Power Systems

Basics of Backlights

VS

CCFL (Cold Cathode Fluorescence Lamp)

- Edge-Light
- Direct Backlight

LED (Lighting Emiting Diode)

- Edge-Light
- Direct Backlight
- White or RGB

EL (Electro Luminance)

- Direct Backlight

Objectives of the Course

- White LED Technology
  - Types of white LEDs
- Design Advantages of the Technology
  - Life
  - Efficiency
- Design Considerations
  - Color matching
  - Heat dissipation
  - Cost
- Range of Products Available Today

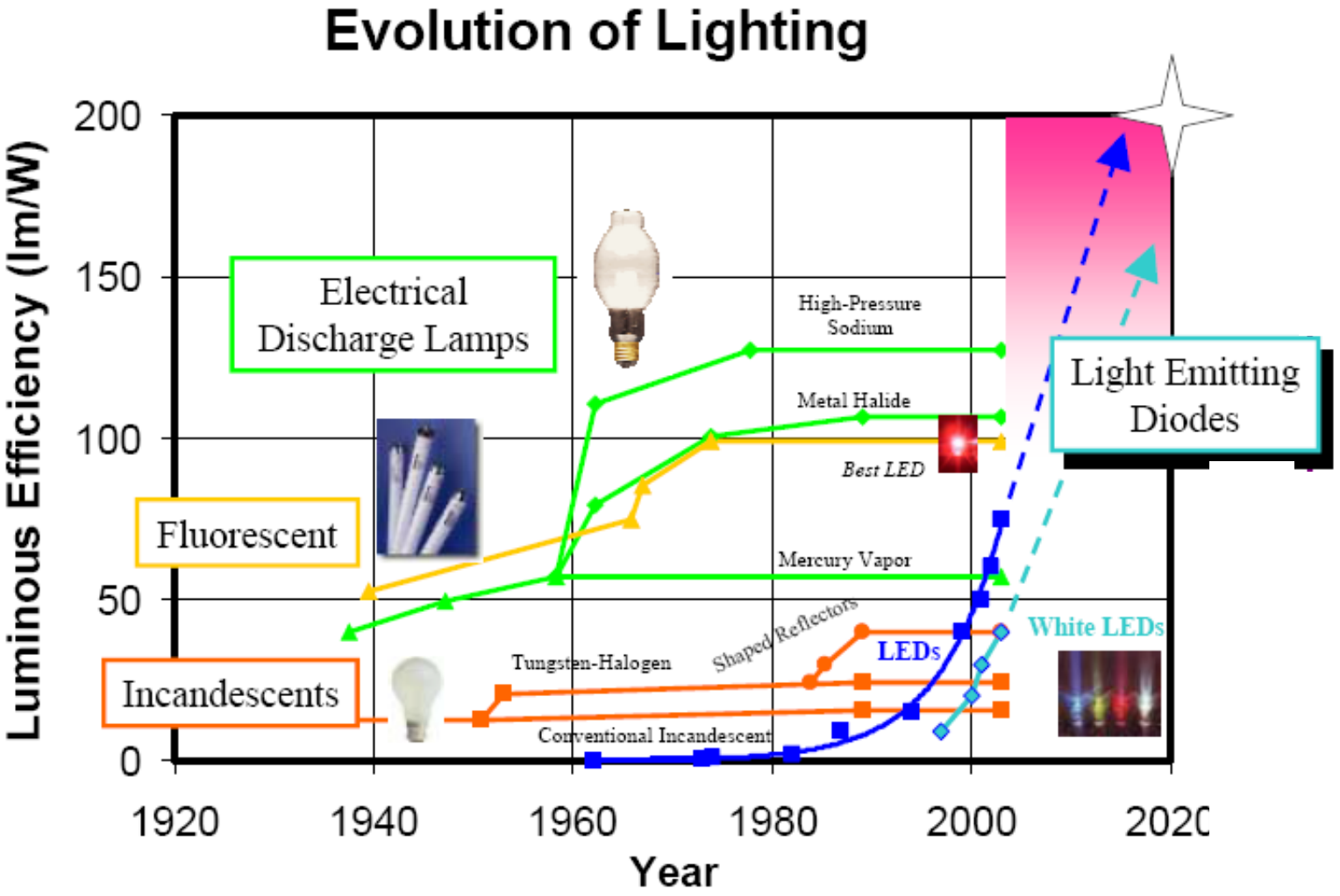
White Through History

Progress in lighting

Luminous Efficiency (lm/W)				
Candle 1400's	Incandescent 1800's	Floursecent 1920's	HID 1950's	LED 2000's
1	10-15	70-100	80-120	80-100

Progression of White Lighting

VS

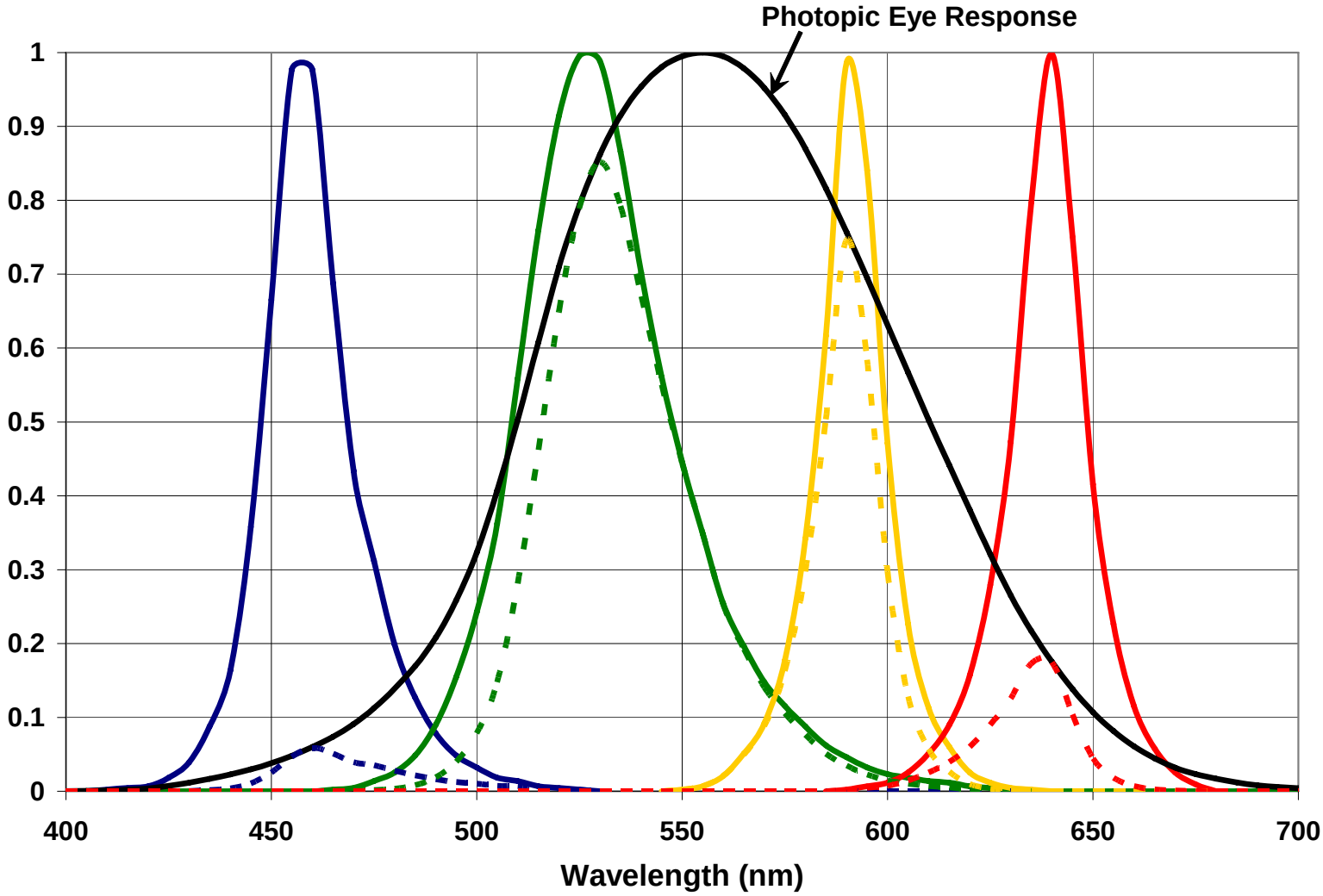


Specifying LEDs (in general)

