Accurately Plot Colors from Power Spectrum Data

Accurate color mixing of light from LEDs requires precise knowledge of the primary colors used for mixing. While some manufacturers provide bin data for color LEDs, many do not. What is almost always provided is a power spectrum diagram (**Figure 1d**) of the LED.

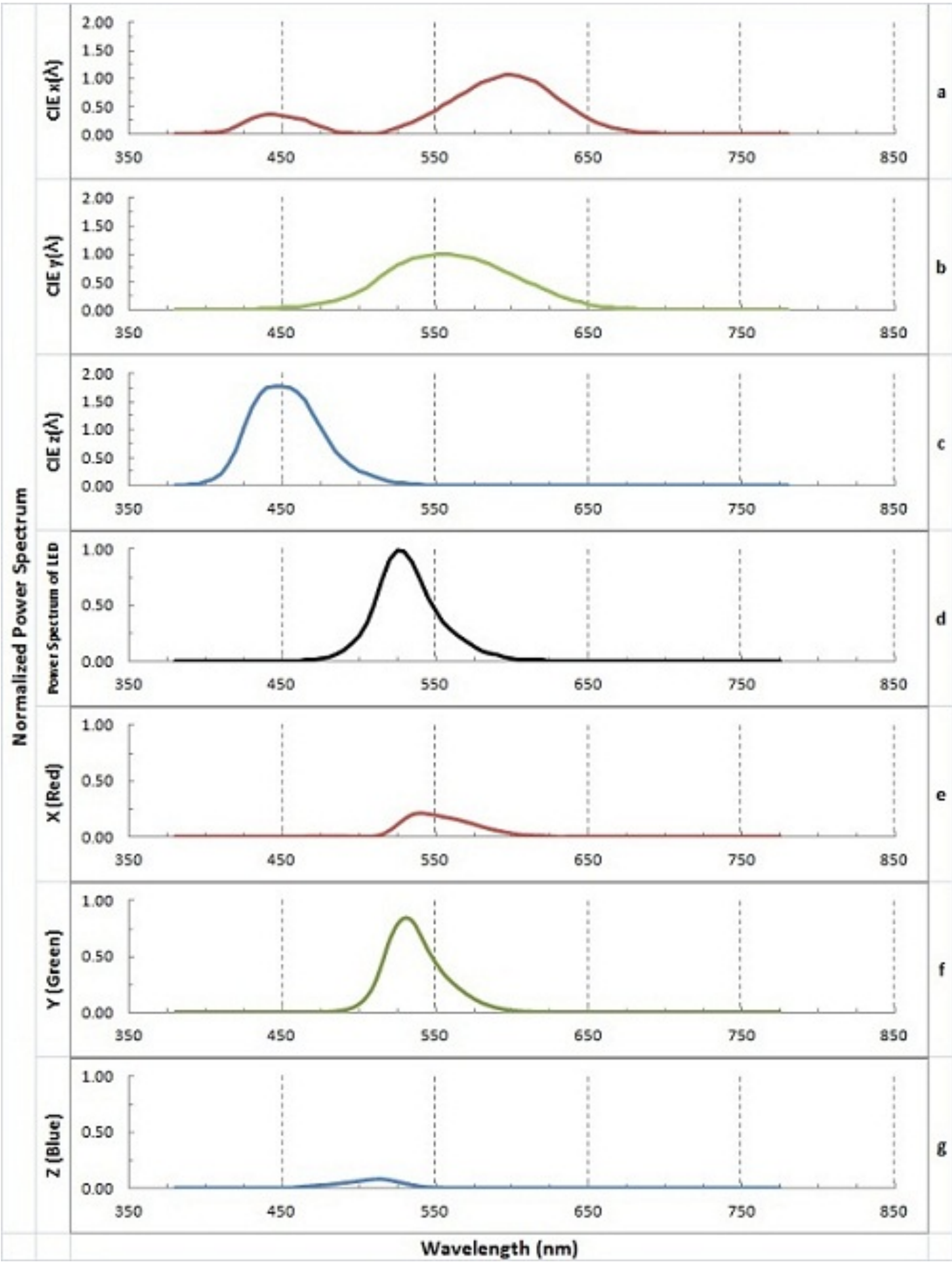

Figure 1. Generate XYZ tristimulus values by multiplying CIE standard observer

functions with a power spectrum and integrating the area underneath the resultant curves.

