VioLight -
Improving Color in Real-life Applications

VioLight

As LED technology for lighting applications begins to mature in terms of reductions in energy consumption and therefore overall cost savings, an opportunity emerging, yet still unrealized, for higher quality of light than what is experienced today for indoor applications. A prime candidate is retail, where color reproduction and presentation are paramount to the in-store experience. In accordance with this demand, Solais Lighting Group has developed a technology called VioLight™ that provides cleaner whites and vibrant colors, while maintaining a pleasant and warm color temperature.

Overview of Lighting

Before we can begin to explore the VioLight technology, we must first take a step back and form a general understanding of lighting. Light is defined as electromagnetic radiation with a frequency range of 380nm to 780nm that entails a human response (typically referred to as the visual spectrum). Any radiation outside this range or not referring to a human response is not light. Within the visual spectrum, there are different levels of sensitivity for each wavelength (or color), which is based off the brain's interpretation of the rod and cone signals from within the eye. The human visual system, under daylight conditions, is therefore defined by the photopic luminous efficiency function, or V(λ), as represented in Figure 1. Exploring this function, it becomes evident that peak visual sensitivity occurs at 555nm (seen as green). In essence, V(λ) means that two sources with identical spectral power functions (mW/nm) but centered at different wavelengths will have varying levels of visual sensitivity to a human.

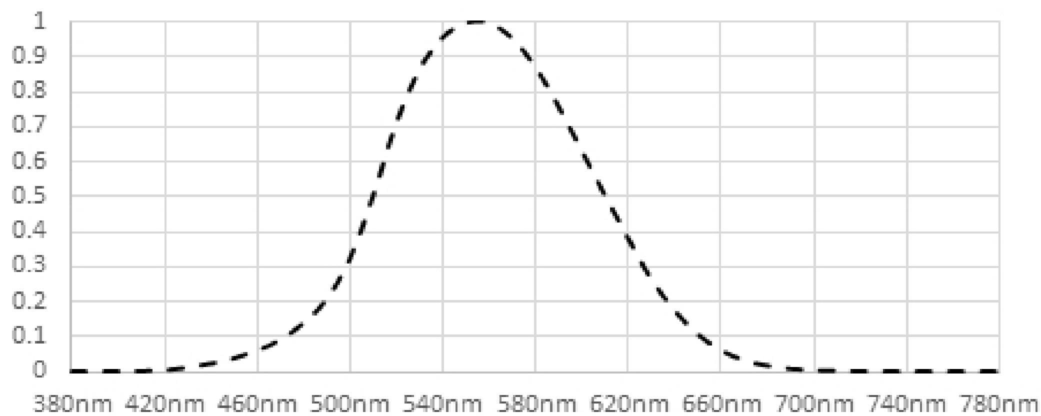

Figure 1: Human Photopic Luminous Efficiency Function, V(λ)

To describe an electromagnetic source, we can create a profile consisting of a combination of wavelengths with their associated radiometric powers. This is called the spectral power distribution, or SPD. An example of sunlight can be seen in Figure 2, with red lines indicating the threshold for the visual spectrum. Compared to other sources (which we will detail later), sunlight has a relatively uniform power output across all wavelengths.

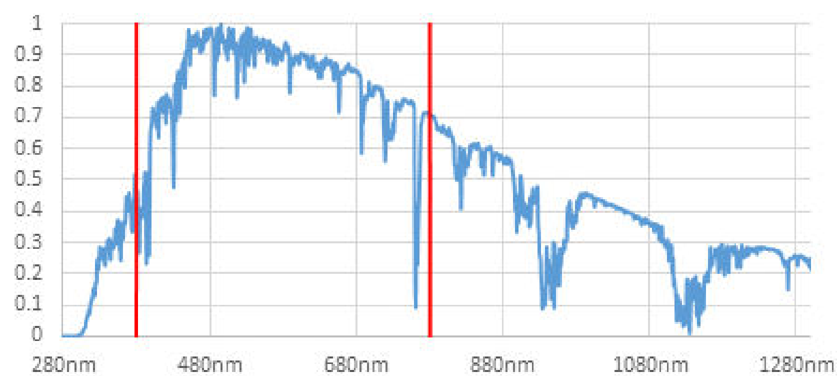

Figure 2: Spectral Power Distribution of Sunlight

Describing Color

The information in the previous section helps us describe the spectral components of a light source, but it does not give us information on the color reproduction of the light source. Humans interpret each wavelength of light as a different color. Color reproduction is dependent on both the object's properties and the spectral function of the illuminating source. The most commonly used metric for describing the depiction of color by a light source is called the color rendering index, or CRI, which measures the chromaticity shift caused by a light source on a standard color space, as defined by a function of sunlight.