- Type (3mm, 5mm, High Flux, etc.)
- R-G-B with different LED’s
- White LED’s

Definitions—Flux

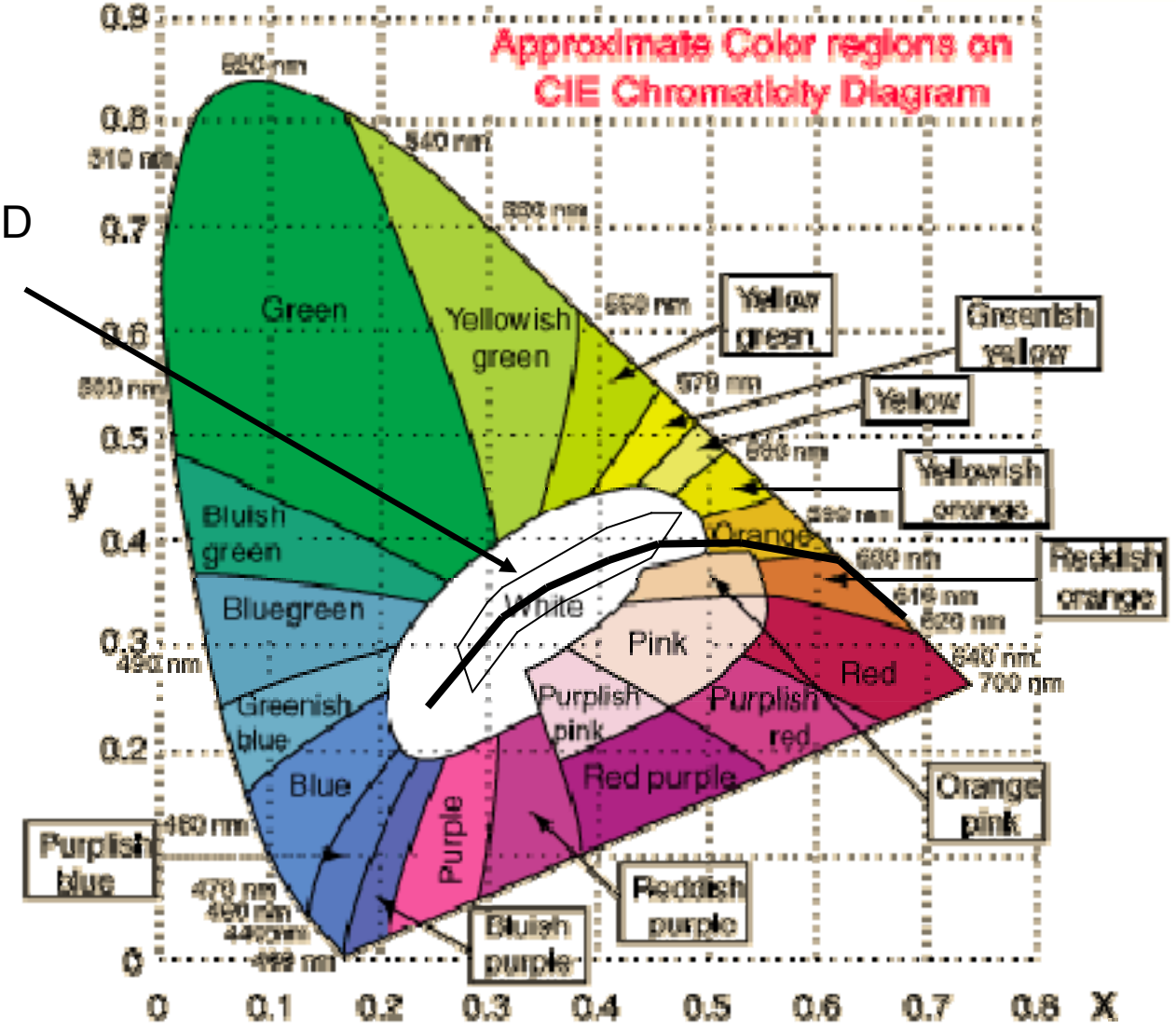
Radiometric Flux to Luminous Flux



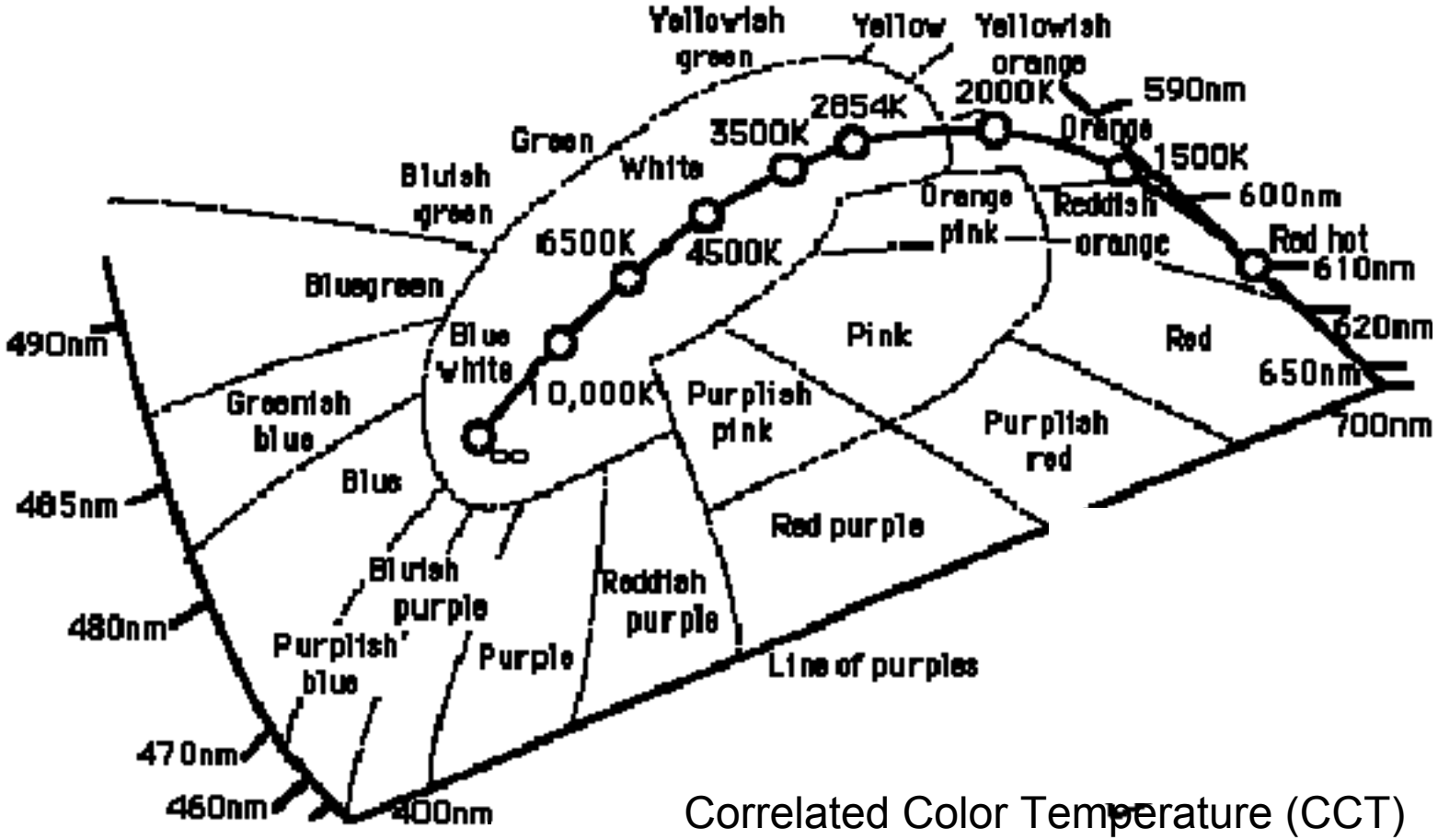
Definitions - Color

VS

White LED Range



Definition – White



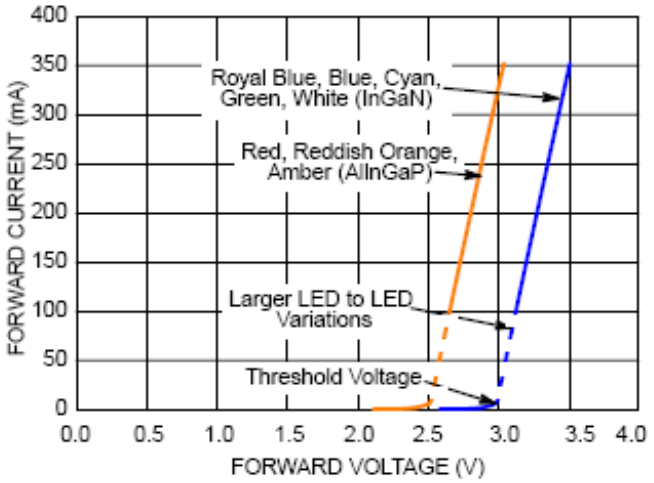
Correlated Color Temperature (CCT)

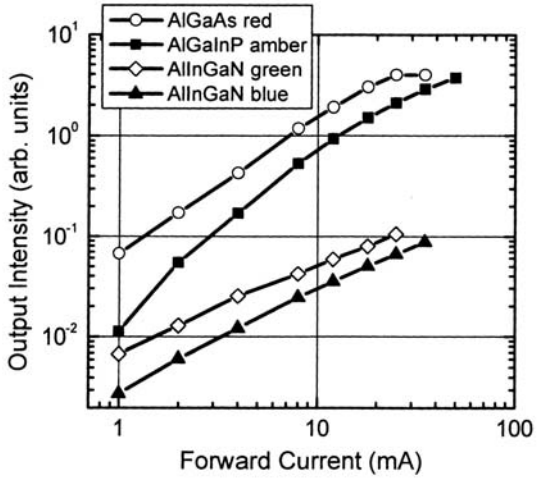
Definitions – Forward Voltage

- Forward Voltage V_f is roughly equal to the bandgap energy of the LED semiconductor divided by the elementary charge

  $V_f = E_g / q$

  where $q = 1.6 \times 10^{-19}$ coulombs



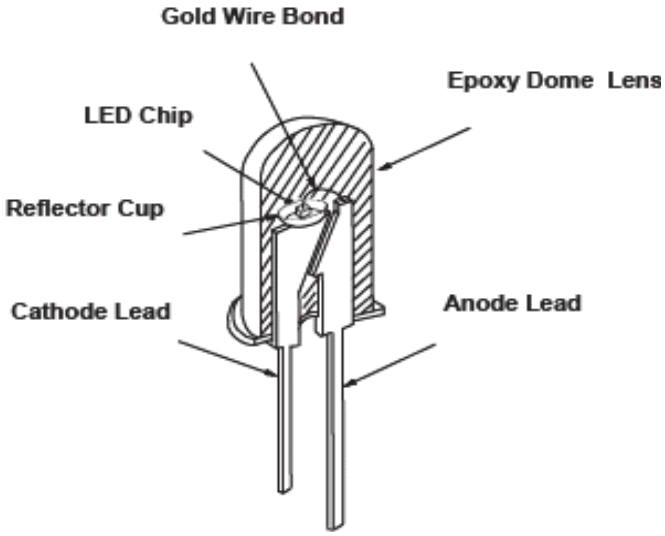


- Output Intensity of typical high brightness LEDs is dependent on the Forward Current I_f

Power Systems

Construction Difference

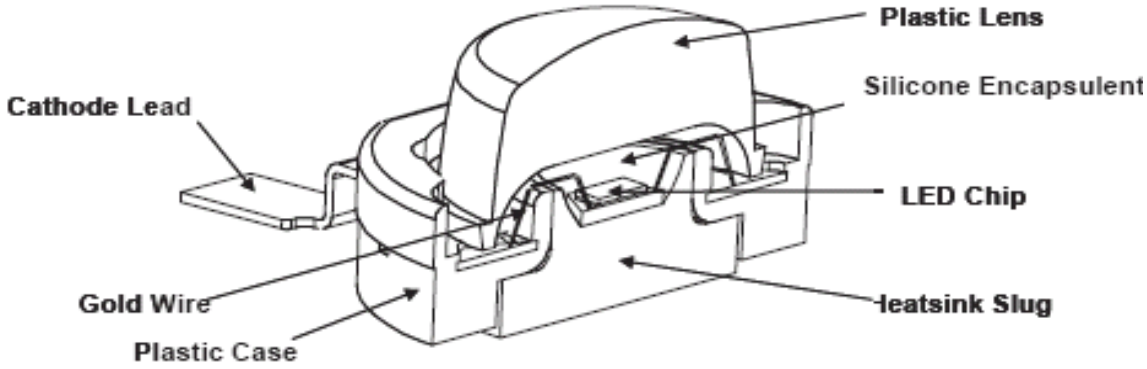
(5mm versus High Flux LEDs)



Typical construction for a 5mm LED

Typical Flux = 3 lm

Number of LEDs to equal the output of a 60W incandescent light bulb = 200



Typical construction for a High Flux LED

Typical Flux > 30 lm

Number of LEDs to equal the output of a 60W incandescent light bulb < 20

AlInGaP
Red, Red-Orange
Yellow

AlInGaN
Green, Blue,
White

Group XIII	Group XIV	Group XV
5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.006
13 **Al** Aluminum 126.981	14 **Si** Silicon 28.0955	15 **P** Phosphorus 30.973
31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.921
49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760

Base Elements
P-Type Dopants
N-Type Dopants

Substrates
Silicon Carbide (SiC)
Sapphire (Al_2O_3)

How do you make LEDs?

Lens Materials

3 mm and 5 mm

- **Epoxy lens**
  - Bad expansion coefficient (stresses bond wire)
  - Yellows
  - Degradation blue/UV

HIGH FLUX

- **COC, other hard plastic lens with silicone gel**
  - Plastic with silicone gel
  - Not reflow solderable
- **Silicone polymer lens with silicone gel**
  - Robust for reflow, lead free temperature 260C
  - Better moisture handling
  - Susceptible to dirt and scratches
- **Glass lens with silicone gel**
  - More robust
  - Higher cost

How do you make LEDs?

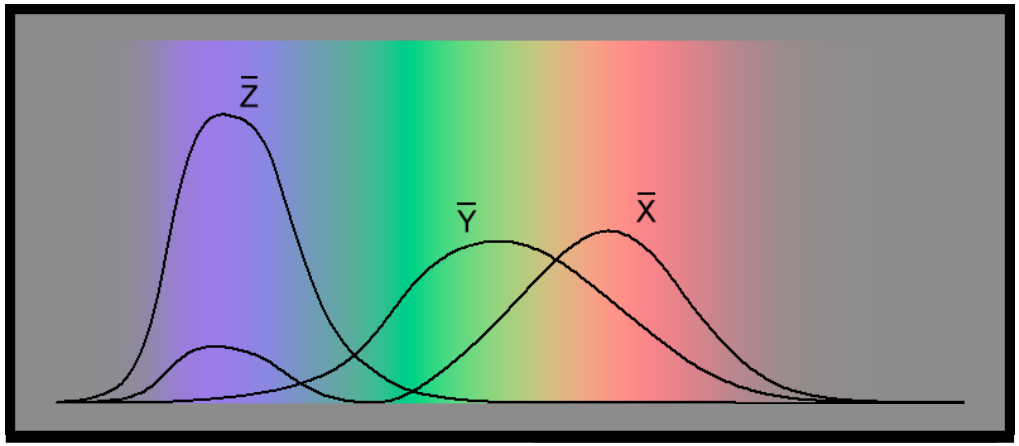
Substrate Materials

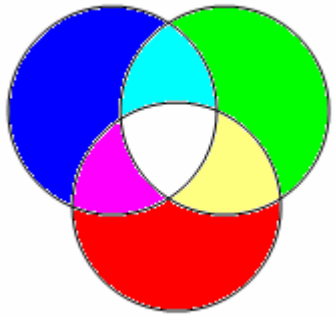
- Sapphire (Al_2O_3)
  - Lower cost (estimated at $3/cm^2)
  - More transparent (more light output)
  - Low thermal conductivity (40 W/m/K)
- Silicon Carbide (SiC)
  - Higher cost (estimated at $12/cm^2)
  - Better ESD protection
  - High thermal conductivity (350-490 W/m/K)

How do you make a White LED?

VS

RGB Method





Mixing light from red, green and blue LEDs (either discrete or combined in one package) can produce white light

How do you make a White LED?

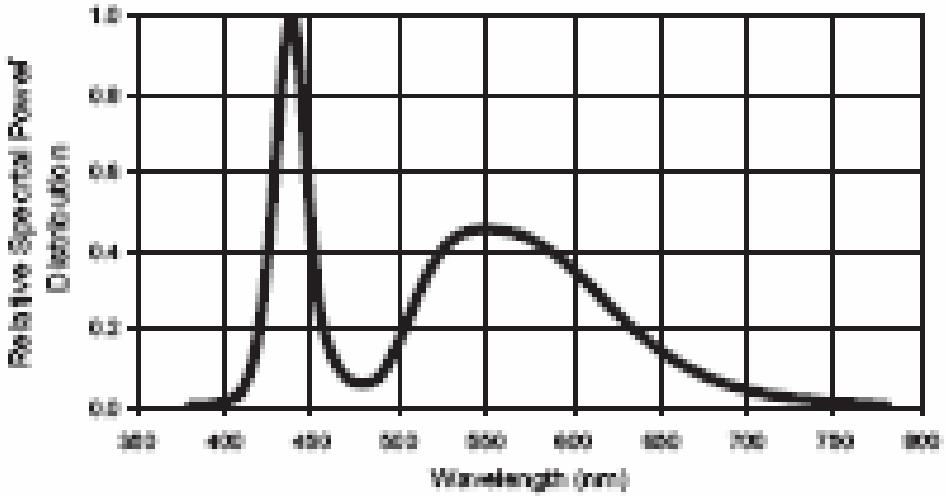
Visible LED Pump + Phosphor Method

Blue LED + YAG **Cool White**

Blue LED + YAG + Other phosphor (red, green, etc.) **Warm White**

UV LED Pump + Phosphor Method

UV LED + Red phosphor + Green phosphor + Blue phosphor



Luxeon K2

Power Systems

How do you make a White LED?

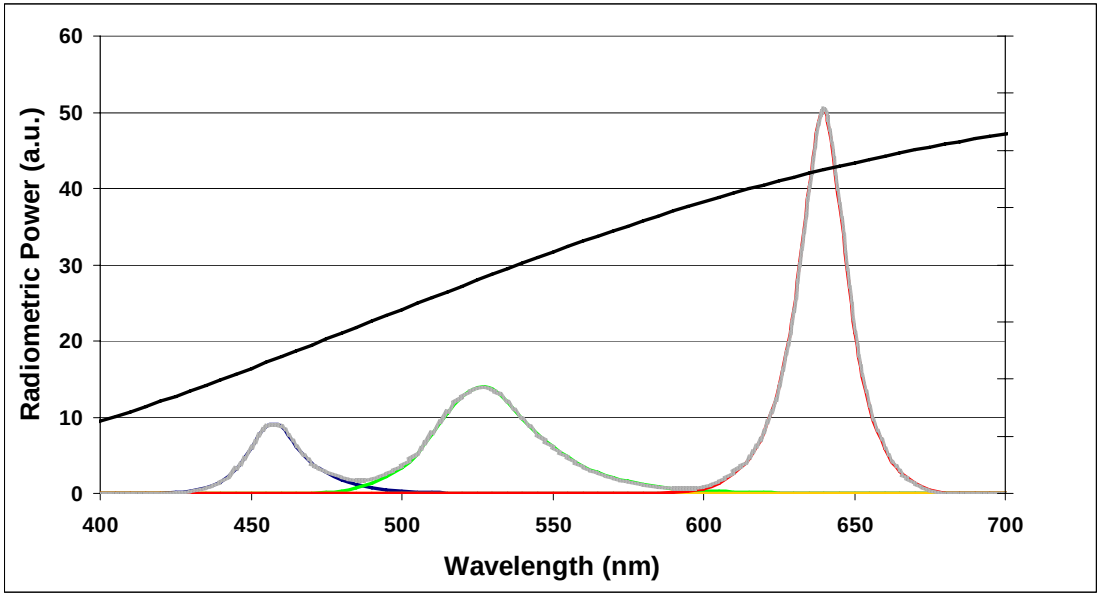
VS

(Blue + Phosphor) VS (Red + Green + Blue)

Warm White (3500K)

Blue + Phosphor	
100	lumens
34	lumens/watt
2.92	watts

Blue	Green	Red	Total	
2.3	66.7	30.7	100	lumens
13.4	38.9	29.9	n/a	lumens/watt
0.17	1.71	1.03	2.91	watts

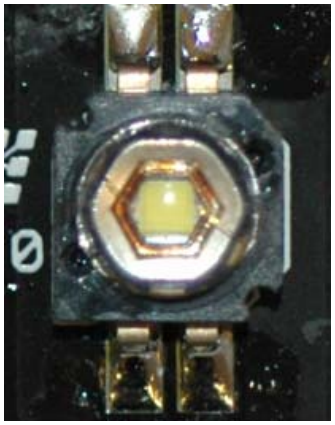


How do you make a White LED?

