LED Fundamentals

Colorimetry

07-07-2011

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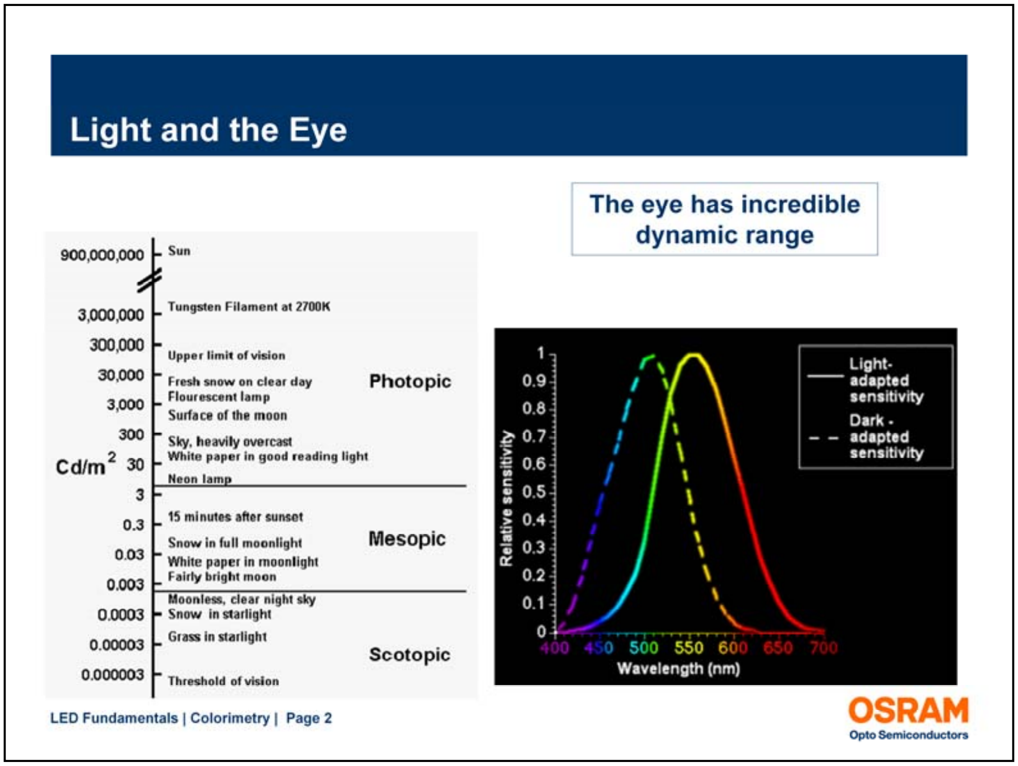
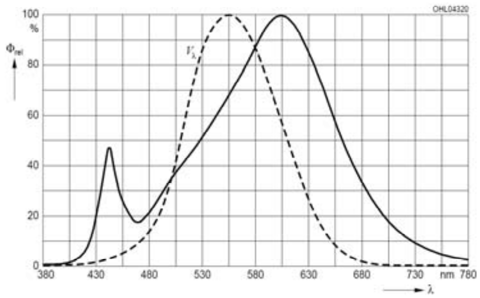
Welcome to this presentation on Colorimetry, part of OSRAM Opto Semiconductors‘ LED Fundamentals series. In this presentation we will look at how the eye perceives color and discuss several metrics which describe color.

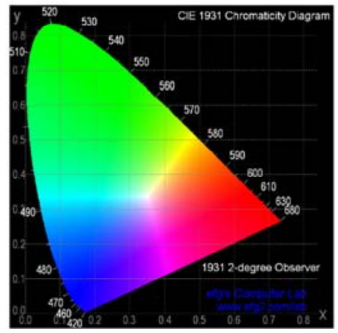


The human eye can adapt to a wide range of brightness. Under well-lit conditions, the eye is operating in the photopic range, which is dominated by the color-sensing cones. Color calculations are for the photopic range only.

Colorimetry

Colorimetry is the science that describes colors in terms of numbers.





