Development of Methods to Reduce Blue Light Hazard from Displays

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Abstract

New materials have been developed for LED backlit displays to reduce the hazard associated from shorter wavelength blue light. This can be done without sacrificing luminance or color gamut.

Author Keywords

Blue Light; Blue Light Hazard; BLH; Blue Light Ratio; BLR; Blue Light Toxicity Factor; BLTF; Eyesafe

1. Risk of Blue Light from Digital Devices

In today's ever-connected, always-on digital world, people use electronic devices for a variety of reasons, including work, schooling, and entertainment. Our time spent on devices has been rising steadily for the last twenty years, now accounting for more than 13 hours a day for the average adult.[1] The effects of excessive screen time for both children and adults are a topic of concern with the health community.

The increased use of digital displays is now being implicated as a health issue. Recent studies have shown growing concerns over potential long-term eye health impacts from digital screen usage and cumulative blue light exposure.[2,3] In addition, studies have recognized the impact of device use on circadian rhythms and sleep patterns.[4,5] These disruptions are associated with multiple health problems.[6,7]

Blue light exposure research and studies on animals' cells have shown that the greatest phototoxic risk to retinal pigment epithelium cells from blue light peaks between 435 nanometers (nm) and 440nm. The risk peaks in that range but extends through the blue region with photoreceptor cell apoptosis seen early after the retina is damaged by blue light.[3,8]

Eye strain and other immediate effects of display use affect people on a daily basis. Digital eye strain is estimated to impact nearly 65% of Americans, with symptoms including eye strain, headaches, blurred vision and dry eyes.[9]

Long-term health implications are now being studied. Retinal damage, myopia, and age-related macular degeneration are of increasing concern to eye care professionals because of the dramatic rise of these eye diseases globally over the last 20 years.[10]

The potential for risk increases with the advent of near-eye devices like Virtual Reality Headsets. The short focal lengths of these devices increase the light being collected from the screen and the devices themselves make it harder for users to look away. "The proximity of AR/VR HMDs to the user's face significantly reduces the distance between screen and retina compared to conventional displays while also removing the ability to temporarily divert gaze from the screen." [11]

2. Risk of Blue Light from Digital Devices

Addressing potential blue light risk from digital devices requires a closer look at the LED blue light spectrum, as all wavelengths within the blue light range don't represent equal risk. The blue light hazard scales the blue light toxicity (levels between 0 and 1 by wavelength), as defined by the ANSI Z80.3-2018 standard. It peaks at 435 to 440nm but extends at decreasing levels of toxicity through the blue range of the spectrum.

Display makers have historically evaluated blue light hazard as a ratio of light energy originating within the 415-455nm range compared with the energy across the full blue range (400-500nm), commonly referred to as the **Blue Light Ratio (BLR)**. This was perhaps done to ease the design for the display manufacturers, simplifying it to a binary "toxic or not" scaling between that truncated range of 415nm to 455nm. The shortfall of assessing blue light risk as BLR becomes evident in looking at the blue light wavelengths that fall just outside 415-455nm, as shown in Figure 1.

Figure 1: Blue light scaling measures of assessing toxicity risks to the retina.

nm	*BLH - ANSI Z80.3 Table	BL Ratio	Toxicity Factor
Far UV	0	0	0
Near UV	0	0	0
380	0.006	0	0.006
385	0.012	0	0.012
390	0.03	0	0.03
395	0.05	0	0.05
400	0.1	0	0.1
405	0.2	0	0.2
410	0.4	0	0.4
415	0.8	1	0.8
420	0.9	1	0.9
425	0.95	1	0.95
430	0.98	1	0.98
435	1	1	1
440	1	1	1
445	0.97	1	0.97
450	0.94	1	0.94
455	0.9	1	0.9
460	0.8	0	0.8
465	0.7	0	0.7
470	0.62	0	0.62
475	0.55	0	0.55
480	0.45	0	0.45
485	0.4	0	0.4
490	0.22	0	0.22
495	0.16	0	0.16
500	0.1	0	0.1

For example, at 460nm, the toxicity factor is 0.80, indicating potential risk that is unaccounted when relying on BLR as a primary metric of blue light exposure risk. As research progresses, entities such as TÜV Rheinland, a global leader in independent inspection services and low blue light certification, are increasingly adopting **Blue Light Toxicity Factor** (BLTF) as a better benchmark for blue light risk, considering its use of the entire range of blue light hazard scaling factors (fig. 1). The equation for BLTF is as follows:

$$BLTF = \frac{100}{683} * \int_{380}^{780} L(\lambda) x\, B(\lambda) x\, \Delta\lambda \,/\, \int_{380}^{780} L(\lambda) x\, g(\lambda) x\, \Delta\lambda,$$

in which:

$\Delta\lambda = 1$

$L(\lambda)$: spectral irradiance in $\mu W \cdot cm^{-2} \cdot nm^{-1}$

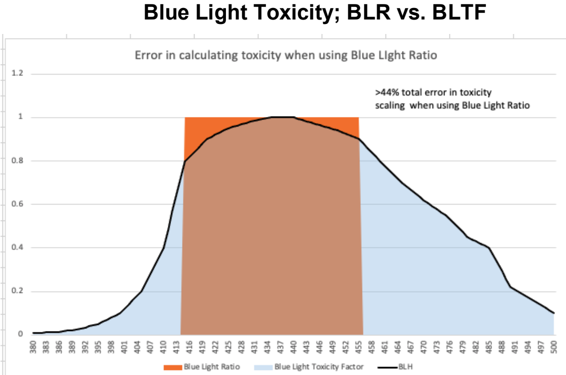
$B(\lambda)$: Blue-Light Hazard Function

$g(\lambda)$: CIE 1931 RGB luminosity function

683 - *maximum spectral luminous efficacy constant (683 lumens per Watt at 555 nm)*

Another way to view the improvement possible with BLTF versus BLR is shown in the curve in Figure 2, below. This shows both calculations for a given display and compares them to the Blue Light Hazard (BLH) function. If you consider the difference between the two ratios and the BLH as error, one can see that BLR has an error of more than 44% in predicting the toxicity of a particular display. With today's technology, there is no reason to settle for this kind of error.

Figure 2: Differences in methods to characterize Blue Light Toxicity; BLR vs. BLTF



Approaches to managing the blue light hazard of a backlit LED display must balance front of screen (FOS) performance characteristics (color brilliance and accuracy, switching rates, working life, etc.) with an effective reduction of high-energy blue light.

The China Video Industry Association (CVIA) adopted a ratio similar to BLTF in their 2017 standard for low blue light displays. In that standard, the emission from the display is weighted against the same blue light hazard scaling factors listed in Figure 1 and then divided by the total luminance from the display.[12]

3. Eyesafe® DTX Technology Overview

Eyesafe® DTX is the recently announced marketing name for the advanced low blue light protection described herein. The problem approached is to find a more effective, cheaper, and easier way to reduce blue light hazard inside the display than existing technologies. These include software and low blue light LED solutions. Aftermarket filters are not considered, as they are not part of the base display product.

Software-only solutions, whether implemented in display scalar firmware or device Operating System/Application SW, all fundamentally work on the assumption that the blue value in RGB can be reduced by some arbitrary scaling amount. This brute force method causes a rapid deterioration in Correlated Color Temperature (CCT) and white point. Users are likely familiar with the yellowish coloration of the display with this feature enabled. As a result, users may shy away from this solution, especially for applications requiring better color.

Low blue light LEDs are generally white LEDs that have shifted the peak blue wavelength higher, generally to 455nm and above. Many complexities are introduced with this approach, which leads to other changes being required in the LED's phosphors and the panel's color filter. At longer blue wavelengths, luminous efficacy, and therefore power efficiency, are lost due to a reduction in quantum yield of the phosphors. Next, due to color filter design, as blue wavelengths increase, the blue intensity at FOS increases. This causes a counter-intuitive increase in CCT and changed white point. Additionally, as the blue wavelengths move into the green emission area of the spectrum, the blue/green valley required for a good color gamut is compromised, resulting in less color gamut coverage overall. These are a few of the complexities that lead to an expensive and time-consuming redesign of the panel to use more costly phosphors with different peak wavelengths, quantum efficiencies, and Full Width Half Maximums (FWHM). This summary is by no means complete, but illustrates the difficulty and expense involved with this approach. Perhaps the primary flaw, however, is that actual toxicity is not reduced significantly, according to a review of current Eyesafe® Certification data. Rather, the wavelength is shifted minimally to move 50% of the energy outside of a specific window targeted by the BLR metric. Feasible decreases in actual hazard are minimal compared to Eyesafe® DTX technology presented here, typically less than a third.

The approach taken by the authors was to absorb the problematic source energy directly rather than moving it several nanometers. The first generation Eyesafe® DTX1 technology is superbly effective at reducing blue light hazard and compensates for color change with color correction. This technology is achieved by adding proprietary materials to the backlight unit. In our implementation, materials were coated on the smooth side of the diffuser, but other options exist for placement of the materials. While a good cost-effective approach to reducing toxicity, Eyesafe® DTX1 does require a tradeoff in luminance for best performance. This may or may not be a limiting factor for a feasible display. Accordingly, the authors continued to pursue technologies that could address luminous efficacy.

4. Eyesafe® DTX Technology Addition

For the second generation of Eyesafe® DTX2, light absorbing materials were augmented with proprietary materials that recycle toxic blue energy to green for optimal luminous efficacy. This approach combines the best of all worlds, resulting in:

1) Decreased blue light hazard/toxicity (~3x more than LED solutions)
2) Increased color gamut coverage
3) Balanced CCT/white point
4) Increased luminance/power
5) Simplified, cost-effective drop-in technology

The results can be measured on existing panels by simply replacing the diffuser with a sheet of similar diffuser material that has been coated with a formulation of Eyesafe® materials. Results are encouraging.

Below we compare the before and after performance metrics of two commercially available panels chosen for their differences. The first is a 31.5" UHD wide color gamut (WCG) flat panel from Company A that is sold into the content creation market. The second is a 27" FHD sRGB curved panel from Company B that is sold into the gaming market.

