DISPLAY OF THE YEAR AWARDS ISSUE

Information DISPLAY

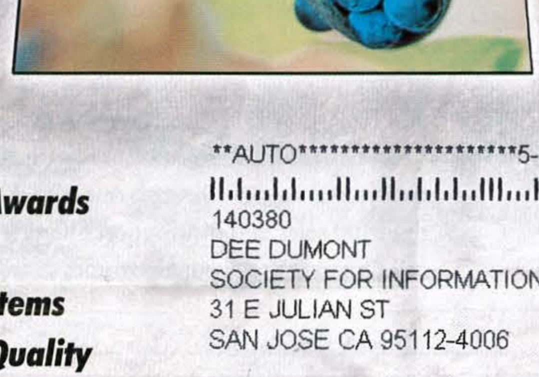
December 1999
Vol. 15, No. 12

SID

Official Monthly Publication of the Society for Information Display

The Best of '99

dvi
digital visual interface

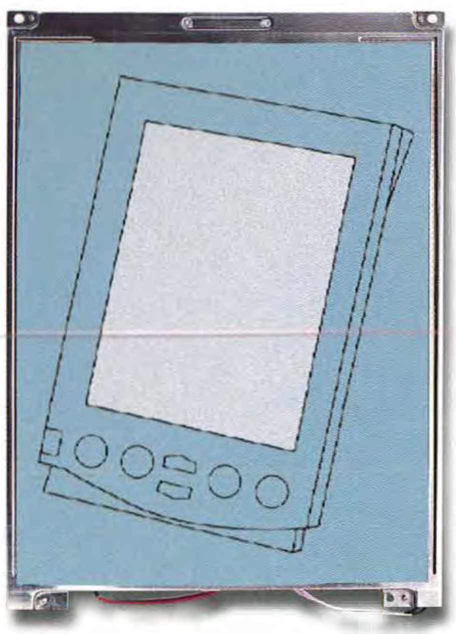


- ***Display of the Year Awards***
- ***Electronic Cinema***
- ***Medical Imaging Systems***
- ***Fewer Pixels, Equal Quality***
- ***NIST Colorimeter Calibration***

At Optrex, We Can Put Any Bright Idea On Display.

Dot Matrix Character Module

Color Graphics LCD Module



Monochrome Graphics LCD Module

Custom LCD Module

OPTREX AMERICA, INC.

Whatever your LCD needs – standard or custom – Optrex can offer an effective, cost-efficient solution. For over 30 years, manufacturers have relied upon Optrex for technologically-advanced character, monochrome, color and custom LCD configurations. Founded as a joint venture between Asahi Glass Co. LTD. and Mitsubishi Electric Corp., Optrex provides technical design and support through our own sales organization, and through more than 100 sales and distribution offices worldwide. For more information call Optrex, or see your electronics distributor today.

44160 Plymouth Oaks Blvd. • Plymouth, MI 48170 • (734) 416-8500 • FAX: (734) 416-8520
E-mail: lcdinfo@optrexusa.com

Circle no. 1

Information DISPLAY

DECEMBER 1999
VOL. 15, NO. 12

*COVER: Toshiba's family of direct-view polysilicon TFT-LCDs with integrated drivers earned the SID/*Information Display *Display of the Year Gold Award. To learn more about Toshiba's displays and the other five award winners, see the article beginning on page 12.*

Toshiba, MicroOptical Corp., Sharp, Silicon Graphics, Pixelworks

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

Next Month in
Information Display

LCD Markets / DVI & Digital CRTs
- AMLCD Markets
- The DVI Specification
- Helmet-Mounted Laser Displays
- EuroDisplay '99 Report

INFORMATION DISPLAY (ISSN 0362-0972) is published eleven times a year for the Society for Information Display by Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003; Leonard H. Klein, President and CEO. EDITORIAL AND BUSINESS OFFICES: Jay Morreale, Managing Editor, Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003; telephone 212/460-9700. Send manuscripts to the attention of the Editor, ID. Director of Sales: Michele Klein, Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003; 212/460-9700. SID HEADQUARTERS, for correspondence on subscriptions and membership: Society for Information Display, 31 East Julian Street, San Jose, CA 95112; telephone 408/977-1013, fax -1531. SUBSCRIPTIONS: Information Display is distributed without charge to those qualified and to SID members as a benefit of membership (annual dues $55.00). Subscriptions to others: U.S. & Canada: $36.00 one year, $7.50 single copy; elsewhere: $72.00 one year, $7.50 single copy. PRINTED by Sheridan Printing Company, Alpha, NJ 08865. Third-class postage paid at Easton, PA. PERMISSIONS: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limits of the U.S. copyright law for private use of patrons, providing a fee of $2.00 per article is paid to the Copyright Clearance Center, 21 Congress Street, Salem, MA 01970 (reference serial code 0362-0972/99/$1.00 + $0.00). Instructors are permitted to photocopy isolated articles for noncommercial classroom use without fee. This permission does not apply to any special reports or lists published in this magazine. For other copying, reprint or republication permission, write to Society for Information Display, 31 East Julian Street, San Jose, CA 95112.

2 **Editorial**
Where Are You.com?
Kenneth I. Werner

4 **The Display Continuum**
Christmas Shopping ...
Aris Silzars

12 **Fifth Annual Display of the Year Awards**
For 1999, a low-temperature-polysilicon AMLCD wins the Display of the Year Gold Award.
Ken Werner

18 **Electronic Cinema Is Inevitable**
Now that the technology for projecting motion pictures without film has been demonstrated, the movie industry won't be able to resist its benefits – but there are still bumps in the road to this digital future.
Curt Behlmer

22 **Reducing Pixel Count without Reducing Image Quality**
A new FPD color-pixel arrangement offers reduced blue resolution, which offers a better match for human vision and promises to lower display cost.
Candice Hellen Brown Elliott

26 **Medical-Imaging Systems Move Toward AMLCDs**
Medical-imaging systems have favored CRTs for high-resolution applications, but the improving image quality of AMLCDs is tantalizing the medical field with new opportunities.
Wayne Connell

30 **Calibrating Colorimeters for Display Measurements**
Some commercial colorimeters have uncertainties in display-color measurements that are too large for many commercial, industrial, and military applications – but new NIST-developed calibration procedures solve the problem
S. W. Brown, Y. Zong, and Y. Ohno

42 **SID News: Dr. Sanai Mito Dies at 88**

42 **Calendar of Display-Related Events**

44 **Index to Advertisers**

44 **Sustaining Members**

editorial

Where Are You.com?

Minute by minute, business lives in the global economy and breathes the air of omninationalism.

Research scientists have long held that science is greater than national borders, and they made "the international scientific community" a reality long before the phrase became a cliché. (High-energy physicists created what became the Internet so they could quickly share their results.) But even the most enlightened of national governments don't really understand that national borders and national jurisdictions are dissolving. They can't. If they did, they'd have to put themselves out of business - and politicians do not relinquish power easily.

National governments are wrestling with how they can control - for good or ill - global corporations. They probably can't - at least not in any sensible way. It's going to take a global government to do that. And most people would hesitate to implement a permanent, global government bureaucracy without giving the matter a lot of thought. The European Parliament - an obvious if imperfect parallel - is not a confidence-inspiring example.

I began writing this in an airport lounge in Paris on my way back from EuroDisplay 99, which was held in Berlin. I had never been to Berlin before, but the moment I walked into the conference, I felt at home. Here were many of the colleagues I had seen in Seoul a year ago at Asia Display, in Taipei at ASID five months ago, and in San Jose at the SID International Symposium three-and-a-half months ago. This is the international display community, meeting periodically to communicate developments, share ideas, and do business.

It would be an over-simplification to say that the location of these meetings doesn't matter. Berlin, for example, is a special city, and its spirit permeated the conference. And although there is a substantial contingent of display people who attend many of the major international display meetings, there are also many people who are only able to attend and deliver papers at meetings that are relatively near where they live and work. Knowing this, meeting organizers are likely to include content that has a specific regional resonance, and exhibits are strongly flavored with regional companies, as well as international ones that have a regional customer base. This is good for everybody, but the fact remains that a substantial portion of the meeting content is largely independent of the meeting's location.

Similarly, I sometimes find myself quite unconcerned about the geographical location of the people and companies I deal with. Why should I care about street addresses when my primary means of communication is the Internet? This is the perspective of the information society: Ideas and information flow freely - hopefully subject to legitimate IP and proprietary considerations - without regard to national borders.

But we have already gotten carried away by this perspective. When the earthquake struck Taiwan in September, concern for friends and colleagues made it very clear that geography can matter greatly. Establishing alternate lines of supply for electronic components, although far less important than human life and safety, consumed many people in the electronic-products industry.

On a happier note, when José Oton of the Universidad Politécnica de Madrid recently sent me a CD-ROM containing the Proceedings of the Third Ibero-

continued on page 37

Information DISPLAY

Editor: Kenneth I. Werner
Managing Editor: Jay Morreale
Administrative Editor: Ralph Nadell
Assistant Editor: Dian Mecca
Contributing Editors: Aris Silzars, Bryan Norris, Chuck McLaughlin, Joe Hallett, Alfred Poor
Advertising Manager: Jay Morreale
Sales Manager: Tracy Leibowitz

Regional Associate Editors

Allan Kmetz **(Americas)**
Lucent Technologies
Liberty Corner, New Jersey

Shigeo Mikoshiba **(Asia)**
University of Electro-Communications
Tokyo, Japan

Alan Mosley **(Europe)**
Central Research Laboratories
Hayes, Middlesex, U.K.

Advisory Editors

Carl Machover
Machover Associates
White Plains, New York

Alan Sobel
Consultant
Evanston, Illinois

Webster E. Howard
FED Corp.
Hopewell Junction, New York

Ernst Lueder
University of Stuttgart
Stuttgart Germany

Sungkyoo Lim
Information Display Research Center.
Choongnam, Korea

Christmas Shopping ...

by Aris Silzars

It's a little after five o'clock on a rainy Friday afternoon and I am sitting in rush-hour traffic on a Seattle freeway. The drive home, which would normally take about twenty minutes, will today take well over an hour. On this day, I am experiencing why Seattle is listed as one of the top five U.S. cities for rush-hour congestion.

As I creep along at a pace I could exceed by walking, I look around at the other commuters. Few are relaxed. I spot one or two who seem to have created their own audio cocoons of highly amplified contemporary music, and a few others who are continuing to transact business on their cellular phones - or maybe attempting to get an early start on "quality family time." But by and large, the fingers drumming on the steering wheels and the frown-adorned foreheads hint that this really is not such a fun way to start the weekend.

For me this is fortunately not a daily exercise. It reminds me not to grumble the next time I need to get up for an early morning drive to the airport. At least when I'm not travelling, I don't have to endure two hours of rush-hour commuting traffic each day.

Nevertheless, here I am, participating in what for many is a daily ritual of getting to work and then getting back home again - just so it can be done all over again the following day, week, and month. Couldn't there be a better way? Look at all this lost productivity and wasted energy. If all these folks are spending roughly an hour each morning struggling with traffic just to get to their places of employment, aren't they already tired when they get there - too tired to do their best work? These two hours dedicated each day to commuting are conservatively a 25% productivity loss to our economy, except for the petroleum companies, of course. What about the Internet and the interconnected society? Can't we creative technology types come up with a way to provide our colleagues with some relief?

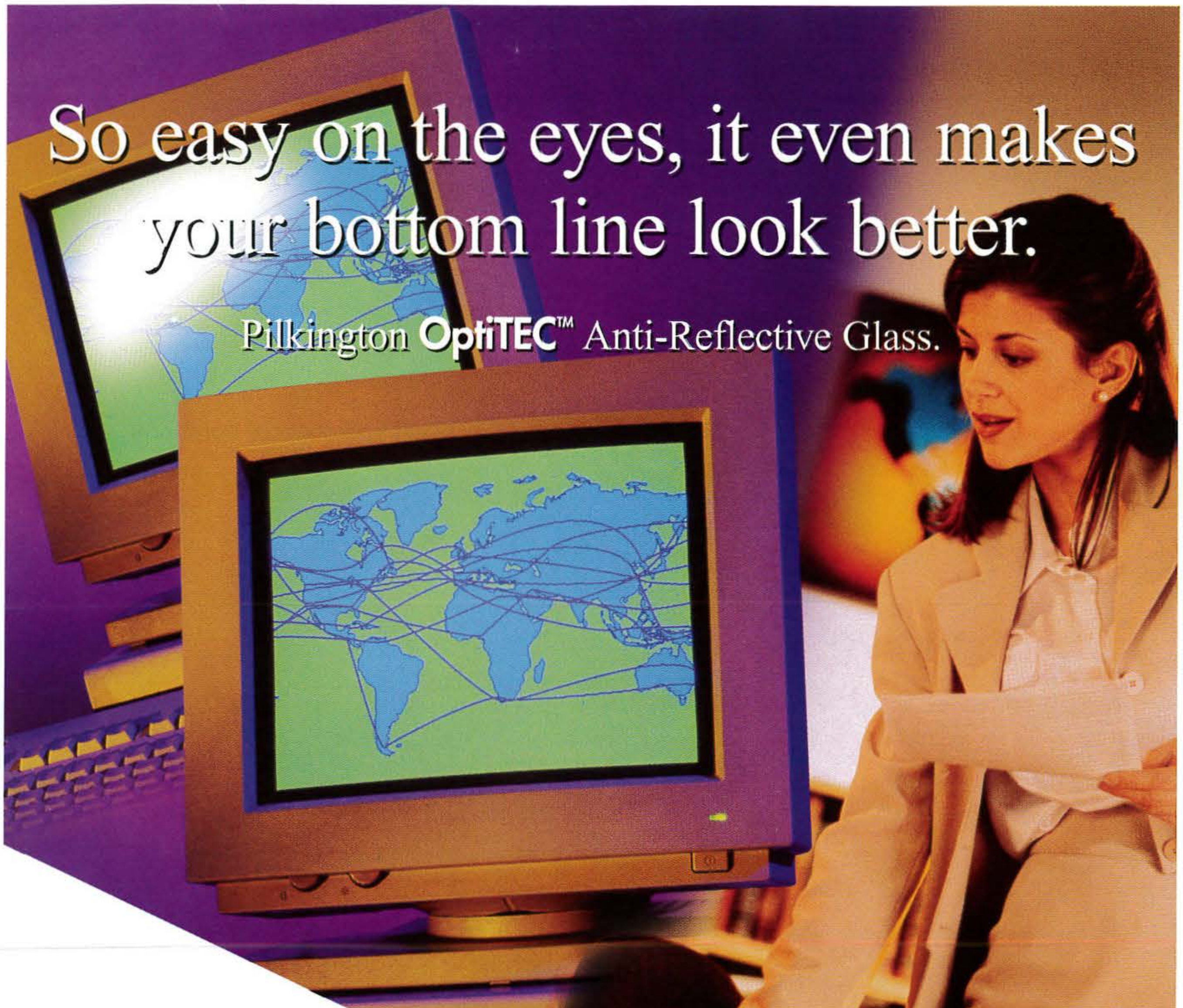
As you can see, deep philosophical contemplation is one of the symptoms brought on by sitting-on-the-freeway hypnosis.

Then the inescapable conclusion hit me! We are doing it all backwards! All those over-funded new Internet businesses are chasing after the wrong opportunity. We don't really need to be doing book buying and grocery shopping over the Internet. Au contraire! What we really need is to be doing more of our work over the Internet, and only show up at the office – at varying but pre-appointed times of the day or night – to make an occasional visual contact with our colleagues and bosses, and to attend those all-important staff meetings.