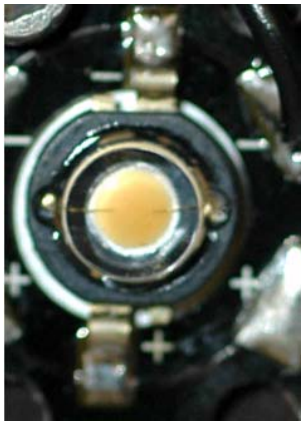
VS

Phosphor Deposition Examples

Lumileds



Lumileds



Seoul Semiconductor

Cree

Nichia

Osram

How do you make a White LED?

VS

Which method is better for making white?

	RGB	Blue + Phosphor	UV + Phosphor
Advantages	• Color can be changed dynamically • As a luminance source, millions of colors can be produced • Highest theoretical luminous efficiency of all three methods • No UV output	• High theoretical luminous efficiency • Can provide color temperatures between 3200 K (warm white) and 10,000 K (cool white) • No UV output	• Good color uniformity • Simple driver electronics • Potential for limited tint variation • Eliminates the pump color variation; only phosphor variation
Disadvantages	• Color can shift due to aging and temperature • Requires more sophisticated electronics • Poor color rendition • Fixture efficiency drop caused by color mixing	• Potential to create variations in tint • Must be controlled using optics and binning	• Lowest luminous efficiency • Shorter life • Clouding of the epoxy (UV packaging problems) • New phosphors necessary

How long do light sources last?

VS

Time to change the lightbulb!

The sun	>4.5 billion years (so far)
Candle	<12 hours
Oil Lamp	<24 hours
Incandescent (Bulb)	1k-1.5k hours
Fluorescent (CCFL)	25k-60k hours
Mercury Vapor	10k-20k hours
Sodium Vapor	24k hours
Metal Halide	20k-30k hours
5mm LEDs	<10k hours
High Flux LEDs	>20k hours

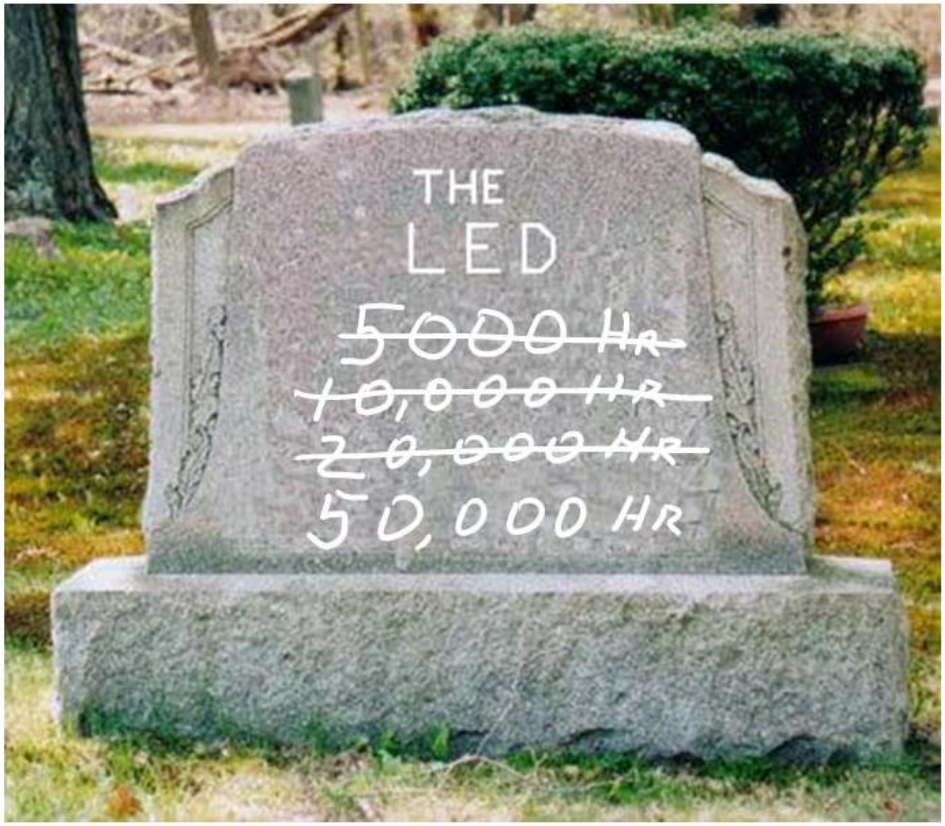
What is End of Life for some illumination sources?

How long do light sources last?

VS

LED Lifetime

How long do they last?



How long do light sources last?

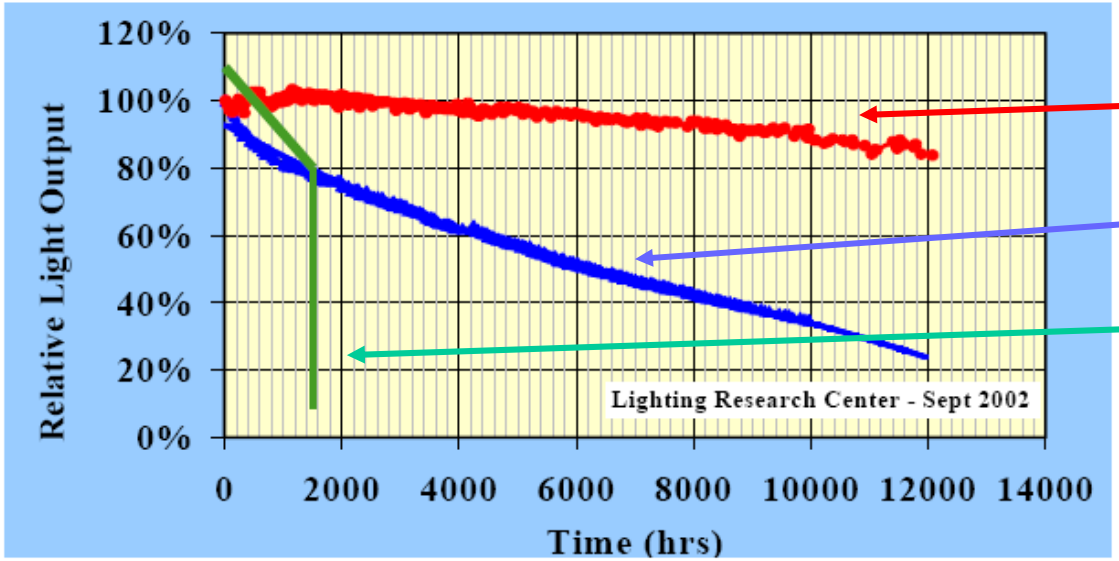
VS

What do we mean by Lifetime?

Traditionally Lifetime was the time it took for 50% of the population of incandescent bulbs to fail

Many light sources don't fail catastrophically—Define EOL by reduction in light output from initial values for example 70% or 50% of initial value

Under what conditions do we measure lifetime?



High Flux LED

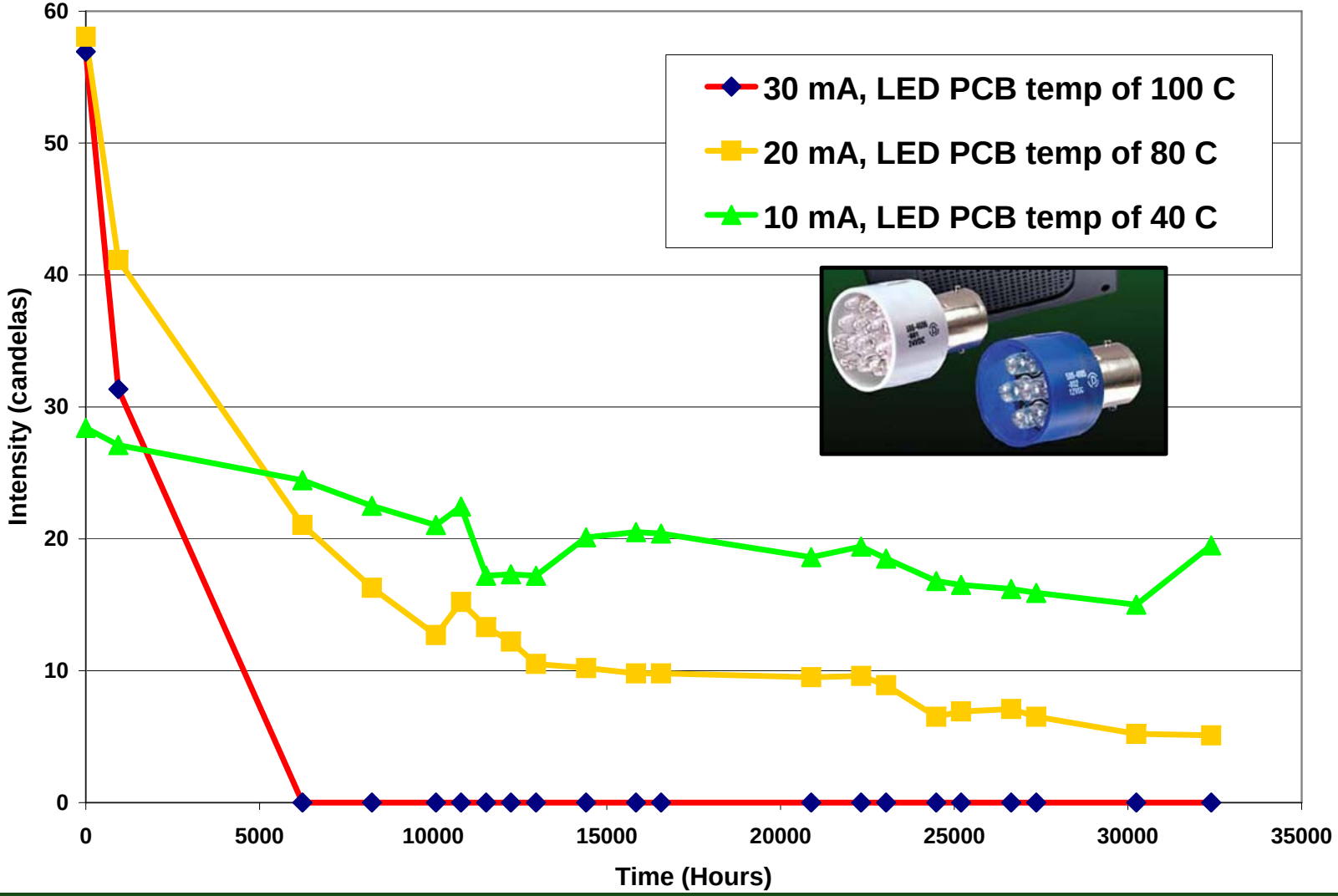
5mm LED

Incandescent

How long to light sources last?

VS

Lab Data on 5mm LED Lifetimes



Lifetime (half-life) shortens with increasing Temperature and Drive Current

LW Y3SG

Exemplarische mittlere Lebensdauer[2) Seite 17]
für typische Helligkeitsgruppe
Exemplary median Lifetime[2) page 17]
for typical Brightness Group

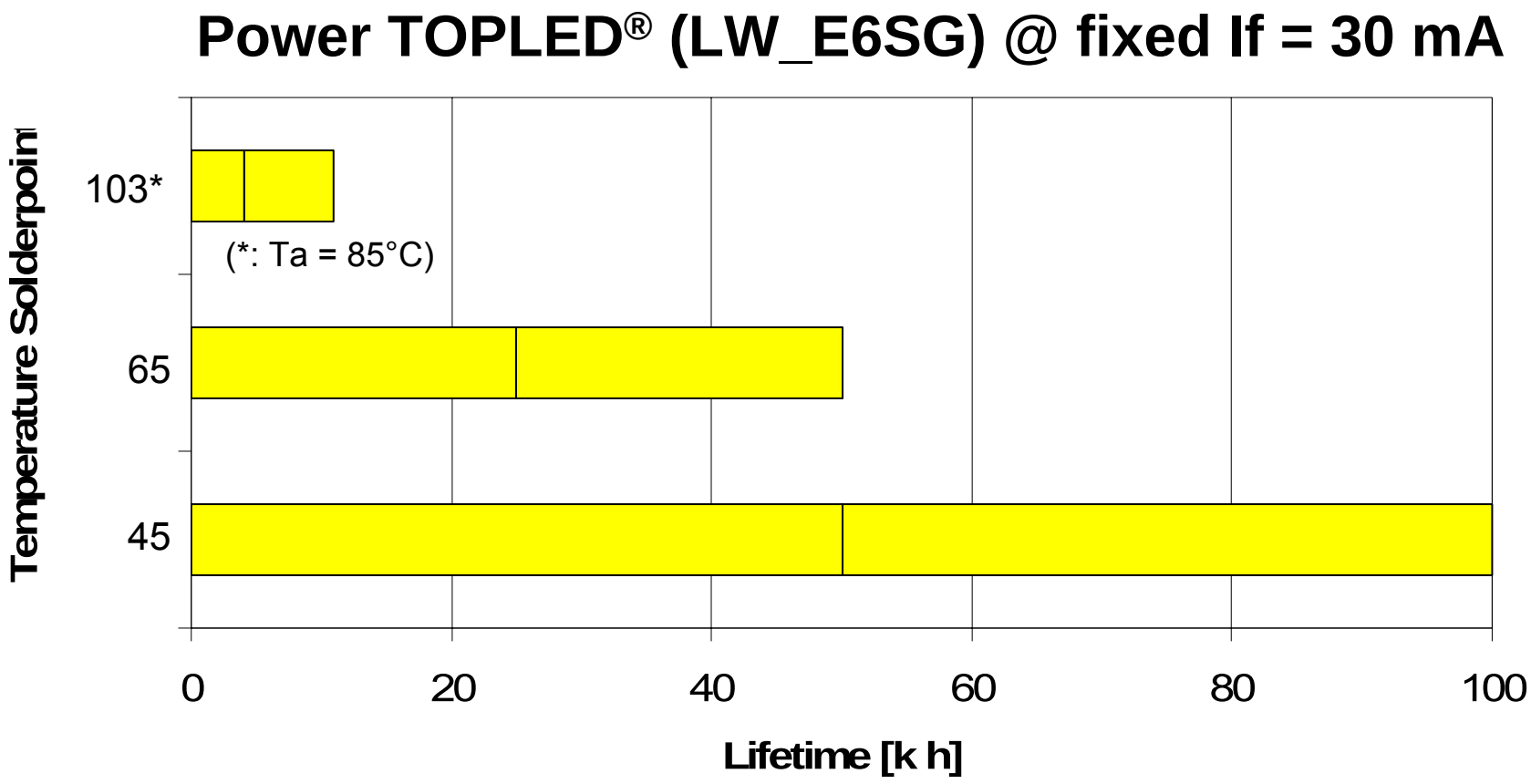
Bedingungen Conditions	mittlere Lebensdauer median Lifetime	Einheit Unit
I_F = 15 mA T_A = 25°C	>50.000	Betriebsstunden operating hours
I_F = 30 mA T_A = 85°C	4.500	Betriebsstunden operating hours

Data extracted from page 11 of LW Z3SG data sheet.

