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Information DISPLAY

January 2000
Vol. 16, No. 1

SID
Official Monthly Publication of the Society for Information Display

A Scanning-Laser Retinal Display for Pilots

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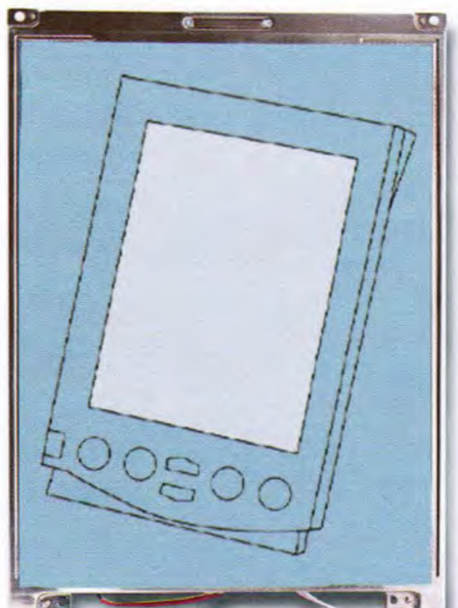

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Circle no. 4

Information DISPLAY

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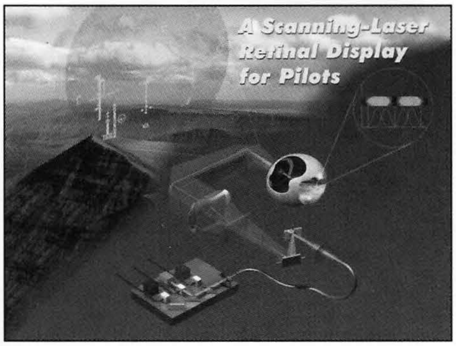
COVER: A laser beam scanning the retina is revolutionary technology, but for pilots trying to view data against a sunlit sky, it may be the only practical approach.



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Next Month in *Information Display*

Flat-Panel Issue
- Reflective Color LCDs
- Laser Displays
- Polymer-Display Development
- PC and Non-PC Display Sales

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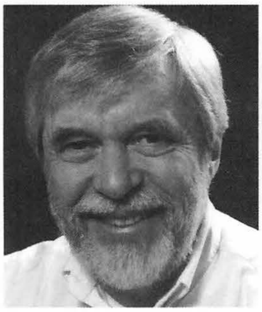
president's message



Dear SID Members:

Shortly after I became President in 1998 I wrote a message outlining the changes and improvements we were intending to make in our service to you. I also promised you periodic updates. Well, I'm afraid I kept you waiting for longer than intended, but I did make it for the start of the new century! Nonetheless, I hope that you have already started to experience the improvements I shall outline in more detail now.

Membership Services

First, we were aware that our response time in answering members' requests was too long and that we were taking too long to activate our service to new members. In 1998 we started making progress to rectify both these situations. We have accelerated the processing of new member applications following the annual Symposium, by far the busiest time of the year for us, and this year all new member packs were mailed within four weeks of the Symposium. This is about the best we shall be able to achieve, given the degree of checking that is required to ensure that your data are accurate and given the fact that we are now issuing personalized membership cards bearing your name and membership number. We hope to make further improvements in the future, possibly by adding a bar code to your card so that future on-site registration at our conferences can be simplified by swiping your card, avoiding the need to register manually.

We have also implemented a new Symposium registration procedure to reduce queuing time. E-mail registration from our Web site was used by a larger number of you than ever before and it worked perfectly in almost every instance. We hope to make further improvements next year so that even if you miss the deadline for having your documents mailed to you, you can simply collect them from a pre-registration desk. SID HQ and Palisades Institute have worked together very effectively to make these improvements.

Last November, we introduced a rolling membership year so that you will receive full membership benefits for a full year starting on the day you join. However, because your personal membership renewal date may not now coincide with the Symposium, you will need to take care to ensure that your membership does not accidentally lapse. Our computer system will automatically generate a renewal request about one month prior to your renewal date – and it will send out reminders – but it will help our very busy HQ staff tremendously if you can respond promptly.

Our Executive Director, Dee Dumont, and Jenny Needham, who has made our iMIS database run very effectively, have focused on improving the availability of SID services at major conferences and have really made an effort to meet chapter officers and members. They have been doing this to better understand the diverse needs you have in different geographical areas so they can tailor their services to meet your requirements. They have done a great job over the last 18 months since they took over management of our HQ. However, we realize that there is still room for improvement, so please send them any comments and suggestions for improving their service to you still further. They will make sure I am kept updated.

continued on page 37

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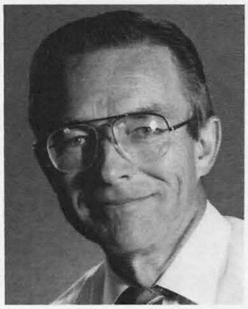

But What About 50 Years from Now? ...

by Aris Silzars

Imagine with me, for a few moments at least, that you are still young and will soon celebrate your tenth birthday. In this imaginary scenario, for the last several years you have been living in a small town in Kansas – maybe a bit like Dorothy in *The Wonderful Wizard of Oz*. The time is in the early fifth decade of the last century. With the strong encouragement of your parents, you have been taking piano lessons for a few years and are showing some modest talent for this activity. Recently, your mother has begun to have visions of you someday performing as a concert pianist.

In order to capture your promising musical accomplishments, your parents have made an appointment with the local studio, which also happens to be the one and only local radio station, for a recording session. You observe the grand piano sitting in the middle of an otherwise bare room, with ominous-looking egg-crate-like sound-absorbing material covering all the walls and ceiling. This recording studio is enough to intimidate most adults, let alone the typical ten-year-old. A few practice runs through your prepared ten-minute program produces some decent passages but also plenty of wrong notes. The recording engineer informs you that the performance should be as mistake-free as possible because there will be only one opportunity to do the recording. You think to yourself, "that's easy for you to say," as your stress level and stage fright climb to new highs. All the while your mother is giving you words of encouragement, but also contributing to the growing intensity of the experience by trying to reassure you how well you are going to do. "Sure, Mom, but just what makes you think that?" are more words left unspoken.

Finally, you can't stall any longer, and the recording engineer tells you to prepare for his cue. He walks over to a piece of equipment that looks like an overgrown and very sturdy phonograph and places a new shiny black platter on it. The machine begins to spin the platter, an arm descends, the cue is given, and you begin to play. Meanwhile, the black platter continues its spinning, and the "needle" generates a growing blob of a black stringlike substance as the piano music is translated into tiny wiggly patterns in the spiral groove being cut into the black plastic. With great concentration, you make it through your program with only one small bobble. Your mother smiles and gives you a big hug. You have just participated in the marvel of creating your very own 78 rpm recording.

And, yes, some 40-plus years later, I still have that recording, and when properly encouraged will get it out for you and play it. That moment of my life has been captured and can be expected to be "archival" for many years yet to come.

While in this nostalgic frame of mind, I took a look at our family's photo album, which by now contains photos representing all the decades of the 20th century. The earliest photos were from a time when my parents were younger than I was during my traumatic piano-recording experience. These early photos were of course monochromatic, but the images continue to be as perfect today as the day they were created. The large-format negatives that, like the photos, have survived wars, refugee trains, ocean journeys, and the harshest of storage conditions also show no noticeable degradation. Over the years, I have printed duplicates from them with perfect results.

continued on page 36

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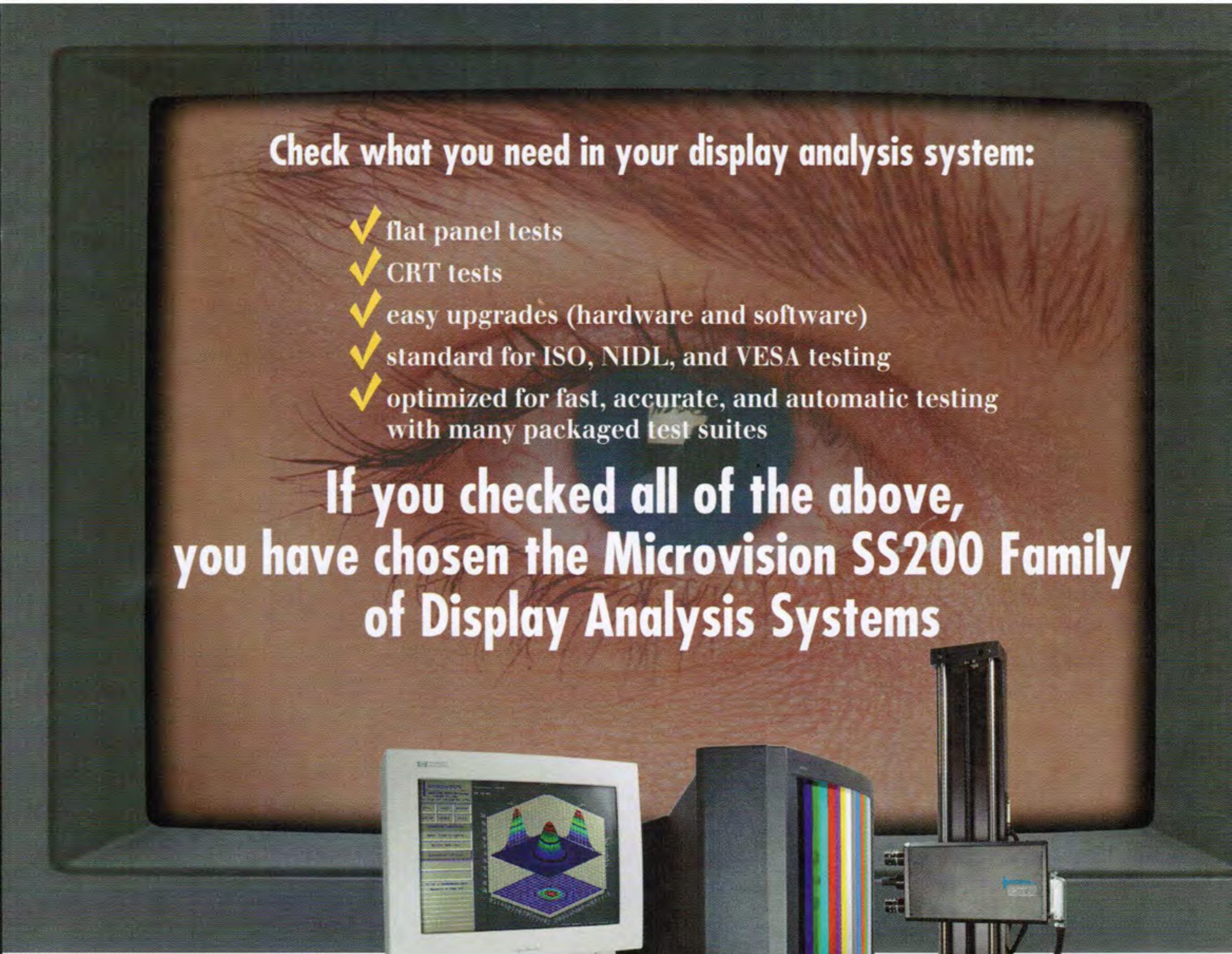

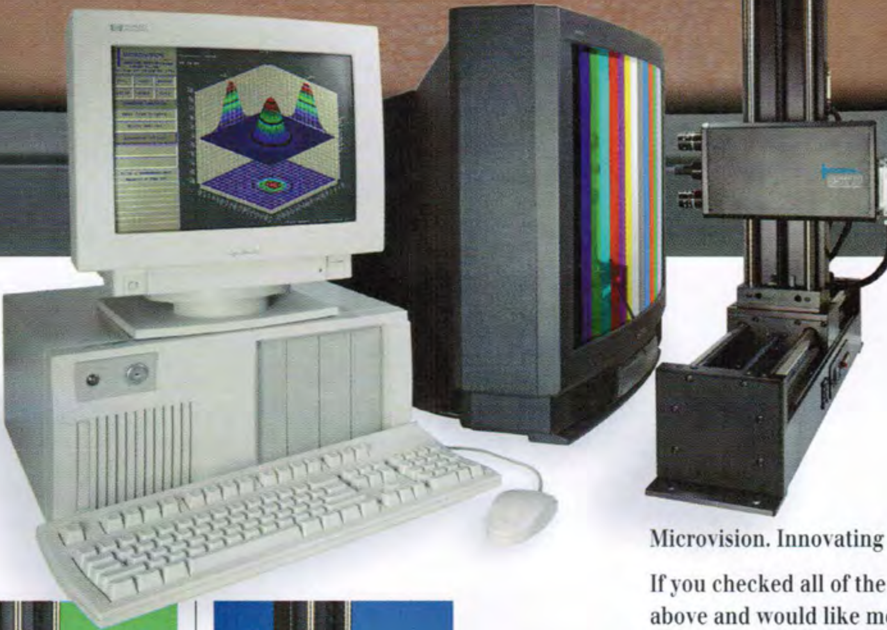

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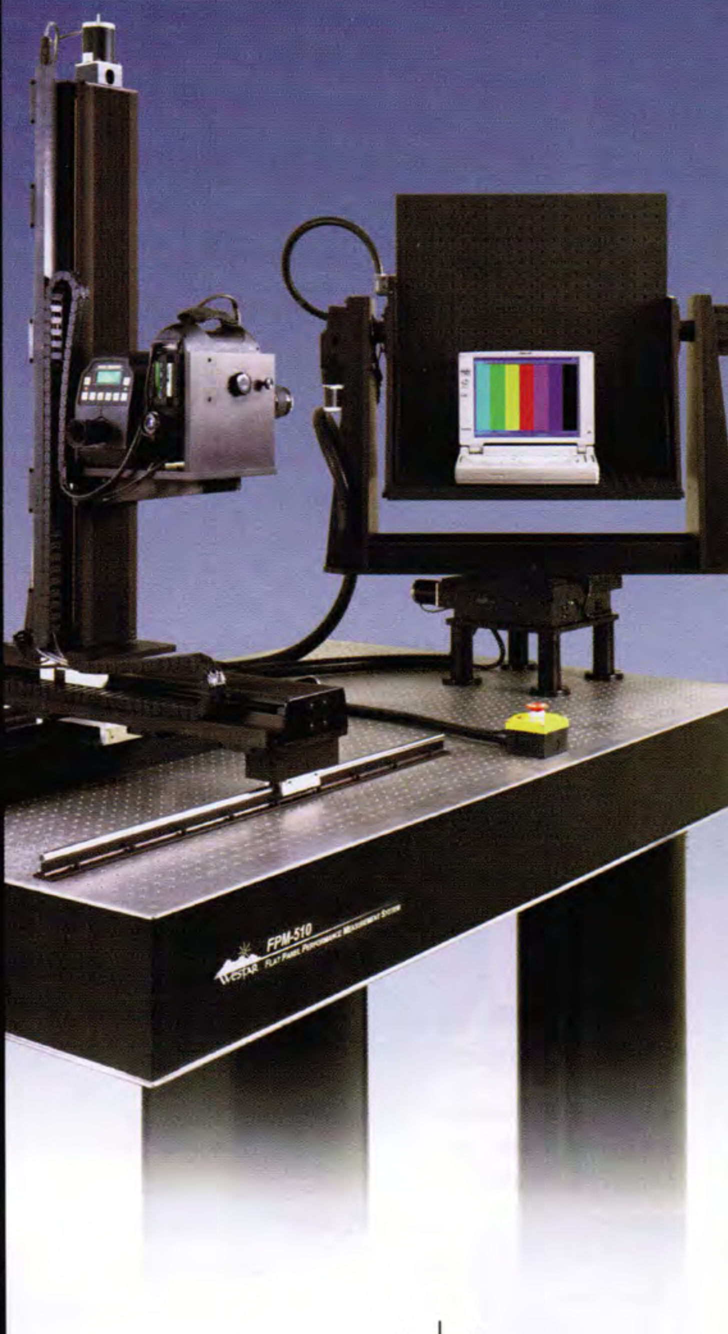

