2017 DISPLAY WEEK SHOW ISSUE / AUTOMOTIVE DISPLAYS

Information DISPLAY

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SOCIETY FOR INFORMATION DISPLAY

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May/June 2017
Vol. 33, No. 3

SID Recognizes 6 Products for 2017 Display Industry Awards

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ON THE COVER: The winners of this year's Display Industry Awards are, clockwise from top: LG Display's 65-in. Wallpaper OLED TV, Apple's MacBook Pro with Touch Bar, Sony's PlayStation VR, Samsung Display's Quad-bended Flexible AMOLED Display, Nanosys's Hyperion Quantum Dots, and Luminit's Transparent Holographic Component for Motorcycle Head-up Display. The automotive interior artwork in the background was provided by BMW/Inova Semiconductors.

Cover Design: Jodi Buckley

In the Next Issue of *Information Display*

Wearable/Flexible Technology

- Smart Fabrics
- Stretchable Oxide TFT
- Digital Signage Based on Electronic Ink
- Polysulfide Substrate Materials for Flexible Electronics
- Market Outlook for Flexible Technology
- Q&A with Pixel Scientific

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For Industry News, New Products, Current and Forthcoming Articles, see www.informationdisplay.org

editorial

Display Week Comes Home

by Stephen P. Atwood

Welcome to Los Angeles for our 54th annual Display Week event! This year we visit the city widely considered the cultural, financial, and commercial center of Southern California. It's also the birthplace of the Society for Information Display, back in 1962 on the campus of UCLA, and the home of one of our most active SID chapters. There is a deep and rich history of display technology development in this place, and Southern California continues to be a hotbed of innovation in many important display-related areas.

If you are new to LA, I hope you will find the time to get around the city and see some of the more famous landmarks, such as Hollywood Boulevard and the Hollywood Bowl, the Capitol Records Building, the Cathedral of Our Lady of the Angels, the TCL Chinese Theatre, the Dolby Theatre, Griffith Observatory, the Getty Center, the Los Angeles County Museum of Art, the Venice Canal Historic District and boardwalk, the Wilshire Grand Center, the Battleship *USS Iowa*, Dodger Stadium, and Olvera Street.

However, I bet it will be hard to make the time because of the incredibly busy calendar right here at Display Week 2017, which includes the SID International Technical Symposium and Exhibition as well as the Market Focus Conferences, Business Conference, Investors Conference, Seminars, Short Courses, and the many other great happenings that are organized each year for your benefit and enjoyment.

This year, Display Supply Chain Consultants (DSCC) and the Society for Information Display have co-organized the SID Display Week 2017 Business Track. The Business Track will consist of three whole-day conferences held from Monday to Wednesday, featuring presentations from prominent executives of leading companies throughout the display ecosystem. There will be two Market Focus conferences this year, one concentrating on the critical market development issues facing automotive displays, and the other focusing on AR/VR/wearables. New this year on Sunday will be a full-day training course on display metrology and the methods of the SID/ICDM Display Metrology Standard. Also new this year is a very special forum on Wednesday afternoon titled Women in Tech, which will feature personal and professional insights from some of today's top female technology leaders.

When exploring the exhibits, don't forget to make time for the I-Zone. The Innovation Zone is a three-day exhibit of pre-commercial prototypes by academics, startups, and large companies. Following SID's mantra of "showing you tomorrow's technology today," the I-Zone has been a big hit since its debut in 2012, and 2017 similarly promises to have the most exciting prototypes on display.

Display Week is a big event, and no one person can see it all. Hopefully you brought along some colleagues to help you divide and conquer everything of interest, but in case you didn't, we have you covered. *Information Display* has invited a prestigious team of freelance technology enthusiasts to report on all the happenings, and they will be hard at work covering everything they can. We will have daily blog updates on the *ID* website (www.informationdisplay.org) and a full issue of post-show coverage later in the year. If you see anyone from our team walking around with a press badge that reads "Information Display" on it, please introduce yourself, ask questions, and share your interests so we can make sure we cover the things that interest you most.

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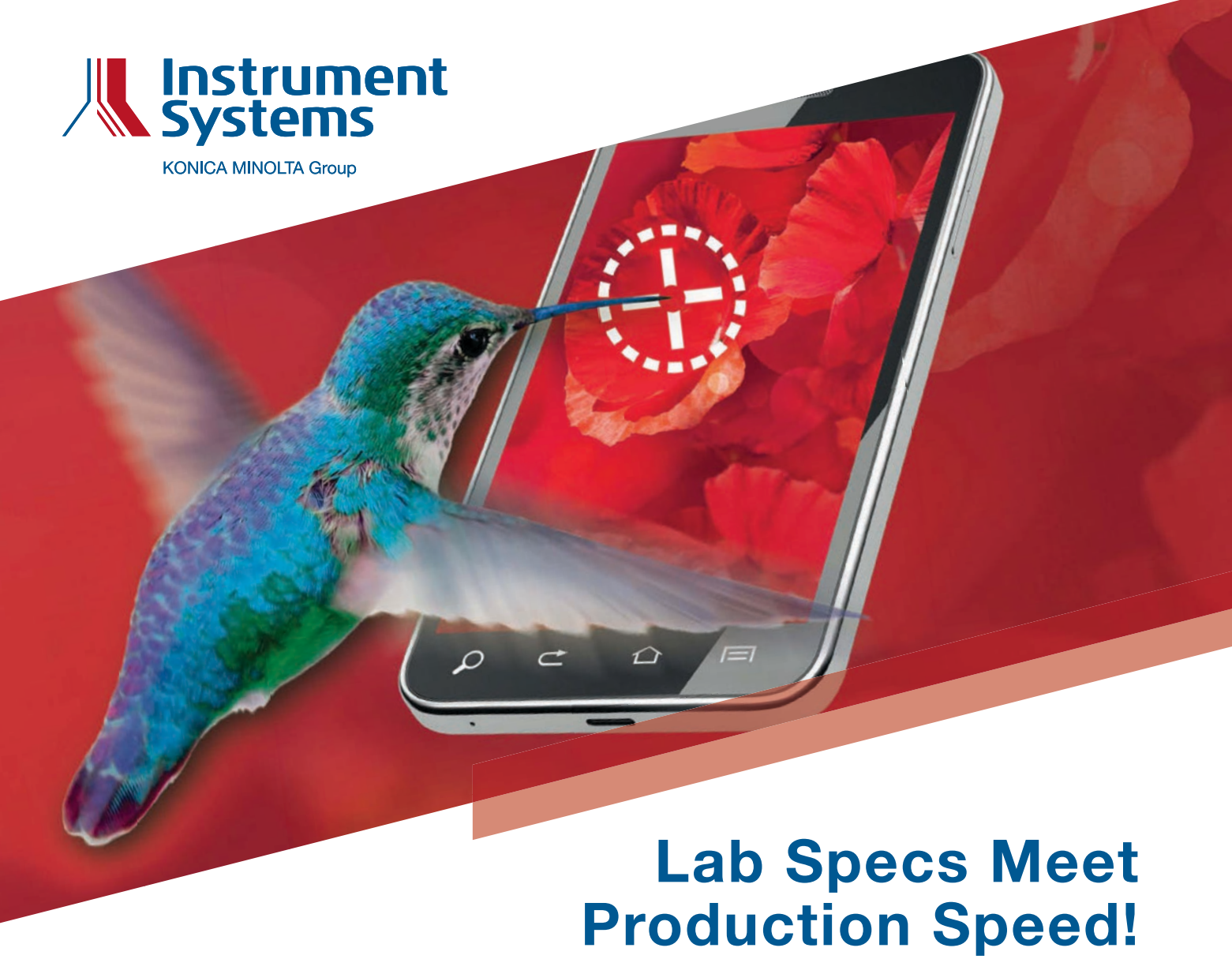

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president's corner

SID: The Society for "Interactive" Display?

by Yong-Seog Kim
President, Society for Information Display

Greetings and a warm welcome to all at Display Week 2017 in Los Angeles!

As of this writing, final preparations are under way as SID heads to Los Angeles for its annual Display Week event. Los Angeles is a beautiful city that is well known for its movie industry and international culture. Therefore, the Los Angeles Convention Center (LACC) is a perfect fit for this year's Display Week: SID has been covering more augmented-reality (AR) and virtual-reality (VR) technology in recent years, and half of its membership is now from countries other than the US. Los Angeles is easily accessible, with many daily nonstop flights from major cities throughout Asia, Europe, and the US. It's important to note that the neighborhood immediately surrounding the LACC has been recently redeveloped, making the environment safer and more convenient for the attendees of Display Week. I hope you will enjoy LA during your visit to Display Week 2017.

It's an exciting time for SID, as we continue to grow and adapt to newly developing technologies related to information displays. When SID was established in 1962, cathode ray tube (CRT) was the dominant display technology. Over the past two decades, Display Week became the must-visit event for the introduction of new flat-panel technologies and products. Now, as the result of intense research activity, flat-panel display technology has become fairly mature, and SID is again morphing its focus to include new areas such as AR/VR, vehicular displays, and wearable displays, to name just a few.

To provide a forum at Display Week for newly developing technologies, SID creates special technology tracks each year within its technical symposium. This year's tracks are AR/VR, Digital Signage Display Solutions, Display Materials and Processes, and Wearable Displays. These special tracks have always drawn significant interest from attendees and in past years have attracted large audiences – sometimes as many as 500 people – to the sessions. This is in part a reflection of the rapidly growing industry of system integration in the United States, which in turn is reflected in the growth of US SID members in recent years. This US membership growth is coming from the system integrators rather than the core panel-display industry, which is now based primarily in Asia.

Display Week Is a Hub for System Integrators, Material Suppliers, and Panel Makers

The rapid growth of the system integration industry sector in the US puts SID in a unique position within the information display industry. Display Week has become the place where display material suppliers from Europe, panel makers from Asia, and system integrators from the US meet to discuss the future of the display industry. Display Week provides the ideal forum for these attendees to share their visions and to find ways to collaborate with each other in their research as well as in product development.

As is the case every year, Display Week 2017 promises to reveal many exciting technical developments. The event will kick off with keynote presentations featuring three renowned leaders in the fields of OLED displays, AR/VR, and vehicular electronics. These keynote presentations have always been a source of inspiration and a signpost to where the industry is heading. This year will be no exception.

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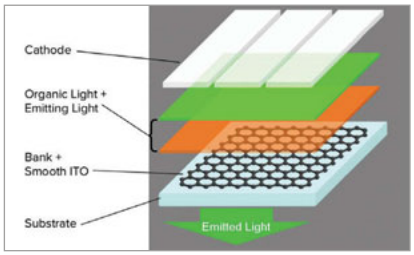
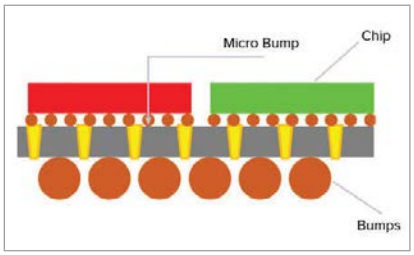
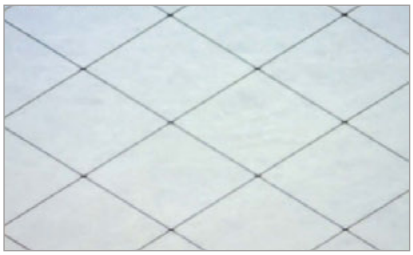


OLED + Bank



Glass Interposer



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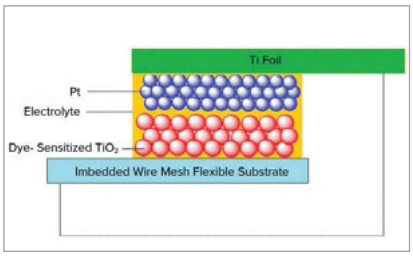
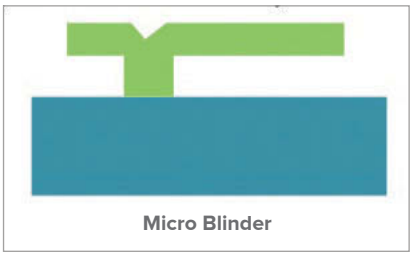


Flexible Dye Cell



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DisplayMate Rates the Galaxy S8

DisplayMate's Ray Soneira has released his report on the OLED display in Samsung's newest flagship smartphone – the Galaxy S8. Here are a few of the highlights from his extensive report, which can be accessed in full at www.displaymate.com/Galaxy_S8_ShootOut_01.htm.

The Galaxy S8 (5.8 inches) and Galaxy S8+ (6.2 inches) have new, state-of-the-art flexible OLED displays, together with a radical new full-display screen design that fills almost the entire front face of the phone, providing a significantly larger display for the same size device (Fig. 1).

Fig. 1: *Samsung's new 5.8-in. Galaxy S8 (left) and 6.2-in. Galaxy S8+ (right) feature displays that cover nearly the entire front face of the phone. The Galaxy S8 has a 570-ppi display, and the Galaxy S8+ has a 529-ppi display. Photos: Samsung*

Both models have dual-edge, curved-screen, flexible OLED displays. While the display itself is flexible, the screen remains rigid under an outer hard cover-glass that is hot-formed into a rigid curved screen. The curved screen provides two additional user-configurable edge-screen areas that can be viewed from both the front and the sides, even when the phone is placed face down. With the "always on display mode," the edge screen can even be used as a night-time clock for your bedside table.

Below are some of the outstanding features of the Galaxy S8 (the unit tested by DisplayMate):

- A new 3K, 2,960 x 1,440 display that fills almost the entire front face of the phone from edge to edge, resulting in a 5.8-in. display with a taller height-to-width aspect ratio of 18.5 : 9 = 2.05. (The S8's predecessor, the Galaxy S7, had a 2.5K, 2,560 × 1,440 resolution display.) The display area of the Galaxy S8 is also 18% larger than that of the Galaxy S7 for the same size phone.
- A new and accurate, 100% DCI-P3 color gamut that is also used for 4K TVs. This is the first smartphone to be certified by the UHD Alliance for Mobile HDR Premium to play all of the latest content produced for 4K UHD Premium TVs.
- The native color gamut of the Galaxy S8 is the result of its new, high-saturation "Deep Red" OLED, resulting in a very impressive 113% of DCI-P3 and 142% of sRGB/Rec.709 gamut. It also produces better on-screen colors in high ambient light.
- The Galaxy S8 has 5% to 19% higher screen luminance than its predecessor, plus a record peak luminance of over 1,000 nits.

The Galaxy S8 is the first in a new generation of OLED smartphones. OLEDs have now evolved and emerged as the premium mobile smartphone display technology. More than two dozen manufacturers already make OLED smartphones, and the full-screen display design using a flexible OLED will be the new standard for all future top-tier smartphones. In short: The Galaxy S8 is the most innovative and high-performance smartphone display that DisplayMate has ever lab tested, earning a highest-ever grade of A+.

E Ink and Sony Semiconductor Solutions Establish Joint Venture

E Ink and Sony Semiconductor Solutions Corporation have announced a joint venture for planning, designing, developing, manufacturing, selling, distributing, and licensing products that use electronic paper displays, as well as related applications.

E Ink and Sony have worked together on various e-paper related projects since 2004. The joint venture is officially registered in Taiwan; operations will commence pending regulatory approvals.

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PRODUCT BRIEFS

Instrument Systems recently previewed its new CAS 140D spectroradiometer, the fourth generation of the company's CAS series. The CAS 140D has improved optical and mechanical construction and is smaller and simpler to integrate into existing measurement environments than its predecessors. It also has a changeable interface between the spectrometer and control computer.

LCDTERM's new programming-free LCD user interface (UI) uses a three-button keyboard for seamless and code-free integration onto any embedded platform, eliminating the need for developers to write software to control the display. The LCDTERM interface includes all control firmware on board, utilizes a speedy ARM M0 processor, and comes with a free application programming interface (API). Included fonts and user-defined bitmaps allow for the addition of 64K-color displays to any embedded system. Display sizes include 1.77, 2.8, and 5 inches.

Osram Opto Semiconductors is expanding its Oslux product family for biometric security solutions with a specially designed variant for facial recognition, the SFH 4796S. This compact infrared LED (IRED) ensures uniform illumination of facial features for high image quality.

Solar-Tectic LLC recently announced that it has succeeded in developing a new sapphire glass technique involving the deposition of a highly transparent crystalline Al2O3 (aluminum oxide) thin film on ordinary soda-lime glass, via a thin buffer layer, using a simple and common deposition technique (e-beam evaporation). The resulting material is lighter and much less expensive than single-crystal sapphire, and is easily scalable for manufacturing and commercialization. Solar-Tectic's sapphire film is extremely thin, which it claims is important for cost reduction in manufacturing, and is rated an 8 on the Mohs scale of mineral hardness, which equates to a topaz. (Quartz is rated a 7 and a diamond is rated a 10 on the scale.)

2017 Display Industry Awards

Each year, SID's Display Industry Awards Committee selects products that have advanced the state of the art of display technology in the categories of Display of the Year, Display Component of the Year, and Display Application of the Year.

Compiled by Jenny Donelan

THREE out of six Display Industry Award winners this year are based on OLEDs. That includes LG Display's sizable 65-in. Wallpaper TV, as well as two much smaller panels – Samsung's 139.5-mm. quad-bended display for the Galaxy S7 Edge, and the 5.7-in. OLED display in the PlayStation VR. Even the LCD-based MacBook Pro, recipient of an application award, won in large part on the basis of its novel, integrated OLED-based touch bar.

This isn't the first time that OLED innovations have led the way in SID's annual awards. But it is the first year they have done so in a field so largely devoid of LCDs. (Although it should be noted that one of the component winners, Nanosys's Hyperion quantum dots, exists – at least at present – primarily to enhance LCD panels.)

This is not to say that OLEDs are replacing liquid crystals as the dominant display material in the same way that LCs pushed aside cathode ray tubes (CRTs) years ago. LCD TVs, whether enhanced with LEDs, quantum dots, or both, still outsell OLED TVs, and are expected to do so for the foreseeable future, according to market analyst Jennifer Colegrove. She is quoted in this issue's SID News to say that she predicts OLED TV market share will not exceed 6% of the overall market through at least 2021. For smartphones, the OLED *vs.* LCD battle is much closer, with an increasing number of smartphones based on AMOLED technology. (See DisplayMate's review of Samsung's new OLED-based smartphones in this issue's Industry News.)

The point, of course, is not so much which technology is leading the marketplace by itself, but how many cool products we can make with that technology. It's exciting to imagine the future evolution of products like LG Display's Wallpaper TV – what if we had "peel and stick" displays that we could move around the house wherever we wanted? And devices like Sony's PlayStationVR, which offer a greater sense of immersion than users have enjoyed before, seem like a step closer to the virtual "holodeck" of *Star Trek TNG* fame. What's exciting is that there are so many technologies available for firing the imaginations of researchers. It's a good time to work in displays.

With that, we applaud the winners of this year's Display Industry Awards. May the researchers, engineers, chemists, and designers at these companies never stop innovating. Please join us in saluting their efforts.

Jenny Donelan *is the editor in chief of* Information Display. *She can be reached at jdonelan@pcm411.com.*

Display of the Year

This award is granted to display products with the most significant technological advances or outstanding features.

LG Display's 65-in. Wallpaper OLED TV

In 2013, LG Display launched one of the world's first 55-in. full-high-definition (FHD) OLED TVs. In 2015, the company introduced a lineup of 55-in., 65-in., and 77-in. ultra-high-definition (UHD) OLED TVs. LG Display then incorporated high-dynamic range (HDR) and Digital Cinema Initiative (DCI) technologies into these TVs to improve the picture quality, and developed curved, 4-sided-borderless, and slim designs for improved design differentiation.

In 2016 and 2017, LG Display launched its Wallpaper OLED TV panels. Its 65-in. Wallpaper OLED display demonstrates a combination of excellent image quality and streamlined design that is possible only with OLED technology. The panel's most notable feature is the unique form factor: It's much slimmer and lighter (with a thickness of 3.9 mm and a weight of 7.4 kilograms) than conventional TVs, and fits right against a wall – hence the name "Wallpaper."

For the Wallpaper display, LG developed a unique interface based on the V-by-One HS digital signaling standard, and included high-bandwidth digital-content protection (HDCP) in order to transmit video data and control signals between the display and the driver circuit board. The company also designed a slim, flat external cable (0.47 m) that enables simultaneous transmission of panel power and video data to the UHD panel – 700 watts of power and a frame rate of up to 120Hz. This is an industry first, and allows the driver circuit board and power unit to be separate from the panel rather than mounted on the back, as is typically done for TVs. This is part of what enables the panel to be so thin – the driver circuit board and the power unit together are about one-third the size of the panel, with a thickness of more than 20 mm. For optimal

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DISPLAYS OF THE YEAR

*The **Displays of the Year** are LG Display's 65-in. Wallpaper OLED TV (left) and Samsung Display's Quad-bended Flexible AMOLED Display (right).*

attachment to the wall, LG Display also developed a back cover less than 3 mm thick that uses magnetic sheets and a hook.

LG Display anticipates that the Wallpaper form factor will be a trendsetter in the TV market.

Samsung Display's Quad-bended Flexible AMOLED Display

Since 2013, Samsung Display has regularly launched new products based on flexible displays that enable smartphone design innovation. The company's first flexible product was a curved AMOLED display (SID's 2014 Display of the Year); the next was a bended AMOLED display (YOUM, which was SID's 2015 Display of the Year).

In 2016, Samsung Display launched a new flexible product, the Quad-bended AMOLED Display, which surpasses the company's previous flexible offerings in many ways. To begin with, its "quad edge" flexible technology, a world's first, is not only on the sides of the display, but on the top and bottom as well. Samsung created this display, used in the Galaxy S7 Edge smartphone, by adopting special curved technology that varies the radius for the curvature of the OLED panel from 35R to 3.8R. This enables the Galaxy S7 Edge to attain extremely fine contours and provide a more comfortable grip for the user. To make a naturally appearing curved edge, a four-step radius (35R, 9.4R, 5.4R, 3.8R) design process was applied to the left and right edges and a 25R radius was applied to the top and bottom.[1] The quad-bended AMOLED flexible display's efficient circuit plan also dramatically reduces dead space around the edges of the display to 1.09 mm – a record metric for Samsung Display.

In addition to all these design advantages, the display provides very high image quality. It has quad HD (2,560 x 1,440 resolution at 577 ppi) and meets Adobe RGB at 100% with an infinite contrast ratio.[1]

[1]http://www.samsungsemiblog.com/displays/quad-edge-display-accelerating-the-evolution-of-curved-smartphones/

Display Components of the Year

This award is granted for novel components that have significantly enhanced the performance of a display. A component is sold as a separate part destined to be incorporated into a display. A component may also include display-enhancing materials and/or parts fabricated with new processes.

Luminit's Transparent Holographic Component for Motorcycle Head-up Display

Luminit's patented holographic master recording technology has led to a number of breakthroughs in special-purpose head-mounted displays (HMDs) and head-up displays (HUDs), including, most recently, the company's transparent holographic components (THCs). These components offer multiple opportunities for the automotive and wearables industries for head-up, helmet-mounted, or near-to-eye display systems. REYEDR, a developer of HUDs for motorcycles, created the first display product for the public that uses Luminit's optical components.

With Luminit THC, holographic wavefronts are embedded onto a thin, clear photopolymer film that can be applied to glass or acrylic surfaces such as a helmet visor or eyeglasses. When an image is projected onto the surface, the THC translates that information into a virtual image to the viewer. The transparent film is lightweight and allows the maximum amount of light (>90%) from the forward field of view to pass through to the viewer. Because the holographic information is captured on thin, flexible film, engineers can create unique displays that would otherwise be too heavy or impractical with conventional optics. THC replaces conventional, prism-based optics with fully see-through technology that allows the images to be viewed at a virtual distance without added weight to the user.

Luminit's THCs are the first mass-produced, volume holographic components to be utilized in displays. In the REYEDR product, the holograms are integrated into a novel, non-planar waveguide, offering improved ergonomics and industrial design relative to conventional, flat, waveguide optics. THC enables HUD systems with a virtual image, eliminating the need for eye accommodation while riding or driving. Luminit's roll-to-roll mass production of volume holograms allows THC to enter the market at a cost point consistent with consumer electronics pricing for augmented reality.

Nanosys's Hyperion Quantum Dots

Nanosys's Hyperion Quantum Dots represent a significant development breakthrough for enabling displays to meet the BT.2020 ultra-high-definition (UHD) color standard. These quantum dots match the color performance of the industry's best cadmium-based materials without requiring an exemption to the European Union's Restriction on Hazardous Substances (RoHS) Directive.

Nanosys has partnered with Hitachi Chemical to begin mass-producing quantum-dot enhancement film (QDEF) with Hyperion quantum dots immediately. These materials integrate seamlessly into Nanosys's current QDEF manufacturing process.

Nanosys has demonstrated over 90% BT.2020 color gamut using Hyperion Quantum Dots in a sheet of QDEF with cadmium levels below the 100-ppm limit established by the RoHS Directive, thereby eliminating the need for an exemption. This is accomplished by combining an entirely cadmium-free red quantum dot with a green quantum dot engineered to have an exceptionally narrow emission spectrum and ultra-low cadmium content. With Hyperion quantum dots, display makers finally have a long-term, RoHS-compliant quantum dot material for BT.2020 displays.

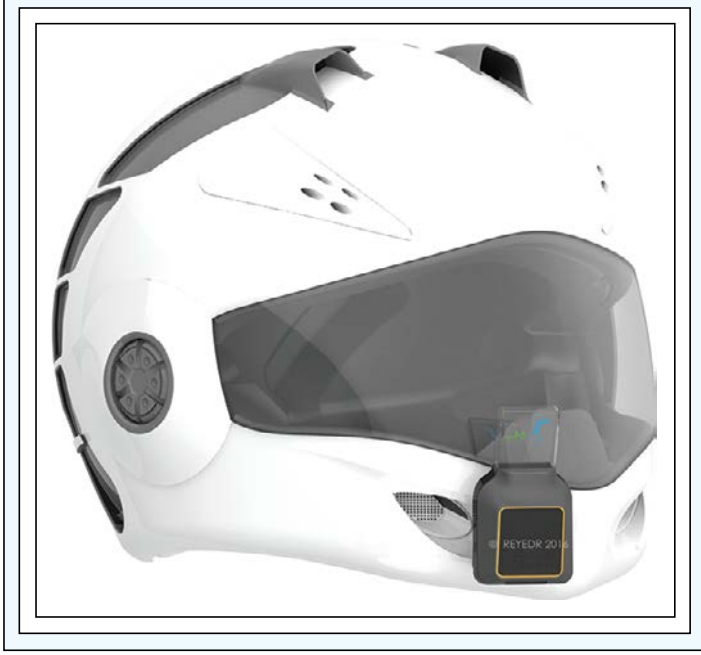
Display Applications of the Year

This award is granted for novel and outstanding applications of a display, where the display itself is not necessarily a new device.

Apple's MacBook Pro with Touch Bar

Apple brings a new dimension of interactivity to the MacBook Pro with the revolutionary new Touch Bar. The Touch Bar is a multi-touch, Retina-resolution OLED display right on the keyboard. It delivers useful shortcuts

DISPLAY COMPONENTS OF THE YEAR



*The **Display Components of the Year** are Luminit's Transparent Holographic Component for Motorcycle Head-up Display (left), shown here on a helmet from REYEDR, and Nanosys's Hyperion Quantum Dots (right).*

DISPLAY APPLICATIONS OF THE YEAR

*The **Display Applications of the Year** are (left) Apple's MacBook Pro with Touch Bar and (right) Sony's PlayStation VR.*

and tools to your fingertips, based on the app you're in and what you're doing within it. By delivering context-specific features and controls, the Touch Bar can make an unfamiliar app more accessible to a new user, and it can empower pros by enabling greater efficiency in their workflows.

