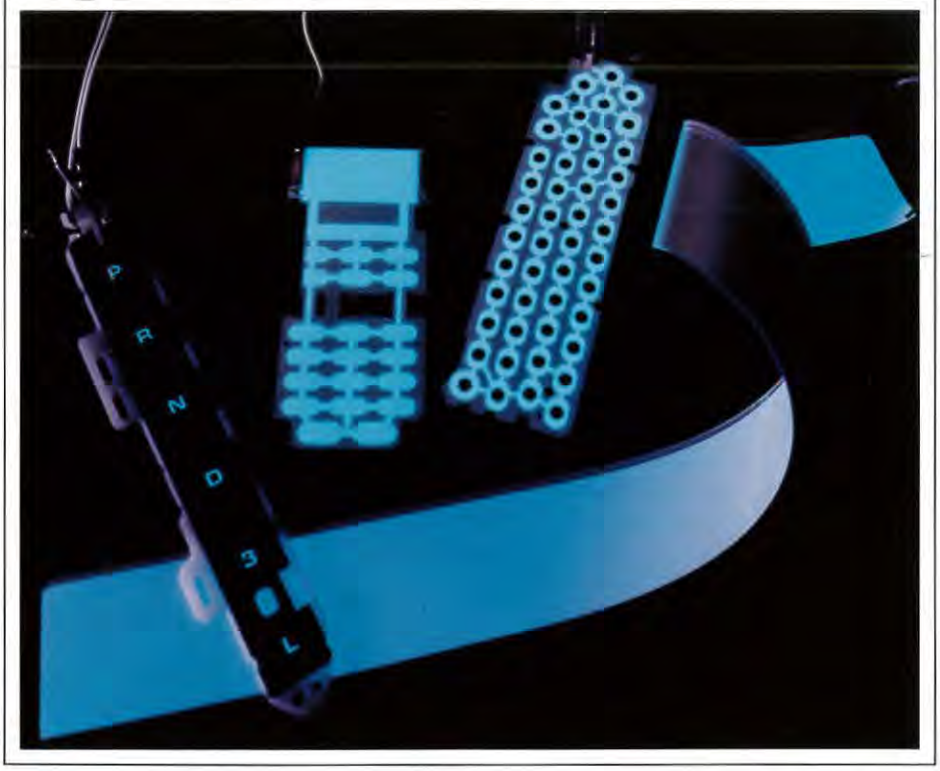
Villa Precision was upping the traditional glass-separation ante with its FAST-50 line of multi-head precision glass scribers, which are the only such scribers designed for Gen 4 LCD panels, according to Villa's managing director, Tom Muir. A 9-up array of LCDs can require 12 scribes on each side. Model 5010V, with six scribeheads, can do the job with a total TACT time of 60 sec, including invert, said Muir. The maximum substrate size for models 5010V and 5000S is 1.27 × 1.27 m, but Model 5080S accepts a substrate up to 1.27 × 2.03 m!

FAS Technologies announced its new FAS-Coat™ moving-head system for the extrusion coating of materials such as photoresists, polyimides, and color filters on substrates up to 1200 × 1600 mm, including those for plasma panels and Gen 4.5 and Gen 5.0 LCDs. The system cuts material waste by more than 90% compared to spin coating and has twice the throughput, said sales and marketing director Kyle Gardner. Tokyo Ohka Kogyo (TOK) and FAS are currently working to integrate FAS technology in TOK's mass-production equipment, said Gardner.

Dave Kettering, senior manager for special products operations at ***Nikon Precision***, was singing the praises of Nikon's FX-701M photolithographic stepper. With a larger lens field of 132 × 132 mm, the 701M uses fewer steps to make a display and produces fewer stitching boundaries. Coupled with a faster stage, this results in a throughput 30% greater than Nikon's preceding model, the 601F, Kettering said. He reported a good reception for the new model. The first systems will be delivered to Asia in the second half of this year, with initial delivery to North America in 1999. In general, Kettering said, sales to Korean companies were starting to come back, and Taiwan was strong. In the U.S., Motorola's FED operation is a customer.

ORC Electronic Products introduced the ProForm 9000 UV exposure system. Designed particularly for plasma-display manufacturers, the system can process substrates from 42 to 78 in. on the diagonal.

In their suite, ***autronic-Melchers*** showed its new conoscopic display-measurement system, which it calls The ConoScope®. Cono-



Durel Corp.