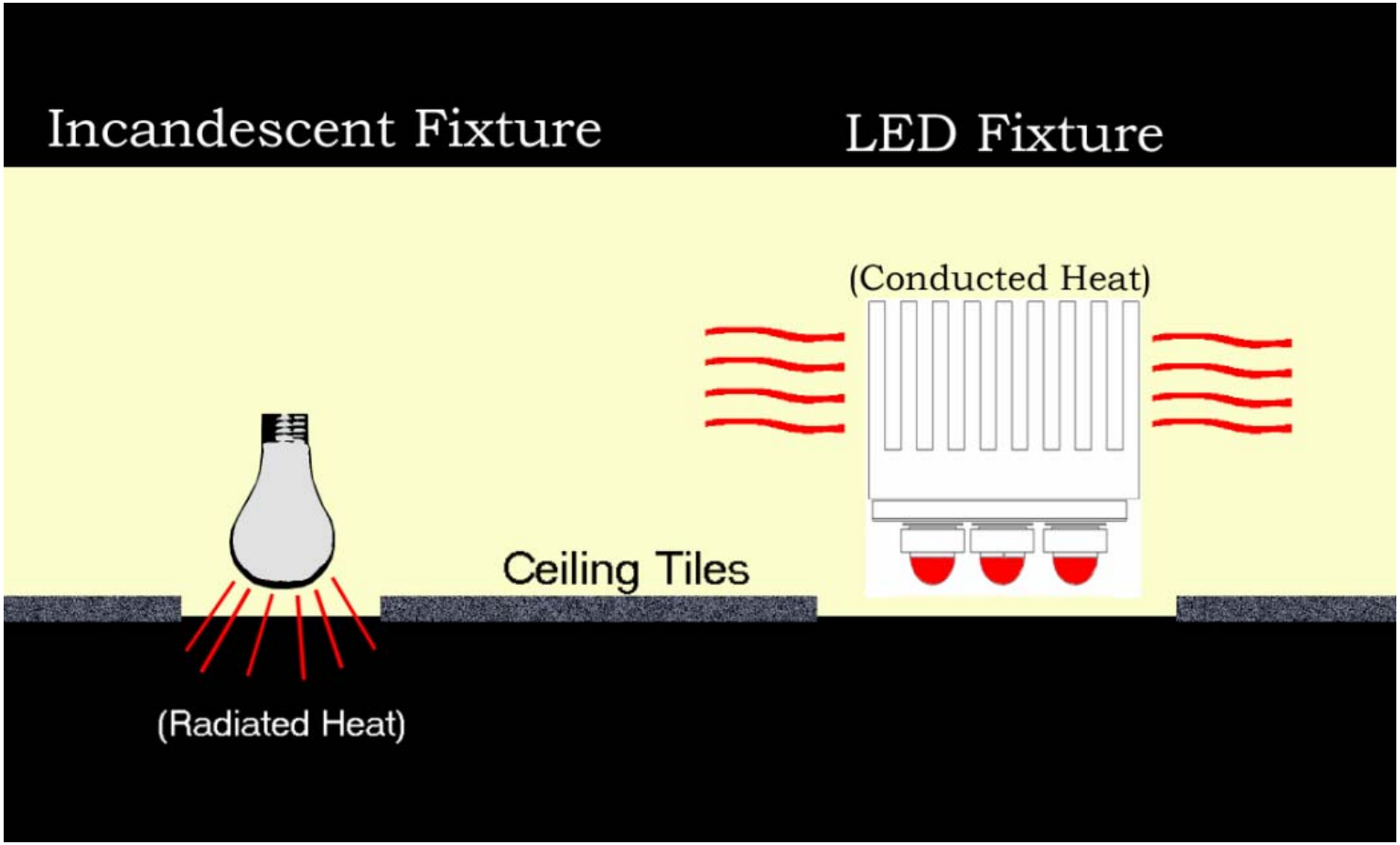
Examples OSRAM

Generic white LED lifetime vs. Temperature

VS

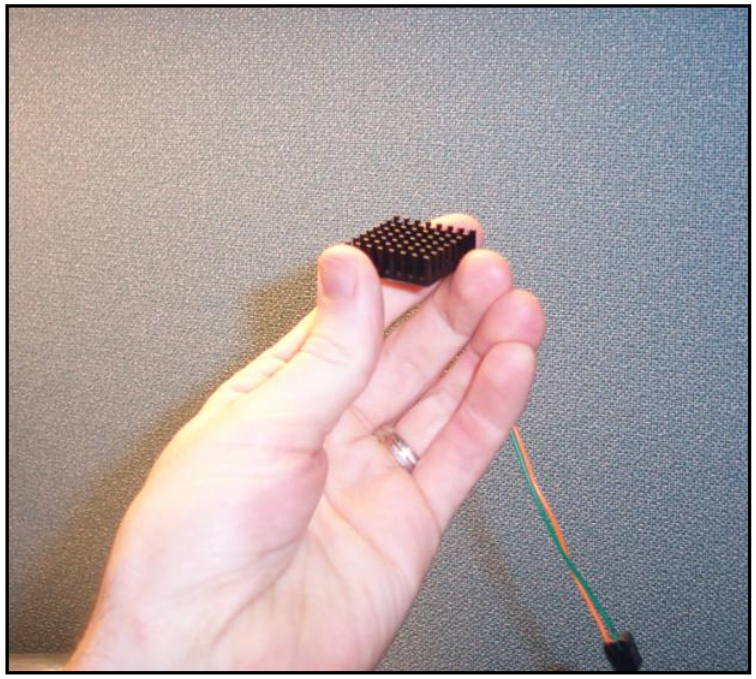


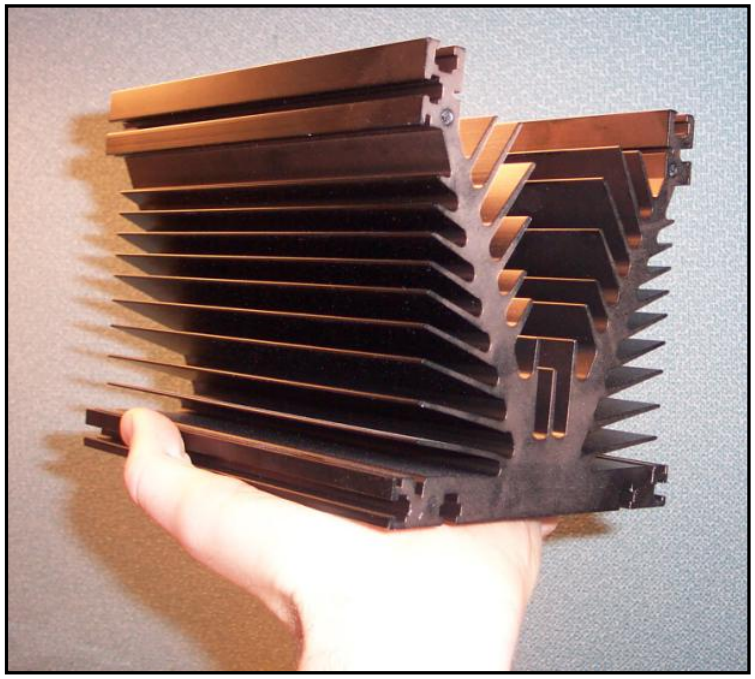
Thermal Management Issues



Thermal Management Issues

Which heat sink do I need?

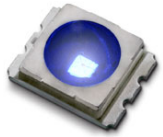




40 °C/W or 0.4 ° C/W

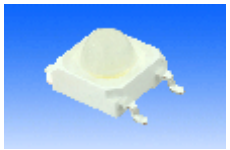
Manufacturers Examined

- Cree
  - XLamp Series

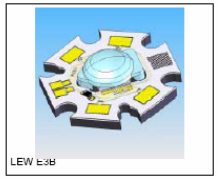


- LumiLeds
  - Luxeon Series
  - K2 Series

- Nichia
  - Jupiter Series



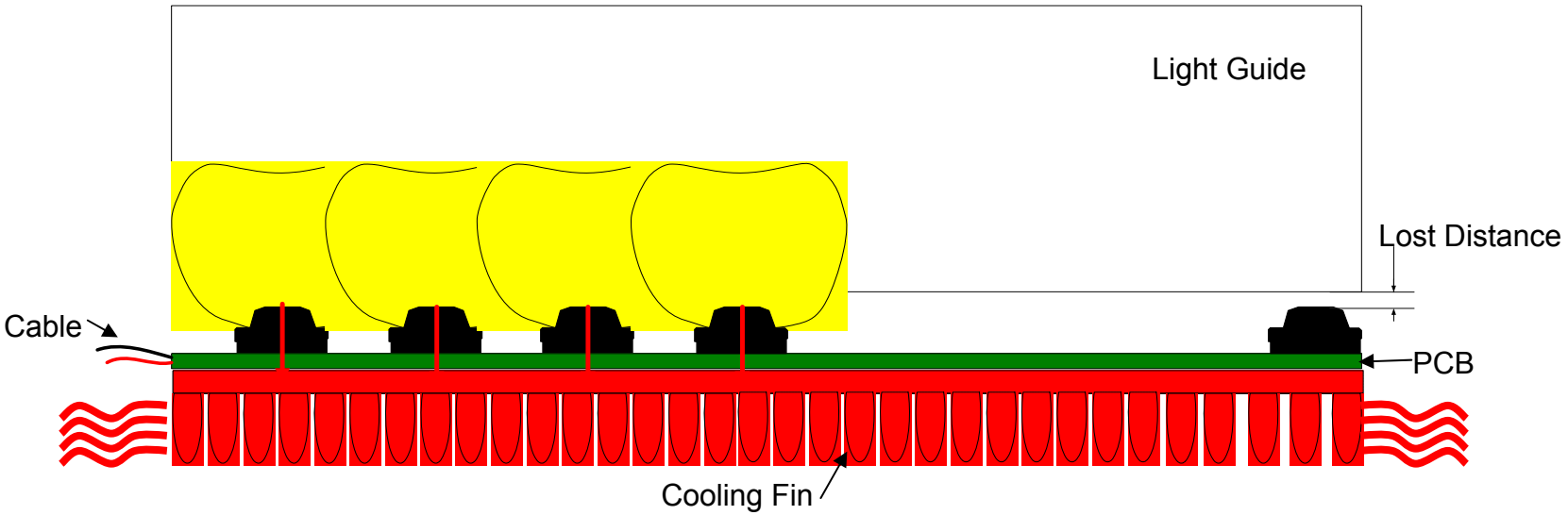
- Osram
  - Golden Dragon Series



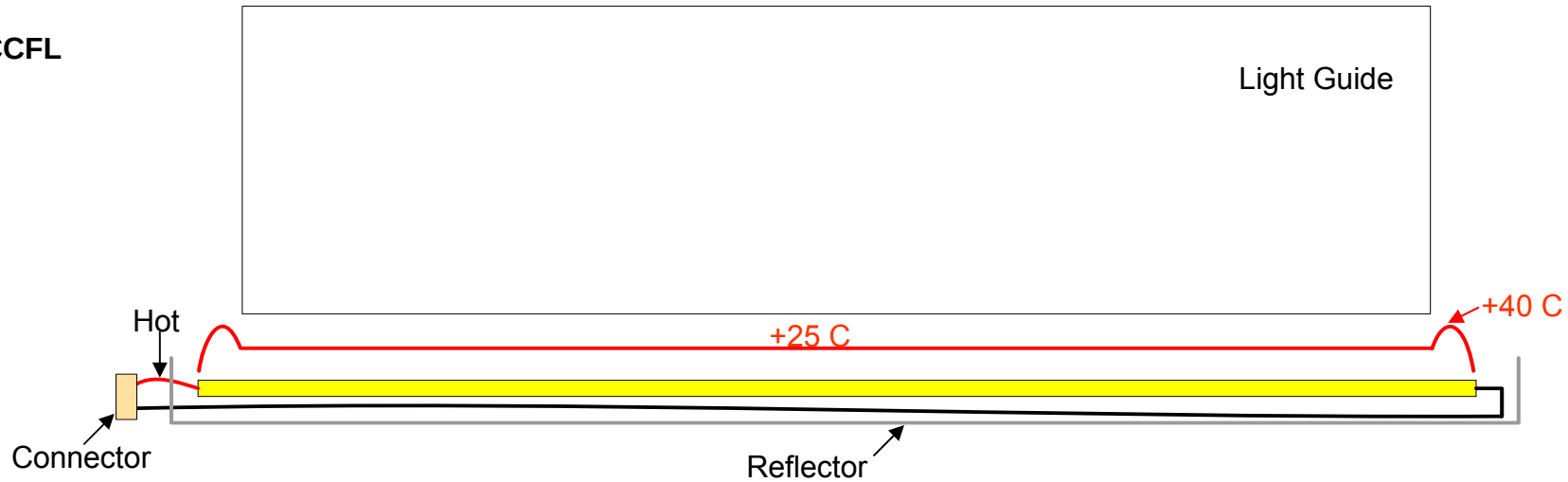
- Seoul Semiconductor
  - Z-Power Series

