The quality of light

Based on Light Distribution and CRI Options

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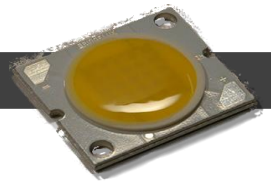
Why look for Light Quality?

- “Natural” - faithful representation to daylight
- “Vividness” - Attractive & appealing color
- “Emotion” - Revenue improved
- “Clarity” - Medical diagnosis

Array Benefits over Emitter based light engines

COB

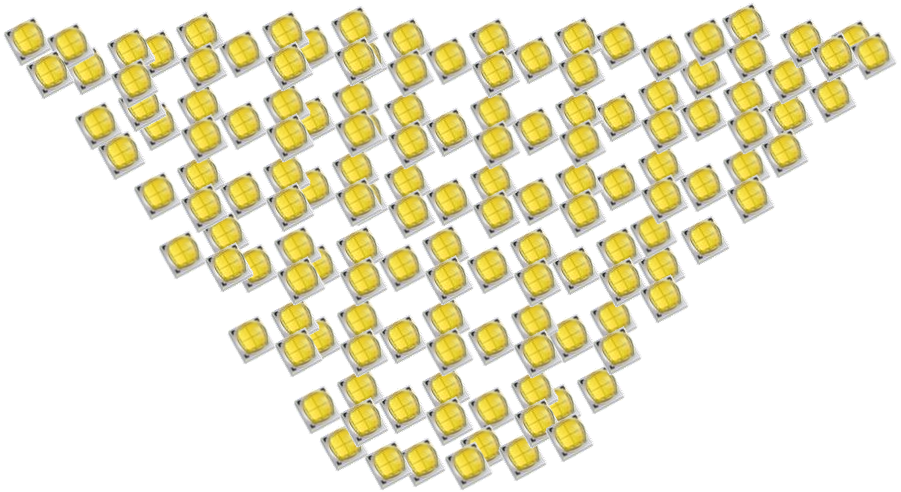


SMD

Array Benefits over Emitter based light engines

Emitter vs. array

Low end model: 100's of discretely packaged LEDs



Bridgelux model: single integrated & optimized LED array

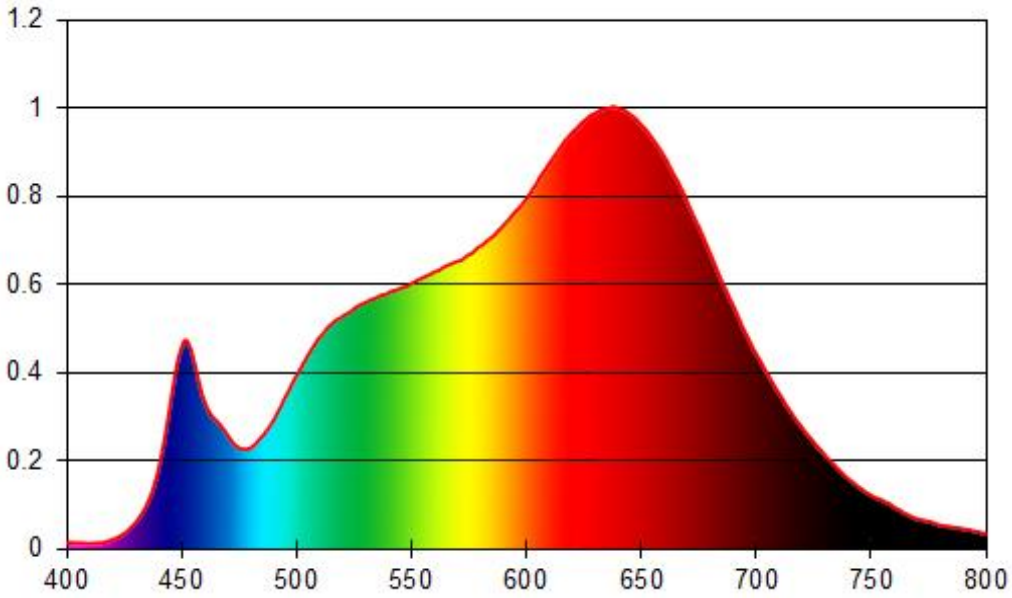
Critical benefits of arrays

- Reliability improvement through system component reduction
- Improved color consistency & binning
- Improved optical control through source – size reduction
- Ease of integration through wire bond reduction
- Capable of producing a high lumen output
- Fewer SKUs, supply chain management

Arrays provide customers flexibility and differentiation in design

What is CRI?

