LCD LED Lighting Technology Conference

January 19, 2007, Costa Mesa, California

Geoff Walker reports on the latest in a continuing series of one-day conferences about "LEDs in Displays" hosted by the SID Los Angeles chapter. Total attendance was 117 people, of which 33% came from outside of Southern California (13% from Northern California and 20% from outside of California). Considering that this was a local SID chapter event, the numbers show both the currency of the topic and the strength of the chapter.

The overall structure of the conference was built on incremental layers of information, divided into sections devoted to light-controlling elements, driver electronics, LED backlights for LCDs and LED light sources for projection, and industry forecasts

Bill Kennedy (Program Chair) from **Toyoda Gosei** opened the conference with introductory remarks. Bill's presentation emphasized the vibrancy of the movement towards LEDs in displays by pointing out the following signposts (among others):

- Laptops from major OEMs with LED-lit LCDs in 2007
- 32-inch LED-lit TV LCDs with 50K-hour lifespan at 1/3 the thickness of CCFL panels
- Prototypes of larger LED-lit panels such as Samsung's & Sony's 80-inchers at CES
- Rear-projection TVs, pocket projectors and micro projectors with LED light sources
- Display applications for both white ("practical") and RBG (enhanced color gamut) LEDs

Eric Bretschneider from **Toyoda Gosei** presented on the topic of "High Brightness Side-View LEDs". Eric likened the current state of the LED business to the "wild west" because of a relative lack of standards. For example, Eric pointed out that it's impossible to directly compare the flux (lumens) output of different LEDs because they are specified in terms of milli-candela (mcd), which ignores the effect of viewing angle. LEDs with wider viewing angles emit more flux and couple more light into a waveguide – even with identical milli-candela specs. Eric's recommendation is that every engineer using LEDs should make his or her own measurements of the LEDs' characteristics.

Eric described four factors that cause LED performance declines over time: die aging, die attachment, encapsulation and the reflector. In the last two years, performance has increased substantially in two dimensions: side-view LEDs have gone from 1,000 mcd with 10,000 hours lifetime to 1,800 mcd (60 lumens per watt) with 50,000 hours lifetime. The limiting factor of the current lifetime (measured to half-brightness) is the LED packaging materials, not the emissive material. Another reliability factor that Eric described is the aperture size, which is the size of the cup that holds the phosphor and binder. Larger cups produce higher reliability because they allow the use of a lower phosphor density. Yet another reliability factor is the effect of solder reflow. The use of lead-free solder due to RoHS regulations has increased soldering temperatures; this can cause a chromaticity shift and a reduction in intensity.

Naturally, examples of all of the above were given in terms of Toyoda Gosei's LEDs vs. unspecified competitive LEDs, and as expected, Toyoda Gosei's LEDs were better in every case. One final comparison was of chromaticity binning. Using MacAdam ellipses, Eric showed that Toyoda Gosei's LEDs had no perceptible color difference inside each bin, while unspecified competitive LEDs with chromaticity bins ~8x larger had noticeable color differences inside each bin.

In the Q&A at the end of Eric's presentation, several interesting points came out, as follows:

- Current LED package thickness is 0.6 to 0.8 mm; the next generation will be 0.45 mm, which is expected to be a "realistic limit"
- In the last 12 months, LED price erosion has been 30-40% while intensity has increased by 30%
- The typical total cost of the three LEDs used in a 2-inch cellphone display is 60 cents.

Jun Qi from **Wavefront Technology** presented on the topic of "Tailored Holographic Micro-Diffusers for LEDs & Non-Emissive Displays". Jun's presentation compared standard diffusers, typically made with a solvent-based coating of inorganic materials, with holographic diffusers, made with organic polymers and a UV-replication process. Jun explained some of the advantages of holographic diffusers, as follows:

- Easier to make thinner (50 microns vs. 130-160 microns for standard diffusers)
- Surface morphology and refractive index can both be modified to vary performance
- Aspect ratio (the shape of the transmittance vs. viewing angle curve) can be tailored
- Lower zero-order component, which means a higher haze value (higher hiding power)
- Intensity peak can be intentionally offset for avionics or automotive applications.