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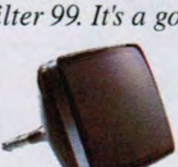

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Circle no. 10

A Helmet-Mounted Laser Display

A laser beam scanning the retina is revolutionary technology, and provides the brightest image for pilots using an HMD in sunlight.

by Thomas M. Lippert, Clarence E. Rash, and James J. Hauser

FOR MORE THAN 30 YEARS, researchers and designers have worked to give military pilots safer, more-effective helmet-mounted displays (HMDs) so that mission-critical information would always be available "eyes-out," which is not the case with traditional "head-down" panel-mounted cockpit instrumentation.

U.S. Army AH-64 Apache helicopter pilots are equipped with such an HMD, enabling nap-of-the-earth navigation and combat at night by means of video from a visually coupled infrared imager and data computer. The Army proudly claims, "We own the night." This particular pilot-vehicle interface has proven its reliability and effectiveness in over 1 million hours of flight and was employed with great success in the Desert Storm Campaign. Still, it lacks the luminance required for optimal gray-scale display during typical daylight missions.

***Thomas M. Lippert,** Ph.D., is Chief Scientist at Microvision Inc., 19910 North Creek Pkwy., Box 3008, Bothell, WA 98011; telephone 425/415-6700, fax 425/415-6602, e-mail: thomasl@mvis.com. **Clarence E. Rash** is a Research Physicist at the U.S. Army Aeromedical Research Laboratory, Ft. Rucker, AL; telephone 334/255-6814, fax 334/255-6977, e-mail: clarence.rash@se.amedd.army.mil. **James J. Hauser** is HGU-56/P Helmet Project Engineer with the Department of the Army Aircrew Integrated Systems Office, Redstone Arsenal, AL; telephone 256/313-4267, fax 425-313-4346, e-mail: hauserj@peoavn.redstone.army.mil.*

The low luminance and contrast required for nighttime readability is relatively easy to achieve, but it is far more difficult to develop an HMD bright enough and of sufficient contrast for daylight use. The information must be displayed as a dynamic luminous transparency overlaying the view of the real world's complex features, colors, and motion (Fig. 1). In order to display an image against a typical real-world daytime scene with a luminance of 3000 fL, the virtual display's peak luminance must be about 1500 fL at the pilot's eye. And depending on the efficiency of the specific optics employed, the luminance at the display light source may need to be many times greater.

From CRTs to MFPs

Army Aviation is the U.S. military leader in deployed operational HMD systems. The Apache helicopter's monochrome green CRT helmet display unit (HDU) presents pilotage forward-looking infrared (FLIR) imagery overlaid with flight symbology in a 40° (H) × 30° (V) monocular field of view (FOV). The Apache HDU was developed in the late 1970s

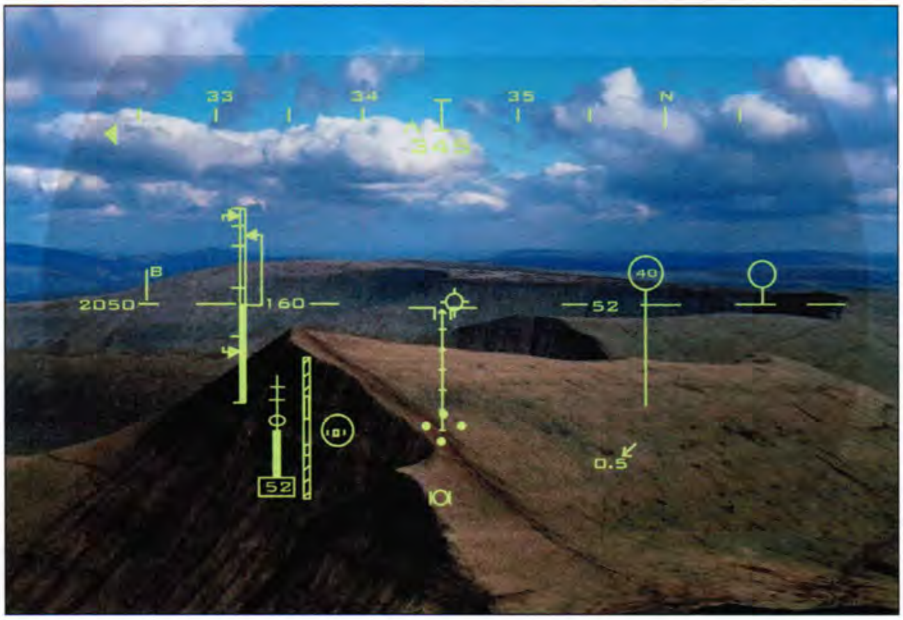

***Fig. 1:** HMD information must have sufficient luminance to be seen when overlayed on real-world views.*

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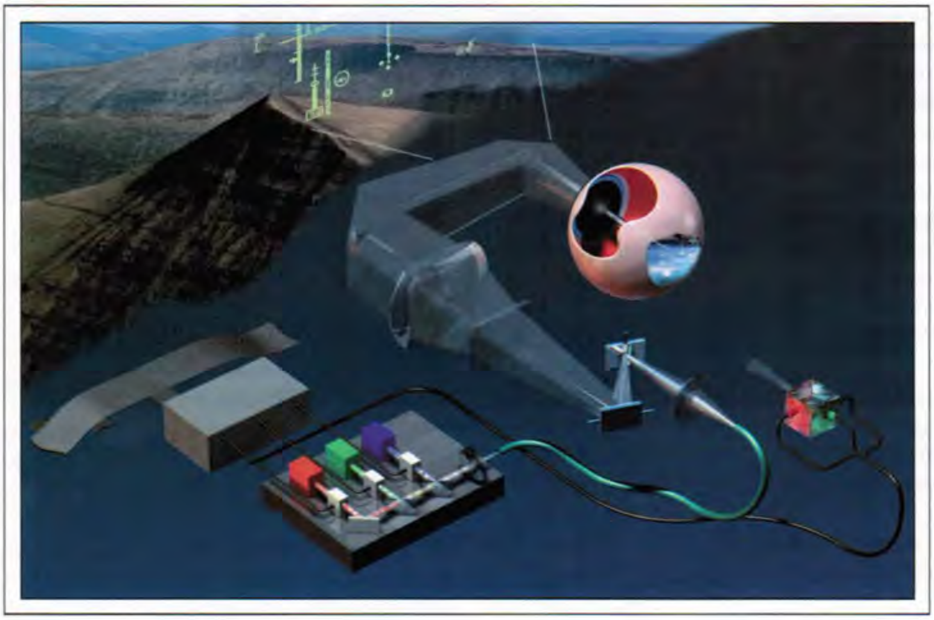

Fig. 2: This schematic diagram illustrates the functional components of a laser-scanned display system.

and early 1980s using the most advanced display technology then available. The new RAH-66 Comanche Helicopter Program has expanded the display's performance requirements to include night and day operability of a monochrome green display with a binocular 52° (H) × 30° (V) FOV and at least 30° of left/right image overlap.

The Comanche's Early Operational Capability Helmet Integrated Display Sighting System (EOC HIDSS) prototype employed dual miniature CRTs. The addition of a second CRT pushed the total head-supported weight for the system above the Army's recommended safety limit. Weight could not be removed from the helmet itself without compromising safety, so even though the image quality of the dual-CRT system was good, the resulting reduction in safety margins was unacceptable.

The U.S. Army Aircrew Integrated Systems (ACIS) Office initiated a program to explore alternate display technologies for use with the proven Aircrew Integrated Helmet System Program (AIHS, also known as the HGU-56/P helmet) that would meet both the Comanche's display requirements and the Army's safety requirements.

Active-matrix liquid-crystal displays (AMLCDs), active-matrix electroluminescent displays (AMELs), field-emission displays (FEDs), and organic light-emitting diodes (OLEDs) are some of the alternative technologies that have shown progress. These postage-stamp-sized miniature flat-panel (MFP) displays weigh only a fraction as much as the miniature CRTs they seek to replace.

AMLCD is the heir apparent to the CRT given its improved luminance performance. But future luminance requirements are likely to be even higher, and there are growing needs for greater displayable pixel counts to increase effective range resolution or FOV, and for color to improve legibility and enhance information encoding. It is not clear that AMLCD technology can keep pace with these demands.

Enter the Laser

Lasers offer distinct advantages over other display technologies; for one, luminance is limited only by eye-safety considerations. The light-concentrating aspect of the diffraction-limited laser beam can routinely produce source luminances that exceed that of the solar disc.

Strict engineering controls, reliable safeguards, and careful certification are mandatory to minimize the risk of damage to the operator's vision. Of course, these safety concerns are not limited to laser displays; any system capable of displaying extremely high luminances should be controlled, safeguarded, and certified.

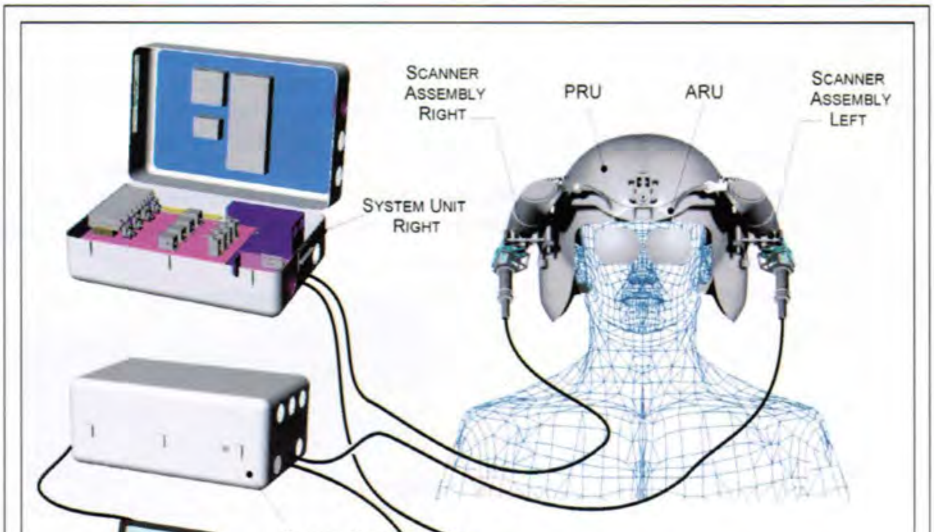

Fig. 3: Microvision's components meet the EOC HIDSS requirements.

Microvision's products are routinely tested and classified according to the recognized eye-safety standard – the maximum permissible exposure (MPE) – for the specific display in the country of delivery. In the U.S., the applicable agency is the Center for Devices and Radiological Health (CDRH) Division of the Food and Drug Administration (FDA), and the American National Standards Institute's Z136.1 reference, "The Safe Use of Lasers," provides MPE standards and the required computational procedures to assess compliance. In most of Europe, the IEC 60825-1 provides the standards.

Compliance is assessed across a range of retinal exposures to the display, including single pixel, single scan line, single video frame, 10 sec, and extended-duration continuous retinal exposures. For most scanned laser displays, the worst-case exposure, leading to the most conservative operational usage, is found to be the extended-duration continuous display MPE. Thus, the MPE helps define laser power and scan-mirror operation-monitoring techniques implemented to ensure safe operation. Examples include shutting down the laser if the active feedback signal from either scanner is interrupted, and automatically adjusting unmodulated laser-beam attenuation for luminance control independent of displayed contrast or gray scale.

Another challenge to manufacturers of laser HMD products centers on access to efficient low-cost lasers or diodes of appropriate collectible power (1–100 mW), suitable wavelengths (430–470, 532–580, and 607–660 nm), low video-frequency noise content (<3%), and long operating life (10k hours). Projection engines and suitable infinity-focus viewing optics are also needed. Diodes present the most cost-effective means because they may be directly modulated up from black, while lasers are externally modulated down from maximum display power. Except for red, diodes still face significant development hurdles, as do blue lasers. Operational military-aviation HMDs presently require only a monochrome display which can be obtained by using a 532-nm diode-pumped solid-state (DPSS) laser with an acoustic-optic modulator (AOM).