Durel's technology for encapsulating individual grains of EL phosphor permits the fabrication of long-lived EL lamps in many configurations.

autronic-Melcher

autronic-Melcher's The ConoScope® provides multi-angle display measurements in 1/60 the time taken by the company's main competitor, says Michael Becker.

scopic systems are able to measure display characteristics as a function of angle in a sort of quick "snapshot," instead of painstakingly moving a sensor to each set of vertical and horizontal angles at which a measurement is to be made. Perhaps the best-known conoscopic system for display measurements is ***ELDIM***'s EZContrast™, which was exhibited on the show floor. But the newer autronic-Melcher system makes a full set of measurements in a second, compared to 60 sec for the ELDIM system, said autronic-Melcher managing director Michael Becker. The ConoScope has a measurement range of ±80°, a focal-plane stage, fiber-optic output to an optional spectroradiometer, and real-time graphic display of what the system is seeing on the display under test. Quite a few measurements have to be made to accomplish this wizardry. The basic system is $85,000, including a full colorimetric detector. Many accessories are available, including some for making measurements at reduced and elevated temperatures.

Among the extensive offerings shown by ***Schott Glass*** were FED spacers made from optical fibers and Foturan® photo-etchable glass for FED and ink-jet-printer components.

Durel Corp., a joint venture of 3M and Rogers Corp., was exhibiting its expanded family of Durel® 3 EL lamp and inverter systems in the 3M booth. Durel 3 technology encapsulates each phosphor grain in a glass-like coating. The particles can then be applied – by screen printing, for instance – in any pattern to make inexpensive long-lasting lamps that do not have to be passivated between sheets of plastic as conventional EL lamps do. The lamps are being used in a new line of Motorola pagers and in the Ford Taurus instrument panel. "There will be many product introductions over the next year," said Durel's Van Potter.

SI Diamond announced an increase in the density of emitting sites in their diamond-like carbon (DLC) cold-cathode material, along with improvements in material characterization. From this base, company president Zvi Yaniv enthusiastically projected a flat CRT architecture using an array of DLC cathodes instead of a traditional hot cathode. This produces a hybrid between a CRT and a FED, which SI Diamond is therefore calling HyFED™, but the overall structure is similar to that of Panasonic's short-lived Flat Vision™ CRT of 1993 (which, however, used hot cathodes instead of cold). Responses of industry watchers to the HyFED proposal have ranged from comments that it is a creative conceptual application of what DLC films can actually do as emitters in the real world, to complete dismissal as a construct designed to impress investors rather than technologists.

And ***MicroJoin*** (formerly Toddco) representatives were happily discussing the 56% sales increase for their bonding equipment, attributed to the sharp growth in the display repair and rework business.

What we've described here is just a sampling of the materials and manufacturing companies that exhibited at SID '98, because the event has become a major forum for display manufacturing, materials, and components. As Durel's Van Potter said, "This is a great show for us; all our customers are here." ■

Display Technology Showcase

How do we know which display technology is best for a particular application? Four thousand SID attendees went to the DTS to find out.

by Joe Hallett

A NEW EVENT at this year's SID show was the Display Technology Showcase (DTS). The main idea - a side-by-side comparison of technologies - proved to be a hit. An estimated 4000 of SID's 6200 attendees saw about 30 large and small offerings.

DTS was modeled after the INFOCOMM Projection Shoot-Out™, but the concept was significantly modified to allow viewers to see displays of differing technologies, sizes, and production status, optimized for different applications.

Organized in less than 6 months, the showcase was an elaborate array of signal sources and distribution arrangements by courtesy of Extron Electronics. Similar test patterns, images, photos, and moving video were delivered to all the participants in a specific group.

There were three groups of participating displays: small displays (2.0–8.8 in. on the diagonal); desktop displays (10.4– 21-in. units); and large video/graphics displays, including plasma panels, a PALC display, and projectors which could generate images from 20 to 300 in. (although the front projectors were all adjusted to produce the same-sized image).

Placards provided basic information and specifications for each display and identified production status as technology demonstrator, prototype, soon-to-be-shipped product, or commercially available product. The large-display category featured both prototype and commercially available plasma displays.

Mitsubishi, Fujitsu, NEC, Plasmaco, and ***Pioneer*** had entries ranging in size from 40 to 50 in. on the diagonal. They were shown along with a 42-in. demo of a PALC panel, jointly developed by ***Philips, Sony,*** and ***Sharp,*** and a 52-in.-diagonal rear-projection display cube from Clarity Visual Systems.

Small displays included active-matrix and passive diode-matrix LCD panels from Epson, and a desktop-display category that included

Joe Orlando for SID

SID's new Display Technology Showcase (DTS) drew 4000 people interested in seeing different display technologies compared side by side.