- CRI measures the ability of a light source to reproduce the colors of various objects faithfully compared to natural light
- Light sources with a high CRI are very desirable in color-critical applications
- CRI is calculated by comparing the test source to a "perfect" black body radiator



CRI – An Overview

In the calculation of the CRI, the color appearance of 14 reflective samples is simulated when illuminated by a reference illuminant and the test source.

After accounting for chromatic adaptation with a Von Kries correction, the difference in color appearance ΔEi, for each sample, between the test and reference illumination, is computed in CIE 1964 W*U*V* uniform color space.

The special color rendering index (Ri) is calculated for each reflective sample by:

$$Ri = 100 - 4.6\Delta Ei$$

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)	

CRI – An Overview

The general color rendering index (Ra) is simply the average of Ri for the first eight samples (shown in Figure 1), all of which have low to moderate chromatic saturation:

A perfect score of 100 represents no color differences in any of the eight samples under the test source and reference illuminant.
color samples for calculating CRI.

- Figure 1. The eight color samples used in the calculation of Ra.

CRI Ranges

Color Rendering is about source

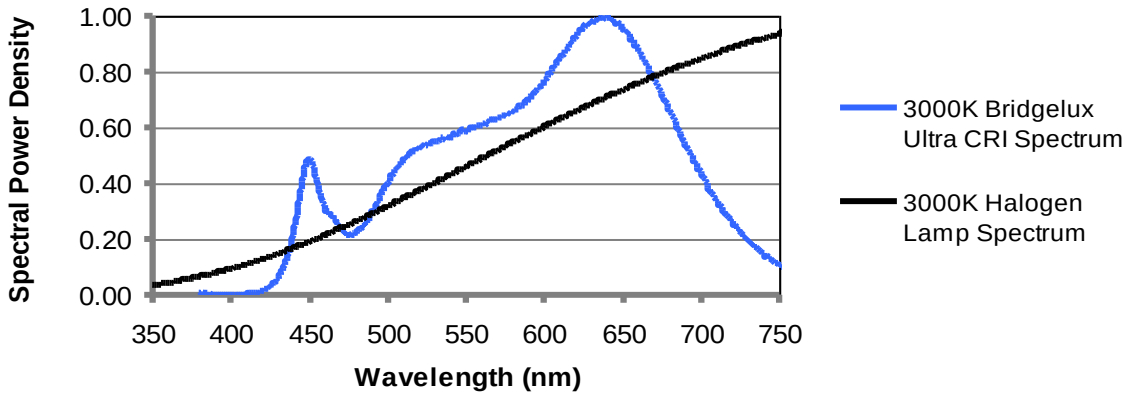
Lght source	CCT (K)	CRI
Clear mercury-vapor	6410	17
High-pressure sodium (HPS/SON)	2100	24
Coated mercury-vapor	3600	49
Halophosphate warm-white fluorescent	2940	51
Tri-phosphor warm-white fluorescent	2940	73
Quartz metal halide	4200	85
Tri-phosphor cool-white fluorescent	4080	89
Ceramic metal halide	5400	96
Incandescent/halogen bulb	3200	100

Human eye has adapted to natural light it responds best to a light source with a color spectrum close to natural light (high CRI)

Décor Color Spectrum and Rx Values

Décor products deliver high CRI light that accurately reproduces colors compared with natural light.