Table 1. AIHS HIDSS Test Parameters and USAARL Performance Test Results

Test Parameter	Performance
Exit pupil size and shape	Circular and slightly greater than 15 mm in diameter.
Eye relief	Physical eye relief, 19 mm Optical eye relief, 40 mm
Monocular fields of view	Nominally, 40.4° (H) × 30.1° (V)
Binocular field of view	52.1° (H) × 30.0° (V)
Angular left/right image overlap	26°
Binocular alignment	<1 mrad
System transmittance	Notched at 538 nm (42-nm bandwidth) Photopic transmittance, 59.3%
Field curvature and spherical/ astigmatic aberrations	All <0.5 diopter.
Gamma response	Slightly compressed, but monotonic; channels not balanced for peak luminances.
Luminance uniformity	Measured using a 25 square pattern, uniformity was within ±20% for 21 of the 25 squares.
Interpupillary distance (IPD) range	57-73 mm
Vertical adjustment range	±5 mm
See-through color discrimination	While all observers passed this test, there was difficulty in discriminating among greens, which might manifest itself in increased reaction times.
Contrast transfer function (CTF)	Unacceptable, with only 10% contrast at half Nyquist frequency.
Modulation transfer function (MTF)	Poor high-frequency response.

Laser-Scanning Concept

Microvision has developed a flexible component architecture for display systems (Fig. 2). RGB video drives AOMs to impress information on Gaussian laser beams, which are combined to form full-color pixels with luminance and chromaticity determined by traditional color-management techniques. The aircraft-mounted photonics module is connected by single-mode optical fiber to the helmet, where the beam is air-propagated to a lens, deflected by a pair of oscillating scanning mirrors, and brought to focus as a raster-format intermediate image. Finally, the image is optically collimated and combined with the viewer's visual field to achieve a spatially stabilized virtual-image presentation.

The AIHS Program requires a production display system to be installed and maintained as a helicopter subsystem [designated Aircraft Retained Unit (ARU)] and an individually fitted protective helmet, or Pilot Retained Unit (PRU), for each pilot. Microvision's initial concept-demonstration HMD components meet these requirements (Fig. 3).

Microvision's displays currently employ one horizontal line-rate scanner – the Mechanical Resonant Scanner (MRS) – and a vertical refresh galvanometer. Approaches using a bi-axial microelectromechanical system (MEMS) scanner are under development. Also, as miniature green laser diodes become available, Microvision expects to further reduce ARU size, weight, and power consumption by transitioning to a small diode module embedded in the head-worn scanning engine, which would also eliminate the cost and "coupling losses" of the fiber-optic link.

For the ACIS project, a four-beam concurrent writing architecture was investigated to effectively multiply the line rate achievable with the 16-kHz line-scanner frequency employed in unidirectional horizontal writing mode. The vertical refresh scanner was of the

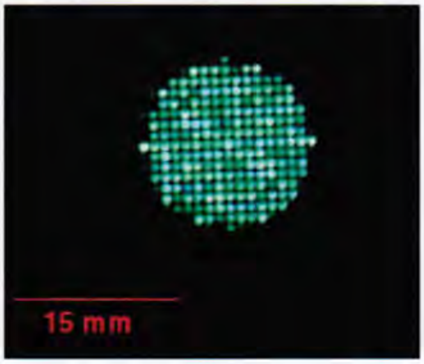

Fig. 4: This image shows the far-field beamlet structure of a spot-multiplied (expanded) exit pupil. The unexpanded 1-mm exit pupil is represented by a single central spot in this image.

60-Hz saw-tooth-driven servo type for progressive line scanning. The f/40 writing beams, forming a narrow optical exit pupil (Fig. 4), are diffraction-multiplied to form a 15-mm circular matrix of exit pupils.

The displayed resolution of a scanned-light-beam display is limited by three parameters: (1) spot size and distribution as determined by cascaded scan-mirror apertures (*D*), (2) total scan-mirror deflection angles in the horizontal or vertical raster domains (θ), and (3) dynamic scan-mirror flatness under normal operating conditions. Microvision typically designs to the full-width half-maximum (FWHM) Gaussian-spot-overlap criterion, thus determining the spot count per raster line. Horizontal and vertical displayable spatial resolutions, limited by $D \times \theta$, must be supported by adequate scan-mirror dynamic flatness for the projection engine to perform at its diffraction limit. Beyond these parameters, image quality is affected by all the components common to any video projection display. Electronics, photonics, optics, and packaging tolerances are the most significant.

Testing the Concept

Under the ACIS program, the concept version of the Microvision Virtual Retinal Display™ (VRD™) HMD was delivered to the U.S. Army Aeromedical Research Laboratory (USAARL) for testing and evaluation in February 1999. The unit was evaluated, and the test results are reported in Table 1.

As expected, the performance of the concept-phase system had some deficiencies when compared to the RAH-66 Comanche requirements. However, these deficiencies were few in number, and the overall performance was surprisingly good for this initial development phase. Measured performance for exit pupil, eye relief, alignment, aberrations, luminance transmittance, and FOV met the requirements completely. The luminance output of the left and right channels – although high with peak values of 808 and 1111 fL, respectively – still will not provide the contrast values required by Comanche in all combinations of ambient luminance and protective visors. Of greatest concern was the modulation transfer function (MTF) – and the analogous contrast transfer function (CTF) – exhibiting excessive roll-off at high spatial frequencies, and indicating a "soft" displayed image.

Hitting the Spot

The second AIHS Program phase concentrates on improving the image quality. Microvision has identified the sources of the luminance, contrast, and MTF/CTF deficiencies found by USAARL. A few relatively straightforward fixes – better fiber coupling, stray light baffling, and scan-mirror edge treatment – are expected to provide the luminance and low-spatial-frequency contrast improvements required to meet specification, but MTF/CTF performance at high spatial frequencies presents a more complex set of issues.

Each image-signal-handling component in the system contributes to the overall system MTF. Although the video electronics and AOM-controller frequency responses were inadequate – and easily remedied through redesign and component specification - several optical problems emerged. The first class of optical MTF problems is the improper mounting of fixed fold mirrors in the projection path, which leads to an accumulation of several wavelengths of wave-front error and resultant image blurring. This problem can be solved via improved mounting techniques and, where necessary, the use of thicker mirror substrates.

Fig. 5: The effect of improved mirror design is apparent in these two pixel spot images – normalized for size but not for intensity – for a scanned spot at ~λ/4 p-p mechanical mirror deformation (left image) and a scanned spot at ~2λ p-p mechanical mirror deformation (right image).

The second class of problems pertains to the figure of the scan mirrors. Interferometric analyses of the flying spot under dynamic horizontal scanning conditions have indicated excessive mirror-surface deformation (~2λ peak-to-peak mechanical mirror deformation), resulting in irregular spot growth and MTF/CTF performances below design specification (Fig. 5).

Three consecutive in-house design and fabrication iterations brought the mirror surface under control (~λ/4) to achieve acceptable spot profiles at the raster edge. The component improvements described above are expected to result in MTF/CTF performances meeting U.S. Army specification in a single system design iteration.

Toward Production

The next step in the evolution of the helicopter pilot's laser HMD is to introduce high-resolution daylight-readable color. Microvision first demonstrated a color VGA format in 1996, followed by SVGA in 1998. A color 1280 × 1024-pixel binocular HMD project is being made possible by ACIS's Virtual Cockpit Optimization Program (VCOP), which begins with software-reconfigurable virtual flight simulations in 2000 and proceeds to in-flight virtual cockpit demonstrations in 2001.

Various "virtual" technologies will be integrated under VCOP to immerse the pilot in a highly intuitive multi-modal display environment within the cockpit. In addition to the HMD, the virtual technologies may include sensor vests, 3-D audio, and virtual gloves with tactile feedback.

The Microvision laser-scanning HMD is the key to VCOP because it is the only display technology known that can provide high-resolution binocular wide-FOV *color* virtual imagery at operationally relevant, daylight-readable luminances. This next-generation pilot-vehicle interface will serve as the primary flight reference, most likely aboard a Black Hawk helicopter conducting mock

new technology

transport and enemy-evasion mission scenarios. The aircraft's traditional control-panel instrumentation is expected to provide only emergency backup functions.

The display research for these HMD projects can also lead to commercial applications, such as head-worn displays for wearable computers in medical and industrial markets. The technology also has application in ophthalmic screening and visualization products, and even a binocular 3-D autostereoscopic projection system for surgeons that requires no viewing aid whatsoever. Clearly, the future looks bright for scanned laser displays.■

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MICROJOIN, INC
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ACF Bonding System for FPD

The Model 6800 is a computer controlled ACF bonding system. It can perform TAB and chip-on glass assembly operations on flat panels of up to 40″ (1.02M). It is ideal for high mix, low volume assembly or rework environments. The system incorporates MicroJoin's Ceramic Hot Bar Technology™ providing highly repeatable part co-planarity and superior heat conduction. The 6800 features high precision hot bar z-axis actuator for pressure control, vision alignment system option for parts to 90 microns, multi-axis motion system, Windows NT-based operating system. The computer controls motion, vision, lighting, and logs process parameters for SPC analysis. The system is Class 100 clean room compatible.

Circle No. 1

MICROJOIN, INC
Poway, CA 858/877-2100

Polarizer Laminator for FPD

The Model 6300 is an all new workstation for application of polarizing film to flat panel displays diagonals of up to 21″ (533mm) with an aspect ratio of 4:5. The 6300 features five standard roller lengths for a variety of film sizes and vacuum hold-down for LCD panels. Lamination repeatability is +/- 0.3mm. Typical cycle times range from 39 to 66 seconds including load/unload. The system is Class 100 clean room compatible.

Circle No. 2

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4200 PDI for LCD Module Bonding, Testing

The 4200PDI provides two bonding and two testing positions for LCD module assembly. Using two bond heads with MicroJoin's Ceramic Hot Bar Technology,™ the 4200 can increase throughput by a factor of three times. While two modules are bonding, another two are tested then unloaded. Its computer controller and camera provide real-time viewing of LCD pixels for quick assessment of bond quality.

Circle No. 3

A Digital-Interface Standard for Displays

The DVI initiative is already changing CRTs for the better and is destined to promote the growth of flat-panel monitors.

by Marc McConnaughey

COMPUTERS are radically changing the way we work, play, and interact. Frequent improvements have been made to the performance and functionality of processors, networks, peripherals, and software. But aside from resolution increases, the video display – a computer's fundamental interface – has remained largely unchanged over the past 10 years. The time has come for a major update to the connection technology between computers and their displays.

Digital is replacing analog everywhere in our lives. Just as audio buffs hear their favorite tracks from digital CDs rather than analog vinyl LPs, home video systems today feature digital video disk (DVD) players rather than analog VHS tape machines. Even cellular phones are going digital. In the digital realm of computers and networks, the analog cathode-ray tube (CRT) remains a steadfast holdout. But this too is beginning to change.

The vast majority of computer video monitors today are connected using an analog video-graphics-array (VGA) interface, an aging technology that represents the minimum standard for a PC display. In fact, the VGA interface now represents an impediment to the adoption of new technologies such as the digital flat-panel liquid-crystal display, largely because of the added cost for these systems to support the analog interface. Another fundamental problem is the loss of image quality that occurs when a digital signal is converted to analog and then back to digital before driving an LCD with an analog connection.

Dislodging the analog VGA interface from the computing world is a daunting task; nearly 99% of all video displays sold in 1998 were based on analog CRT technology. Yet flat-panel displays (FPDs) are beginning to make significant inroads on the CRT's dominance because of lower price levels and their growing popularity. These modern space-saving monitors are even standard items in computer retail stores today. Unfortunately, without a standard in place for a digital interface, today's digital monitors must either employ the antiquated VGA connector or some sort of proprietary digital interface which requires its own video card.

Efforts to define and standardize a digital interface for video monitors, projectors, and display support systems began in earnest in 1996. But the process moved rather slowly in ensuing years, causing concern among manufacturers desperate for a standard. Finally, the Digital Display Working Group (DDWG) came together at the Intel Developer Forum in September 1998 with the intent to put the digital display-interface-standard effort back on the fast track.

With the ambitious goal of clearing the confusion of digital-interface-standards efforts

Fig. 1: *DVI uses a low-cost connector that can accept adapters for legacy systems.*

Marc McConnaughey *is the Vice President of Technology and Sourcing at ViewSonic Corp., 381 Brea Canyon Rd., Walnut, CA 91789; telephone 909/444-8712, fax 909/869-7958, email: mcconnaughey@viewsonic.com.*

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to date, the DDWG set out to develop a specification that could win broad acceptance. The Digital Video Interface (DVI) specification represents a turning point in the history of display technology. Essentially declaring that the days of analog are numbered for display interfaces, the DDWG's effort represents a comprehensive, well-defined, and highly suitable specification that describes a dual-edged deployment strategy. The first supports both analog and digital, while the second phase does away with analog support altogether. Based on existing standards work, the DDWG's DVI specification delivers a digital display interface that will serve an entire industry, and help bring the digital visual experience to the mass market.

Long Live VGA?

Developed in 1987 by IBM, the VGA interface was originally designed to support a resolution of 640 × 480 pixels and 16 colors. Shortly thereafter, VGA was improved, giving rise to super VGA (SVGA), which supports an 800 × 600-pixel screen resolution, and then XGA, which supports a 1024 × 768-pixel resolution. These modes were eventually standardized by the Video Electronics Standards Association (VESA), the primary standards body for computer display interfaces. Although VGA-based display adapters today support up to 32-bit color, and resolutions up to 2048 × 1536 pixels, the interface is still designed for an analog-only world.

A key problem with VGA is that the signal-output quality varies greatly between different display cards, an understandable result of the conflict between the inherent complexities in dealing with analog signals and the system maker's desire to make a profit.

Whenever analog video information is transmitted or stored, any inherent signal noise and distortion contributed by the system are additive: the effects of each are combined to cause a degradation of image quality. Systems that provide higher-quality images are likely to be more costly to develop. Another underlying problem with analog is that once the graphics information is corrupted, it's virtually impossible to remove anomalies in the image.

