COLOR LIGHT OUTPUT IN PROJECTORS AND THE NEW ICDM COLOR BRIGHTNESS STANDARD

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There is a major transition happening in the world of electronics, and it's picking up steam with each passing year. Everything is going digital, from televisions and phones to automobiles, appliances, and even homes.

The digital transition has impacted display technology in several ways: Display screens are wider and larger. Resolutions have increased by several magnitudes, even on handheld electronics. Content can be streamed over a variety of connections, even wireless ones.

Now, we're hearing talk about even higher pixel resolutions, and seeing demonstrations of flexible displays. Projectors in particular are moving away from conventional short-arc lamps to so-called "lampless" illumination systems, relying on lasers, light-emitting diodes, or a combination of the two.

COLOR MATTERS

One interesting but rarely discussed side effect of the digital transition is the general public's increasing awareness of color quality in projected images. Digital signal coding techniques can preserve and accurately reproduce a variety of standard color gamuts. The public then expects that the color seen on a tablet, smartphone, and television to be accurately reproduced when projected on a large screen.

This shift in thinking contrasts with a movement away from the "sheer horsepower" approach that dominated the projector industry for years. In the early days of microdisplay light engines, lumens mattered more than anything else: The brighter the image, the more success a given line of projectors would experience.

Unfortunately, the race to high brightness sacrificed color quality, not to mention grayscale and color temperature accuracy. Projector shoot-out competitions were usually judged based on who had the brightest image, and that award often went to projectors using a single-light modulator and sequential color wheels.

That's all changed now with the advent of digital video and the maturing of projector technology. Now, the emphasis isn't just on white lumens, but color lumens as well. The theory is that a well-designed projector should produce the same level of illumination for a full-color image as a pure-white image.

You may be surprised to learn that's not always the case. Projectors that use sequential color systems with a white segment (usually a spinning color wheel) always exhibit lower color brightness. In contrast, projectors that use a tristimulus color system maintain their rated light output with both full-color and black-and-white images.

Our awareness of color accuracy has been fine-tuned by digital cinema, HDTV, high-resolution point-and-shoot and digital SLR cameras, and the increasing sophistication of presentation programs such as PowerPoint and Encore. Monitors for desktop and notebook computers have also seen quantum jumps in color imaging.

In short, we've become more sensitive to color quality, whether we know it or not. And our choice of projection systems now reflects that sensitivity, whether we are choosing a home theater projector or presenting to a classroom.

MEASURING UP

There are many ways to measure color. Standards exist to define color saturation and hue for different color gamuts and spaces, such as BT.709 and sRGB. We can also determine a value for "white" (the presence of all colors in an additive system) in terms of color temperature.

Until recently, there was no standard for measuring color brightness, or the presence of 100 percent values of red, green, and blue. The need for a color brightness standard arose in the past decade when sequential color and tristimulus projectors were being sold for the same applications, but turned out to have very different color brightness measurements.

In June 2012, the Society for Information Display (SID) released its long-anticipated Information Display Measurements Standard (ICDM). This 550-page reference manual is intended *"…to detail various measurement methods to characterize electronic displays"* with the goal of expressing *"…good display metrology in an unambiguous manner."*

In other words, the ICDM is intended to be a benchmark for measuring and quantifying the performance of direct-view and projection displays. The reference describes a variety of tests related to grayscale and color, spatial and uniformity measurements, and viewing angle performance.

Equipment and procedures for conducting these tests are detailed, along with potential errors and deviations that may occur. The ICDM was developed by representatives of major manufacturers, research institutes, universities, government agencies, and consulting firms, and reviewed by nearly 60 additional subject matter experts.

Pertinent to the issue of color, a section was included in the ICDM on measuring color brightness. Here, for the first time, is a description of what the term means and how it can be quantified. Color brightness (also referred to as color light output) is defined by the ICDM as *"calculated luminous flux from a front projector by using sampled illuminance measurements of RGB primary colors, using nonatile-trisequence patterns."*

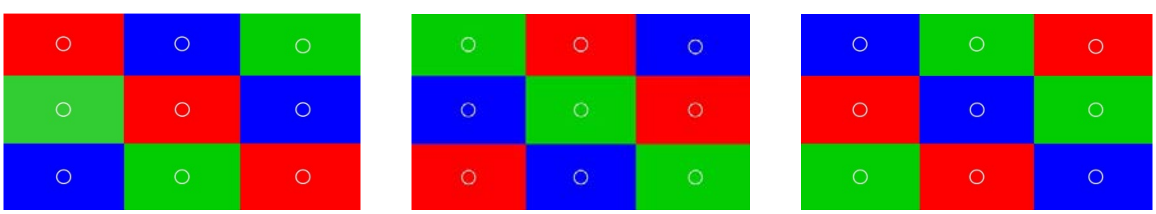

Figure 1. The Nonatile trisequence test patterns used to measure color light output.

