SPECTRACAL C6 HDR

HIGH LUMINANCE COLORIMETER

By Tom Schulte and Darrell Bird

High Dynamic Range (HDR) and Ultra HD TV (UHD) have been big news items in the entertainment industry lately and they are definitely here to stay. Many who are involved with creating, transporting, delivering, displaying, or calibrating television content are already far down the path of preparing for HDR TV in the home. VIZIO, Samsung, LG, Panasonic, Sharp, TCL, and Sony have all introduced or will soon introduce HDR-capable consumer TV models. Professional reference HDR monitors are also becoming available.

A new version of the SpectraCal C6 Colorimeter is now available to address the extended measurement and calibration requirements of these new UHD TVs. The new C6 HDR Colorimeter specifically addresses the enhanced HDR and wide color gamut capabilities of UHD TVs.

UHD TV Capabilities

The UHD Alliance is a multi-industry alliance that formed to promote UHD standards development and UHD branding and certification. The alliance members include DirecTV, Disney, Dolby, LG, Netflix, Panasonic, Samsung, Sharp, Sony, Technicolor, 20th Century Fox, and Warner Bros. The UHD Alliance is now including HDR in the upcoming specs for UHD TV.

The enhanced capabilities of UHD TV will include at least the following:

High Resolution Video – Higher spatial resolution is the most promoted feature of UHD TV. A UHD TV's native resolution will be 3840 pixels horizontally by 2160 pixels vertically. This is four times the total number of pixels produced by HDTV at 1080p.

High Dynamic Range (HDR) – The dynamic range of a TV refers to its luminance, the maximum and minimum amount of light the TV is capable of producing. HDR creates brighter whites, darker blacks, and brighter colors that better match images we see in the real world. The HDR specification is still being finalized, but current trends suggest that HDR-capable TVs should be able to produce "specular highlights" with luminance of 500-1,000 cd/m^2 or greater. This compares to the current Rec. 709 HDTV spec of 100 cd/m^2 (or nits).

Wide Color Gamut (WCG) – A TV's color gamut indicates the level of saturation and number of colors that a TV can produce. The UHD spec will call for a wider color gamut, allowing for more vivid colors and more detailed color gradation than with HDTVs. It appears that the P3 color gamut may initially be provided with some UHD TVs, with the ultimate target being the Rec. 2020 color gamut.

High Frame Rate (HFR) – Frame rate indicates how often the light output of all the screen pixels is updated, creating a new image frame. For initial UHD TVs, this frame refresh rate is expected to be 60 frames per second for 4K resolution (vs. 24 fps for HDTV cinematic content) and 120 frames per second for 1080p resolution.

Advanced Audio – Enhanced audio capabilities of the new UHD TV standard are still being discussed, but may include object-based audio rendering to create positional sound.

High Dynamic Range (HDR)

High dynamic range will provide certainly the most significant UHD picture quality improvements over HDTV. It provides a more lifelike range of image light levels than previously possible. The average picture level (APL) of UHD images will remain relatively the same, but the contrast range and light levels in specular highlights will increase dramatically, coming closer to reproducing the rich contrast and bright picture highlights that the human visual system perceives in nature. This also creates a

more natural range of colors, without the artificially muted saturation of bright colors that is inherent with the Rec. 709 HDTV system.

The entertainment industry is already heavily invested in the transition to HDR TV imaging:

HDR Standards – Standards have been and continue to be formulated for every aspect of HDR image creation, transport, delivery, and display. The Consumer Electronics Association (CEA), International Telecommunications Union (ITU), Society of Motion Picture and Television Engineers (SMPTE), Motion Picture Experts Group (MPEG), Dolby, Blu-Ray Disc Association, and the UHD Alliance have all developed standards relating to some aspect of UHD and HDR. Dolby has developed an end to end HDR system called Dolby Vision that is being adopted by VIZIO, Sharp, and TCL.

One goal of the UHD Alliance is that UHD content will be backwards compatible with HD and SD display devices. This will be accomplished by layering enhanced content on top of legacy-level content and allowing a receiving device to use content metadata to determine how to display the content to its best capability.

HDR Cameras – Arri, Canon, Panasonic, Red, and Sony are currently selling HDR cinematic cameras.

HDR Content – Technicolor, Disney, Fox, and Warner Bros. have each already released or will soon release HDR movie and/or episodic TV content. Hollywood is also implementing HDR for cinema theater presentation. Disney's *Tomorrowland* was the first of a number of films already screened in HDR at Dolby Cinema theaters, and Imax's recently launched laser projection system provides HDR support.

HDR Streaming – Amazon, Netflix, Vudu, and M-Go are among the first video streaming services already offering or planning to stream HDR content.