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Ken Werner

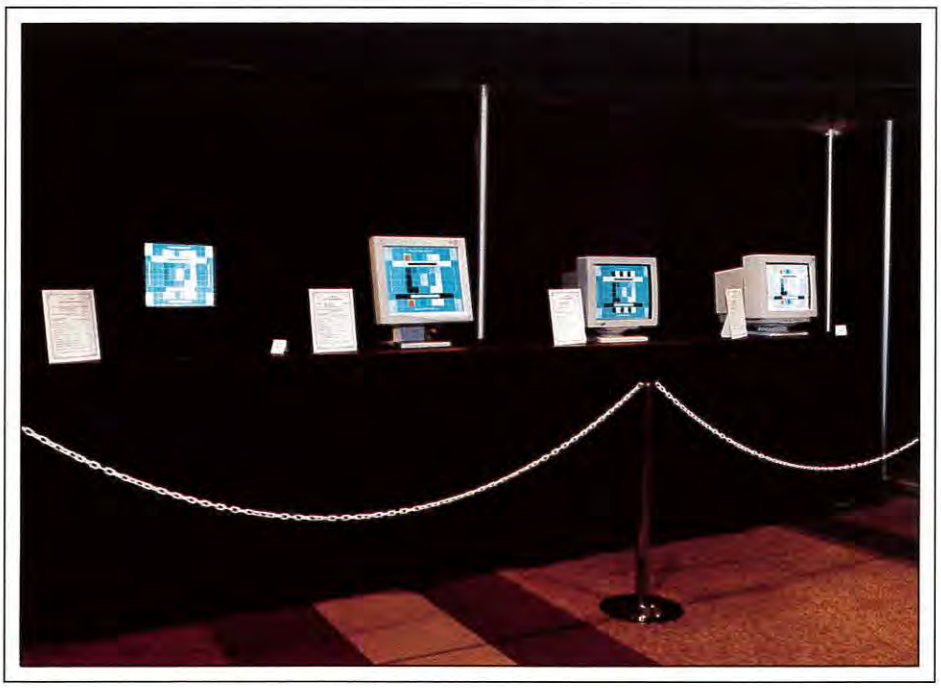
Delivering the same images simultaneously to many different displays using different formats requires a substantial infrastructure.

CRTs, electroluminescent displays, and active-matrix LCDs in various sizes.

Most people have not seen plasma displays, LCDs, projection displays, and CRTs side by side, said Larry Weber, president and CEO of Plasmaco (Highland, New York) and a member of the DTS steering committee. He said that when the displays are all lined up and receiving the same image, all the trickery that goes on in the exhibit hall – where images are limited to those that don't show the defects of the displays – is eliminated.

John O'Donnell, a display consultant from Honeywell Business and Commuter Aviation Systems (Phoenix, Arizona), said, "I love the display comparison. It shows the performance of the displays under numerous conditions, most of which we don't see in the booths."

Steve Somers, vice president of engineering at Extron and the DTS technical director, said, "The SID show is the place to see new display technologies, and I think the DTS has created a new form of excitement by providing the ability to view competing technologies in a controlled environment. It is this type of environment that should be synonymous with the display research and development atmosphere that SID promotes. I see the Display Technology Showcase as the optimum venue for viewing leading-edge display technologies prior to full market development."



Joe Orlando for SID

LCD and CRT monitors are displayed side by side at the DTS.

A Little History

Ken Werner, chair of the DTS steering committee, said that the DTS was designed to illuminate significant technology, format, and application questions confronting members of the display and display-integration communities. The idea of an inter-technology comparison, although on a much smaller scale, was initiated by PixTech's Tom Holzel in a guest editorial in the March 1997 issue of *Information Display.* "Holzel's editorial generated a suggestion from industry veteran Fred Kahn to put on a technology 'shootout,'" said Werner, "and that was the triggering event." The DTS became a reality early this year, when SID's board of directors authorized both the project and the formation of a standing steering committee.