From a technical standpoint, the creation of the Touch Bar required many breakthroughs in the field of OLED displays. In particular, the Touch Bar features a Retina-resolution (221-dpi) display, which enables sharp, print-quality icons and fonts. Additionally, the Touch Bar cover glass is engineered with nano-structures to minimize surface reflection and distortion, giving the Touch Bar a look and feel that blend seamlessly into the keyboard. The inclusion of the Touch Bar on the MacBook Pro also inspired enhancements to its high-luminance liquid-crystal main display. The polarizers in both displays are designed to minimize surface reflection from the other display and to reduce other ambient cross-talk. Color management is synchronized in both displays to provide matching color between the Touch Bar and the main display, an aspect that visual artists and creative pros especially appreciate. Overall, the Touch Bar marries the input and display of information within a laptop architecture in a novel way and radically reimagines the interplay of hardware and software on the MacBook Pro.

Sony's PlayStation VR

The PlayStation VR (PS VR) is a virtual reality (VR) system that takes the PlayStation4 system to the next level of immersion, and demonstrates the future of gaming. PS VR enables players to experience a sense of presence, where they feel as though they are physically inside the virtual world of a game.

The PS VR headset is equipped with a 5.7-in. 1,920 × RGB × 1,080 resolution OLED display, which enables low persistence and removes motion blur or flicker. With full RGB sub-pixel structure in full HD resolution and an original optical element on the top of the display, "screen door effect" (a visual artifact of displays, in which the fine lines separating pixels or subpixels become visible in the displayed image) is minimized, even with an approximately 100-degree-wide field of view.

In addition, the OLED display supports a 120Hz refresh rate and produces extremely smooth visual imagery, achieving a new level of visual experience. All those optimized display features for VR help deliver that sense of "being there" for the player. ■

Automotive Interior Lighting Evolves with LEDs

A new platform to revolutionize in-car lighting control incorporates up to 4,096 LEDs that are individually addressable from a single system controller.

by Robert Isele, Roland Neumann, and Karlheinz Blankenbach

CAR interiors have undergone more than 100 years of development, and now constitute an unmistakably modern, technologically rich environment, sometimes also referred to as the driver's workplace. Over this long period, even over the past few decades, we have been witness to several truly revolutionary milestones, with entertainment systems, driver assistance, displays, and lighting raising the expectations of both drivers and passengers. Today, developments in car sharing, electrification, and autonomous driving are putting greater focus on the car's interior. Modern materials, interactive displays, and ambient lighting are all a part of this development.

Interior lighting inside today's motor vehicles is becoming an increasingly important selling point. Ambient light inside a car has the power to elicit both positive and negative emotional responses from drivers and passengers. It can also play a key role in shaping a potential customer's initial reaction when seated inside a vehicle in a showroom. First impressions count! So, logically, carmakers are seeking to create a lighting experience "like no other" that will make their brand stand out from the competition by creating a unique in-vehicle atmosphere that enhances users' emotional connection with the vehicle.

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LED Control Issues

In recent years, LEDs have become an accepted standard for high-end, in-car lighting; nevertheless, there exist significant limitations to the way they are controlled. Present state-of-the-art "ambient light" technology typically consists of a multicolor LED feeding an optical fiber (Fig. 1).

The flexibility and visual impact of this existing technology are severely limited, and its effect is often somewhat mediocre, due to the fact that the luminance and color performance of these LEDs can, as a rule, only be configured en masse or in relatively large groups. A central controller manages the LEDs via a local interconnect network (LIN), a serial network protocol that has become popular in many automotive applications as a lower-cost alternative to the controller area network (CAN) bus variant.

A more innovative approach is to mount 10 to 30 LEDs on a flexible light strip, where a controller converts commands into current pulses for each RGB LED individually, thereby enabling various colors and lighting effects (Fig. 2). Unfortunately, this solution involves significant drawbacks, as wavelength and luminance tolerance variations lead to

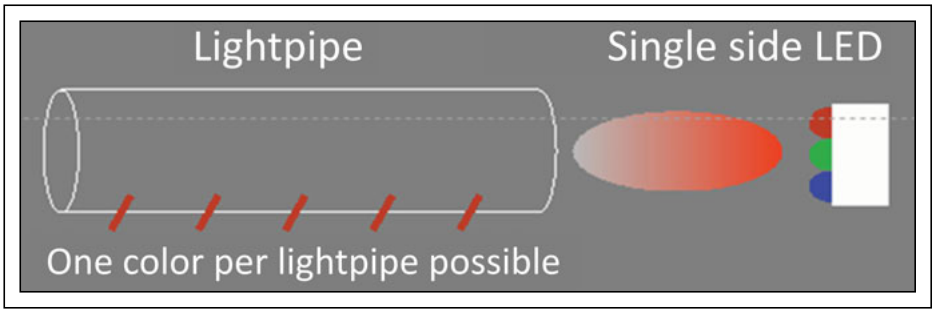

***Fig. 1:** Most automotive interior color lighting uses multicolor LEDs that feed into optical fibers. Source: BMW*

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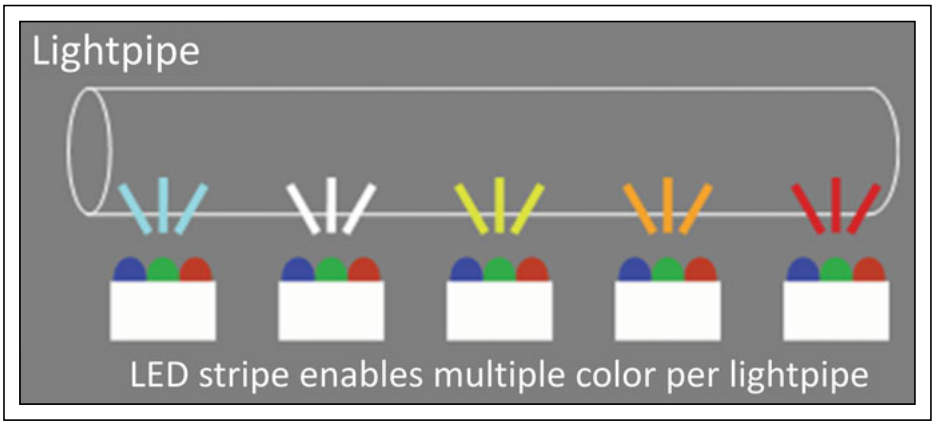

Fig. 2: *Multiple RGB LEDs addressed by a system controller enable various colors and lighting effects. Source: BMW*

non-uniform brightness and color perception. These effects are further exacerbated over a vehicle's lifetime due to aging effects and varying temperature conditions along the length of the LED strip. Another flaw of this approach is circuit and wiring complexity (see below; Fig. 4 *vs*. Fig. 5), increased weight, and reduced flexibility.

This aging effect manifests itself in declining luminance caused by falling efficiency, which is strongly affected by the LEDs' temperature, and in particular, high temperatures of long duration. Furthermore, temperatures can vary widely throughout a car's interior, and in some cases temperatures exhibit noticeable divergence even along a single LED strip. Another unfortunate detail is that the temperature-related characteristics, *i.e.* luminance and color coordinate shifts of green and blue LEDs, differ substantially from the characteristics of red LEDs.

These limitations notwithstanding, car manufacturers continue to demand further LED functionality in order to support innovative features and improve daytime LED visibility. While in 2010, a typical high-end vehicle might have been fitted with fewer than 50 LEDs, by year 2021 it is expected that more than 300 LEDs will be on board (Fig. 3). This growth is primarily in RGB-type LEDs, where three LEDs are integrated into a single light emitter. A controller is then required to set the individual color by means of RGB pulse-width modulations (PWMs), thus adding a further unwelcome layer of complexity and creating a system significantly more complex than the white and monochrome LED platforms that had dominated the market only a few years ago.

Requirements for In-car LED Control

To meet their objectives, carmakers require a sophisticated LED control platform that meets a lengthy list of challenging requirements. First, each RGB LED on the color strip must be individually controllable in terms of luminance and color, and second, it must enable calibration. An example is the cross-fading of adjacent LEDs from one color into another, where no brightness and color differences should be noticeable. Next, it must be possible to compensate for the effects of temperature and the non-uniform aging of the LEDs. Control must be possible over various architectures, and it must be straightforward to handle and manage the entire system. Such systems must also meet and ideally even exceed the rigorous automotive quality standards for technology, production, and testing, and must provide advanced diagnostic capabilities. Furthermore, LED control electronics must meet the safety and risk requirements as defined by the Automotive Safety Integrity Level (ASIL) scheme and the International Organization for Standardization (ISO) 26262 functional safety standard. Specific safety risks include, for example, spontaneous switching on of LED lighting, which could disturb the driver. It is also vital to ensure that warnings by LEDs are definitively provided (*e.g.* ensure the LEDs are really lighting up by checking the current through the LED at time of activation).

Only by ticking all these boxes can vehicle manufacturers be assured of achieving their goals of daytime visibility, fine control over luminance and color, and homogenous lighting with consistent output over the long term. These requirements simply cannot be met utilizing today's LED control technology – a new approach is needed.

At the present point on the technology timeline, a microcontroller containing LED-specific data utilizes current-mode drivers to individually control each RGB LED. This solution typically proves to be too cumbersome and expensive to be viable, plagued by the high number of integrated circuits and extensive wiring needed. This system design (see Fig. 4) requires high-speed, one-way communication to the LEDs and sub-con-

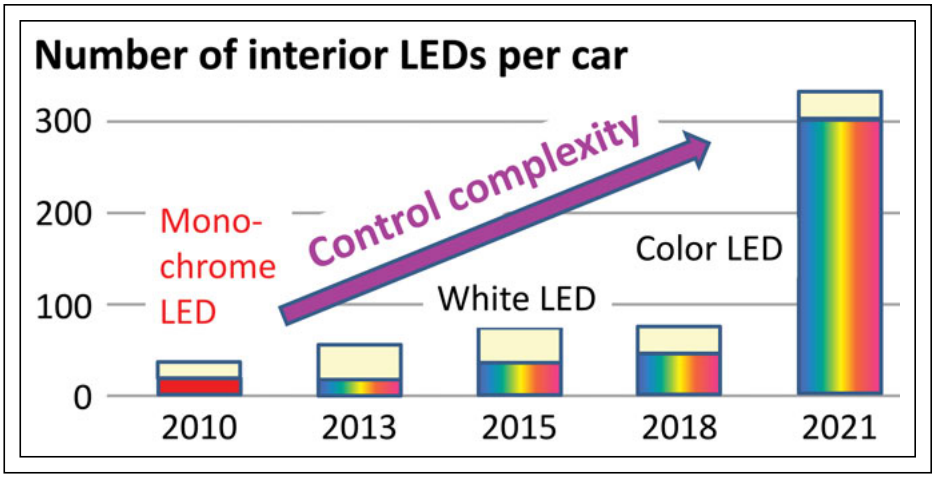

Fig. 3: *The number of LEDs used in automotive interior lighting is rapidly increasing. Source: BMW*

trollers, which impacts electromagnetic interference (EMI) robustness, hampers useful diagnostics, and leads to latencies. To make matters worse, it is not feasible to capture individual LED parameters such as functionality and temperature degradation. In general, solutions similar to those used for LED video walls are not suitable for advanced high-quality automotive interior lighting.

A New LED Control Concept

A new industry body – the Open ISELED (Intelligent Smart Embedded LED) Alliance – was formed to meet the challenge of providing reliable, modern in-car LED lighting. Its purpose is to provide a full and comprehensive ecosystem for a new digital LED concept. The founding partners are Inova Semiconductors, Dominant Opto Technologies, NXP, TE Connectivity, and Pforzheim University. Working together, and in close cooperation with BMW, these organizations have taken a new approach to interior automotive LED lighting, which is now set to redefine the world of automotive lighting. ISELED technology enables true "digital" LEDs to be integrated into a motor vehicle, without the complications of today's "analog"-based LED concepts.

Inova Semiconductors unveiled this revolutionary digital ISELED concept for automotive applications at the recent Electronica exhibition in Germany. It addresses the need for precise control of interior lighting within the automotive temperature range and lifetime, respecting multiple automotive quality and robustness requirements and inherent cost implications. It represents a completely new technical architecture for high-speed LED control.

This new concept (see Fig. 5) is built around a smart digital LED controller that is embedded in a tiny 3-mm × 4-mm RGB LED package. The scalability of this approach will enable substantial cost savings and open up new market opportunities. The upcoming generation of interior car lighting will typically consist of 10 to 30 LEDs mounted on a flexible light strip. Each group of one red, one green, and one blue LED will form a "pixel," which at 24-bit resolution (3 × 8 bit) can be set to more than 16 million colors.

The smart digital embedded LED controller from Inova provides sophisticated calibration features, with no need for binning classes or bar coding. This ensures that every LED renders the same color and luminance over the full temperature range, thereby guaranteeing automotive-level illumination consistency, even accepting greater LED manufacturing tolerances than are currently attainable. The actual emission of each of the three LEDs is optically measured during the final test in real time, thus enabling the delta between measured and target value to be stored in the integrated LED controller. The LED controller then utilizes this information to correctly set the LED drivers, thus ensuring that color and luminance correspond to the RGB settings.

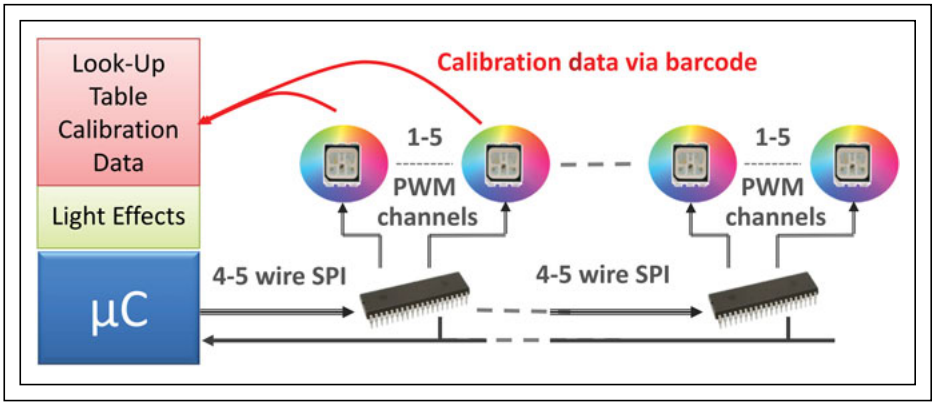

Fig. 4: *This traditional system concept for RGB LED lighting is derived from LED video walls. Source: Inova Semiconductors*

Leveraging the experience gained during the development of its automotive pixel link (APIX) display interface standard, Inova has built a high-speed communications protocol that allows every LED to be individually addressed. By supporting data rates of up to 2 Mbit/s, the new protocol enables fast, dynamic lighting effects.

A single microcontroller (Fig. 5, blue box on the left), acting as the system controller, can now manage an LED strip containing up to 4,096 LEDs, and each RGB LED module now has its own smart digital embedded LED controller (Fig. 6). Bi-directional communication between the system microcontroller and each LED module is achieved with very low latencies, and coupled with a 2 Mbit/s communication capability (without a dedicated clock), this ensures a reliable EMI-robust design. Bandwidth is utilized very efficiently due to individual addressing of each LED – while all LEDs can be addressed together via broadcasting, if required.

The system interface is provided by a microcontroller from NXP, which acts as the lighting controller (see "µC" in Fig. 5). The ISELED concept is ideally aligned with NXP's recently announced S32K microcontroller product line. The S32K provides performance of up to 112 MHz, with a FlexIO configurable serial communication interface. Devices in the family provide from 8K to 2M

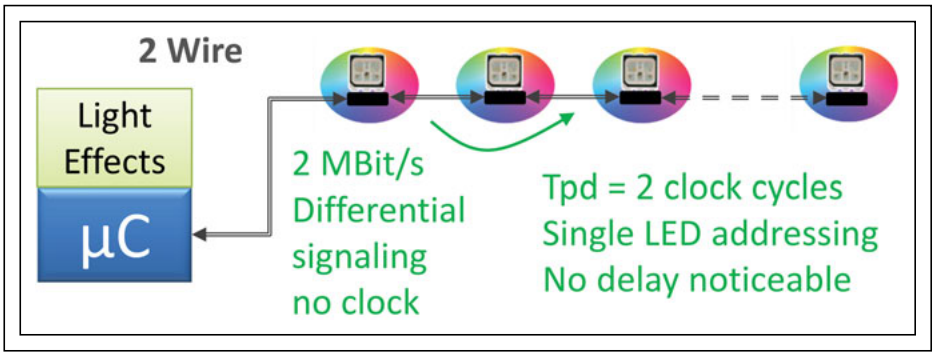

Fig. 5: *This new controller concept from Inova features a digital controller (visualized as black boxes) built into each tiny RGB LED package. Source: Inova Semiconductors*

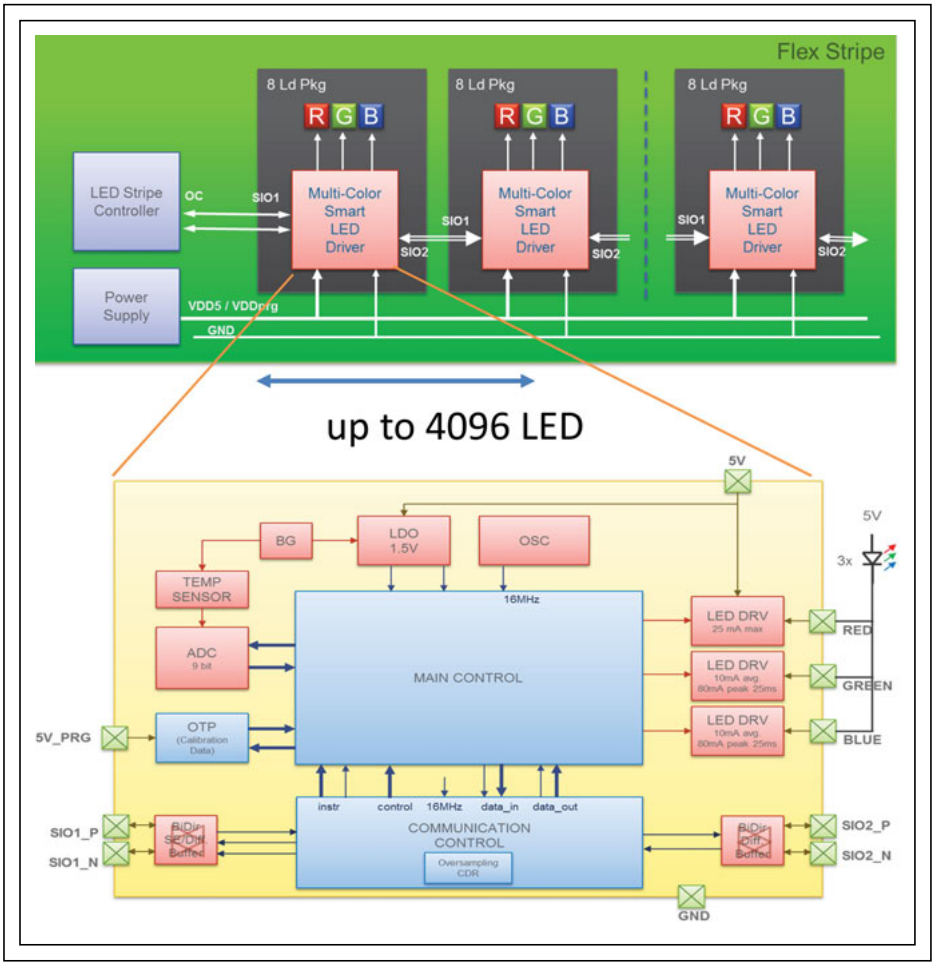

Fig. 6: At top is an RGB LED with embedded driver and at bottom, a connectivity system concept for up to 4,096 LEDs. Source: Inova Semiconductors

Flash, all with an ARM Cortex M core. NXP is taking this new concept to market as a complete solution including hardware, software, and a fully developed ecosystem.

For system diagnostics, the temperature, status, and functionality of each LED can also be accessed individually. Characteristics, such as function and power consumption of each LED, are fully retraceable and can be read retrospectively, which is particularly important for automotive ASIL-compliant lighting.

It goes without saying that an RGB LED with an integrated driver (Fig. 6) will cost more than a "conventional" RGB LED. Nevertheless, the challenge has always been to keep this additional cost to a minimum by making the controller chip highly compact and integrated, utilizing sophisticated packaging. The key cost advantage of this new ISELED concept comes from eliminating individual RGB strip calibration tasks and tighter binning for lower tolerances. Dedicated light strips were engineered by TE Connectivity in order to properly mount a higher number of "smart" (or digital) LEDs to fit seamlessly into the car interior.

First Product Sees Light

The first samples of a smart LED utilizing this new concept have recently become available from Dominant Opto Technologies. The samples consist of a smart LED controller from Inova with a bidirectional serial interface and daisy-chain capability. Each LED is calibrated to the required white point at the factory and can be used without any further compensation or measurements.

The driver includes three constant current mode (CCM) drivers to control the red, green, and blue LEDs. The color of each RGB LED "trio" can be set with 24-bit resolution (3 × 8 bit) for "display-like" performance in terms of gamma. For temperature and manufacturing tolerance compensation, or so-called binning, the luminance of each individual LED can be controlled with 12-bit resolution including daytime/night-time dimming. The LEDs have precise RGB calibration up to 1-step MacAdam Ellipse, with auto-compensation at high temperature, and dominant wavelength calibration (Fig. 7). A built-in temperature sensor ensures accuracy, while the calibration values of the CCM LED drivers and temperature compensation parameters are securely stored in non-volatile memory, an indispensable prerequisite for safety-related applications.

Packed and Ready to Go

The packaging is very compact and provides outstanding corrosion resistance and electrostatic discharge (ESD) protection exceeding 2kV. The extremely low thermal resistance of the LEDs' housing, 30% below that of comparable products, further reduces power consumption of the LED by delivering improved light efficiency with cooler LEDs (Fig. 8). Further details will be available once the patent application is granted.

Looking Ahead

The first applications for the new ISELED concept are in automotive interiors, but there

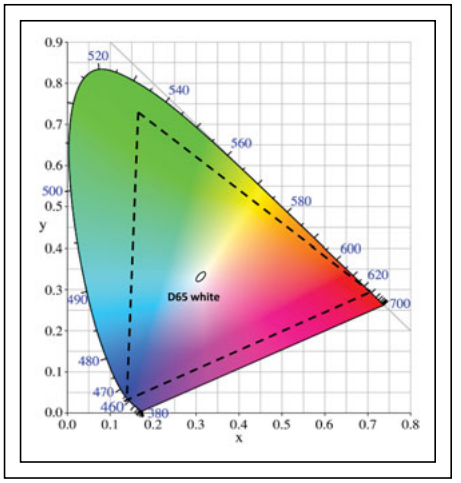

Fig. 7: Calibrated LED color space. Source: Dominant Opto Technologies

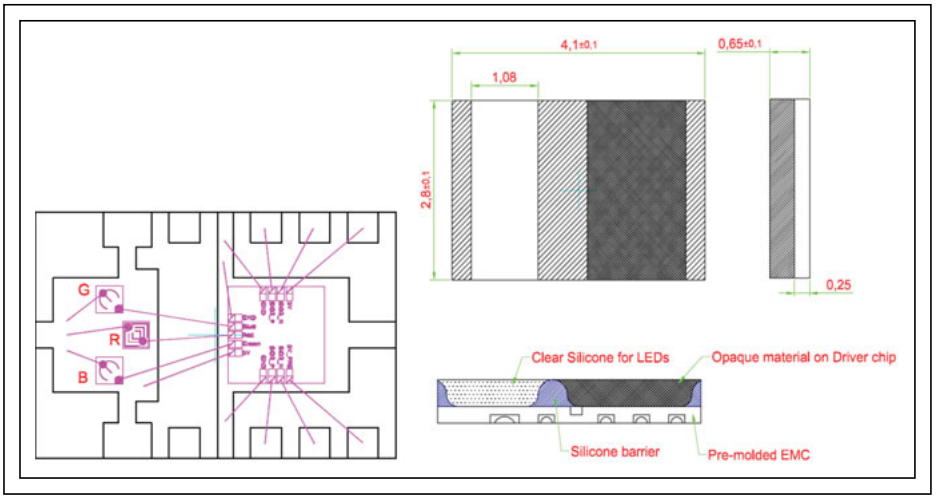

Fig. 8: This die-and-package schematic shows state-of-the-art LED packaging. Source: Dominant Opto Technologies

are multiple other potential use cases – including exterior car signaling. The fact that this communications protocol enables a large number of LEDs to individually change color and brightness in real time also makes it a candidate for non-automotive applications like aircraft and cruise ships.

Trends in the automotive sector will also open up new applications. As the market moves toward autonomously driven vehicles, lighting will become more and more important, and requirements will be more rigorous and challenging. "Take back control" warnings and pleasant, high-quality in-car lighting in autonomous vehicle applications are just a few examples.

Not only will interior lighting play a major role in future design, it is essential that vehicles are able to better communicate with the world around them. The ability of autonomous vehicles to inform pedestrians that they have been recognized is very important from a safety standpoint.

The key concept here is that LED lighting is now undergoing a revolution that will forever transform the way people perceive the car interior. Technology has, in this case, simplified a previously troublesome issue for car manufacturers and promises to help early adopters stand out and gain market share in the premium vehicle segment.

About the ISELED Alliance

The ISELED Alliance develops LED-related products and solutions based on a new in-car LED lighting concept, which integrates a smart LED driver with three color LEDs into a tiny package. This drives down costs, simplifies control, and expands the functionality of LED lighting and display solutions. Founding members are Inova Semiconductors, Dominant Opto Technologies, NXP, TE Connectivity, and Pforzheim University. The last is involved in system design and optical measurements and optimizations. ■

Plastic Displays Will Play a Major Role in Automotive HMIs

Automotive trends, including increasing reliance on the human-machine interface (HMI) for the vehicle, indicate that future displays will need to be curved and shaped to fit any surface in the car. To speed adoption and reduce costs, it is desirable that this new generation of displays is manufactured using the existing automotive supply chain and building as much as possible on proven technologies.

by Simon Jones

THE automotive industry is on the threshold of several parallel disruptive changes driven by technology advancements and business model evolutions. For example, the combination of increasingly autonomous vehicles and new shared-ownership models is expected to lead to a much greater number of passenger miles being traveled without a pro rata increase in vehicles on the road.[1]

These changes will impact the driving experience as supported by the human machine interface (HMI) of the car. This is already happening as vehicles become more connected and more automated on their way to being driverless. Displays and touchscreens will represent a major platform for the new HMI, and flexible, conformable, plastic displays will help meet safety and usability needs while also enabling manufacturing and cost efficiencies.

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Fig. 1: *The transparent pillar concept is illustrated here. The supporting pillar on the left next to the windshield appears transparent to the driver, revealing potential road hazards. This is enabled by a conformed wrap-around display that is projecting an image from an external camera. Image: FlexEnable*

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Safety, Efficiency, Usability

HMI innovations that address both safety and usability will incorporate multiple sensors and cameras around the car that, if well integrated with the HMI, can warn of hazards on the road. A compelling example is the transparent A pillar concept in which the pillars on either side of the windshield are equipped with conformable wrap-around displays. Cameras on the outside of the car capture images that are then projected onto the display to make the A pillar seem transparent, as illustrated in Fig. 1. This will allow the driver to respond more intuitively to the hazard than if the warning came from the instrument panel or the center stack display.