The standard color space for defining CRI is a set of eight Munsell® chip color samples, which are of neutral colors in terms of wavelength reflectivity. The CRI value, RA, is determined by the average for each of these eight chips, R1-R8. The International Commission on Illumination, or CIE, recommends four saturated samples (R9-R12), and two additional samples (R13 and R14), which are Caucasian skin tone and a leafy green, respectively. Again, only R1-R8 are considered for the CRI value, but R9 has gained importance in the lighting field and is typically also specified. Figure 3 below depicts each of these color samples.

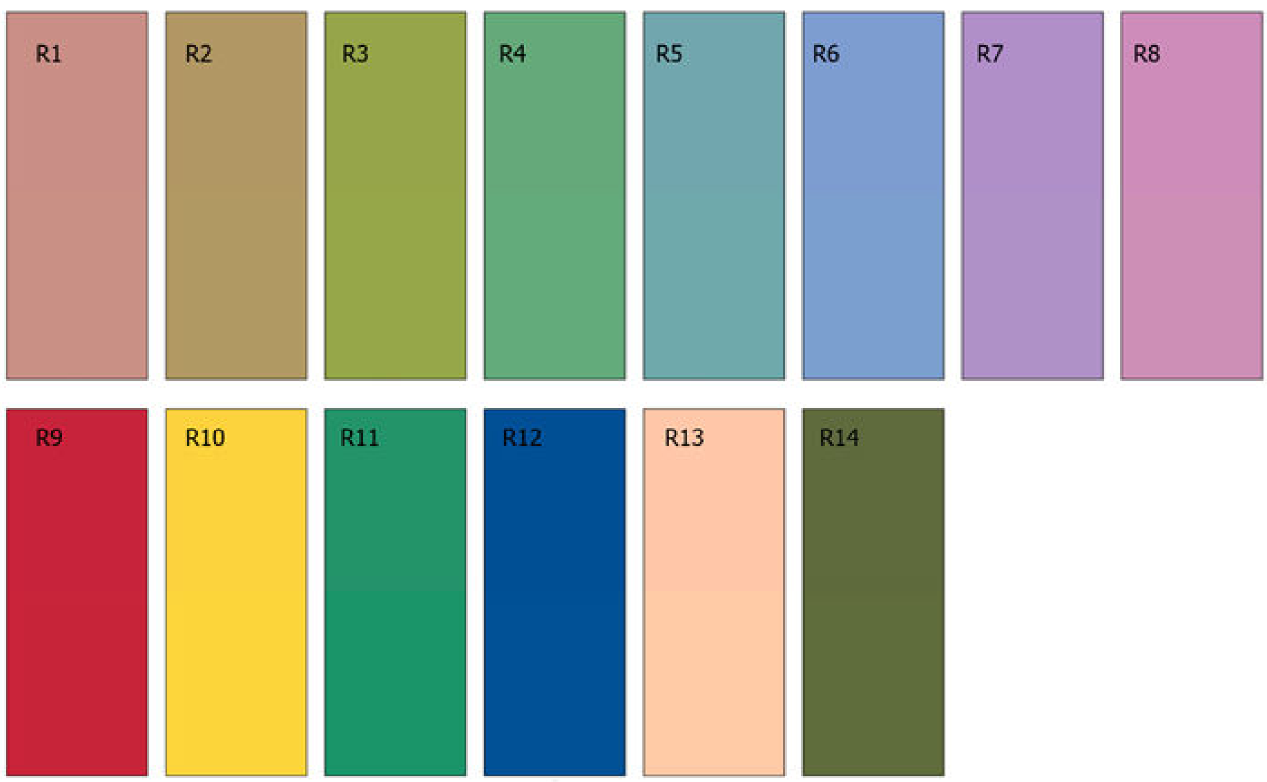

Figure 3: Munsell Color Chips used for CRI measurement (R1-R8) and additional "special" color chips (R9-R14)