The concept of Internet shopping has never seemed all that appealing to me anyway. Frankly, I can't see how it is fundamentally any different from traditional mail-order shopping, which originated to serve the needs of rural farm families who could not conveniently travel to the centers of commerce to do their buying. As we enter the new millennium, few of us have that problem. In fact, merchandise the world over is remarkably the same. In spite of that, isn't it

continued on page 36

Society for Information Display
31 East Julian Street
San Jose, CA 95112
408/977-1013, fax -1531
e-mail: office@sid.org
http://www.sid.org



The low-cost
solution to glare control for
CRT and flat panel display applications.

Now, there's an affordable, low-cost solution to glare control for computer screens, televisions, flat screen and electronic displays, and even glass display cases.

Pilkington **OptiTEC**™ Anti-Reflective Glass.

With a pyrolytic anti-reflective coating that's actually bonded to the surface of the glass while the glass is being made.

So not only is it more economical, but more durable as well, for easier handling, fabricating, tempering, bending and more.

That means faster turn-around and lower costs, too.

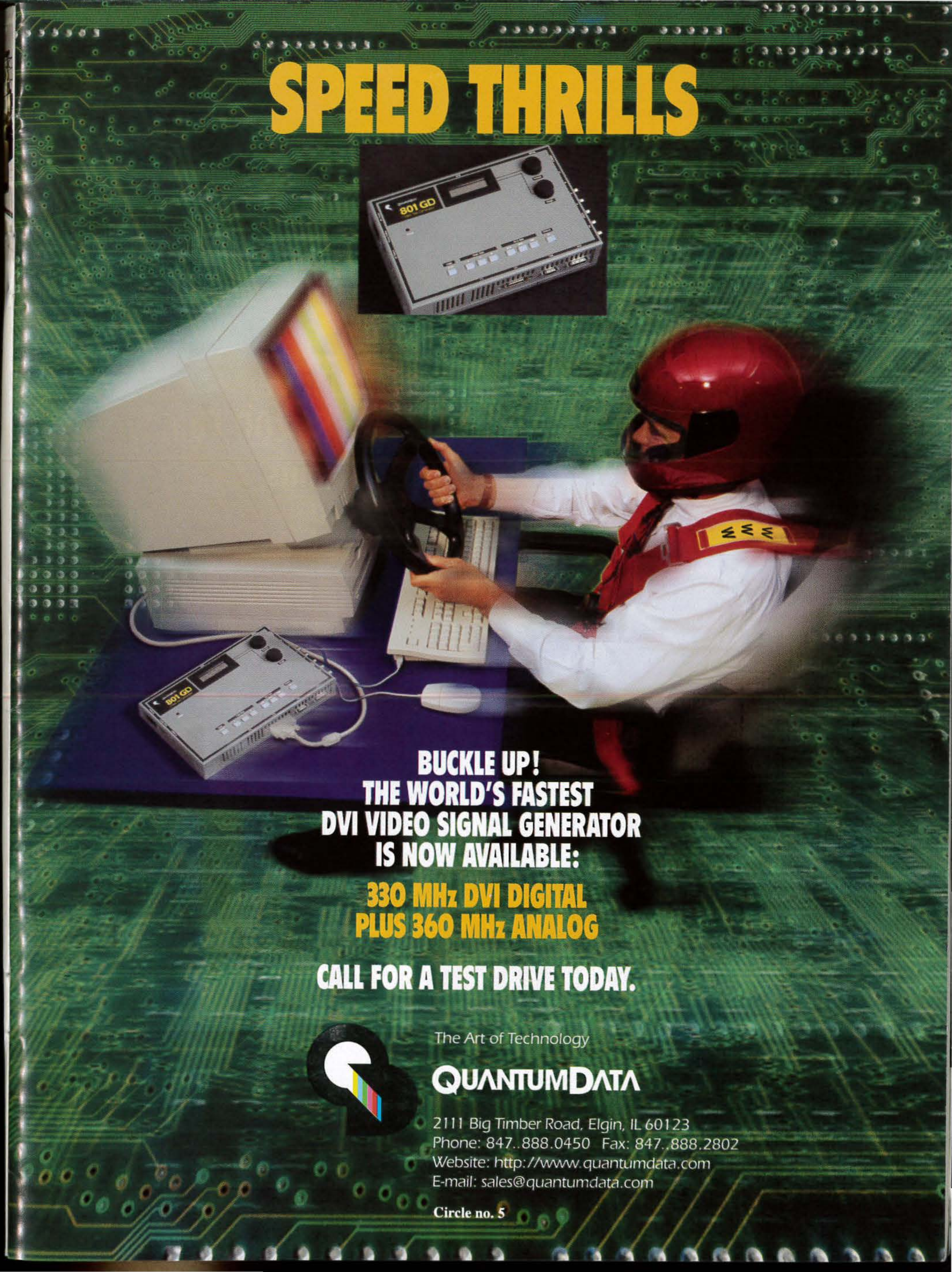
And that's the bottom line.

For more information, visit us at www.pilkington.com/specialty or contact your Pilkington representative.

Pilkington Libbey-Owens-Ford, Specialty Glass Products
P.O. Box 799, Toledo, OH 43697-0799
Tel: 419 247 4724; Fax: 419 247 4517

PILKINGTON

Circle no. 3


SPEED THRILLS
801 GD
BUCKLE UP!
THE WORLD'S FASTEST
DVI VIDEO SIGNAL GENERATOR
IS NOW AVAILABLE:
330 MHz DVI DIGITAL
PLUS 360 MHz ANALOG
CALL FOR A TEST DRIVE TODAY.
The Art of Technology
QUANTUMDATA
2111 Big Timber Road, Elgin, IL 60123
Phone: 847..888.0450 Fax: 847..888.2802
Website: http://www.quantumdata.com
E-mail: sales@quantumdata.com
Circle no. 5


Hal's Electronics

Precision Flexibility

Westar's FPD Performance Measurement Systems give you something unique -- precision and flexibility. Westar's FPM Systems provide photometric and colorimetric measurements, real-time reporting of test results, increased test and analysis productivity, and performs standard tests as well as your own custom tests.

Westar's FPD Performance Measurement System

- Tests displays up to 54" automatically.
- Tests for luminance, chrominance, contrast & viewing angle performance...and more!
- Performs standard tests including: VESA, ISO, NIDL & SAE.
- Uses popular sensors, such as PR, Minolta, and Topcon.

Powerful ViewPoint™ software integrates sensors, motion control, analysis, and reporting functions. It also includes a wide variety of fully integrated display interfaces!

FREE Video and CD

For more information on Westar's revolutionary new systems, call today for our **FREE** video and CD.

Westar

USA:	Westar Corp., 314-298-8748 ext.286
Japan:	Kyokuto Boeki Kaishi, Ltd., 03-3244-3795
Korea:	Truco, Inc., 02-3487-1070
Taiwan:	Advanced Team Enterprise Co., Ltd., 02-27035466
China:	Advanced Team Technology Service, 769-632-6399
Europe:	Ginsbury Electronics, Ltd., +44 (0) 1634-298900

http://www.westar.com

Circle no. 8

Fifth Annual Display of the Year Awards

For 1999, a low-temperature-polysilicon AMLCD wins the Display of the Year Gold Award, and the Committee also honors an innovative lightweight HMD, an LCD TV, an LCD monitor, a highly integrated image processor, and the Digital Video Interface standard.

by Ken Werner

WHEN THE MEMBERS of the SID/*Information Display* Display of the Year Awards Committee (DYAC) met in San Jose, California, during SID '99, they initiated a painstaking four-month process of nominations and voting.

The Committee is fully international (see text box, 1999 Display of the Year Awards Committee) and consists of both distinguished members of the technical display community and distinguished technical journalists who cover displays. This combination ensures that the committee's deliberations are carried out with both technical sophistication and breadth of view.

The displays and products considered for the awards were nominated either by the members of the committee or by interested parties who submitted their nominations to the DYAC Secretariat. The Secretariat distributed the names of all the nominees to the committee members, who then voted for the winners. The Display of the Year Awards (DYA) bylaws require the committee members to consider many factors when they vote, including technical innovation, commercial significance, and likely social impact. Displays, products, components, and materials must have become commercially available - either to OEMs or end users - between July 1, 1998, and June 30, 1999, to be eligible for this year's awards.

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

0362-0972/99/1512-012$1.00 + .00 © SID 1999

DISPLAY OF THE YEAR AWARD

Gold Award: Toshiba's Family of Direct-View Low-Temperature-Polysilicon TFT-LCDs with Integrated Drivers

Toshiba has been developing low-temperature-polysilicon (LTPS) technology over the last several years, more than once showing direct-view prototypes that startled the display community by breaking what was thought to be the size barrier at the time. The company has now become the first to commercialize a family of high-resolution direct-view LTPS TFT-LCDs. The start of production at Toshiba's Fukaya Works in Saitama Prefecture was announced at SID '99 in May.

The backlit display family consists of a 10.4-in. XGA with a luminance of 230 cd/m^2, a backlit 8.4-in. SVGA with a luminance of 130 cd/m^2 and a typical power consumption of 1.9 W, and a 4-in. VGA that consumes 350 mW exclusive of backlight. The 4-in. unit has a pixel density of 202 pixels/in., which made it the world's finest-pitch commercially available LCD when it was introduced.

Toshiba's aggressive development and commercialization of LTPS TFT-LCDs is providing system designers with thin, lightweight displays that do not require external LCD drivers and sharply reduce the number of external connections (from 4000 to 200 for XGA). This results in more reliable displays that are more resistant to mechanical stress, and has halved the field failure rate compared to traditional designs.

DISPLAY OF THE YEAR AWARD

Silver Award: MicroOptical's EyeGlass Display

The resurging interest in head-mounted displays (HMDs) is based on the increasing availability of economical high-resolution displays and the appearance of increasingly attractive lightweight headset designs. Perhaps the most innovative of these lightweight designs is The MicroOptical Corporation's EyeGlass Display (EGD), which puts a microdisplay in the earpiece of a superficially ordinary pair of eyeglasses, and reflects the image into the eye by means of a virtually invisible prism embedded in the eyeglass lens – which can be a corrective, sunglass, or safety lens.

The current quarter-VGA model, which weighs only 110 grams and adds only about $250 to the cost of a pair of prescription eyeglasses, uses a Kopin CyberDisplay. The company plans to introduce a higher-resolution version using an electroluminescent VGA microdisplay.

Current models of the EGD have a see-through image, making the device suitable for applications that overlay data or images on the real-world view.

This innovative application of optical design to HMDs not only produces an attractive product in its own right, but also points the way to the increasingly sophisticated use of optics in display-system design.

DISPLAY PRODUCT OF THE YEAR AWARD

Gold Award: Sharp's 20-in. LCD TV

With the introduction in Japan of its LC-20V family of LCD television sets, Sharp Corporation is selling a direct-view AMLCD TV with the largest screen commercially available. The display incorporates a high-luminance backlight with a 9000 K color temperature and a 40,000-hour lifetime.

The electronics includes the first three-dimensional Y/C separation circuit to be included in an LCD television and a wideband video chromatic IC that increases the video bandwidth from 4 to 10 MHz, a panel-adjustable gamma-correction circuit, and an outline correction/enhancement circuit.

The 640 × 480-pixel display has viewing angles of 120° horizontal and 100° vertical, and an enhanced color filter that combines with the bright backlight to produce substantially enhanced color purity, says Sharp. With high-style design, a slim 2-in.-deep cabinet, a variety of mounting and application choices, and options such as wireless IR connection to VCRs, the LC-20V is leading Sharp's charge to a "Crystal AV World" – the replacement of all domestic color TVs with LCD-based products.

Whether viewed as a symbol of corporate philosophy or simply as a striking LCD TV set, Sharp's LC-20V incorporates advances in display technology to deliver an impressive product.

DISPLAY PRODUCT OF THE YEAR AWARD

Silver Award: Silicon Graphics' 1600SW Digital Wide-Screen Professional LCD Monitor

Wide-aspect-ratio monitors are still unusual enough to be startling, but Silicon Graphics Incorporated (SGI) – working with technical partner Mitsubishi Electric – is doing something far more interesting than just using aspect ratio as a product differentiator. The company has carefully mated the characteristics of an advanced LCD to the top-of-the-line monitor needs of the professional content creators, engineers, and financial professionals who traditionally use SGI workstations.

That LCD is a 17.3-in.-diagonal panel with a 16:10 aspect ratio and 1600 × 1024 pixels (110 pixels/in. and a 0.23-mm pixel pitch) that delivers 24-bit color. White color temperature is user-adjustable from 5000 to 7000 K. The 1600SW monitor combines wide viewing angles of 120° horizontal and +45°/−55° vertical with a response time fast enough for viewing video and interacting with 3-D models.

The monitor maximizes image quality with end-to-end digital data transfer. A choice of digital controller card for PC or SGI platforms comes with the monitor. In addition to providing excellent performance, the 1600SW clearly makes a design statement, appropriate for a high-end product that has design professionals as a significant part of its market. The attractive case is adjustable for screen height and tilt.

DISPLAY MATERIAL OR COMPONENT OF THE YEAR AWARD

Gold Award: Pixelworks' PW364/PW264 Single-Chip ImageProcessor™ Display Controllers

A top item on the agenda of liquid-crystal-display (LCD) manufacturers and computer-system vendors is the roll-out of liquid-crystal monitors (LCMs), but two things have been impeding that roll-out: the stubbornly high prices of LCDs appropriate for LCMs and the variety of complicated functions that must be implemented into an LCM controller. That complexity has been particularly frustrating because the LCM's prime competitor is the CRT monitor, and many of the control functions that are difficult and expensive to do for an LCM are easy and cheap for a CRT. A traditional LCM controller – including auto-configuration, frame-rate conversion, and upward and downward image scaling – costs $300 to $500, more than many complete CRT monitors.

In developing the PW364/PW264, the world's first single-chip flat-panel-display controllers, Pixelworks has taken a giant step toward reducing the size and cost of LCM controller boards and toward bringing LCMs into the monitor mainstream. Pixelworks, along with technology partner Toshiba America Electronic Components, implemented advances in semiconductor technology to create this ambitious system on a chip. The chip – the first 0.25-μm system-level-integration ASIC with embedded DRAM – contains half a million gates of random logic, a 32-MB SDRAM core, and an on-board integrated 16-bit processor running at up to 133 MHz.

To the great benefit of the LCD and computer-peripherals industries, other companies are already entering the door Pixelworks opened with the PW364 and PW264.

DISPLAY MATERIAL OR COMPONENT OF THE YEAR AWARD

Silver Award: The Digital Display Working Group's Digital Video Interface

The Digital Video Interface (DVI) is a digital interface standard that was developed by a group of industry leaders including Compaq, Fujitsu, Hewlett-Packard, IBM, Intel, NEC, and Silicon Image, and appears to have earned the general acceptance of the display and computer industries. Silicon Image's PanelLink®, an award winner last year, provides the technical basis for the interface specification.

The specification answers the industry need "for a common digital connectivity specification for digital displays and high-performance PCs while allowing for existing analog support. The specification defines a robust, comprehensive, and extensible interface specification addressing protocol, electrical, and mechanical definitions." The standard – designed to unite the workstation, desktop, laptop, and other segments of the PC industry – is available *via* a non-royalty-bearing license.

The standard specifies a single plug and connector that encompasses both the new digital and legacy VGA interfaces, as well as a digital-only plug and connector. Use of the combined connector or the digital-only connector creates the opportunity to remove the legacy VGA connector when business conditions make that advisable.