In addition to the safety benefits, conformed and shaped displays can also contribute to increased fuel efficiency by allowing the removal of the outside side-view mirror, which the Auto Alliance estimates can reduce drag by up to 7%.[2] The obvious and natural location for the mirror replacement display is on the A pillar on the inside of the cabin.

Another driver for increased use of displays is the very strong preference of users. According to research conducted by IHS Markit, users prefer touchscreens over all other forms of input.[4] In contrast, physical buttons tend to be the least popular input device, so it is no surprise that buttons are fast disappearing in favor of touch displays.

As vehicles become more autonomous over time, needing less and less intervention from drivers, users may be seated in different areas of the vehicle, where they can perform a variety of tasks other than driving (Fig. 2). If surfaces within the car have been made active through the integration of conformed and shaped displays, then it becomes possible for the HMI to move around with the user to provide connectivity and entertainment wherever the user happens to be.

A more near-term trend in automotive displays is that the instrument panel and center stack displays are rapidly getting larger. However, it is becoming increasingly difficult to accommodate large and flat displays in an ergonomically optimized interior design where every other surface is curved.

A Significant Opportunity for Automotive Display Makers and Tier 1s

A trend toward rapidly increasing unit volumes and larger sizes of displays in vehicles is already clear. According to IHS Markit,

Fig. 2: *The XiM17 interior concept from Yanfeng Automotive Interiors demonstrates several potential uses of curved displays, including a door-panel display and a floor-console display.[3] Yanfeng is actively sourcing conformable display technologies from a number of sources to make this concept a reality. Image: Yanfeng Automotive Interiors*

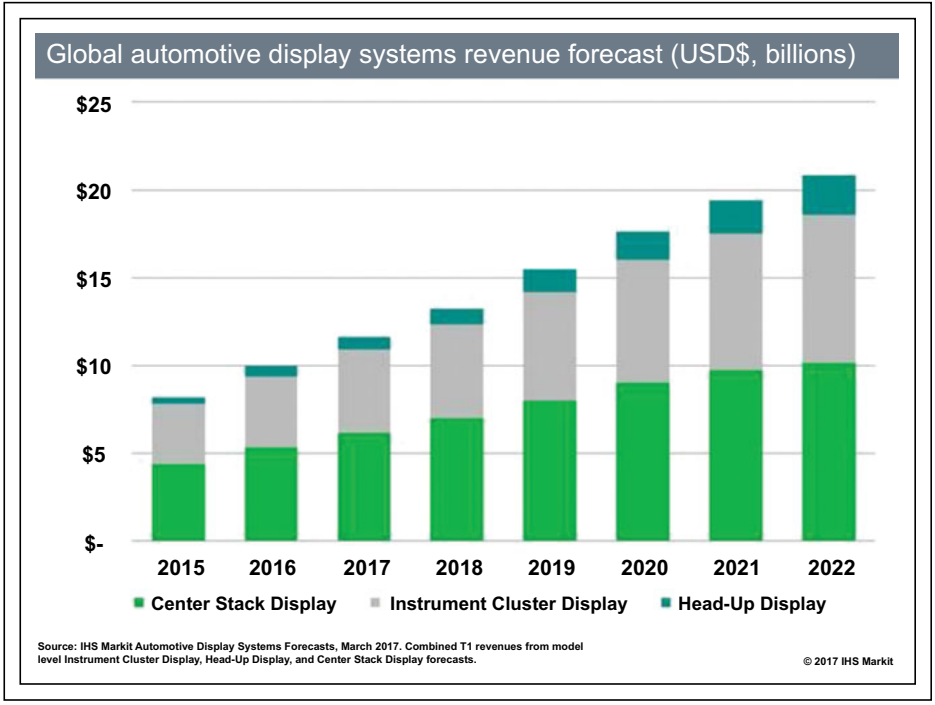

Fig. 3: *Growth for head-up, instrument cluster, and center stack displays is projected to rise steadily through 2022 and beyond.[4] Image: IHS Markit*

growth for head-up, instrument cluster, and center stack displays is projected to rise through at least 2022 (Fig. 3). IHS Markit also predicts a growth hot spot in 7-in. to 8-in. displays for the center stack and instrument cluster, which will alone account for more than 50 million units in 2020. FlexEnable projects that A pillar displays, steering wheel displays, entertainment displays, and many other new display applications in the car will represent significant upside opportunities to these forecasts.

The longer-term advent of self-driving cars does not negate this trend for two reasons. First, the industry expects that partially self-driving cars will be prevalent for a long time before we have cars that can self-drive in all circumstances. This means that the HMI has the additional task of managing the handover of responsibility between the car and the driver, with obvious safety implications. Second, even a fully self-driving car will have an extensive HMI to address the entertainment, information, and communication needs of the passengers. This underscores the desirability of using the curved surfaces of the interior to implement an extensive, seamless, and customizable HMI.

Non-flat and non-rectangular displays present new system integration challenges.

Fig. 4: *FlexEnable's plastic organic LCD (OLCD) is shown here in a cylinder form factor. OLCD displays can be curved to bend radii of below 30 mm.*

The displays will typically be manufactured in a flat state and will then need to be formed into the shape that is required for the final vehicle design. This will typically require lamination and assembly into a shaped cover glass or "window." The design of the window is likely to be highly customized to the vehicle interior design. This creates an opportunity for Tier 1s to add more value at the display module level, working closely with display makers and vehicle manufacturers. In many cases, the HMI features enabled by the conformed display will also require the Tier 1 to design and deliver a system that may include cameras and significant image processing. All of this means that there is more at stake in the supply chain and more value creation opportunity than is represented by the display module alone.

The challenge for the supply chain is clear. It needs to deliver conformed and shaped displays that meet the automotive industry's tough environmental standards at reasonable cost, and at a pace that matches accelerating innovation in vehicle design and use.

Flexible OLED *vs.* Flexible LCD

OLED and LCD are the two leading candidates for conformed and shaped displays in cars, and both present manufacturing challenges in that special techniques and methods are needed to be able to make the display on a flexible plastic substrate.

Flexible OLED is typically made by coating polyimide on a glass carrier. The OLED stack is then fabricated on the substrate using conventional high-temperature processes and later separated from the glass using a laser release method. A key challenge of this methodology is the relatively low yield of the laser release process, which typically destroys the glass carrier. After fabrication, another challenge is meeting the demanding reliability and lifetime requirements of automotive applications. OLEDs are highly susceptible to contamination from moisture and oxygen, driving the need for an extremely high-performance, flexible-barrier-layer solution. Automotive applications are particularly challenging because the range of temperature and humidity conditions are much wider than for consumer devices, and the display is required to last for at least 10 years. In addition, automotive OEMs are currently specifying a luminance of up to 1,000 cd/m^2 and may require even brighter displays in the future. These very high levels of luminance may be impossible to achieve with OLED while simultaneously achieving the required lifetime.

The key challenge with LCD-based panels is that they require the substrate to be optically very clear. Substrates that can survive high-temperature processes and maintain optical clarity and non-birefringence exist but are very expensive. However, the industry already has extensive experience in how to engineer LCDs to work in vehicles, and an automotive-qualified supply chain for LCDs already exists. The high-luminance requirement can be met with a high-performance backlight without limiting the lifetime of the display, whereas with an OLED display, increased luminance will directly reduce its lifetime.

Figure 4 shows a flexible, plastic organic LCD (OLCD) that has been developed by the author's company.

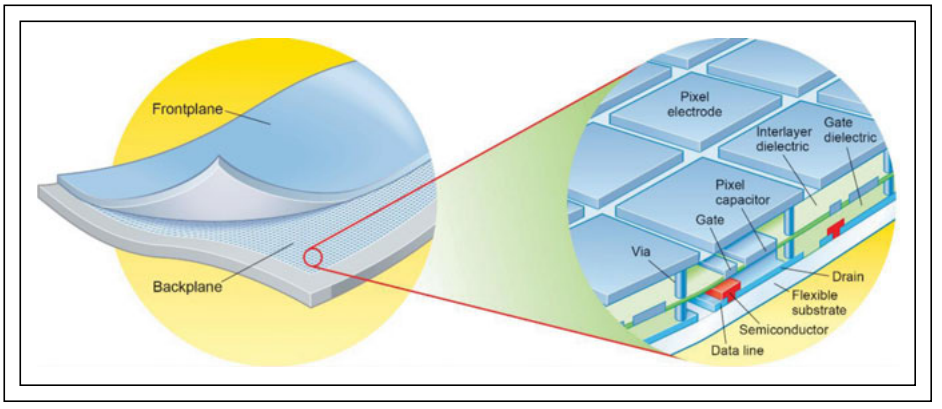

Fig. 5: *Plastic active-matrix backplanes can be applied to a number of frontplane technologies, including electrophoretic, LCD, and OLED.*

Low-temperature Processes and Commodity Substrates Enable Cost-effective, Flexible LCD

An alternative to sourcing expensive, high-temperature substrates is to use low-temperature processes to enable the use of commodity substrates. This is particularly critical for the fabrication of the active-matrix TFT array, which conventionally relies on high-temperature vacuum deposition of semiconductors and dielectrics. The author's company has developed an industrial process for fabricating the active matrix at low temperatures in air using solution-coated organic materials (Fig. 5).

Organic TFT (OTFT) technology is already in commercial production for flexible electrophoretic displays by Plastic Logic GmbH and this same technology platform has now been adapted to flexible organic LCDs (OLCDs) by FlexEnable. This adaptation has been made possible by rapid progress in the performance of OTFTs, which now exceed conventional amorphous silicon TFTs in mobility (Fig. 6) and stability, as has been described, for example, in the paper, "Photolithographic Integration of High Performance Polymer Thin-Film Transistors," presented at Display Week 2016 by Merck.[5]

This low-temperature process allows the use of triacetylcellulose (TAC) film as the substrate, which is already used as the substrate for LCD polarizers. This opens the prospect of using the same substrate for the polarizer and the active-matrix backplane for ultimate thinness.

OTFTs manufactured with this process are also fundamentally stable, as indicated by gate bias stress tests (see Table 1). As the semiconductor is p-type, the key parameter is positive gate bias stress (PGBS). The PGBS test is conducted by applying a constant bias voltage to the TFT for a fixed amount of time. The switching characteristics of the OTFTs are tested before and after the fixed stress. The results indicate that there is only a 1V shift in the switch-on voltage of the OTFT, which is half the shift seen in amorphous silicon devices.

Of course, the automotive industry requires qualification over an extensive set of environmental parameters. This work is under way for OLCD, and FlexEnable's 14-in. prototype line is running at up to three shifts per day to produce the prototypes and test samples necessary. Working with manufacturing partners, FlexEnable is already in the early stages of scaling OLCD to volume production. Final automotive qualification of production OLCD modules is targeted to start in 2018.

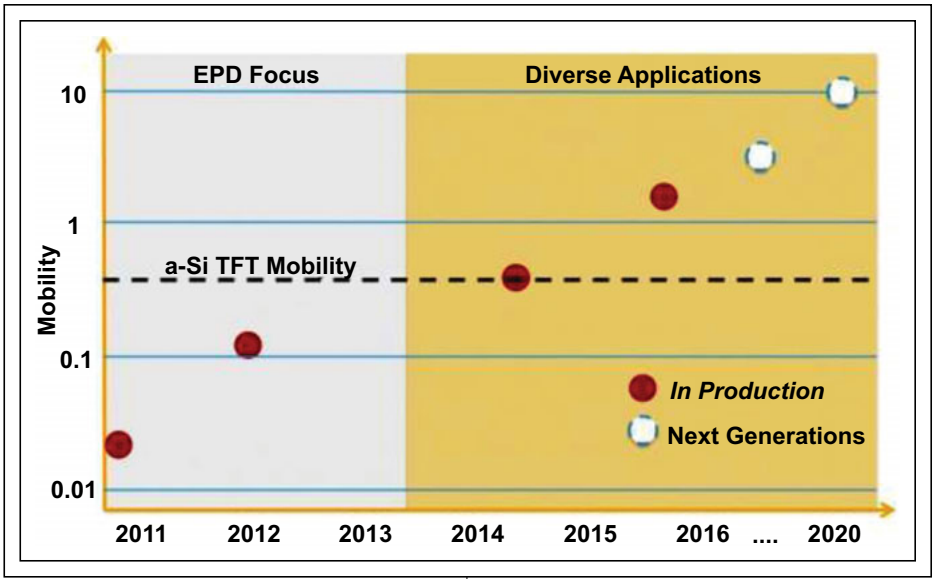

Fig. 6: The mobility of production OTFT processes now exceeds the performance of amorphous silicon.

Re-purposing Existing Fabs to OLCD

The OLCD process has been developed to minimize the investment required to convert an existing amorphous-silicon-on-glass TFT fab to OTFT. Often, a fab can be reconfigured to make OTFT samples with no capital investment at all, although to create a fully balanced fab will require some additional coating and lamination machines. This is a very modest investment compared with the original capital investment required to build the fab.

The process begins by laminating the low-cost plastic substrate to a carrier glass. The OTFTs are then fabricated on the substrate before the LCD frontplane is created using largely conventional (and therefore low-cost) materials and processes.

A simple process is used to de-mount the finished displays from the glass carrier at extremely high yield and allows the glass carrier to be re-used. Before individual displays are de-mounted from the carrier glass, they can be laser cut using a commodity CO_2 laser trimming tool to almost any arbitrary shape. In the example shown in Fig. 7, a laser is being used to cut out a non-rectangular test sample.

The ability to re-purpose existing active-matrix LCD fabs to make OLCDs, together with process simplifications and efficiencies that result from using a low-temperature process, means that the OLCD is an extremely cost-competitive approach to making plastic conformable displays. Cost modeling based on analysis of specific partner fabs indicates that flexible LCD can reach the cost of standard glass-based LCD at scale, which means that flexible OLCD will maintain a significant cost advantage over flexible OLED even when the latter process is fully scaled.

Today's LCDs for automotive applications are typically manufactured on Gen 4.5 lines

Table 1: Gate Bias Stress Test Results

TFT Technology	Test	Voltage	Temperature	Time	|ΔVth|
Organic	Positive Gate Bias Stress (PGBS)	+20V	60°C	10,000sec	1V
Amorphous Silicon[6]	Negative Gate Bias Stress (NGBS)	–20V	60°C	10,000sec	2V

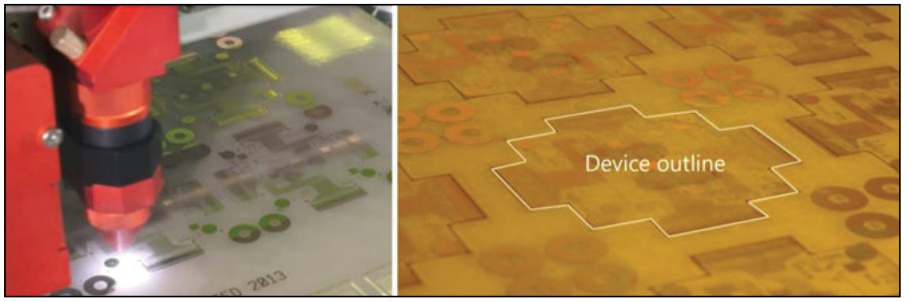

Fig. 7: *Cutting OTFTs to arbitrary shapes is done with a standard CO_2 laser trimming tool. The left-hand picture shows the laser cutting tool cutting the non-square outline of the fabricated device shown in the right-hand picture. The cutting process takes place while the plastic device is mounted on the glass carrier for processing. The device is de-mounted using a low-stress heat-based de-mount process.*

(730 mm by 920 mm). The tool set typically used is listed in Fig. 8.

When a line is re-purposed to make plastic OLCD panels, the chemical vapor deposition tools are replaced with solution deposition tools such as slot-die coaters. Also, laminators would typically be added to mount the low-cost plastic substrate to the glass carrier for processing. After these modifications to the fab are made, the manufacturing process for the OLCD is very similar to a glass LCD. The OTFT array and color filter array are made on separate sheets and assembled together on a one-drop fill line with photospacers added to define the cell gap. Significantly, no special equipment is needed to de-mount the plastic from the glass because the low-stress heat-based de-mount process is an exceptionally elegant step that protects the integrity of cell gap when the glass carrier is removed.

OLCDs are driven in the same way as are glass-based displays. Row and column drivers are bonded to the array substrate using standard interconnect technologies like chip on film (COF) or chip on glass (COG), which have been adapted for processing on plastic. Row drivers can be integrated on the OTFT array substrate for certain display designs.

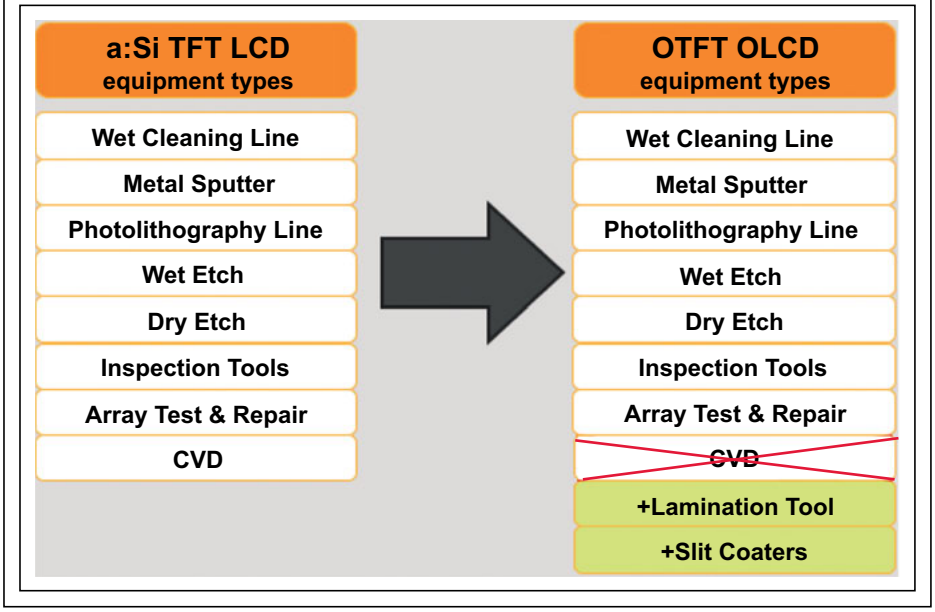

Fig. 8: *A fully balanced line conversion for OLCD will typically require some additional lamination and coating tools.*

HMI Innovation Is Enabled by Conformed and Shaped Displays

One of the great advantages of re-purposing the existing automotive LCD supply chain is that time-to-market can be minimized as well as the cost and risk of adoption. Already, visionary manufacturers are implementing radically new HMI features with prototype conformed and shaped displays.

Looking further into the future, we can imagine a car interior where there is a "hidden until lit" touchscreen almost everywhere there is a physical button today. Every aspect of the HMI would then become highly personalizable, upgradable, and reconfigurable, according to the application being used. Personal customization of the HMI, and even the ambience of the interior, will become possible, and this will be increasingly important as "shared mobility" models lead to each car being used by more people on average.

In order to realize the applications described in this article, major car brands are working toward product introductions starting in 2019, enabled by supply-chain-friendly technologies like OLCD. The car interior of the near future is going to look very different, very soon.

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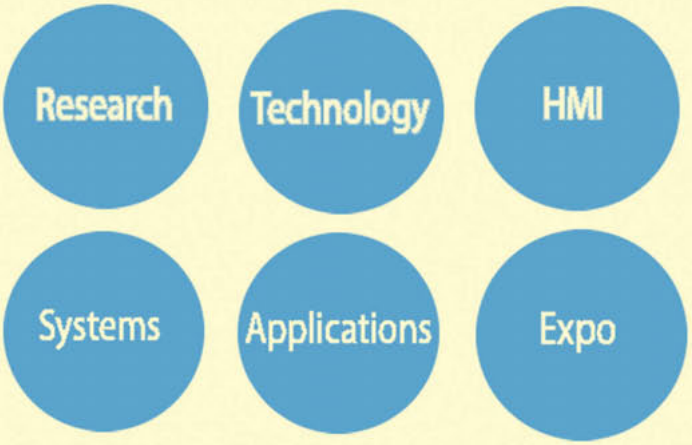

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Create Higher Resolution Displays with the VESA DSC Standard

As consumer demand for ultra-high-definition display products grows, designers are faced with many system design challenges associated with handling increased video throughput. The VESA Display Stream Compression (DSC) standard offers a compelling solution for enhancing display resolution up to 8K for a number of applications without having to compromise on display quality, battery life, or cost.

By Alain Legault and Emma-Jane Crozier

In recent years, ultra-high-definition displays have become a key component of success for products across the consumer electronics industry. Users expect vibrant images and video, while manufacturers have seized the opportunity to differentiate their products through higher resolution displays.

The Need for Compression

Whether for a smartphone, a computer monitor, or a car infotainment system, almost all display interfaces send uncompressed pixel data from the graphics processor to the display using a serial interface (Fig. 1).

As display resolutions have increased, so too has the amount of pixel data transferred across the serial transport interface. For example, a 4K mobile device at 60 frames per second requires a data rate of 16 gigabits per second (Gbps). Using the Mobile Industry Processor Interface (MIPI) display serial interface (DSI) physical layer (D-PHY) 1.2, a total of eight transmission lanes are required to transfer the video data.

The bandwidth needed to achieve higher resolutions has increased much faster than the serial interface speed used by video transport interfaces. While display resolutions have essentially doubled year after year, the serial interface speed has increased by only approximately 20% every year, resulting in a considerable gap (Fig. 2).

One possible solution to manage more pixel data would be to increase the number of serial lanes used in parallel. However, this would mean adding additional power, as well as increasing the number of pins and wires. For devices such as smartphones, this would seriously compromise battery life, as well as significantly increase overall system costs.

Another, better option is to use compression to handle the increased pixel data. By reducing the pixel data rate, compression alleviates pressure on transport links while keeping power consumption lower.

Figure 3 highlights in red the impact of compression for a 4K video stream such as WQUXGA on a mobile device using MIPI

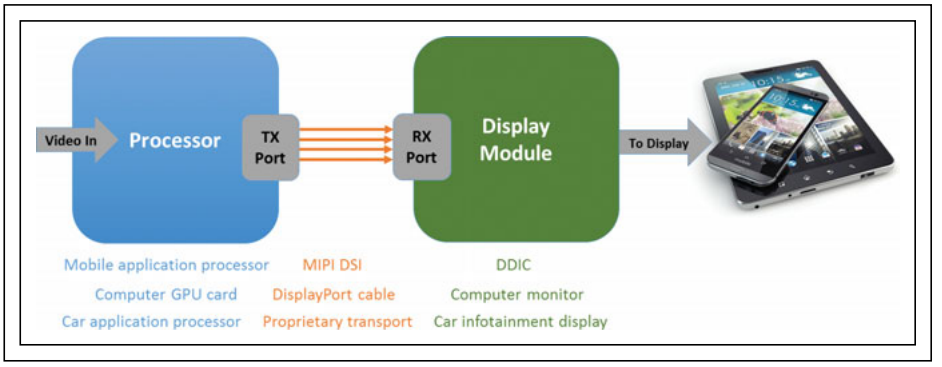

Fig. 1: *Data flow occurs between an application processor and a display module using uncompressed video. (MIPI Alliance = Mobile Industry Processor Interface Alliance. DDIC = display driver integrated circuit. DSI = display serial interface.)*

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DSI transport. With a limit of eight lanes for the transmitter, it would not be possible using 1.5 Gbps per lane to develop a viable 4K product without compression. Using 2.5 Gbps per lane, eight lanes would be required. It would still be possible to develop a product, albeit with a considerable increase to overall development costs. With the addition of compression, it is now possible to develop a product with a 4K display using only four MIPI DSI lanes. Compression, therefore, presents a viable option for dealing with the challenge of designing higher resolution display products.

Background to VESA DSC

Having recognized the need for compression on display links, the Video Electronics Standards Association (VESA) first initiated efforts for a common, industry-wide compression standard in 2012, with the formation of the Display Stream Compression Task Group. A call for proposals in the industry was released in January 2013, with the objective of developing a compression standard that emphasized visually lossless picture quality, had a constant bit rate (CBR), offered the ability to update small regions of the image, supported many video formats (RGB, YCbCr 4:2:2, or 4:4:4; 8, 10, or 12 bits/component), and was easy and inexpensive to implement in real time. Six proposals were evaluated by the Display Stream Compression Task Group.[1] DSC was announced in the spring of 2014 and the v1.1 specification and C-model (a software representation of DSC used for verification and testing) were released in July 2014. The VESA Embedded DisplayPort (eDP) v1.4 and MIPI DSI v1.2 standards adopted DSC as a supported standard upon its release.

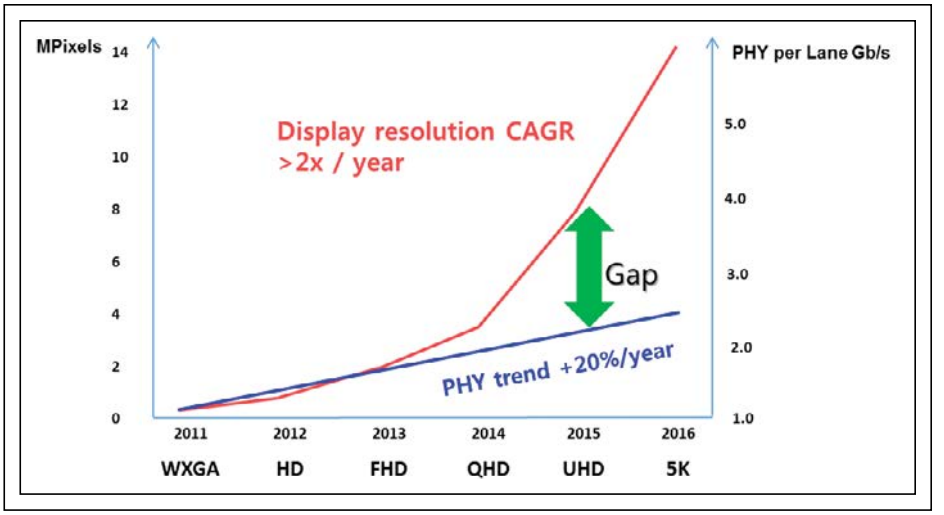

Fig. 2: The display resolutions in devices, from wide extended graphics array (WXGA) to 5K and up, and the physical layers (PHY) used to transport the display information have not grown at the same compound annual growth rate (CAGR).

VESA DSC Algorithm

The VESA DSC algorithm is designed to compress video in real time for use in display transmission links with a CBR. The DSC algorithm is based on delta-pulse-code modu-

D-PHY v1.1 1.5 Gbps / lane

Resolution	FHD (1080x1920)	WQHD (1440x2560)	WQXGA (1600x2560)	UHD (2160x3840)	WQUXGA (2400x3840)	5K (2880x5120)	8K (4320x8192)
Bandwidth	3.58Gbps	6.37Gbps	7.08Gbps	14.33Gbps	15.93Gbps	25.49Gbps	61.16Gbps
No compression	3 lanes	6 or 8 lanes	6 or 8 lanes	N/A	N/A	N/A	N/A
2x compression	2 lanes	3 lanes	3 lanes	8 or 6 lanes	8 or 6 lanes	N/A	N/A
3x compression	1 lane	2 lanes	2 lanes	4 lanes	4 lanes	8 lanes	N/A

D-PHY v1.2 2.5 Gbps / lane

Resolution	FHD (1080x1920)	WQHD (1440x2560)	WQXGA (1600x2560)	UHD (2160x3840)	WQUXGA (2400x3840)	5K (2880x5120)	8K (4320x8192)
Bandwidth	3.58Gbps	6.37Gbps	7.08Gbps	14.33Gbps	15.93Gbps	25.49Gbps	61.16Gbps
No compression	2 lanes	3 lanes	3 lanes	8 or 6 lanes	8 lanes	N/A	N/A
2x compression	1 lane	2 lanes	2 lanes	3 lanes	4 lanes	8 or 6 lanes	N/A
3x compression	1 lane	1 lane	1 lane	2 lanes	3 lanes	4 lanes	N/A

Fig. 3: Based on a limit of eight lanes for the transmitter, it would not be possible to develop a viable 4K product without compression using 1.5 Gbps per lane. Compression allows for a 4K (or WQUXGA, as shown outlined in red) product using only 4 MIPI DSI lanes.

lation (DPCM), and requires a single line of pixel storage; this enables extremely low latency performance results (of only a few microseconds). A rate buffer is also required. Figure 4 shows the DSC encoder block diagram.[1]

There are multiple encoding tools included in the algorithm to ensure excellent visual performance for all types of content, including images, text, graphics, and complex test patterns (codec buster images). These encoding tools include the midpoint predictor (MPP), the block predictor (BP), the modified median adaptive predictor (MMAP), and indexed color history (ICH).