A Level Viewing Field

In the INFOCOMM Projection Shoot-Out's first year, big differences were evident among displays, but over time those differences diminished. "Certainly among products of like technology, that's going to happen," said Plasmaco's Larry Weber, "but I don't suspect that's going to be the case among technologies. You can't make a liquid crystal look like a plasma panel, and you can't make a CRT the thickness of a flat panel. Projectors are always going to have a different set of viewing characteristics. So people need to be educated as to what those differences are." Or, as Karel Kuijk, senior research Fellow at Philips Research Lab in Eindhoven, The Netherlands, irreverently put it, "Every medium is allowed to have its own artifacts."

debut of the DTS

"Generally," said Weber, "these technologies don't kill each other off. Instead, they all find their market segment, where they can excel. I had a fair idea of what our display looked like compared to our PDP competitors, but I didn't have a good idea of how we looked compared to the projection displays and compared to the plasma-addressed LCD. If we look at what they had to show a year ago and compare that with what they have today, it's a fantastic set of advances. It's nice to know where you stand relative to these advances."

The Future

According to Weber, we have a challenge for next year. Many flat-panel displays and monitors have digital interfaces, whereas the only signals available this year were analog. Werner added, "Extron has done a fantastic job, but we need a digital interface next year. Even this year, some companies couldn't participate because of the lack of a digital interface, but we felt we had to keep things relatively simple the first time out and strive to do a limited number of things well. However, it's clear that the DTS must supply digital signals next year."

So, look for a Display Technology Showcase at SID '99 in San Jose, California, that includes displays being driven with digital signals and could feature exciting new developments in the "microdisplay" area. "I think it's long overdue, and we should keep it as a fixture forever," said Honeywell's O'Donnell. ■

Display Viewability

There is still no agreement on what combination of measurable characteristics makes a display "viewable" – but it is agreed that the combination is not the same for all technologies.

by Stephen Atwood

THE two Tuesday evening panel discussions at this year's SID Symposium continued the tradition of spawning spirited discussions with a good deal of audience participation. The more broadly interesting of the two, hosted by Chris Curtin of Candescent Technologies, covered the issue of "Display Viewability: What Factors Make One Display More Pleasing Than Another?"

This was tackled by a variety of well-known and highly respected contributors to the field of display characterization and specification:

Tom Holzel, V.P. of sales and marketing for PixTech, a producer of monochrome and color field-emission displays.
Carlo Infante of CBI Technology Consultants is a longstanding contributor to the field of display measurement, design, and modeling.
Edward F. Kelley, physicist with the National Institute for Standards and Technology (NIST). He has been a frequent contributor to SID symposia and seminars in the field of display measurement and specification.
Louis D. Silverstein, chief scientist at VCD Sciences and a well-known authority on color perception and the characterization of display visual performance.
Russel A. Martin, principal scientist at Silicon Image and a longtime developer of LCD technology.
Larry F. Weber, president & CEO of Plasmaco, has pioneered many elements of current PDP technology.

The broad topic on the floor was to try to ascertain what metrics, subjective or objective, measurable or not, could be used to qualify the visual performance of a display. Tom Holzel, speaking from the perspective of a particular end-application, suggested that the true measure would be to "... present real video- or NTSC-style images and let the user decide by comparison." For example, to quantify a new display one could run a series of comparisons with a known display. Russel Martin pointed out that the problem with such efforts is that human perception is variable, and any studies of this nature must be double-blind to avoid false conclusions. The problem is that we don't have a true measure of video quality. "Any proposed metric is confounded by human perception."

The question then evolved into one of whether it was even worthwhile to continue on this path. Carlo Infante was adamant that although one answer or approach is not universally acceptable, it is absolutely essential that we continue to research metrics for displays. Manufacturers will continue to publish specifications, and designers will continue to need metrics in order to judge their work.

Given that metrics are critical, in a broad sense, which ones are really needed? For example, Martin pointed out that "... humans perceive a change in contrast much more readily than a change in brightness." Louis Silverstein pointed to another example: in many cases the size of a pixel or total resolution may be less important than the available contrast.

Does this mean that contrast is always a more important metric, thus implying that brightness, one of the most common specifications, is not generally that important? Or does the importance of a metric depend on the display technology and the intended application? The panel consensus was that it almost certainly does. Specifications must be based on the technology to be meaningful.

Ed Kelley pointed out how difficult and sometimes unrepeatable the measurement of these parameters can be without very careful methods and equipment. Certainly, performing these measurements comparatively on different displays can be almost impossible, or at least misleading, between technologies.

Terminology and published specifications are certainly misleading today, especially in the absence of industry standards. For example, when comparing the stated contrast-ratio performance of CRTs to LCDs, dramatically different values exist. CRT contrast ratios are frequently defined in terms of an overall reflectance, so a 17-in. desktop monitor with 12% reflectance and 30-fL white-area brightness used in an office environment with about 50-fC of incident light might have a contrast ratio of approximately 5:1. A similarly sized 15-in. desktop-LCD-panel data sheet simply states a contrast ratio of 200:1 with no reflectance data referenced. (This article was

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created on such a panel, and it looked slightly worse under the same lighting conditions on a 17-in. CRT monitor.)