Temperature

LED

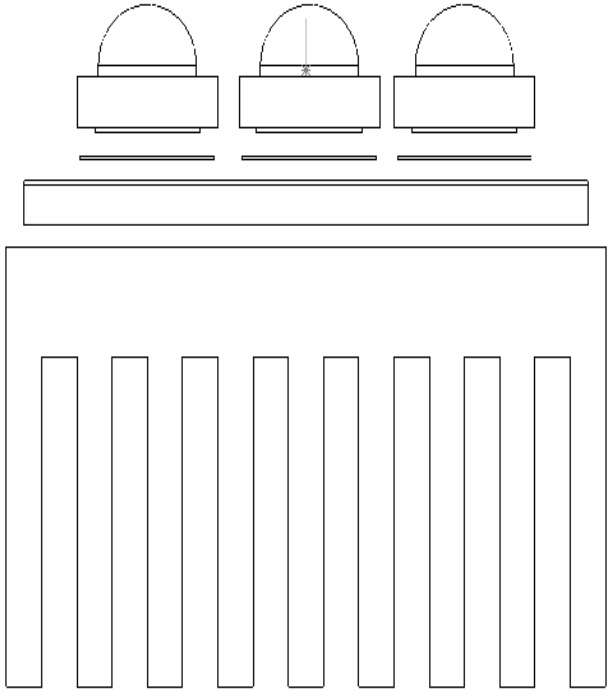


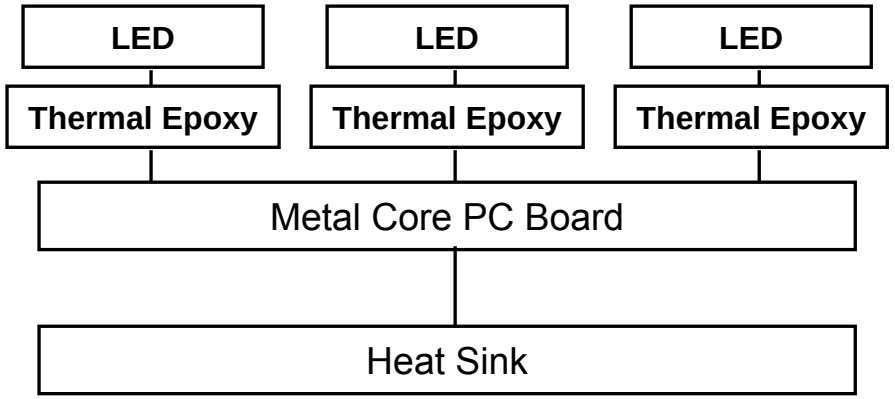
CCFL



Thermal Management Issues

Calculating Safe Junction Temperatures

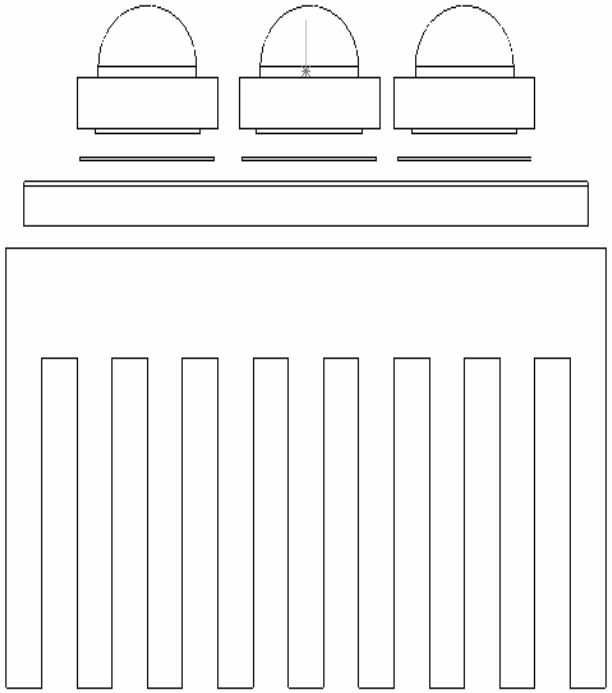


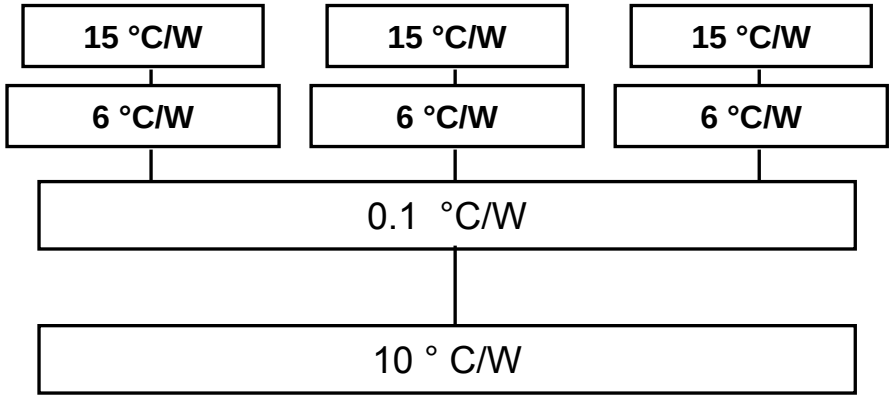


$$T_{Junction} = T_A + (P_{LED}) \cdot (R\Theta_{LED}) + (P_{LEDs}) \cdot (R\Theta_{Heat\sin k})$$

Thermal Management Issues

Increasing from 1W to 3W LEDs
Operating temperature of +25°C





$$T_{Junction} = 25°C + (1W) \cdot (21°C/W) + (3W) \cdot (10.1°C/W)$$

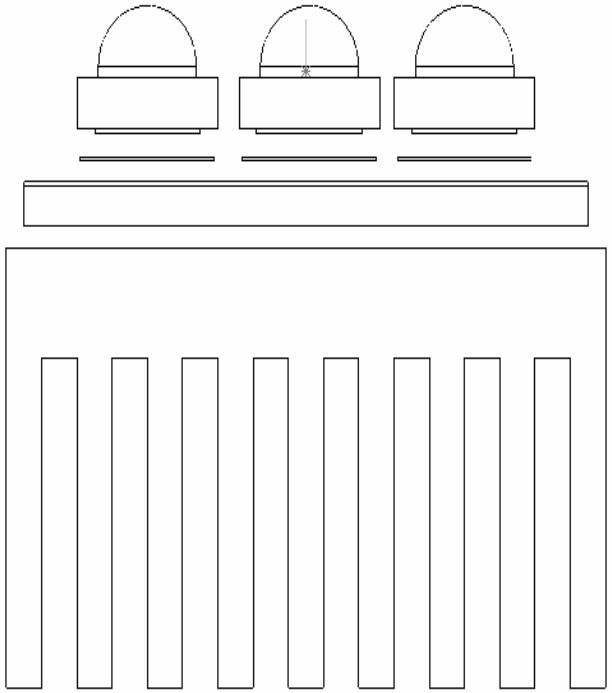
$$T_{Junction} = 76.3°C$$

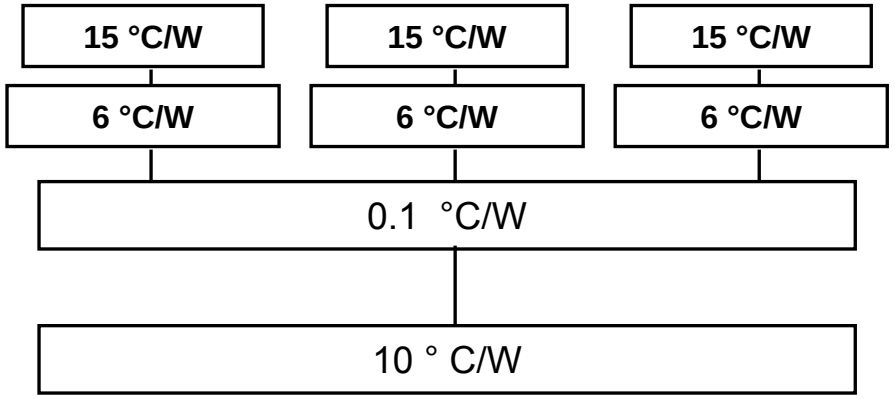
$$T_{Junction} = 25°C + (3W) \cdot (19°C/W) + (9W) \cdot (10.1°C/W)$$

$$T_{Junction} = 172.9°C!!!$$

Thermal Management Issues

Increasing from 1W to 3W LEDs
Operating temperature of +60°C





$$T_{Junction} = 60°C + (1W) \cdot (21°C/W) + (3W) \cdot (10.1°C/W)$$

$$T_{Junction} = 111{,}3°C$$

$$T_{Junction} = 60°C + (3W) \cdot (19°C/W) + (9W) \cdot (10.1°C/W)$$

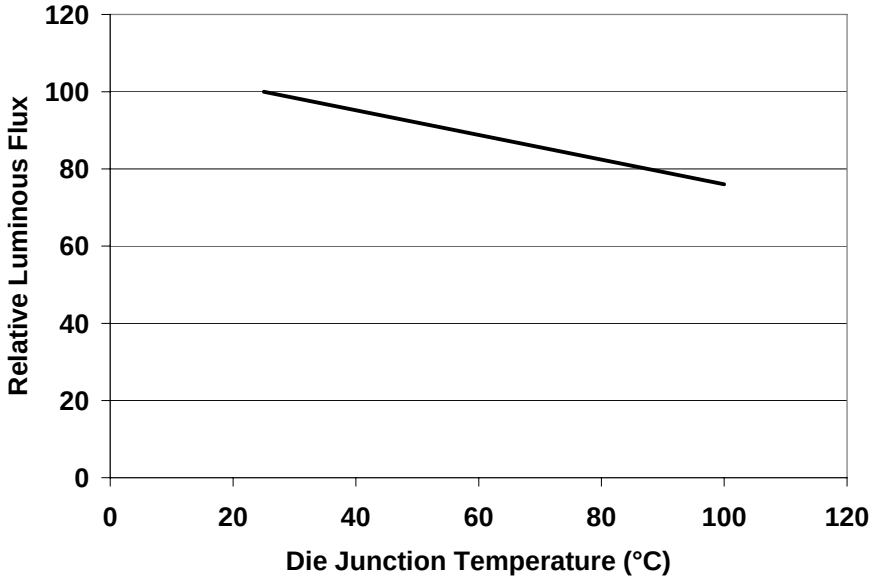
$$T_{Junction} = 207{,}9°C!!!$$

Datasheet Lumens vs Actual Lumens

1-Watt LEDs, 25 °C ambient temperature

Datasheet: 45 Lumens at a 25 °C die temperature
Dynamic resistance: 1 Ω
Temperature coefficient of Vf: -2.0 mV/ °C

15 °C/W thermal resistance for the LED
6 °C/W thermal resistance for the thermal epoxy and PCB dielectric
10 °C/W for the heatsink, board interface, etc.



Power Systems

Cool White LED Comparison

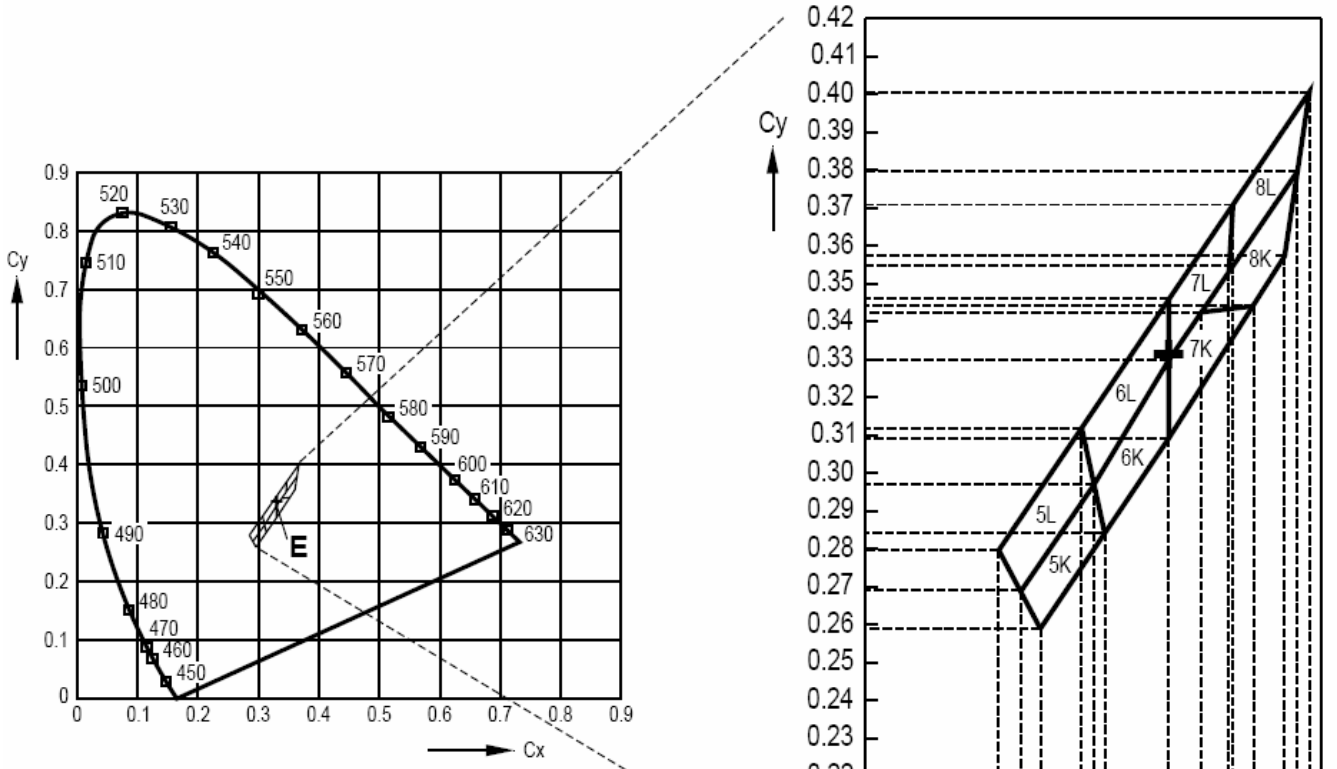
	Dice #	Viewing Angle Degees	Typical Lumens 350 mA	500 mA	700 mA	1000 mA	1400 mA	1500 mA	Typical Current mA	Typical Voltage Vf	Typical Power W	Thermal Restist-ance °C/W	Rise LED Only °C	Max Junction °C	CRI
Osram LW W5SG Cool	1	120	21-39	41					350	3.8	1.3	9	12	125	80
Osram ZW W5SG Cool	1	120	33-71	60					350	3.2	1.1	15	17	125	80
Osram LW W5SN Cool	1	120			52-97				700	3.8	2.7	8	21	135	80
Osram LW W5SM Cool	1	120		64					350	3.2	1.1	15	17	125	80
Osram LEW E3A Cool	6	120			300				700	22.5	15.8	3.6	57	150	80
Osram LEW E3B Cool	6	120			420				700	22.5	15.8	3.6	57	125	80
Osram LEW E2A Cool	4	120			200				700	15	10.5	5	53	150	80
Osram LEW E2B Cool	4	120			280				700	15	10.5	5	53	125	80
Lumileds LXHL-PW01 Cool	1	120	45						350	3.42	1.2	15	18	135	70
Lumileds LXHL-DW01 Cool	1	Side-emit	40.5						350	3.42	1.2	15	18	135	70
Lumileds LXHL-BW02 Cool	1	Batwing	45						350	3.42	1.2	15	18	135	70
Lumileds LXHL-PW09 Cool	1	120			65	80			700	3.7	2.6	13	34	135	70
Lumileds LXHL-DW09 Cool	1	Side-emit			58	70			700	3.7	2.6	13	34	135	70
Lumileds LXHL-PW03 Cool	4	150			87.4				700	6.84	4.8	8	38	135	70
Lumileds LXK2-PW etc Cool	1	150	52.5		87.5	110		135	1000	3.72	3.7	9	33	150	70
Nichia NCCW002, etc Cool	1	35,70,120	42	?					350	3.7	1.3	17	22	105	80
Nichia NS6W083 Cool	4	120	60	?					350	3.6	1.3	10	13	120	80
Cree XL7090 Cool	1	100	52		?				350	3.5	1.2	17	21	125	75
Cree 3XL7090 Cool	1	100			76				700	4	2.8	17	48	145	75
Cree XL7090XR Cool	1	100	53.5		?				350	3.5	1.2	8	10	145	75
Seoul Semi W10190 Cool	1	70,110	52						350	3.5	1.2	8	10	125	70
Seoul Semi W10290 Cool	2	70,110			103				700	3.5	2.5	6	15	125	70
Seoul Semi W10490 Cool	4	70,110					178		1400	3.5	4.9	4	20	125	70
Cotco LD-700AWN1-70 Cool	1	70	27						350	3.6	1.3	15	19	125	

