Tangled up in Blue

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Unraveling the effects of LED lighting on our health and safety

When the American Medical Association (AMA) released its official policy statement on LED outdoor lighting in June of 2016, the popular media's reaction was swift and alarming. Headlines screamed: "Doctors Warn Use of LED Street Lights Can Be Harmful to Health."[1] Many of the news reports seemed to say that LED lighting is not only annoyingly bright, it can make us fat, sleepless, and sick, too.

To be clear, the AMA statement does in fact mention all of these maladies as possible side-effects from the blue light contained in LED outdoor lighting and LED lighting in general.[2] But what is it about the blue light from LEDs that the AMA finds so harmful? And does the blue light from other lighting technologies not have the same bad effects?

To better appreciate what all the fuss is about, we first need to know a little about how LEDs create the light we see and how our eyes and our bodies react to this light.

CCT and the Imitation Game

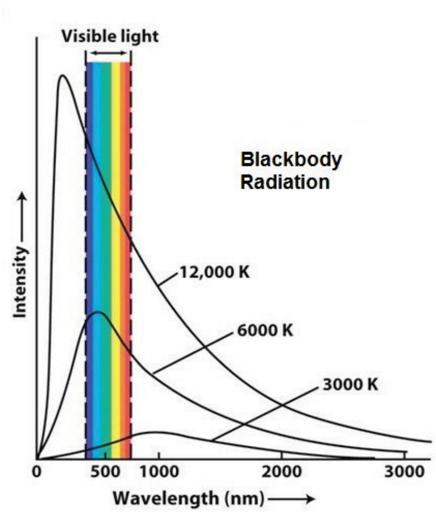

Figure 1: The hotter a blackbody gets, the bluer and more intense the light from it gets. Shown here are three relative intensities and wavelength distributions at temperatures of 3000K, 6000K, and 12,000K.

Like most artificial light sources used for general lighting, LEDs try to imitate the white light that we get from our sun at various times of the day. Anybody who has seen a rainbow knows that this "white" sunlight actually contains many colors from violet to deep red. The sum of all these colors looks white to our eyes.

At noon on a clear day, the sun appears "cool" white, with the sky adding a strong blue component to the overall effect. Late in the day, when the sun is low in the sky, the light quality changes and is much "warmer" looking with more red and less blue.

One method used to measure this "cool" or "warm" quality in any white-light source, is to compare it with the light emitted from a white-hot reference object, which ironically is called a "blackbody." (See Figure 1.) When a blackbody is hot enough, it will glow (or "radiate") like the sun. The hotter it gets, the bluer, cooler, and brighter the light from it will look. The cooler it gets, the redder, warmer, and dimmer the light will look. Although this may seem counterintuitive and a little confusing, it is a fact of nature.

The lighting term used for this effect is “Correlated Color Temperature,” or CCT for short. CCT is the temperature of a blackbody (measured in Kelvin) at which the overall color of the light coming from it “correlates” to the overall color emitted from the artificial light source. For example, the midday sun has a blue-white CCT of about 6500K, but at sunset its CCT drops to a redder-looking 2000K. Any artificial light sources designed to mimic these same light qualities would need to have the same CCTs: 2000K or 6500K.

All lighting manufacturers use this CCT metric to generally characterize the color content of the light from the products they make. Most incandescent bulbs, for example, emit a warm, yellowish light with a CCT of 2700K to 3500K. Other light sources, such as LEDs, metal-halides, and fluorescents, can accommodate a broader CCT range from about 2700K to 6500K or even higher.