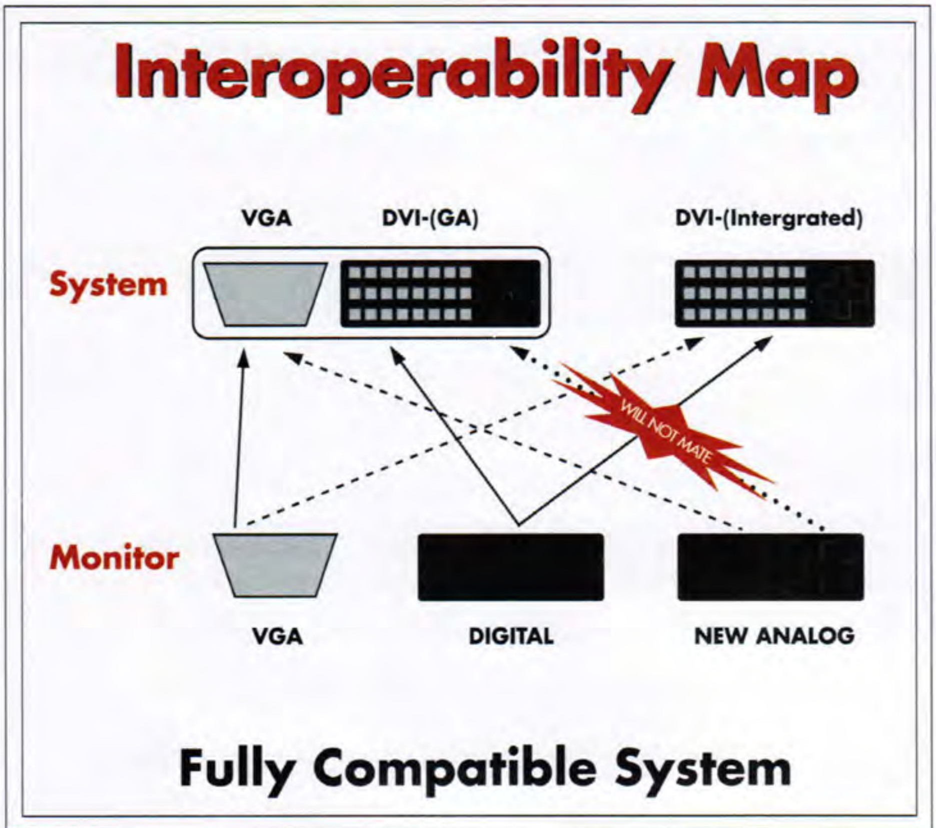

Fig. 2: The DVI connectors can handle either digital-only or digital-analog hybrid connections.

The Path to DVI

One of the earliest widely used digital display interfaces is low-voltage differential signaling (LVDS), a low-speed low-voltage protocol optimized for the ultra-short cable lengths and stingy power requirements of laptop PC systems.

Standardization efforts took a turn for the worse when a split occurred in early LVDS protocol development efforts between chip makers Texas Instruments and National Semiconductor. The two flavors of LVDS being promoted - National's FPD-Link and TI's Flat-Link - carried different signal levels and different formats for transmitting data. Fully incompatible with one another, the existence of two versions of LVDS represented a serious impediment to digital-interface-standards efforts at the time.

Digital display-interface technology took a decidedly different turn with the introduction of Silicon Image's PanelLink protocol: transition-minimized differential signaling (TMDS). This was designed to handle larger LCDs as well as serve remote LCDs connected *via* longer cables. Although TMDS provides the faster data rates required for higher resolutions and expanded color capability, it requires more power and therefore has garnered little support from within the portable-computing industry.

In the end, the PanelLink TMDS protocol earned more backing than LVDS. In time, VESA's Plug and Display (P&D) and Digital Flat Panel (DFP) committees both endorsed TMDS as the basis for a standard digital interface for video monitors, projectors, and display controllers on motherboards and video cards. For all intents and purposes, the digital-interface standard effort became stalled at this point, in large part because of the inevitable delays inherent in reaching agreement with a large group.

DVI Technology

The DVI specification defines a digital interface for use between a computing device and a display device. Its simple low-cost connector provides ample performance to allow system developers to add features appropriate to their specific applications (Fig. 1). The specification enables manufacturers to implement

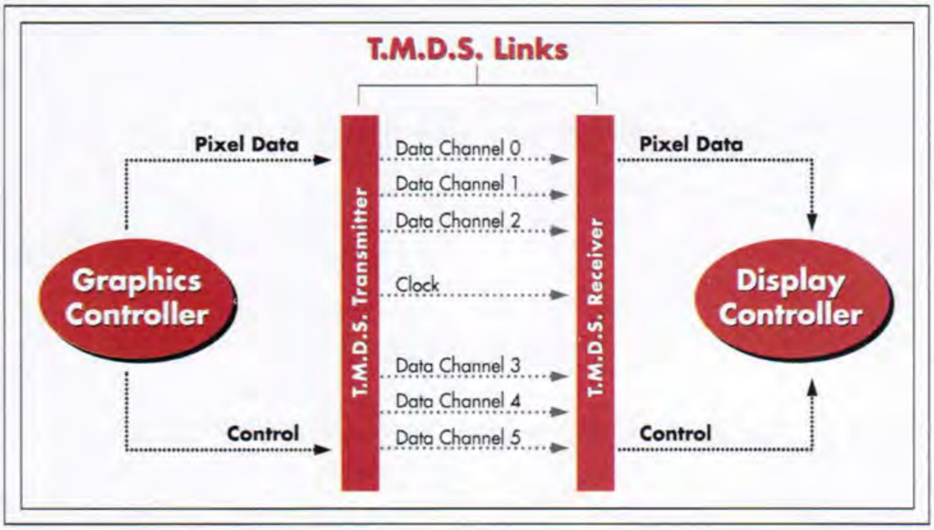

Fig. 3: The TMDS links each have separate channels for red, green, and blue data, and can share a clock channel.

either a complete transmission and interconnect solution or just a portion. The specification also supports transmission using alternative media types such as fiber-optic cable.

To address the wide range of requirements within the industry and to ease the transition to digital, the DDWG has defined two types of implementation. Two connectors with identical mechanical characteristics are specified; one is digital-only (DVI-V) and the other supports digital and analog signaling (DVI-I). Both connectors present system developers with the opportunity to eliminate legacy VGA connectors altogether (Fig. 2).

The comprehensive DVI specification defines the entire computer-to-monitor interface, including a detailed description of the TMDS protocol developed by Silicon Image, configuration of the TMDS links (up to two), plus connector mechanical specifications and signal-pin placement. The anticipated bandwidth requirements and pixel formats supported by DVI are also described. The specification also covers issues such as signal-quality characteristics for high data rates, power management, and plug-and-play. The specification is available for downloading at the DDWG Web site at http://www.ddwg.org.

TMDS Overview: Scalable Design

DVI uses transition-minimized differential signaling (TMDS) to send graphics data to the monitor. The term "transition minimized" refers to a reduction in the number of high-to-low and low-to-high swings on a signal. "Differential" describes the method of transmitting a signal using a pair of complementary signals. These features are important to providing robust, reliable, high-speed data transmission over a wide range of cable lengths and media types. Each TMDS link consists of three data channels and a clock reference.

Two TMDS links can be integrated into a single connector interface, according to the DVI specification, which provides ample bandwidth for large-format digital displays (Fig. 3). These two TMDS links share the same clock signal, so that when both are in use the bandwidth required to drive the monitor is divided between them evenly. Once the capability of the monitor is detected, the system automatically chooses whether to enable one or two of the TMDS links.

With only a single TMDS link operating, the interface is capable of transmitting data at rates up to 1.65 Gbits/sec (up to approximately 165 Mpixels/sec); in dual-link mode, the data-transfer capacity reaches 3.30 Gbits/sec (Fig. 4). DVI has the ability to handle any current or proposed digital LCD-monitor resolution with room to spare, from VGA (640 × 480 pixels) all the way up to HDTV (1920 × 1080) and QXGA (2048 × 1536).

The amount of bandwidth required for a specific display at a given resolution is technology dependent. For example, CRTs typically specify blanking intervals and time slots when display data must be transferred. This blanking period effectively increases the bandwidth required for the interface. It is anticipated that advances in display technology will reduce and eventually eliminate the blanking overhead requirement, maximizing the amount of bandwidth available over the interface to the display.

A single DVI TMDS link provides enough bandwidth to support resolutions greater than HDTV with the blanking interval reduced. In dual-link mode, DVI can provide the higher bandwidth demanded by displays that do not support reduced blanking, such as high-resolution digital CRTs.

The key difference between a digital CRT and a conventional analog CRT is that the signals received by the display are digital instead of analog, and digital-to-analog conversion must be carried out within the monitor. While the image quality is likely to be better, digital CRTs will require additional bandwidth overhead for horizontal and vertical retrace intervals. This is facilitated through the use of two TMDS links which can easily support digital CRTs compliant with VESA's Generalized Timing Formula (GTF) at resolutions exceeding 2.75 million pixels at an 85-Hz refresh rate.

DVI Connection System

A DVI-compliant host system can provide either a digital-only or combined analog-digital interface, and the host connector determines the system's capabilities. The connection receptacle on the system side has two choices for implementation. One is designated DVI-V and supports the digital portion of the interface only. The other, dubbed DVI-I, supports both digital and analog signaling and includes additional pins for the analog interface. Both have identical mechanical characteristics.

For DVI's two defined connectors, the digital signals are always present and the same physical outer dimensions are the same. In that way, monitors equipped with a digital interface can attach to either DVI-system connector. Since the digital-only system connector does not have analog pin sockets, the plug of a DVI-compliant analog monitor cannot be attached.

The digital-analog DVI-I connector is designed for applications with minimal port space or those with special performance requirements. DVI-I includes an analog interface that enables end users to use a DVI connector on the monitor side regardless of whether the display technology is LCD or CRT, or has an analog or digital interface. DVI-I does require an adapter dongle to work with VGA. While digital-only DVI-V can coexist side by side with standard VGA to support legacy display systems, both types of DVI connectors offer system developers an opportunity to eliminate the legacy VGA connector altogether.

Target applications for DVI-I include conventional desktop PCs that may require the use of legacy VGA displays. On the other hand, the digital-only DVI-V connector will not drive an analog VGA display without a D/A converter. Therefore, target uses for DVI-V are digital input displays.

The mechanical connector for the DVI interface includes definitions for 29 physical signal connections in the DVI-I configuration. These are divided into two sections. The first section is made up of three rows of eight contacts comprising 18 TMDS signaling pins plus shielding, and five pins dedicated for plug-and-play interoperability. The second section includes six pins designed specifically for analog support: red, green, blue, horizontal and vertical sync, and ground.

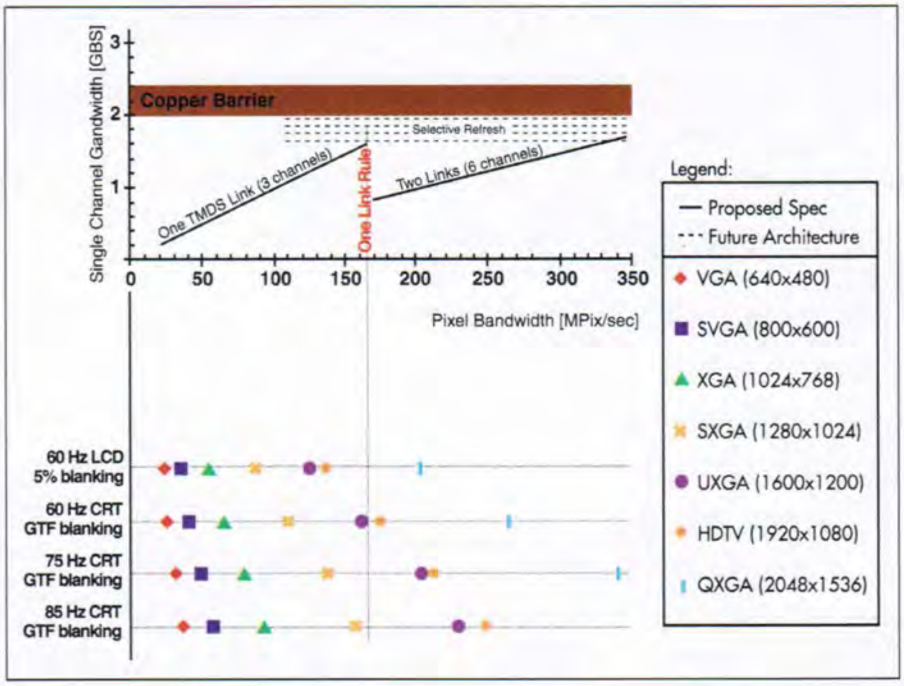

Fig. 4: The road map for single- and dual-link DVI connections provides adequate bandwidth for current and future display resolutions.

DVI Advantages

The digital interface has several inherent benefits over the standard VGA connector. First, a digital interface for an FPD ensures that all content is transferred in a digital format from creation to consumption, meaning that data integrity is maintained during transmission from host to monitor at the highest possible level. By using a digital interface rather than an analog VGA, the average end user will, in general, see images that are sharper and crisper overall, whether the display technology employed is CRT or FPD.

Another key benefit of a DVI-based display is that it improves the user's overall visual computing experience. DVI enables manufacturers to add many low-cost features and advanced capabilities, including gamma correction, video in and out, and picture-in-picture. Also, digitally driven CRTs and FPDs require fewer adjustments, resulting in easier operation - an integral component to the Intel/Microsoft-led Easy PC initiative. Another side effect of DVI is that some of the host system's processing requirements are offloaded, enhancing overall PC performance.

The DVI specification also comes at a critical juncture for the FPD industry - precisely at a point when the market is starting to really heat up. The DVI interface has the potential to lower prices for finished products because it simplifies the overall interface, which can lower the cost of components, system development, manufacturing, and testing. The DVI specification is destined to promote growth in the FPD industry. It also increases the system developers' control over real-world interoperability, which should serve to minimize product returns and technical support costs.

Why Digital CRTs?

In addition to DVI's obvious application for digital displays, it is also the death knell for analog VGA interfaces. Incorporating DVI in a traditional analog CRT monitor enables manufacturers to gain added control over image quality, making differentiation based on image quality much more of a factor than it is today.