White is White is White

VS

Binning Issues

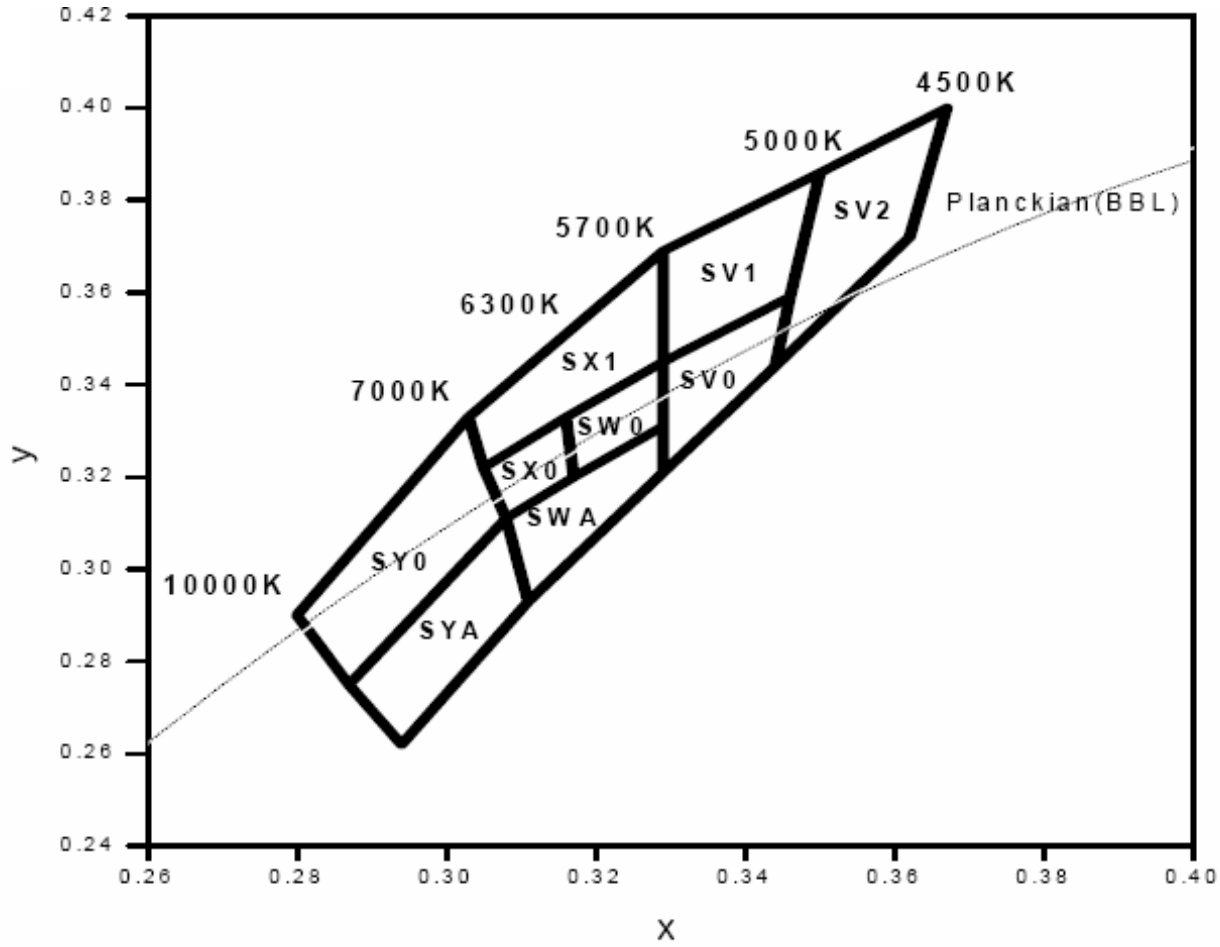
Osram White Binning



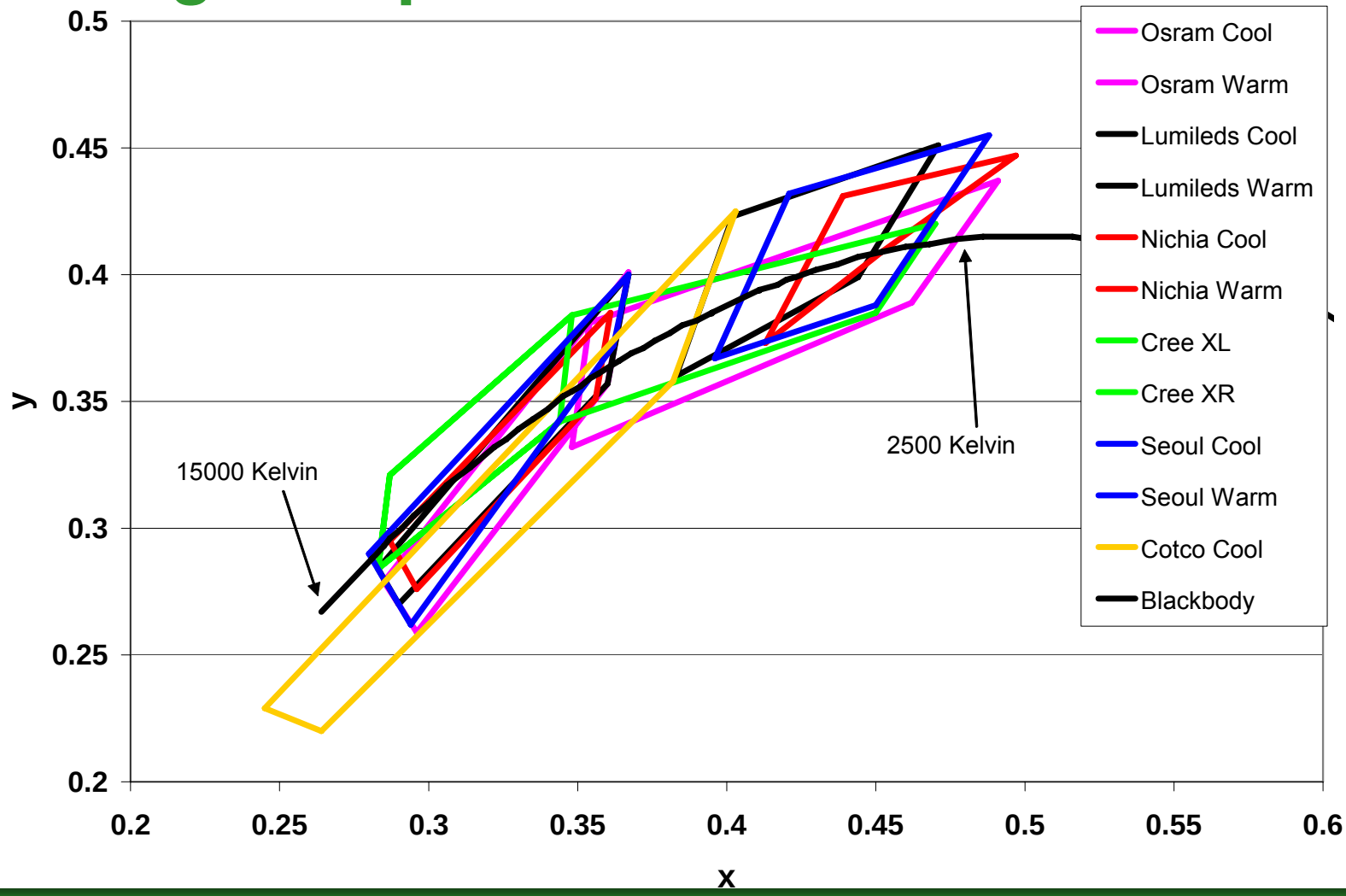
White is White is White

Binning Issues

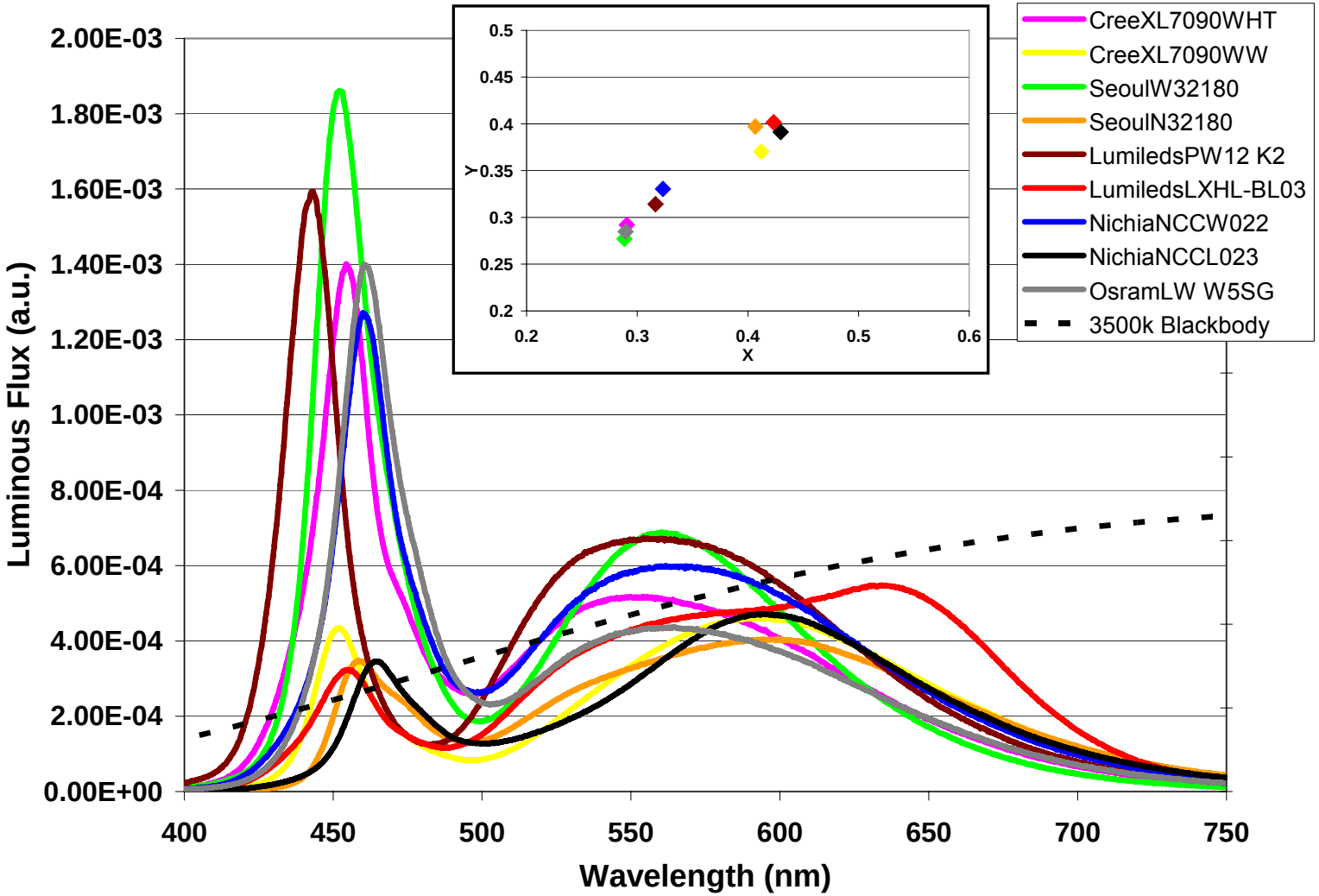
Seoul White Binning



Chromaticity Binning Comparison

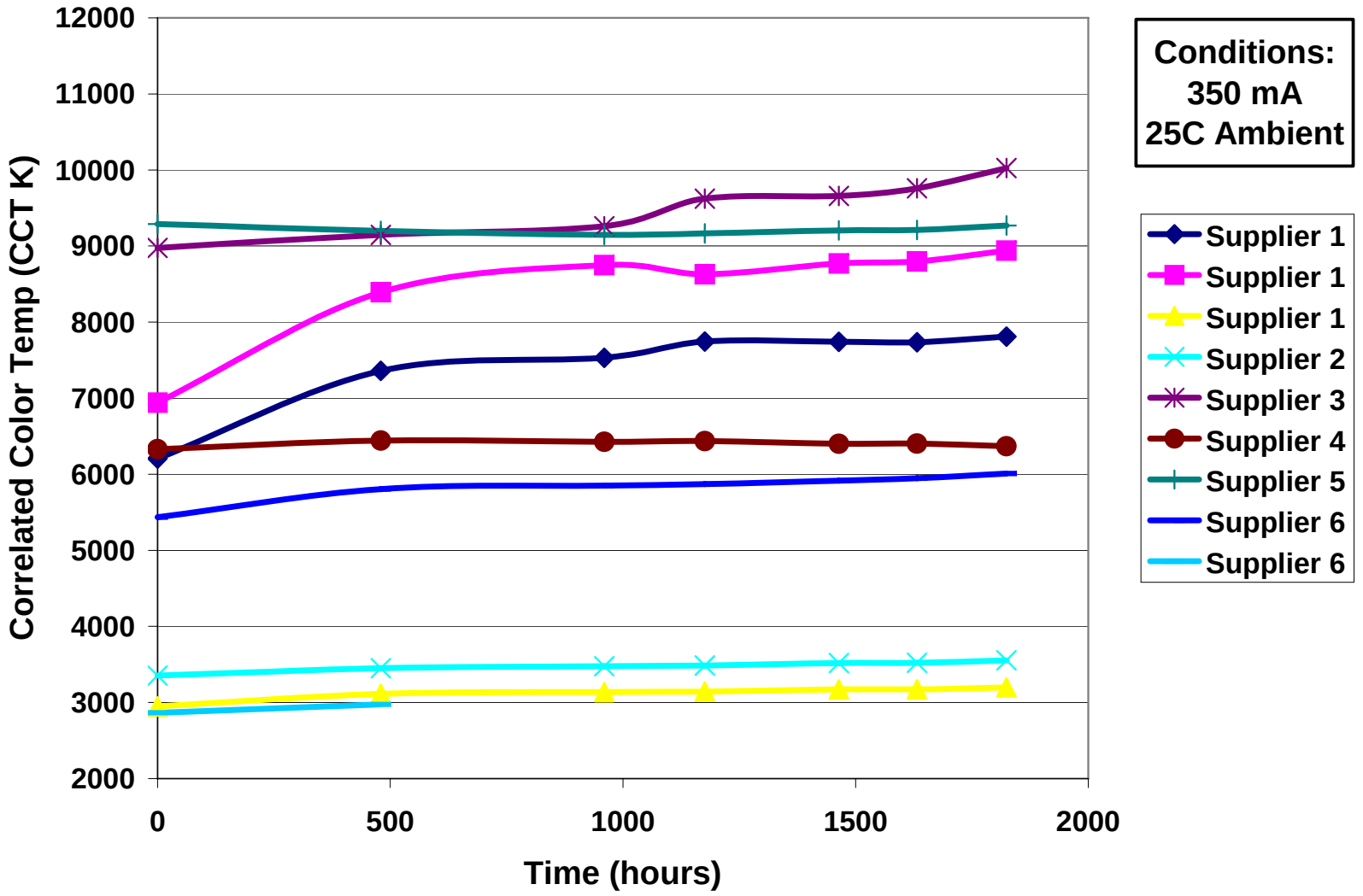


Spectral and Chromaticity Measurements

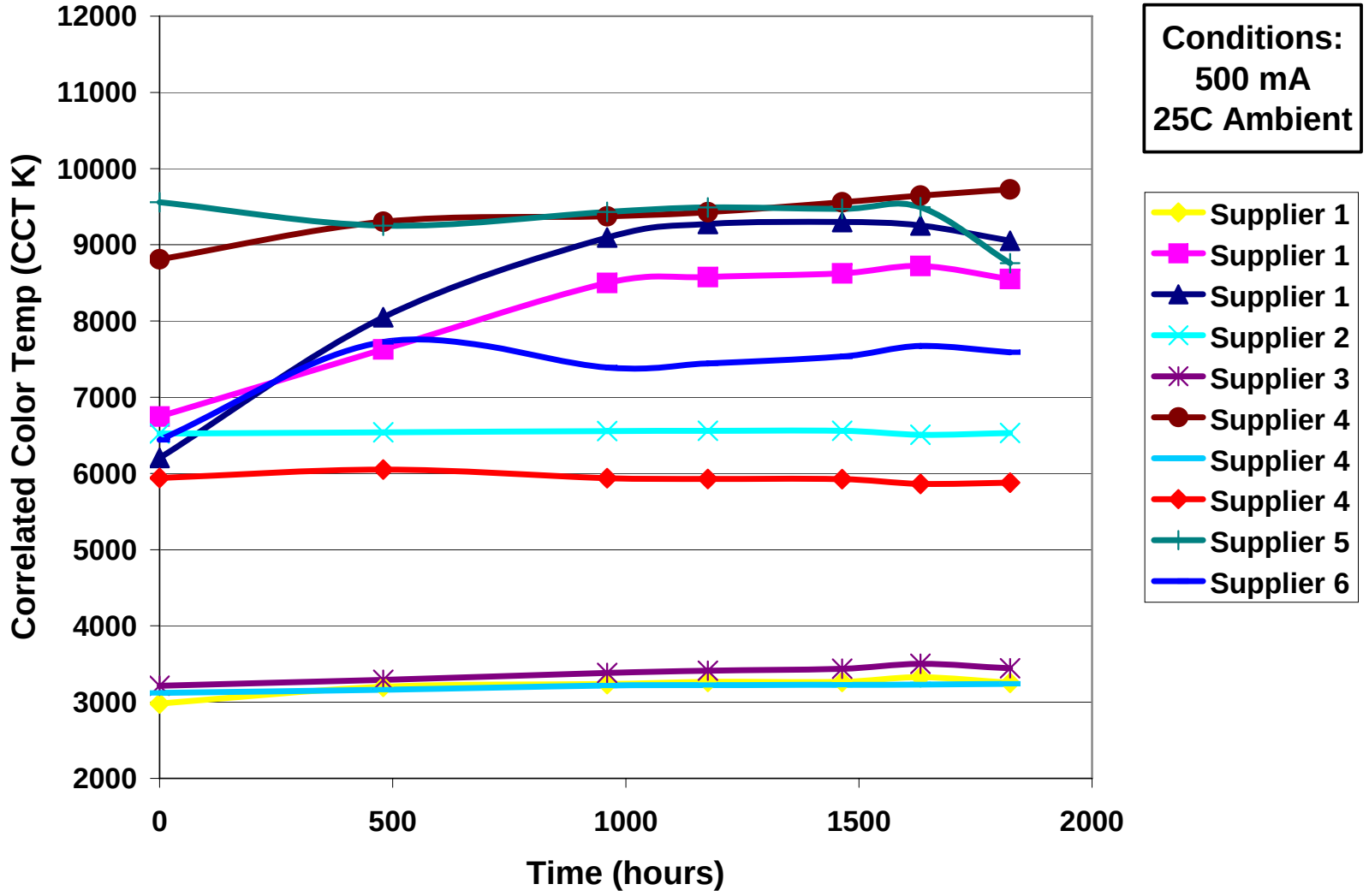


CCT Change with Time

VS