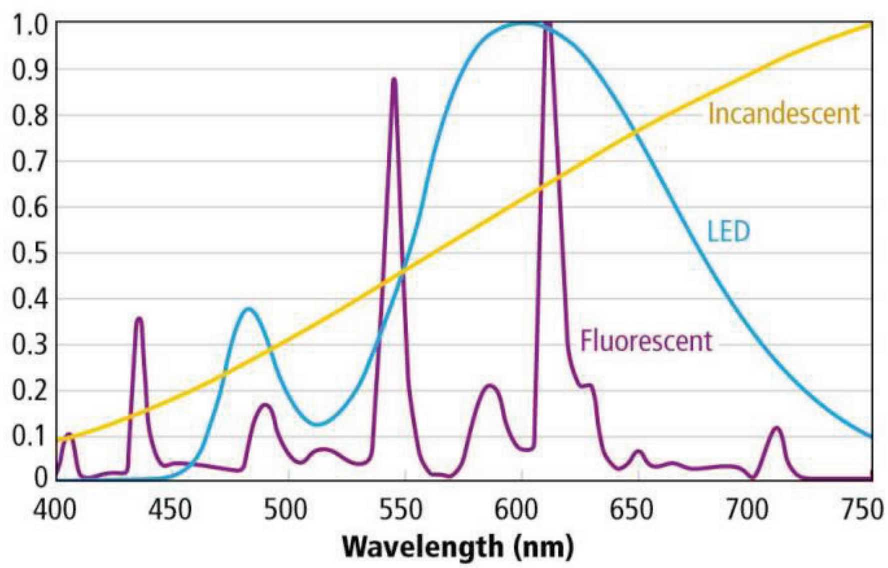

Figure 2: All three types of light sources above (Incandescent, LED, and Fluorescent) have the same CCT of 3000K, yet their spectral power distributions (SPDs) look very different.

The important thing to remember about CCT is that the actual color content of an artificial light source never exactly matches that of a blackbody with the same CCT. It “imitates” it. This means that when we look at all of the colors coming from an artificial “white-light” source—by looking at its spectral power distribution (SPD) across all visible wavelengths from violet to red—those colors do not match the colors contained in the blackbody spectrum, even though their CCTs are the same. In fact, the color contents of many artificial light sources don’t even come close to a match. (See Figure 2.) Nevertheless, if their CCTs are the same, the overall quality of the light looks the same to us. For this reason, CCT does not provide an accurate picture of a light source’s full color distribution or its full effects on our vision and health.

The differences between the spectra from artificial light sources and a blackbody with the same CCT depend on how the light is created. Incandescent lamps offer the closest match to a blackbody because they create light by heating an object (a tungsten filament) to a very high temperature, just like a blackbody does. A fluorescent lamp, on the other hand, uses an entirely different and more complicated method, in which a mercury vapor excited by an electric discharge gives off ultraviolet rays that excite (or "pump") a phosphor coating, which emits a white light.

Virtually all white-light LEDs used for today's general lighting start with an LED that produces a beam of blue light with a central wavelength around 450 nm. This blue beam pumps a phosphor coating painted on the LED's output surface, which emits a white light.

As Figure 2 shows, each lighting technology has its own unique spectral signature, like a fingerprint, which reveals itself when we measure the light output across the entire visible spectrum (SPD). When we look at the SPD of a white-light LED, the blue 450-nm LED output sticks out like a sore thumb, as does the much broader fluorescence spectrum of the phosphor, too. (See Figure 3.)

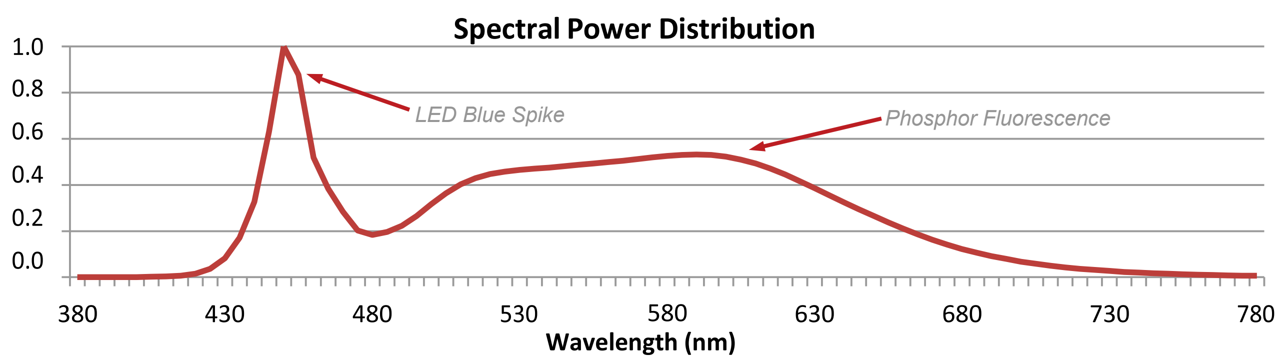

Figure 3: The SPD for Tri-State LED's 5000K Eco Linear High Bay reveals the prominent 450-nm blue spike from the LED (left) and the broad fluorescence from the phosphor (right).

This blue light from LEDs is what the AMA believes affects our sleep patterns and also intensifies glare. In fact, the AMA report explicitly blames "the excessive blue spectrum" of LEDs for sleep disorders, debilitating glare, light pollution, and disruption of nighttime animal life. Two of the AMA's three recommendations advocate the reduction of this "blue-rich" light, prescribing instead that outdoor LED lighting use a CCT of "3000K or lower." [2]

But is a lower CCT for LED lighting really the cure? In a word, no. In truth, LEDs have little if anything to do with the host of ills listed in the AMA report.