Jun described two applications for holographic diffusers, the first of which was a bottom diffuser for an LED backlight. In this application, the holographic diffuser produced higher brightness and eliminated the typical brighter edge seen with standard diffusers. The second application was as the diffuser film in several different configurations of a large LCD monitor or TV with a direct-lit backlight. In one configuration, the use of a holographic diffuser to replace two standard diffusers produced a simpler configuration with broader angular performance at the same brightness. In another configuration, the use of two holographic diffusers produced the same advantages with an enhanced horizontal viewing angle at slightly lower brightness.

In a Q&A following his presentation, Jun said that the current thickness of holographic diffusers used in cellphone backlights was 80 microns; the next generation will be 60 microns, decreasing to 35 microns in the future.

Tim Ward from **Microsemi** was to have presented on the topic of "LED Driver Technology" but he, like several of the intended conference participants, was temporarily incapacitated by the norovirus that was circulating through California during January.

Karl Volk from **Semtech** presented on the topic of "LED Driver ICs". Karl's brief presentation described several approaches to powering strings of backlight and camera-flash LEDs, including the use of boost converters, charge pumps and current sinks.

Ahmed Masood from **Supertex** presented on the topic of "LED Driver Solutions for Backlighting LCD Displays". Ahmed's presentation described several different methods of powering strings of LEDs. The theme of his presentation was that there's no ideal solution – everything is a tradeoff. Some of the tradeoff variables include the relative difficulty of thermal management, the need for binning, cost, the availability of dynamic dimming, efficiency, the number of LEDs per string, power loss in supply lines, hazardous voltages, failure modes, input surge immunity and LED current accuracy. In the TV and monitor area, Ahmed described the tradeoffs for using two varieties of switcher-plus-linear architecture, one variety of boost architecture and two varieties of buck architecture. In the car display and pocket projector area, Ahmed described the tradeoffs for using buck-boost architecture (also called the "Cuk Converter", named after its inventor, Dr. Slobodan Cuk at Caltech) vs. single-ended primary-inductance converter ("SEPIC") architecture.

In the Q&A at the end of his presentation, Ahmed said that the cost of a boost driver IC for a string up of to 10 LEDs is currently around 22 cents in quantities of 5M to 10M. Ahmed also pointed out that as the current through an LED changes, the color temperature also changes, which is a big problem in big TVs.

George Panagotacos from **Teledyne Lighting and Display** presented on the topic of "LED BLUs for LCDs and Microdisplays". George started by segmenting the high-brightness LED market into the following levels:

- Level 0: Basic semiconductor chip (die level)
- Level 1: Single bonded, encapsulated and mounted device (device level)
- Level 2: Devices or arrays with generic optics
- Level 3: Devices or arrays with application-specific optics, plus a higher level of electrical and mechanical integration.

George stated that the large semiconductor companies are competing fiercely at levels 0 and 1, but with ever-broadening LED usage (traffic signals, channel letters, etc.) the devices are poised to become commodities. Teledyne Lighting and Display is targeting level 3, integrating devices into value-added products while benefiting from the competition at levels 0 and 1. As an example of such a product, George briefly described a sunlight-readable, RGB-LED backlight for aerospace applications. Some of its more interesting specs included a luminance of >2,600 nits, maximum power consumption of 16.8 watts, an operating temperature range of -40°C to +85°C and a lifetime of >20K hours.

The remainder of George's presentation described the characteristics and applications of some of Teledyne's patented optics. This included two low-profile lenses, the "TIR-Lens" that collimates a light source up to +/- 2°, and the "Blackhole Lens" that provides uniform radial light distribution from an LED aimed perpendicular to the plane of the lens.