The VESA website states: "Compared to other image compression standards such as JPEG or AVC, etc., DSC achieves visually lossless compression quality at a low compression ratio by using a much simpler codec (coder/decoder) circuit. The typical compression ratio of DSC ranges from 1:1 to about 3:1, which offers significant benefit in interface data rate reduction. DSC is designed specifically to compress any content type at low compression with excellent results."[2]

Testing and Performance

A series of rigorous tests was conducted by the DSC Task Group throughout the standard's development process to guarantee the visually lossless performance of the DSC algorithm.

Participants were asked to compare a randomly chosen reference image with an encoded test image placed side by side to determine if it was possible to detect a difference between the two. According to VESA, "… the visual performance of DSC was evaluated through clinical testing by VESA in collaboration with member companies. The evaluation included a statistically significant number of observers who viewed many images over four image categories including artificial engineered images, text and graphics, such as street maps or different examples of printed material, people, landscape, animals and stills. Overall, observers completed nearly 250,000 subjective image comparisons. VESA members also concluded subjective testing as a far more robust method to verify visually lossless quality … ."[2] A complete overview of the subjective test methodology used by the task group is outlined in the 2015 article, "A new standard method of subjective assessment of barely visible image artifacts and a new public database: subjective analysis of image quality," by David M. Hoffman and Dale Stolitzka in the *Journal of the SID* **22**/15, 2015.

Based on the criteria defined by VESA prior to the development of DSC, the results of the testing confirmed the visually lossless picture quality of DSC for all types of images up to a compression factor of 3X.

VESA DSC Developments

Since its release in 2014, several important developments have further expanded the capabilities of DSC.

VESA DSC version 1.2a was released by VESA in January 2016. Backward compatible with DSC 1.1, DSC 1.2a offers additional features that enable the standard to be used across a wider range of display applications, including higher resolution televisions and external display monitors of 4K and beyond. DSC 1.2a supports 14- and 16-bit color bit depth and offers native compression for 4:2:0 and 4:2:2 in the YCbCr color space, the video formats used in digital TVs. Another key feature is support for up to 16 bits per color component, versus the 8, 10, and 12 bits supported by DSC 1.1.

The latest version of the DisplayPort standard (1.4), a digital display interface used for video transport between GPUs and computer monitors, was released in March 2016 and added support for VESA DSC 1.2a and forward error correction (FEC). As compressed video images can be affected by transmission errors, and even a single bit error can have a catastrophic impact on the visual experience, the Reed Solomon (254,250) FEC algorithm is used with DisplayPort 1.4 to improve the resiliency to link errors. The use of the Reed Solomon FEC substantially improves the bit error rate (BER) from 10^{-9} to 10^{-20}, making transmission errors occur less than once a year instead of every few seconds.

DisplayPort 1.4 maintains the link speed at 8.1 Gbps, but by using DSC with HBR3 transmission rates, it can support 8K UHD (7,680 × 4,320) at 60 Hz with 10-bit color and HDR, or 4K UHD (3,840 × 2,160) at 120 Hz with 10-bit color and HDR. Using DSC 1.2a with DisplayPort 1.4 also provides the ability to support multiple parallel streams over interleaved packets.

Version 2.1 of the HDMI specification was announced in January 2017 and will include support for VESA DSC 1.2a.[3]

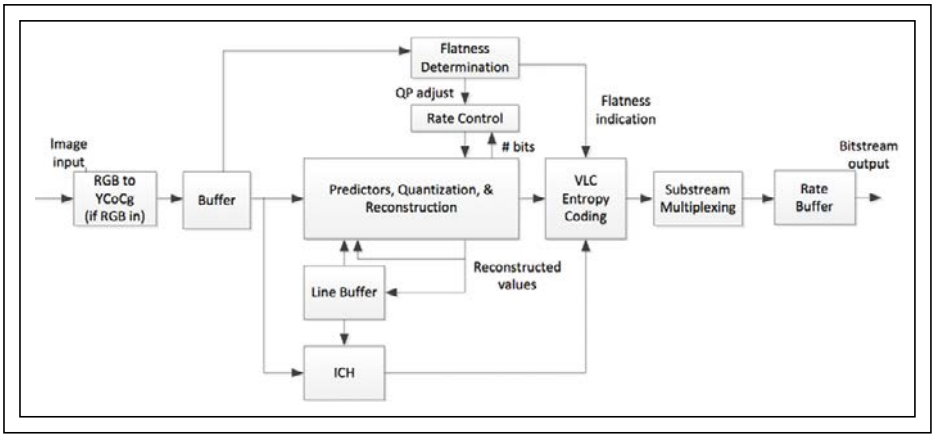

Fig 4: *This block diagram shows the main elements and data paths of the DSC encoder. These include the rate buffer, line buffers, the predictors, rate control feedback loop, VLC entropy coder, and the substream multiplexer. Source: VESA Display Stream Compression white paper.*[1]

Use Cases for VESA DSC

VESA Display Stream Compression was originally utilized by smartphone and tablet manufacturers; however, with the emergence

of new display-based products, such as augmented- and virtual-reality (AR/VR) headsets, as well as display technology advances in areas such as the automotive industry, video compression is now being used across a wide range of applications. Whether it be the challenge of dealing with faster frame rates for AR/VR applications, or the simultaneous transport of multiple video sources for in-car video systems, DSC compression can be used to support higher resolution displays across a range of different applications. The following use case descriptions demonstrate the range of uses to which DSC can be successfully applied.

Compelling UHD Mobile Displays Without Sacrificing Battery Life and Cost

Since its release in 2014, VESA DSC has seen broad adoption from across the mobile industry. The NVIDIA Tegra X1 and the Qualcomm Snapdragon 820 are two examples of mobile processors currently making use of DSC 1.1.[4]

By adding a DSC encoder within the application processor and a DSC decoder within the display driver IC, it is possible to reduce the number of MIPI DSI TX and RX transport lanes needed, resulting in overall lower power consumption for the device (Fig. 5). It is also possible to reduce the size of the synchronous dynamic random access memory (SDRAM) frame buffer by the compression factor (*e.g.*, 3X) if the images are stored in the compressed domain, enabling a reduction of overall system costs.

Simultaneous Transport of Multiple Video Streams in Automotive Video Systems

Automotive electronics have evolved greatly in recent years, with considerable influence stemming from the growing trend of equipping vehicles with multiple displays at higher resolutions. Cars now contain multiple video sources for Advanced Driver Assistance Systems (ADAS), infotainment, climate control, side-view cameras, and driver navigation. As the number of video sources grows, so too does the challenge of processing and transporting video content around the vehicle. Manufacturers face high cabling costs and weight, peaked bandwidth, and increased electromagnetic interference (EMI) when developing systems containing multiple video streams inside cars.

In vehicles, several competing serial transport links are used to transport video, audio, and other telematic information over the local car network. These networks have a fixed bandwidth. The example in Fig. 6 shows how DSC can be implemented with multiple video streams using an ethernet transport backbone.

With DSC compression, the data transport capacity is increased by up to 3X, enabling designers to use the existing physical interfaces in the vehicle with an increased number of displays at higher resolutions. By freeing up data bandwidth through compression, DSC enables more parallel video sources to be transported simultaneously over the same cabling, hence reducing the need for extra

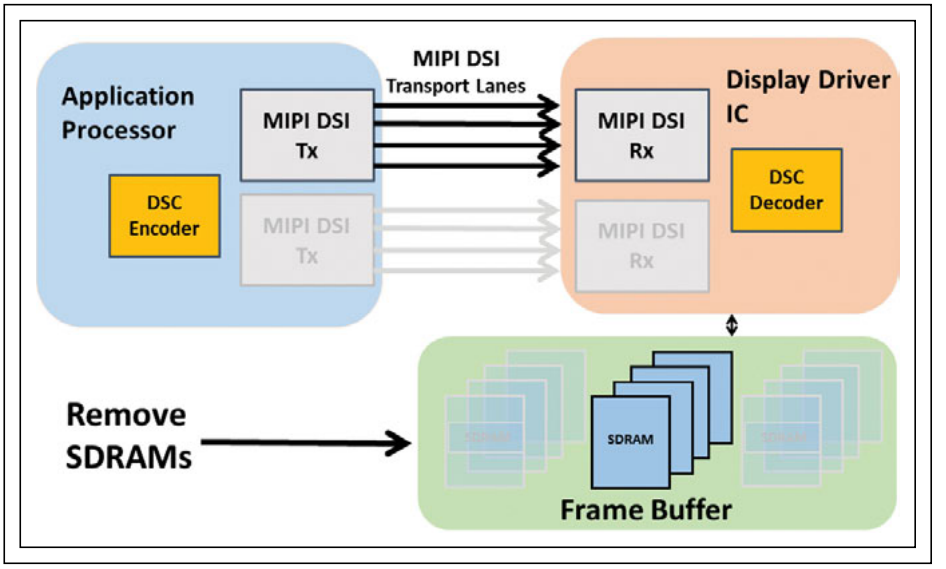

Fig. 5: *Using VESA DSC, it is possible to reduce the number of MIPI DSI TX and RX transport lanes and SDRAM memory needed.*

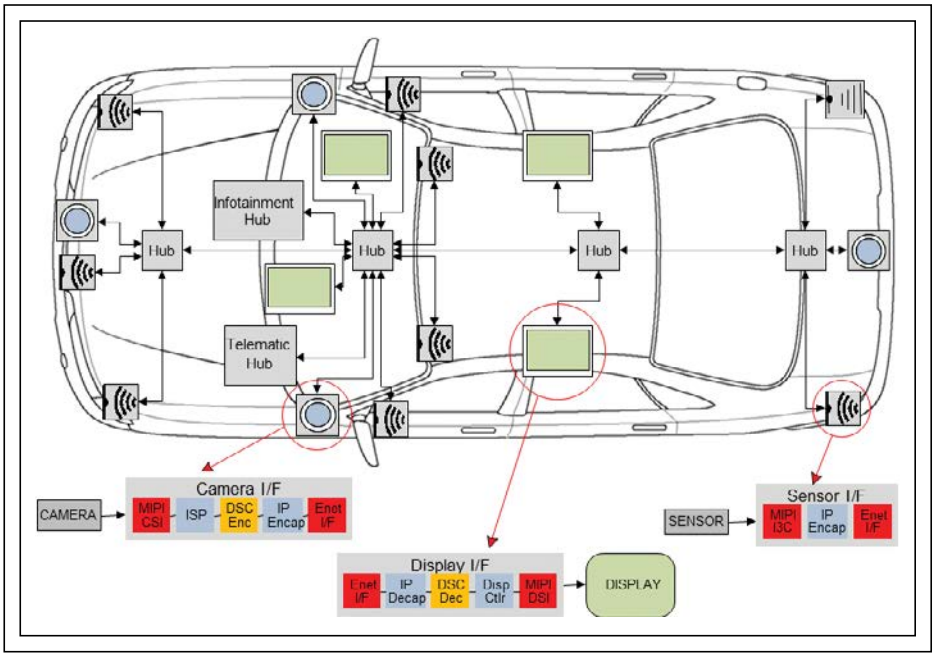

Fig. 6: *By freeing up data bandwidth through compression, DSC enables more parallel video sources to be transported simultaneously over the same cabling.*

cabling and the potential expenses and weight associated with this.

Immersive High-Resolution Displays for AR/VR Products

Immersive, high-resolution displays form a key part of the experience offered by AR/VR products. Both AR and VR applications require high-resolution displays due to the proximity of headsets to the human eye; they also require very high frame rates for maximum fluidity (90 or 120 Hz), and minimal latency in order to avoid the potential motion sickness associated with the brain detecting small delays between the body's physical movement and the image from the head-mounted device. In the quest to achieve higher resolution displays, manufacturers are often faced with many challenges, including power, footprint, and memory bandwidth considerations.

Figure 7 illustrates how DSC compression can be implemented between the application processors and micro-display driver ICs inside AR/VR head-mounted displays. By adding a DSC encoder at the image capture subsystem, a DSC encoder and decoder in the video/graphics processor, and a DSC decoder at the output, it is possible to increase the effective bandwidth capacity at every stage, reducing the overall shared memory bus bandwidth requirement, the number of SDRAMs, and hence the cost of materials and power consumption.

DSC compression offers extremely low latency performance. With a delay of a few microseconds, the addition of DSC compression is not perceptible to the human eye.

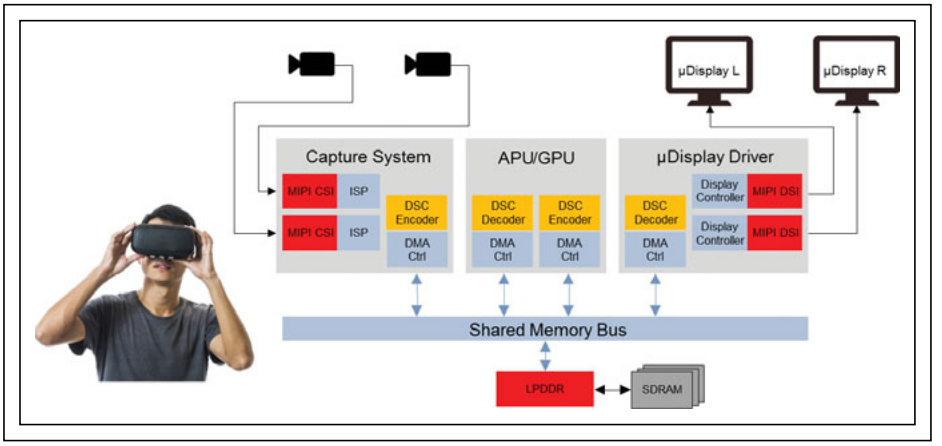

Fig. 7: *DSC compression can be implemented between the application processors and micro-display driver ICs inside AR/VR head-mounted displays.*

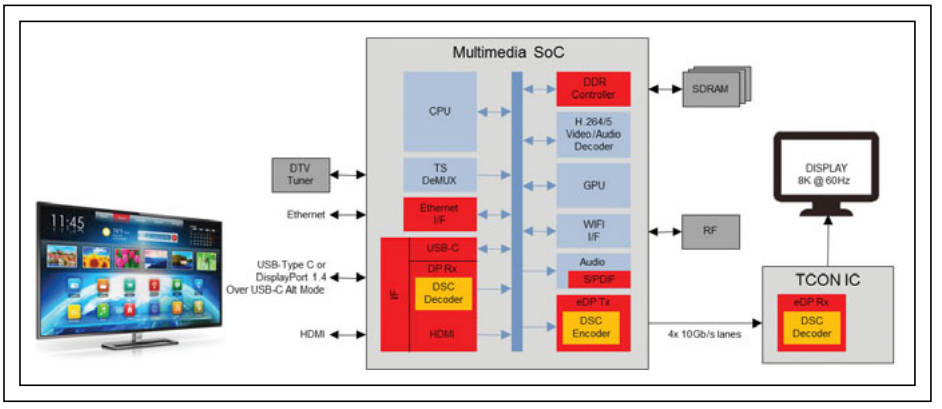

Fig. 8: *With support for up to 16 bits per color, compression with DSC 1.2a can be used to develop HDR-compatible 8K digital televisions.*

8K Digital Televisions and Digital TV Products

The extended capabilities of DSC v1.2a opened up the potential for DSC compression to be used for digital TV applications, including UHD televisions and other associated digital TV products such as set-top boxes (STBs) and DVRs. By supporting 14- and 16-bit color bit depth (to display very high-color depth content), as well as adding native coding for 4:2:0 and 4:2:2 in the YCbCr color space (for more efficient compression), DSC 1.2a directly addresses the requirements of the digital TV market for developing HDR-compatible 8K televisions at high frame rates.

As shown in Fig. 8, DSC can be implemented within the television's multimedia system-on-chip (SoC) processor and the TCON (timing controller). The bandwidth reduction offered by DSC eases the challenge of using long transmission lines between the SoC processor and the TCON on the back of the display panel. DSC helps to reduce EMC and signal integrity issues caused by the high-frequency challenges that usually come with designing ultra-high-resolution products.

Because DSC compression is scalable, super-high resolutions such as 8K @ 120Hz can be achieved with today's semiconductor technology at an affordable price.

USB Type-C Laptop and Extended Display Using DisplayPort Alternate Mode

The most recent USB Type-C compatible devices allow the use of a symmetrical reversible connector to provide all the I/O interfaces to and from the computers; this single cable can carry USB data, audio, and video information using DisplayPort Alternate or "Alt Mode," as well as power delivery up to 100 W. USB Type-C offers a maximum data bandwidth of 32 Gbps. If this single interface were, for example, to be used with two external 4K desktop monitors (each with 16 Gbps of data bandwidth), there would not be a lot of data bandwidth left to carry other USB information; using compression to increase the amount of available bandwidth is, therefore, an interesting solution.

There are several possible implementations of DSC with USB Type-C. For example, DSC compression can be used in the DisplayPort transmitters inside the GPU source combined

(continued on page 53)

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Herbert DeSmet
Editor-in-Chief

Announcements

Expanded Distinguished Papers of Display Week 2017

As of this year, having **a peer reviewed expanded version** accepted in **JSID** is a prerequisite for achieving the **Distinguished Papers** status at Display Week. This adds to the importance of the recognition. At the same time it increases and extends the worldwide visibility and availability of these papers.
An expedited peer review process was installed to get all accepted papers published in JSID simultaneously with the symposium Digest. The expedited review was somewhat stricter than the regular review because manuscripts requiring major revisions were rejected due to time constraints.
A **virtual JSID issue** containing the 20 Expanded Distinguished Papers will be **freely accessible** until the end of the year at http://tinyurl.com/edpdw17. Some of those papers are highlighted below.

Special Section on Vehicle Displays

Most of the January issue is dedicated to our Special Section on Vehicle Displays, guest edited by **Rashmi Rao** and **Haruhiko Okumura**. One of those papers is also highlighted below.

Best of IDW 2016

Review is presently ongoing for the expanded papers submitted for the Special Section 'Best of International Display Workshops 2016'. The IDW program committee has nominated only the top 3% of all conference papers. Publication of the accepted papers is expected in Q3.

Invitation to submit review papers

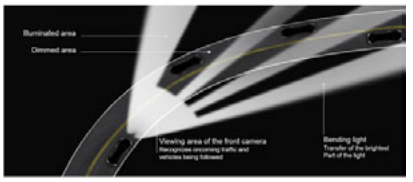
The Journal is presently looking for review papers on any display-related topic. If you have a great idea for a review paper, please contact the editor at editor@sid.org.

Selected authors will be invited and the page charges will be waived.

Highlighted recent papers

Vehicle Displays

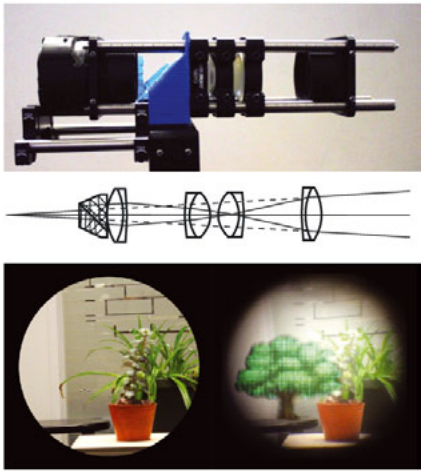
Development of active matrix LCD for use in high-resolution adaptive headlights | Christiane Jasmin Reinert-Weiss *et al.*| DOI: 10.1002/jsid.534



By integrating an active-matrix liquid-crystal display module, it is possible to realize fully adaptive high-resolution headlamps without mechanical elements and a finite number of LED with 30 k switchable pixels. The realized monochrome display is able to withstand high illuminance (≥ 20 Mlx) and high temperature (80°C) at the same time while providing reliably a contrast ratio up to 490:1.

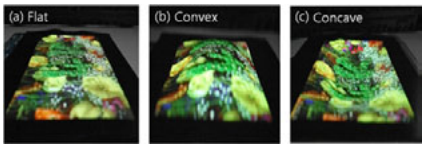
Expanded Distinguished Papers of Display Week 2017

Perspective correct occlusion-capable augmented reality displays using cloaking optics constraints| Isela D. Howlett and Quinn Smithwick | DOI: 10.1002/jsid.545



Perspective-correct occlusion-capable augmented reality displays are generalized using optical cloak constraints for ray transfer analysis; any ray entering the optical system exits at a height and angle as if passing through empty space. Two-lens, three-lens, and four-lens groups in inline, folded, and looped configurations are analyzed; a four-lens looped optical cloak and a three-lens inverted cloak with an erecting prism are demonstrated.

9.1-inch stretchable AMOLED display based on LTPS technology | Jong-Ho Hong *et al.*| DOI: 10.1002/jsid.547



We demonstrate a freeform-shaped AMOLED display based on low-temperature polycrystalline silicon technology. It was found that our AMOLED can withstand various desired shapes featuring its stretchable property with no degradation of image quality and device characteristics. We successfully fabricated a 9.1-in. AMOLED display with convex and concave shapes by using a low-temperature thermoforming process.

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Automotive Trends Drive Vehicular Displays

Display Week will offer many opportunities to learn about the latest advancements in vehicular displays. Trends such as larger and more plentiful automotive displays, HUDs, the connected car, ADAS, and autonomous driving are informing these new developments.

by Ken Werner

SID's Display Week 2017, held in Los Angeles, May 22–26, at the Los Angeles Convention Center, will feature an automotive Market Focus Conference on Tuesday, May 23, and a substantial vehicle displays technology track on May 24 and May 25. There will be plenty to see and hear at these events; in the meantime, let's look at some of the ongoing developments in automotive systems for perspective on where and how the various technologies that will be discussed at Display Week might – or might not – fit in.

More and Bigger Displays

The average size of automotive displays is increasing, with center-stack displays heading toward 8 inches for now. As Tesla has demonstrated, it can, and will, go much larger, and on cars far more affordable than the first two Tesla models. Of course, sizes and configurations will vary with the automotive interior design approach, vehicle market position, and trim level.

Automotive OEMs are also planning on more displays per vehicle (Fig. 1).

***Ken Werner** is Principal of Nutmeg Consultants, specializing in the display industry, manufacturing, technology, and applications, including mobile devices and television. He consults for attorneys, investment analysts, and companies re-positioning themselves within the display industry or using displays in their products. He is the 2017 recipient of the Society for Information Display's Lewis and Beatrice Winner Award. You can reach him at kwerner@nutmegconsultants.com.*

One near-term application for luxury vehicles is replacing side-view mirrors with cameras and interior displays. This will get the mirror structures out of the airflow for reduced wind noise and slightly improved gas mileage. In addition, designers are looking forward to getting the mirrors off their carefully sculpted surfaces. A more fanciful idea is putting displays on the B and C pillars, which will show camera images of what is on the other side of the pillars, thus making the pillars "transparent" and doing away with their blind spots. (For more about these "transparent" pillar displays, see the article, "Plastic Displays Will Play a Major Role in Automotive HMIs," in this month's issue.)

Most important, though, is that the display suite must support increasingly complex

***Fig. 1:** There is no such thing as too many displays in a car, Mitsubishi seems to be saying with this PHEV concept car. Rendering: Mitsubishi Motors*

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automotive systems and various levels of connectivity and autonomy. That means that the displays must work together with other input/output technologies such as touch, audio, gesture control, and haptics to create a reliable and effortless human-machine interface (HMI). Given the increasingly multimodal nature of these interfaces, system designers are calling them MMIs (multimodal interfaces). There will be presentations at Display Week evaluating the relative effectiveness of different modal combinations and implementations.

Touch-panel makers worry about how to make touch panels reliable in automotive environments, but no matter how reliable they are, a driver reaching to touch a center-stack panel will be distracted and may have to remove his eyes from the road. Here is one place where haptics developers see an opportunity, both for displays and for soft buttons on steering wheels.

I did not see any papers on voice recognition in the program, but its development for automotive use is inevitable because it solves the problem of reaching for soft buttons while driving. Given the rapidly increasing sophistication of digital assistants using AI and voice recognition, we are sure to see voice recognition's increasing use for information inputs and control beyond phone dialing.

Heads Up!

Automotive original equipment manufacturers (OEMs) and suppliers see a big future for head-up displays (HUDs), especially in combination with augmented-reality (AR) systems. Many developmental systems and components were shown at the Consumer Electronics Show (CES) in January. There has been speculation that when HUDs get good enough, there will be no need to show the same information on an instrument cluster. Certainly removing the cluster will free up precious space behind the dash.

Projection HUDs do face challenges with image size, viewing angle, eye box, and the volume the projector occupies under the dash, but automotive suppliers such as Continental are working on those problems vigorously. Although it is likely that projection will be the dominant HUD technology, alternative approaches are being demonstrated. Among these are Lumineq's thin-film electroluminescent (TFEL) display sandwiched inside the windshield and LG Display's transparent OLED mounted on the dash between the windshield and the driver, but these displays are early in their development and have challenges of their own to overcome.

Developmental issues aside, HUDs are fated to become commonplace in vehicles for many market segments, and the instrumentation and AR content they show will become far more extensive.

ADAS

Advanced driver-assist systems (ADAS) – such as automatic emergency braking, lane keeping, adaptive cruise control, and self-parking – are proliferating now and have consumer buy-in rates between 5 and 20%. In other words, up to 20% of consumers currently are willing to pay significantly more for their new vehicles to include these options. In the US, back-up cameras and sensor alerts had a buy-in of 80% in 2016, assisted by a National Highway Traffic Safety Administration requirement that they be included on new light vehicles (cars and light trucks), phasing in by mid-2017 and required on all new light vehicles by mid-2018.

As is well known, original equipment back-up cameras generally send their output to the vehicle's center-stack display. Aftermarket cameras generally send theirs to a separate display. The cameras usually require power from the vehicle's electrical system, and also require that a video cable be run from the camera to the display, which also requires vehicle power. Recently, wireless back-up camera systems have been introduced. The camera is integrated into a replacement license-plate frame and uses battery power, which may be supplemented with solar cells. The signal is carried forward by WiFi or Bluetooth, and in two recent examples, the display is the user's cell phone. In at least one case, data from the vehicle's on-board diagnostics (OBD)-II port tells the system when the car is in reverse.

Making an aftermarket system wireless is an excellent idea, but using the cell phone for the display is not, and is the lazy way out. Readers of *Information Display* will be able to think of many ways to incorporate a dedicated display. One way is to integrate the display into a replacement rear-view mirror. Since many OEM mirrors are powered, there will often be a convenient source of 12 volts for such installations. (This has in fact been offered for a number of years.)