The DVI handles bandwidths in excess of 160 MHz, and thus supports UXGA (1600 × 1200) and HDTV (1920 × 1080) with a single set of links. Higher resolutions can be supported with a dual set of links.

The DVI should accelerate the trend to routine support of digital displays by PC-based controllers, thus reducing the cost of digital liquid-crystal monitors. But it is not for LCMs alone. ViewSonic is incorporating DVI in its plan to manufacture substantial numbers of digital CRT monitors in the coming year. Many other manufacturers of flat-panel and CRT monitors are sure to join them.

dvi digital visual interface

ORIGIN OF THE DISPLAY OF THE YEAR AWARDS

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

1999 DISPLAY OF THE YEAR AWARDS COMMITTEE

Mr. Jean-Noel Perbet, Chair
Sextant Avionique – APN
Commercial Air Transport Avionics
Le Haillan, France

Professor Shunsuke Kobayashi,
Founding Chair
Professor of Electronic Engineering
Science University of Tokyo in Yamaguchi
Onoda, Yamaguchi, Japan

Ms. Cheryl Ajluni
Western Editor
Electronic Design
San Jose, California, U.S.A.

Professor Shou-Qian Ding
Department of Electron Science
Nankai University
Tianjin, China

Professor Jin Jang
Kung Hee University
Seoul, Korea

Ms. Florence Ladouce
Editor
Electronique International
Paris, France

Mr. David Lieberman
Northeast Editor
Electronic Engineering Times
Townsend, Massachusetts, U.S.A.

Mr. David E. Mentley
Vice President
Stanford Resources
Richmond, California, U.S.A.

Professor Shigeo Mikoshiba
Department of Electronic Engineering
The University of Electro-Communications
Tokyo, Japan

Dr. Alan Mosley
CRL
Hayes, Middlesex, U.K.

Mr. Alfred Poor
Contributing Editor
PC Magazine
Perkasie, Pennsylvania, U.S.A.

Dr. Aris Silzars
President
Northlight Displays
Issaquah, Washington

Professor Chuji Suzuki
Advisor
International Center for Materials Research
Nara, Japan

Mr. Chizuka Tani
NEC Corporation
Kanagawa, Japan

Mr. Kenneth I. Werner
Editor
Information Display Magazine
Norwalk, Connecticut, U.S.A.

For further information, please communicate with the Committee Secretariat:
Nutmeg Consultants
Att: Dian Mecca
2 Shady Brook Lane
Norwalk, CT 06854, U.S.A.
Phone: 203/853-7069
Fax: 203/855-9769
e-mail: kwerner@home.com

Electronic Cinema Is Inevitable

Now that the technology for projecting motion pictures without film has been demonstrated, the movie industry won't be able to resist its benefits - but there are still bumps in the road to this digital future.

by Curt Behlmer

IT MAY BE A COUPLE OF YEARS LATE, but the replacement of cinema film projection by electronic projection will be a truly millennial event. Not since 1902 – when the Lumière Brothers adapted Thomas Edison's motion-picture viewing device for theatrical presentation so that a group of people could share the experience of viewing a moving-picture show – has there been such a revolutionary change in the theatrical cinema experience.

That is not to say that change has been rare over the last century. In fact, it has been almost continuous. A particularly dramatic change occurred in 1926 with the advent of "talkies" – movies with recorded sound. The first recorded sound was from poorly synchronized phonograph records, but these were quickly replaced with perfectly synchronized optical sound tracks recorded directly on the film. This was followed (over time) by multiple magnetic sound tracks, stereo optical sound tracks, the Lucasfilm THX specification, and six- and eight-channel digital sound systems. When coupled with a good theatrical sound system, the formidable audio of some modern movies substantially changes the theatrical experience.

As important as high-fidelity multi-channel sound has become, the moving image is cinema's defining characteristic. And the image projected on the screen has changed dramatically since 1902. Increasing the frame rate to 24 frames per second (fps), which remains the standard today, essentially eliminated flicker from the moving image.

Directors appreciated the value of color early in the history of cinema. In the silent era, long before film technology could provide full color, film stock was tinted to enhance the mood of different scenes in relatively high-budget movies. In a single film, different scenes might be tinted different colors. In 1939, *Gone with the Wind* was shot impressively using an unusual Technicolor process. Most people loved it, but there were naysayers. In his *New York Times* review of the movie, Frank S. Nugent praised director Victor Fleming's use of color, but he also wrote, "...we still feel that color is hard on the eyes for so long a picture...." Clearly, this opinion did not become dominant in the film world.

Beginning in the 1950s, wide-screen formats started giving moving images the expansiveness we now take for granted, and improved film stocks broadened the creative possibilities for cinematographers and directors.

It may not be technically compelling, but the physical plant in which films are shown has changed greatly over this century, and the changes certainly affect the theatrical experience. The movie "palaces" of the 1920s and 1930s made going to the movies an exciting occasion, and the development of stadium seating gave each patron an unobstructed view of the screen. Snack concessions in the lobby are still popular with patrons and provide a welcome additional revenue stream for theater owners. For many patrons, seeing a movie without a bag of popcorn is almost unthinkable.

Larger screens and improved viewing angles have added to the theatrical experience, and comfortable seating has allowed patrons to concentrate on the film instead of on their aching backs. And let's not forget a fairly recent addition to the theatrical experience: cup holders! But this enhancement pales in comparison to the developing trend to provide an extra-cost VIP experience and full service – the cinematic analog of a football-stadium skybox.

But What About Projection?

Projection technology has been quite static for years, but it has seen dramatic changes in the past. Early developments included motor drive, a solution for the tired arms and variable speed associated with hand-cranked projectors. More recently, the development of film "platters" permitted the creation of a seamless program, with all the reels of the feature film spliced together with public-service notices, theater announcements, and trailers. Carbon arcs were replaced with metal-halide lamps in the 1970s.

But we are still projecting light through transmissive photographic film in a process

Curt Behlmer is President of Studio Systems, Inc., 1150 Canton Dr., Studio City, CA 91694; telephone 323/993-5930, fax 818/508-1322, e-mail: curt_behlmer@ancinc.com. He was responsible for the conceptual design and implementation of a new post-production digital infrastructure at Warner Brothers Studios, and served as the Governor of the Sound Branch of the Academy of Motion Picture Arts and Sciences. This article is based on the keynote address he delivered at SID '99 in San Jose, California, on May 18, 1999.

0362-0972/99/1512-018$1.00 + .00 © SID 1999

that would be instantly recognizable by the Lumière brothers. Although that process continues to produce dramatic cinematic experiences, it's clear that the era of film-based projection is inevitably coming to its end and that electronic projection will replace it.

As the demonstrations at SID '99 and theatrical showings of *Star Wars – The Phantom Menace* and *The Perfect Husband* made clear, large-screen electronic projection has arrived. The technical challenge has been to simultaneously provide high resolution, increased light output, reduced cost, and improved stability; and that challenge has now been overcome, although further cost reductions are needed to encourage an industry-wide roll-out of electronic projectors.

The Case for Electronic Projection

The case for electronic projection – really the inevitability of electronic projection – rests on five powerful issues: consistent presentation quality, improved time to market, scheduling flexibility, reduced distribution expense, and new revenue opportunities.

In cinema film projection, those lucky enough to see a movie during the distribution print's first pass through the projector are likely to see a relatively good image. If the print is making its twentieth pass through the projector, the deep black space of *Star Wars* is likely to have as many white scratches as white stars. In electronic projection, the quality of a feature's last presentation at a theater looks as good as the first, with no scratches, jumps, weave, or focus flutter.

There are a variety of issues associated with the difficult, pressure-ridden process of ordering, producing, and delivering distribution prints of a film in time for its scheduled debut. With digital "prints," quality control will be immensely simplified because digital copies are inherently identical.

Quality aside, theater owners must currently estimate the numbers of prints of a presentation they will need. If a presentation is more popular than anticipated, it may take too long to obtain additional prints to take advantage of the film's popularity by showing it on more screens. Conversely, it may not be possible to obtain a print of a different feature to replace one that fails to draw its anticipated audience.

Although film "platters" were an advance over segueing between reels on two projectors, they require time-consuming assembly of the theatrical program. With digital prints, no physical assembly is required – just an electronic definition of file sequences.

Although it is generally regarded as good marketing practice to release a film to theaters around the country simultaneously, the logistics of shipping film prints around the country may make this impossible. Digital distribution will make "day and date" release much easier.

All of this impacts scheduling flexibility. With digital cinema, screenings are not limited by the availability of physical media, and the configuration of language and audio tracks can be independent of the visual image. For instance, today a distribution print of a feature with an English-language sound track is a different object from the same feature with a Spanish-language sound track. With digital media, any available sound track can be selected when different languages are presented in the same theater, and it will no longer be necessary to prepare different physical prints for different countries. And, of course, it will be possible to instantly add or drop screenings to meet audience or distributor demand.

Film-based distribution prints are heavy, bulky, and expensive to ship. Electronic cinema will permit two different distribution models, each of which reduces distribution expenses. The first of these is the transmission-based model, in which the digital stream will be transmitted to theaters via cable or satellite. This model completely eliminates physical media and shipping costs, but it requires a high-bandwidth connection and potentially expensive server hardware. In addition, it raises security concerns, which have to be resolved with encryption techniques.

The media-based model would distribute features on a physical medium, probably something resembling DVDs on steroids! Such a physical media would cost far less than film, offer a familiar process and operation, and be potentially more secure than a bit stream launched into the ether, but it is less flexible than using transmission. The author suspects that the media-based model will be used first, and is likely to be a stepping stone to a system based on the transmission model.

Movie theaters geared to electronic cinema, particularly those designed to receive transmitted digital bit streams, offer theater owners new revenue opportunities. The theater, in effect, can be used as a large-screen high-definition television – but one offering the quality, intensity, and social interaction of a theatrical experience. Thus, there is the opportunity for live pay-per-view events, educational programs, town meetings, business meetings, advertising, and interactive programming.

Implementation

It has been said that cinema today is a digital sandwich between two slices of analog bread. Much editing and processing is digital, but movies are shot on film and projected from film. Even as we consider replacing analog projection with digital, most people on the creative side of things in Hollywood are not inclined to consider replacing film as the capture medium (George Lukas is a notable and vocal exception). Different film stocks form the palette from which directors and cinematographers create different moods and looks, with different color balance, contrast, graininess, and film speed. A tremendous amount of knowledge has been accumulated on these issues, and few cinematographers are willing to trade their sophisticated bags of tricks in for a digital camera and videotape. So development of standards and procedures for telecine transfers (transfer from film to electronic media) geared to theatrical release rather than television are critical. We also need presentation standards comparable to those now in place for film so that a feature will look the same regardless of where it is seen.

Clearly, electronic cinema is more than just a projector. It requires the making of distribution media or encrypted transmitted bit streams that are faithful to the creative vision of the film makers, that can be distributed reliably and quickly, and that can be decoded and shown on projection systems around the world.

The most rapid roll-out could probably be accomplished with an integrated end-to-end system provided by a single company or consortium, and this is precisely the approach being developed by CineComm, a joint venture of Qualcomm and Hughes-JVC Technology Corp. However, there are those who would prefer the flexibility of a component system, even though it places more demands on distributors and exhibitors. Texas Instruments, which has a digital cinema projector based on its Digital Light Processing™ (DLP™) technology, is promoting such an approach.

Recently, Christie Inc., the 70-year-old manufacturer of film-based theatrical projection equipment, agreed to purchase the Projection Systems Group of Electrohome, the maker of high-end electronic projectors based on DLP™ technology. The combination of Electrohome's well-respected technology with Christie's marketing clout could be formidable. Interestingly, Christie CEO Jack Kline has been quoted as saying that digital cinema will not completely arrive for 3–5 years (*Microdisplay Report*, September 1999), but he said nothing about whether Christie would lean toward the component or end-to-end approach. When they do arrive, new electronic systems will have to integrate and co-exist with existing systems, and there will be a critical need for technical support and training.

Electronic cinema provides more options, which is an opportunity, but managing those options is a challenge. For example, because an electronic "print" is likely to be a multinational product, it will have to contain sound tracks for all applicable languages when first released. It will no longer be possible to first produce the English-language release, leaving the French, German, and Japanese versions for subsequent production. This implies the need for parallel post-production to produce the different tracks needed for the different market areas simultaneously without delaying release.

Bumps in the Road?

The initial costs and benefits of electronic cinema are not distributed evenly. Distributors are likely to reap the immediate reward because distribution costs will be reduced, but exhibitors will be faced with the appreciable costs of replacing their film projectors with digital ones. To avoid implementation delays, an industry-wide means of distributing the costs and benefits will have to be developed.

Once its product is a bit stream, the movie industry will surely not be immune from the piracy concerns that have already confronted the software, video, and music industries. Encryption will be a major topic (and is one of the areas of expertise that Qualcomm brings to the CineComm joint venture).

There is also the problem of backward compatibility. How can valuable old movies on film be shown if there are no film projectors to show them? None of these problems are show-stoppers, but they must be resolved.

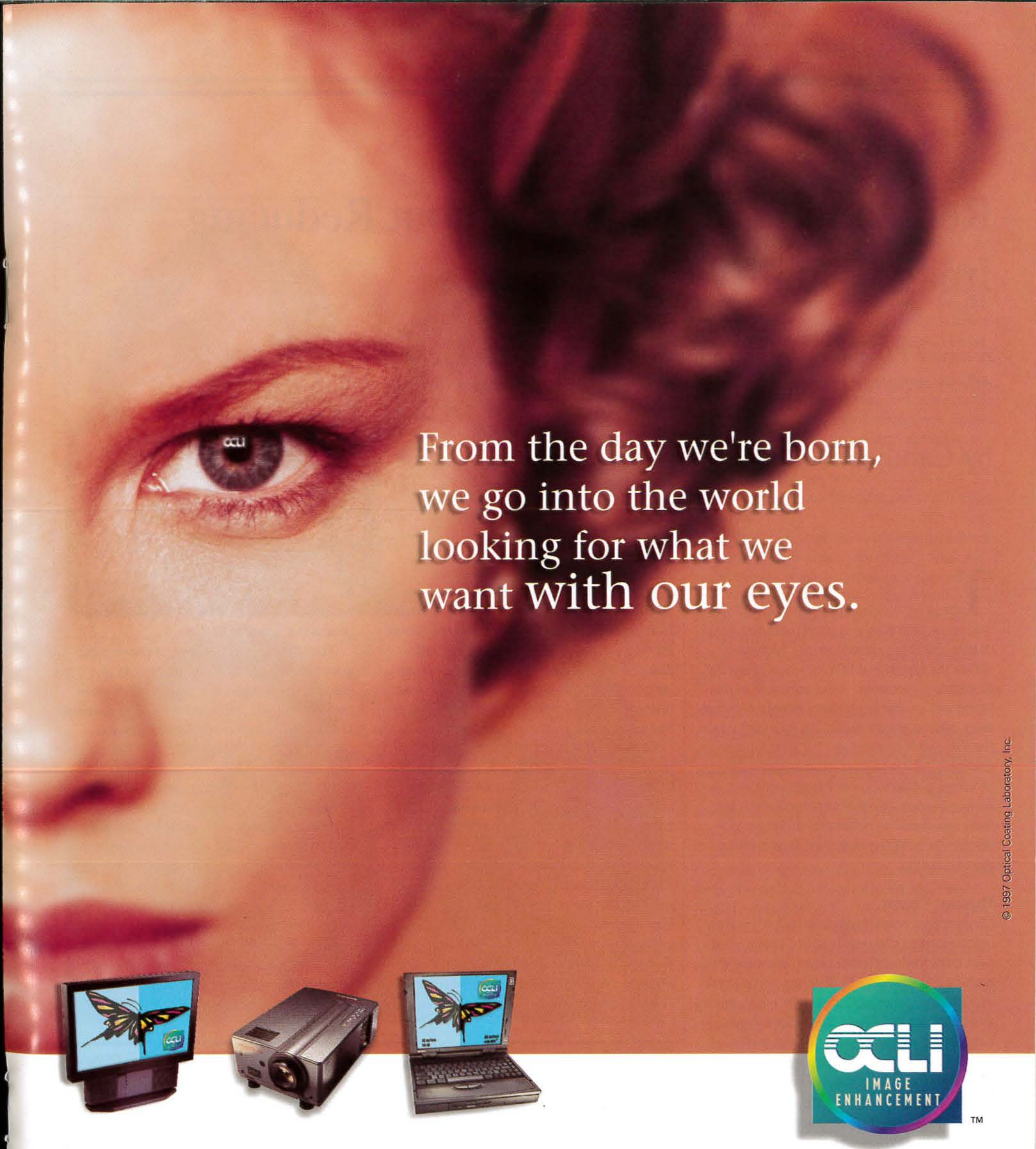
Things to Come

We are going to change the technology with which movies are exhibited, and that leads us to think about what the theater of the future will look like. First, it will be a location-based entertainment environment, as today's theaters are. It will not be an audio-visual headset because an important part of going to the theater is sharing the experience with other people. That's one of the things that differentiates the motion-picture industry from television in an increasingly large-screen high-definition era.