Anatomy of a Misdiagnosis

Many reports have blamed the blue spike of LED lighting for a variety of lighting hazards in recent years, and the technical literature is full of examples on both sides of the issue. However, a report on this topic from the Department of Energy's EERE sums it up best:

"[J]ust because there may be a distinct blue peak in their SPD—in contrast with some other light sources, such as incandescent or daylight—LEDs do not necessarily have greater potential to cause retinal, material, or photobiological harm. In fact, typical, commercially available LEDs present approximately the same risk in those three areas as other sources having the same CCT…." [3]

The simple explanation for this fact is that no matter how the light is created, if two different light sources have the same CCT, then the total amount of blue (450-495 nm) from each source must balance out the other color intensities if the CCT is to stay the same. A 3000K incandescent lamp, for example, has more red (620-750 nm) in its spectrum than a 3000K LED does (see Figure 2). Therefore, the total amount of blue from an incandescent could easily be higher than the total blue from the LED in order to offset the influence of the dominant incandescent red light.

Our eyes aren't as sensitive to blue or red light as they are to green, so the ratio of colors from two sources having the same CCT can vary subtlety. But it is entirely feasible for an incandescent lamp to have more "harmful" blue light than an LED with the same CCT. In practice, LEDs typically emit no more blue light than any other light source with the same CCT.[3]

The blue LED peak, therefore, matters very little. What does matter is the power distribution across the entire spectrum and the quantity and duration of light illuminating the object, whether it's a human eye or a work of art.

Make no mistake, intense blue light from any kind of source can cause material damage, photobiological damage, disability glare, and disruptions in circadian rhythm. These facts are very well established. But lighting engineers and vision scientists have yet to agree on a single standard to represent the various hazards of blue light, since different hazards have different physical causes.

For example, the disruption of circadian rhythm brought on by sustained nighttime exposure to blue-rich light results from the suppression of "melatonin," which is the hormone that makes us feel sleepy. In the evenings, our bodies naturally respond to the waning sunlight by producing more melatonin. Bright artificial lighting during the evening and night hours can disrupt this cycle. A better understanding of how this happens came with the discovery of a fifth photoreceptor (ipRGC) in the eye's retina. (For more information on ipRGC, read our White Paper "*How Light Meters Can Fool Us*.")

Vision scientists now understand that ipRGCs act like light-sensitive messengers, transferring signals from all five photoreceptors of the eye (rods, three kinds of cones, and the ipRGCs themselves) to a part of the brain that stimulates the production of melatonin. When exposed to bright, blue-rich light, ipRGCs work with the other four photoreceptors to contract our pupils and suppress the production of melatonin.

The disruption of circadian rhythm caused by nighttime exposure to artificial lighting defines one important concern for today's human-centric lighting designs, which also must consider customary factors such as CCT, color rendering (CRI), glare, and illuminance (footcandles or lux). To help quantify circadian disruption for designers, researchers at the Rensselaer Polytechnic Institute's Lighting Research Center (LRC) in New York, N.Y., have proposed a new metric called Circadian Stimulus (CS), and they have developed a useful new Excel tool for calculating it. (Open the attached Excel file or download the Circadian Stimulus Calculator from LRC's website at: http://www.lrc.rpi.edu/resources/CSCalculator_2017_05_05.xlsm.)