A digital interface means that the CRT-monitor manufacturer maintains control over the digital-to-analog conversion process, and can choose the quality of components used to perform this task. The digital connection also eliminates the loss of data associated with sending analog signals across a cable.

Responding to these advantages, we at ViewSonic are committed to the DVI standard, and enthusiastically support efforts to promote and implement DVI. ViewSonic is the first company to introduce digital CRT displays based on the DVI specification, and the company's OptiSync™ technology will allow users to optimize their display image using either analog, digital, or standard video inputs. The first two products are flat-faced 17- and 19-in. models with both analog and digital interfaces, expected to ship in production quantities at the start of the year 2000. While these initial products will carry a price premium of about 15%, digital CRTs are expected to reach price parity with analog models before long.

Whether one's display is based on analog or digital principles, it is becoming apparent that digital connections are poised to change the way we look at our computers.■

AMLCD Markets Diversify

As the demand for AMLCDs grows and broadens, the roller coaster of AMLCD supply and demand may get gentler - but the cyclical patterns will continue.

by Joseph A. Castellano

THE WORLDWIDE MARKET for active-matrix liquid-crystal displays (AMLCDs) continues to grow rapidly as prices fall and production capacity increases. This article will forecast unit consumption and the value of shipments in the major application segments. These display-market forecasts are based on long-term equipment-production forecasts, the consequent demand for AMLCDs resulting from this anticipated equipment production, and technology trends. This information was obtained mainly from primary research that analyzes both the supply and demand for electronic displays and rationalizes the results.

The total world market for AMLCDs will grow to over $23.7 billion (152.8 million units) in 2005 from $11.3 billion (56.4 million units) in 1999. Computer and consumer products represent the first and second largest market segments throughout this forecast period. The computer segment accounts for $8.6 billion (76%) in 1999, growing to $19.4 billion in 2005. The consumer category will grow from $1.3 billion in 1999 to $1.8 billion in 2005.

Joseph A. Castellano is the founder, president, and CEO of Stanford Resources, the oldest market and technology research firm specializing in the display industry, located at 20 Great Oaks Blvd., Ste. 200, San Jose, CA 95119-1309; telephone 408/360-8400, fax 408/360-8410, e-mail: sales@stanford-resources.com. The market information in this paper was taken from Liquid Crystal Displays – 1999, *an annual multi-client report published by Stanford Resources, and* Global LCD Supply/Demand Quarterly, *published jointly by Stanford Resources and Techno Systems Research, Japan.*

Where Will They Go?

All application categories are growing rapidly (Fig. 1). The business category, led by presentation projectors and gaming machines, will grow to $1.1 billion in 2005 from $677 million in 1999. The market for AMLCDs in transportation equipment, mainly automotive displays, will reach nearly $1 billion in 2005 from $585 million in 1999. Other categories include industrial equipment, which will reach $235 million, and communications equipment, which will grow to $112 million, both in 2005.

Desktop monitors with AMLCDs will show a unit compound annual growth rate (CAGR) of 45% throughout the forecast period, with a major shift toward larger screen sizes for monitors. This category will grow to 32.5 million units in 2005 from 3.5 million units in 1999 despite continued competition from low-priced CRT monitors. But with this unit growth will come a decline in prices for AMLCD color monitors. Consequently, the value of AMLCD-monitor shipments will reach $11.9 billion in 2005 from $2.3 billion in 1999, a CAGR of 31%. The dominant

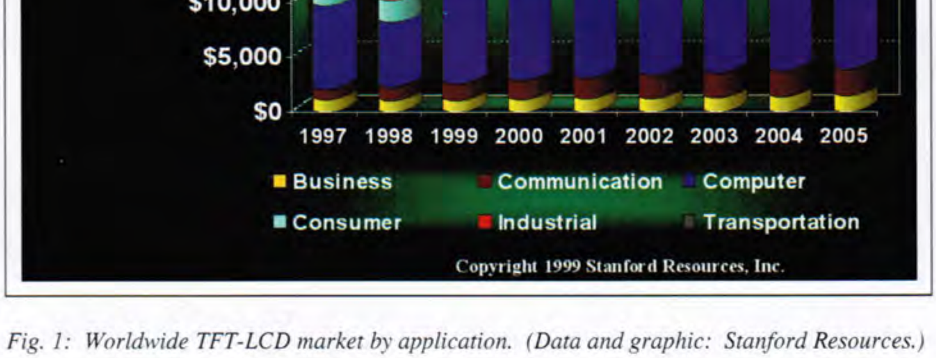

Fig. 1: Worldwide TFT-LCD market by application. (Data and graphic: Stanford Resources.)

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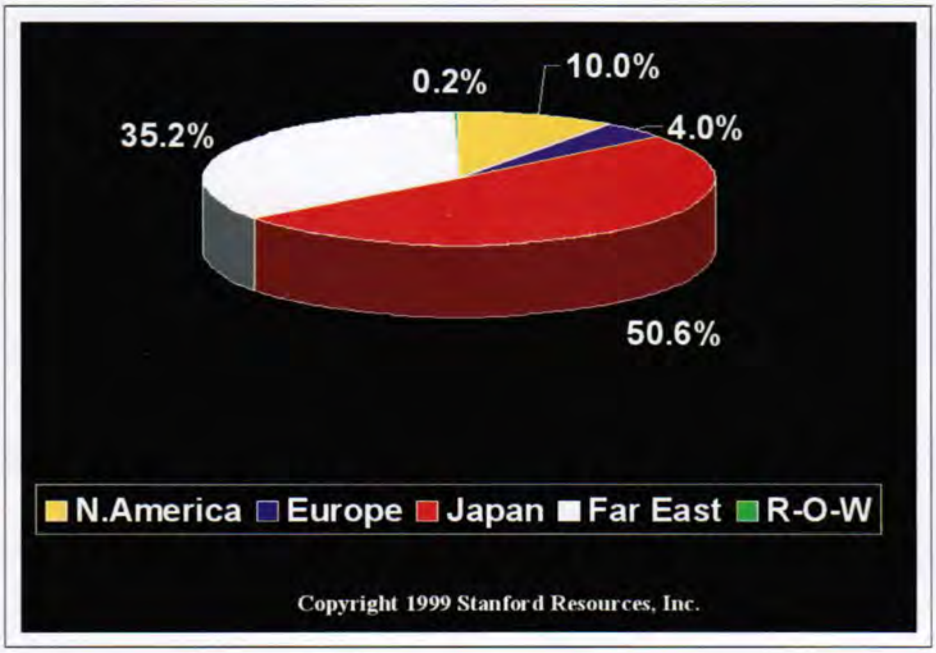

Fig. 2: Worldwide TFT-LCD market by region, in percent, 1999. (Data and graphic: Stanford Resources.)

product in the desktop-color-monitor market for AMLCDs will be the 15.x-in. panel with 1024 × 768 pixels, which will hold 82% of the market. Panels with a diagonal screen size of 18.x in. and 1024 × 768 pixels will be second, with a 7% share.

Portable computers will continue to be a major application segment for AMLCDs, with growth to 25.6 million units in 2005 from 14.8 million in 1999. But declining prices will limit dollar growth to just $7 billion in 2005 from $6.2 billion in 1999.

In other segments, AMLCDs will continue to be used for consumer-electronics products, such as camcorder viewfinders, digital cameras, CD viewers, small-screen color televisions, and hand-held games. For all of these consumer products combined, the world market will grow to 62.5 million units valued at $1.85 billion in 2005 from 32 million units valued at $1.3 billion in 1999.

Regional Markets

Over the forecast period (1999 through 2005), Japan will have the largest unit consumption of AMLCDs of any region. The Far East and North America will hold the second and third spots in terms of units through 2005. However, in terms of revenue, the Far East, with an $11.5 billion market, will surpass Japan's $8.9 billion market in 2005. North America will be third at $1.9 billion, and Europe fourth at $1.3 billion (Fig. 2). These regional-consumption values reflect the fact that products that use AMLCDs are made primarily in Japan and the Far East. If one looks at the market for the finished products, North America and Europe would be the first and second largest market regions.

Performance Trends

Although active-matrix addressing schemes have advanced considerably over the past few years, display quality is still limited by the viewing angle. As the viewing angle becomes more oblique, contrast is reduced, making it difficult to distinguish the ON-state from the OFF-state.

One method for improving the viewing angle and reducing the reverse-image problem at severe angles is the multi-domain process. This involves dividing each pixel into parts, with one part using a high pre-tilt of the liquid-crystal-molecules surface layer and the other using a low pre-tilt. Other variations use two different rub directions, but still maintain a low pre-tilt. Still others might use four domains. Fujitsu has developed a process to form protrusions on the alignment layer to align the liquid-crystal molecules vertically, resulting in a claimed viewing angle of 160° horizontally and vertically. All of these approaches are effective in improving the viewing angle, but at the expense of increased manufacturing cost because additional processing and masking steps are needed.

Perhaps the most effective method to date for improving the viewing angle is the in-plane-switching (IPS) mode. This mode uses a structure with both electrodes on the same substrate (sometimes called interdigitated electrodes), in contrast to the conventional LCD, which has electrodes on opposing substrates. The use of interdigitated electrodes in LCDs was first demonstrated by the author and R. N. Friel in 1970, and the method was first applied to TFT-LCDs by researchers at Hitachi and by G. R. Baur at the Fraunhofer Institute for Applied Solid State Physics.

Hitachi quickly developed the technique into a manufacturing process, and in 1996 the company entered the market with LCD panels that were dubbed "Super TFT-LCDs." These displays provide a much wider viewing angle than conventional TFT-LCDs. The only disadvantage is a slower response time and a somewhat higher current consumption. But the displays now on the market appear to have an adequate response for most applications and are certainly superior to STN-LCDs.

The general trend in notebook computers has been to steadily increase the number of pixels on the display. In 1995, the majority of computers used a VGA (640 × 480) pixel format; by the end of 1996 the majority had shifted to an SVGA (800 × 600) format, which dominated the notebook-computer market throughout 1997 and 1998. While notebook computers with 12.1-in. color TFT-LCDs in XGA (1024 × 768) format were introduced in early 1996, they were not well accepted because of high prices. Both 13.3- and 14.1-in. TFT-LCD panels with XGA formats were introduced in the second half of 1997. While they fared better than the 12.1-in. XGA models, less than 20% of portable computers had an XGA pixel format by the end of 1997. The notebook-computer market shifted mostly to XGA format by the end of 1998 because of a shift to larger panels (13.3 and 14.1 in.). The XGA format will dominate the notebook-computer market for the near future (Fig. 3).

AMLCD computer-screen sizes have steadily increased over the past several years. In 1996, notebook computers with a 10.4-in.

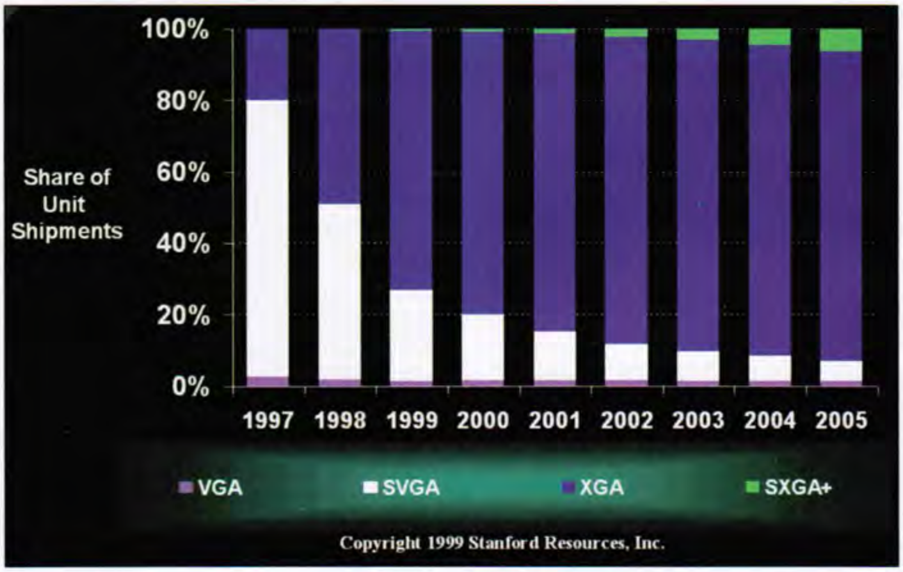

Fig. 3: Worldwide market for TFT-LCDs in notebook computers, share of unit shipments by pixel format. (Data and graphic: Stanford Resources.)

display dominated in the U.S. market during the first half, and 11.3-in. displays dominated in the second half. By 1997, the majority of notebook computers used 12.1-in. displays, and many vendors introduced products using 13.3-in. TFT-LCD panels. Some notebook-computer suppliers introduced products with 14.1-in. TFT-LCD panels, but 12.1-in. panels still remained dominant in the notebook-computer market in 1998.

More notebook-computer suppliers are expected to introduce 15-in. TFT-LCD notebook computers in the future, although there will be limited interest in this size until the end of 1999. All of these sizes (12, 13, 14, and 15 in.) will coexist throughout 1999, but 13-in. displays will dominate. Even though some notebook-computer suppliers are quickly shifting to 14.1-in. TFT-LCD models, the top suppliers have focused on 13.3-in. TFT-LCD models. The 14-in. TFT-LCD models will gain more market share in the second half of 1999 and will achieve a dominant position in 2000. The 14-in. display will have a dominant share through 2005, although 15-in. displays will increase rapidly.

Supply and Demand

Supply-and-demand issues are now central to the AMLCD industry, placing AMLCDs in the same category as DRAM, hard-disk drives, cathode-ray tubes, CRT monitors, and many other high-volume (commodity) components. In the early 1990s, the intense focus on manufacturing costs was a necessary part of the debate on the very viability of the device. The cost of producing color-graphics LCDs was rightly blamed as the major source of the high price of these advanced flat-panel displays.