Image and sound must be of top quality, and there will be additional sensory experiences. Expect luxury appointments and guest services, as well as thematic design and production elements. All of this is based on the obvious requirement that the theatrical experience be noticeably better than the home television experience.

What's the bottom line? Digital cinema is inevitable. We now need to develop standards and incorporate continuing advances in display technology. We must proselytize to encourage the creative community to accept the new technology (the process is under way). And with the creative and technical benefits of the new technology firmly in mind, we can step forward to develop the next generation of theatrical cinema entertainment. ■

Please send new product releases or news items to Information Display, c/o Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003.


From the day we're born,
we go into the world
looking for what we
want with our eyes.
© 1997 Optical Coating Laboratory, Inc.
OCLI
IMAGE
ENHANCEMENT
TM

Reducing Pixel Count without Reducing Image Quality

A new FPD color-pixel arrangement offers reduced blue resolution, which offers a better match for human vision and promises to lower display cost.

by Candice Hellen Brown Elliott

THE MOST COMMON CONFIGURATION for red, green, and blue sub-pixels on a flat-panel display (FPD) is vertical stripes because it makes the layout and fabrication of the panel as simple as possible. Advances in manufacturing processes now make it practical to consider other configurations, but how else might the sub-pixels be arranged for an optimum display? As it turns out, the neurophysiology of vision points to a novel layout that can reduce the number of blue sub-pixels – and their associated switches and drivers – in a display without any reduction in perceived display quality.

Human Vision

We perceive color through the impulses from color-receptor nerve cells called cones. Our eyes have three different types of cones, and each type is sensitive to different wavelengths of light: long, medium, and short – red, green, and blue, respectively). These three types are not found in equal numbers on the surface of the retina. There are slightly more red receptors in the eye than green, and there are very few blue receptors compared to red or green.

The human visual system processes the information detected by the eye in separate perceptual channels referred to as the luminance and chrominance (chroma) channels. Luminance is related to that luminous power leaving a given position in an image and directed toward the eye (or any other receptor), and is the physical quantity most closely related to the perception of the brightness at that location.

Chrominance is the color of a given position in an image. A dark green object and a bright green object would have the same chrominance, but differing luminance. A bright red object and a bright green object would have differing chrominance but (perhaps) the same luminance.

The luminance channel takes its input primarily from the red and green cones. The blue receptor's contribution to luminance perception is less than 5% – just one part in 20. With equal power inputs and equal device efficiencies, a blue pixel does not look as "bright" as a green one. The luminance channel enhances the contrast of edges, in effect producing a bandpass filter.

The chroma channel does not have edge-contrast enhancement, acting instead as a low-pass filter. Because the luminance channel uses the red and green together, the luminance channel has a higher resolution than the chroma channel. This means that as they get finer and closer together, black and white lines can be better distinguished than contrasting but equally bright colored lines.

The chroma channel is further divided into two sub-channels, the red-green opposition channel and the yellow-blue opposition channel. The red and green colors combine to form the yellow that is opposed to the blue color. The red-green sub-channel has approximately one-half the resolution of the luminance channel, while the yellow-blue sub-channel has one-quarter the resolution of the luminance channel. In other words, we can

Candice Hellen Brown Elliott is a Senior Process Engineer at The MicroDisplay Corp., 3055 Research Dr., San Pablo, CA 94806; telephone 510/243-9515 x119, fax 510/243-9522, e-mail: cbelliott@microdisplay.com.

Table 1: Comparison of Drivers Required for Different Color-Pixel Arrangements

VGA (640 × 480) display driver requirements	RGB Stripe	RGB Triad	PenTile Matrix™
Number of column drivers	1920	642	800
Number of row drivers	480	480	480
Sub-pixels	921,600	308,160	384,000
Logical pixels perceived	307,200	204,800	307,200
Drive-scheme efficiency	0.33	0.66	0.80

0362-0972/99/1512-022$1.00 + .00 © SID 1999

C. H. Brown Elliott

Fig. 1: *These photos have progressively lower yellow-blue resolution while holding the red-green resolution constant. The photo at upper left shows equal resolution; at upper right, -1 octave; at lower left, -2 octaves; and at lower right, -3 octaves. Close up, the effects of the low blue-pixel resolution in the lower-right photo are obvious, but they become harder to see as the distance between the page and the viewer's eye increases.*

only resolve lines with the yellow-blue sub-channel that are four times as wide as those that we can perceive with the luminance channel.

Color perception is influenced by a process called "assimilation," or the Von Bezold color-blending effect. This is what allows the separate color pixels of a display to be perceived as a mixed color. This blending effect happens over a relatively large angular distance in the field of view. Because of the relatively scarce blue receptors, this blending happens over a greater angle for blue than it does for red or green. This angle is approximately 0.25° for blue, but only about 0.12° for red and green. At a viewing distance of 12 in., 0.25° subtends 50 mils (1270 μm) on the panel. Thus, if the blue pixel pitch is less than one-half of this blending pitch, *i.e.*, if it is less than 25 mils or 635 μm, the colors will blend without loss of picture quality.

This might not be the way an engineer would design a visual system, but it is reasonable to suppose that color perception is finely tuned for survival in the wilderness rather than for reading CAD drawings. It does not take much resolving power to perceive the yellow sun against a blue sky, nor is it terribly important.

But spotting a ripe red apple against a green backdrop of leaves delivers dinner. And seeing menacing shadows among the green leaves keeps one from becoming dinner. As a result, even the most perceptive viewer will barely notice that the blue resolution in an image has been reduced compared to red or green (Fig. 1).

Color-Pixel Arrangements

Color-pixel arrangements must put the separate colors close enough to blend. The colors must also be evenly distributed to maintain color value across the display. The best arrangements surround any given color with the other two.

The conventional color display for a laptop computer uses three sub-pixels: red, green, and blue. Typically, these are placed in vertical lines, or stripes (Fig. 2). This makes each column in the display a single color, and makes it easy to interface the panel in a manner similar to CRTs.

These columns may have different widths to provide color balance by adjusting the area of each color. Three sub-pixels, one of each color, in a row combine to form a logical pixel. Each color is bracketed on either side by the two other colors.

For color blending, the best arrangement is to form color triads in a pattern similar to shadow-mask-CRT phosphors (Fig. 3). This surrounds each color sub-pixel with three each of the two other colors. This system is popular for LCD television displays. The row electrodes may be straight, while the columns zigzag back and forth. Because the same column driver is turning on different colors at different locations and times, the triad system

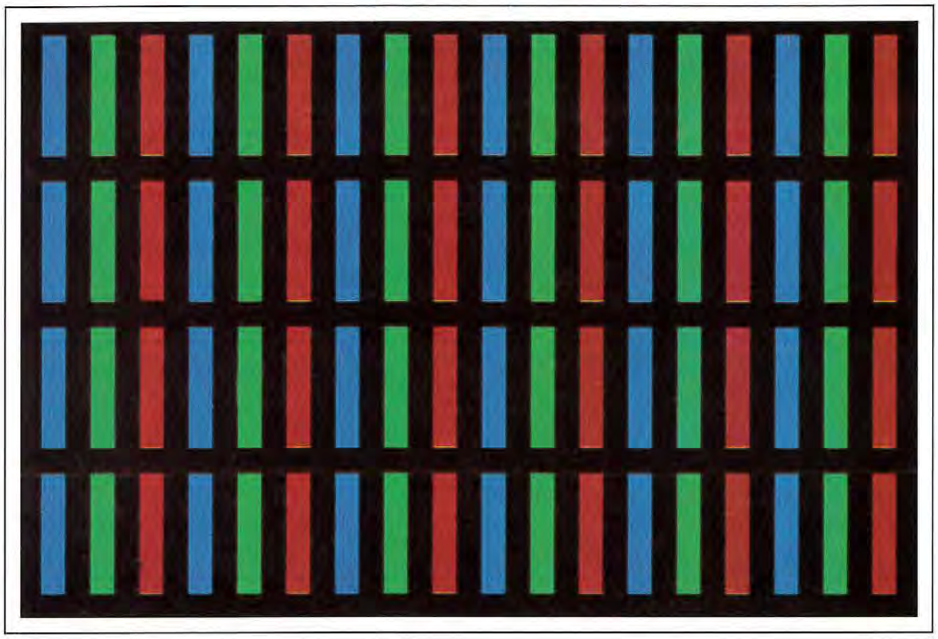


Fig. 2: The classic RGB striped color-pixel arrangement, used on most laptop PCs, provides more blue information than the eye can use.

requires slightly higher overhead to multiplex the color signals.

One advantage of the triad arrangement over the striped arrangement is that less area is lost to borders (spaces) between sub-pixels, leading to higher fill factors for greater brightness. A principle disadvantage of the triad is its reliance on the blue sub-pixel to carry high-resolution luminance information, a task that it cannot fulfill because of the limitations of the human visual system already discussed. The blue sub-pixel represents a loss of one-third of the logical-pixel information, significantly reducing the image quality. The triad configuration also has one-third less full-color resolution in the horizontal axis as compared to the vertical because a single white line can be displayed with only one straight horizontal row of pixels, while a single white line in the vertical direction requires a wider zigzag column.

So how does the display designer reduce cost without sacrificing image quality? The answer is surprisingly simple: optimize the color sub-pixel arrangement to work most efficiently with the human visual system.

The PenTile Matrix™ color-pixel arrangement is designed for just this purpose (Fig. 4).[1] The layout uses a "checkerboard" pattern of alternating red and green sub-pixels to carry the logical pixel information, and reduces the resolution of the blue information by one-half compared to the red and green, thus matching the capabilities of the human visual system. The blue now serves as a super-pixel, carrying only low-resolution chroma information - and each color is surrounded by the other two colors.

As with the color-triad layout, the PenTile Matrix™ color-pixel arrangement offers reduced cost and increased brightness due to reduced loss to borders. It also has the additional advantage that the logical pixels are in an orthogonal array – which is expected for computer graphics – with no loss of information because the blue super-pixel is not required to carry high-resolution luminance information.

The PenTile Matrix™ is driven by two rows and five columns for every two sets of pixel cells. The two blue super-pixels are driven by the same column driver, with one row of blue super-pixels being driven by alternating row drivers shared with the red and green rows.

The blue super-pixels are turned on to display the average blue value of the surrounding logical pixels; the calculations can be handled through software or hardware optimized for this task. This provides a more accurate value for the blue super-pixels than simply taking the value of the logical pixels to their left or right.

Cost and Performance

Reducing the number of blue sub-pixels can

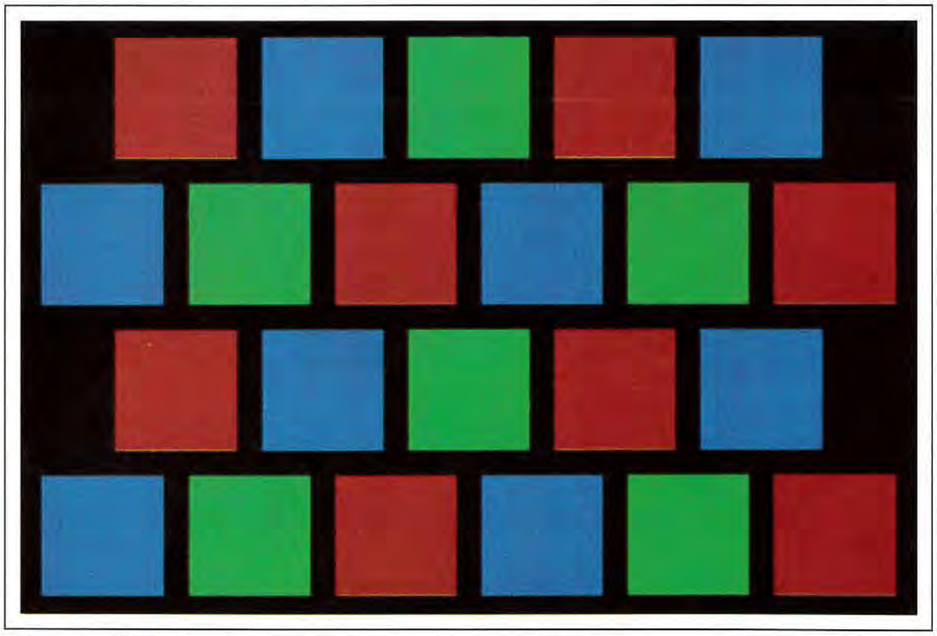


Fig. 3: The RGB triad color-pixel arrangement, used on some LCD TV displays and in many CRT TV displays, has less black space than the RGB striped array but still provides excessive blue information.

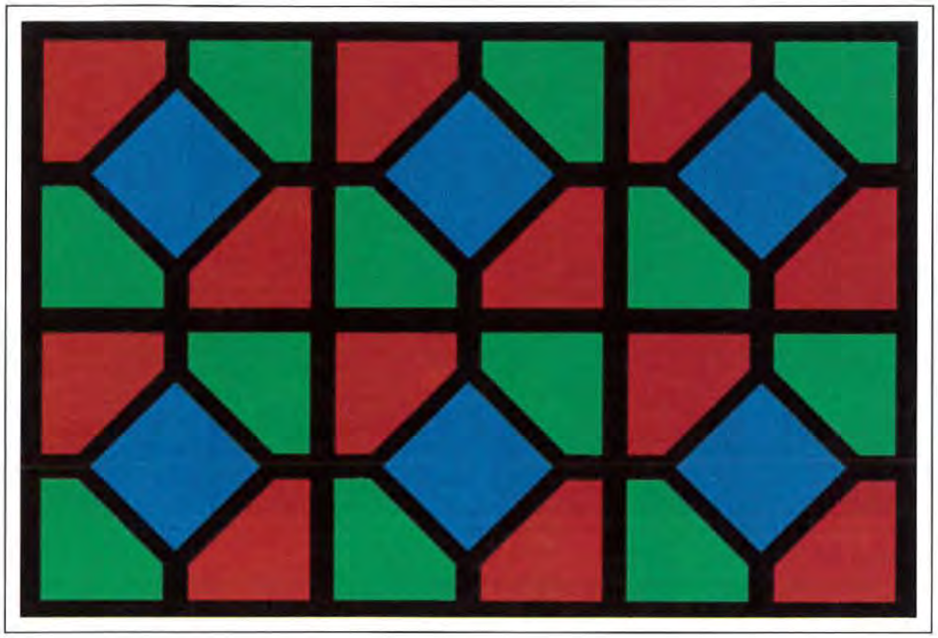


Fig. 4: The PenTile Matrix™ color-pixel arrangement provides only as much blue-pixel density as they eye can utilize, thus reducing the number of needed drivers and pixel switches.

lower production costs and increase image quality (Table 1). A full-color RGB striped arrangement using 2400 drivers will display a 640 × 480-pixel VGA image. In contrast, a PenTile Matrix™ design requires only 1280 drivers for VGA, and can display a 1024 × 768-pixel XGA image with only 2048 drivers.