In layman's terms, color light output is measured using three test patterns, each of which contains nine rectangles: Three red, three green, and three blue. The colors in each rectangle sequence from red to green to blue as each test pattern is projected.

Three brightness (E, or lux) measurements are taken in each rectangle and added ($E_{RED} + E_{GREEN} + E_{BLUE}$). The nine resulting values are then averaged. Next, the area of the projected image is calculated in square meters, and multiplied by the average brightness of all nine rectangles. The resulting product is the color brightness (color light output) of the projector.

If this procedure sounds familiar, it's essentially the same as that used to measure white-screen brightness – take nine lux measurements across a projected image, sum and average them, and multiply the average by the area of the screen in square meters. The difference for color brightness is that three measurements are taken in each of the nine areas, as red + blue + green = white.

COLOR BRIGHTNESS IN THE REAL WORLD

The difference in color intensity between a 3LCD projector and one that uses a single-chip DLP (1DLP) modulator is easy discerned by the average observer. Figure 2 (below) shows a demonstration at the 2013 Integrated Systems Europe trade fair, comparing a high-brightness installation-grade 3LCD projector with a comparably rated 1DLP model. The 3LCD projector was specified at 7000 lumens of both white & color light output and the 1DLP projector specification was 7500 Lumens of white light output.

While the 1DLP model on the right can easily hit the 7500 lumens target, it must flash its white color wheel segment more often than the red, green, and blue segments. The result is a bright image with low color saturation and inaccurate color rendering: Red has more of a brownish hue, while yellow and green are quite subdued.

In contrast, the 3LCD projector achieves the 7,000 lumens target by driving its polysilicon LCD chips at 100 percent light output, mixing the three colors to produce a more spectrally-balanced white light. Not only that, the 3LCD light engine achieves a much higher brightness and color uniformity over the entire projected image area, so that there minor differences in color brightness between the center of the image and the four corners.

For the 1DLP projector to achieve the color accuracy and intensity of the 3LCD image, brightness must be reduced to about 3200 lumens. This is caused by flashing the red, green, and blue segments of the color wheel at greater intervals and blanking during the white color segment. So there is an unavoidable trade-off between high brightness and color accuracy using 1DLP technology, one that does not occur with 3LCD projectors.

Figure 2. This image shows visible differences in color saturation between a 3LCD projector (left) and a single-chip DLP projector (right). The 3LCD projector is operating at 7,000 lumens and the DLP projector at 7,500 lumens.

THE NEXT GENERATION OF COLOR

Display technology continues to evolve, and the next step is widely agreed to be ultra-high definition TV (UHDTV). Displays with this classification will have at least 3840x2160 pixels of resolution, which is four times that of today’s 2K (1920x1080) displays.

Demonstrations have also been made of 8K resolution at the Consumer Electronics Show in 2012 and 2013, and the Japanese television network NHK provided 8K coverage of the 2012 London Olympics to selected worldwide locations.

Producers, editors, and distributors of 4K video and cinema content increasingly agree that at least 10 bits per pixel (30 bits total) must be used to reproduce 4K color, and if possible, 12 bits per pixel (36 bits) should be used. This depth of color requires billions of color shades to be reproduced accurately, which precludes using any other illumination system than a tristimulus design.

Support for 10-bit, 12-bit, and 16-bit color (also known as *xv*YCC and Deep Color) has been in the HDMI and DisplayPort standards for several years now, and numerous movies and TV shows are in production using 4K cameras with expanded color gamuts.

Figures 3a-b: A 4K 3LCD home theater projector (left) and a 4,000-lumens 3LCD projector powered by lasers.

Light sources are changing as well. There is a concerted effort by projector manufacturers to move beyond conventional short-arc lamps that use salts of mercury to more environmentally friendly technology. At present, the leading contenders are lasers (used directly and with phosphor color elements) and light-emitting diodes (discrete red, green, and blue chips). There are also hybrid light engines that combine both lasers and LEDs.

The color gamuts produced by these devices far exceed those created by conventional mercury and xenon lamps, particularly shades of green. Even so, the tristimulus approach used for imaging in 3LCD projectors is perfectly suited for use with these light sources and will produce equivalent white brightness and color brightness specifications.

SUMMARY: A new standard for measuring color brightness from projectors has been released as part of the Information Display Measurements Standard (IDMS) and provides a more accurate indicator of projector performance. The release of this standard is timely, as end-user attention increasingly shifts away from simple white light brightness measurements to color brightness.