Metamerism – different power spectra, same color coordinates

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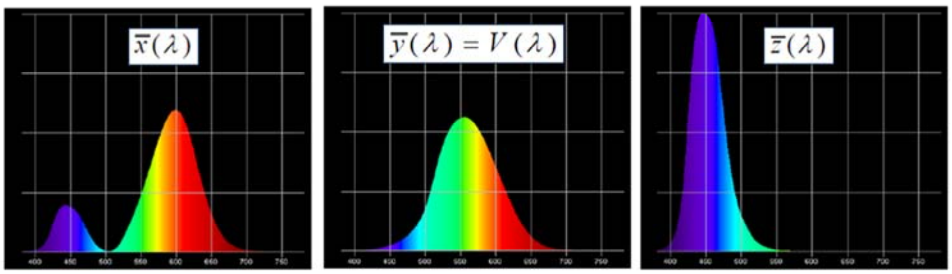
Colorimetry is the science that describes colors in terms of numbers. In LED lighting, we generally start with the spectral power distribution of the light, scaled to the response of the human eye, and calculate coordinates in color space. While working with color coordinates is convenient, information has been lost in the process – there is no way of getting back to the power spectrum from the coordinates. This loss of information can lead to a condition called Metamerism, in which a different power spectra can produce the same color coordinates.

Colorimetry

- Roughly speaking, the retina of the human eye has photoreceptors for red, green, and blue.
- Spectral distribution coefficients have been defined which allow us to compute color coordinates.



$$\sum \bar{x}(\lambda) = \sum \bar{y}(\lambda) = \sum \bar{z}(\lambda)$$

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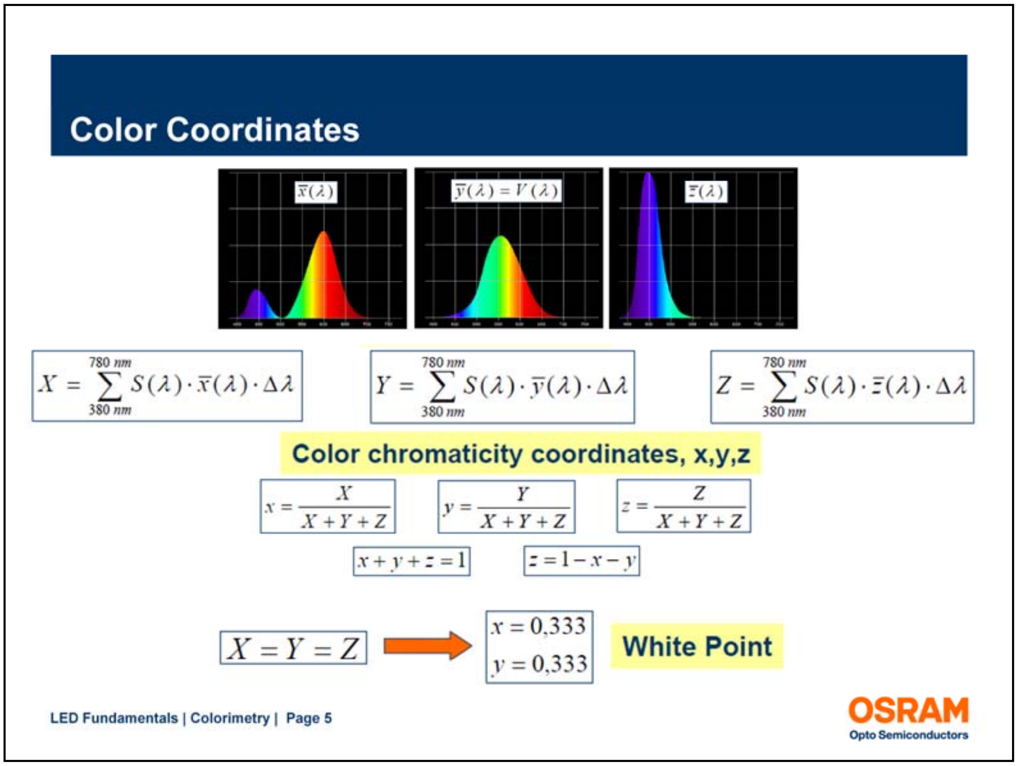
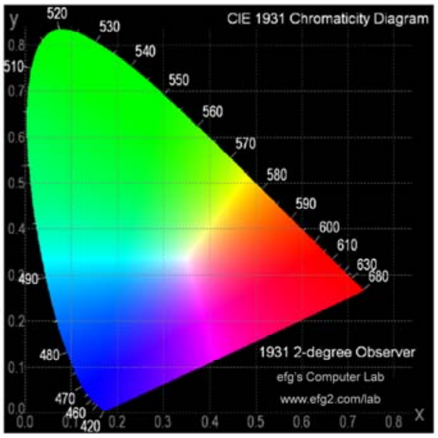
The eye has three kinds of photoreceptors, or pigments, for sensing color. In accordance with the sensitivity curves for these three pigments, spectral distribution coefficients have been defined. Color coordinates can then be calculated using these coefficients.