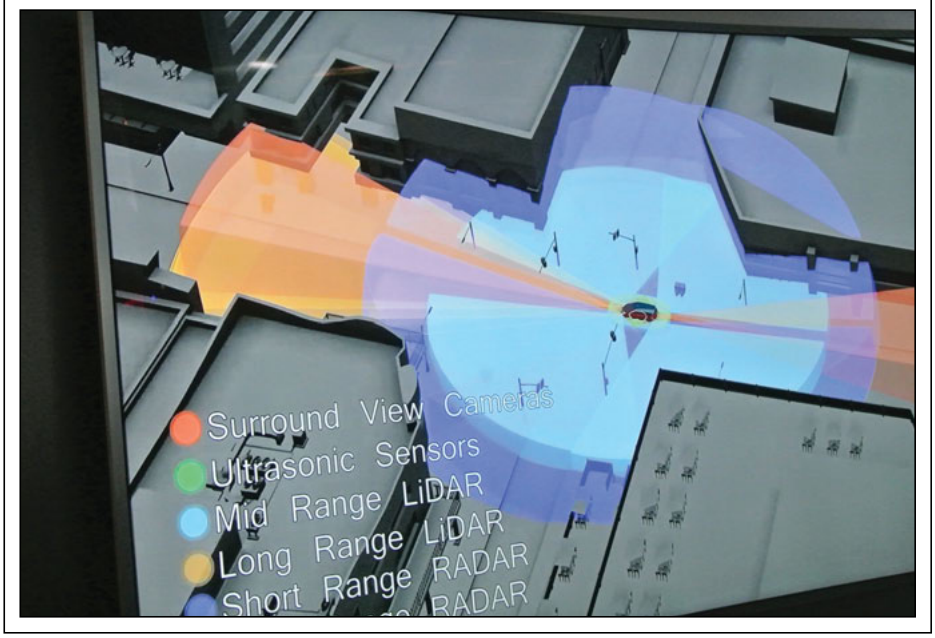

Fig. 2: *Autonomous vehicles may mount a full array of sensors for situational awareness. The outputs of the sensors will be combined through what is called sensor integration, and the results analyzed with an AI system located either on board or in the cloud, which will identify surroundings and threats. Photo: Ken Werner*

John Sousanis, managing director at WardsAuto, outlined the appeal of ADAS at a recent conference: "ADAS has a very efficient path forward in the industry. It has a simple goal: Save lives immediately. ADAS doesn't require changes to the infrastructure, doesn't require connectivity, doesn't take away the driver's independence; the change it asks of us is incremental and largely situational. And it's very cost efficient.

"Furthermore, ADAS fits within the existing industry model, it has lots of room for independent supplier innovation, [and] innovation can continue past the initial installation with software and algorithm updates and advancements so that it's an ongoing process."

There are significant opportunities here, both for original-equipment and aftermarket products, some of which require or could make use of displays.

Fig. 3: *A Velodyne lidar sensor is mounted on a developmental Ford vehicle. Lidar is regarded as an essential technology for autonomous vehicles. Ford recently announced it would field Level 5 autonomous vehicles in 2021. Photo: Ken Werner*

The Connected Car

ADAS may be appealing right now because current implementations don't require connectivity, but limited connectivity is already here, and more – a lot more – is coming. The 2017 Infiniti Q50, for example, uploads selected vehicle and infotainment data by default. Some high-end radar/lidar detectors use uploaded data crowd-sourced from all of the brand's users to create a "map" of fixed-location radar sources. Such sources include alarms from automatic doors and other non-law-enforcement sites, and can thus be safely ignored, which the radar detector does. (Law-enforcement lidar measures the speed of a target by illuminating that target with a laser light.)

But the next wide-spread type of connectivity will be vehicle-to-vehicle (V2V), which will permit more effective collision avoidance, traffic merging, adaptive cruise control, and other functions. Next will be vehicle-to-network (V2X), which will also be used in conjunction with V2V. At this point the applications become almost mind-boggling. The German company HERE, which maintains a cloud-based digital mapping service, is collaborating with New York University's Multimedia and Visual Computing Lab on an HD live map program. Eventually, connected vehicles will continually update the map in real time to maintain car-to-map precision within 10 cm (4 inches).

BMW will be installing data-generation technology from the Israeli company Mobileye in its cars beginning with the 2018 model year. The data will be uploaded to HERE, which will use the data to update its real-time cloud service for automated vehicles.

Another type of application is "broad data." One example is uploading speed and brake-point data for many vehicles at a particular turn. That data could be used for reprogramming the safe distance between autonomous cars at that turn.

Cars with lots of artificial intelligence, whether they are autonomous or not, will require software updates. It is clearly more attractive to download the updates to all applicable vehicles rather than sending letters to their owners and hoping that they bring their vehicles into the dealership. OEMs and artificial intelligence (AI) companies are very concerned that once an upgrade is decided upon, all vehicles be updated reliably and more or less at the same time.

Autonomous Vehicles

The Society of Automotive Engineers defines five levels of automation for vehicles. All levels will require sensors for situational awareness (Fig. 2). ADAS bridges Levels 1 and 2, depending on whether we're talking about a single function or the integration of two or more functions. In either case, the driver is always responsible for controlling the car, even if the car may intervene under special circumstances, such as automatic emergency braking.

Level 5 is full autonomy under all conditions: set your destination and go to sleep. Level 4 is full autonomy under certain sets of conditions, such as "highway driving in clear weather with no more than moderate traffic density."

That leaves Level 3: autonomous driving, but without the expectation that the car will always have adequate situational awareness. When the car loses adequate situational awareness, say when a light snow obliterates highway lane markings, it passes control back to the driver. And that's a problem. People are not good at switching tasks quickly, and that's especially true when a driver has lost situational awareness because he's texting, reading, or video conferencing. So, when the car tells the driver to take over, the driver must realize what the car is instructing him to do, withdraw from the task he's performing, spend the needed time to attain situational awareness, resume control, and – hopefully – take appropriate actions. And by the time the driver does all that, there is a reasonable chance that the car will be in an even worse situation.

After studying how this process might be reliably accelerated, many investigators have

concluded that Level 3 should be skipped, while others still feel it's feasible. Ford made its position official in mid-February. It will skip directly to Level 5, and will introduce driverless cars in 2021 (Fig. 3). Ford is guaranteeing a human driver won't be able to foul things up by omitting the steering wheel, brake, and gas pedal from these cars, said Ford product development chief Raj Nair, according to Bloomberg Technology. These cars may very well be Uber-style taxis.

Some manufacturers, including BMW and Audi, will be rolling out Level 3 cars next year that give drivers at least 10 seconds to take over from the system. That may be enough time for the driver to do his task-switching and acquisition of situational awareness, but can the system guarantee that nothing untoward will happen during those 10 seconds? This will be interesting.

OEMs feel that displays are critical for introducing drivers – or, at Level 5, owner/passengers – to the systems and developing confidence in them. According to this thinking, it is important for drivers to know what the system knows and how it is making its decisions, so the driver can learn to trust the car.

And there's another entire area for enhanced displays. When your car does the driving, what are you going to do? See Fig. 4. (Suggestions: video conference, email, text, watch a movie, read something.)

The car must entertain and inform you, but the ways in which it does that will be subject to constant change. When OEMs can no longer differentiate their products on the basis of the conventional driving experience, they will have to innovate elsewhere. With many concept vehicles featuring displays that conform to interior curved surfaces, there's no question that flexible OLED will play an important role. Continual novelty will be essential.

Displays Beyond the Imagination

Autonomous vehicles will talk to each other, talk to the cloud, and talk to you. But the communication will go both ways. Particularly for semi-autonomous vehicles, it will be useful for the car to observe you through video and perhaps bio-sensing to determine if you're awake, alert, and looking out the windshield as you should. But even in full autonomous vehicles, a vehicle that can determine your mood could, for instance, provide you with the appropriate music or video, or suggest that it take you to a bar or coffee shop, as is appropriate. Perhaps OLED lighting over the surfaces of the car's interior would supply appropriate mood lighting.

Fig. 4: *When the car drives itself, what do you do? You might want to watch the multiple wide-aspect-ratio door-mounted displays. Photo: Daimler Benz*

OEMs, Tier 1 suppliers, and university researchers are reimagining the automobile. Those reimaginings include displays, including displays that do not yet exist. ■

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2017 Editorial Calendar

Issue	Editorial Coverage	Ad Closing Date
January/February	**Applied Vision** **Special Features:** Reducing Stereoscopic Artifacts, Realizing Augmented and Virtual Reality, New Display Frontiers, Cool New Devices for a New Year **Markets:** Game developers, medical equipment manufacturers, research institutions, OEMs, software developers, wearable designers, entertainment industry research and developers	**December 28**
March/April	**Display Week Preview, Display Materials** **Special Features:** SID Honors and Awards, Symposium Preview, Display Week at a Glance, MicroLEDs, Progress in OLED Manufacturing, Disruptive Materials, Nine Most Important Display Trends from CES **Markets:** OEMs, deposition equipment manufacturers, entertainment industry research and developers, display and electronic industry analysts	**February 27**
May/June	**Display Week Special, Automotive Displays** **Special Features:** Display Industry Awards, Products on Display, Key Trends in Automotive Displays, Head-up Designs for Vehicles, Novel Interfaces for Automobiles **Markets:** Consumer products (TV makers, mobile phone companies), OEMs, research institutes, auto makers, display module manufacturers, marine and aeronautical companies **Bonus Distribution: Display Week 2017 in Los Angeles**	**April 18**
July/August	**Wearable, Flexible Technology and HDR & Advanced Displays** **Special Features:** Flexible Technology Overview, Advanced Displays Overview, Wearables Round-up, Overcoming HDR Challenges **Markets:** Research institutions, OEMs, OLED process and materials manufacturers, entertainment industry research and development, measurement systems manufacturers	**June 16**
September/ October	**Display Week Wrap-up, Digital Signage** **Special Features:** Display Week Technology Reviews, Best in Show and Innovation Awards, Digital Signage Trends, Ruggedization Challenges for Digital Signage **Markets:** Large-area digital signage developers; in-store electronic label manufacturers, advertising and entertainment system developers, consumer product developers, retail system developers	**August 22**
November/ December	**Light-field and Holographic Systems** **Special Features:** Real-world light-field applications, holographic approaches, solving problems of next-generation displays **Markets:** OEMs, Consumer product developers, research institutes, auto makers, entertainment and gaming developers; measurement systems manufacturers	**October 20**

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ID Interviews Seth Coe-Sullivan, Vice President and Chief Technical Officer for Luminit

Seth Coe-Sullivan is well known as a co-founder of the quantum dot company QD Vision. He holds numerous patents relating to quantum dots (QDs) and organic light-emitting devices (OLEDs). Coe-Sullivan's role at Luminit, a maker of light diffuser films and holographic components, includes intellectual property strategy, technical marketing, and business development.

Conducted by Jenny Donelan

ID: For our readers who don't know a lot about Luminit, can you explain what the company does?

Seth Coe-Sullivan: The products and technology that Luminit has had for the last 10 years – or actually 15, since the technology was conceived at our parent company [Luminit was spun off from Physical Optics Corporation in 2006] – are based on holographic diffuser technology. We use a holographic process to create a master that allows us to make roll-to-roll, surface-relief diffusers with very high precision and control.

Our single largest market is the lighting industry, but we also serve the display and various other high-tech industries that have a need for our diffusers. We've had a profitable small business for the last decade, and part of our strength is that there are just so many different applications for this technology. Today, our largest single market is LED lighting. Beyond that, our market is what we call high tech, which is sort of a catch-all for various medical imaging devices, barcode scanners, fingerprint scanners – anywhere that controlled lighting is an important part of the product function.

ID: Can you describe the holographic process used to create the films?

SCS: We use a laser-based interference process to create the primary structure. The master that holds all the information is created in a holography lab. Once we've got that master, which is like a big rolling pin, we use a physical, mechanical process to transfer that pattern into the film that we sell.

The use of this product has nothing to do with holography. The diffuser can accept monochrome laser light, but also white or colored LED light. And it diffuses that light in a controlled way, which in this context means we can determine how exactly the light spreads out onto a sheet. It can be spread in a narrow cone, a very broad cone, a circular cone, an elliptical cone, and so forth.

ID: In addition, Luminit is now making something new, an actual holographic product. Can you tell us about that?

SCS: We've introduced what we're calling a transparent holographic component. It works with various products such as augmented-reality (AR) glasses, smart glasses, vehicular displays, near-to-eye displays, and vehicular head-up displays. The component doesn't form the image – it relies on another display device to do that, so there'll be a projector or a microdisplay of some sort in the system. The system renders the image holographically. So you look through this transparent piece of glass, and you see all the information on the display without having to look at the display. It's an optical element, and can function as if it were a lens, a grating, or a mirror. But it's diffractive, which allows the element to be selective, only having the desired effect on a limited range of colors and angles. All the other light can pass through unaffected by our component.

The fact that these holograms are transparent is absolutely critical in all the markets I just mentioned. You can't put anything on a windshield that isn't transparent. You can't wear eyeglasses that aren't transparent.

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ID: So you're looking through the transparent component, but the image will appear to you as if it is in thin air.

SCS: Exactly.

ID: Where did this concept come from?

SCS: The idea actually goes back a couple of decades. It was the same with quantum dots. People talked about using them for displays well before I started working with them. What we did then, and what we're doing now, is to reduce the technology to something practical that fits within the display ecosystem – such as the display optical system – and serves a current need.

Seth Coe-Sullivan

ID: Speaking of quantum dots, you were involved with them for years. How does that experience relate to what you're doing now?

SCS: It's fair to say that I was known as the quantum dot guy. So I wanted to prove to myself that I could be more than just a quantum dot guy. What brought me to Luminit was this combination of another really hard technology – quantum dots and holography are both optical technologies and they're both sort of the stuff of science fiction, as well as the stuff of hard science. The challenge is trying to make them into an easy-to-buy, easy-to-use commercial, consumer technology.

When I got involved with quantum dots – which was the subject of my Ph.D. thesis at MIT, spun out into the company QD Vision – they were sort of a lab curiosity, and now you can buy eight different brands, and they are used for monitors, and for TVs at Best Buy. I'm not quite sure quantum dot is a household name yet, but still – what I am excited about here at Luminit is the chance to do the same. It's another cycle of taking something complicated in a lab and turning it into an impactful product instead of just a cool technology.

ID: In a related question, how does your experience in a start-up like QD Vision compare with where you are at now?

SCS: Well, the diffuser technology we discussed earlier is well established and well known, and has been sold into the industry for a decade. But what I'm doing at Luminit is going back to the company's roots in holography, and instead of just applying that technology to diffusers, we're applying it to the main display function. What's exciting is they're clearly experts in holography; Luminit has a large list of people who have Ph.D.s in holography.

ID: So where is this technology today in terms of development?

SCS: We're working with consumer electronics companies, pulling together whole systems with our components. These systems were shown at CES, and even before that, but Luminit's role has been anonymous. I can't list a specific customer for you yet, but if you were able to walk around CES, you would see prototypes with our stuff in it. [At press time, however, Luminit had just won a Display Component of the Year Award for its Transparent Holographic Component, as used in a commercial prototype, a HUD for a motorcycle helmet from a developer called REYEDR.]

Right now we're scaling up production – Luminit has created a whole new facility for production of these Transparent Holographic Components, and we're in the process of receiving all the equipment needed to mass-produce these. Today we're able to produce them in quantities of tens and hundreds per month, and very quickly we should be able to produce them in quantities of tens of thousands, if not hundreds of thousands, a month. This capacity will be in place by mid-year, and we should be shipping to our customers in 2017.

What we're finding is a need for head-up displays for the avionic and automotive markets, and transparent displays for augmented reality. These are relatively new topics. People have talked about them for a long time, but taking them seriously as a small electronics class that could have a big impact on the market in a few years is a relatively new discussion. I think a decade ago, it wasn't clear that the world was ready or that the ecosystem existed for augmented reality to be useful to consumers. But everybody's excited about it now. All of the various components – software, user interface, operating system – can be worked on in parallel, and we think that a transparent optical element is absolutely critical to the success of this industry.

ID: From a personal standpoint, what has it been like to change companies and work with a completely new technology, even if there are commonalities in terms of optics? Has that been a challenge for you?

SCS: For me it's just been fun and exciting. I'm happiest when I'm learning. Making it up that learning curve to understanding a new market, and understanding a new technology, is what keeps me engaged. ■

> **"... quantum dots and holography are both optical technologies and they're both sort of the stuff of science fiction, as well as the stuff of hard science. The challenge is trying to make them into an easy-to-buy, easy-to-use commercial, consumer technology."**

Products on Display at Display Week 2017

Those products on display at North America's largest electronic-display exhibition that were offered for preview are described here.

by The Editorial Staff

THE SID 2017 International Symposium, Seminar, and Exhibition (Display Week 2017) will be held at the Los Angeles Convention Center in Los Angeles, California, the week of May 21. For 3 days, May 23–25, leading manufacturers will present the latest displays, display components, and display systems. To present a preview of the show, we invited the exhibitors to highlight their offerings. The following is based on their responses.

4JET

Alsdorf, Germany
+49-(0)-2404/55230-0; www.4jet.de
Booth 1413

Laser Processing for Glass or Film Substrates

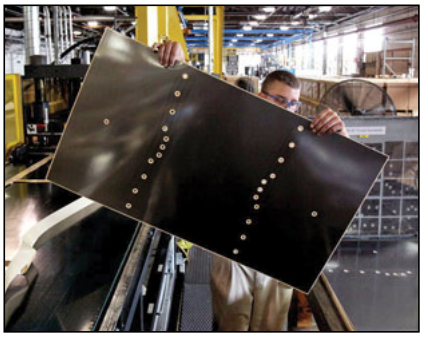
4JET's TWIN platform is designed for laser processing of glass or film substrates. The modular design allows the integration of up to two parallel or sequentially working process heads – for increased throughput or a combination of different processes in one machine. Standard applications include the cutting of technical glass with the PearlCut process, glass drilling, or the precise patterning of thin conductive films for the production of optoelectronic devices such as touch panels, LEDs, OLEDs, or smart windows, as well as in automotive and life sciences applications. Integration into automated production environments is possible.

ADVANCED ENERGY TECHNOLOGIES, A SUBSIDIARY OF GRAFTECH INTERNATIONAL

Lakewood, Ohio, USA
+1-216-676-2358; www.egraf.com
Booth 1235

Graphite Heat Spreaders

SPREADERSHIELD flexible graphite heat spreaders are the industry standard used to prevent hotspots on displays, improve image quality, and cool hot display components. These products are ideal for display sizes ranging from smaller cell phones up to the largest consumer televisions. The graphite spreaders are pre-cut to any custom shape, have a durable pre-applied adhesive, and are laminated with a thin, tough, plastic coating for ease of handling and dielectric protection. Advanced Energy Technologies is a subsidiary of GrafTech International Inc.



AGC ASAHI GLASS

Tokyo, Japan
+81-50-3481-3589; www.agc.com/english
Booth 1321

Advanced Glass Products for Vehicle Displays

Glass has become the design material of choice for next-generation vehicles. Its performance and aesthetics are unparalleled. As a global leader in advanced glass solutions, AGC is developing a range of glass platforms designed to increase driver safety, comfort, and convenience specifically for the automotive sector. The AGC exhibition showcases developmental automotive platforms, including a digital dashboard with 3D instrument cluster, CID, and passenger-side displays.

AMPIRE CO., LTD.

New Taipei City, Taiwan, ROC
+886-2-2696-7269; www.ampire.com.tw/en
Booth 335

LCD Bar Displays

Ampire produces customized displays and provides value-added services to meet customers' LCD and touch-panel project needs. The company specializes in bar displays with ultra-wide aspect ratios that provide excellent performance, especially for market-

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ing applications. The displays are available in sizes ranging from 6.3 to 28 inches, and are also offered with touch integration and sunlight readability.

BOE

Shenzhen, PR China
+86-1861-1949-171; www.boe.com
Booth 717

27-in. 8K 3D Display

BOE's 27-in. 3D panel is an advanced amorphous silicon (a-Si) 8K (7,680 × 4,320) resolution display. The 325 pixels per inch offer a highly realistic viewing experience. With HADS and Bright View technology, the transmittance is increased by 30%. The color gamut is above Adobe 100% through the adoption of quantum dots. The border has been reduced to 3.5 mm, owing to innovative gate-driver-on-array (GOA) technology, which is obviously competitive with other MNT products. Moreover, BOE proposes a glasses-free 3D display based on this panel; with the switchable 3D barrier, it offers a better 3D experience with a larger 3D view angle that is free of crosstalk.

CARESTREAM CONTRACT MANUFACTURING

White City, OR, USA
+1-800-234-8069; www.tollcoating.com
Booth 1311

Hardcoat Films

Carestream Contract Manufacturing will showcase its hardcoat films at Display Week. Carestream's crystal clear, super-hard polymer film coatings impart a durable, scratch-resistant surface that looks and wears like glass when adhered to any product surface. It is available as a coated polyethylene terephthalate (PET), polymethyl methacrylate (PMMA), or polycarbonate (PC) film in 5-mil (125-µm) and 7-mil (175-µm) thicknesses. Typical hardcoat film applications include touch screens, consumer product cover-glass replacement, improved membrane and capacitive switch wear layers, appliance and automotive decorative films, and point-of-purchase (POP) and point-of-information (POI) displays.

CHROMA

Irvine, CA, USA
+1-949-421-0355, ext. 128; www.chromaus.com
Booth 1513

8K Display Testing Solutions

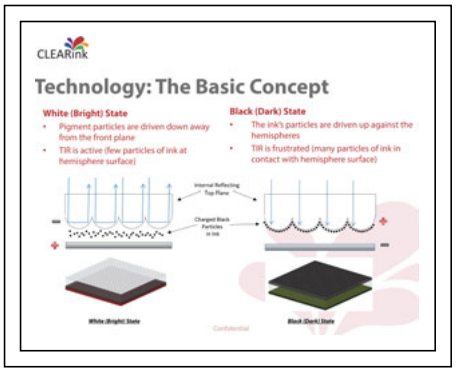
The latest addition to Chroma's broad range of display testing solutions, the 8K Super Hi-Vision Video Pattern Generator, is an industry leader and one of the most competitive display testing units on the market. It is designed to meet the highest standards for customers' display testing needs at the lab or on the production floor. From high-definition multimedia interface (HDMI) 2.0a, to DisplayPort 1.3, to traditional analog signals, Chroma 2238 is capable of incorporating up to four modules and outputting both timing and pattern signals from all 4 modules simultaneously. Its modular design allows easy upgrades to the latest industry signal standards without customers having to replace whole units.

CLEARINK DISPLAYS

Fremont, CA, USA
+1-510-624-9305; www.clearinkdisplays.com
Booth 209

Reflective Displays

CLEARink Displays is a venture-backed startup, with R&D in US and Canada. CLEARink's reflective displays are low-power, full-color, outdoor-readable, and video-capable – all at a cost comparable to that of LCDs. These displays will revolutionize the use cases for wearables, smartphones/tablets, e-School books, electronic shelf labels, and outdoor signage – the total combined accessible market of which will be over $12 billion by 2018. CLEARink's technology is based on varying the brightness of a specially designed reflector film by modulating the total internal reflection of ambient light from the film, using a single electrically charged particle suspended in a liquid.

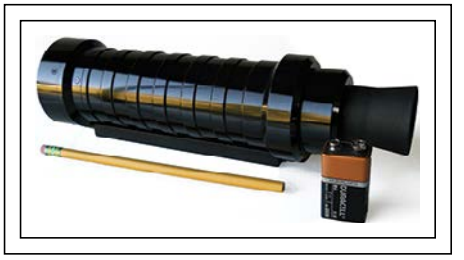


COLORIMETRY RESEARCH, INC.

Santa Clarita, CA, USA
+1-661-296-2790; www.colorimetryresearch.com
Booth 1445

Portable, High-performance Spectroradiometer

The CR-300 is a portable, high-end spectroradiometer with the performance of a laboratory grade instrument. Specifically designed to address the calibration of new laser projectors, it provides high color accuracy and measurement stability. The CR-300 is built with a 512-pixel CMOS sensor and provides a spectral resolution of 0.8 nm/pixel with an optical bandwidth of 2 nm. Colorimetry Research specializes in measurement and calibration of display panels and projectors.

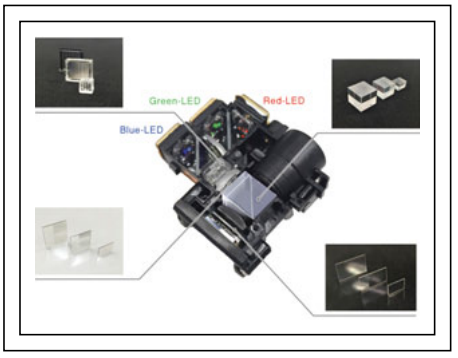


COLORLINK JAPAN

Tokyo, Japan
+81-3-6231-1311; www.colorlinkjapan.com/brand
Booth 1408

Precision Polarization Optics

ColorLink Japan offers unique capabilities with regard to assembling precision polarization optics.

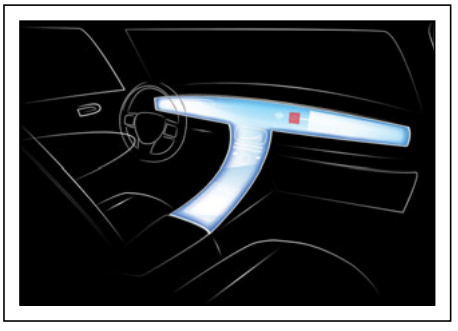


CORNING, INC.

Corning, NY, USA
+1-607-974-7185; www.corning.com
Booth 929

Advanced Glass to Enhance the Consumer Driving Experience

Corning, a world-leading innovator in specialty glass, will show the connected car interior of the future at Display Week 2017. The display-rich dashboard and center stack, covered by thin, tough Corning Gorilla Glass for Automotive Interiors, represent the same look and aesthetics consumers love about their smartphones. The Gorilla Glass has been cold-formed into complex shapes, creating a smooth, luxurious, and cost-effective solution for manufacturers that inspires creativity among designers and excitement from consumers.

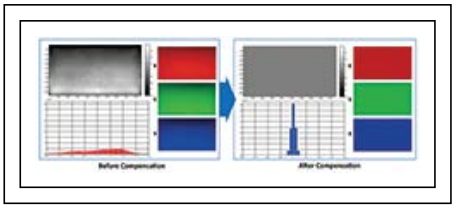


CYBERNET

Tokyo, Japan
+81-3-5297-3010; http://cybernet.co.jp
Booth 1517

Mura Correction System for OLED Production Lines

Cybernet provides a mura correction system (FPiS-HPS) for use on OLED display production lines. The system performs high-precision, high-speed mura correction in consideration of the impact of "gray-scale dependent for mura (sub-pixel unevenness, voltage drop)," which is a characteristic problem for OLEDs. Automation is achieved for all processes, from measurement to mura correction, as well as mura compensation data writing via customization based on applicable panels and production lines. Cybernet also provides mura correction intellectual property (IP). By cooperating with major semiconductor manufacturers whose products have been adopted for smartphones, tablet products, *etc*., Cybernet has optimized mura correction IP for display driver integrated circuit (DDIC) implementation.