Now, with LCDs recognized as commodity products, pricing is more closely tied to the balance between supply and demand than it is to manufacturing costs. This relationship was demonstrated in mid-1996, as prices for some models actually rose (quite rare in the electronics industry), and the larger TFT-LCD panels stabilized in price. This trend was caused by the increased demand for 11.3- and 12.1-in.-diagonal panels. But by the end of 1997, the industry supply exceeded demand and prices plummeted. The prices for 12.1-in. TFT-LCDs from the fourth quarter of 1997 to the first quarter of 1998, for example, dropped 25%.

In 1999, a combination of increased demand (in response to falling prices) and lack of manufacturing capacity for larger panels used for desktop monitors led to a reversal of the cycle. Prices for popular sizes of TFT-LCD panels rose 30% during the first three quarters of 1999. Expansion of capacity in Korea and Japan, along with the opening of new factories in Taiwan, have occurred in response to the higher prices and supply shortages. This expansion of capacity, together with the effect of higher panel prices, is likely to cause yet another reversal in the supply-demand balance in the year 2000. Other cycles are certain to develop in the future as new factories come on line and other product categories develop in the computer, consumer, and industrial markets.■

laser cutting technology update

P.T.G.
Precision Technology Group

by Precision Technology Group

A few years ago PTG introduced a method of laser cutting of glass using branded 0WCT® (Zero Width Cutting Technology). It is protected by the Fonon UK patent - 5609284 on the ***method*** of controlled propagation of a Micro-Crack™ known as "blind crack" through the subsurface layer of the glass.

PTG in the past has sold several licenses to use the patent to a number of companies in order to capitalize on the licenses and royalties.

Most licensees who have attempted to implement the "Full Body Cut" have gone back to the historical beginning of laser glass cutting - **uncontrolled thermal fracturing,** announced more then 30 years ago by the Pilkington Brothers and further developed by R. Lumley (more than 50 patents were issued at that time). Technical evolution rejected this approach and marked the "uncontrolled propagation" of a thermal crack at a supersonic speed as a "dead-end" technology. They did not have a clear understanding of the ***method*** and its capabilities. Also, without investing into the mathematical and scientific support, they did not achieve sales results that were satisfactory to the patent owner.

PTG set up its own manufacturing and R&D, conducted thousands of tests and filed more than 20 additional patents applying the basic ***method*** to the industry.

The figure illustrates Fonon's ***method*** of controlling the propagation of a Micro-Crack™ where $\boldsymbol{\delta}$ is the depth of the crack, known as a "blind crack," υ is the relative displacement speed of the laser beam, **P** is the power density and **t** is the glass substrate thickness. From the equation $\delta = fk(\mathbf{P}/\upsilon)$, δ is a function of $\mathbf{P}/\upsilon$. This means that as the laser power increases the depth of the Micro-Crack™ increases. In comparison, decreasing the speed also increases the depth of the Micro-Crack™. A "Full Body Cut" is achieved when $\boldsymbol{\delta} > \mathbf{t}$. Unfortunately, due to the physical properties of glass such as energy absorption, thermal conductivity, Young's Modulus, and the melting point, $\boldsymbol{\delta}$ is limited typically to 0.4-0.7 mm. Further decrease of υ converts the process into conventional thermal breaking.

We have concentrated 0WCT® research to perfect the ***method*** of increasing the depth of the Micro-Crack™ without loosing the speed and accuracy.

The good news is that glass for FPD is moving towards 0.4-0.5 mm where the ability of Zero Width Cutting Technology® and FPD technology requirements converge.

At Display Works 2000 in San Jose, PTG is presenting the new generation of laser cutting systems for FPD.

FPD Laser Cutting Machine

FPD Laser Chamfering Machine

Large Format FPD Laser Cutting Machine

New Process Capabilities - with 200W laser it scribes 1.1 mm Corning 1737 at a speed higher then 1 m/sec.
- separates without cooling 0.5 mm thick Corning 1737 at a speed of 250 mm/sec (application sensitive)

Laser Cut Initiation Tool™ - (patent pending) - eliminates particle debris

Carbon Dioxide Chill Jet - (patent pending) or CO_2J is a major advance in thermal stress generation for critical applications

Micro-Compensator™ - adds the capability to operate with an accuracy and repeatability of +/- 5.0 microns

Planar Linear Stepper - maintenance free and clean room compatible motion platform

Titanium Vacuum Holder - no contact surface vacuum table

New Structural Design - smaller footprint for the same substrate size

Setting Up the Industrial Standards

Our goal is to set the industrial standards for laser cutting in the FPD industry.

We invite everyone interested in Laser Glass Cutting to participate in the FPD Forum at **www.ptg.nu/fpd/**. Your input is welcome and needed.

For more information contact us at
www.ptgindustries.com
Phone: 407-804-1000 or
Fax: 407-804-1002
Email: ptgusa@ptgindustries.com

Circle no. 14

EuroDisplay in Berlin

A week of unseasonable warmth and sunshine - during which the German parliament began its first regular session in Berlin since World War II - provided an historic framework for EuroDisplay '99.

by Ken Werner

THE 19th International Display Research Conference - EuroDisplay '99 - was held in Berlin, September 6-9, 1999. The conference was a numerical success. There were 402 pre-registered participants, plus an agreeably surprising 154 on-site registrants, said Dr. Dietmar Theis of Siemens Munich, Chair of the Society for Information Display (SID) Mid-Europe Chapter, which organized the event with the support of the Verband der Elektrotechnik Elektronik Informationstechnik (VDE).

Although the conference had some specific European content, and the Berlin location helped draw 125 registrants from Germany, EuroDisplay was very much an international event, with 126 registrants from Japan (one more than from Germany!), 73 from the U.S., 37 from the U.K., and 36 from Korea, with most of the remainder from other European countries. The Monday workshop associated with EuroDisplay drew 320 registrants, Theis said.

There were 14 exhibitors, most of whom said they were pleased at the response they received and the number of contacts they made. One commented that he thought more exhibitors would have come if exhibition information had been distributed earlier.

EuroDisplay Workshop

The well-attended workshop on Monday, September 6, consisted of eight hour-long invited papers. The first was a tutorial by Gunter Haas (Robert Bosch GmbH) entitled "Angular Dependency of Liquid Crystal Displays," which analyzed the comparative viewing-angle dependence of different LCD modes, along with symmetry, gray-scale inversion, and the use of discotic films for improving viewing angle.

Among Haas's comments were:

- The Pi cell is inherently symmetrical, but stabilizing the structure is a problem, so it has not found any practical application.
- Two-part discotic films are widely used in TN displays for PDA and automotive applications and small 6-in. LC monitors. They're not perfect but they greatly

Ken Werner

Agfa-Gevaert used the exhibition to show that its new Orgacon film with organic conductor (intended to replace ITO) is flexible. This curvaceous EL lamp was one of several demonstrators.

Ken Werner is editor of Information Display Magazine.

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Ken Werner

EuroDisplay '99 was held in the strikingly modern Hotel Maritim ProArte located in what was formerly East Berlin. The hotel's decor centered on original works of contemporary German art.

improve both viewing angle and gray-level inversion.

- The VAC mode in Fujitsu's award-winning panels is the same as the ECB mode.

Yoichi Taira's (IBM Research, Japan) talk, "Reflective Color LCDs," encapsulated a variety of points concerning reflective design. The increasing interest in stacked systems stimulated Taira to comment that vertical wiring is a critical enabler for such systems.

In "Projection Television," Robert L. Melcher (IBM Research) commented that the annual world market for TV sets is 120 million units and $60 billion, both growing slowly. The average price per set is $500, but the average is lower than that in North America, higher in Japan. Projection TV (PTV) sales were 1.2 million units in 1998. Said Melcher, "I want to convince you that projection TV is much more important than these figures imply." Melcher commented that data projection may be the "killer ap." Sony and Matsushita regard PTV as a major priority.

The greatest problem with projection CRTs today is the trade-off between light output and resolution. "Punch" can be high but average luminance is somewhat limited. If we go to data applications with black characters on a white background, luminance will be even more important.

But there are two interesting competitors for CRTs: transmissive polysilicon light valves and reflective microdisplays. Initially, the light efficiency of polysilicon LCDs doesn't look very good, but microlenses are now being used to improve efficiency by directing input light to transparent area. The efficiency can be improved by as much as 60%, which is significant for small pixels.

The potential for low cost in liquid-crystal-on-silicon (LCOS) microdisplays has not yet been realized, but the potential is there because one can reduce pixel size *almost* arbitrarily, thus reducing silicon real estate.

In a "remarkable design," Sanyo has made a 50-in.-diagonal rear-projection (RP) microdisplay set that is only 12 in. deep by using a multiple folded optical path utilizing reflective optics.

Some of Melcher's projections for PTV are:

- Commercial light-valve (LV) PTVs will be introduced in 2000 in low volume for about $7000.
- In 2001, prices will decline and sales will begin to take off.
- In 2002, LV PTVs will take 30% of the market, with prices around $4000.
- In 2003, LV and CRT RPs will compete with each other directly.

Paul Bonnett (Sharp Labs of Europe) gave an extensive presentation analyzing the possibilities of "Large Light-Modulating Flat Displays." He concluded that STN offers little in the way of cost benefit in large displays, that the manufacturing cost of plasma-addressed liquid-crystal (PALC) displays *versus* plasma-display panels (PDPs) is a critical issue, that TFT-LCDs will have a large market share for applications up to about 30 in., and that tiled panels are ideal for public-information displays above 60 in.

During the question and answer session, Plasmaco's Larry Weber challenged Bonnett's assertion that PALC image quality is better than that of PDP. "The last time I saw them side by side," said Weber, "was at the SID Display Technology Showcase, and in a subdued ambient the PALC contrast was not as good and was uneven." Bonnett said, "PALC contrast ratio is better in bright ambient." Weber agreed, but commented subsequently that people seem to enjoy watching TV in a subdued ambient.

In "Trends in CRTs," new SID Fellow Makoto Maeda (Sony) took a careful look at the future and benefits of CRTs, the benefits being low cost, high luminance, and long life. One of the major CRT trends today is the move to flat-faced tubes. Maeda compared the flat-CRT approaches of several companies in detail, commenting that Matsushita's Pure Flat tube, with the shadow mask mounted on a pre-compressed frame, has a simple structure but a difficult manufacturing process. "I don't know how they continue to make these tubes," he said.

Sony's flat-faced FD Trinitrons use face-plate glass that is fabricated so that the outside is in compression and the inner sixth of the thickness is in tension. This tempering process produces very strong glass. Sony has introduced many FD models into the marketplace over last 6 months, said Maeda, and in the next year, almost all tubes from Sony will be flat-faced.

Maeda concluded that "CRT growth is not affected by flat-panel growth." The CRT growth rate is predicted to be 3% through 2004, which is consistent with the past performance of 3-5% a year. The future holds a

Ken Werner

In the exhibits, Luxell showed a prototype three-color OLED featuring the company's contrast-enhancing "black layer."

Ken Werner

The organizers coped with 35 late-news papers by presenting them as part of the poster session. This resulted in intimate technical communication and a very warm room with an overtaxed ventilating system. Shirt sleeves were the uniform of the day, as adopted by CRL's Alan Mosley (facing camera).

greater penetration of larger screen sizes (up to 36 in.) and flat faces, and "the digital-television era will stimulate improved pictures."

Richard H. Friend (Cambridge Display Technology) summarized OLED technology in "Organic Electroluminescent Displays." He observed that molecular semiconductors can be deposited by sublimation. Friend himself is working on conjugated polymers, which can be deposited from solution. The rapid development of OLEDs is particularly impressive, he said. Their efficiencies are nearly as good as AlInGaP inorganics after a much shorter period of development.

Color gamut has been a problem for polymer phosphors, but polymers developed in the last year provide primaries close to those specified on the PAL CIE diagram. Lifetime is also looking good from accelerated life data, and efficiency is looking good, but more science needs to be done to ascertain theoretical maximums, Friend said. There is interest in active-matrix driving for high-resolution displays for the usual reasons. Polysilicon has good characteristics for OLEDs, and if one has a poly process, device processing should be easier than for passive displays.

The difficulty in obtaining full-color displays is not the colors themselves but in patterning the display to get them because traditional chemical processes will remove the organic phosphor. The quarter-VGA 5-in. display demonstrated by Pioneer earlier this year at the SID International Symposium, Seminar & Exhibition was done by performing vacuum deposition through shadow masks. It worked, but it could be an expensive process. Idemitsu-Kosan is getting around this with color-converting filters, but complexity and lower efficiency are problems. TDK has done color-by-white.

Cambridge Display Technology and Seiko-Epson are converting a standard ink-jet printer to squirt organic phosphors on a substrate, and Friend showed a photograph of 30-μm-diameter pixels. Getting registration accuracy on a prepared substrate is a challenge, but it's possible to pre-pattern the surface free energies to ensure that a drop missing the bulls-eye will be drawn to the right place.

There have been lots of great developments in OLEDs, Friend said, but much work needs to be done to develop manufacturable structures. However, two sources of commercial products exist today: Pioneer Tohoku and Philips.

Keynote and Invited Addresses

EuroDisplay's technical sessions began on Tuesday, September 7, the day that the German parliament celebrated the 50th anniversary of post-war democratic government in Germany by opening its first regular session in Berlin. Reports of improvements in the German and EU economies and the first reduction in unemployment in years added to a generally optimistic mood - a mood that was shared by the keynote speakers.

In the first keynote address, "Development of LC Materials for New LCDs," B. S. Scheuble and T. Geelhaar (Merck, Darmstadt) began by saying that none in the business would complain about the overall growth of the LCD industry (a continuing CAGR of 13%).

Notebook-display trends, such as growing TFT percentage, shrinking STN percentage, video response, larger sizes (the mix is moving toward 14 in.) with lower cost, increased resolution (XGA is just about standard, a con-

Ken Wern

In the Poster/Late-News session, the Electronics Research & Service Organization (ERSO) of Taiwan's Industrial Technology Research Institute (ITRI) showed this reflective display with 42% reflectivity and a contrast ratio of 30:1. A reflectivity of 60% has been obtained in the lab said I-Wei Wu, ERSO's Deputy General Director. The display was visible even in the room's somewhat dark ambient, and looked impressive under a spotlight.

tinuing move to higher resolutions that favors polysilicon), and lower power consumption, are leading to the need for materials changes, including new materials with lower viscosity.