Holzel stressed that in his view, "Issues of image quality will be settled by the market, not human-factors people." But that argument is somewhat circular because in order for a display to be successful in the marketplace, it must be designed to satisfy the intended application, and then the relevant parameters must be quantified to ensure that the product is manufactured consistently and can be improved upon in a non-random fashion.

Comments from the floor included a great deal of disagreement as to which metrics were important for each display technology. In the end, it was clear that the industry needs both a universal generalized display specification that can be used to compare different displays, as well as a set of well-defined and accepted detailed specifications within each technology group. Can the industry get there? Nobody could answer that definitively. ■

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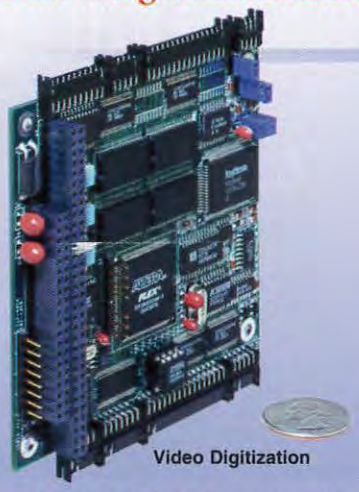

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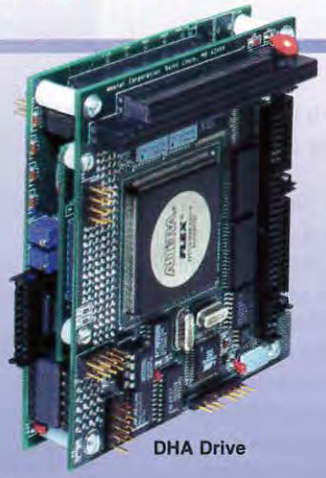

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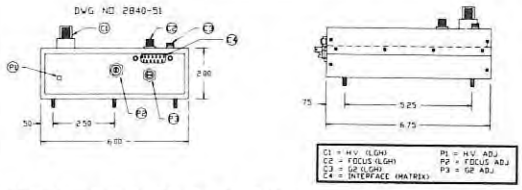

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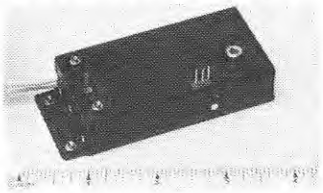

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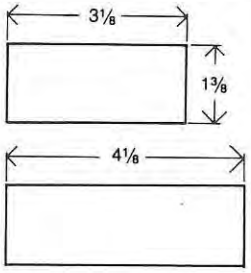
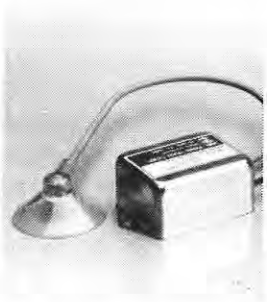
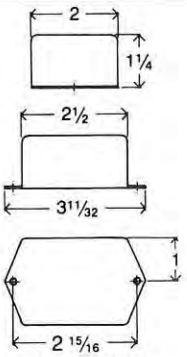
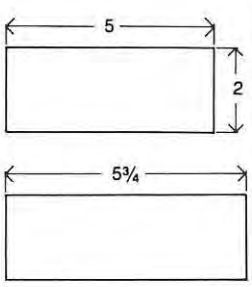


10 Watt -	B+	HV(KV)	SEC	SEC	SEC
HVS 2610	26	10	400	–100	
HVS 2617	26	17	1000	–110	





3 Watt -	B+	HV(KV)	SEC	SEC
HVS 1509	15	9.0	400	–100
HVS 1512	15	12.0	400	–100



30 Watt –	B+	HV(KV)	SEC(KV)	SEC	SEC
HVS 2825	28	25	(5.0-8.0)	(200-1000)	–150
HVS 3625	36	25	(5.5-8.5)	(200-700)	–200

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Circle no. 27

continued from page 4

mud. Ha! That should have aroused our suspicions right there about this great three-primary-color theory. But being such good students and having respect for higher authority, we accepted what we were taught – no questions asked. Besides, we needed to know the right answers for next Friday afternoon's quiz. Way down deep, we hated those Friday afternoon quizzes. "Waaa… ."