Typical spectral curve for Décor 3000K



- Typical Ra value of 97
- R9 value of 98 to enhance reds
- R15 value of 98 allows realistic representation of human skin tones

	Ra	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Bridgelux Decor Series	97	97	100	96	96	98	98	99	98	98	99	92	87	98	97	98
Halogen (Typical)	98	98	99	99	99	98	98	99	97	92	97	98	97	98	99	97
Compact Metal Halide (Typical)	82	90	94	69	82	81	81	87	71	27	59	62	55	93	78	88
Compact Fluorescent (Typical)	87	91	93	86	91	89	90	88	70	17	76	91	81	93	92	81

Typical R values compared to conventional light sources

CRI Ranges

Color Rendering is application

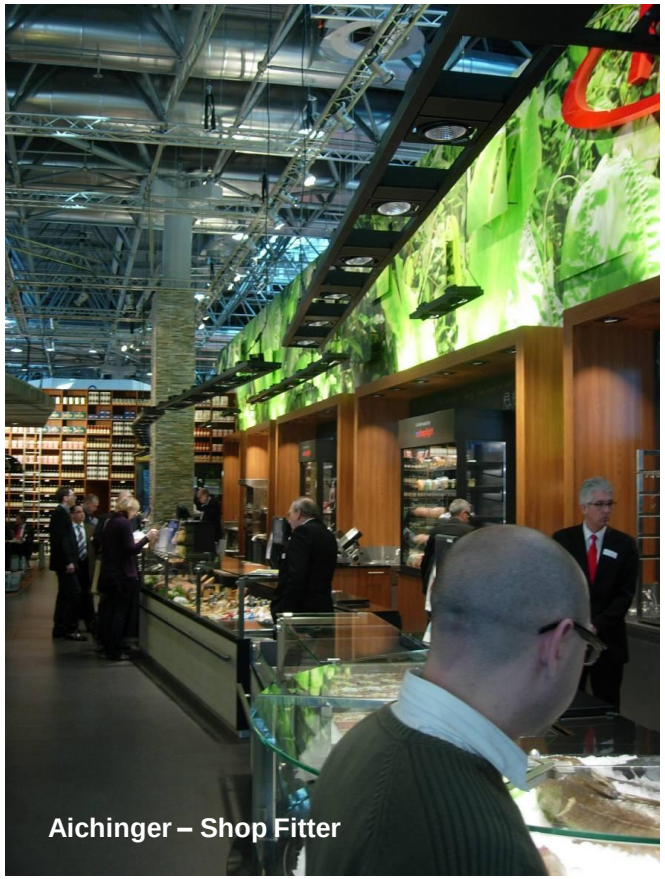
R_a	Importance	Typical application
90-100	accurate color matching	Galleries, medical examinations
80...90	accurate color judgement	Home, hotels, offices, schools
60...80	moderate colour rendering	Industry, offices, schools
40...60	accurate colour rendering is of little importance	Industry, sports halls
20...40	accurate colour rendering of no importance	Traffic lighting

High CRI enhances the visual perception :

- Creates inviting and interesting, ambience
- Increases traffic and time (money) spent in space
- Visitors see exhibits in an authentic way