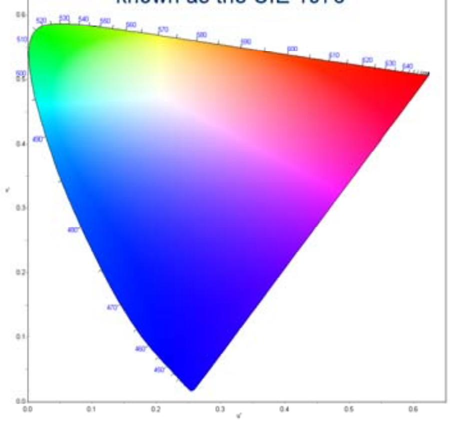


These figures show how the color coordinates, small x and y, are calculated from the spectral distribution coefficients (x, y, and z bar) and the power spectrum (S(lambda)). Capital X, Y, and Z are called the tristimulus values.

CIE Chromaticity Diagram



(u', v') chromaticity diagram, also known as the CIE 1976



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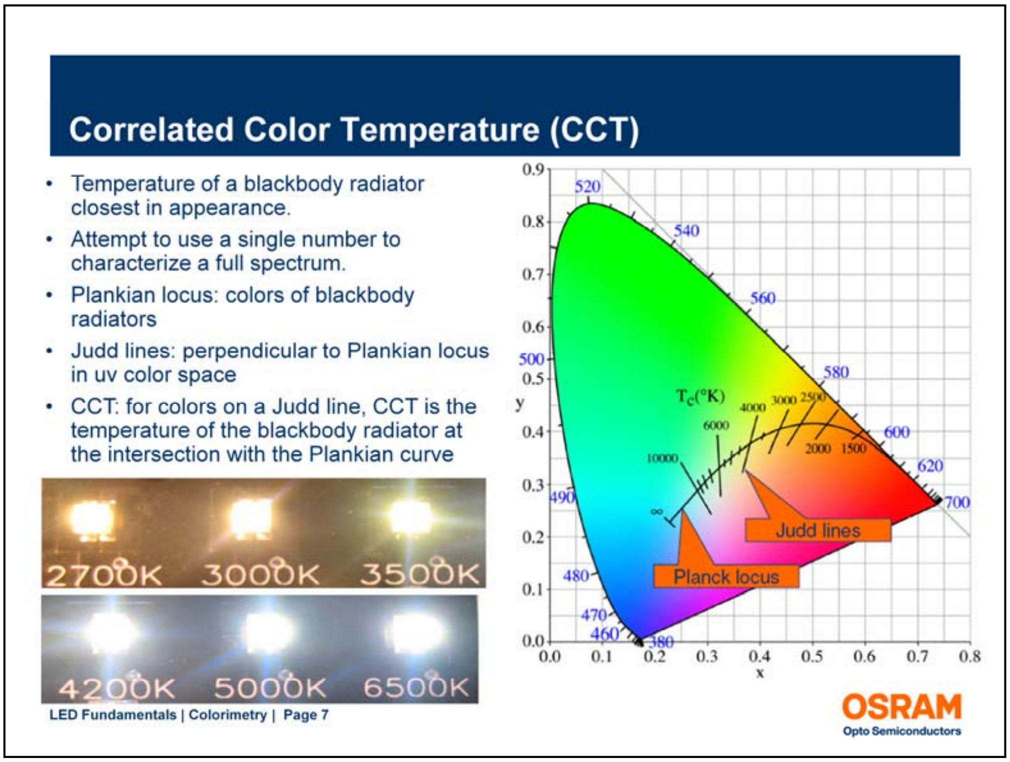
The x and y color coordinates fall within the so called CIE 1931 chromaticity diagram. Other diagrams have since been calculated, which have certain advantages over the 1931 version. However, the older version is the most commonly used.