CIE1931 standard observer functions (**Figure 1a, b and c**) are available directly from CIE. Recreate the LED spectrum power in Microsoft Excel (**Figure 1d**) by tracing a screen capture from the LED datasheet. The resulting X, Y, Z power spectrums (**Figure 1e, f and g**) can be calculated by multiplying the power spectrum of the LED with the **International Commission on Illumination** (CIE) standard observer functions. Use **Equations 1 – 3** to integrate the area beneath the curves and obtain final X, Y, Z tristimulus values:

$$X = \sum_i \overline{x_i} \cdot P_i \qquad \textbf{Equation 1}$$

$$Y = \sum_i \overline{y_i} \cdot P_i \qquad \textbf{Equation 2}$$

$$Z = \sum_i \overline{z_i} \cdot P_i \qquad \textbf{Equation 3}$$

Convert the XYZ [1] tristimulus values to standard CIE 1931 xyY coordinates with **Equations 4 – 6**:

$$x = \frac{X}{X+Y+Z} \qquad \textbf{Equation 4}$$

$$y = \frac{Y}{X+Y+Z} \qquad \textbf{Equation 5}$$

$$Y = Y \qquad \textbf{Equation 6}$$

The example power spectrum shown in **Figure 1d** has coordinates of (x = 0.224, y = 0.702, Y = 7.179) and is plotted on a CIE 1931 color space diagram (**Figure 3**) for reference. Note that while the predominant color of the selected LED is green, it is not monochromatic.

Calculating coordinates for red, green, and blue light sources is the first step towards accurately mixing RGB primaries to obtain a desired color. When the desired output is white light, an understanding of the Planckian black body model is also required.

Fortunately, the same techniques can be applied to calculate coordinates on the Planckian black body model [2] curve. **Equation 7**, originally proposed by Max Planck, accurately models black body radiation at a given temperature for a desired wavelength:

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \times \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1} \quad \textbf{Equation 7}$$

where,

h = Planck Constant = 6.6260695729 x 10^{-34} Js

k_B = Boltzmann Constant = 1.3806488 x 10^{-23} J/K

λ = Wavelength in m

c = Speed of Light = 299,792,458 m/s

T = Desired Temperature in ^oK

Power spectrum curves for a sampling of color temperatures are plotted in **Figure 2**. Normalize each color temperature curve before calculating XYZ tristimulus values as previously shown.

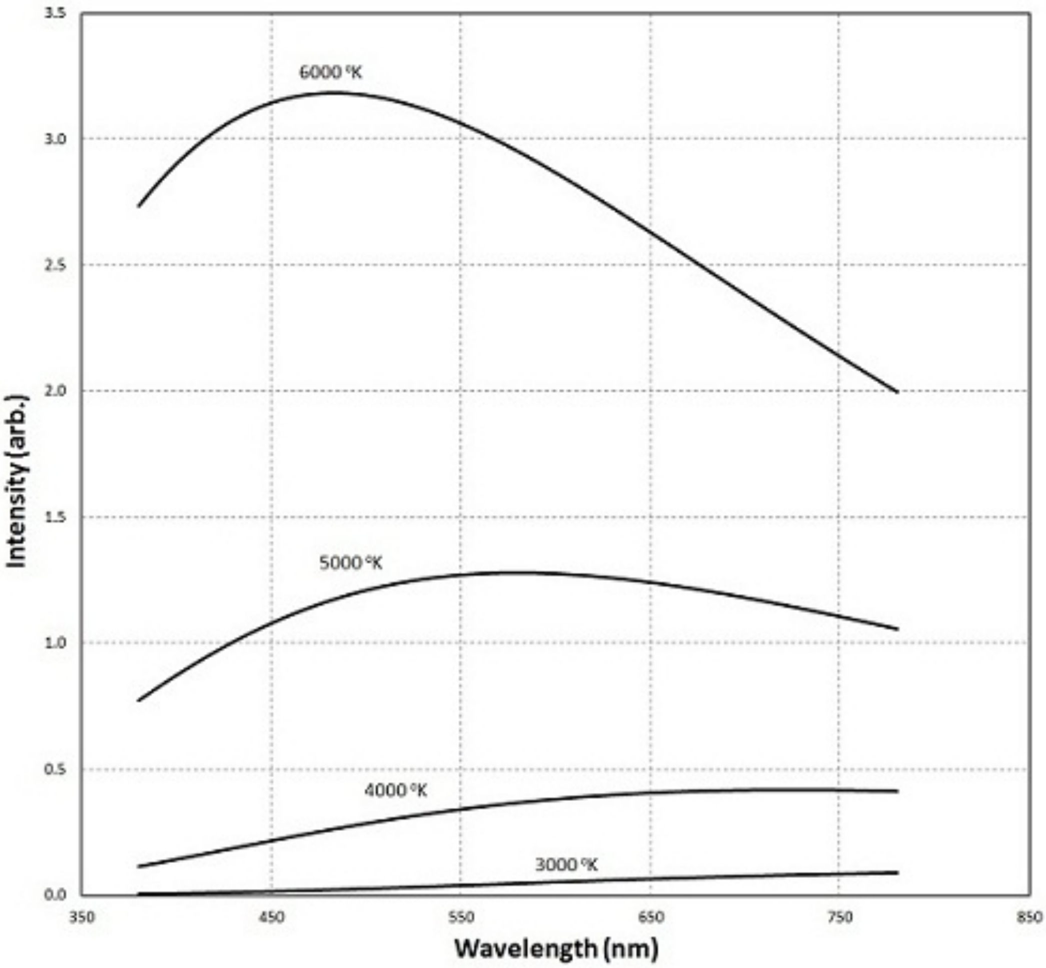

Figure 2. Planck's law can be used to generate power spectrum data for a black body at varying temperatures.