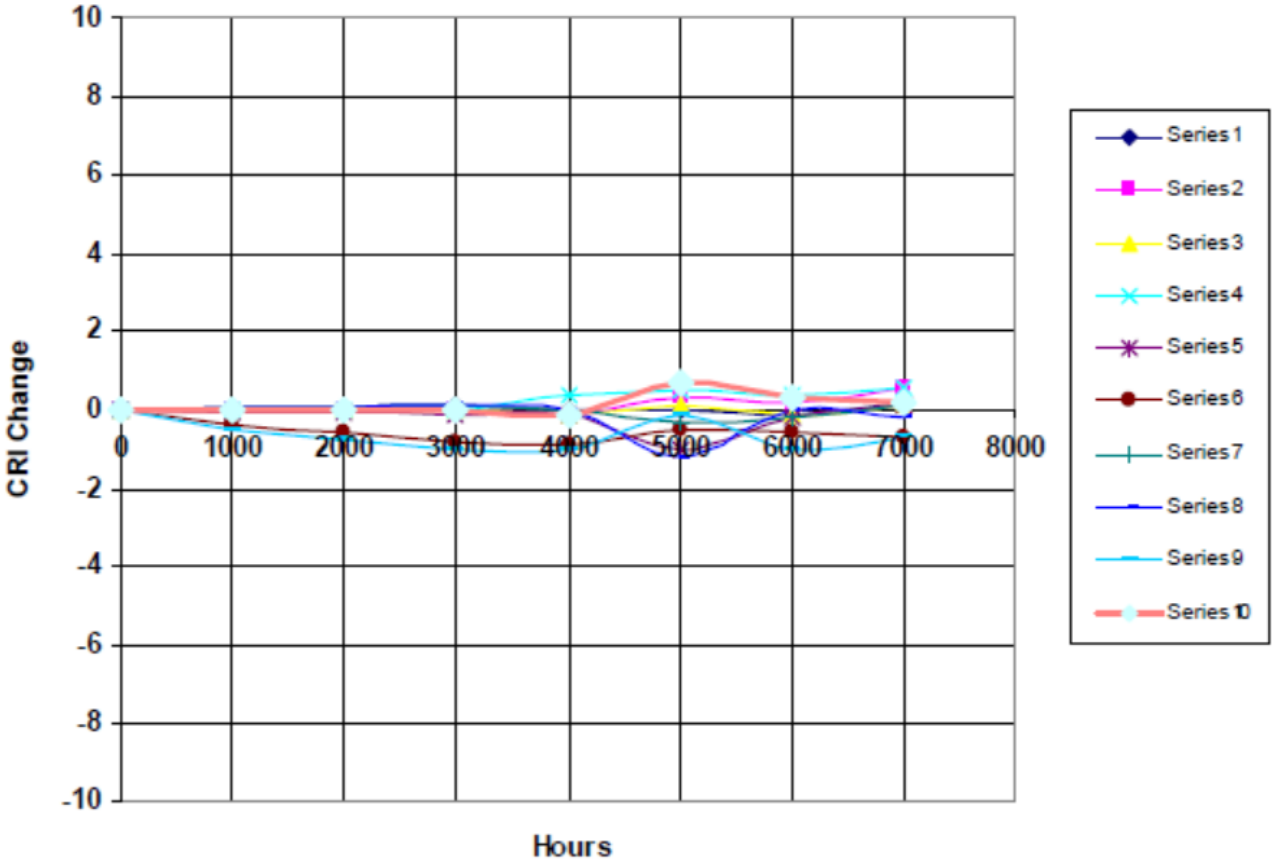
Lighting Customers Love High CRI!

In retail, lighting is like a moth to a flame.” Light really is the key factor that draws someone to a product. The more light and color rendering on a product, the better it is for sales on the floor.” Molly McKnight, senior lighting consultant at ARUP, New York City