Correlated color temperature (or CCT) is the color of a blackbody heated to a particular temperature (in degrees Kelvin) which is closest in appearance to the LED color.

In the figure, the Plankian locus and several Judd lines have been overlaid on the CIE chart.

Note that the CCT value is valid only for colors near the Planck locus.

Color Rendering Index (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	
TCS14	5 GY 4/4	Moderate olive green (leaf)	

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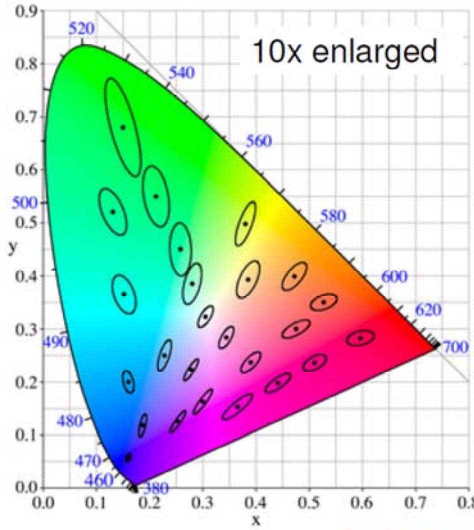
The Color rendering index (or CRI) is a measure of how well a light source reproduces the color of an object compared to a standard source.

The index value is computed from how well the light source under test reproduces the color of a number of standard color swatches. Generally speaking, higher CRI values are required for indoor lighting than for outdoor lighting.

MacAdam Ellipse

Region in color space containing those colors which are indistinguishable to the average human eye from the color at the center of the ellipse.



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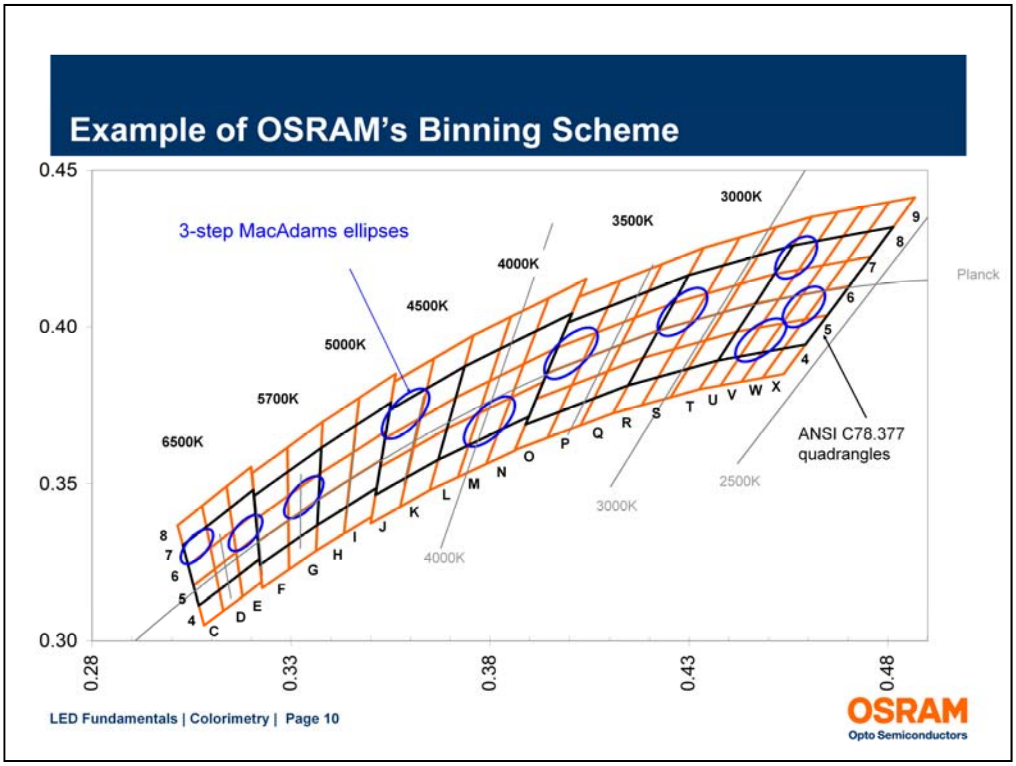
A common method to represent how people perceive color differences is through the use of MacAdam ellipses. For a 1-step ellipse, the color at the center and a color at the edge of the ellipse are indistinguishable.