The sample green LED, a complete Planckian black body model curve and an outline of monochromatic light are plotted on **Figure 3**. All data points are calculated using the techniques described above. Download the Excel spreadsheet (goo.gl/1TPeS) for a detailed understanding of the calculations.

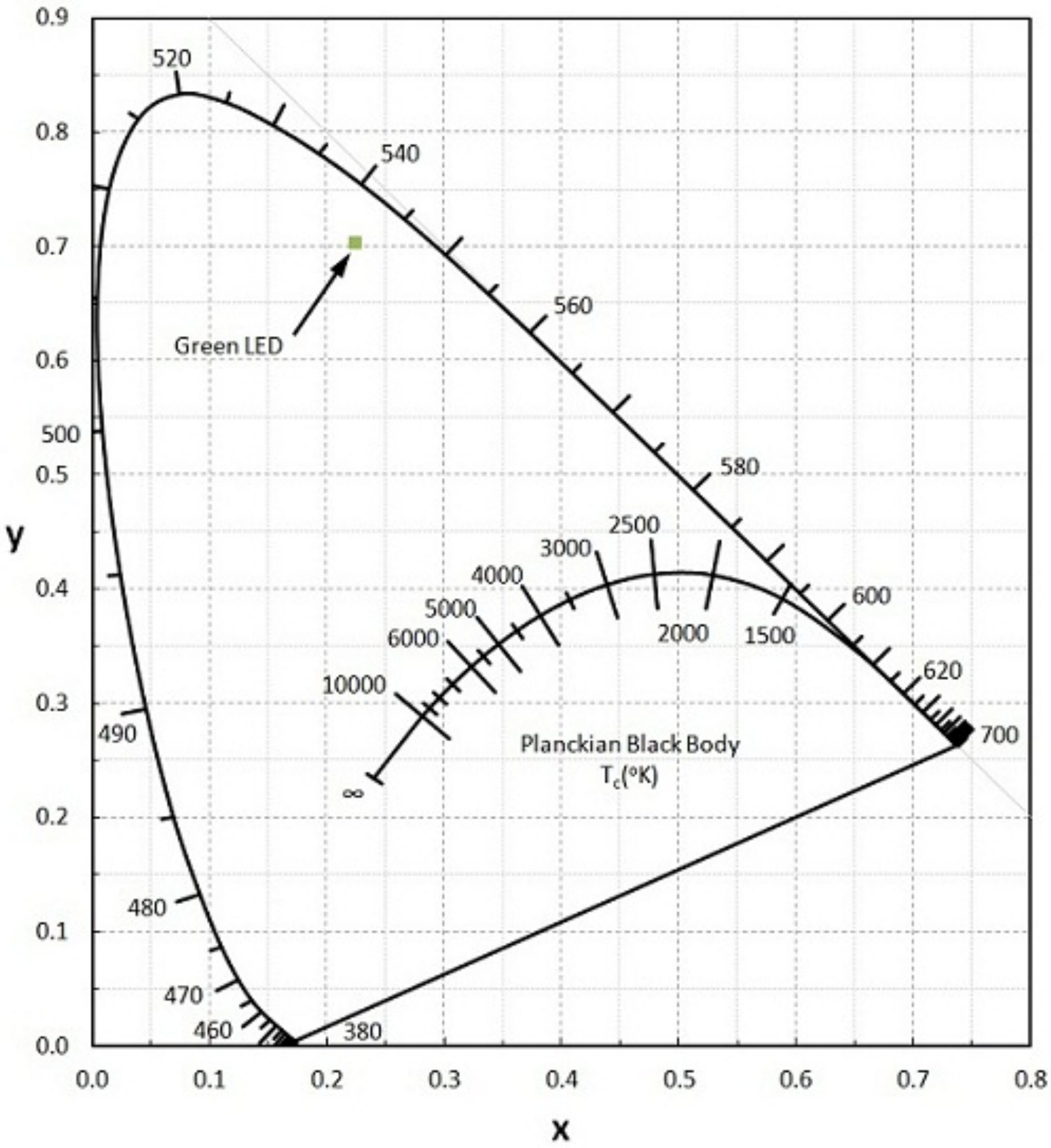

Figure 3. A mathematical color translation results in an accurate xyY placement of the light source on a standard CIE 1931 spectral plot. The same color translation is also used to accurately plot loci representing a Planckian black body and visible monochromatic light.

References

1. Computing XYZ from spectral data (emissive case): http://www.brucelindbloom.com/index.html?Equations.html

2. Black body model: http://en.wikipedia.org/wiki/Black_body

About the Author

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