Chuck McLaughlin from the **McLaughlin Consulting Group** presented on the topic of "The Impact of High Dynamic Range (HDR) Displays on LED Demand". Chuck began by observing that approximately 70% of the TV exhibitors at CES 2007 were showing HDR, so "it's very real". Chuck described the problem that HDR is trying to solve: LCDs and projection displays can't even match the dynamic range of cinema, much less that of the real world. The goals of HDR are therefore as follows:

- Use the full gray level and contrast capability of the display, especially in dark and bright images
- Achieve darker blacks, brighter whites and the use of all gray levels
- Improve color contrast and gray-level resolution
- Reduce power consumption.

HDR works by synchronously and simultaneously modulating the LCD backlight and the gray-level equalization (stretching the gamma function) on a frame-by-frame basis. The latter improves the image detail and contrast, while the former adjusts the image brightness. Chuck defined three levels of HDR, as follows:

- Level 1: White-light modulation plus histogram processing
- Level 2: RGB light modulation plus RBG histogram processing (independent processing for each primary color)
- Level 3: HDR Level 2 plus spatial modulation of RGB LED backlights.

It's worth noting that with Level 1 you can't see any effect in a single frame; the effect is only visible in video because it's dynamic.

Chuck reviewed progress from some major LCD manufacturers are making in implementing HDR, as follows:

- BrightSide offers integrated image capture, data storage and display for HDR Level-3 imaging. (*Author's note: For a very interesting 10-page review of BrightSide's product, go to* http://www.bit-tech.net *and search for "BrightSide"*.)
- Sharp offers an LCD with a 1,000,000:1 contrast ratio for use in the professional TV and movie production industry. At CES 2007, Sharp was showing consumer TVs with contrast ratios of 15,000:1

with HDR vs. 3,000:1 without HDR

- Panasonic uses a "dynamic iris" to modulate projection lamp output while simultaneously adjusting the gamma to achieve a dynamic contrast ratio of 2,000:1
- AUO has presented papers indicating they're in the process of developing HDR Level 1
- Samsung and CMO have shown HDR-related technologies in the past but haven't shown anything new recently in this area.

In 2006, the McLaughlin Consulting Group conducted their own study of LED backlight penetration; the results were as follows:

- >30% penetration in notebooks by 2009
- >10% penetration in TVs by 2010
- Only minor penetration in differentiated niche monitor markets due to market maturity.

Midway through his presentation, Chuck revealed that he is the patent licensing agent for Fergason Patent Properties (http://www.fergasonpatents.com). This may explain part of his apparent eagerness to promote HDR. Jim Fergason, one of the early pioneers of LCD technology, holds over 150 US patents and 500 foreign patents on LCD technology. Among these are two fundamental patents on backlight modulation, which he called "System Synchronized Brightness Control" (SSBC). As of the end of 2006, SSBC has been licensed to Panasonic, LG.Philips, Epson, Sharp, Samsung and Chinontec. Products utilizing SSBC include LCD modules for TVs, monitors, notebooks & mobile, as well as projection engines and projectors.

Edwin Bernard from **IEE** presented on the topic of "Advanced LCD Displays with Full Color LED BLUs". Edwin's presentation was given from the point of view of a display modifier/enhancer/integrator (IEE's business). To that end, Edwin discussed the reasons why LED BLUs are growing, system-level considerations, white vs. RGB LEDs, performance optimization, failure modes and drive alternatives.

Of particular interest in Edwin's presentation was a service IEE offers in which the CCFLs in existing LCDs are replaced with "LED strips" – without any mechanical change in the display! A typical industrial display that produces 240 nits with two CCFLs yields 280 nits with this enhancement.