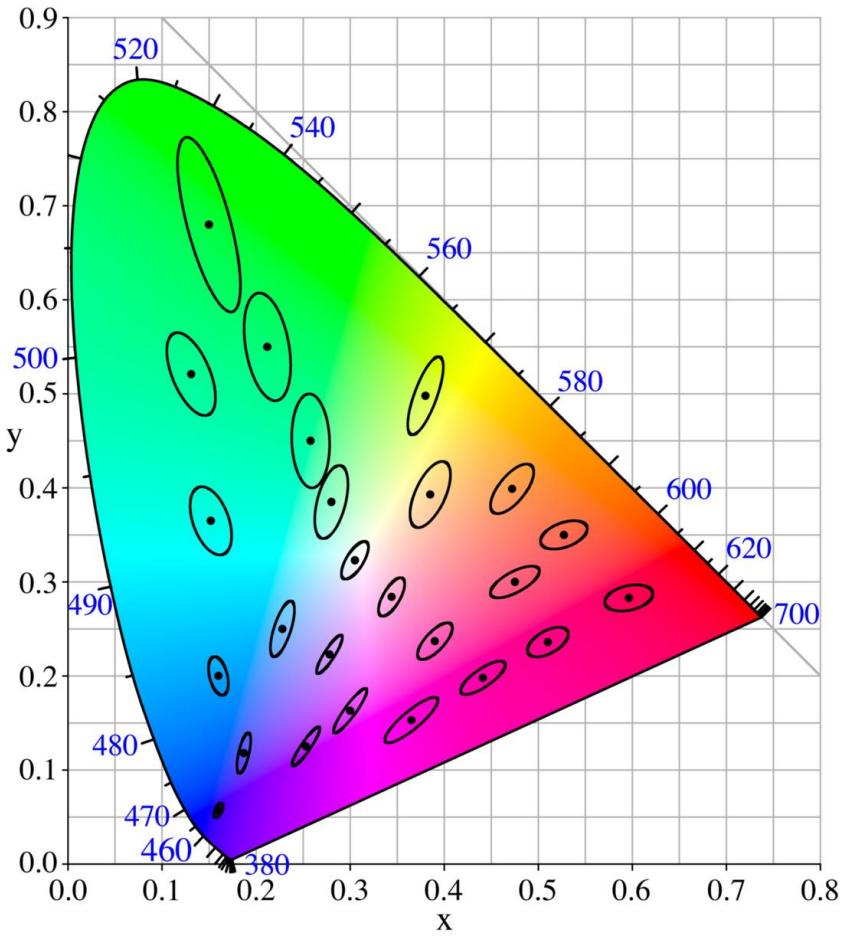
CRI Shift Over Time

There are no standards or models to predict CRI beyond the tested time.



Color Binning

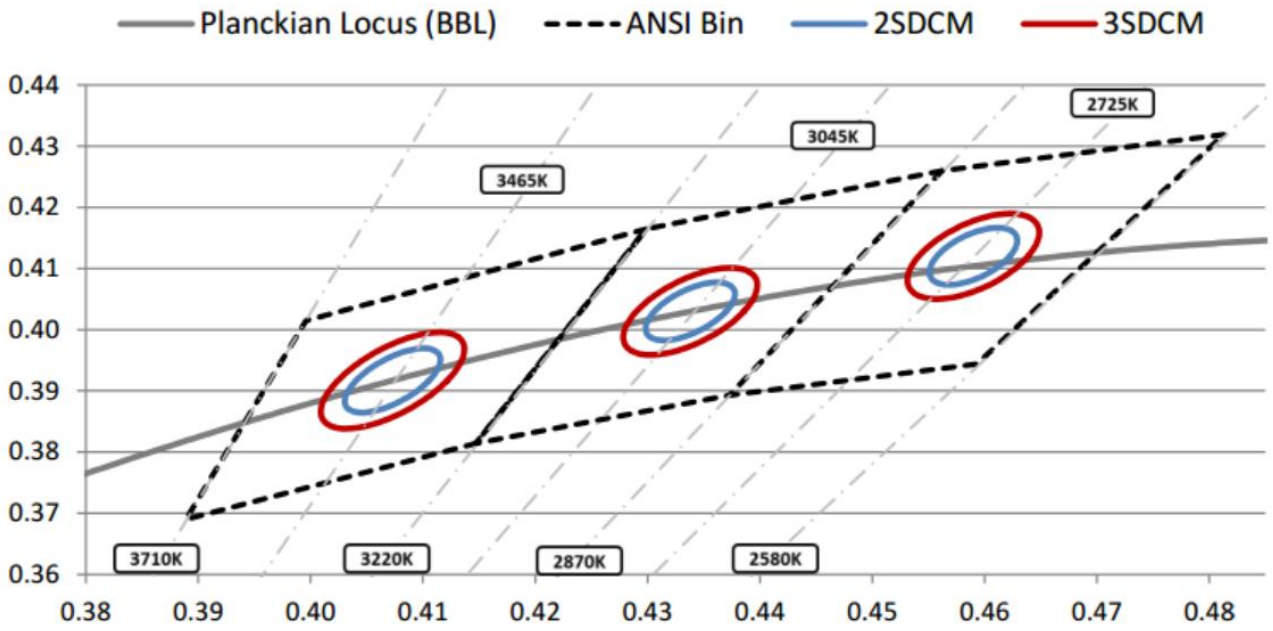
MacAdam Ellipses



- MacAdam ellipses refer to the region on a CIE chromaticity diagram which contains all colors which are indistinguishable, to the average human eye, from the color at the center of the ellipse.
- It should be noted that SDCM ellipses are often shown in the CIE color space diagram at a ten times magnification because they would otherwise be too small to be seen clearly when viewed in the complete CIE