5. Results

All spectral measurements were taken with the same panels, driver electronics, and spectroradiometer. Panels were measured in native mode, with no scalar adjustments for color. Scalar-supplied voltages controlling LED current were left unmodified between measurements for the most accurate comparison of color and brightness. CIE 1931 coordinates were used.

As Table 1 indicates, for the WCG panel, both Eyesafe® DTX1 and DTX2 technologies reduced BLTF significantly. Both increased sRGB and DCI-P3 gamut coverage and maintained a reasonable white point. DCI-P3 coverage was increased by up to 2.0%. With Eyesafe® DTX2, luminance was increased by up to 4.8% with the same input power.

Table 1: 31.5" WCG Panel Results

31.5" UHD Flat (A)	Original Panel	Eyesafe® DTX1	Eyesafe® DTX2
BLTF	0.084	0.073 (-13.1%)	0.072 (-14.3%)
Color sRGB Color DCI-P3	99.8% 93.4%	99.9% 95.0% (+1.6%)	99.9% 93.6%-95.2% (up to +2.0%)
Luminance	390	367 (-5.9%)	390-409 (up to +4.8%)
CCT	6500K	6000K	6000K
Ease of Implementation	n/a	☑	☑

As shown in Table 2, for the sRGB panel, both Eyesafe® DTX1 and DTX2 technologies reduced BLTF significantly, up to 23%. Both increased sRGB and DCI-P3 gamut coverage and maintained a reasonable white point. sRGB coverage increased up to 1.7% (and near 100%) while DCI-P3 coverage increased up to 4.6%. With Eyesafe® DTX2, luminance was increased by up to 7.9% with the same input power.

Table 2: 27" sRGB Panel Results

27" FHD Curved (B)	Original Panel	Eyesafe® DTX1	Eyesafe® DTX2
BLTF	0.096	0.082 (-14.6%)	0.074 (-23.0%)
Color sRGB Color DCI-P3	98.1% 78.0%	99.7% (+1.5%) 79.6% (+1.5%)	98.7%-99.8% (up to +1.7%) 78.5%-81.5% (up to +4.6%)
Luminance	257	240 (-7.1%)	257-278 (up to +7.9%)
CCT	7300K	6400K	6000K
Ease of Implementation	n/a	☑	☑

Figures 3 and 4 show the before and after spectra for each panel respectively, with curves for formulations of maximum luminance and maximum color compared to the original panels.

Figure 3: Original 31.5", Max Luminance, Max Color

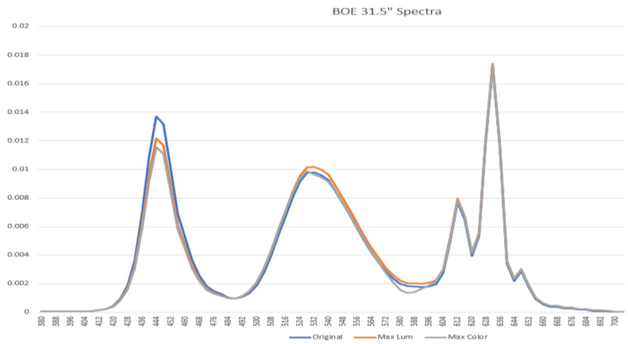
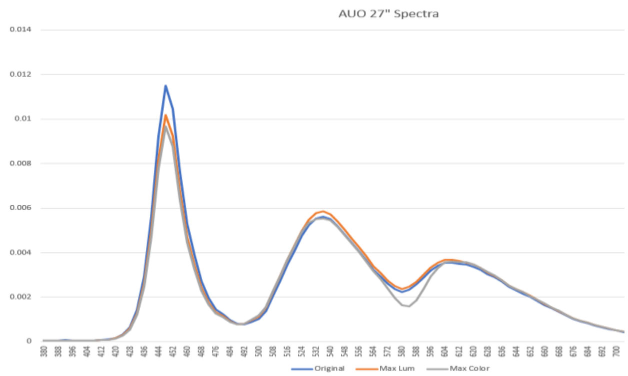


Figure 4: Original 27", Max Luminance, Max Color



6. Conclusion

Low blue light awareness is increasing dramatically, as are solutions and regulation. Eyesafe customers are indicating that health and wellness have become primary purchase considerations for IT products.[13]

The BLTF metric is the best standardized metric for measuring true hazard. BLR is far less effective in reducing actual hazard.

The authors have demonstrated that a variety of proprietary materials, coated on a diffuser in the backlight of two very different LCD panels, demonstrates a superior low blue light solution to today's commercially available technologies.

The Eyesafe® DTX technology will help open the door to more and better low blue light solutions, with few compromises, and at lower cost. Initial estimates suggest about 3x the toxicity reduction of LED solutions at half the cost. The increased energy efficiency will help enable better solutions for the planet. All of this can be accomplished while still meeting customer experience expectations for brightness and color.

7. Acknowledgements

Eyesafe Vision Health Advisory Board

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