At last came senior year in high school. Senior year, and you were finally studying physics. During spring term came the section on optics. By now, you had also discovered photography and were enjoying learning all about exposures and shutter speeds and the properties of various films. You very much wanted to try printing your own pictures, but couldn't afford an enlarger or the other equipment that would be necessary. But you had been reading some of the photography magazines and were starting to search out photography-oriented books in the city library. You were especially interested in learning how colors are produced and how our eyes detect and process color images.

And the physics teacher said, "There are three primary colors. They are red, green, and blue. And when you combine them you get white." Huh? What happened to yellow? And, by the way, don't green and blue make a greenish blue and red and green make a brownish muddy mess? you wondered quietly to yourself. But now the teacher projected circles of green, blue, and red light onto a screen and then overlapped them. Sure enough, they made a reasonable approximation of white. And the physics teacher, not at all concerned with your previous art-class experiences, was justifiably proud of having made such a conclusive demonstration. As far as the physics teacher was concerned, nothing more needed to be said. In any case, your immediate needs were to know the right answers for the year-end final. So you absorbed the information you were taught. This time you had seen the demonstration with your own eyes – it wasn't just respect for authority that caused you to absorb this new, yet conflicting, information. You decided to resolve the conflict at some later date. With graduation coming soon, life was becoming too hectic already.

In contrast to grade school and high school, your college years seemed to go by more quickly than you had anticipated. In freshman physics, there was a brief review of many of the same optics principles you had already encountered in high school. Once again you learned about prisms and colors, but this time with a few more equations and definitions to remember. Definitions and formulas are darn important when you want to get a good score on next week's midterm exam.

Your final school encounter with color theory came in graduate school, when a semester of optics brought you in contact with the CIE

diagram and a few examples of how the equations using the CIE-diagram's X and Y coordinates can be used. But this time you had a professor who liked to show how theory and reality sometimes only partly mesh. You learned that the colors on the printed page in your book were really not an accurate representation of all that the CIE diagram is supposed to show. The professor also went into a discussion of how television phosphors only cover a portion of the CIE diagram, and therefore some colors cannot be seen on a television set or computer monitor. Wow, this was getting interesting but also more confusing. In passing, the professor also mentioned that high-quality art books are often printed with six or more colors. You really didn't understand what that comment was all about, but didn't want to sound too stupid by asking for an explanation.

Looking at the CIE diagram, you tried to place the three primaries – blue, green, and red – so that all the colors would be reproduced. But no matter how you tried, some colors were left out. In order to cover the entire CIE diagram, you would need five or six "primaries." Four would be a minimum to get reasonable coverage. Three just didn't seem to do it at all. So, where did the three-primary color theory originate? And is that what the professor was talking about when he said that art books used more colors? All you could think of was that the three-primary color theory must be based on how the human eye works. In the various texts describing the cones and rods, the cones are said to be sensitive to three color ranges approximating the red, green, and blue regions of the spectrum. But where would one put the eye's color sensors on the CIE diagram? In order to detect all the colors, with only three sensors, at least one of them would have to be *outside* the CIE diagram's boundary! Or another possibility would be that each of the eye's sensors covers a region rather than just a discrete point. But wouldn't that mean that each cone "knows" more than the textbooks say it does? Memories of the simple but self-consistent explanations from high-school physics class came flooding back. OK, just tell me what equations I need to know for the semester's final exam! Otherwise, this was now getting way too confusing.

In college, you couldn't get a BA or BS degree in "displays." So you graduated with a BA in Physics. And in graduate school, you couldn't get and MA or Ph.D. in "displays" either. So you ended up with a Ph.D. degree in EE. But since you liked physics and you liked EE, and you liked things that glow in the dark, you became a display scientist/engineer.

And with your interest in nature and the great outdoors, you retained your love for photography and art as well.

Finally, with a real job and a more stable income, you were able to buy the darkroom

equipment you had wanted since high school and take some art classes in your spare time. And that's when the world of color got even more complicated. In learning how to make color prints, you found that for making prints from negatives, the three primaries are not red, green, and blue, but cyan, magenta, and yellow. They are the "opposites" of red, green, and blue. "You mean as the opposite of light is dark?" "Well, yes," said your instructor. "The opposite of red is un-red, and the opposite of green is un-green." "Oh, sure. That explains everything." "No, no. What I mean is that if you look at the color spectrum and subtract out the red, you will be left with the green and blue end, which makes a cyan. And if you subtract out all the green, you will be left with red and blue, and together those make magenta. So that is why they are called the subtractive primaries. When you print color negative film, you get this color reversal, just as you would get with light and dark in printing black-and-white negative film."