Color Binning

For LEDs, these ellipses have been defined as quadrangles

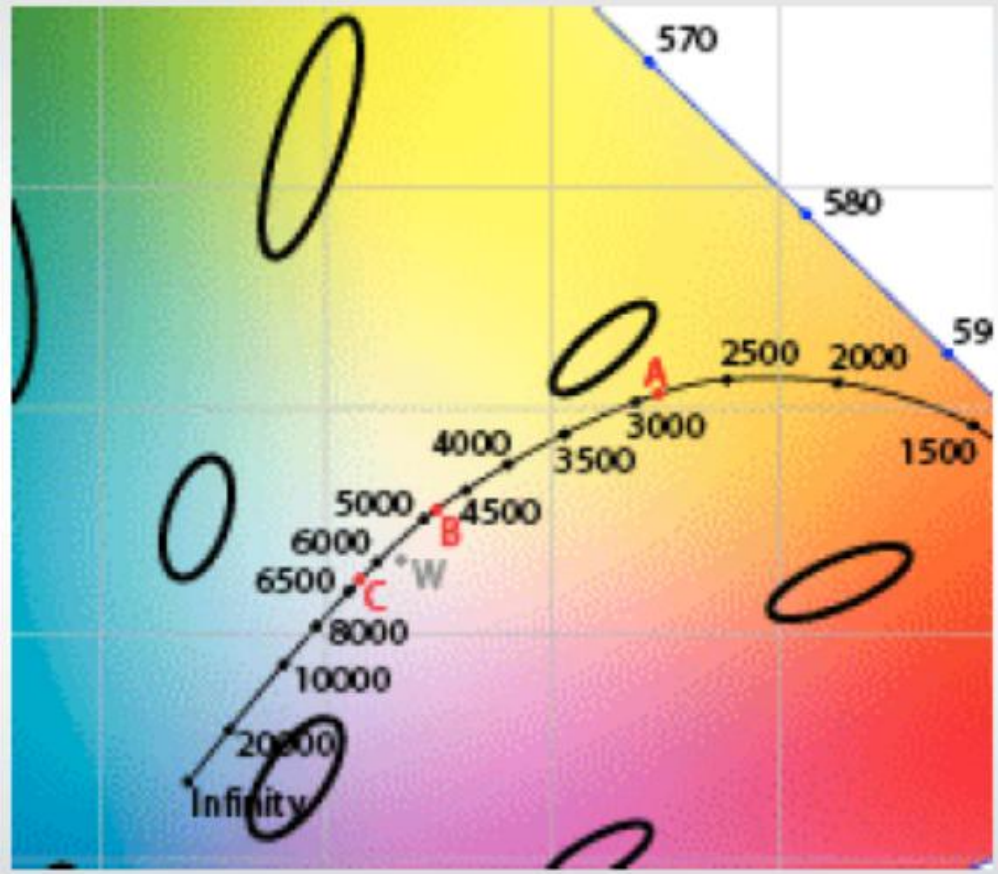


Bin Code	4000K
ANSI Bin (for reference only)	(3710K - 4260K)
03 (3SDCM)	(3851K - 4130K)
02 (2SDCM)	(3895K - 4081K)

Center Point (x,y)	(0.3818, 0.3797)