Display technologies that use fine-line photolithography, such as active-matrix liquid-crystal displays (AMLCDs), may substitute the PenTile Matrix™ arrangement with no process changes. The reduced number of pixel switches is likely to increase the yield of the panel, further lowering the cost.

Technologies that use lower-resolution printing, such as thick-film electroluminescent (TFEL) displays, may have to adjust the shape of the pixels to reach a compromise between the optimum shapes and the fabrication design rules. However, virtually every display technology can use the PenTile Matrix™ arrangement. When this article was submitted for publication, two display manufacturers were involved in licensing negotiations.

The PenTile Matrix™ color-pixel arrangement offers both cost and performance benefits by creating displays that take advantage of the way we perceive color images – a concept that can be applied to any direct-address display, from microdisplays to billboards.

Note

[1]For more information on the PenTile Matrix™ contact PenTile Matrix Licensing, 531 York Street, Vallejo, CA 94590; telephone 707/552-1902, e-mail: pentile@monitor.net, www.monitor.net/~pentile. ■

25 **00**

SEPTEMBER

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

Medical-Imaging Systems Move Toward AMLCDs

Medical-imaging systems have favored CRTs for high-resolution applications, but the improving image quality of AMLCDs is tantalizing the medical field with new opportunities.

by Wayne Connell

SEVERAL medical-imaging techniques are used for examining soft tissue, connecting tissue, bone, and blood flow within the body. Today, the CRT is the only viable display choice for high-performance medical-imaging systems because of its high resolution, fast temporal response, and sustained performance at extreme viewing angles (Fig. 1). But tomorrow's display of choice will most likely be a flat-panel display (FPD).

The acceptance of FPDs for medical-imaging applications will be based on several factors not necessarily significant to other applications. Understanding the obstacles to the eventual transition from the CRT to FPDs will help facilitate a successful and timely acceptance.

The medical diagnostic imaging industry has undergone many changes in the last two decades. While advances in image-data acquisition and processing have significantly improved the performance of diagnostic systems, advancements in applicable display technology have occurred at a much slower pace. Although the image quality of LCD monitors (LCMs) has improved significantly in the past few years, LCMs still have problems in gray-scale rendition, viewing angle, uniformity, and response time.

Wayne Connell is Display Program Manager for Advance Technological Laboratories Ultrasound (A Philips Company), P.O. Box 3003, Bothell, WA 98041-3003; telephone 425/487-7636, fax 425/486-5220, e-mail: wconne@corp.atl.com.

The Clinical Environment

Diagnostic ultrasound, along with several other medical-imaging techniques, are concerned with subtle differences in the body. The display that is a part of such a system should present all available information to the clinical specialist with sufficient detail to permit accurate identification of the region of interest. This is especially true when the display is the only system output device providing diagnostic information to the clinician.

Because the monochrome image data from a diagnostic-ultrasound system is displayed on

ATL Ultrasound

Fig. 1: Today's medical-imaging systems use CRTs because of their high resolution, fast temporal response, and wide viewing angle, but interest in FPDs is increasing.

0362-0972/99/1512-026$1.00 + .00 © SID 1999

ATL Ultrasound

Fig. 2: The gray-image data in a typical ultrasound display is generated by a 24-bit video driver that supports 256 levels of gray. The pseudo-color data is presented with two color progressions of 128 colors that represent the direction and velocity of blood flow.

a color CRT or FPD, the limited dynamic performance of these displays tends to compromise the image quality. The users of such systems expect the image luminance to range between 0.3 and 250 cd/m^2. This translates to a black-to-white contrast ratio of about 800:1.

To minimize the amount of light reflected from the display and the consequent degradation in the perceived dynamic performance of the display, illumination in the examination room should be maintained at less than 0.2 lux. The darkened exam room maximizes the luminance range of the display and optimizes the contrast threshold, assuring the visualization of all available image information obtained in the diagnostic exam. The rendition of gray scale is managed by the video subsystem with a look-up table (LUT), enhancing the differentiation of subtle visual targets. The LUT should also manage the chromaticity of the "gray" shades because the clinical user is typically very sensitive to low-level errors in background color. It is likely that display controllers will have to be modified to accommodate the differences in color characteristics between CRTs and FPDs.

Display Performance

As medical systems increasingly use FPDs instead of CRTs, there will also be changes in the techniques for evaluating display quality. The factors that determine image quality are luminance range, veiling glare, contrast threshold, color, reflectance, brightness uniformity, viewing angle, resolution, response time, stability, and test metrology.

The information shown on a display is composed of text, graphics, color, and gray-image data. The gray-image data in a typical ultrasound display is generated by a 24-bit video driver that supports 256 levels of gray. The pseudo-color physiological data associated with ultrasound displays is presented with two color progressions of 128 colors, with each progression representing the direction and velocity of blood flow (Fig. 2).

Some of today's CRT-based imaging systems have a 10-bit digital-to-analog converter (DAC). Since the human visual system can resolve up to about 500 gray shades at best, the 10-bit CRT display is perhaps sufficient today. However, the 10-bit DACs are typically not used to present 1024 shades of gray but to present 256 gray shades out of a palette of 1024, which could present a perceptually optimal display function.

A commonly used specification is contrast ratio. Although this specification appears simple, it is actually complicated because it is determined by the maximum luminance, the black level, the intrinsic veiling glare of the display, and reflected ambient light. To complicate things even more, the maximum and minimum luminance of a display (L_{min} and L_{max}) vary with viewing angle. Veiling glare, which is caused by the electron scattering generally associated with color CRTs, reduces the intra-image contrast in real imagery, particularly small-detail contrast in dark image areas. Veiling glare is significantly less in active-matrix liquid-crystal displays (AMLCDs) than in CRTs (Fig. 3).[1]

Uniformity Is Critical

Regardless of technology, the display must present a high degree of parameter uniformity across the active image area. A perceived lack of uniformity diminishes the image quality of the particular display and may degrade the quality of diagnostic information obtained from the display. This is particularly important when considering luminance and color uniformity within a typical viewing-angle range of ±45°.

Manufacturers are beginning to supply AMLCD monitors with claimed viewing angles up to 160° horizontally and vertically. But our experience indicates that these claims contain some degree of creativity. We found considerable deviation when measuring the center luminance at various horizontal angles.

When one evaluates display performance at non-perpendicular orientations, it is important to maintain luminance, color, luminance uniformity, and color uniformity over the entire viewing cone. This is required to comply with the user's expectation that display performance, and therefore image accuracy, does not depend on the display's position relative to the observer.

Unlike most other components in a diagnostic or clinical system, displays slowly degrade over time. Designers must consider performance stability when developing a display for a medical application. The luminance and color bias must be maintained within a few just-noticeable-difference (JND) units over the lifetime of the display.

The environmental robustness of the display and backlight technology are essential factors. While CRT decay characteristics are well known, FPD technologies pose different aging issues that must be considered when applying a specific flat-panel technology to a medical-imaging application. If automatic compensation is not provided, frequent maintenance may be necessary.

It is also important to provide consistency of image presentation from unit to unit over their entire lifetimes. In many clinical set-

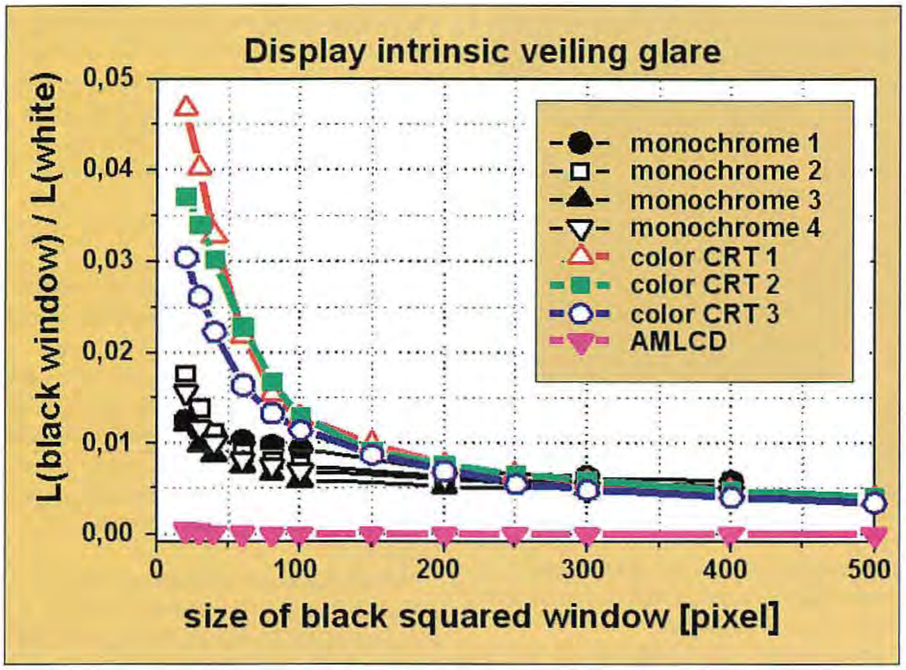


Fig. 3: Veiling glare, which generally goes up as the size of the "black squared window" goes down, reduces the intra-image contrast in real imagery, particularly small-detail contrast in dark image areas. Veiling glare is significantly less in AMLCDs than in CRTs. [Figure courtesy of G. Spekowius, "Image quality assessment of color monitors for medical softcopy displays," SPIE (1999).]

tings, multiple systems operate in close proximity to one another. If the perceived performance of these systems is not identical, confidence in the system and display is generally compromised. In addition, if performance parameters change over time, a long-term patient diagnosis may be compromised. Although it is not important for an FPD's aging process to match that of a CRT, a mechanism is needed to assure that the FPD's perceived image quality does not change over its functional life.

In general, noticeable differences between two displays in a clinical setting first appear in background color and maximum intensity. We have found that the optimum neutral gray color for diagnostic ultrasound displays should be x = 265 ± 10, y = 240 ± 10 at 0.3 cd/m^2. White should be x = 270 ± 10, y = 275 ± 10 at 170 ± 5 cd/m^2. This tolerance on the color coordinates must be maintained over the life of the display system.

Unlike CRTs, FPDs can provide a precise relationship between the synthesized pixel and the viewable image element. It is therefore important for the display of monochrome medical images to select an image matrix that corresponds to the display's dot matrix. Specifically, the horizontal dot pitch of a display must be smaller than the horizontal pixel distance to prevent observable aliasing.

Some medical diagnostic procedures rely on real-time visualization of anatomical structures, and some – such as cardiac motion or blood-flow analysis – rely on visualization of rapid motion as a significant diagnostic marker. If the display's response is so slow that these motions are rendered with diminished luminance, the perceived motion may appear blurred or may be missed completely.

Because display defects may compromise a diagnostic procedure, there can be little tolerance for defects – a more difficult requirement for FPDs than for the more mature CRT. In general, a defective pixel or visible optical defect anywhere on the active display area is considered unacceptable. However, we need to establish a new standard for the just-noticeable-defect as it applies to FPDs.

Cost *vs.* Performance

In general, the overall performance of medical-imaging systems has increased substantially over the last few years, while display performance has not increased very much. This has generated the notion that display performance has constrained system performance.

The challenge is that diagnostic medical systems continue to increase in sophistication, with images that are more complex and detailed, with better graphics, and with better consistency of imaging results. It is important to recognize these advances and to integrate a display that complements the system's capabilities.

With the transition to FPDs, new ergonomic features are being considered to enhance systems. These features are not related to image quality, but they will add to overall system value. Because FPDs have a much different physical profile, new packaging opportunities will become available to system designers and eventually become significant cost drivers. So we are faced with a situation that is more complicated than simply replacing a CRT with an FPD of similar cost but which also provides more opportunities.

Developing Technology

In medical-imaging systems today, the display is generally a component at the end of the image-processing pipeline. Tomorrow, the display will be integrated into the system, with display-performance information fed back to the image-generation engine. This kind of integration is not yet provided in the mass-market display systems used in personal computers, and may be very difficult to implement under mass-market cost constraints.

Flat-panel technology is changing rapidly, which is not true of the mature and stable CRT technology that medical-systems designers have relied on for many years; consequently, there will be rapidly developing applications, performance, and product form factors. The downside of this rapid technological development is the difficulty in maintaining display-supply stability over a number of years. System designers using this new technology must accept the added expense of ever-changing display designs or demand a less costly upgrade path to improved performance.

Conclusion

The medical community has many expectations for medical-imaging displays, most of which are rooted in their experience with CRTs. The dynamic gray-scale range and general image quality of CRTs set today's standard, but expectations in the medical-care industry will evolve as the FPD increasingly penetrates medical applications. Of course, degradation of subjective performance will not be acceptable, but the emergence of FPDs in diagnostic medical applications will precipitate a change in operational procedures and display-performance expectations.

The FPDs available today are not suited to high-quality diagnostic interpretation and the dynamic clinical community – especially in cardiology and fluoroscopy. But that will change, and the potential impact of FPDs on diagnostic systems will be exciting.

A great deal of effort must go into developing flat-panel technology optimized for the medical-diagnosis and clinical-imaging community. It will also require enormous resources to provide a display technology that is focused on this community's unique needs. Most FPD development is intended for the mass markets, with little emphasis placed on niche markets such as medical imaging.

With the emergence of FPD technology, there's a greater need for collaborative development and a cooperative environment in which costs can be shared and in which FPD-based products can be brought to market expeditiously and without compromise. This process will not be easy, but with medical displays moving toward standardization and away from differentiation, we should at least see a convergence of expectations that will provide a well-defined target.

Notes

[1]G. Spekowius, "Image quality assessment of color monitors for medical softcopy display," SPIE (1999). ■

Please send new product releases or news items to Information Display, c/o Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003.

Calibrating Colorimeters for Display Measurements

Some commercial colorimeters have uncertainties in display-color measurements that are too large for many commercial, industrial, and military applications - but new NIST-developed calibration procedures solve the problem.

by S. W. Brown, Y. Zong, and Y. Ohno

HOW RED IS RED? Many display applications have stringent requirements for color accuracy where precision is critical, yet measuring that accuracy is more difficult than one might think. Medical and avionics displays must have reliable color to convey essential information. Color-management systems must have accurate color data in order to perform effectively. The manufacturers who develop these products and the people responsible for purchasing them typically rely on results from commercial color-measuring instruments, both colorimeters and spectroradiometers.

In many cases, results from these instruments are used to accept or reject display products without much attention paid to the accuracy of their measurements. If the colorimetric measurements of these displays are inaccurate, a user may accept an inadequate product or reject a perfectly good one.

In order to make effective use of any instrument, one needs to know the measurement uncertainty, and this is true for colorimetry. Only then can one tell how well the color-mea-

__Steven W. Brown__ is a physicist, __Yuqin Zong__ is a guest researcher, and __Yoshi Ohno__ is a physicist in the Optical Technology Division at the National Institute of Standards and Technology, 100 Bureau Dr., Stop 8442, Gaithersburg, MD 20899. All correspondence should be addressed to Y. Ohno at 301/975-2321, e-mail: ohno@nist.gov.