For monitors, film-compensated displays are down to 65% of the market from 80%, and IPS and VA are up to about 18% each from 12% and 8%, respectively. Film-compensated displays have viewing angles of 140°/110° and a response time of 35 msec. Newer solutions can improve the response time modestly to 25 msec. Faster response will require a new LC material with low rotational viscosity, which is being developed.

Scheuble predicted substantial growth in TFT-LCD TV, with the mix going from 125 million CRT TVs, 0.5 million TFT TVs, and 0.1 million PDP TVs in 1998 to 180 million CRT TVs, 3.5 million TFT TVs, and 2.0 million PDP TVs in 2005.

In many applications, there is a clear direction toward polysilicon, and for these applications we need materials with high optical anisotropy for improved reliability and fast response time. Merck will try to develop new materials to enable monitor, TV, and portable applications.

Ken Werner

Jóse Oton (Polytechnic University of Madrid) discussed his poster paper on the EC-funded MINDIS antiferroelectric gray-scale microdisplay.

In answer to a question from Shunsuke Kobayashi, Scheuble said that Merck has ceased development of ferroelectric LC materials because they determined that FLC would not attain substantial market share.

In "Trends in TFTs," K. Kanzaki (Toshiba Corp.) noted the structural changes in the TFT-LCD market. The monitor market is growing this year and will become an increasing percentage of the total market in the future - ultimately matching the size of the notebook-PC market.

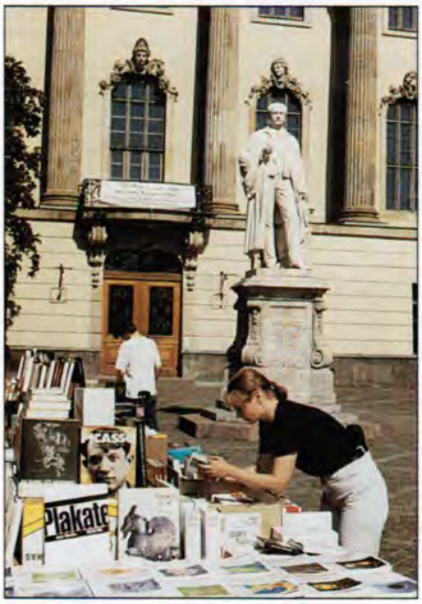
In 1996, Japan had more than 90% of the TFT market. Now Korea has 30% and Taiwan will be ramping up strongly. In the 21st century, Japan's share will be about 50%, with the remainder being divided by Korea and Taiwan. Taiwan's emergence will double world capacity by 2002, Kanzaki said, but system growth should more than absorb that capacity. Prices will decline moderately from this year's level.

Kanzaki enunciated Toshiba's case for its aggressive development of low-temperature-polysilicon (LTP) TFTs. Among the considerations is that the maximum TAB pitch of a-Si TFT displays is about 130 ppi while polysilicon has no limit on TAB pitch. At the moment, Kanzaki said, only Toshiba is making commercially available large-sized LTP panels.

One of the great attractions of LTP is the ability to do circuit integration on glass. Current technology has the CMOS driver circuit (without DAC) integrated on glass. The next step is to put the DAC on the glass as well. The eventual goal is to make a "sheet computer," with everything integrated on the glass. Sheet computers should be a reality in about 10 years, with sheet mobile devices coming earlier. Toshiba's road map includes having a 32-bit CPU on glass by 2010.

In the question and answer session, Shunsuke Kobayashi asked how fast a computer on glass can be. Kanzaki said there will be some speed deficit compared to CMOS, but there will still be many applications.

In his survey of PALC technology, Tom Buzak (Technical Visions, Inc.) observed that charge localization allows one to produce HDTV with a VGA PALC structure because it's possible to double the 480 lines of the structure to an effective 960. All large-screen technologies are changing from an emphasis on improving performance to an emphasis on reducing cost, he said.



Ken Werner

A few blocks from the convention hotel, booksellers' tables and a statue of Helmholtz shared the courtyard of Humboldt University, where Einstein once taught.

In the first invited address, "Photo-Aligned Liquid-Crystal Displays and LC-Polymer Optical Films," Martin Schadt (ROLIC Research Ltd.) outlined the benefits of replacing rubbing by photoalignment using patterned linearly polarized light. Since the process is three dimensional, one can generate bias tilt angle in the same step that establishes alignment. It is relatively straightforward to create multidomain displays using this approach.

One can photo-pattern LPP/LCP layers on a single substrate, and use the same technology to make a two-color, yellow and blue, filter from two layers of retarder film. These optical retarders can be used to make a variety of optical elements, all by the same process. RGB can be generated from five stacks for a color display without an absorbing color-matrix filter. A prototype of such a display was finished just prior to the conference. If films are made thin to avoid parallax, one can make a plastic LCD with integral color.

In "Polymers for Light-Emitting Diodes," Hermann Schenk and his colleagues (Covion Organic Semiconductors) commented on the very rapid development of polymer light-emitting diodes (PLEDs). Current efficiencies are in the vicinity of 16 lm/W. Efficiency increases with cleanliness, and while current cleanliness is high by a chemist's standards, it is not so high by a physicist's semiconductor-based standards. Lifetime depends on minimizing defects in a physicist's sense, but these are defects in polymer chains (which are not chemical defects). Performance in general is increasing rapidly, and much more is to come.

Technical Sessions

There were 165 technical papers delivered at EuroDisplay. Here is a brief sampling.

C. T. H. Liedenbaum and his colleagues (Philips Research) presented a paper, "Polymer LED-Matrix Displays," on driving-system considerations for polymer LEDs. Power issues are important as one goes to larger matrix displays. There are a variety of methods for improving the situation, but the way to go for larger displays is active matrix, the authors said. The question is, at what size does one need to go to active matrix?

Seyno Sluyterman (Philips Components) discussed the various approaches for implementing flat-faced CRT displays, using the major commercial implementations as examples. The design process is a trade-off between mask curvature (flat, singly curved, or doubly curved), optical appearance (flatness and position of the image plane within the glass), screen pitch (and whether fixed or graded), and mask rigidity (with implications for doming, microphony, and drop tests).

Philips' design adopts a faceplate that is flat externally and nearly flat internally; a shadow mask slightly curved horizontally, quite curved vertically; and gun-pitch modulation, which reduces the gun pitch as a function of vertical deflection. The result, said Sluyterman, is a flat image impression, low weight (no heavy frame), and good convergence.

Joe Castellano (Stanford Resources) surveyed the market opportunities for active-matrix LCDs. Here are some excerpts:

- The largest TFT suppliers are Sharp (15% of the market), NEC, Samsung, Toshiba, IBM, and Philips-LGE (10%).
- 72% of notebooks will have XGA in 1999, 86% in 2005.
- Demand will exceed capacity through 1999, but oversupply will be seen in Q2 or Q3 '00.
- There will be 3 million LCD monitors sold in 1999, 31 million in 2005.
- The LCD market in 1999 is $15.1 billion.
- 28% of notebook screens will be 14 in. in 1999, 58% in 2005.

In the very well attended talk "Future Prospects for Manufacturing LCDs," Shinji Morozumi (Hosiden and Philips Display Corp.) said that the market for TFT-LCDs will be increasing through 2008 and selling prices will come down to about $350.

But the industry has several problems, one of which is that annual turnover is smaller than capital investment. To solve this, the industry must reduce its capital investment by 50% – half with equipment price cuts and half with productivity improvements.

A second problem is that variable costs (materials and components) are too high with respect to fixed costs, and these variable costs must be reduced to one-third their current value.

Among many approaches to process optimization, Morozumi mentioned using in-line architecture to minimize energy consumption. He also observed that AMLCD manufacturing is moving to Generation 4 for four-up manufacture of 20-in. displays.

In "Mass Production of AMLCDs," Bob Wisnieff (IBM) observed that many people project that the processor will be incorporated in the display, which makes the AMLCD a key component. He then presented an historical sketch of the various generations of LCD factories and their characteristics, starting with the wafer-based "Generation Zero" factories of the 1980s that used prototype tools to fabricate pocket-TV displays.

The price per area of AMLCDs has gone from $30/sq. in. in the early '90s to $4 today. It must go lower if AMLCDs are to compete with a "Coke bottle filled with air." Wisnieff agreed with Morozumi that we must use fewer materials and reduce capital cost per part. The straight-ahead approach of driving costs down further by doing what we're doing in a larger fab is not good enough. Among other things, polysilicon is needed. But larger fabs will be part of the mix. Gen 4 fabs will utilize 1-m-square substrates and will be able to run multiple display sizes efficiently within a totally automated factory.

In the FED session, Samsung introduced a 5.2-in. full-color FED with a focus electrode that produces 400 nits at an anode voltage of 5000 V. Daewoo Orion Electronics Company described a FED using three types of spacers for low and high voltages.

Zvi Yaniv (FEPET, Inc.) described the light-producing elements in the company's outdoor billboard technology: vacuum fluorescent display (VFD) elements made for the company by ISE. Next year, said Yaniv, the company will begin to use its signature carbon-film electron-emitting elements – also to be made by ISE – for higher-resolution, probably indoor, sign applications. This paper resolved a rather widespread uncertainty concerning which technology was being used.

On Thursday, M. Matsumura (Tokyo Institute of Technology) described the production of crystalline-silicon TFTs on glass by excimer lasers. Several micrometer-diameter crystals have been made with a single shot. Grain sizes to 7 or 8 μm have been obtained.

Tony Lowe (IBM Greenock) discussed the fabrication of reflective displays without polarizers. If one uses polarizers, reflectivity is limited to about 45% unless some kind of optical gain is used. Obtaining good images from displays without polarizers can be a challenge, but the rewards would be considerable.

In "High Performance Reflective Color LCDs," Tatsuo Uchida (Tohoku University) observed that a good reflecting surface is critical. Performance can be substantially

Ken Werner

During the week in which the German parliament began its first regular sessions in Berlin since World War II, the renovated and expanded Reichstag drew long lines of visitors. The inscription over the columns translates as "For the German People."

Ken Werner

I. Berlin remains, arguably, the world's largest construction site. This is the Brandenburg Gate viewed from the north. (The traditional postcard view is from the east.)

improved by replacing the random surface structure one normally encounters with a designed surface structure that yields a reflectance that is constant with reflection angle over an appreciable range. This behavior is produced by a surface composed of similar figures with different periods, which suppresses diffractions.

The approach is currently being used in a Sharp panel for a PDA application, and is also in the Sharp panel for the Nintendo Gameboy. The approach is used with OCB and ECB displays, and it is applicable to the cholesteric LCs from Kent State.

At one of the author interviews, Larry Weber (Plasmaco) presented a high-speed photo sequence of a plasma developing in a PDP cell, showing striations never seen before. (The sequence is illustrated in monochrome in a printed version of Weber's conference paper.) These striations and the unexpectedly slow movement of the infrared front of the developing plasma have implications for increasing luminous efficiency and optimizing circuit design, Weber said.

Exhibits

Although there were only 14 exhibitors, several of the booths were substantial and traffic was heavy during the conference breaks. Most of the exhibitors said they were pleased with their overall contacts. One said that conference management did not seem to understand the needs of the exhibitors for advance planning; had information been available earlier, this exhibitor said, it is likely the exhibition could have been larger.

Luxell (Mississauga, Ontario, Canada) showed their TFEL displays, including a 4 × 8-in. (half-ATI) data-entry panel for the P3 surveillance aircraft. Typical true contrast ratio (CR) is 2:1 at 10,000 fC ambient (direct sun) and 300:1 at 50 fC (typical office environment). But Luxell's big news is their involvement in OLED technology and their three-way association with Kurt J. Lesker (exhibiting in the next booth) and UDC, which includes a licensing agreement between UDC and Luxell. The group's intentions are to license Luxell's contrast-enhancing "black layer" to OLED makers, to make OLEDs for high-end applications, and to partner with other companies for high-volume applications, said Luxell CEO Brian Kennedy. Lesker will sell turnkey OLED manufacturing systems that have been proved in Luxell's production environment. A prototype three-color display (three individual colors in different locations) was shown in a cellular phone (see photo). Luxell calls its high-contrast OLED technology "Firefly" for that insect's natural organic display. "The OLED display was created by Mother Nature and perfected by Luxell," was the extravagant comment gleefully delivered by Luxell sales director Fred Prins.

Agfa-Gevaert (Mortsel, Belgium) was showing its flexible polyester film with organic conductive coating. Agfa was displaying a variety of inorganic EL displays and lamps made with the film (see photo). The conductivity of the film remains unchanged when the film is curved, folded, or even crumpled. It can also be stretched or embossed, and the coating can be patterned or printed. The price is $12 per square meter, half that of ITO, said Agfa's Louis Bollens.

The film and the organic coating have the same refractive index; patterning is done by oxidizing the conductor, which destroys conductivity. Therefore, the patterning is virtually invisible and the patterned surface remains smooth. Sheet resistivities of 200–3000 Ω/sq. are available today on polyester, and will soon be available on PES, polycarbonate, and other isotropic films. Agfa is working on lower sheet resistivities for the future.

The company was also showing its Agfaspheres™, spherical micropearls available in diameters from 0.8 to 6.5 μm in steps of 0.2 μm. They are designed for plastic displays. The micropearls, which are made of polymethyl methacrylate, perform similarly to today's standard product at half today's price, said Agfa's Jaen-Pierre Tahon. The micropearls being offered are transparent, but if there is demand for black, for example, or sticky ones, Agfa would be happy to talk.

Covion (Frankfurt am Main, Germany) is a small company that develops and manufactures the organic electroluminescent materials that its partners, such as Philips and Uniax, use to make OLEDs. At the moment, the company has green and yellow materials with good efficiency and stability, and an orange with acceptable efficiency, said U.K.-based business manager Kevin McAloon. A good red and good blue are under development and expected in the near future. The company is also working on low-molecular-weight phosphors for automotive applications which will have better performance at higher temperatures than do polymers.