CCT Shift Over Time

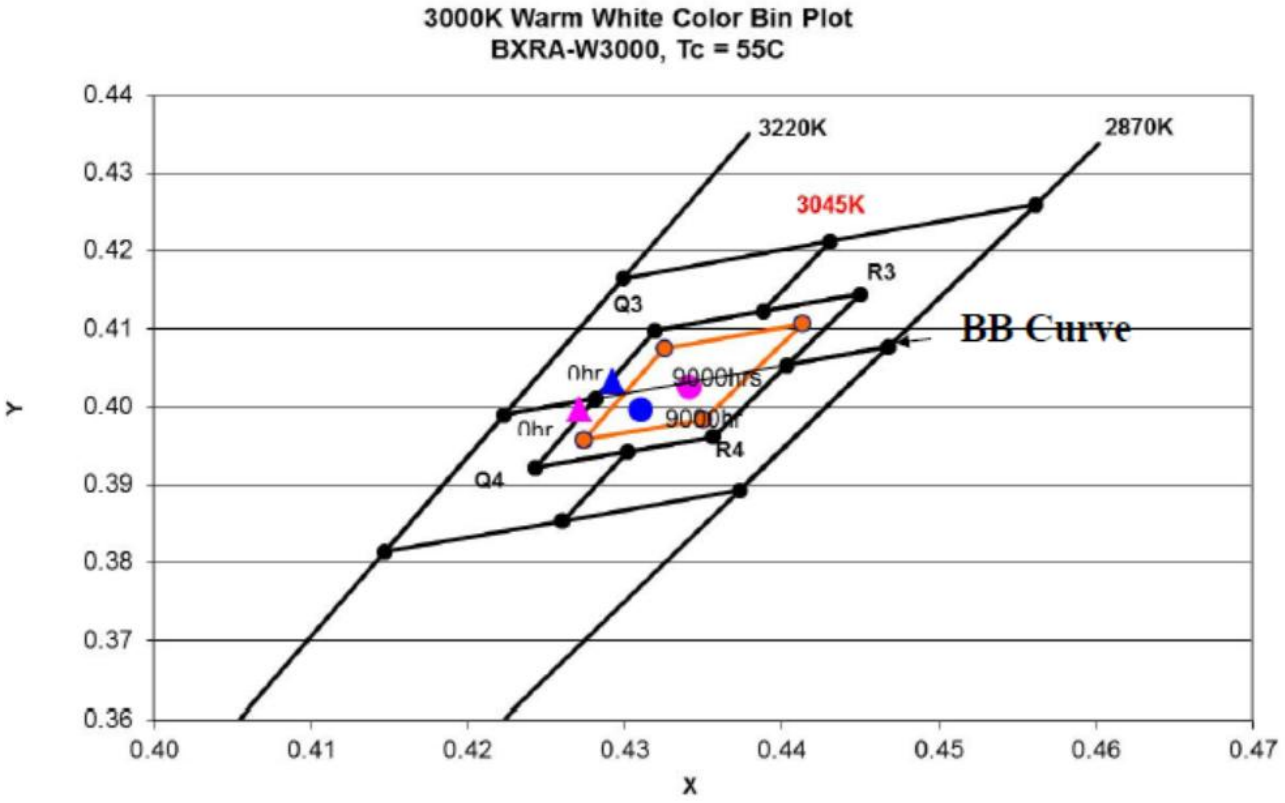
Shifts allong Black Body (BB) curve are less noticable