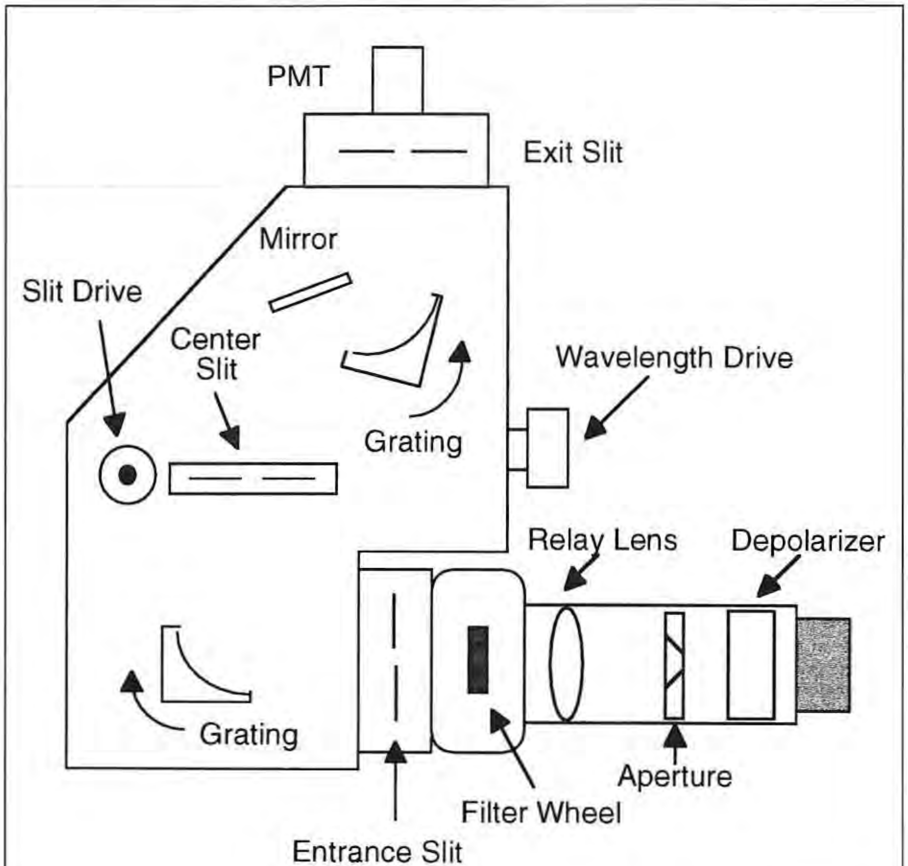


Fig. 1: Schematic diagram of the NIST reference spectroradiometer.

0362-0972/99/1512-030$1.00 + .00 © SID 1999

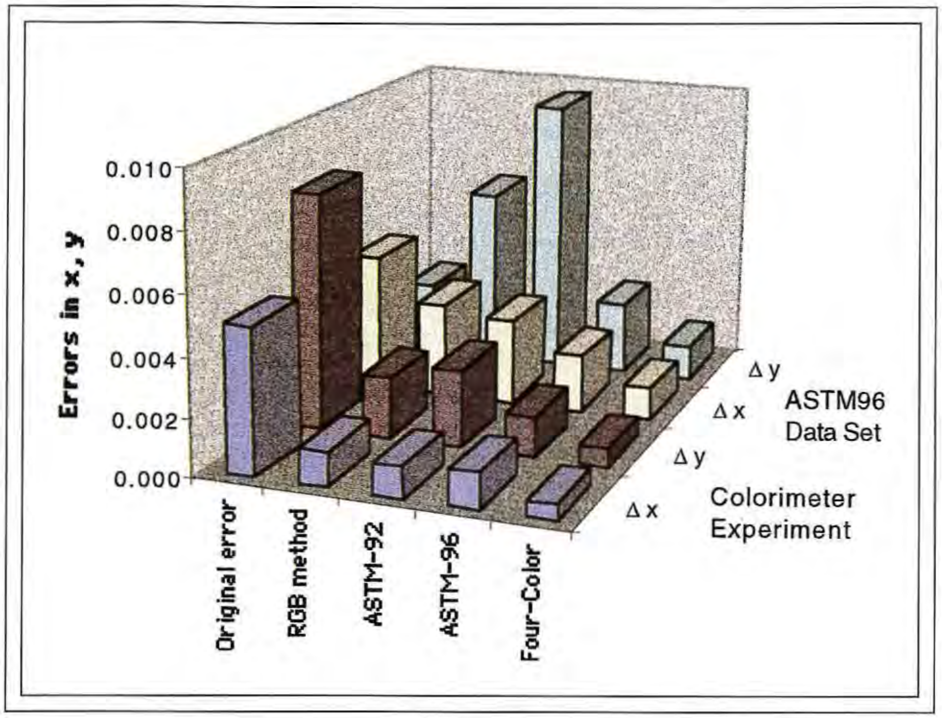


Fig. 2: Root-mean-square differences in chromaticity for 10 CRT colors, after correction by various matrix methods.

surement system is performing, and whether or not it can do the job one needs it to do.

There is an increased appreciation of this issue in military and commercial fields; many applications now include requirements for the uncertainties for display color measurements. For example, some military specifications require expanded uncertainties ($k = 2$) of 0.004 in chromaticity (x,y) for test equipment, while uncertainties of 0.005 or less in x,y are recommended in international standards for color measurements of cathode-ray tubes (CRTs) and liquid-crystal displays (LCDs). An expanded uncertainty of $k = 2$ means that the measurements will agree with the true value to within the stated uncertainty 95.4% of the time.

Instrument manufacturers typically calibrate their colorimeters. Product data sheets routinely specify uncertainty values on the order of 0.002 in x,y, and 2% in luminance (Y). A note of caution: these values may be misleading; in particular, for display measurements. They are often based on measurements of an incandescent source with a color temperature of approximately 2856 K. These sources approximate the spectral power distribution of the Commission Internationale de l'Eclairage (CIE) Standard Illuminant A, which is a common standard source used in both photometry and colorimetry.

There are problems with using just this type of source. As long as one uses the instrument to measure sources with spectral power distributions similar to that of Illuminant A, one could expect to get accurate results.

However, we typically want to measure the color and luminance of displays having spectral distributions that are quite different from Illuminant A. Comparative testing shows that the accuracy of color-measuring instruments can vary significantly, depending on the spectra of the colors measured.

In the case of colorimeters utilizing three or four broadband detectors, called "tristimulus colorimeters," the relative spectral responsivities of the individual channels to the CIE color-matching functions (x-bar, y-bar, and z-bar) may not be matched well. This results in errors when the device is used to measure different spectral distributions.

In the case of array spectroradiometers, a number of factors can contribute to the accuracy of color measurements, including stray light, wavelength scale errors, and the linearity of the detector array.

No matter what type of device is used, the error analyses are complex and the uncertainties of color-measuring instruments for various displays – and for different colors – are often not well known. So even if an instrument is calibrated accurately against an incandescent source, we don't know how well the instrument can subsequently measure the chromaticity and luminance of display colors.

Empirical evidence demonstrates how significant this problem can be. We took a number of colorimeters and measured the chromaticity of various colors of a display. We found that inter-instrument variations in the measurements were as large as 0.01 in x,y and 10% in Y, depending on the color and type of display being measured. These variations are an order of magnitude larger than expected from the manufacturers' specified calibration uncertainties, and imply that the uncertainty of some of the commercial instruments is at this level for display color measurements. Uncertainties in color measurements on this order are too large for many current commercial, industrial, and military applications.

In many applications, calibration approaches relying solely on incandescent sources are not adequate to meet current needs in display measurements. The National Institute of Standards and Technology (NIST) has addressed this problem by developing a calibration facility in Gaithersburg, Maryland, for colorimeters tailored to display measurements.

During a calibration, test instruments – colorimeters or spectroradiometers – are calibrated in direct comparison with a reference instrument while measuring various colors of actual displays. Upon calibration, a colorimeter can be used to measure any color of the display with a known uncertainty in chromaticity and luminance.

NIST Calibration Facility

Both source-based and detector-based methods are commonly used as transfer standards in calibrations. Unfortunately, displays are not colorimetrically stable and reproducible enough over long time periods to be used as a source for transfer standards. As a result, we have employed a detector-based calibration strategy.

The detector-based scheme starts with a reference instrument with known characteristics. This reference instrument and the instrument to be calibrated are used to measure various colors of a particular display. The differences in results determine the errors of a test instrument. Once these errors are known, they can be corrected when the test instrument is subsequently used.

In general, the errors – in both chromaticity and luminance – vary depending on the color of the display. A look-up table for the errors with different colors would be difficult to maintain. We chose a more manageable approach, deriving a correction matrix for the test instrument based on measured errors. This matrix makes it possible to correct for any color of a particular display, transferring the calibration from the NIST reference instrument to the test instrument.

In order for this strategy to work reliably, three cornerstones must be in place. We require a stable, well-characterized reference detector to be used for the display measurements, an effective matrix-correction technique, and a display that is colorimetrically stable over the course of a typical calibration measurement sequence.

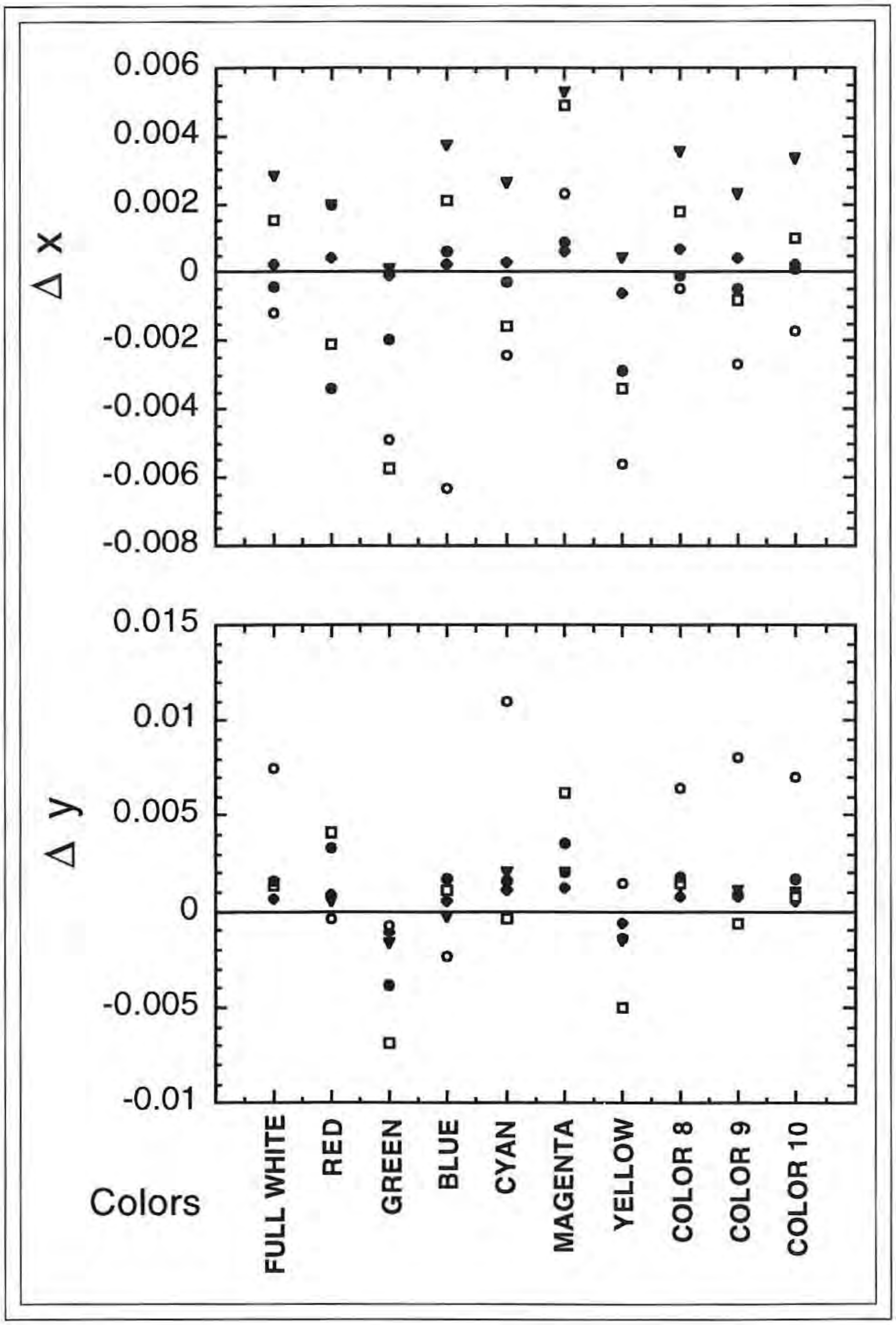


Fig. 3: Uncorrected chromaticity differences between five test instruments and the NIST reference instrument for 10 colors of a CRT display.

The NIST Reference Instrument

The reference spectroradiometer consists of imaging optics, a double-grating scanning monochromator for wavelength selection, and a photomultiplier tube (PMT) (Fig. 1). The output of the PMT is sent to a digital voltmeter and the voltage is recorded as a function of wavelength by a computer. The input optics include a depolarizer and order-sorting filters. The depolarizer reduces the polarization sensitivity of the instrument to less than 1% while order-sorting filters placed in front of the spectrometer entrance slits eliminate higher-order grating diffraction effects.

This design results in a reference instrument with suitable characteristics (Table 1). It can measure CRT colors with an expanded uncertainty of approximately 0.001 in chromaticity and 1% in luminance.

Four-Color Matrix-Correction Method

The second cornerstone is an effective correction-matrix technique that can be used to improve the accuracy of tristimulus colorimeters for color display measurements. The first step is to measure the differences in results

Table 1: Reference Spectroradiometer Characteristics

Parameter	Value
Wavelength uncertainty	±0.1 nm
Slit scattering function	5 nm ± 0.1 nm; triangular
Stray light factor	$<2 \times 10^{-6}$
Polarization sensitivity	<1%
Random noise	<0.2% of the peak signal

from the reference instrument and the instrument being tested, when both measure various colors of a display. This data can then be used to create a 3 × 3 correction matrix. The correction matrix can then be used to transform the test instrument's tristimulus values to more closely approximate the reference values. The corrected values from the test instrument are thus expressed as linear combinations of the uncorrected values.

The trick here is to create a correction matrix that accurately transforms the values, and several different approaches have been developed. For example, the American Society for Testing and Materials (ASTM) recommends a method that minimizes the root-mean-square (rms) difference between measured and reference tristimulus values for several different colors of a display. The chromaticity values are then calculated from the corrected tristimulus values.

But this method does not always work as well as expected. Because the ASTM method is based on the transformation of tristimulus values, it is susceptible to luminance errors arising from display instabilities and inconsistent alignment of the instruments that affect the accuracy of the corrected chromaticity values.

Measurements of chromaticity values are normally more stable and reproducible than measurements of tristimulus values. They are relative measurements, so many of the sources of luminance error tend to be reduced or canceled. Consequently, a matrix-correction method – the Four-Color Method – was developed that reduces the difference between measured and reference chromaticity values rather than tristimulus values. Because the new method is based on chromaticity values, it is insensitive to luminance errors and consequently tends to work better than previous methods.

A comparison of corrections by various matrix methods demonstrates the differences in residual post-correction errors (Fig. 2). In a test with 10 display colors, the Four-Color Method reduced the corrected rms chromaticity differences more than the other techniques.