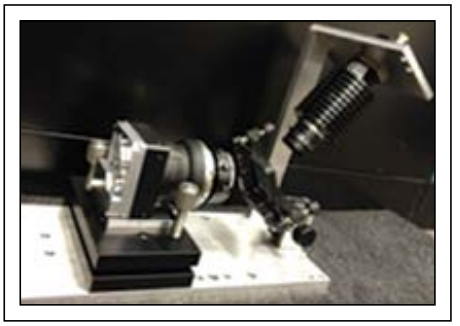


DARK FIELD

Orange, CT, USA
+1-203-298-0731; www.darkfield.com
Booth 1538

High-Resolution In-Situ Defect Detection

Vacuum deposition on film and glass is a high value-added operation. Products must be contaminant free, and in-situ inspection for defects of 1µm and larger is required in real time. Currently, deposition is performed "blind" – there is no feedback for contamination or defect detection until after the roll or sheet has been produced. A robust, elegant solution has arrived: The next generation of solid-state -laser reflection (SSLR) technology marries line-scan cameras and lasers with new high-resolution optics into a single scan unit. This scanner is easily installed and delivers 100% inspection during deposition. All active modules are located outside the chamber and the inspection is performed inside the chamber, in transmission, reflection or both.



DAWAR TECHNOLOGIES, INC.

Pittsburgh, PA, USA
+1-412-322-9900 x 308; www.dawar.com
Booth 1205

Projected Capacitive and Resistive Touch

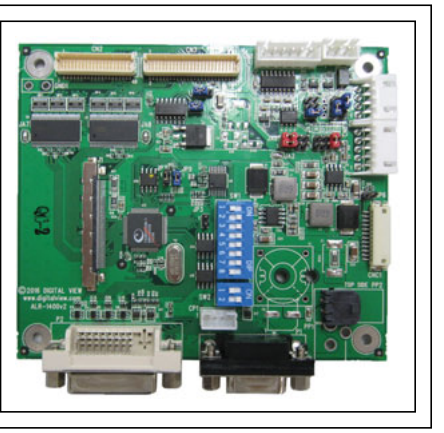
Dawar Technologies provides projected capacitive and resistive touch solutions, as well as value-added services for custom user interface for the medical, military, aerospace, instrumentation, industrial, POS/kiosk, and marine markets. With manufacturing and design facilities in the US and Asia, Dawar controls and manages the entire touch system fulfillment process, including engineering, production, and supply chain management. Customers benefit from consistently high-quality products and services that support their businesses and help them succeed.

DIGITAL VIEW

Morgan Hill, CA, USA
+1-408-782-7773; www.digitalview.com
Booth 514

New-Generation LCD Controller

The Digital View ALR-1400v2 replaces the ALR-1400. After more than 10 years of production, the ALR-1400 has reached end of life (EOL), and notification has gone out. In its place, the ALR-1400v2 has been released and is now available. Mirroring the original, together with a small number of enhancements and updates, this new workhorse looks set to be every bit as solid and reliable as the first release. Digital View will be showing the ALR-1400v2 at its booth, together with other new products.



DLC DISPLAY CO., LTD.

ShenZhen City, China
+86-755-86364060; www.dlcdisplay.com
Booth 215

Bar-Type TFT Displays

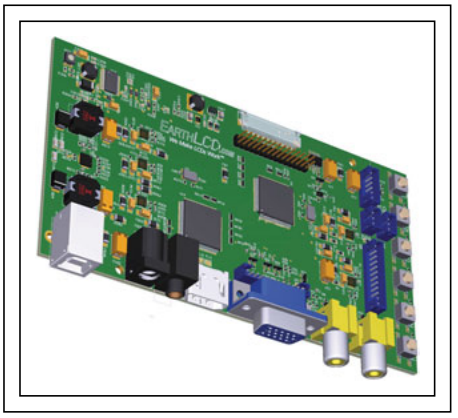
DLC Display makes products including an 8.01-in., bar-type, IPS thin-film transistor (TFT) display with 1,600 (RGB) × 480 resolution, low-voltage differential signaling (LVDS) interface, and 500 candelas per square meter (cd/m^2).

EARTHLCD

Irvine, CA, USA
+1-949-248-2333; www.earthlcd.com
Booth 545

HD-Resolution LCD Controller

The new EarthVision-X1 features up to HD-resolution, 1,920 × 1,080 low-voltage differential signaling (LVDS) panels, and a built-in LED backlight driver plus a header for external driver. EarthLCD will scale other resolutions to native panel resolution, up or down. Other features include: wide power range input (6 to 40 volts DC; standard video inputs high-definition multimedia interface (HDMI) DVI VGA 2×, a composite via board header, full on-screen display (OSD) control via on-board buttons or external button board; full control of board features via serial (RS232) interface; and on-board DIP switch to select options like disable OSD buttons, *etc*.



ELDIM

Hérouville, Saint-Clair, France
+33-2-31-94-76-00; www.eldim.fr
Booth 1121

Optical Measurement Systems

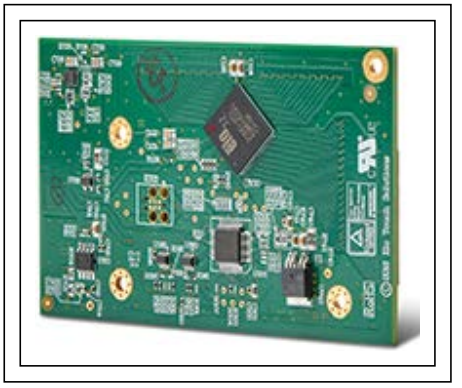
ELDIM's new VCProbe from its series of optics and sensors includes many innovations. The new product enables a full-viewing angle plot in less than 2 seconds. It offers the strength of ELDIM's well-known EZContrast line linked to an efficient robotic. The robotic arm, combined with a viewing-angle system, makes an ideal solution for fast and accurate measurements. The technology can easily go from small to large displays, whatever their shapes: flat, curved, or flexible. An on-axis spectrometer and an IR camera to test the spatial temperature variation of displays are now also available.

ELO

Milpitas, CA, USA
+1-408-597-8000; www.elotouch.com
Booth 1229

Projected Capacitive Controller

Elo is excited to announce the launch of the 9200 Series PCAP controller. Optimized for 15- to 32-in. touchscreens with a completely configurable touchscreen interface architecture, this in-house designed controller addresses the unique needs of industrial touch applications. Features include custom algorithms programmed to handle liquids in harsh environments, and mixed mode scanning and frequency hopping for challenging noise interference, providing for versatile commercial application use. Elo, a global leader in touchscreen solutions, architected the 9200 Series for maximum performance regardless of aspect ratio, screen size, or shape. The controller is available for sampling to customers now.

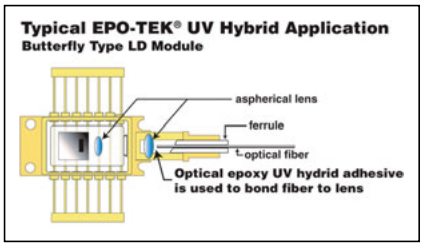


EPOXY TECHNOLOGY, INC.

Billerica, MA, USA
+1-978-667-3805; www.epotek.com
Booth 1145

UV-Hybrid Adhesives

Epoxy Technology (EPO-TEK), a market leader in advanced epoxy, UV, and UV hybrids, is showcasing its expanded line of epoxy-based, UV-hybrid chemistry adhesives. These novel formulations allow for improved handling and process control by utilizing both UV and thermal curing. The company's UV-hybrid adhesives can be tack free in under 20 seconds, have lower shrinkage, less stress, and excellent 85°C/85%RH resistance.

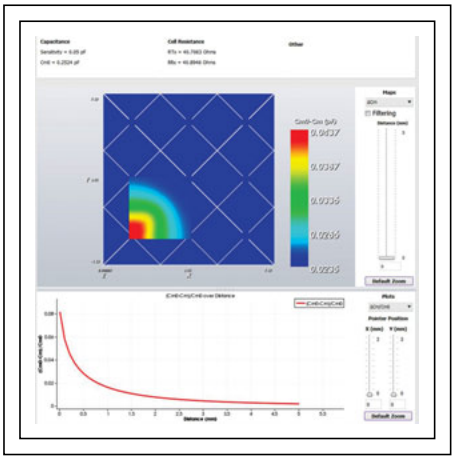


FIELDSCALE

Thessaloniki, Greece
+30-6982-56-51-78; www.fieldscale.com
Booth 1045

Touch Sensor Design Software

Fieldscale SENSE is the first touch sensor design and analysis simulation software exclusively developed to help engineers create the most advanced touchscreens in a swift modeling process. SENSE utilizes a state-of-the art boundary element method to simulate the behavior of a touch sensor when a pointer approaches its vicinity. Touch sensor specifications, such as the hovering effect, the touch response, and bezel influences can be modeled with SENSE. SENSE streamlines the product design process by automating its most demanding steps. It integrates with all parts of production positioning and is an indispensable tool for integrated circuit (IC) and touch-screen manufacturers.



FRAUNHOFER FEP

Dresden, Germany
+49-(0)-351/8823-238; www.fep.fraunhofer.de
Booth 623

OLED Microdisplay with Fingerprint Sensor

Fraunhofer FEP has developed an OLED microdisplay with an embedded optical fingerprint sensor. The display is built from nested display and sensor pixels and is based on OLED-on-silicon technology. In this set-up, the active area can show and capture images in the same plane. In fingerprint mode, the display uses a controlled illumination of the finger touch that is captured by the embedded image sensor. The first prototype has a native resolution of 1,600 dpi. This is three times higher than required by the FBI. One of the most interesting applications for the new optical fingerprint technology is identification in mobile devices.

FUTABA CORPORATION OF AMERICA

Schaumburg, IL, USA
+1-847-884-1444; www.futaba.com
Booth 737

Capacitive-Touch Panels

Futaba's capacitive-touch panel products were developed using thin-film formation technologies perfected in the company's electronic component manufacturing processes. With their outstanding sensitivity and resistance to harsh environmental conditions, these products are finding an increasing number of applications in consumer products and automotive in-vehicle equipment that require a high level of reliability.

GE

Cleveland, OH, USA
www.geradiantred.com
Booth 204

LCD Color Technology

Whether we're looking at a beautiful photo on our phone or watching a blockbuster movie on the couch, display screens have the power to transport us to other worlds. It's no wonder that desire for televisions and devices with ultimate picture clarity and wide color gamut is greater than ever. GE has innovated RadiantRed Technology to unlock true-to-life colors and the truest red available in LCDs without compromise – and it's available today.

GOOCH & HOUSEGO

Orlando, FL, USA
+1-407-422-3171; www.GHinstruments.com
Booth 1244

Tunable LED Source

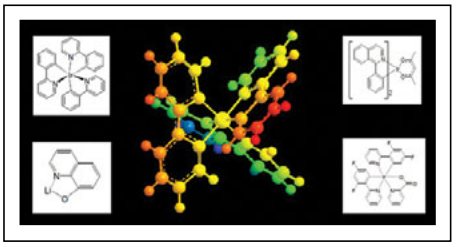
The OL 459 is a unique and innovative, tunable LED source designed for replication of spectra to enable calibration of cameras and other optical instruments. Separate optical output power modules enable remote location of either unit, making alignment or positioning of the source with respect to an instrument a breeze. The OL 459 is ideal and unsurpassed for camera calibrations, blackbody color temperature replication, customizable spectra for R&D, and more.

GUANMAT OPTOELECTRONIC MATERIALS, INC.

Pingxiang, Jiangxi Province, China
+86-799-3607525 (fax); www.guanmat.com
Booth 236

AMOLED Materials and Electroluminescent Intermediates

GuanMat Optoelectronic Materials offers custom synthesis and original equipment manufacturing (OEM) chemical manufacture of OLED intermediates and materials with high efficiency, greater stability, and higher throughput in the area of organic electronic materials used for OLED, organic thin-film transistor (OTFT), and organic photovoltaic (OPV). The company has adopted and certified the quality management and environmental management system of ISO 9001 and ISO 14001.



HENGHAO TECHNOLOGY

Hukou Shiang, Hsin-chu County, Taiwan
+886-3-5971875, ext. 12705; www.henghao.com.tw
Booth 1508

Touch Technologies

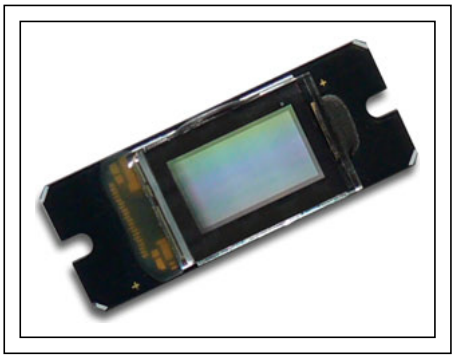
HengHao has more than 20 years' experience in touch-panel and display design and manufacturing. The company offers solutions for touch, liquid-crystal monitors (LCMs), lamination, and system integration. It also has capabilities in one-glass solution (OGS), one-film solution (OFS), direct bonding, back-light module (BLM), and LCM assembly. These products can be used in smart watches, smartphones, tablets, notebooks, vehicles, Internet of Things (IoT), and industrial/medical original design manufacturing.

HOLOEYE

Berlin, Germany
+49-(0)-30-63-92-36-60; www.holoeye.com
Booth 606

Color LCOS Display

HOLOEYE introduces a new color liquid-crystal-on-silicon (LCOS) projection microdisplay with HD resolution (1,920 × 1,080 pixels) and integrated ASIC driver chip, including the following features: pixel pitch of 4.5 µm, display diagonal of 0.39 inches, active area of 8.64 × 4.86 mm, and package dimensions of 23.4 × 9.0 × 3.3 mm.



INNOLAS SOLUTIONS GMBH

Krailling, Germany
+49-89-8105-9168-1050; www.innolas-solutions.com
Booth 1521

Laser Processing Workstation

InnoLas Solutions provides laser systems for micro material processing with various applications in the semiconductor, electronics, display, and photovoltaic industries. The ILS-LT is a versatile laser processing workstation designed for high-precision applications. Up to two laser sources (µs - fs pulses, 355-nm to 10.600-nm wavelength) and galvo scanners or fixed optic processing heads can be installed in the machine. The ILS-LT handles format sizes of up to 18 × 24 inches. A double x/y table configuration (ILS-DLT) with two processing heads significantly increases the productivity of the laser system; two substrates can be processed in parallel.

INSTRUMENT SYSTEMS GmbH

Munich, Germany
+49-89-454943-153; www.instrumentsystems.com
Booth 1135

Spectrally Enhanced Colorimeter

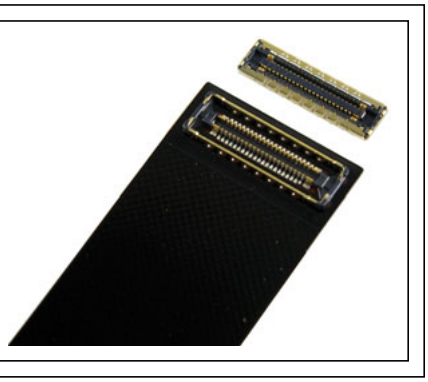
The new LumiTop 2700 from Instrument Systems combines the spectroradiometric accuracy of the well-known CAS 140 series with the obvious advantages of imaging light-measurement devices. This innovative system merges an RGB camera and a flicker-diode with a high-end array spectroradiometer. Using the extremely accurate spectral information of the spectrometer as reference, it guarantees the highest precision across the whole camera image, enabling fast and accurate testing of displays. Moreover, the combination of three devices in one makes the LumiTop 2700 perfect for display testing in production lines, because different test applications can now be organized in a single test station.

I-PEX

Austin, TX, USA
+1-512-339-4739; www.i-pex.com
Booth 510

Shielded Connectors

I-PEX NOVASTACK 35-HDP shielded board-to-FPC connectors signal contacts support high data-rate transmission standards for applications up to at least 20 gigabits per second (Gbps). These connectors are used to transfer four differential lanes of



VESA high-bit-rate (HBR)2 5.4 Gbps graphics data to 4K × 2K resolution displays. These connectors provide 360-degree electromagnetic interference (EMI) shielding, which allows for versatile placement locations near wireless antennas and radios. The connectors' 0.35-mm pitch, 3.7-mm depth, and 0.75-mm low-profile maximum mated height interconnection enables use in small spaces. The connector contact material is a copper alloy with higher-current carrying capacity on the four larger contacts designated for power transmission.

IRYSTEC

Montreal, Quebec, Canada
+1-514-227-5132; www.irystec.com
Booth 238

Better Readability for Automotive Displays

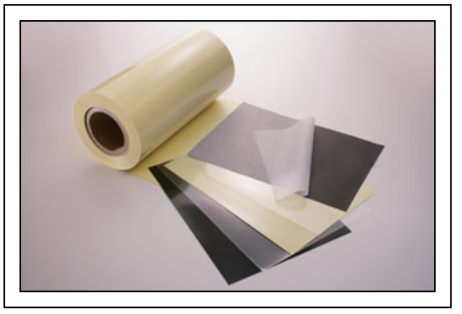
IRYStec's DRIVEvue can be used with any automotive display device to improve display content readability in bright and dark driving conditions. The goal of DRIVEvue is to keep the perceived image quality constant, because varying lighting conditions affect the time it takes drivers to focus on the material displayed on screen (dwell time). IRYStec's solution is designed to reduce dwell time, increasing driver's safety. DRIVEvue can also reduce display power and heat by decreasing the average display brightness, thereby reducing the cost for cooling, and prolonging the life of the display panel.

IWATANI CORP.

Tokyo, Japan
+81-3-5405-5741; www.iwatani.co.jp
Booth 1421

High-Impact Absorbent Acrylic Foam and Silicone Optically Clear Adhesive

Iwatani provides functional film and industrial tape products specialized for electronic devices, backed up by the company's innovative technology and excellent analysis that enable flexible design capabilities for customers. Its ISR-ACF acrylic foam series features high-impact-absorbing performance and is widely used for display breakage prevention. Its ISR-SOC silicone optically clear adhesive (OCA) series has high durability, heat resistance, and flexibility suitable for specialized displays such as reflective, flexible, and OLED. Furthermore, its low refractive index improves the visual quality of the display.



JDI

San Jose, CA, USA
+1-408-501-3720; www.j-display.com
Booth 917

High-Transmittance (80%) Transparent Color Display

This newly developed display achieves a high transmittance level of 80% by applying JDI's proprietary technology that permits the removal of the usual color filter and polarizer layers. Viewers are able to see the background image and the displayed foreground image clearly and at the same time. By fully utilizing this unique technology, displays can be developed for new applications, such as shop windows, education tools, automotive, *etc*. Specifications: 4 inches, 300(H) × 360(V) pixels, 16.7 million colors, and 80% transmittance. More information will be presented during Session 79.4 on Friday, May 26.

KONICA MINOLTA

Ramsey, NJ, USA
+1-201-236-4215; http://sensing.konicaminolta.us
Booth 1234

Display Color Analyzer

Building on the benefits offered by the Display Color Analyzer CA-210, Konica Minolta's CA-310 offers even higher accuracy when measuring the LED-backlit LCD TVs that are becoming increasingly popular. Although conventional backlights such as fluorescent lamps provide relatively uniform light, the spectral emission distribution of LEDs varies slightly with each unit. The CA-310 overcomes this problem with color sensors that more closely match the CIE 1931 color-matching functions, offering higher measurement accuracy while providing high measurement speed, even at low luminances.

KYOCERA

San Diego, CA, USA
+1-734-781-4879; www.kyocera-display.com
Booth 421

Multi-function Haptic Display

Kyocera will demonstrate its innovative multi-function display for the first time at Display Week. Its patented technology, Haptivity, generates a programmable vibrational feedback to the user. A fine-tuned vibration through a piezo device mimics a real mechanical button's impact on human skin. This 10.25-in., vertically convex display features high brightness and contrast ratio. For input, it supports either gesture input or touches on the optically bonded P-CAP touch screen with cover glass.

LITEMAX TECHNOLOGY

Fremont, CA, USA
+1-510-509-7506; www.litemax.com
Booth 413

27.5-in. Resized Ultra-Wide USB 3.0 Display

Litemax will be featuring the SSD2755, an innovative, resized ultra-wide LED-backlit LCD. The 27.5-in. resized panel demonstrates a brightness of 400 nits with a 1,366 × 70 aspect ratio of 16:0.8 for

retail shelving to replace paper price tags for digital signage, department stores, vending machines, and industrial applications. It uses a simple one-USB 3.0 cable, carries power and signal input simultaneously, and enables full-color video with 4.5-watt low-power consumption. It is also available with digital video interface (DVI).

LUMINIT

Torrance, CA, USA
+1-310-320-1066, ext. 314; www.luminitco.com
Booth 508

Direction Turning Film for Display Applications

Luminit Direction Turning Film (DTF) can be incorporated into display panels, such as those used in avionics, and offers a practical solution for designers and engineers. DTF can redirect the image 20° up, down, left, or right to gain optimal viewing angles in limited spaces such as instrument panels. Because of the high efficiency of the DTF, the redirected image is virtually distortion free. Direction Turning Film can be used either within the display under the LCD or on top of the LCD.

MAC THIN FILMS

Santa Rosa, CA, USA
+1-707-791-1650; www.macthinfilms.com
Booth 1435

Infrared Radiation (IR) Blocker Coated Glass for Outdoor Displays

IR Blocker Coated Glass enables easily viewed outdoor displays in bright sunlight while reducing/eliminating the requirement for active cooling. Key features include: excellent sunlight readability; reduced solar heat gain; and extreme ruggedness. Key applications are: digital information displays (DIDs); outdoor kiosks/menu boards; and ruggedized displays. The product is available in two performance ratings: IR Blocker 40 with IR reflective peak of ≥40%R and IR Blocker 70 with IR reflective peak of ≥68%R.

MCSCIENCE

Suwon, Korea
+82-31-206-8008; www.mcscience.com
Booth 214

Cubic Colorimeters

Qbism HEXA is a product series of colorimeters designed for various optical test and measurement applications. These colorimeters have special features such as object-adaptive hardware design that is compatible with DeJign test jig and other environmental systems, dual-mode functions of color and spectrum measurement, wireless data communication, and powerful interface features for Windows PC, Android tablet, and ParaMetric test instruments.

MITSUBISHI ELECTRIC

Cypress, CA, USA
+1-714-229-3838; www.mitsubishielectric.com
Booth 221

Tough Series TFT-LCD Color Module

Mitsubishi Electric's AT070MP11 TFT-LCD color module offers a high-vibration resistance of 6.8Gs, seven times that (1.0 G) of conventional products, and thus is suitable for equipment subject to strong shocks, such as construction vehicles, agricultural vehicles, and factory-automation machines. The product has a market-leading operating temperature range of –40 to 85 °C, compared to –30 to 80 °C for conventional products, so it is suitable for outdoor use and in vehicles operated in extreme environments. The module has super-wide viewing angles of 170 degrees, both horizontally and vertically, ensuring excellent visibility for off-center installations. It has a high brightness of 1,100/1,000 cd/m^2 and a high-contrast ratio of 1,000:1 for easy visibility in bright environments.

NANOCOMP

Lehmo, Finland
+358-50-463-6970; www.nanocomp.fi
Booth 211

Ultra-thin Light-guide Film for LCD Backlights

Nanocomp has developed an ultra-thin light-guide film for medium-sized LCD backlights. While it is

ultra-thin, the film offers superior efficiency and excellent uniformity. It is the thinnest and most efficient light-guide solution available in the size range of 7 to 15.6 inches. The exceptional thinness and efficiency are enabled by Nanocomp's proprietary UV-R2R manufacturing process and special double-sided micro-imprinting technology used for the light out-coupling. Nanocomp's ultra-thin (0.375–0.5 mm) light guide provides superior performance for all LCDs in its size range. The backlight unit can be made flexible, making a perfect match with flexible or bendable LCDs.

NANOSYS

Milpitas, CA, USA
+1-408-240-6745; www.nanosysinc.com
Booth 321

Hyperion Quantum Dots

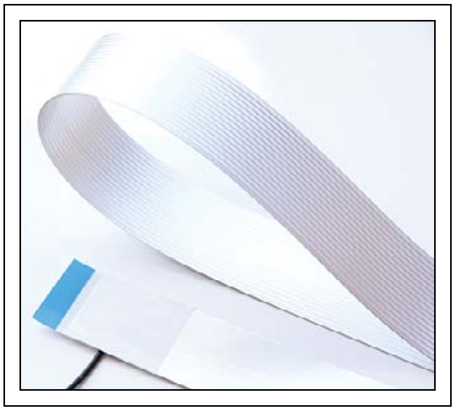
Demos at Display Week featuring quantum dot technology from Nanosys will include a BT.2020 display based on the Display Industry Award Component of the Year winner for 2017: Hyperion Quantum Dots. Visitors will also have a chance to see a demonstration of the company's next-generation photo-emissive quantum dots.

NICOMATIC

Warminster, PA, USA
+1-215-444-9580; www.nicomatic.com
Booth 1313

Shielded Flat-Flexible Cables

Nicomatic will introduce its new V Shield Flat Flex Cable, the next generation of FFC shielding, during Display Week 2017. Its new flat-flex cables are a twist on the traditional polyester-laminated FFC; during the manufacturing process, the polyester receives an added aluminum base layer. The new V Shield process provides electromagnetic interference (EMI)/radio-frequency interference (RFI) and electrostatic discharge (ESD) signal protection for customers' specific designs, while maintaining the key characteristics of lightweight, thin, and flexible.



NIDEK CO., LTD.

Aichi, Japan
+81-(0)533-67-6611; www.nidek.co.jp
Booth 744

Antireflective and Performance-Enhancing Coatings and Thin Films

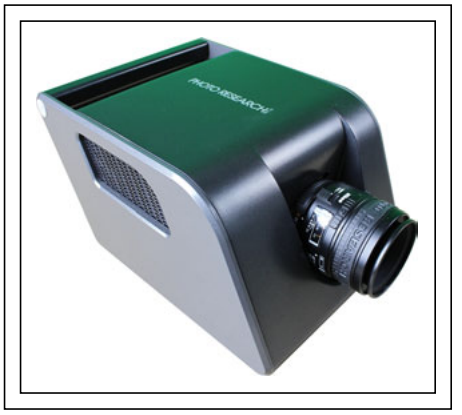
NIDEK's coating technology controls visible and invisible light to offer anti-reflection and transmittance/reflectance of specific wavelengths. The coating also provides functions like surface protection, conductivity, and anti-smudging. NIDEK offers its coating technology to a variety of fields such as automotive, information, and communication technology; electrical appliances; and spectacle lenses. Its thin-film coating technology includes hard coating, vacuum deposition coating, and transfer tinting that all enhance the performance of day-to-day advancements in various optical components. A combination of nano-level thin films from NIDEK allows transmission and reflection of specific light wavelengths according to customers' various needs.

PHOTO RESEARCH

Syracuse, NY, USA
+1-818-725-9750; photoresearch.com
Booth 1305

Imaging Colorimeter

Photo Research, a leader in color and light measurement, is featuring its enhanced Tru 8 2D imaging solution with superior reliability. In addition, check out Photo Research's boosted VideoWin software application, highlighting six fundamental mura measurements: luminance edge area; luminance mura area; luminance lightness area; color edge area; color mura area; and color lightness area. Photo Research has been a worldwide, trusted brand for more than 70 years.



PILKINGTON NORTH AMERICA

Toledo, OH, USA
+1-800-221-0444; www.pilkington.com/na
Booth 645

Smart Mirrors

The NSG Group introduces the next generation of its leading Pilkington MirroView products. Designed to meet the needs of the growing smart mirror market, Pilkington MirroView has a highly reflective mirror coating that is used to hide digital displays in retail, commercial, and residential applications. The Generation 2 Pilkington MirroView offers a number of refinements, including improved reflected color, giving a more natural, mirror-like

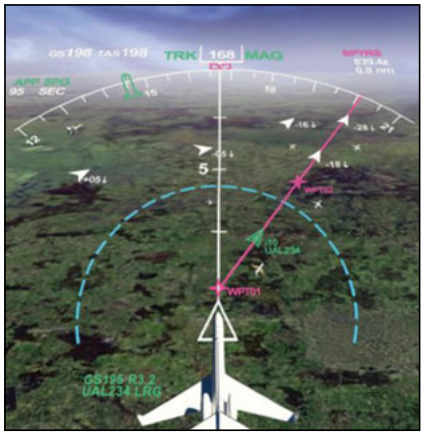
appearance. Due to the growing demand for touch-enabled surfaces, the product is fully compatible with all touch technologies, including projected capacitive. The second-generation product also offers a smoother surface for an improved touch experience.