In taking art classes, you now learned that the idea of three pigment primaries (blue, yellow, and red) is just that - an idea. In real life, no artist can or is likely to work with just those three. There are no pigments in existence that are that pure and that good. So most artists settle on at least a dozen "primaries" for their palettes. These usually consist of three reds, ranging from a bluish red to an orangish red, three yellows, ranging from a cool lemon yellow to a warm sunny tone, and so forth. By choosing the tone and also the particular brand's unique blend of color materials, each artist ends up with a characteristic palette that is best suited to his or her particular subject matter and style. You learned that, after some familiarization, the works of the better artists can be recognized just from the pigment choices that they have made and the unique way in which these pigments are combined. So much for the three-primary color theory! Life was much simpler in kindergarten art class, before I knew all this, you decided.

Then one day you were sitting at the dining-room table, having a midday snack. Outside it was cloudy but still cheerfully pleasant. The sun was occasionally making its presence known. Your significant other had placed a bud vase on the table with a perfectly shaped Tropicana rose from the garden. This rose had a warm red color with hints of magenta in the petals. The colors were intense. For some time, you admired this example of nature's beauty. Then you began to think about your ability to appreciate this flower's tonal subtleties. Your eyes were detecting all those delicate tones and describing their variation from petal-to-petal and shade-to-light with a speed and sensitivity that is unmatched by any known measuring instrument. And not only that, there was an emotional response that

display continuum

only a caring intelligence can bring to such a situation.

Finally, you couldn't resist the temptation. You got your camera and took a number of photos of this perfect flower. But, even as you did this, you knew you would never see all the delicate colors on the film version that you saw with your eyes. Film is quite good and covers much of the CIE diagram, but not all. A few colors are missing altogether, while others are not rendered accurately. Typically, what happens is that the subtle variations, such as those between a warm red and a delicate reddish magenta are rendered as essentially the same saturated red. Some shades of delicately varying bluish greens come out all looking like the same green, usually a nice healthy grass green.

Suddenly, something very strange began to happen. It was like the beginnings of a runaway fission reaction. Perhaps it was caused by an irreconcilable right-brain left-brain conflict – the artistic side suddenly colliding with the scientific side. In any case, the mental fireworks were something to behold. The insight was sudden. You realized that, for any self-respecting display engineer, all this represented a huge problem and therefore a huge opportunity.

With the serious advent of the Information Age, what an incredible mess we have created for ourselves. Here we have more and more people who need to specify colors accurately and who are doing more of their work using various CAD systems, but no one has provided them with the basic tools to do accurate and repeatable color representations with these systems. Nothing matches anything, and many colors can't be represented at all. CRTs use phosphors originally optimized for television and which leave a large area of the CIE diagram inaccessible. LCDs use filters and backlights that have an even more limited color response. The new plasma panels are different in yet another way, but no better than CRTs. Every hardcopy device uses inks that have different color characteristics from the displays. And the printing industry uses another set of pigments and inks that are not matched to any of the display devices either.

Wouldn't it be great to bring all the display and printing technologies into harmony by designing displays and printers that produce most of the colors on the CIE diagram and do so predictably and with built-in calibration? How many "primaries" would we need? At least four. A few "photo-quality" printers have recently been introduced that use up to six colors. There may be a need for some tradeoff in display performance to get the right phosphors or right color filters, but wouldn't that be acceptable to those working in the color-sensitive industries, such as art, advertising, printing, photography, fabric design, paint manufacturing, archiving, mapping, and many others? Here lies an opportunity spawned by the Information Age that few have yet made a serious attempt to address.

Art and science fusing to create new Information Age capabilities and new business opportunities – now that's something worthy of a headline or two in the technology section of *USA TODAY!*

Should you wish to become a headline maker, or if you would like to discuss any of this further with me, you may reach me by e-mail at silzars@ibm.net, by fax at 425/557-8983, by phone at 425/557-8850, or by pieces of paper with inks in colors of your choosing sent to 22513 S.E. 47th Place, Issaquah, WA 98029. ■

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european views

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CEO's few years in office. (Again, Dietrich: Where are all the industrial leaders of past times gone? – the Siemens, the Ericssons, the Teslas, the Zeiss & Abbes, the Marconis, the Nobels – those scientist/engineers who invested their lifetimes, not just a few years, in what they invented and believed in.) So far, we haven't seen much emanating from these consortia and E.C. programs.