HDR Discs – The Blu-ray Disc Association has released it new Ultra HD Blu-ray specification, which includes provision for 10-bit HDR video and optional Dolby Vision.

HDR Broadcast, Satellite, Cable – The Advanced Television System Committee (ATSC) is working toward an ATSC 3.0 IP-based "Candidate Standard" in 2016 that promises UHD video, more efficient use of broadcast spectrum, greater interactivity, and better compatibility with mobile devices. Field tests for UHD delivery via both terrestrial ATSC channels and satellite channels have been on-going.

To enable UHD carriage in cable systems, Technicolor has developed a DOCSIS 3.1 cable modem that enables downstream speeds of up to 5 Gbit/s and upstream speeds of up to 1 Gbit/s.

HDR TVs – In the final link to consumer UHD viewing, Hisense, LG, Panasonic, Philips, Samsung, Sharp, Sony, TCL, Toshiba, and VIZIO have released or have imminent plans to release HDR-capable television displays. Initial consumer HDR displays will be able to produce about 500-1,000 cd/m^2 (vs. the 100 cd/m^2 spec of Rec. 709). High-end consumer HDR displays are expected to increase above 1,000 cd/m^2 in the next few years.

HDR images are authored to a 10,000 cd/m^2 maximum luminance. Each HDR display then maps the images to the display's individual maximum luminance capability. The average picture levels of HDR images will remain consistent with HDTV images. The black level detail will be enhanced and the highest luminance levels will occur only in specular highlights within the HDR images. This new HDR luminance response is detailed in the SMPTE ST.2084 HDR EOTF (also called PQ EOTF) specification.

HDR TV Compatibility – The Consumer Electronics Association (CEA) has defined the following minimum guidelines for a TV, monitor, or projector to be referred to as an HDR-Compatible Display:

- Includes at least one interface that supports HDR signaling.
- Receives and processes static HDR metadata. (An HDMI input needs to be HDMI 2.0a to pass HDR metadata.)
- Receives and processes the HDR-10 Media Profile from IP, HDMI or other video delivery sources. Other media profiles may additionally be supported.
- Applies an appropriate Electro-Optical Transfer Function (EOTF), before rendering the image.

In May of 2015, the Blu-ray Disc Association (BDA) announced its specification for new 4K Ultra HD Blu-ray players. The base-layer spec requires the HDR-10 Media Profile, which is defined as:

- EOTF: SMPTE ST 2084
- Bit Depth: 10 bit
- Metadata: SMPTE ST 2086

Optional media profile layers that a content provider and/or player may support include Dolby's Dolby Vision and Philips HDR technology.

HDR Test Pattern Sources – To measure or calibrate the HDR performance of a compatible display, the display must first be switched to its HDR mode. This is done by providing the display with a video test signal from an HDR-compliant test pattern source.

The Astro VG-876 and VG-877 video signal generators and the Quantum Data 780, 800, and 900 series video generators support the HDR-10 media profile. The HDMI output of these generators can provide SMPTE ST 2086 HDR metadata to enable a display's HDR-10 operating mode.

The Astro and Quantum Data generators are automatically controlled for display measurement and calibration by CalMAN display calibration software. The generators' HDR-10 output capabilities are enabled and configured on the Source Settings tab in the CalMAN software.

Wide Color Gamut (WCG)

Wide color gamut will enable more true-to-life hues and saturation levels, especially in very bright and dark image objects. You'll be able to see accurate color representations of objects like sports jerseys and Coca-Cola cans.

To produce a wider color gamut, a display needs to have highly saturated RGB primary colors that are closer to the edges of the CIE Chromaticity Diagram (figure 1). The edge colors on the diagram are pure, monochromatic colors, created by light energy that is concentrated at a single wavelength. Colors closer to the center white point are less saturated (more pastel).

The current color gamut standard for HDTV is contained in the ITU-R Rec.709 specification. As seen the in the diagram, the DCI-P3 color gamut that is currently used for cinematic theater presentation is significantly larger than the Rec. 709 HDTV gamut. The recently specified Rec. 2020 color gamut, with absolutely pure RGB primary colors, is the ultimate goal of the UHD TV system.