PIXEL SCIENTIFIC

Scotts Valley, CA, USA
+1-408-659-4630; http://PixelScientific.com
Booth 504

Custom AMLCDs

Pixel Scientific makes small-volume, custom AMLCDs possible. The company's unique, patented technology allows it to excise custom displays from high-volume donor displays. Pixel Scientific provides a full range of custom and conventional displays with large color envelopes, high-brightness, and other performance-related features. The example shown below is a 6-in. × 6-in. 768 × 786 AMLCD module with a 1,000-nit backlight. This product, part number PS101-06061-00, is in full production.

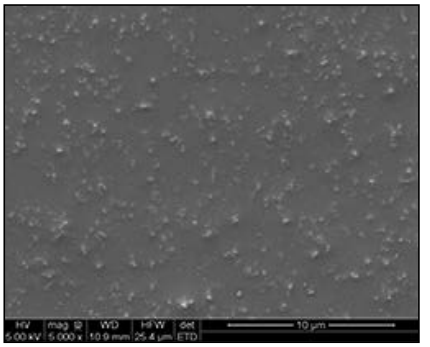


PPG

Pittsburgh, PA, USA
+1-724-304-1338; www.ppg.com
Booth 1409

Sprayable Anti-glare Coatings for Display Applications

PPG has commercialized sprayable, sparkle-free anti-glare (AG) coatings for glass and plastic substrates for display applications. The thermally cured AG coating on glass substrates exhibits a tunable gloss range of 50GU to 120GU, a haze range of 3% to 12%, and pencil hardness of ≥8H after curing at 150°C for one hour. The UV-curable anti-glare coating on plastic substrates has a tunable gloss range of 40GU to 100GU, a haze range of 5% to 20%, and pencil hardness determined by plastic substrate type (*e.g.*, ≥4H on PET and PMMA, and ≥1H on PC).

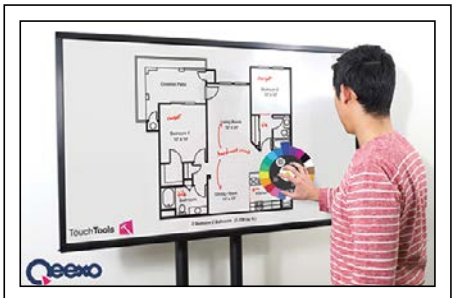


QEEXO

Mountain View, CA, USA
+1-925-357-5140; www.qeexo.com
Booth 1504

Innovative Touch Interaction

At Qeexo, the company's passion is to enhance the user experience of touch devices. TouchTools is a touch interaction innovation that allows users to easily summon and manipulate a variety of virtual tools simply by using intuitive hand poses. With TouchTools, cumbersome toolbars are a thing of the past. Users need only to mimic the way they hold objects in the real world, place their hands on the screen, and TouchTools will choose the right virtual tool accordingly. TouchTools can be deployed on a variety of devices from tablets, to auto infotainment systems, to large displays.



QUADRANGLE PRODUCTS, INC.

Englishtown, NJ, USA
+1-732-792-1234, ext. 109;
www.quadrangleproducts.com
Booth 1345

Ruggedized Cables and Connectors

Quadrangle Products now offers ruggedized mil-spec cables and connectors. New connectors, tooling, and designs are added weekly as the company continually expands this product line. Quadrangle Products was approached by several of its partners in industry, who requested support for this style of cable, and it has quickly become one of the most popular product lines. Quadrangle is a certified ISO 9001 custom cable manufacturer with over 30 years of experience in the design and manufacture of custom cable assemblies. Volumes from prototyping to production are offered.

Q-VIO, LLC

San Diego, CA, USA
+1-858-777-8299; www.q-vio.com
Booth 314

High Resolution HDMI to MIPI Rotator and Converter Board

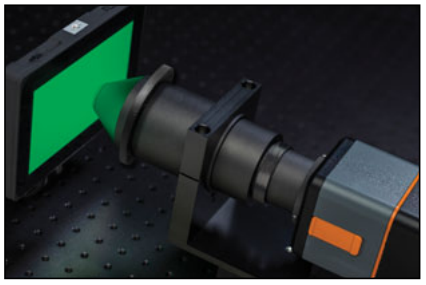
Q-VIo and Cypher Scientific present the Q-Vio high-definition multimedia interface (HDMI) or low-voltage differential signaling (LVDS) to Mobile Industry Processor Interface (MIPI) rotation and conversion system, which utilizes an elegant, low-cost board solution to facilitate the use of the latest technology MIPI LCD panels in designs with industry standard HDMI and LVDS input sources. Features include: up to wide-screen ultra-extended graphics array (WUXGA) resolution with quad high definition (QHD) on the way; true real-time image rotation and mirror/flip capability on board; HDMI or LVDS to MIPI variations; programmability for any four-lane MIPI panel; LED backlight power circuit built in (standard or high bright); convertibility from portrait LCDs to landscape orientation; and small form factor.

RADIANT VISION SYSTEMS

Redmond, WA, USA
+1-425-284-0596; www.radiantvisionsystems.com
Booth 1129

Conoscope Lens

The Radiant Vision Systems conoscope lens enables high-resolution photopic measurement of angular distributions of color, luminance, and contrast of displays and display components. Using Fourier optics to map emission angles to charge-couple device (CCD) pixels, the lens captures a full cone of viewing angle data in a single measurement to ±60 degrees. No rotation of the camera or the display is necessary to capture angular data, providing quick, accurate results and making the system ideal for R&D projects and in-line quality control. The lens is well-suited to a wide range of display types, including LCD and OLED, as well as backlights.



RAMPF HOLDING GmbH & CO. KG

Grafenberg, Germany
+49-71-23-93-42-1045; www.rampf-gruppe.de
Booth 718

Liquid, Optically Clear Adhesives

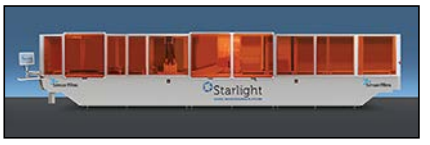
RAMPF makes liquid, optically clear adhesives that are specially developed for mixing and dispensing systems. The company offers a fully automated joining method featuring the air bubble-free application of bonding materials with the subsequent joining of components. Material is applied in a vacuum and components joined in an airless environment in vacuum. Thin-film degassing of single components facilitates processing of highly degassed bonding material. Degassing of undercuts and gaps between frame and display is performed while material is applied, minimizing the risk of air bubbles. RAMPF also offers silicone systems, and adhesives for attaching displays, frames, supports, *etc*.

SENSOR FILMS

Victor, NY, USA
+1-585-738-3500; www.sensorfilmsinc.com
Booth 729

Inkjet Deposition

The Starlight Digital Manufacturing and Printing Platform features industrial inkjet deposition of decorative and functional inks on flexible and rigid substrates. A modular system, Starlight can be customized with pre- and post-printing operations for high throughput manufacturing. A large-area heated vacuum platen accommodates cut-sheet formats that meet the demands of high-volume production. The Starlight systems can be configured to print stretchable UV inks for thermoformable plastics and decorative glass bezel applications. The recently announced Starlight 3000FHE will print conductive and dielectric materials with in-line curing and sintering, and automated placement of discrete semiconductor components for flexible display electronics.



SEVASA

Barcelona, Spain
+34-93-828-03-33; www.sevasa.com
Booth 410

Anti-Glare Cover Glass for Touch and HD Displays

SEVASA's HapticGlas offers among the largest cover glass sizes on the market – up to 154 inches (88 × 26 inches/2,250 × 3,210 mm). The product offers exceptional tactile feedback, very low sparkling, wide gloss range, tight gloss control, and HD resolution. It is resistant to scratches and stains, and shows few fingerprints. It is bendable, temperable, and perfect for public use and outdoors. Custom specifications are available. HapticGlas is ideal for HD applications such as multitouch walls/tables, displays, digital signage, ATMs, point of sale, *etc*.

SIOPTICA

Jena, Germany
+49-(0)-3641-6345901; www.sioptica.com
Booth 607

Privacy Solutions for Display Applications

siOPTICA is a leading provider of innovative switchable privacy solutions. With its optical strength and new materials, the siOPTICA technology offers a high level of security for all LCD-based panels. The sioSHIELD solution is used in the payment industry and in the automotive industry, as well as for laptops and other mobile devices.

SLENCIL CO.

Orange, MA, USA
+1-978 544-2171; www.slencil.com
Booth 307

Braided-Steel Touch-Screen Stylus

The SLENCIL MW20-11-RJ1 is a military-constructed touch-screen stylus with a 20-in. (50-cm) braided steel cable tether that is black-plastic coated and features "sure-crimp" ring terminal anchoring hardware. The tether is designed with 200-lb. tensile strength. A cushion-tip stylus provides impact resistance to screen. The stylus may be imprinted with corporate logo or brand. Made in USA.

SUN-TEC AMERICA

+1-480-922-5344; www.sun-tec.net
Booth 535

Flexible Lamination Manufacturing

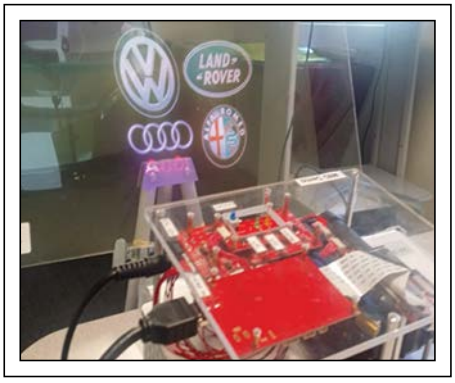
The TMS-22TS laminator offers users complete manufacturing flexibility by performing flex-to-flex, flex-to-rigid, and rigid-to-rigid substrate lamination work. It is ideal for displays, touch sensors, and other flexible hybrid electronics (FHE) applications in a production or an R&D environment. By using the Sun-Tec proprietary "tail-stopper" mechanism to enable out-gassing during a rigid-to-rigid substrates lamination, trapped air between the substrates is significantly reduced. Additional features of the TMS-22TS include PLC storage for 100 production recipes, programmable digitally controlled lamination speed and pressure settings, min/max substrate processing of 10-in./22-in. diagonal, and placement accuracy of +/– 0.2 mm.

SUPER IMAGE TECHNOLOGIES, INC.

Fremont, CA, USA
+1-510-651-1329 or 510-573-3913;
www.sun-innovations.com
Booth 513

Multi-color LED HUD

Super Image Technologies' newest multi-color LED digital light processing (DLP) head-up display (HUD) offers compact body design, high optical efficiency, low power consumption, long LED life, bright emissive display, and standard HD video interface. Additional features include: water-clear emissive screen that adheres to any windshield or glass surface; scalable image size with unlimited viewing angles; bright teal, white, and red information display; compatibility with HD video or image; and mini-HDMI and micro-USB interfaces.



TACTILE AUTOMATION, INC.

Monroe, WA
+1-425-248-1833; www.tactileautomation.com
Booth 1515

Robotic Touch and Pen Testing

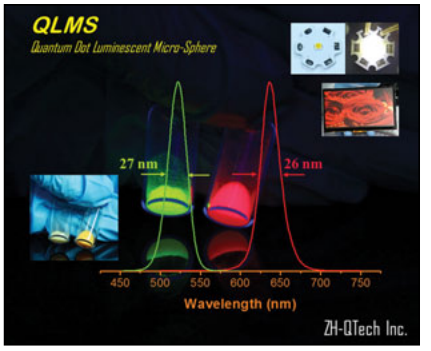
Tactile Automation will introduce the TakTouch 1000, with its new force-sensing and reporting end effector, which is a 4-axis robotic touch and pen-testing platform designed specifically for testing a variety of different gestures on touch screens, touch-pads, keyboards, stylus, etc. This robot eliminates multiple test fixtures and operator inaccuracies while allowing companies to automatically run a wide variety of tests sequentially without operator input. Therefore, customers can allocate their most precious resources (people's time and money) to higher revenue producing tasks.

TIANJIN ZHONGHUAN QUANTUM TECH CO., LTD. (ZH-QTECH)

Tianjin, Tianjin, China
+86-13923123229; www.zh-qtech.com
Booth 308

Quantum Dot Luminescent Micro-Spheres (QLMS)

Quantum dot (QD) luminescent micro-spheres (QLMS), developed by Tianjin Zhonghuan Quantum Tech (ZH-Qtech), are a new kind of highly robust QD composite featuring high-efficiency, narrow full width at half maximum (FWHM), and excellent long-term operational stability. QLMS is fully compatible with current LED packaging processes and can be used as phosphors for direct on-chip applications – tube or film is not required anymore. QLMS will make it more convenient and cost effective for manufacturers to adopt QDs in flat-panel displays with wide color gamut and LED lighting with high color rendering.



TIANMA NLT USA INC.

Chino, CA, USA
+1-909-590-5833; http://usa.tianma.com
Booth 1005

Bendable, Foldable AMOLED for Mobile Devices

TIANMA's first real flexible AMOLED is 5.5 inches, with vivid color and high pixel density. It can be bendable or foldable, and it is also thin and light. TIANMA is bringing its bright AMOLED products to the smart device market. To create color in life is TIANMA's mission.

TOPCON TECHNOHOUSE CORP.

Tokyo, Japan
+81-3-3558-2666; www.topcon.co.jp
Booth 1344

2D Spectroradiometer

To satisfy demand for expanding color gamuts, OLEDs and lasers have become mainstream. But luminance and chromaticity uniformity and mura are inevitable phenomena of this technology. Topcon's groundbreaking 2D spectroradiometer SR-5000 is the perfect tool for defect finding, analysis, and material development for OLEDs. Also, SR-5000H is a higher grade hybrid model built with 2D spectral filters and XYZ filters. This versatile model enables the fulfillment of lower luminance levels up to 0.005 candelas per square meter (cd/m^2), and minimizes the site space in one unit. It will enable high productivity and quality for every OLED site.

TORAY RESEARCH CENTER, INC.

Tokyo, Japan
+81-3-3245-5633; www.toray-research.co.jp
Booth 1511

Analytical Service for OLED Devices

Toray Research Center provides an extensive range of high-quality material analysis services. The company has 38 years of experience serving the world's top R&D/manufacturing companies in a variety of industrial fields, including OLED. Learn how its benchmarking/degradation material analysis can work for customers.

UBI RESEARCH

Seoul, Korea
+82-2-577-4940; www.ubiresearch.com
Booth 1238

OLED Event Organizer

UBI Research organizes international events throughout the year, with the goal of growth for the industry, and also of gathering together experts and businesses for open discussion and networking. The UBI Research Report covers markets and technology. It is designed for the in-depth understanding of the entire OLED industry, including market forecasts, competition, supply chain analysis, and investment trends.

UNITED RADIANT TECHNOLOGY CORP.

Taichung, Taiwan, ROC
+886-4-2531-4277, ext. 3868; www.urt.com.tw
Booth 220

LCD and Touch Panels

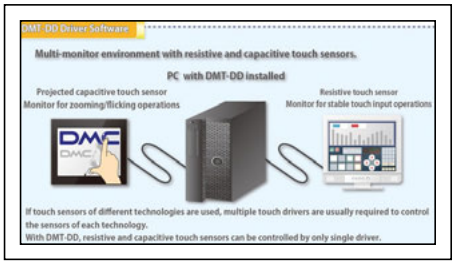
United Radiant Technology (URT) manufactures professional LCD panels and modules, including twisted nematic (TN), super-twisted nematic (STN), film-compensated-twisted nematic (FSTN), and thin-film transistor (TFT). The company also produces touch screens.

USCO AMERICA

Elmhurst, IL, USA
+1-630-832-0438; www.uscoamerica.com
Booth 234

Touch Driver Software

USCO America Inc. presents a new idea with its own touch driver software. Its affiliate company, DMC Co., Ltd, in Japan, developed the DMT-DD driver for USCO's touch screens. DMT-DD is a touch driver for P-Cap and resistive touch sensors, and can control both of those at the same time. It is possible to construct a multi-monitor environment with just one Windows (XP/7/8/81/10)PC system. This solution is already used for Japanese's train ticket kiosks, and also works well for bank ATMs and various information terminals. It is possible to use two operation terminals – one for customers and the other for administrators.



WACKER CHEMICAL CORPORATION

Munich, Germany
+1-517-264-8400; www.wacker.com
Booth 1412

Optical Bonding Materials for Vehicular Displays

As the inside of automobile cockpits are exposed to broad temperature extremes, high humidity, UV radiation, and constant vibration, it's essential to select an optical bonding material that will remain stable and compliant in those conditions. WACKER's LUMISIL silicone optically clear resins (OCRs) were specifically developed and extensively tested to meet the rigorous testing demands of the automotive industry. The WACKER

LUMISIL OCRs are superior to acrylics in many ways, including outstanding reliability at broad temperature extremes, UV stability, and low volume shrinkage, ensuring long-term stability and performance for automotive displays.

WAMMES & PARTNER

Gundersheim, Germany
+49-(0)-6244/9197-100; www.wammes.eu
Booth 609

Display Consulting

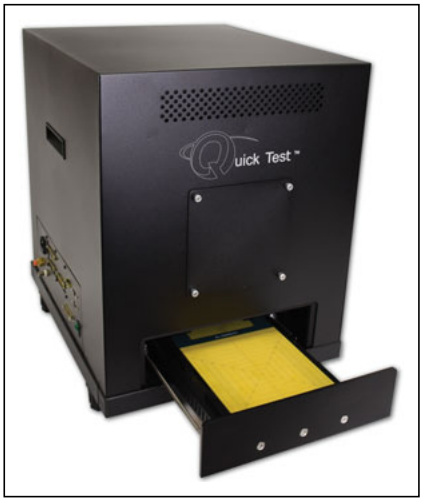
Wammes & Partner – a long-term Deutsches Flachbildschirm Forum or German Flat-Panel Forum (DFF) member – provides display networking and best-practice advice for display customers.

WESTAR DISPLAY TECHNOLOGIES

Saint Charles, MO, USA
+1-636-300-5115;
www.westardisplaytechnologies.com
Booth 1245

Mobile Display Test System

Westar Display Technologies is demonstrating the QuickTest II+ automated test system – an upgrade to the company's industry-standard QuickTest II system. The QuickTest II+ characterizes mobile displays up to 9 inches and includes: a camera, spectrometer, and Westar TRD-100A to provide measurements of uniformity, color, contrast, luminance, cross talk, response time, flicker, and more. The system includes the Westar T-Drive SD-100 video test pattern generator and a computer with the company's QuickTest software, which allows the user to easily create custom test scripts. QuickTest II+ can be extended with several options, including reflection measurement, custom display fixtures, and more.

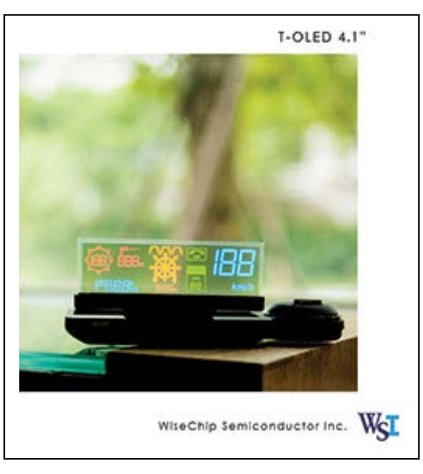


WISECHIP

Chu-Nan, Taiwan
+886-37-587186; www.wisechip.com.tw
Booth 212

4.1-in. Transparent OLED Display

WiseChip has introduced a see-through OLED display for HUD applications. Specifications include: 180° viewing angle without color distortion; wide operating temperature range (-40°C ~+ 105°C); ultra-high luminance of 1,500 candelas per square meter (cd/m^2) that provides a clear and bright image to drivers; and fast response time (≦ 10μs). OLED technology enables safe and easy viewing, with clear visibility in sunlight and at night. It will be used more and more in future head-up displays for vehicles, as well as in dashboard displays, internal lighting, and other applications.



XAAR PLC

Huntingdon, UK
+44-(0)-1480-273575; www.xaar.com
Booth 309

Piezoelectric Printheads

The Xaar 1003 AMx is the latest addition to the Xaar range of market-leading piezoelectric drop-on-demand advanced manufacturing printheads, giving high resistance to functional fluids while still delivering exceptional drop accuracy and placement. Specialized internal and external coatings prevent corrosive and reactive functional fluids from ingressing and possibly damaging the printhead. This increases uptime and decreases maintenance frequency for longer printhead life. The printhead is capable of consistently jetting droplets as small as 6 picoliters to produce fine features, patterns, and coatings. These features enable the industrialization of advanced manufacturing processes in sectors such as displays, PCBs, semiconductors, and photovoltaics.

YUASA SYSTEM CO.

Tokyo, Japan
+81-3-3578-8515; www.yuasa-system.jp
Booth 1434

Test Systems for Flexible Electronics

Yuasa System Co. is introducing its latest tension-free endurance test systems for flexible electronics during Display Week. Based upon established global testing standards, the Yuasa tension-free system is designed to increase reliability and efficiencies for all companies involved in the research and manufacturing of display devices (smartphones, TVs, wearables, *etc*.) The 2017 updated version features interchangeable cartridges designed for ease of use and seamless operation between endurance rigs and microscopes. Additionally, new optional packages include both manual and remote operation by PC and ability to externally save and output all test data.

ZHEJIANG SENSING OPTRONICS CO., LTD.

Deqing, Zhejiang, China
+86-571-89987340; www.sensingm.com
Booth 210

Retina Imaging Luminance Meter

The VDM-200 Retina Imaging Luminance Meter specializes in the measurement and analysis of optical performance, geometric parameters, and image quality of virtual image displays. The device simulates the eye pupil by using a 5-mm diameter of aperture located at the front focal point of the imaging lens in the luminance meter. This guarantees the entrance pupil is matched with the augmented reality/virtual reality (AR/VR) exit pupil, and constant field of vision (FOV) at any image distance in V-H angular coordinates. The photodetection combines the spectral radiance meter and an imaging photometer with high angular resolution so that additional measurements of pixel defects and angular resolution are possible. ■

president's corner

continued from page 4

With all the new and developing technology fields in our symposium, including vehicular displays, the number of submitted manuscripts has increased approximately 15% over last year. Therefore, the symposium will have many high-quality, exciting, and groundbreaking presentations.

In the exhibit hall at Display Week, companies will showcase both prototypes and market-ready products, including wallpaper-type OLED TVs, high dynamic range (HDR) TVs, and flexible displays and related materials. The Innovation Zone, or I-Zone, made its first appearance on the exhibit floor in 2012, and more emerging prototypes will be shown in this sixth year of the I-Zone. These and many other significant developments will be on display at the show, making Display Week 2017 a fun place to discover new display technologies.

Changes, Challenges, and Opportunities

Even with our continuing efforts to remain a relevant and leading society for the information display field, SID is facing tough challenges ahead during a time of major shifts in panel manufacturing to China and the emergence of OLEDs over TFT-LCD technologies. These changes will cause hardships for some of our individual and corporate members, but provide opportunities to grow for other sectors. SID is going to meet these challenges and continue to prosper during a time of global change. The world of information display is an exciting one in which to develop and do business, and we'll continue to meet and bring inspired people together in forums like Display Week, to ensure that SID remains at the cutting edge of technology.

Before I close, I'd like to recognize Past President Amal Ghosh for his extraordinary efforts to secure the Los Angeles Convention Center for this year's gathering after our prior arrangements fell through at the end of last year. This type of mishap has never happened in SID's 53-year history and Amal, president at that time, had to scramble to find an alternative venue as time was running out. SID is indebted to Amal for his hard work in finding and negotiating with the LACC in such a small window of opportunity.

I'd also like to thank each of you for attending our Display Week 2017 Technical Symposium and Exhibition, and for bringing your expertise to our gathering. Your individual vision, knowledge, and experience help us pave the way for the future of the Society for Information Display. You, our members, are truly our greatest asset today and tomorrow, and we could not accomplish what we do without your support and participation. Throughout this conference, I ask you to stay engaged, keep us proactive, and help shape the future of SID. My personal respect and thanks go out to all of you. ■

(continued from page 28)

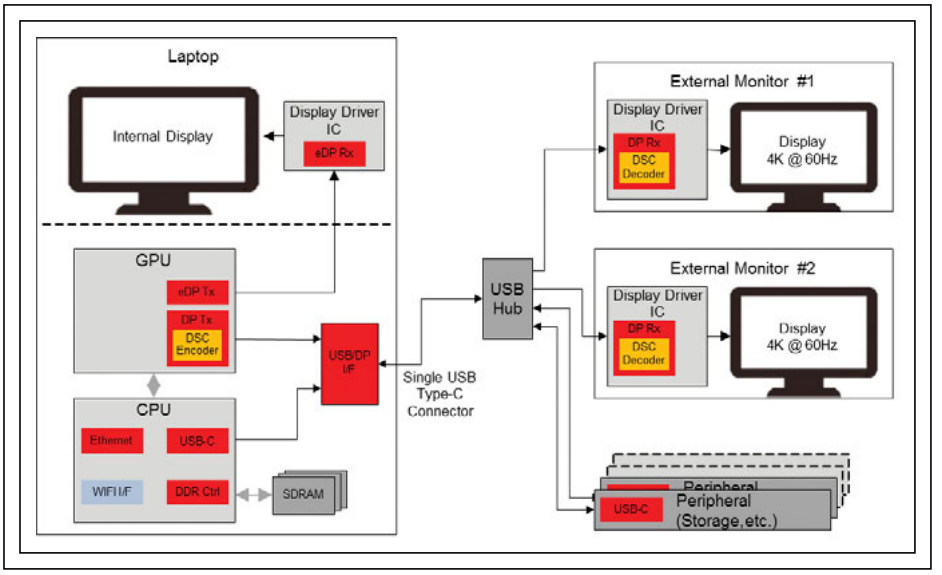


Fig. 9: *DSC compression can be used with a DisplayPort transmitter inside a GPU, and combined with a DSC decoder in the DisplayPort receiver directly inside a USB Type-C monitor.*

with a DSC decoder in the DisplayPort receiver directly inside a USB Type-C monitor, as shown in Fig. 9. The DSC decoder could also be incorporated inside a USB hub that would feed a standard DisplayPort monitor in uncompressed mode. In both scenarios, the data bandwidth saved through DSC compression can be used for other external resources such as storage and networking units.

Compared to DisplayPort 1.3, the DisplayPort 1.4 standard takes advantage of VESA DSC v1.2 to increase the DisplayPort data transfer capacity without changing the link speed. With DSC's video bandwidth reduction, DisplayPort 1.4 enables the transport of multiple ultra-high-definition video streams (using the multi-stream transport [MST] mode) across the single DisplayPort interface.

As resolutions of external displays move beyond 4K, DSC compression offers a solution for developing ultra-high-resolution external displays for use with the existing USB Type-C interface.

In conclusion, the VESA DSC algorithm offers a number of key benefits, including visually lossless compression quality with all types of content, bandwidth reductions of up to 3X, and ultra-low latency. Using DSC compression offers designers a scalable solution to meet the demands of current and future display products.