Matrix-correction techniques assume that the spectral distributions of the three primary colors do not change. However, there are small variations in primary spectra between displays incorporating the same type of phosphors and, frequently, large variations between displays incorporating different types of phosphors. The Four-Color Method works well (within ±0.001 in x,y) for small spectral variations in the primary colors within the same type of display, but is not effective if there are large variations between the measured display and the display used in the derivation of the correction matrix. A calibrated instrument can therefore measure any number of different displays utilizing similar phosphors to the display used for the calibra-

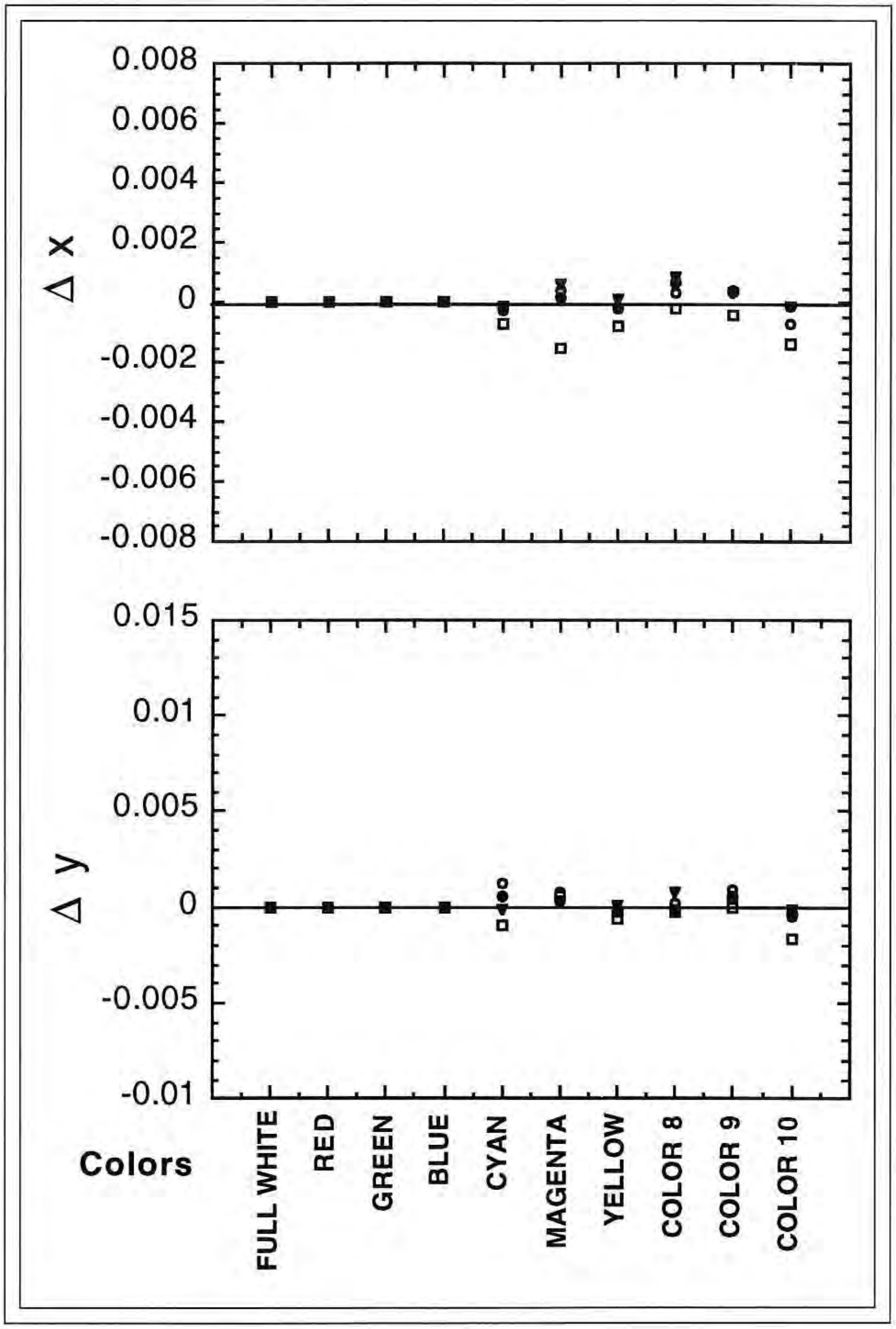


Fig. 4: Residual (post-correction) chromaticity differences between five calibrated test instruments and the NIST reference instrument for 10 colors of a CRT display.

tion, but a separate correction matrix should be obtained for each different type of display.

Calibration Results

At NIST, we calibrated five disparate commercial instruments – including tristimulus colorimeters and array spectroradiometers – for a CRT against the NIST reference instrument. We used a broadcast-quality color CRT as the calibration source. This display demonstrated negligible chromaticity changes over the course of a comparison measurement which took about 30 minutes. The five test instruments and the reference instrument measured 10 of the CRT's colors, and the chromaticity differences between the NIST reference instrument and the test instruments were recorded (Fig. 3).

We observed significant differences in the measured chromaticity values between the different units, with some instruments agreeing with the reference instrument to within ±0.002 in x,y for all colors measured, and other instruments disagreeing by greater than ±0.005 for certain colors. This is perhaps to be expected since these instruments varied greatly in design and complexity – and in price. In general, they were all high-quality instruments; we would expect even larger differences with lower-grade instruments.

Using the primary-color measurements and white, we derived the correction matrix for each instrument using the Four-Color Method. We then applied the corrections to the 10 colors measured, and calculated the residual chromaticity differences between the NIST reference instrument and the calibrated test instruments (Fig. 4). The results provide a dramatic illustration of this calibration method's effectiveness.

We obtained similar results for the luminance measurements, with the calibrated instruments agreeing much better with the reference instrument results for four out of the five instruments. In the one exception, the difference in luminance measurements between the test and the reference instruments was not reduced upon application of the correction matrix. This result underscores that when experimental noise or luminance errors are significantly large, the Four-Color Method is not the most suitable for luminance correction.

We know that we can measure various colors of the CRT with the reference instrument with an expanded uncertainty of 0.0012 or less in x,y and that the calibrated instrument agrees with the reference instrument to within 0.001 in x,y. Therefore, the expanded uncertainty of CRT chromaticity measurements using the calibrated instrument – taking the maximum uncertainty in each case and taking the root-sum-square of the uncertainties – is 0.0015 in x,y or less. Taking into account the repeatability of the test instrument as well, the expanded uncertainty of chromaticity measurements of a CRT using a NIST-calibrated instrument should be on the order of 0.002 or less.

Our results demonstrate that this calibration procedure can be used to correct measurements from different colorimeters, using a reference instrument for comparison, even when those test instruments produce large differences in uncalibrated measurements for the same display colors. This calibration can bring the expanded uncertainty for these devices to 0.002 in x,y or less – well within the limits required for general test equipment, as well as the limits recommended for international standards.

The NIST facility will offer official calibration services using this technique early next year. As a result, display manufacturers and users will be able to know if the red on the screen is truly red.

Acknowledgments

We would like to thank Joe Velasquez and John Grangaard for useful discussions. This work was supported by the U.S. Air Force under CCG contract 97-422. ■

Please send new product releases or news items to Information Display, c/o Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003.

continued from page 4

more enjoyable to examine an object of our dreams before we decide to buy it and take it home? Isn't there something pleasurable about browsing through a bookstore, comparing the latest projection televisions or laptop computer displays, or fondling the new two-megapixel digital cameras before selecting the one that feels the best in our hands? A downloaded low-resolution image along with a cursory spec-sheet somehow doesn't have the same appeal.

On the other hand, when we arrive at work, don't most of us start the day by logging on to our computers, reading (or deleting) the latest e-mails, looking at our daily calendars, and then working on (or responding to) these various communications? Then we spend the rest of our days in meetings - most of which are unnecessary - on more desk work, and perhaps in a few seriously valuable one-on-one interactions. Of course, some of us get to do truly fun activities such as performing experiments in a laboratory (sometimes known as R&D), and a few others actually work at making things (often called manufacturing). This minority of the population and those in service industries of course need to be at particular locations in order to accomplish their hardware-related tasks, and they must arrive at and depart from work at pre-designated times. However, in these days of high-speed voice and data communications, most office-type work could be done at any location that can accommodate a computer and a telephone line. Most meetings can be eliminated and replaced by an occasional encounter - two or three times per week at most. Even those who spend a significant amount of their time in a laboratory seldom need a regular eight-hour day to accomplish their tasks.

Doesn't this seem incredibly logical? For the last three years, I have personally been conducting exactly this kind of an experiment. It has worked out surprisingly well. But then I've never done my best when trying to follow conventional paths.

It may take some time, but I think there is a growing possibility that more and more people will begin to create work environments outside of traditional corporate office structures. What is really fortunate is that all of the Internet appliances that are now being developed and will soon appear in ever greater numbers will be as well suited for doing real work as for doing the currently over-promoted Internet versions of "mail-order" shopping.

Personal computers have become a mature product. In the future, we will not see the dramatic increases in speed and processing capability that we have experienced over the last fifteen years.

For an instructive historical comparison, let's consider how the premier electronics measurement instrument, the oscilloscope, evolved. From its introduction as a precision measurement tool shortly after the Second World War, the oscilloscope has been the most important instrument in most electronics laboratories. For many years, Tektronix and Hewlett-Packard oscilloscopes were considered by many to be the best available. The early oscilloscopes struggled to get to bandwidths of only a few megahertz, and sensitivities were sometimes not all one would have liked. Then, over about a ten-year period, models were developed with bandwidths exceeding 10 MHz, then 20, and then 35.

The next big challenge was to get to 100 MHz. That seemed almost impossible. The first Tektronix product attempting to meet this target fell somewhat short, at around 80 MHz. But then a relatively unknown competitor, Fairchild, achieved the 100 MHz. This set the new standard and the speed race was on. Soon came 200 MHz and then, in what seemed like the realization of a science-fiction fantasy, Tektronix introduced a 500-MHz oscilloscope.

The technology was on a roll. Some expected that soon would come 1-, 2-, then 5-GHz oscilloscopes, and so on. (Well, there actually was a 1-GHz oscilloscope, but it never became a major product.) Even though the technology could reach that lofty performance in a premium product, there were few engineers or scientists who needed such a measurement capability. The analog oscilloscope race stopped at about 500 MHz, and the core of the market for many years was at around 200–300 MHz. What happened and how does this apply to today's desktop-computer technology?

The answer is that the world of circuit design gets ever so much harder once operating speeds get above 500 MHz. And above 1 GHz, we enter the realm of the microwave engineer. At these higher frequencies, signals no longer want to propagate inside or along conductors. The interconnects become antennas. Digital no longer looks like digital; everything looks analog again. Any mismatched impedances result in losses, reflections, and phase shifts. Broadband becomes narrowband. Signal propagation becomes more important than the design of the active circuits. To most digital designers, this is a strange and unfriendly world, and the rules of digital design no longer produce the expected results.

For these reasons, I think we will encounter a barrier with our computers, as earlier happened with test and measurement instruments. We will find that "the wall" is still somewhere around 1 GHz. Fortunately, for just about everything we want to do, including image processing, that will be "good enough." It will also match the foreseeable bandwidth capabilities of communications systems.

If the speed race is about to end, then what will be the next new direction? I think it will be toward more Internet-based appliances, more products that are convenient to use, and, of course, further advances in data storage to accommodate complex image- and voice-based computing. We really don't need 500-MHz computers to read and respond to e-mails. A telephone-based Internet appliance should be more than sufficient for that. Portable telephones will soon have similar capability. A laptop computer should be configured for specific needs and not be a generic device that is too heavy and has too little battery life. The new market opportunities will be to address the needs of specialized tasks. We will move beyond the "Swiss army knife" appliance that the desktop computer has become. We can segment our activities into text processing, image processing, communications, and so forth, and respond to each of these with products having optimized functions. The Personal Digital Assistant is an early, albeit rudimentary, example of what I'm suggesting.

All of these Internet appliances will need new displays in a variety of formats. It's great to know that no matter exactly how these products evolve, we display developers will be at the center of the action. We're a vital part of it all. There will be no end of interesting opportunities.

Therefore, as you cheerfully do your Holiday shopping this year, begin to look for these appliances. We are in the very early stages of what will soon be a wave of new products. Go to the malls. Take a trip to the electronics stores. Visit your local bookstore. Shop on the Internet only as a last resort. And, finally, suggest to your boss that you will stay home

display continuum

and avoid the rush-hour commute because you can be more productive that way. Won't that be a great Christmas present for your company and for you?

Should you wish to send me a Holiday greeting, or to let me know how your boss responds to the above suggestion, you can reach me by e-mail at silzars@attglobal.net, by phone at 425/557-8850, by fax at 425/557-8983, or by conventional letter - which will likely take a portion of its journey to 22513 S.E. 47th Place, Issaquah, WA 98029 on an airplane that will fly no faster than the ones of thirty Christmases past. ■

editorial

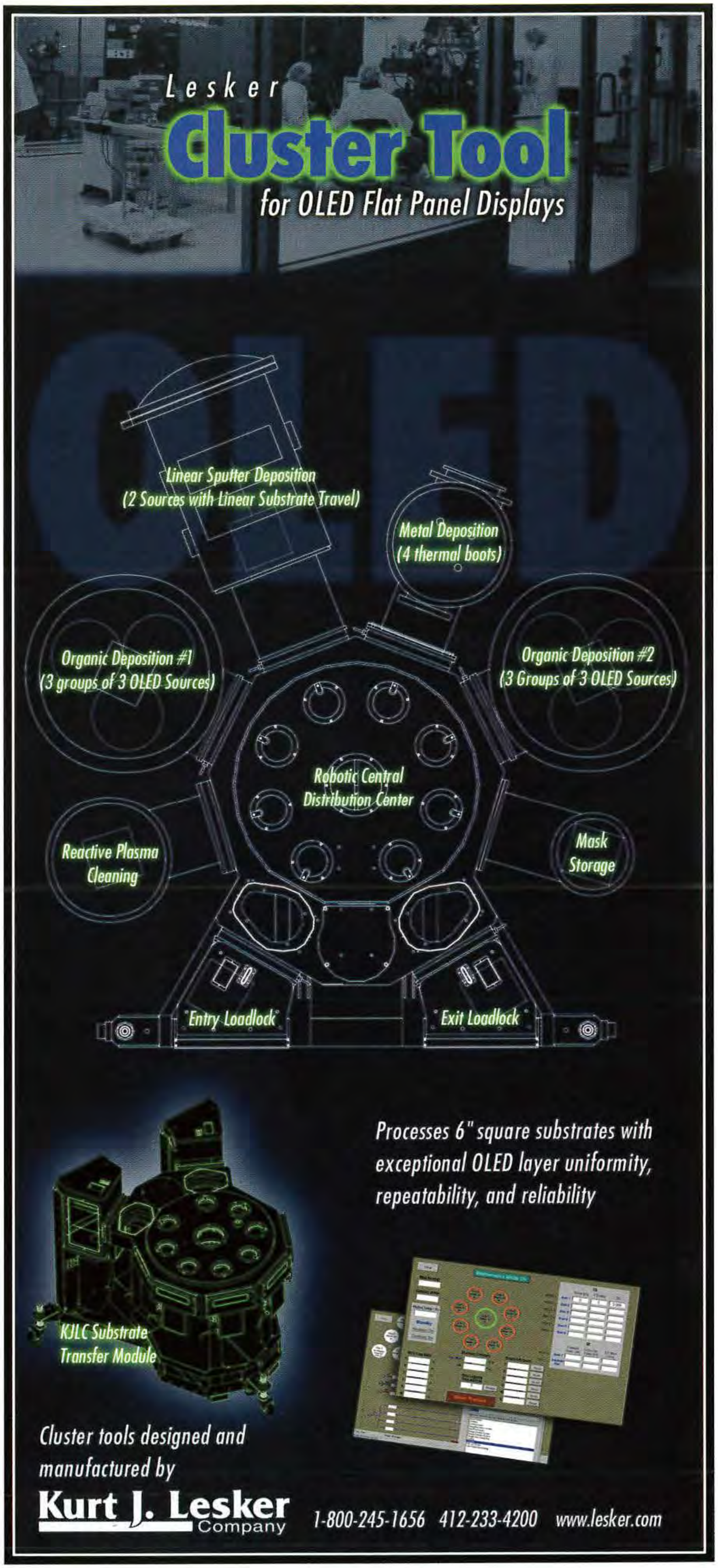
continued from page 2

American LCD Workshop, he regretted he could not squeeze some Iberian ham and good Rioja wine into the bit stream. For that, I will have to return to Madrid and José's warm hospitality. But some of his warmth reaches me along with his Internet-transmitted words, and some of my concern reached around the world to my friends in Hsinchu and Taipei.