Although the CRI metric is by far the most widely used in lighting, quite a few limitations must be considered. We must also remember CRI was only designed to adequately compare the color rendition properties of sources with identical CCTs. First, the CRI value takes into account only the first eight chips. which are unsaturated colors. Next, when calculating the color shift, the directionality information is lost due to the use of absolute values in the calculation method. Finally, it is possible to target certain chips within R1-R8 with color "pumps" to artificially increase the CRI value without actually improving the overall color rendition of the entire source.

In an attempt to solve many of the issues listed above, a competing metric called the color quality scale, or CQS, has been in development by the National Institute of Standards and Technology (NIST). The major advantage of CQS is that it takes into account a total of 15 color samples of more-saturated colors (and does not poorly represent red, as is found with CRI). As a result, color pumping methods can be negatively affected by its rankings with respect to CRI. At this time, however, CIE Technical Committee 1-69 (known as the Colour Rendition by White Light Sources committee) has not recognized the CQS as a replacement for the CRI scale.

Comparison of Different Light Sources

Earlier we defined SPD and provided an example using sunlight. In lighting there are many different technologies used for light sources, all of which have significantly different SPDs. Figure 4 provides a relative comparison of phosphor-converted white LED, fluorescent, high-intensity discharge (HID) and incandescent. In terms of the retail environments today, each of these is found with its own associated advantages and drawbacks.

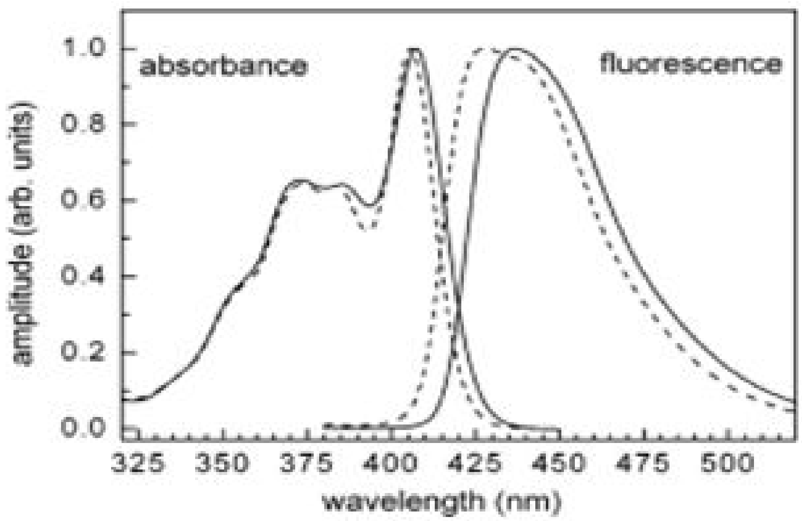

Figure 4: Comparison of SPDs of common light sources

Incandescent is the oldest of these technologies and still sees a decent level of usage today, especially in applications with size constraints, such as in MR16 lamps. Incandescent technology is essentially a black-body radiator that provides a consistent, warm color with a very high CRI (generally ~100), making it the most similar to sunlight in terms of color reproduction than any of the other technologies (except at very low wavelengths in the visual spectrum). However, the incandescent lamp is habitually defined by its very short lamp life and extremely high energy consumption.

Fluorescent technology uses different types of phosphors within the lamps, which absorb spectral energy at shorter wavelengths and release energy at longer wavelengths. The output of the lamp (spectral function, color properties and color temperature) is defined by the mixture of phosphors (as seen as the white coating on the glass walls). These lamps have very long life, provide consistent output and are generally very efficient. Their major drawbacks are: their lack of ability to accept outside control, hazardous materials (mercury is inside each lamp), size constraints and general flexibility in their use.

High-intensity discharge is a technology that relies on the ignition of an arc tube over a small area. These sources generally have similar SPDs to fluorescent lamps, as they rely on mixtures of salts and mercury in their construction. HID lamps are known for their long life, efficiency and small source size. Due to the nature of their light generation, they are very expensive, do not work well with controls, contain hazardous materials and do not maintain stable color over their lifetimes. In addition, their CRI is typically quite low (however, ceramic metal halide lamps have addressed this concern and are found in newer indoor retail applications).