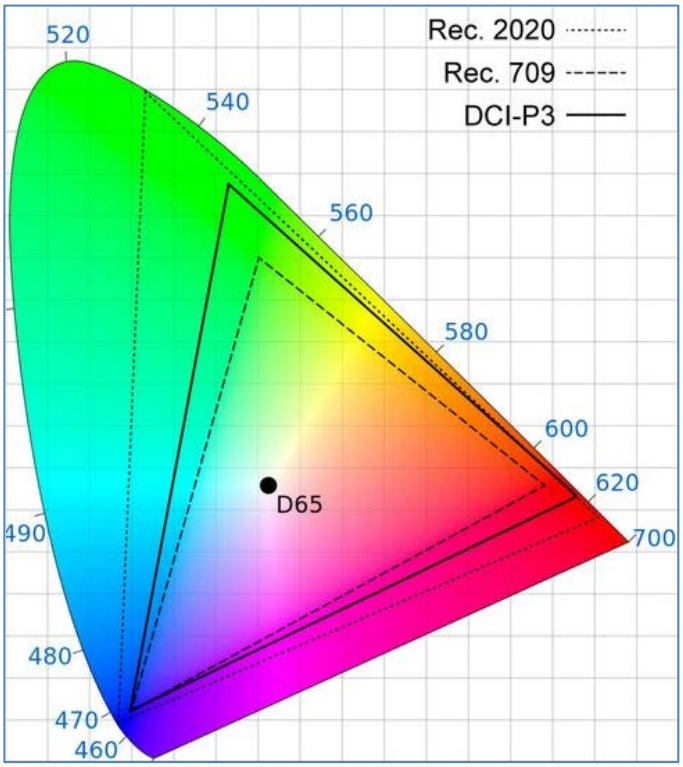

Figure 1: The Rec. 2020 color gamut is the goal for UHD TV. The P3 gamut is currently used for cinema theater presentations and may be an intermediate UHD gamut. The Rec. 709 color gamut, with much lower saturation colors, is the current HDTV standard.

Until recently, RGB LED backlights have been the principal source of highly saturated primary colors, getting close to the P3 gamut. OLED emissive displays, primarily from LG, are now available with color gamuts very close to the P3 gamut.

Quantum Dot red and green nanocrystals, which emit light at very narrow bandwidths when excited by blue LED photon energy, are approaching the Rec. 2020 UHD color gamut.

Laser light sources, as recently implemented in the Dolby Cinema and IMAX Laser projection systems, are able to precisely reproduce the Rec. 2020 color gamut.

The SpectraCal C6 Colorimeter supports a wide range of different display lighting characteristics and has a unique field upgrade capability that allows it to add support for new display types with each CalMAN upgrade, without needing to be returned to the factory for calibration.

SpectraCal C6 HDR

The SpectraCal C6 meters easily meet their accuracy specifications at their maximum luminance specification of 1000 cd/m^2. However, due to conservative design criteria, many of the C6 meters have been found to also produce accurate measurements at much higher luminance levels. This extended maximum luminance capability has become important now that HDR displays are becoming available.

To meet the need for accurately measuring HDR displays at higher luminance levels, SpectraCal now has an HDR meter certification program, to certify C6 meters that maintain their luminance and chromaticity accuracy to at least 1300 cd/m^2. To implement this HDR certification program, the SpectraCal metrology laboratory has fabricated a high luminance certification fixture.

This new HDR certification fixture is a light-tight enclosure that houses a stable light source comprising a high wattage LED with heat sink, and regulated power source. The high luminance light source illuminates a diffuser at an adjustable distance from the source. The illuminated diffuser is then measured, first by the lab's Konica Minolta CS-2000 Spectroradiometer NIST-traceable reference standard, then by each C6 meter being tested.

In the first round of HDR certification testing, the lab tested C6 meters to determine the luminance saturation level of their sensors. The test started with the diffuser set to a distance from the light source to produce a luminance level within the published luminance specification of the C6.

The distance of the diffuser from the light source was then incrementally decreased to produce higher luminance levels at the meter test position. The required shorter diffuser distance to produce a desired higher luminance could be easily calculated, since the diffuser luminance is proportional to the square of the distance from the light source to the diffuser.

At some luminance level, the luminance measured by each C6 stopped increasing proportionally as the brightness of the diffuser was increased. It was found that this luminance saturation level was about 1700 cd/m^2 for most C6 meters.

In the next round of HDR certification testing, the lab tested C6 meters to determine their upper limit of acceptable accuracy at luminance levels below saturation, as referenced to the KM CS-2000. From this testing, it was determined that a significant number of C6 meters could exceed the required ±2.0% luminance and ±0.002 x,y chromaticity specs at luminance levels between 1300 and 1400 cd/m^2. The maximum luminance specification was thus established at 1300 cd/m^2 for the new C6 HDR Colorimeter.

Certification of new C6 HDR Colorimeters is now a simple process of comparing a C6 to the CS-2000 reference meter in the HDR certification fixture, to check whether the C6 exceeds a tolerance of ±2.0% for luminance and ±0.002 for x,y chromaticity at a luminance of 1300 cd/m^2 or greater. An issued Certificate of Performance (figure 2) indicates the individual meter test results.