A so called 3-step MacAdam ellipse represents a color difference that is just perceptable by the average person. OSRAM Opto Semiconductors offers a fine-binning scheme for white LEDs based upon this 3-step ellipse. Note that each bin is actually inside the 3-step ellipse.

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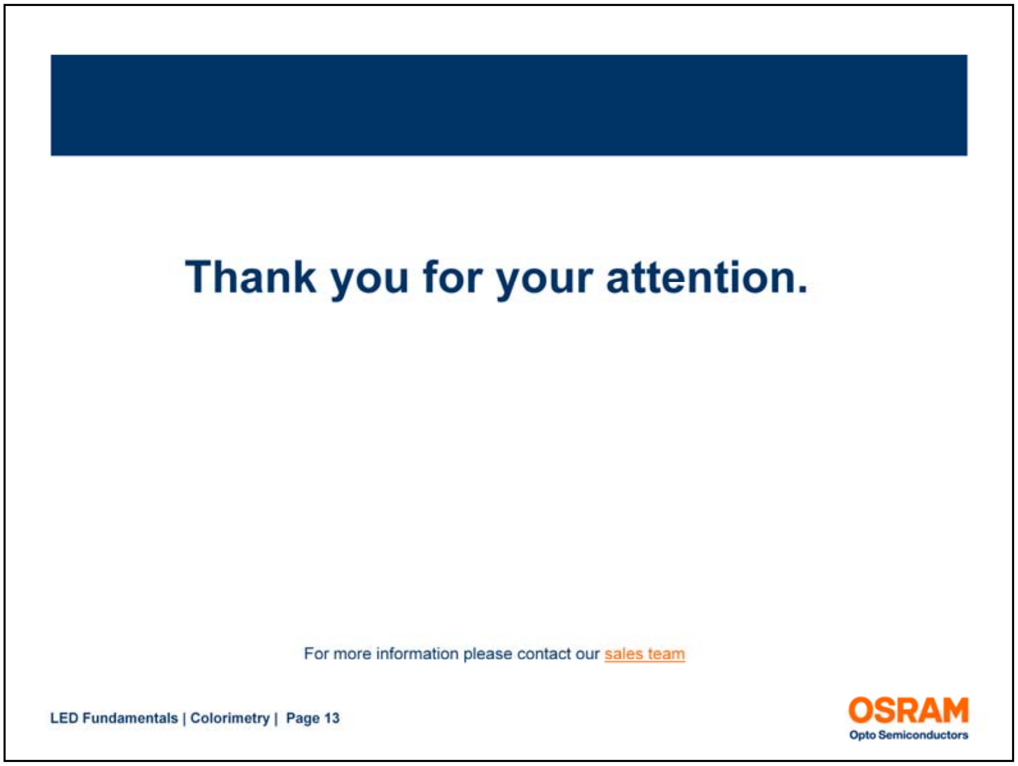

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