CIE 1931 Chromaticity Diagram

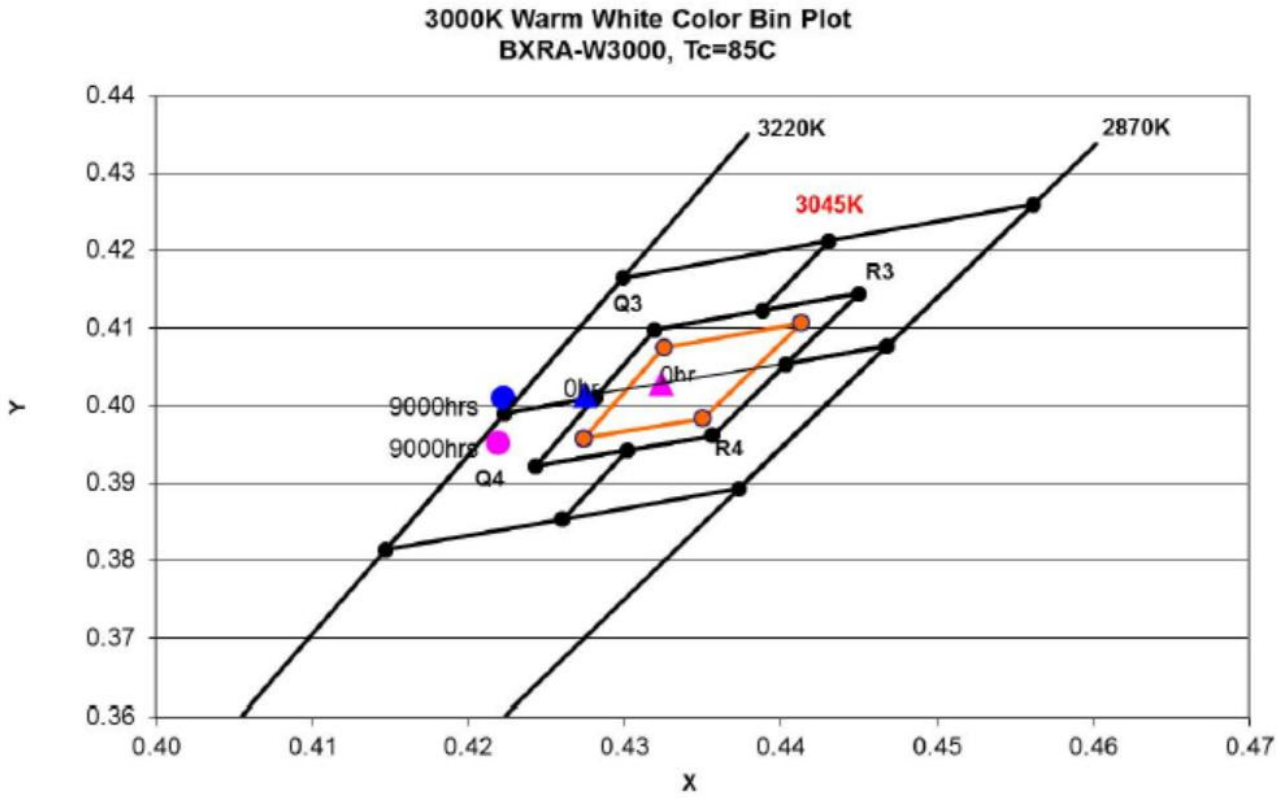
CCT Shift Over Time @ Tc 55°C

- Very little color shift in the y value along the BB curve
- Color shifts in different directions make color maintenance models for long lifetimes very difficult – No international standards available as of yet



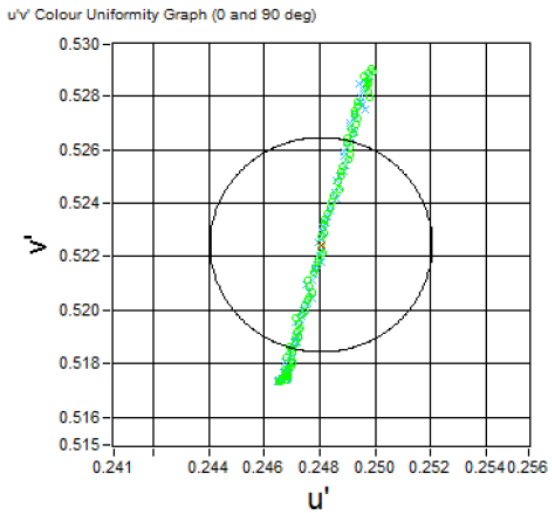
CCT Shift Over Time @ Tc 85°C

- Very little color shift in the y value along the BB curve
- Color shifts in different directions make color maintenance models for long lifetimes very difficult – No international standards available as of yet



Far Field Color Angular Uniformity

- LED Array color uniformity performance tend to be similar for array products, (and for all the arrays that were tested in table below).
- Energy Star does not specify far field CAU requirements for a light source by itself
- In indoor lighting applications were secondary optics are used the color angular performance of the source inside of a luminaire is not of great importance. One reason for this is that color mixing can be done very effectively with secondary optics.



CIE 1976 Colorspace

Device	u'a	v'a	Delta u'v'
BXRA-30E0740	.2464	.5182	.0050
BXRC-30E4000	.2481	.5225	.0068
Array A	.2473	.5192	.0069
Array B	.2218	.5043	.0091
Array C	.2463	.5207	.0077

All arrays that were tested had source sizes that ranged from 10mm to 25mm and their input power ranged from 10W to 31W.

Broad Range of LOP, CCT and CRI

Vero 10

Vero 13

Vero 18

Vero 29

1000lm — **16000lm**

2700K 80/90/97 CRI

3000K 80/90/97 CRI

3500K 80 CRI

4000K 80 CRI

5000K 70 CRI

Thank You