Ken Werner

The Berlin Dome, which was a short walk from the convention hotel, is one of the city's landmarks.

conference report

Custom Display Products (CDP), a division of Chip Supply, Inc., was showing the same line-up of customized flat-panel-display driver products as at SID in May. E. Berry Leonard, Technical Manager for Advanced Products, said the company is getting requests to apply tape automated bonding (TAB) to microdisplays. They can do a 50-μm pitch to the chip, he said, so it's a good match. It's a developmental project at the moment, but they think it has potential because people are looking for practical ways of incorporating microdisplays in systems, Leonard said.

Michael Becker of **autronic-Melcher** (Karlsruhe, Germany) and Jean Noel Curt of **ELDIM** (Herouville, France) were both exhibiting their competing conoscopic display-measurement systems, although in different aisles. Becker was showing both the Conoscope and the DIMOS display simulation software. autronic-Melcher is selling all the Conoscopes it can make, Becker said, and DIMOS is doing very well. They are now working on a 3-D version of DIMOS, which is needed for the subtle modeling required to accurately predict changes in luminance, CR, and colorimetry with viewing angle, said Becker.

ELDIM was introducing its EZLite for microdisplays at EuroDisplay. With its acceptance angle of ±30°, the unit will analyze a bare microdisplay with its own reference beamsplitter or a microdisplay with the manufacturer's beamsplitter in place. A version of the MuraTest for microdisplays is under development, and should be available next year. It will be able to test the microdisplay itself or the microdisplay with optics.

ROLIC Technologies, Ltd. (Allschwil, Switzerland) is and wishes to remain a research company that sells licenses to its photo-alignment technology and the many applications it has developed for it, from LCDs to document security. Currently under development is an integrated LCD without pigmented color-matrix filters or polarizers, said Melanie Edge, and ROLIC is ready for a development partner.

The new **Swedish LCD Center** (Borlänge, Sweden) was offering advanced university-level training in LCD technology. The center was exhibiting with **Hornell Automation** and **LC Tech**, Hornell's LCD company that is offering prototype batch production and small series production with the tag line "LCD production in Europe." Hornell itself was pushing its well-known MELP modular equipment for LCD production.

Balzers Process Systems (BPS) (Balzers, Lichtenstein) was touting its new Aristo 1200/1600 in-line sputtering production system for FED, PDP, color-filter, and other flat-panel applications. The deposition area of the 1600 model is 1600 × 1600 mm. Throughput is in excess of 1.5 million square meters per year, according to company literature.

Ginsbury's John Halton was happily talking up the display-measurement systems and drive electronics of new client **Westar**. Halton had just picked up some new contacts and said he was very happy with the show.

Finally, **Osram** (Munich, Germany) was literally dazzling passers-by with its mercury-free Planon flat 5000-nit backlights, which are being targeted at the new generation of LCD desktop monitors. One bright panel mounted vertically on the back wall of Osram's booth was impossible to ignore.

Next Year

EuroDisplay is the name given to the International Display Research Conference (IDRC) when it is held in Europe every three years. Next year's IDRC will be held in the United States (where it is called, simply, IDRC) at the legendary Breakers Hotel, which is located directly on the Atlantic Ocean in Palm Beach, Florida. The Breakers is a luxurious Italian Renaissance building constructed in 1926 to replace the older wooden hotel of the same name built by early Florida developer Henry Morrison Flagler. The hotel was expanded in 1968 and renovated in 1996 (for more than ten times the cost of its original construction).

In 2001, IDRC will be held in Asia, where it is called Asia Display. The location will be Nagoya, Japan.

In 2002, IDRC will once again be EuroDisplay. Sites in southern France and Northern Spain are currently being evaluated, and the organizers wish to mount an extensive exhibition as part of the conference.■

SID '00

Long Beach, California

Long Beach Convention Center

May 14–19, 2000

SID Conference Calenda

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- AMLCDs and Display Manufacturing
- Applications and LC Technology
- CRTs and Emissive Displays
- Applied Vision, Human Factors, Display Measurement, and Display Electronics
- Projection Displays and Display Systems

· The Seminar Program will once again draw on industry leaders for three days dedicated to short courses, technology overviews, and display applications.

· Over 250 vendors will demonstrate the latest in displays, components, and equipment

· Evening Panel Discussions, an Exhibitor Reception, a Conference Luncheon, and an evening Social Event will complement the technical program.

14 MAY 00

SID '00

LONG BEACH, CALIFORNIA
MAY 14–19, 2000

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

25 SEPTEMBER 00

20th International Display Research Conference (IDRC '00)

PALM BEACH, FLORIDA
SEPTEMBER 25–28, 2000

• 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

6 NOVEMBER 00

Sixth International Conference on the Science and Technology of Display Phosphors

SAN DIEGO, CALIFORNIA
NOVEMBER 6–8, 2000

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

14 NOVEMBER 0

8th Color Imaging Conference: Color Scienc Engineering, Systems & Applications

SCOTTSDALE, ARIZONA
NOVEMBER 14–17, 2000

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

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continued from page 4

As I scanned through these earlier decades of family history, I thought about all the events and challenges. These images were indeed powerful memory joggers. I was glad that my parents had made the effort to carry these images with them through so many years.

I found my own initial photo-appearance in this album in the eventful fourth decade of the century. Most of these early photos were also monochromatic. The first color photos appear in the 50s. And how unfortunate that is. The images have almost disappeared, and what little remains is an ugly orange color. The introduction of color was highly touted as the next generation of photography, and was heavily promoted through advertising as the way to capture precious memories. However, the color film and paper makers didn't bother to let people know that their "memories" were only good for maybe a ten-year period before the images would virtually disappear. Those folks that stuck with the older Kodachrome slide-film process ended up with the longest-lasting results. But even today, none of the color-imaging materials equals the archival qualities of monochrome films and papers.

During the last two decades, there has been somewhat more attention devoted to the archival capabilities of color films and print materials. Cibachrome papers were the first, to my knowledge, to produce archival images that could be expected to last more than 50 years under normal storage and display conditions. Some of the Fuji films and papers have also recently demonstrated good archival qualities. With care, one can expect images made with these films and papers to degrade less than 10% over periods of about five decades. Thus, it may just be possible to show the images you made of your year-2000 New Year's Eve celebration party at the one you will attend 100 years from now.

However, suppose you used a digital camera? What will you have to show and how will you show it? How about in a shorter time – say 50 years from now?

We were recently visiting with our new son-in-law, who does Web-site design for a living and is thoroughly steeped in the latest computer technology. He was showing us the pictures they had taken during their honeymoon. While the photos had been taken with conventional 35mm film, each roll had been put onto a CD for convenient computer viewing. His offhand comment was, "I wanted to get them put onto a CD so I never have to worry about their degrading." That seemed like a reasonable comment. There is no reported information, at least that I have seen, indicating that the materials from which CDs are made are going to disintegrate in ten or twenty years – unlike some of the early movie films. However, what assurances do we have that the CD materials will last 50 or 100 years and that we, or our children, will have a way to view these images five or more decades from now? An actual photo or negative I can always examine. But what can I do with a CD if in the year 2049 there are no players that match the-year-1999 standards?

In the last two decades, we have gone from 5¼- to 3½-in. disks, to CD-ROM, and to various "memory sticks" that are used as semi-temporary storage for the newly emerging digital cameras. What will be the next generation of storage devices? It is clear that there will be a next generation because what we have today is insufficient for the 2-megapixel cameras that will be the mainstream image-capture devices during the first decade of this millennium. For example, a recent article comparing two of these cameras noted that in their highest-resolution mode the "memory stick" could hold only one image. This is clearly not a practical way to capture high-quality images. And if you put them onto a hard disk, Zip™ drive, or CD-ROM, will you have a way to access these media after another three or four decades of computer-technology evolution? Perhaps there is much money to be made creating businesses that do nothing but convert digital information stored in older formats into those storage media currently in vogue.

By the way, do you have any idea of the archival storage capabilities of the color ink-jet printer sitting next to your computer? Well, it's not quite as bad as some of the earliest color-negative films and photographs, but it's not very good either. Current ink-jet printers are most definitely not suitable for the printing of archival images.

It seems that we have made considerably more progress in the last century meeting our needs for "instant gratification" than we have for meeting our needs for predictable long-term information retention. Apparently, the world of bits and atoms is not nearly as easy to distinguish as some well-known prognosticators would have us believe. Without the atoms, there is no place to put the bits. And once we associate the bits with atoms, they seem to want to wander off on us. The business of information retention will, I think, be a growing one. The more information we have and the more we need to access it, with whatever is the latest computer technology, the more there will be a need for updating storage methods and devices.

Perhaps for those of us who cannot make a full-time occupation of updating our databases, we can hope that the CD will be around for some time to come. It seems like the best hope. It is already the medium of choice for audio. It has quickly become the medium of choice for software programs and technical information. It is now becoming the medium of choice for video entertainment. It can be the near-ideal medium for photographs as soon as permanent write capability becomes inexpensive. Perhaps with this broad applications base, it will be the standard medium for some decades to come. For the sake of holding on to our most precious memories and even our personal databases, it is imperative that we have an archival storage technology that will hold still for more than a few years.

Are we there yet? If not, when?

Let me know what you think. You can reach me by e-mail at silzars@attglobal.net, by phone at 425/557-8850, by fax at 425/557-8983, and by the always memorable post office at 22513 S.E. 47th Place, Issaquah, WA 98029.■

continued from page 2

We are in the final stages of testing an upgrade to our iMIS system that will enable you to have personal control over your membership entry. E-mail based, this new system will enable you to update your directory entry and renew your membership. Of course, those of you who do not have e-mail access will still be able to operate as before by fax, telephone, and mail.

Clearly, security is very important with any Web-based activity, and security is imbedded throughout this new system. When it becomes active, you will each be sent a personal identification number, or PIN, that you will need to enter before making any change. We already have secure encryption in place on our Web site so that you can make credit card transactions in complete security. Please note that only individual entries in our directory on the Web site are downloadable, and that obtaining an entry requires the accurate spelling of the name you are searching for, with no "*" wildcards. We have done this deliberately to ensure that mass-circulation organizations cannot download our directory and use it to send out unsolicited e-mails. However, if you would like to receive e-mail notification of SID events, you can subscribe to our information service. See the SID Web site for details.

Membership

It is extremely encouraging, and a reflection on the health of SID, that we have continued to grow our membership through the recent recession. Our membership did show a decline in some countries that were particularly affected by the Asian crisis, but even in those countries our membership is on the increase again. It is really encouraging that we are seeing rapid membership growth not only in new chapters, but in some of our long-established chapters, which are becoming even more vital and dynamic.

The Future

We are about to enter a new millennium. The world of information technology is changing at an unprecedented rate, and the way in which information is being communicated is undergoing a transformation. It is vital that SID stays in the vanguard of these changes. We must, however, be mindful that we are a global organization and that the technological rate of change varies considerably in different regions of the world.

president's message

Our Long Range Planning Committee has as its number one subject for consideration the following topics. How should our society grow? What should the balance be between industrial, product, and academic/scientific activities? To what extent should SID be a provider of educational material? Should we change the ways in which we deliver our publications? On this latter subject, we are aware that *Information Display Magazine* is predominantly U.S.-based, and we are actively investigating ways to increase European and Asian content.

At present these are ideas for discussion and not a policy. At our last Board meeting we spent considerable time discussing these issues, but they are of such importance to the Society that I am asking you, as individual members, to make your views known to us. You can do this through your local chapter, or direct to SID HQ. Remember that this is your society and we wish to develop it the way you, the members, want.

Our society is in good health and is growing. As we leave the 1990s and enter the next millennium, we have a great opportunity to make SID even better and more effective. This will be led by you, the members, through your local chapters. You each have a voice and an opportunity to influence our future. Please make the best of it.

– Tony Lowe

Tony Lowe

President of the SID

letters

To the Editor:

I thoroughly enjoyed Aris' discussion and your reader feedback on color presentation.

My first hand experience was involved with the then evolving paint-matching technology. For a short period of time I directed the activities of a fledgling (at the time floundering) pioneer in this industry.

The essence of the technology utilized a spectrophotometer to read a sample of color. The data was then analyzed in a microcomputer and converted to match the color systems of a particular paint manufacturer. The result was a formula used by a retail paint clerk to mix the paint.

Sounds relatively easy until you realize that the spectrophotometer is a highly complex, sensitive, and generally maintenance demanding laboratory instrument. It was prone to slide out of calibration and its sensing equipment depended on the precise alignment of optical systems as well as the quality of a reflective surface coating (which also deteriorated over time).

Add to that the consistency of sample quality, surface reflectivity, and the flatness of the sample. In addition, the equipment was technically blind in some areas of the color spectrum. This was due primarily to the lack of reflectivity and contrast in the sample. Now that is a list of variables which would gray the hair of any good scientist.

However, the stew wasn't complete yet. Now we address the coloring scheme - a combination of color additives which were precisely (maybe) measured and mixed in what was supposedly a consistent base white paint.

And not to be left out, the colors were displayed side by side on the computer monitor for the customer before the mix took place. Here is where reality left the scene. The monitor and hardware were essentially standard IBM-compatible 286/386 computers. We used 256 colors to represent the paint matches. No questions please.

Needless to say the monitor presentation was useless (at least from our point of view). However, the paint manufacturers presented their color offering on these monitors as an adjunct to the color samples available in most retail paint outlets. (Always go with the paper strip samples - these actually use the standard colors and the correct color formulas.)

In spite of all this slop in the process the color match was correct (read that acceptable to the customer) in over 85% of the cases. I suppose that this speaks volumes about our ability to perceive and utilize colors.

Today you can find computer systems in home centers which claim the ability to custom design the interior of your home - color matching at its riskiest. Certainly the technology has come a long way but still suffers from the quality of the hardware/software, conflicting color standards, and the real-world impact of the lighting and variations in the actually delivered products. My recommendation is to put the components together (or at least samples together) in the room and with the lighting you intend to use (both intensity and source). And listen carefully to your painter and decorator. When their noses wrinkle you should know that you are in serious decorating trouble.

It is also worthy of note that most men are partially or totally color blind. Just ask my wife.

— *Chris Golden, COO*
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