Robert Karlicek from **Luminus Devices** presented on the topic of "Photonic Lattice LEDs for LCD TV Applications". In the author's opinion, this was the best presentation of the conference. The reason is that it was both devoid of sales pitch and totally compelling. Unlike the typical presentation made by Luminus Devices' marketing personnel at conferences such as DisplaySearch FPD or iSuppli FID, Robert's presentation was logical and thorough, building an exceptionally strong technically-based case for the value of "PhlatLight" LEDs in TV applications. (Robert is Luminus Devices' chief scientist, so perhaps the difference is understandable.) While Robert's slides were very good, some of his incidental comments were especially interesting, such as the following:

- A typical 46-inch TV with a direct LED BLU uses between 5K and 10K LED chips
- Using PhlatLight LEDs, a 24-inch edge-lit LCD was shown at SID 2006; a 37-inch will be shown at SID 2007, and a 52-inch is expected to be shown at SID 2008. All of these were or are being developed in partnership with Global Lighting Technologies (http://www.glthome.com) and are lit on only a single edge. The 52-inch LCD will produce 500 nits from only 12 RGB assemblies; this means that a single green chip (for example) must produce between 2,000 and 3,000 lumens.
- The maximum current that the largest PhlatLight can draw is around 30 amps, which makes driver circuits difficult since the pulse width must be as short as 2 microseconds.
- In Luminus Devices' opinion, the cost premium for using PhlatLight as a rear-projection light source is zero because of the problems inherent in the current HP lamp system.

Chris Connery from **DisplaySearch** wrapped up the conference with a presentation entitled "Where Is the Industry Now & Where Is It Going: Solid-State LED Lighting for Non-Emissive Displays". Chris brought along a pair of large Samsung LCDs for a side-by-side comparison of CCFL and LED backlights; the difference in color gamut was definitely noticeable.

Chris' presentation covered all the bases in a very thorough and professional manner. It included information on the following topics:

- Large-area LCD market size overview (big numbers)
- BLU share of TFT LCD material cost (22% for 17-inch and 24% for 32-inch)
- CCFL large-area demand (large panels use many CCFLs)
- White LED vs. RBG LED market segmentation by application (very clear)
- Factors motivating LED BLUs in notebooks (battery life & thinness, not color gamut)
- The challenges with monitors (the world's largest and most mature market)
- Pros and cons of LED BLUs in TVs (CCFL color gamut is catching up)
- Alternative light sources (EEFL, FFL, HCFL)
- LED BLU cost structures (expensive).

But throughout Chris' presentation, the audience was clearly waiting for the bottom line – DisplaySearch's latest forecast of LED BLU penetration. When Chris presented the 2010 numbers (11% for notebooks, 7% for TVs and less than 0.5% for monitors), the audience reaction was basically disbelief. (Note that these numbers are considerably more conservative than the McLaughlin Group's numbers reported earlier in this article.) The typical comment was, "If this forecast is valid, why are we even here [at an LED BLU conference]?" Chris pushed back, saying that the forecast is based on panel manufacturer roadmaps and demand perspectives from NPD (DisplaySearch's parent company).

The author's opinion is that the DisplaySearch forecast is too narrow in scope. It takes the status quo and projects it forward, assuming that the demand from end-users is the major influence and that LED costs are the major impediment. It ignores the possibility that other uses of high-brightness LEDs (e.g., general lighting applications) may drive down LED costs much faster than expected. Admittedly, that's only one possible scenario, and perhaps not the most probable one. But DisplaySearch should have done at least a little "what-if" modeling to give more range to the forecast. Actually that may be asking too much, since forecasting that kind of discontinuity is notoriously difficult. In any case, the audience was clearly happier with the McLaughlin Group's more optimistic forecast.

Overall, it was definitely a worthwhile conference. If it's given again in 2008, I will attend it.

Presenting Company	**URL**
Toyoda Gosei	http://www.toyoda-gosei.com
Wavefront Technology	http://www.wft.bz
Microsemi	http://www.microsemi.com
Semtech	http://www.semtech.com
Supertex	http://www.supertex.com
Teledyne Lighting and Display	http://www.teledynelighting.com
McLaughlin Consulting Group	http://www.mcgweb.com
IEE	http://www.ieeinc.com
Luminus Devices	http://www.luminus.com
DisplaySearch	http://www.displaysearch.com