LEDs are the most recent of the technologies utilized in general lighting. For most applications, white LEDs are created by combining a thin-spectrum LED (typically blue-violet) with a phosphor, called a phosphor-converted LED (PC LED). This method creates a broadband source that is small in size, has excellent color-rendering properties that can be easily tuned, provides a very long service life and consumes very little power.

At first glance, the LED originally looked to be the savior to the lighting industry, because it solved habitual problems exhibited by the other technologies. And, in many ways, LEDs have lived up to their hype in terms of energy savings. But, when we consider color-dependent applications, LEDs have not been the uniform solution, and many have chosen to continue the use of the incumbent technologies. Most of the time, the reason has been related to cost or due to uncertainty associated with using a new technology.

Historically, many retail applications have been lighted by ceramic metal halide HID sources, which provide clean whites and good color reproduction. As retailers began to shift to LEDs, although they approved of the “incandescent-like” look and CRI properties of 3000K, they found their white colors taking on a muddled yellow tinge. This caused many retailers to migrate toward the use of 3500K to maintain a clean, white presentation, at the expense of the color properties and generally more pleasant feel of 3000K.

With these problems in mind, ongoing research at Solais Lighting Group has led to the development of VioLight™, which is the realization of these quality promises providing true-to-life color reproduction to enhance the indoor environment.

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When Solais Lighting Group began to look at these issues we found that although there are many LED manufacturers who boast of a higher CRI product, color reproduction is not so simple. Boosting the CRI does not necessarily mean you have improved color properties, because of (and not limited to) the drawbacks listed earlier in the CRI section. Therefore it became evident that one must consider not only the output of the LED fixture, but how this output interacts with the environment.

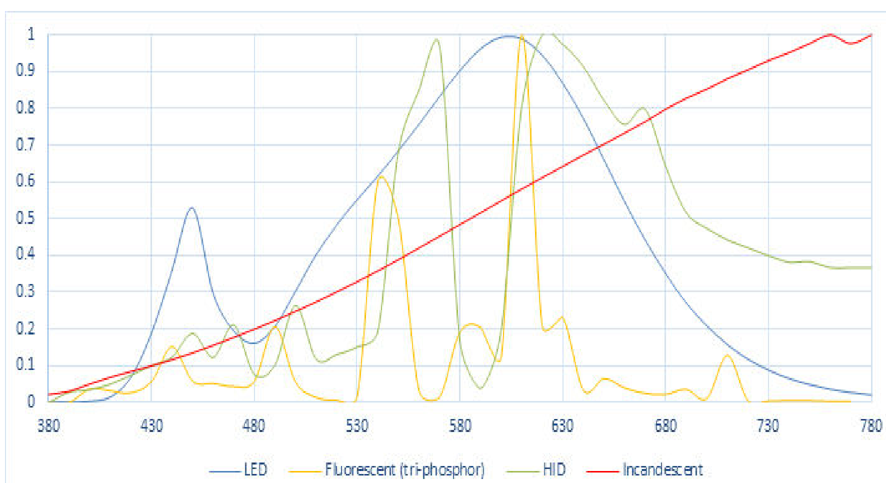

Figure 5: Absorption and Fluorescence Spectrum of a typical chemical dye

In our research, we found that many clothing detergents use dyes that have their own fluorescent properties. Beyond fine-tuning the SPD of the fixture output for CRI improvements, we targeted these chemical properties to improve the presentation of the products being lighted, not just the light output from the fixture. Figure 5 shows an example of one such dye, which shows a peak absorption at 410nm that then fluoresces with a normal-like distribution, with a peak output at 440nm. This knowledge led to the development of the VioLight™ technology.

The advantage of VioLight™ is the ability to maintain the preferred color-temperature-feel of 3000K and its superior color properties, while also achieving the cleanliness of white and even further enhancing color reproduction. For comparison purposes, Figure 6 demonstrates two identical scenes lighted by the traditional 3000K LED and Solais Lighting Group's VioLight technology at the same power level.

Figure 6: Actual results of clothes lit with a regular LED fixture versus clothes lit with VioLight™.