Maybe the author of these views is too impatient, too pessimistic; but should we not, given what has not materialized, reconsider the European strategy by giving to each culture what it needs. Science needs resources and the freedom to use them – discoveries cannot, in any case, be planned. Industry needs financial support only for the long-term commitment to follow and develop technically those good new ideas that pop up now and then, here or there, in stimulating (and stimulated, by support!) academic environments. And this support should be given only to small- and medium-sized enterprises (SME) that today have great difficulty in setting aside the manpower necessary to challenge the big guys in getting E.C. support.

Let me finish with a quite different and definitely more optimistic topic, a report from beyond the future of information display. At a recent meeting of liquid-crystal scientists (The 17th International Liquid Crystal Conference at Strasbourg, France, in July), chemist and Nobel laureate Jean-Marie Lehn of Louis Pasteur University in Strasbourg and of College de France in Paris, told the audience in his opening address to the conference how he envisaged the development of supramolecular structures forming, by self-assembly, a grid of dimensions leading to a periodicity orders of magnitude smaller than what can be achieved by microfabrication. These structures – imagine a screen made up of just ONE molecule! – might further possess a capacity of self-adaption to external physical properties. Molecules like these would be information-containing and information-processing entities.

There seems to be hope after all for a new generation of European researchers and engineers, and today's information displays may look like rune-stones to our descendants. ■

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SID Conference Calendar

Next Show!

The 1998 International Display Research Center (Asia Display '98)

The 18th edition of the International Display Research Conference will be held at the Sheraton Walker Hotel in Seoul, Korea on September 28 to October 1, 1998. The conference will emphasize research and fundamental development activities in display technology and related human interfaces. A full-day workshop on September 28 will focus on AMLCDs/LCs, FEDs, PDPs, and phosphors. Invited talks for these workshops will be presented in a format designed to stimulate discussion on recent advances and future directions of display research. Papers relevant to the advancement of the state of the art of electronic displays will be presented. A vendor exhibit will be on view September 29 to October 1.

28 SEPTEMBER 98

18th International Display Research Conference (Asia Display '98)

SEOUL, KOREA
SEPT. 28 – OCT. 1, 1998

- 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

17 NOVEMBER 98

Sixth Color Imaging Conference: Color Science, Systems & Applications

SCOTTSDALE, ARIZONA
NOVEMBER 17 – 20, 1998

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

2 FEBRUARY 99

Display Works 99:

SAN JOSE, CALIFORNIA
FEBRUARY 2 – 5, 1998

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- Flat Panel and CRT Manufacturing
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- Manufacturing Equipment
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- Industry Forecasts
- Investor Presentations
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16 MAY 99

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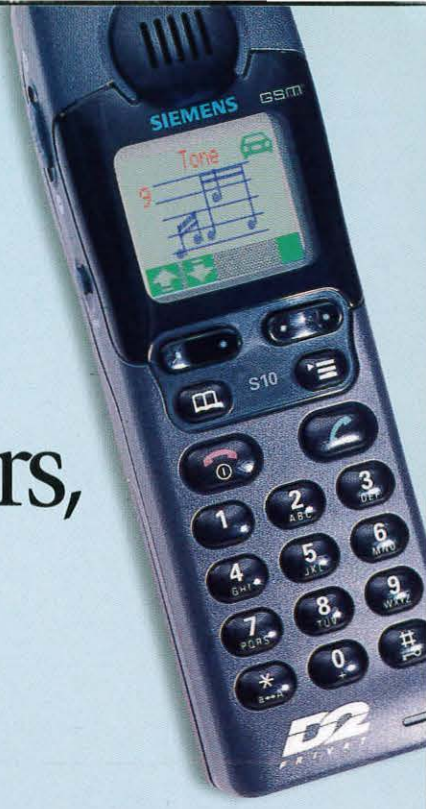

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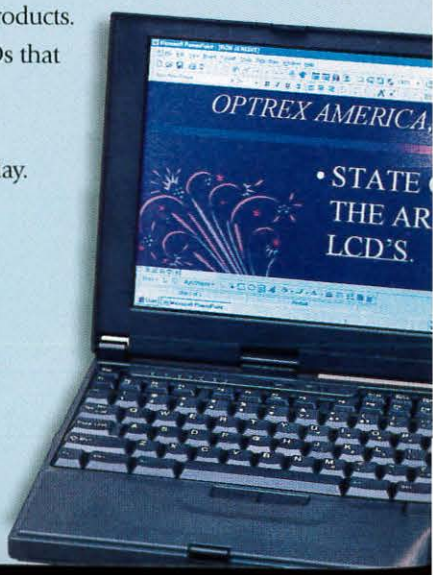

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