SpectraCal

CERTIFICATE OF PERFORMANCE
HIGH DYNAMIC RANGE

Model: SpectraCal C6 **Date:** 10-01-2015 **Serial Number:** 00102152

This certificate is provided for the colorimeter listed above to confirm that the performance and accuracy of the instrument has been inspected and calibrated within SpectraCal's derived specifications. The performance evaluation was conducted in SpectraCal's calibration lab using reference instruments and standards traceable to the National Institute of Standards and Technology (NIST).

- Calibration was performed using Konica Minolta Spectroradiometer Model CS-2000 Body Serial Number 1001360, calibration date June 1, 2015 (Certificate No. KMSA-001-00-024162).
- Our calibration facility is environmentally controlled to maintain a temperature between 69 - 74 F with a relative humidity of between 45 – 65%.

Performance Results – High Dynamic Range

Tolerance: [Δx , Δy : ±0.002] [%Y : ± 2.0%]

	Δx	Δy	Reference Luminance	Measured Luminance	Percent
White Reference	-0.0003	-0.0015	1315.3176 cd/m²	1334.9123 cd/m²	101.49%

Certified By: Darrell Bird
Title: Director, Calibration Lab

Babe Houck
Quality Assurance Manager

Figure 2: The Certificate of Performance issued with each C6 HDR indicates the meter's luminance and chromaticity accuracy at the tested luminance level.

HDR Display Calibration

Color calibrating the new HDR TVs is more critical than ever to assure the highest possible picture realism. Calibrating the reference monitors used for evaluating and color grading HDR content is also more crucial now for the production and post-production industry.

The process of calibrating UHD TVs and reference monitors is no more complicated than calibrating HDTV displays, but you will need to use the proper tools and calibrate to the new standards.

For calibrating UHD displays, calibrators will need software that supports the wider UHD color gamuts, including Rec. BT.2020 and DCI-P3, and the new SMPTE ST 2084 EOTF (PQ curve) for HDR. The PQ curve covers a much wider luminance range than HDTV and maps each signal value directly to the same absolute luminance level on every HDR display, unlike the traditional gamma curve, where a specific signal value produces a different luminance level on each different display, depending upon each display's peak luminance.

Calibrators will also need a light meter, such as the C6 HDR, that accurately reads the higher HDR luminance levels, and an HDR test pattern source that is capable of generating the required 10-bit test patterns and metadata to enable Dolby Vision or HDR10 on the display under test.

Conclusion

The new UHD and HDR TVs have created a need for a higher capability, affordable color meter to help calibrate the new displays to their highest possible picture realism.

The new C6 HDR Colorimeter fills this need perfectly with its high luminance, wide color gamut, field-upgradeability, and affordable $795 retail price. The C6 HDR Colorimeter will be a valuable part of any display calibrator's toolkit.

About the Authors:

Tom Schulte is Product Development Manager at SpectraCal. Tom has extensive experience in electronic systems test, calibration and service, as well as electronics test instrument design and usage and has authored numerous technical white papers. Tom was previously an Application Engineer at Sencore for over twenty years, where he was involved in video, audio, and RF test instrument design, plus training and support for electronic test equipment users.

Darrell Bird is Lab Director at SpectraCal. He designed and built the SpectraCal metrology and calibration lab from the ground up and created a projector screen metrology standard for the characterization and normalization of many common screen metrics. Darrell has three B.S. Degrees; in Physics, Astronomy, and Philosophy. He performed research on large scale dark matter modeling, Earth-asteroid impact prediction, and luminosity to metallicity correlations for non-main sequence stars. Prior to his research, he worked as an environmental analysis lab chemist, testing for semi-volatiles on GC-MS systems. Darrell considers himself a computer programming Luddite; he much prefers motorcycle mechanics.

About SpectraCal:

SpectraCal specializes in the tools and training necessary to achieve images representative of the content creator's intent for environments from low to high ambient light while achieving the colorimetry, contrast, and dynamic range necessary for the image to have the proper impact on the viewer.

SpectraCal CalMAN software was developed to support the display calibrator in the step by step process of screen optimization. The foundation of screen optimization through display calibration is to understand the elements in a display that require adjustment and how each element inter-relates to the others. From its inception, CalMAN has earned rave reviews and has become the preeminent display calibration software package on the market, compatible with virtually all color meters available today. As display technology evolves, CalMAN will continue to provide the first choice for display calibration solutions.

More Information:

For more information on CalMAN professional quality solutions for your displays:

Visit: http://calman.spectracal.com/spectracal-innovations.html

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