HOLOPHANE®
LEADER IN LIGHTING SOLUTIONS

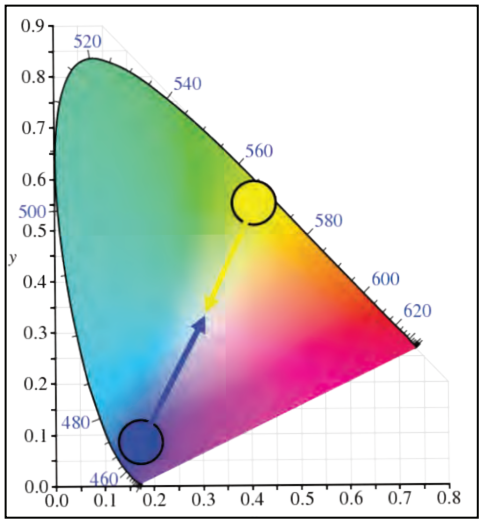
White Paper: Color Quality

# Color Quality With Respect to Digital LED Lighting

- *Color Temperature*
- *Color Rendering Index (CRI)*
- *Color Quality Scale (CQS)*

## *Color Temperature*

Color temperature is a metric that quantifies the color "whiteness" of a light source. For most white light applications, the range of color temperature extends from 2700 K on the low end (warm, incandescent appearance) to higher than 5000 K (cool, metal halide appearance) on the high end.

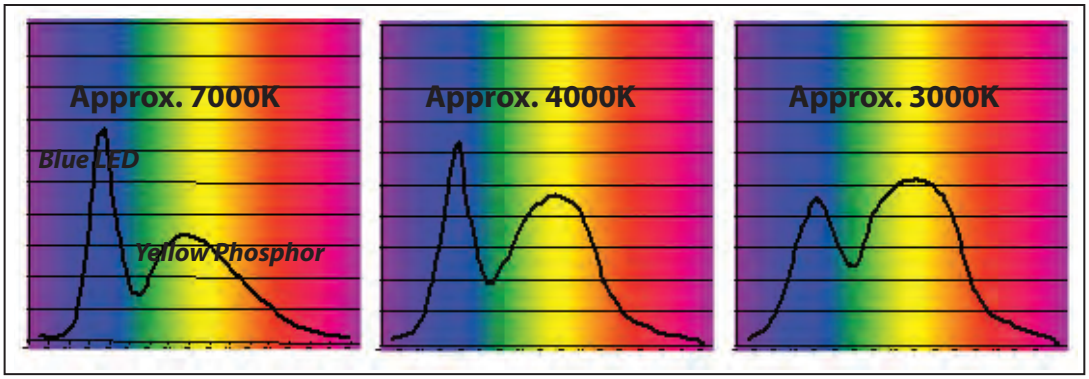



CIE 1931 Chromaticity Diagram

For more information about color temperature – specifically relative to LEDs, refer to this article on the Department of Energy's website: Color Quality of White LEDs, located at: http://www1.eere.energy.gov/buildings/ssl/factsheets.html.

In the world of LEDs today, the predominant method for generating white light is a combination of an LED emitting blue light with a coating of yellow phosphor. The phosphor acts to capture part of the blue emission and converts some of this to yellow light. As indicated by the arrows in the graph above, the combination results in white light. It is important to note that this conversion process incurs efficiency losses. The more blue light is converted to yellow, the higher the losses that are incurred. This explains why the most efficacious LED light engines available today bias toward color temperatures of 4000 K and higher.

As seen in the illustration below, by applying different types of phosphors and/or varying the coating thickness, more of the blue light from the LED is converted to yellow.

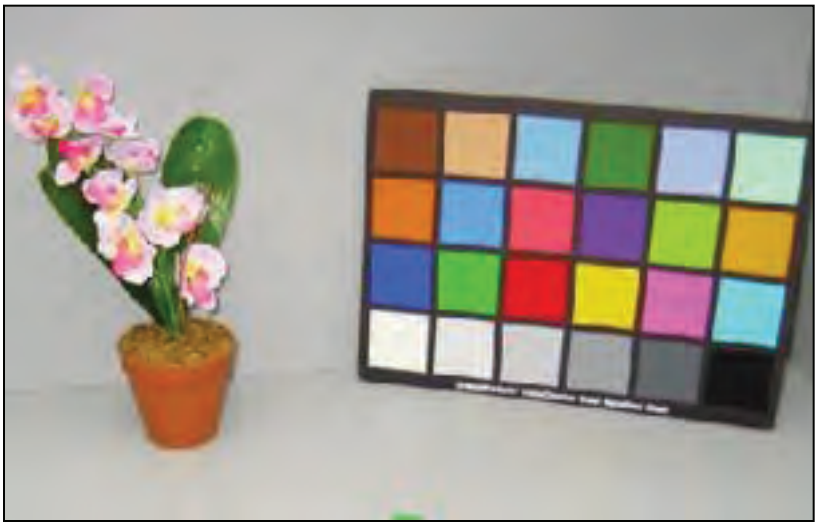



**Special Distribution Charts** - showing varying mix of blue LED with yellow phosphor.

## *Color Rendering Index*

Light sources differ in their ability to accurately portray the true colors of objects. So, while color temperature is an important characteristic of how the source appears, CRI is a characteristic of how the source interacts with its environment. By definition, the ability to accurately "render" all colors by a full-spectrum source such as sunlight (or an incandescent lamp) is defined as 100%.

Through a sophisticated set of calculations, the reflected color of the samples under the test lamp is compared to the color of those same samples under the reference incandescent lamp. The aggregated set of numbers is reported as the lamp's CRI value. It is important to note that the lack of saturated colors in the current CRI definition has driven artificially low values for the LED light source. The National Institute of Standards and Technology (NIST) is currently in the process of creating a new color rendering standard which will be known as



***15 color swatches for CRI***

| Name | Appr. Munsell | Appearance under daylight | Swatch |
|---|---|---|---|
| TCS01 | 7,5 R 6/4 | Light greyish red | |
| TCS02 | 5 Y 6/4 | Dark greyish yellow | |
| TCS03 | 5 GY 6/8 | Strong yellow green | |
| TCS04 | 2,5 G 6/6 | Moderate yellowish green | |
| TCS05 | 10 BG 6/4 | Light bluish green | |
| TCS06 | 5 PB 6/8 | Light blue | |
| TCS07 | 2,5 P 6/8 | Light violet | |
| TCS08 | 10 P 6/8 | Light reddish purple | |
| TCS09 | 4,5 R 4/13 | Strong red | |
| TCS10 | 5 Y 8/10 | Strong yellow | |
| TCS11 | 4,5 G 5/8 | Strong green | |
| TCS12 | 3 PB 3/11 | Strong blue | |
| TCS13 | 5 YR 8/4 | Light yellowish pink (skin) | |
| TCS14 | 5 GY 4/4 | Moderate olive green (leaf) | |
| TCS15 | 1 YR 6/4 | Asian skin | |

Source: National Institute of Standards & Technology

**Color Quality Scale (CQS)** and will address deficiencies of the current standard.

For more information about the development of CQS:
http://physics.nist.gov/Divisions/Div844/facilities/vision/color.html

While the establishment of a new color scale may take some time, it is important to note that deficiencies of CRI are not specific to LED light sources. The scientific migration away from CRI as the definitive metric has been underway for several years as other new sources (ceramic metal halide, induction, etc) have found that the color scale is not complete enough to capture the human visual experience. With LED lighting, it is therefore recommended to use CRI as a starting guide. The judgment of suitability of the system's color quality is ultimately best experienced in the actual application.