It turns out that where we are - together with the consequent differences in our experiences and cultures - matters a great deal. But the almost instantaneous transmission of our thoughts, ideas, mutual concerns, and love for each other binds us together as never before. Where are you? In a particular place on the skin of the world, but you are not alone.

- KIW

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



Circle no. 19

SID Conference Calendar

Next Show!

The Sixth International Display Workshops (IDW '99)

The 6th International Display Workshop (IDW '99) will be held at the Sendai International Center in Sendai, Japan, December 1–3, 1999. This year's workshop is comprised of 265 papers and will feature Poster Sessions, Author Interviews, and Exhibits. The workshops should be of interest not only to researchers and engineers, but also to those who manage companies and institutions in the display community.

1 DECEMBER **99**

6th International Display Workshop (IDW '99)

SENDAI, JAPAN
DECEMBER 1–3, 1999

• Scientific and technological advances in information displays will be presented in ten workshops on:
– LC Sciences & Technologies – AMLCDs
– Passive-Matrix LCDs – FPD Materials and components – CRTs – Plasma Displays
– ELs, LEDs, & Phosphors – FEDs – Large Area & Projection Displays – 3-D Technologies & Human Factors

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

14 NOVEMBER **00**

8th Color Imaging Conference: Color Science, 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

For additional information:
Dee Dumont
Society for Information Display
31 East Julian Street
San Jose, CA 95112
408/977-1013, fax - 1531
www.sid.org

SID

Since 1962, a professional worldwide interdisciplinary society committed to the advancement of information display.

calendar

The 6th International Display Workshops (IDW '99). Sponsored by the Institute of Image Information and Television Engineers and the Japan Chapter of the Society for Information Display. Contact: IDW '99 Secretariat, c/o Conventions, Annecy-Aoyama 2F, 2-6-12, Minami, Tokyo, 107-0662 Japan; +81-3-3423-4180, Fax - 4108.
Dec. 1-3, 1999 Sendai, Japan

The 16th Annual Flat Information Displays Conference. Sponsored by Stanford Resources. Contact: Laura Barretto; 408/360-8400, fax -8410, e-mail: l.barretto@stanfordresources.com.
Dec. 16-17, 1999 Monterey, CA

VISU 2000. Sponsored by Le Club VISU and the French Chapter of the Society for Information Display. Contact: J. Verdez, Le Club VISU; phone/fax +33-2-96-2331-64,
e-mail: jverdez.clubvisu@wanadoo.fr.
March 3-5, 2000 Porte Maillot, France

2000 SID International Symposium, Seminar & Exhibition (SID '00). Sponsored by the Society for Information Display. Contact: Mark Goldfarb, Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003; 212/460-8090 x202, fax -5460, e-mail: mgoldfar@newyork.palisades.org.
May 14-19, 2000 Long Beach, CA

Twentieth International Display Research Conference (IDRC '00). Sponsored by the Society for Information Display. Contact: Ralph Nadell, Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003; 212/460-8090 x203, fax -5460, e-mail: rnadell@newyork.palisades.org.
Sept. 25-29, 2000 Palm Beach, FL

Eighth Color Imaging Conference: Color Science, Engineering Systems & Applications. Sponsored by IS&T and the Society for Information Display. Contact: Dee Dumont, SID HQ, 31 East Julian St., San Jose, CA 95112; 408/977-1013, fax -1531, e-mail: office@sid.org.
Nov. 14-17, 2000 Scottsdale, AZ

SID news

* * * OBITUARY * * *

Dr. Sanai Mito Dies at 88

Dr. Sanai Mito

With great regret we announce the death of Dr. Sanai Mito, who was a SID life member and the first SID Japan Chapter Chair. He died of acute pneumonia on September 14, 1999, at Takarazuka Municipal Hospital in Hyogo, Japan, after a long illness. He was 88 years old.

Dr. Mito was elected a Fellow of the Society for Information Display (SID) in 1976, the first Japanese citizen to receive this honor. His notable contributions to the field of flat-panel-display devices and his leadership in applying them to monitors for personal computers and consumer TV sets won him respect both nationally and internationally during his service as Executive Director of Sharp Corporation from 1965 to 1988.

We shall always remember him, not only as a scientist but as a broad-minded leader of the display-technology field. When Dr. Mito attended the SID Internationl Symposium and some other meetings in 1974, he immediately consulted with the appropriate SID officers and promptly established the SID Japan Chapter in 1975. With many generous acts over many years, Dr. Mito devoted himself to the well-being of SID and the world display community.

We offer our sincere thanks to all those who showed Dr. Mito kindness during his lifetime.

– Chuji Suzuki
SID Fellow

Please send new product releases or news items to Information Display, c/o Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003.

sustaining members

Acer Display Technology
Ad-Vance Magnetics, Inc.
Advance Reproduction Corp.
American Panel Corp.
Applied Concepts, Inc.
Arconium
Artesyn Solutions, Inc.
ATI Technologies
autronic - Melchers GmbH

BPS
Brewer Science, Inc.
Brimar Ltd.
Brown & Sharpe Surface Inspection Systems, Inc.

Canon, Inc.
CELCO
Cherry Electrical Products
Chunghwa Picture Tubes, Ltd.
Clinton Electronics Corp.
Colorado Microdisplay, Inc.
Corning Incorporated
Corning Japan K.K.
Crystaloid Technologies

DigiLens, Inc.
Display Laboratories, Inc.
DisplaySearch
Displaytech, Inc.
Dolch Computer Systems, Inc.

Earth Computer Technologies
ELDEC Corp.
Electro-Plasma, Inc.
Emco Electronics Ltd.
Endicott Research Group, Inc.
ERSO/ITRI

FED Corp.
F-P Electronics
Futaba Corp. R&D Center

General Vacuum, Inc.
Gerome Manufacturing Co., Inc.

Hewlett-Packard Co.
Hitachi, Ltd.
Hoya Corporation USA

IBM
Imaging & Sensing Technology
Imaging Systems Technology
Incom, Inc.
Industrial Electronic Engineers, Inc.
Infinite Graphics, Inc.
Infodex, Inc.
Instrument Systems
Interface Products, Inc.
Interserv Corp.
Interstate Electronics Corp.
Ion Systems
Ise Electronics Corp.

Kent Displays

LCD Lighting
Lexel Imaging Systems, Inc.
LinFinity Microelectronics, Inc.
Lite Array, Inc.

Micron Display Technology, Inc.
Micronic Laser Systems AB
Microvision Corp.
Mitsubishi Electric Corp.
Molex, Inc.
Motorola FPD Division

NEC Corp.
Nippon Seiki Co., Ltd.

OES/ITRI
OKI Electric Industry Co., Ltd.
Optical Coating Lab., Inc.
Optrex America, Inc.

Philips Flat Display Systems
Phosphor Technology Ltd.
Photon Dynamics
Photo Research
Pilkington Micronics Ltd.
Pix Electronics, Inc.
Planar Standish, Inc.
Planar Systems
Plasmaco, Inc.
Polar Vision, Inc.
Polytronix, Inc.
Premium Allied Tool
Progressive System Technologies

Q.C. Optics, Inc.
Quantum Data Inc.

RF Power Products
ROLIC Research Ltd.

Sarnoff Corp.
Schott Corp.
Semiconductor Systems, Inc.
Sharp Corp.
SI Diamond Technology, Inc.
Sony Corp. Research Center
Stanford Resources, Inc.
Superior MicroPowders
Supertex, Inc.
Symbol Technologies, Inc.
Syntronic Instruments, Inc.

Tamarack Scientific
TDK Corp.
TEAM Systems
Techneglas, Inc.
Teledyne Lighting & Display
Terapixel, Inc.
Thomas Electronics, Inc.
Thomson Components & Tubes
Three-Five Systems, Inc.
Torrey Pines Research
Toshiba America Electronic Components, Inc.

Ultra Electronics Command & Control Systems
ULVAC Technologies, Inc.
UNIGRAF
Unipac Optoelectronics Corp.
Universal Display Corp.
Ushio America, Inc.

Viratec Thin Films Inc.
Vishay-Dale Electronics, Inc.

Westaim Advanced Display Technologies
Westar Corp.
White Electronic Designs, Inc.
WINTEK Corp.
WinTron Technologies

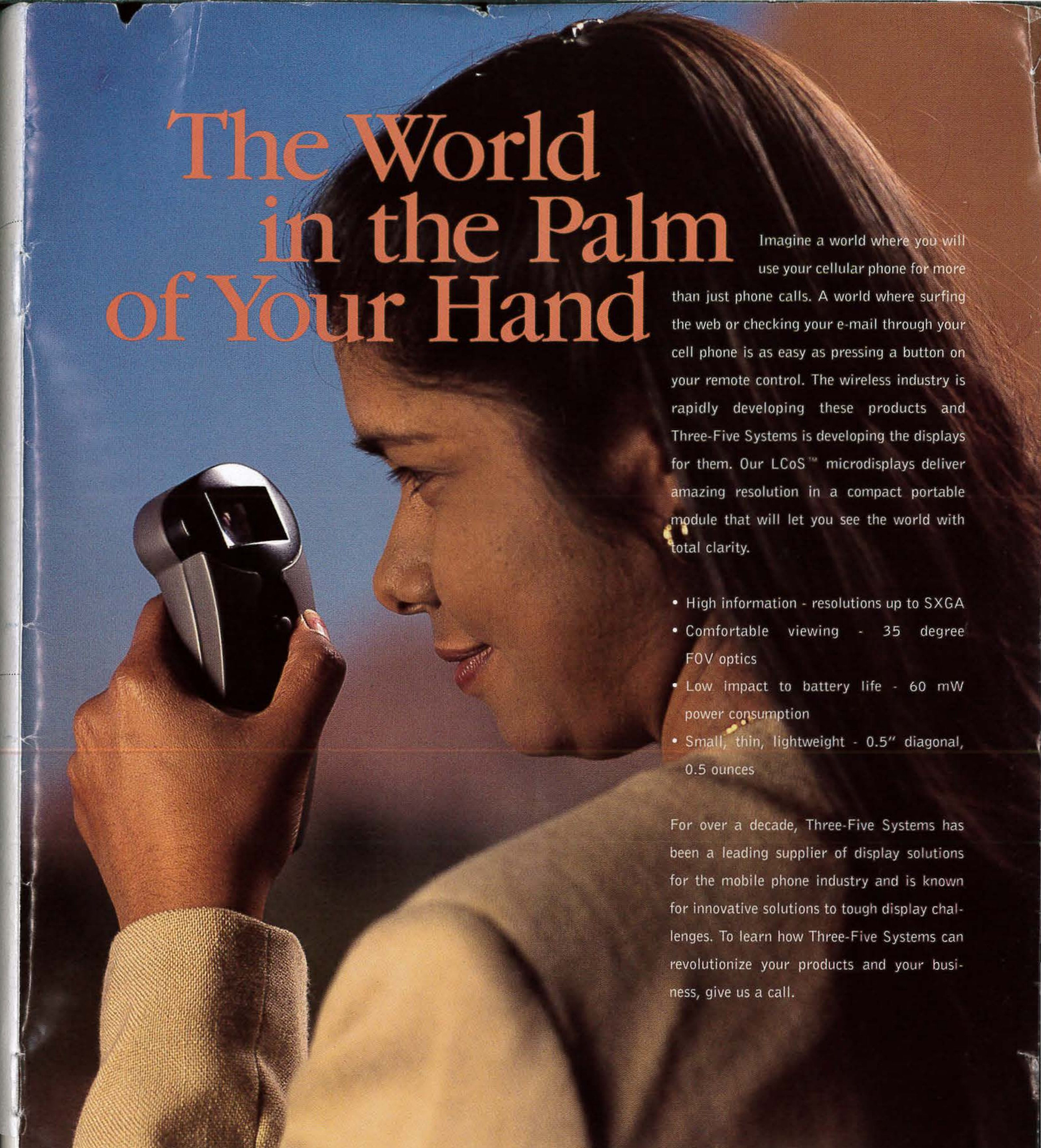
XCITEK, Inc.

index to advertisers

Bergquist....34
BOC Coating Technology....6
CELCO (Constantine Engineering Laboratory Company)....C4
DAPPCOM....43
H. L. Funk Consulting....42
General Vacuum....41
Goldentek....35
Integral Vision....39
Klein Instruments....20
Kurt J. Lesker....37
LMDC....42
Microvision....8,39
OCLI....21
Optrex America....C2
Pilkington Libbey-Owens-Ford....5
Photo Research....17
Polar Vision....25
Quantum Data....7
Silver Cloud Manufacturing....41
Society for Information Display....40
Team Systems....3
Teltron....35
Three Five Systems....C3
3M Optical Systems....9
Toshiba....11
Unigraf....29
U.S. Electronics....35
Westar Corp....1

Business and Editorial Offices
Palisades Institute for Research Services, Inc.
411 Lafayette Street, 2nd Floor
New York, NY 10003
Jay Morreale, Managing Editor
212/460-8090 x212 Fax: 212/460-5460

Sales Office
Palisades Institute for Research Services, Inc.
411 Lafayette Street, 2nd Floor
New York, NY 10003
Tracy Leibowitz, Sales Manager
212/460-8090 x211 Fax: 212/460-5460


The World in the Palm of Your Hand
Imagine a world where you will use your cellular phone for more than just phone calls. A world where surfing the web or checking your e-mail through your cell phone is as easy as pressing a button on your remote control. The wireless industry is rapidly developing these products and Three-Five Systems is developing the displays for them. Our LCoS™ microdisplays deliver amazing resolution in a compact portable module that will let you see the world with total clarity.
• High information - resolutions up to SXGA
• Comfortable viewing - 35 degree FOV optics
• Low impact to battery life - 60 mW power consumption
• Small, thin, lightweight - 0.5" diagonal, 0.5 ounces
For over a decade, Three-Five Systems has been a leading supplier of display solutions for the mobile phone industry and is known for innovative solutions to tough display challenges. To learn how Three-Five Systems can revolutionize your products and your business, give us a call.


1950 CELCO 2000
OUR VISION OF THE NEW MILLENNIUM
CELEBRATING OUR 50TH ANNIVERSARY
CELCO
MAHWAH, N.J.
MY514-P620
Mahwah, NJ
Yokes & Focus Coil
www.celco.com
Rancho Cucamonga, CA
Digital Motion Picture Recorders
Circle no. 28