References

[1]VESA Display Stream Compression by Frederick Walls and Sandy MacInnis, 2014 www.vesa.org/wp-content/uploads/2014/04/VESA_DSC-ETP200.pdf

[2]VESA website www.vesa.org/faqs/#DSC FAQs

[3]www.anandtech.com/show/11003/hdmi-21-announced-8kp60-48gbps-cable

[4]www.vesa.org/featured-articles/vesa-updates-display-stream-compression-standard-to-support-new-applications-and-richer-display-content/ ■

continued from page 6

UDC to Invest in PPG Manufacturing Facility

PPG and Universal Display Corporation have announced that Universal Display will invest $15 million in PPG's Barberton, Ohio, manufacturing facility to double commercial production capacity for Universal Display's proprietary UniversalPHOLED phosphorescent emitter products. The expansion project, which will add more than 20 positions at the facility, is scheduled to be completed in the third quarter of 2017.

PPG and Universal Display opened an OLED materials production facility at PPG's Barberton plant in 2013. The site is owned and operated by PPG.

LG Shows High-concept OLED Lighting

LG Display recently demonstrated some of its latest flexible OLED light panels at the Euroluce 2017 show in Milan, Italy. Among the most eye-catching of these products were collaborations with leading industrial designer Ross Lovegrove, who used the OLED panel technology to create lighting inspired by marine life (Fig. 2).

Lovegrove also designed the lighting with scalability in mind, saying, "I make a module, which is very economical, but then you multiply that and you can make huge installations." LG Display is seeking to highlight the flexibility of its OLED light panels for the high-end residential and premium hospitality markets.

Fig. 2: *"Medusa" (left) and "Pyrosome" (right) are OLED lighting artworks by Ross Lovegrove using OLED light panels from LG Display. The artworks were shown at Euroluce 2017 in Milan, Italy. Photos: LG Display*

SID LA Chapter One-Day Conference Highlights Applications

The Los Angeles chapter's annual event featured presentations on quantum dots, high dynamic range, human vision, head-up displays for cars, direct-view LEDs, light-shaping technology, and smart windows.

By Ken Werner

Last February, the SID Los Angeles Chapter held its 14th annual themed one-day conference, titled "Display Technologies and Applications." As Program Co-Chair Michael Moyer said, "The conference's title ... was chosen to suggest that visual applications and sub-systems will succeed to the extent that their displays contribute to an effective human-machine interface."

Moyer, who is group lead for advanced cockpit displays for the Electro-Optics System Division of the Physical Optics Corporation in Torrance, CA, continued, "But thinking of all display technologies as commodities and assuming a particular off-the-shelf display cannot be improved at low cost is a self-defeating strategy. The human visual system is not totally understood, and there are unexplored display opportunities in the complexities of the human visual experience."

Leading Off with Quantum Dots

The conference opened with a welcome from SID LA Chapter Chair Larry Iboshi of Iboshi Consulting in Fullerton, CA, and introductory comments from the author, Ken Werner of Nutmeg Consultants in Norwalk, CT.

The first speaker for the technical program was Jennifer Colegrove, CEO and principal analyst for Touch Display Research in Santa Clara, CA. She led off with an overview of the OLED vs. quantum dot (QD) market through 2027. Colegrove predicts that roughly 25 million QD-enhanced LCD TV sets will be sold in 2017 compared to about 2 million OLED TV sets. These numbers will grow to roughly 210 million for QD-based LCD-based TVs and 40 million for OLED in 2027, Colegrove said. Even in 2021, OLED TV's overall market share remains under 6%.

Colegrove noted that there are 97 QD materials suppliers, component suppliers, and adopters in 2017. Forty-three of these are in the US; 14 in China; 8 each in Germany and Korea; 7 each in Japan and Taiwan; and 10 in "other regions."

I will editorialize here and note that projecting market percentages 10 years out requires more self-confidence than even I possess. But Touch Display's five-year numbers are in substantial agreement with other sources, and the inevitable conclusion is that OLED TV is going to play primarily in the very-large-screen, super-premium segment for a long time to come. Unless, that is, solution processing becomes viable more quickly than most of us anticipate.

HDR Present and Future

Next, Gerard Catapano, director of quality assurance for Samsung QA Lab in Pine Brook, NJ, presented "HDR, Today into Tomorrow." Catapano introduced high dynamic range (HDR) as "the latest and most innovative technology that helps film studios deliver a better expression of details in shadows and highlights to the consumer," and he quoted the Consumer Technology Association's definition of an HDR-compatible display as one that has these minimum attributes:

- Includes at least one interface that supports HDR signaling as defined in the Consumer Electronics Association's CEA-861-F, as extended by CEA-861.3.
- Receives and processes static HDR metadata compliant with CEA-861.3 for uncompressed video.
- Receives and processes HDR10 Media Profile from internet protocol (IP), high-definition multimedia interface (HDMI), or other video delivery sources. Additionally, other media profiles may be supported.
- Applies an appropriate electro-optical transfer function (EOTF) before rendering the image.

The HDR standard has been endorsed by a variety of organizations, include the Blu-ray Disc Association, the Moving Picture Experts Group (MPEG), the Ultra High-Definition (UHD) Alliance, and the United Nations' International Telegraph Union (ITU). Although HDR is currently a premium feature, Catapano asserted that in the future it will be a basic feature of TVs across all screen sizes and display technologies.

Samsung TV sets are supporting only one HDR media profile, HDR10, because it is an open standard that does not require licensing fees, and also permits customization within the profile. Since use of at least HDR10 is required by the CTA definition of an HDR-compatible display, it will be supported by all major manufacturers. Although Catapano didn't say so, some of Samsung's competitors also include Dolby Vision, and in its new "Wallpaper" OLED TV, LG includes hybrid log-gamma (HLG) HDR for a total of three HDR profiles.

Catapano noted that at NAB in 2016, the major encoder manufacturers were offering 4K HDR as an option, and that the major mastering and editing tool sets were implementing it. He also noted that although the CTA definition only requires the support of static HDR metadata (metadata that is constant throughout the entire film or video), even more impressive results are possible with dynamic HDR metadata (which changes scene by scene).

Society of Motion Pictures and Television Engineers (SMPTE) ST.2094-40 provides dynamic metadata for tone mapping. Tone mapping is a key technology in HDR TVs, Catapano said. It is a color-volume transform that renders incoming HDR contents for a display with a dynamic range that is smaller than the contents were coded for. With static metadata, either every scene must have its color volume compressed so that the scenes with the greatest color volume can be fit into the color volume for which the display is capable, or the most demanding scenes can be insufficiently compressed. With dynamic metadata, each scene can be optimally compressed, which in some cases will mean no color-volume compression at all. Catapano observed that Samsung's 2017 HDR TVs "are ready for ST.2094-40." In the Q&A, Catapano said that HDR works best with movie mode, which he recommends for general viewing, at least with Samsung TVs.

The Human Visual System

In "Human Vision and Displays," Karlheinz Blankenbach, a professor at Pforzheim University in Germany, outlined the characteristics of displays and the human visual system, discussing both the challenges of making them work together and the opportunities for exploiting the visual system's characteristics to improve the subjective

performance of displays (Fig. 1). He noted that between the image source and the display are 1) a signal processor that performs decompression, scaling, de-interlacing, frame rate conversion, and similar functions; and 2) an EOTF (see previous section) that performs dimming and interfaces with the panel hardware and software, *etc*.

The first of two major challenges is to allow the viewer to read a display in an arbitrary environment (think driving into the sun and looking down to read your center-stack display), given the eye's adaptation to bright luminance levels. The second is to represent scenes with very high dynamic range on the display. For this we need "more and better pixels," says Blankenbach. A better pixel is one that produces greater luminance, more gray-scale resolution, more gamut, and higher frame rate.

Among many of the observations in this extensive presentation was that the standard method of determining visual acuity, the Snellen test, which is what your ophthalmologist uses to prescribe eyeglasses, is only part of the story. The human visual system's sensitivity to Vernier acuity (whether line segments line up or not) is 10 times that of Snellen. This is rather well known and is what leads to annoying aliasing on displays that would not show if Snellen were all that mattered. What was new to me is that our color-fusion resolution is 10 times greater than our Vernier resolution, which is why we see color fringes on lines or letters on pixelated displays when we don't see aliasing.

HUDs for Cars

Gaia Dempsey, co-founder and vice president of DAQRI Laboratories in Los Angeles, CA, discussed her company's approach to automotive head-up displays (HUDs) (Fig. 2).

The automotive industry is enthusiastic – very enthusiastic – about presenting both instrument-cluster data and augmented reality (AR) information to drivers via HUDs. In fact, once HUDs become good enough, there may be no need for a conventional instrument cluster at all. That's an intriguing idea for engineers who have had to stuff more and more electronics behind the dash as time goes on.

The demanding requirements for a high-performance HUD include large field of view, high resolution, large contrast ratio, and high luminance range. (If the HUD is going to be the primary, or only, instrumentation display, it must be visible against a very bright background: sunlit snow, for instance.) To these frequently stated requirements, Dempsey added multiple image planes.

Fig: 1: *Karlheinz Blankenbach, who spoke about human vision and displays, listens to one of the other presentations at the LA conference. Photo: Ken Werner*

DAQRI calls its approach "Software Defined Light," by which the company means the image is created by phase-only holography. The audience was understandably curious about how DAQRI's dynamic spatial light modulator (SLM) was implemented, but there weren't many details about it in this presentation. Presumably, there is such an SLM because Dempsey showed a photo of the "first-ever solid-state automotive HUD," which uses the technology. She said the HUD "has passed all automotive certifications." The outstanding questions may be answered at SID's Display Week, where DAQRI will demonstrate its technology.

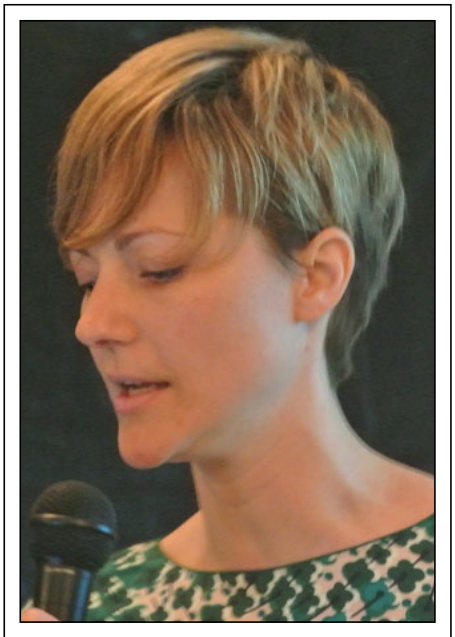


Fig. 2: *Gaia Dempsey, DAQRI Labs VP, talked about her company's holographic technology for HUDs. Photo: Ken Werner*

Direct-View LEDs

The presentation by Grant Wylie, senior product marketing manager for NEC Display Solutions, was entitled "Direct View LED: How We Got Here, What's Available Now and What's to Come." Wylie started with some history, commenting that the first large-format, digital-signage displays were ticker-like devices based on incandescent bulbs. He showed a version of the accompanying photograph, which was taken on June 6, 1944 (Fig. 3).

NEC Display Solutions' goal, said Wylie, "is to show full-color video to our audience, no matter how close or far they are from the display." Clearly, incandescent bulbs did not turn out to be the technology of choice for video walls, but subsequent technologies have also not been ideal.

Front projection, said Wylie, lacks brightness and contrast, doesn't function well in bright ambient environments, and must be set up so there are no obstructions in the projection path. Rear projection has its own problems: limited brightness, difficult color calibration, a deep display module, and lines between individual displays.

Cathode-ray tube (CRT) solutions (Sony's Jumbotron and Mitsubishi's Diamond Vision) were thick, bulky, and heavy; power hungry; low resolution; and expensive. For a time they were the only viable full-color solution bright enough for outdoor displays, but the world was waiting for a better video-wall mousetrap.

That better mousetrap was the LED display, but it didn't come all at once. At first, only red LEDs had sufficient luminous efficiency, and green was really yellow-green. Blue didn't exist yet. But a lot of monochrome LED displays were deployed. Now, red, green, and blue (RGB) LEDs have arrived, and full-color video walls are proliferating.

There are, Wylie said, three main differentiators between indoor and outdoor LED

Fig. 3: D-Day: Early digital displays used incandescent bulbs. NEC's Grant Wylie showed a photo of this ticker-type display on the New York Times Building, June 6, 1944. Photo: Howard Hollem or Edward Meyer for the Office of War Information

signs. First, the luminance of indoor LEDs is typically limited to 800 to 2,000 candelas per square meter (cd/m^2), while outdoor LEDs range from 2,000 to 6,500 cd/m^2. Next, indoor LEDs have ingress protection (IP) ratings of IP30/31, which means they can't get wet. Outdoor LEDs have ratings of IP56 or better. And third, indoor LEDs have a temperature range of 32° to 104°F, while outdoor units are –4° to +122°F, and are also designed to withstand solar heat gain.

Minimum LED pixel pitch has decreased remarkably over the past few years, to the point where most makers have modules with 2.3-mm or 1.9-mm pixel pitches, and even finer pitches have been shown. But less may not always necessarily be better.

Wylie said a "retina display" – one in which the eye cannot resolve the individual pixels – requires that pixel spacing does not exceed 1 mm of pixel spacing for each 2.5 meters of viewing distance, and this is called the "optimum pixel spacing." But 75 to 80% of the substantial cost of an LED display is in the LEDs themselves, which has stimulated makers of LED displays and their customers to think carefully about the cost/image-quality trade-off. They have come to a generally shared conclusion that a 1-mm pitch for each 1 meter of viewing distance is acceptable for most applications. So, for instance, the recommended minimum viewing distance (RMVD) for a display with 6-mm pitch is 20 feet and the RMVD for 1.9 mm is 6 feet (Fig. 4).

Wylie had a few predictions for video walls. Printing of OLED displays will bring the cost down for signage as well as television, but inconsistent pigment lifespan, color shift over time, insufficient brightness for outdoor applications (despite high contrast), and a manufacturing process not ideal for very large formats are likely to limit video-wall applications. HDR LED video walls will be attention-grabbing and they will come, but new hardware and high-bandwidth digital content production (HDCP) 2.2 are required first. On the positive side, LED displays are emissive and thus capable of extremely high contrast.

Chip on board (COB) refers to LEDs being applied directly to the printed circuit board. Eliminating the current surface-mount devices will allow designers to place sub-pixels closer together. "Almost all LED display manufacturers are working on a version of this technology," said Wylie.

In the Q&A, Wylie had the opportunity to add:

- RGB LEDs all degrade at the same rate, with most products today specified as having a lifetime of 100 K hours to half luminance.
- The market growth for LED video walls is expected to be exponential through 2020.
- The refresh rate for these walls is roughly 3,000 frames per second, varying somewhat by model.

Light-shaping Technology

Seth Coe-Sullivan is well known as a co-founder of the quantum-dot company QD Vision, although that company's assets were acquired last year by Samsung. He is now VP of technology at Luminit LLC – and looks far more relaxed than when he was CTO at QD Vision!

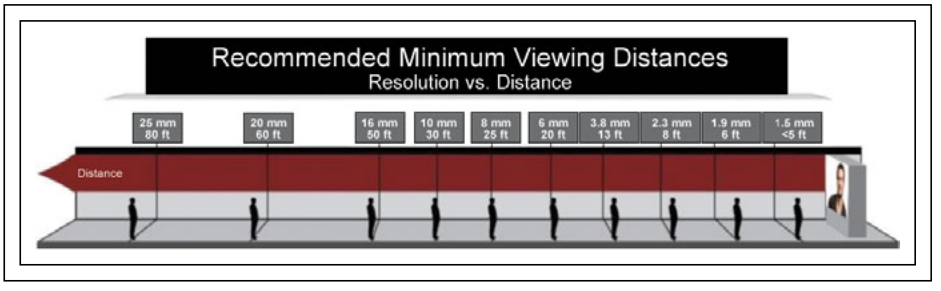


Fig. 4: NEC's Grant Wylie presented this chart of recommended minimum viewing distances for LED displays with different pixel pitches. Figure: Grant Wylie, NEC Display Solutions of America

Although Coe-Sullivan's presentation was devoted to Luminit's use of holographic technology to fabricate light-shaping diffusers, the organizers had asked him to start off with some comments about quantum dots and QD Vision, and he did.

On the subject of putting quantum dots directly on an LED chip (called dot-on-chip), which is very difficult because existing QD materials degrade under high heat and high luminous flux, Coe-Sullivan said, "QD Vision would have solved the heat/lumens problem in another two years, I firmly believe."

On what true QLED should be called now that Samsung is using the name "QLED" for its new quantum-dot TVs, "since the QLED term has been co-opted: 'electroluminescent QD,' " he said. Coe-Sullivan went on to say that he believes Samsung's acquisition of QD Vision was driven primarily by its need for an alternative to LG's OLED.

Then Coe-Sullivan made the transition to his presentation on Luminit, a privately held, 11-year-old, 75-person company with headquarters and manufacturing in Torrance, CA. The company's first application of holography to lighting and displays was light-shaping diffusers (LSDs), which used holographic recording to create a pseudo-random pattern that mimicked the function of a diffuser with surface relief. Since LSDs have no particles, there is no wavelength dependence and no loss from scattering sites. In addition the diffusing effect can be either symmetrical or asymmetrical – even highly asymmetrical. One of the company's LSDs produces a pattern that is 60 degrees by 1 degree. Coe-Sullivan said that Luminit has 50% of the market for light shaping in automotive HUDs.

The augmented-reality (AR) industry would benefit from holographic optical elements (HOEs), Coe-Sullivan said, but worldwide mass-production capacity is negligible today. Luminit is making plastic laser imagers using holography to fabricate the master, and believes it can leverage this technology for volume production. They expect to be making thousands of units per month by the time you read this. These HOEs have a transmittance of more than 90% and are approximately 25µm thick (plus the substrate).

"Volumetric HOE may have finally found its killer app – augmented reality," Coe-Sullivan concluded. (For more about Coe-Sullivan's work at Luminit, see this issue's Business of Displays Q&A, which features an interview with him.)

Smart Windows

As program co-chair, I introduced the conference's final speaker this way: "Robert Miller has an impossibly long title: senior business manager for liquid crystals and advanced technologies for EMD Performance Materials, the North American specialty chemicals affiliate of Merck KGaA, Darmstadt, Germany. I just call him Merck's display man in America."

Miller's presentation was not about displays, but his title was descriptive: "The licrivision Liquid Crystal Window Technology." Smart windows for interior applications are not new, but Merck's licrivision technology is intended for exterior windows, particularly the kind that sheathe modern high-rise buildings. Merck has taken substantial time and effort to develop a material that can survive heat, cold, and ultraviolet light, while still performing its required function for many years. Merck's solution is a guest-host liquid-crystal display (GH-LCD) in which all components have been individually screened for performance and lifetime. In addition, each combination needs to be tested to ensure reliable operation, Miller said.

An architectural liquid-crystal window (LCW) must perform a variety of functions. The obvious one is switch from clear to opaque, but in its transparent state it must admit visible light, block other solar energy, and reflect interior heat back into the room. In addition to architectural applications, Merck hopes to replace existing polymer-dispersed liquid-crystal (PDLC) products such as automobile sunroofs.

Field tests suggest that LCWs can produce 40% savings in energy for summer cooling, depending on floor area, window area, and extent of insulation.

Merck is making its own pilot facility to supply architects and builders with sample windows, but the company's goal is to sell its GH-LCD material. The company is in active communication now with architects and glass makers, and several field installations – including the new Merck KGaA/EMD Innovation Center in Darmstadt -- have demonstrated the impact of the technology, Miller said (Fig. 5).

Tabletop exhibits accompanied the technical program. The exhibitors were Colorimetry Research, Crystalplex, Gamma Scientific, Luminit, NPB Technology, RealD Me, TFD Inc., Touch International, Westboro Photonics, and Z Microsystems. Most of the exhibits were well attended during the breaks, and those exhibitors were happy. The speakers seemed very happy with the number of attendees and the lively Q&A sessions.

The 14th annual one-day conference was held February 3, 2017, at the Costa Mesa Country Club in Costa Mesa, CA. Plans are already under way for the 15th one-day conference in 2018. ■

Fig. 5: The facade of the Merck KGaA/EMD Innovation Center in Darmstadt, Germany, uses switchable licrivision smart windows. Photo: Merck KGaA

***Ken Werner** is Principal of Nutmeg Consultants, specializing in the display industry, manufacturing, technology, and applications, including mobile devices and television. He consults for attorneys, investment analysts, and companies re-positioning themselves within the display industry or using displays in their products. He is the 2017 recipient of the Society for Information Display's Lewis and Beatrice Winner Award. You can reach him at kwerner@nutmegconsultants.com.*

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The issue of *ID* you are reading now can be useful for your planning because it features our Products on Display coverage, which is assembled each year by our staff to help you get the most out of the exhibition. Also, while good planning is essential, don't forgo the opportunity to just wander around the exhibits or pop in on that presentation you might not otherwise consider. Each year I find many surprises and new ideas that I can only discover if I explore as much as possible. It's a wonderful mix of the expected and unexpected that awaits you. I've never left Display Week without at least a handful of amazing new nuggets that have since proven invaluable in my day-to-day work.

Maybe you are a seasoned SID member returning after many previous years, or maybe you are brand new to the display industry scene and this is your first event. If so, you are not alone. Many people discover SID through Display Week when they automatically become new members by registering for the event. Then, later on, they realize that the Society for Information Display is about much more than just one great event per year. In fact, SID offers a calendar abounding with exciting international display-industry events, some focused on a particular technology or field of research and others almost as broad as the Symposium itself.

For example, through the rest of this year you can experience many other world-class events, such as IMID: The International Meeting on Information Display, in Korea; the IDMC: International Display Manufacturing Conference, Taiwan; and EuroDisplay, in Belgium. These are all outstanding events and give you an excuse to see great parts of the world as well.

However, some of the most important Society activities are those that take place regularly on a local and regional level at each of SID's 30-plus chapters worldwide. It is hard to find any industrialized part of the world that does not have some chapter activities going on. And if all that is not enough, SID's publications, online resources, and network make the organization a truly indispensable tool to a successful display-industry career. Even if you attend only one additional SID event or take even partial advantage of your local-chapter activities and the online resources, you get the value of your membership back many times over. So, if you are new to SID, I hope you find it a truly enriching experience, and do not forget about your membership after Display Week 2017 is over.

DIAs and Vehicle Displays

We have a full issue for you, and we begin with our cover story on the six great products recognized by SID for the 2017 Display Industry Awards. Each of these products has advanced the state of the art of display technology in one of the categories of Display of the Year, Display Component of the Year, or Display Application of the Year. This year, OLED panels, virtual reality, projection, and quantum dots were the story, and each product made fundamental strides in its technical area. You can read all the details in our cover story compiled by Jenny Donelan.

Our technical focus for this issue is automotive displays, and our great lineup was developed with help from our guest editor, Dr. Karlheinz Blankenbach from Pforzheim University in Germany. Karlheinz is also co-author on our first article, revealing a new architecture for controlling high numbers of LEDs for automotive lighting applications. In their Frontline Technology story, titled "Automotive Interior Lighting Evolves with LEDs," authors Robert Isele, Roland Neumann, and Blankenbach discuss the well-known challenges of getting large arrays of LEDs to all produce the same luminance and color without excessive electronic and wiring complexity. Their solution involves a distributed driver topology with a 2-wire control interface. With this new approach, they can control as many as 4,096 RGB LEDs with one controller and create all kinds of coordinated and uniform lighting effects inside the vehicle. This has the potential to greatly reduce wiring complexity and bring new beauty to the vehicle interior.

Our next article comes from Simon Jones at FlexEnable, and describes the challenges and opportunities for populating displays around the vehicle interior, especially in clever positions such as the A pillar, in ways intended to eliminate blind spots and replace outside mirrors. However, doing this requires unique form factors and displays that can conform to complex surface shapes. This forecast of the need for conformable displays has been a common observation for many years; in fact, I can remember this very concept being promoted in the earliest days of flexible OLED development. However, the big difference now is that it really is achievable, and as Simon explains in his Frontline Technology article, "Plastic Displays Will Play a Major Role in Automotive HMIs," a number of innovative steps have been demonstrated to achieve conformable displays with LCDs using organic TFTs to produce a system his company calls the organic LCD (OLCD). Yes, you read that right – not OLED, but OLCD, and it can be done by re-purposing existing a-Si LCD lines. The potential opportunity is quite exciting, as you will see in his article.

Display Stream Compression

From the very first time engineers put multiple pixels together in an array, we've struggled to find innovative ways to address those pixels and manage the flow of video information to them. We've gone from lots of individual wires to parallel addressable matrices, to serialized data streams, and now to compressed data streams such as the most recent new VESA display stream compression (DSC) standard. As video rates continue to increase (such as QHD, UHD, 5K – 8K), a gap is rapidly emerging between the fastest physical layers of serialized video transport interfaces (HDMI, for example) and the required data rates. Without compression, this necessitates more parallel lanes, which adds cost and complexity to everything from home entertainment systems to smartphones. One way to address this is to incorporate a real-time compression-decompression layer before the physical layer. To explain how this works, authors Alain Legault and Emma-Jane Crozier explain the details of the problem and the advantages of this solution in their Making Displays Work for You article, "Create Higher Resolution Displays with the VESA DSC Standard."

I confess that whenever I hear about compression methods, I immediately think about loss of resolution and/or the introduction of artifacts. I've opined often about the heavily compressed MPEG4 streams coming in on my satellite feed, but the authors of this article explain how this DSC standard is a very different type of compression that is based on delta pulse code modulation (DPCM) and works on a single line of video data at a time. This approach does not significantly alter the spatial frequency content of the stream. In their article, the authors describe the extensive amount of user observation testing, comprising almost 250,000 subjective image comparisons to establish this as a visually lossless

approach. I can't say if it is truly imperceptible because I have not seen it, but I believe the reported results, and I'm very excited about the prospect of bringing even higher resolution to all kinds of video interfaces for numerous applications, including handheld devices, VR headsets, monitors, and of course, automotive applications.

Ken Werner is a longtime loyal contributor to *Information Display*, and most recently, a recipient of SID's prestigious Lewis and Beatrice Winner Award. He's also a certified "car guy," as I can attest to after having had many a car talk with him over the years. Since automotive displays have become a vibrant area of development lately, we thought it would be exciting to get Ken's take on the topic. He agreed and wrote this month's Display Marketplace feature, "Automotive Trends Drive Vehicular Displays." There is no shortage of innovative ideas to enhance the cockpit experience, and finally there are displays capable of meeting those needs. Ken walks us through a number of key focus areas, including head-up displays (HUDs), advanced driver assist systems (ADAS), the connected car, autonomous vehicles, and so much more. Don't know what all of these things mean? That's okay. Read the article and you will. Afterward, I suspect you might be re-thinking your next car purchase!

I hope you enjoy this issue and your stay in LA. Don't forget to check our website and the blogs each day, and if you see me around, please say hi and let me know what you like about Display Week this year. We produce this publication to serve our membership and their interests, and we can do so only because of the generosity of the many wonderful companies that support SID through sponsorships and exhibitions. Please support them in any way you can. ■

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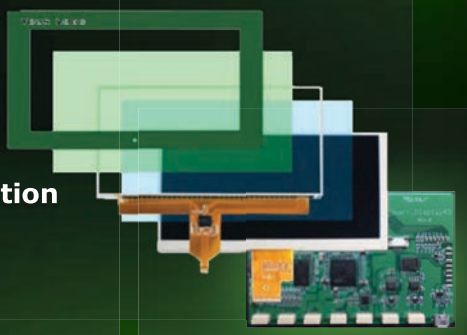

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