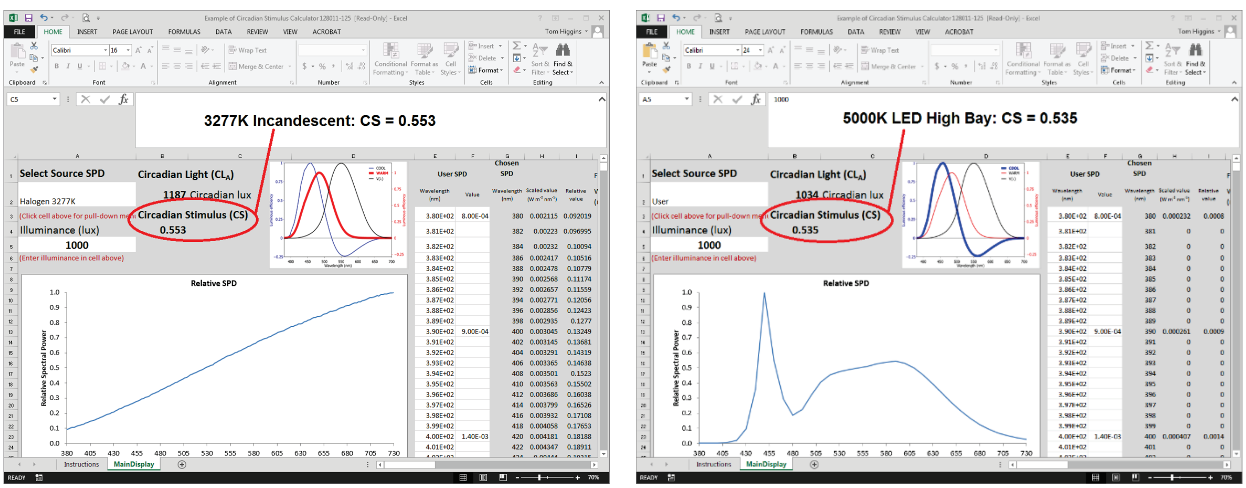

Figure 4: The Circadian Stimulus (CS) of a 3277K incandescent bulb (left) measures 0.553, while the CS of a 5000K LED High Bay (right) is lower (0.535). Illuminance at the eye is set to 1,000 lux for both light sources.

Using the CS calculator, designers can now compute the CS of a light source based on its illuminance (measured in lux at the eye) and its SPD. The tool also offers an effective way to compare the CS of different light sources (see Figure 4).

In Figure 4 we use the calculator to compare the CS of a 3277K tungsten halogen bulb with Tri-State LED's 5000K Eco Linear High Bay. Even though the LED high bay has a CCT of 5000K, its CS is still less than the 3277K incandescent bulb, which means that the LED has less influence on circadian rhythm. The results of this calculated comparison vividly illustrate that the blue spike of LEDs has nothing to do with circadian disruption, and what counts is the whole spectrum of a light source, not its CCT.

Making the Right Lighting Diagnosis

Despite claims to the contrary, the blue light of LEDs does not pose any special risk to our health and safety. If anything, LEDs offer significant enhancements that other lighting technologies cannot. Unlike the high-pressure sodium (HPS) still widely used for street lighting, LEDs deliver higher CRI for better visibility; directionality, dimmability, and occupancy sensing for superior control; and high efficiency and low maintenance for eco-friendly, low-cost operation. In fact, LEDs are the ideal technology to use in the drive toward more human-centric lighting.

"This is a second opinion. At first, I thought you had something else."

Regardless of which technology we use, however, good lighting requires good lighting practices. To that end, the Illuminating Engineering Society (IES) has established many of the lighting standards that designers use to achieve good lighting. In its position statement on the AMA report, the IES respectfully disagrees with the AMA about LEDs and CCT but agrees that outdoor lighting must use "proper optics and shielding to reduce glare and light trespass," and that designers "consider the ability to reduce light levels during off-peak periods." [4]

In other words, the path to safe, human-centric lighting requires that we continue to follow proven illumination standards, but with more attention paid to the environmental consequences of our pervasive artificial lighting. Thus, designers of outdoor lighting not only should adhere to established standards for reducing light pollution by controlling backlight, uplight, and glare (BUG rating), but more effort should be made to control light levels at night without compromising safety. Fortunately, LED lighting is particularly well-suited for this kind of control with both outdoor and indoor lighting applications.

Meanwhile, lighting engineers and scientists continue to work on new standards for human-centric lighting. Proper outdoor lighting will involve a delicate balance between our needs for safety and environmental harmony. Professional organizations like the AMA and the IES must work together to create safe, human-centric, and eco-friendly lighting standards that we all can live with.

References

1. *Doctors Warn Use of LED Street Lights Can Be Harmful to Health*. [Online] June 22, 2016. [Cited: June 22, 2017.] http://www.fox5dc.com/health/164675950-story.

2. American Medical Association. Report of the Council on Science and Public Health, CSAPH Report 2-A-16. *Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting*. [Online] June 14, 2016. [Cited: June 23, 2017.] https://www.ama-assn.org/sites/default/files/media-browser/public/about-ama/councils/Council%20Reports/council-on-science-public-health/a16-csaph2.pdf.

3. Energy Efficiency and Renewable Energy (EERE). *True Colors.* [Online] Oct. 2014. [Cited: June 21, 2017.] http://www1.eere.energy.gov/library/asset_handler.aspx?src=https://www1.eere.energy.gov/buildings/ssl/pdfs/true-colors.pdf&id=7104.

4. *IES Board Position on AMA CSAPH Report 2-A-16, Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting*. [Online] June 28, 2017. [Cited: June 28, 2017.] https://www.ies.org/policy/position-statements/ies-board-position-on-ama-csaph-report-2-a-16-human-and-environmental-effects-of-light-emitting-diode-led-community-lighting/?utm_source=Illuminating+Engineering+Society&utm_campaign=f1d753bf0f-EMAIL_CAMPAIGN_2017_06_27&utm_medium=email&utm_term=0_0671b8e8c8-f1d753bf0f-101375733