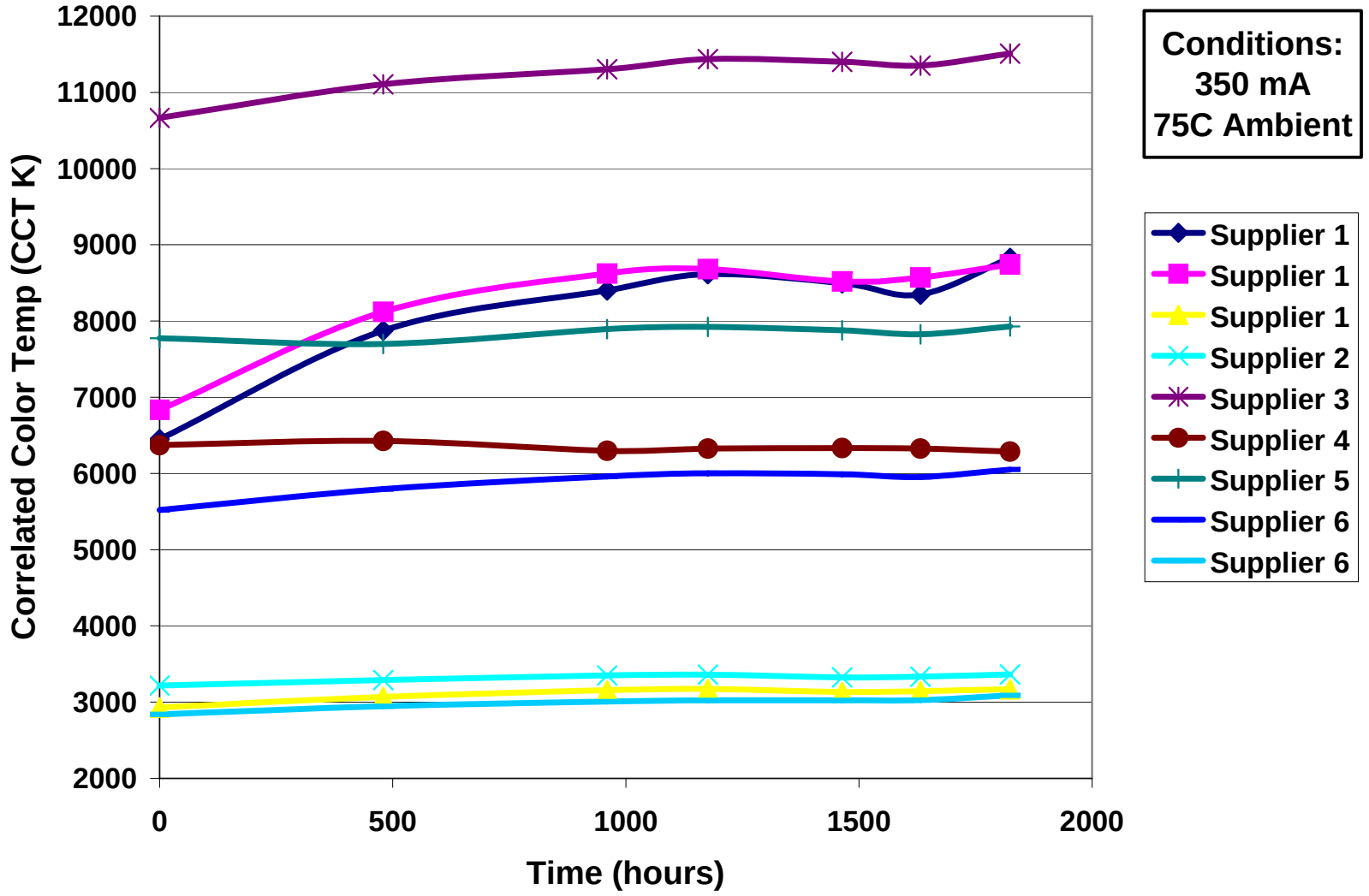


CCT Change with Time



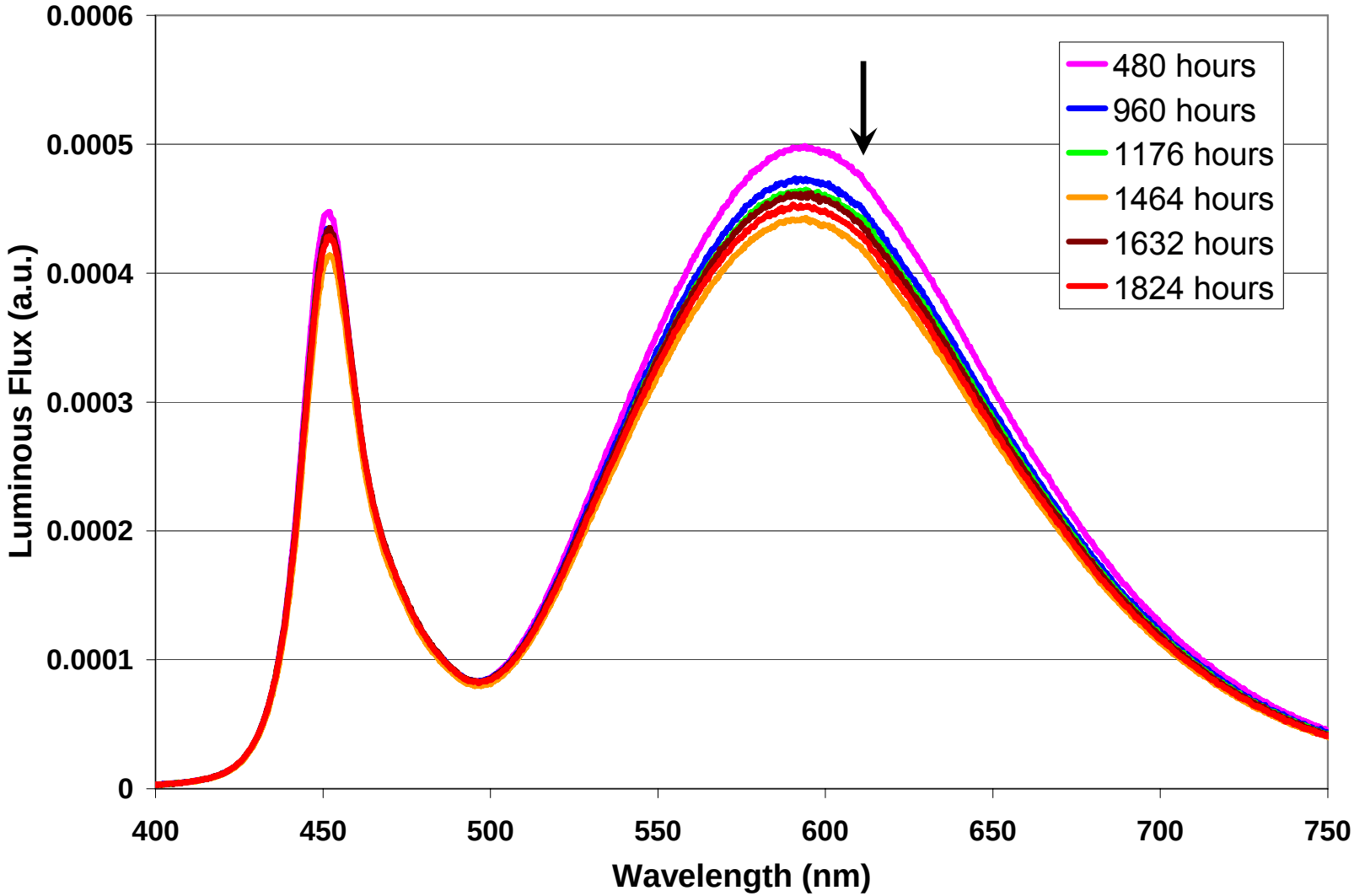
CCT Change with Time

VS



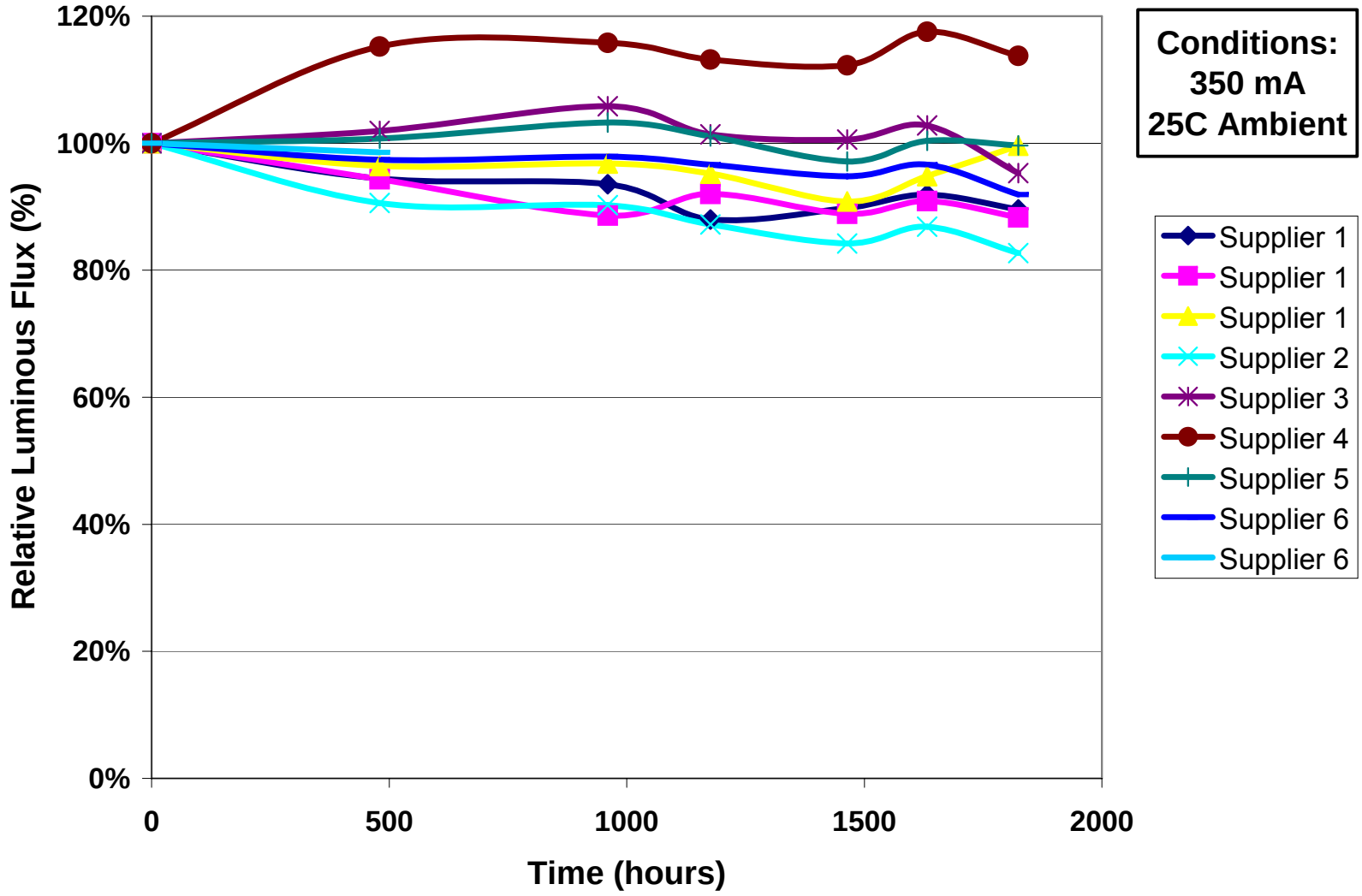
CCT Change with Time

VS



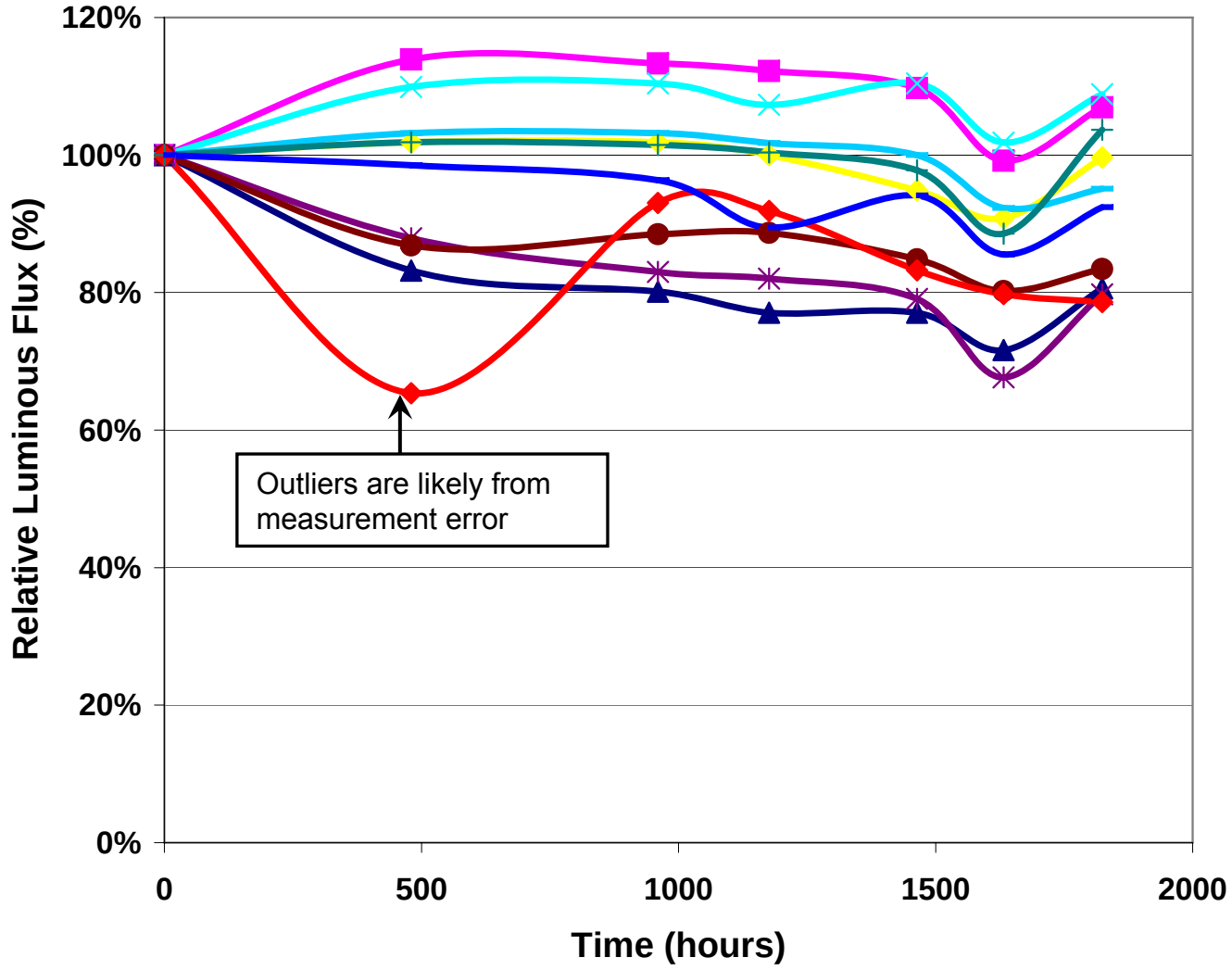
Luminous Flux Change with Time

VS



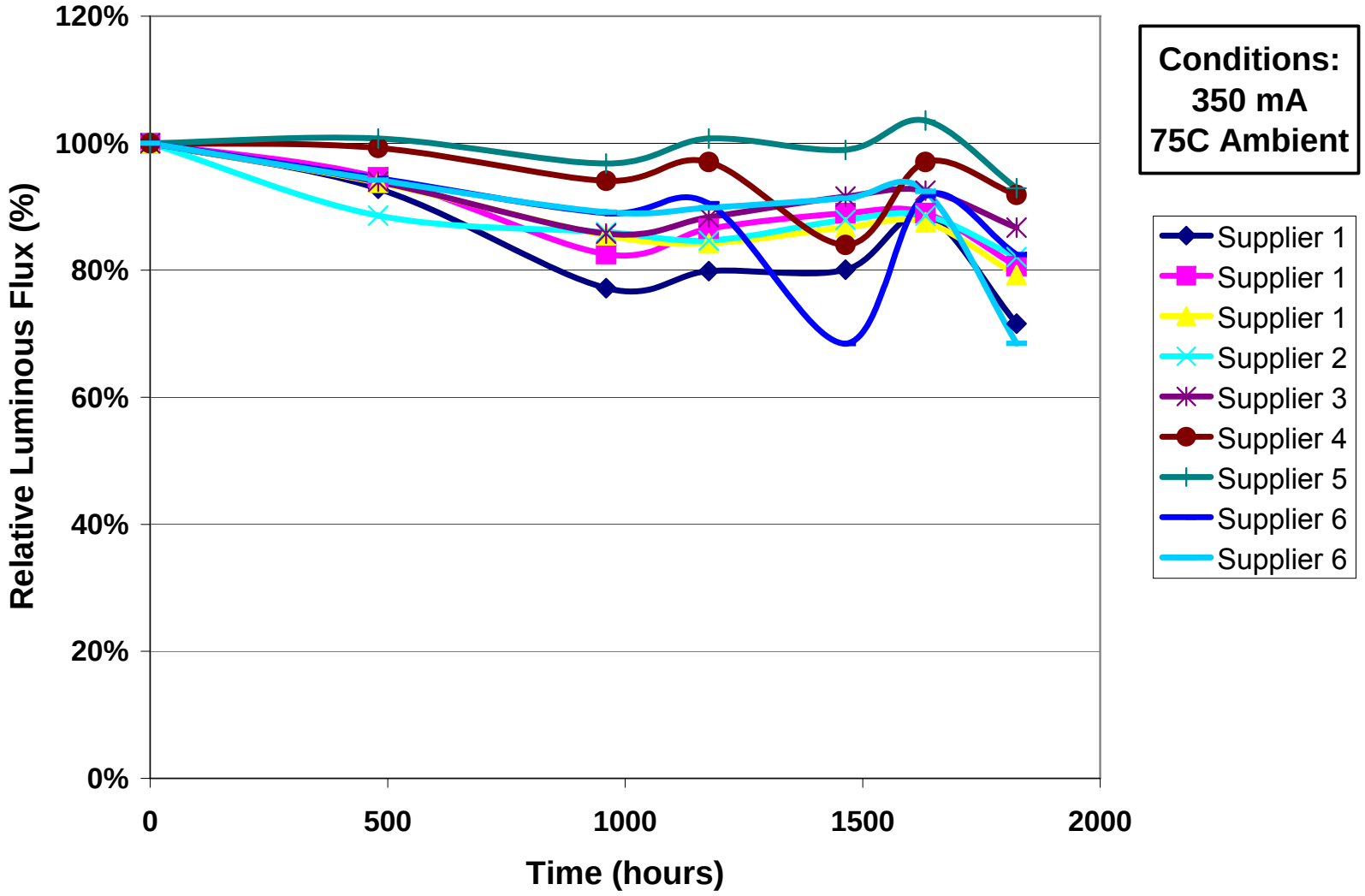
Luminous Flux Change with Time

VS



Luminous Flux Change with Time

VS



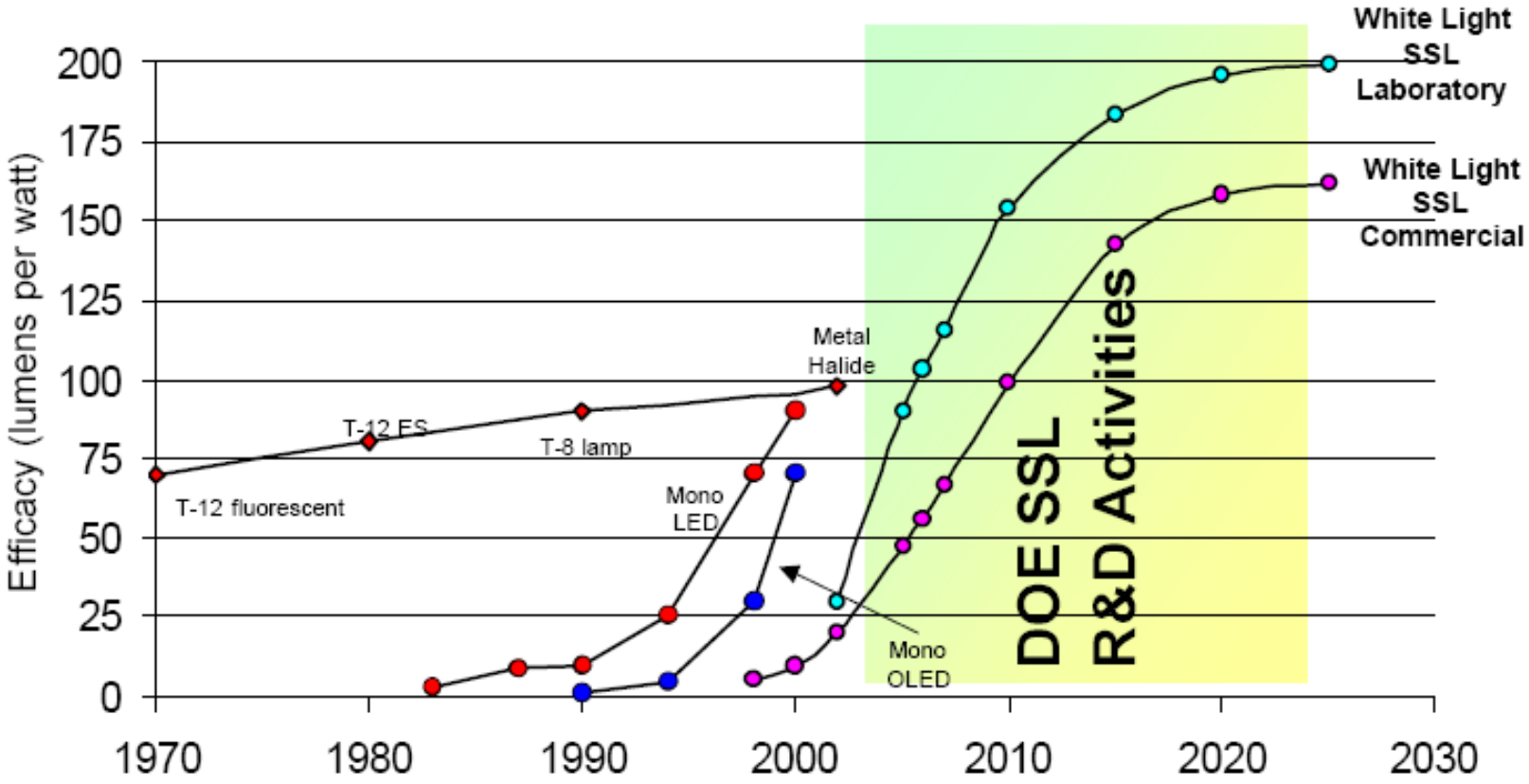
The Cost of Light

Lamp Type	Watts	Life	Initial Lumens	Maintained Lumens	Price	Luminous Efficiency	klm/$	$/Mlmh
Incandescent	60	1.000	850	850	$0,90	14	0,94	$12,82
Flourescent	32	24.000	3.000	2.900	$1,50	91	2,00	$1,18
High Pressure Mercury	250	24.000	11.000	8.500	$21,00	34	0,52	$3,06
High Pressure Sodium	250	24.000	28.000	27.000	$27,00	108	1,04	$0,97
Metal Halide	400	20.000	36.000	24.000	$70,00	60	0,51	$1,82
White LED (Luxeon K2)	5	50.000	100	75	$3,50	15	0,03	$8,67

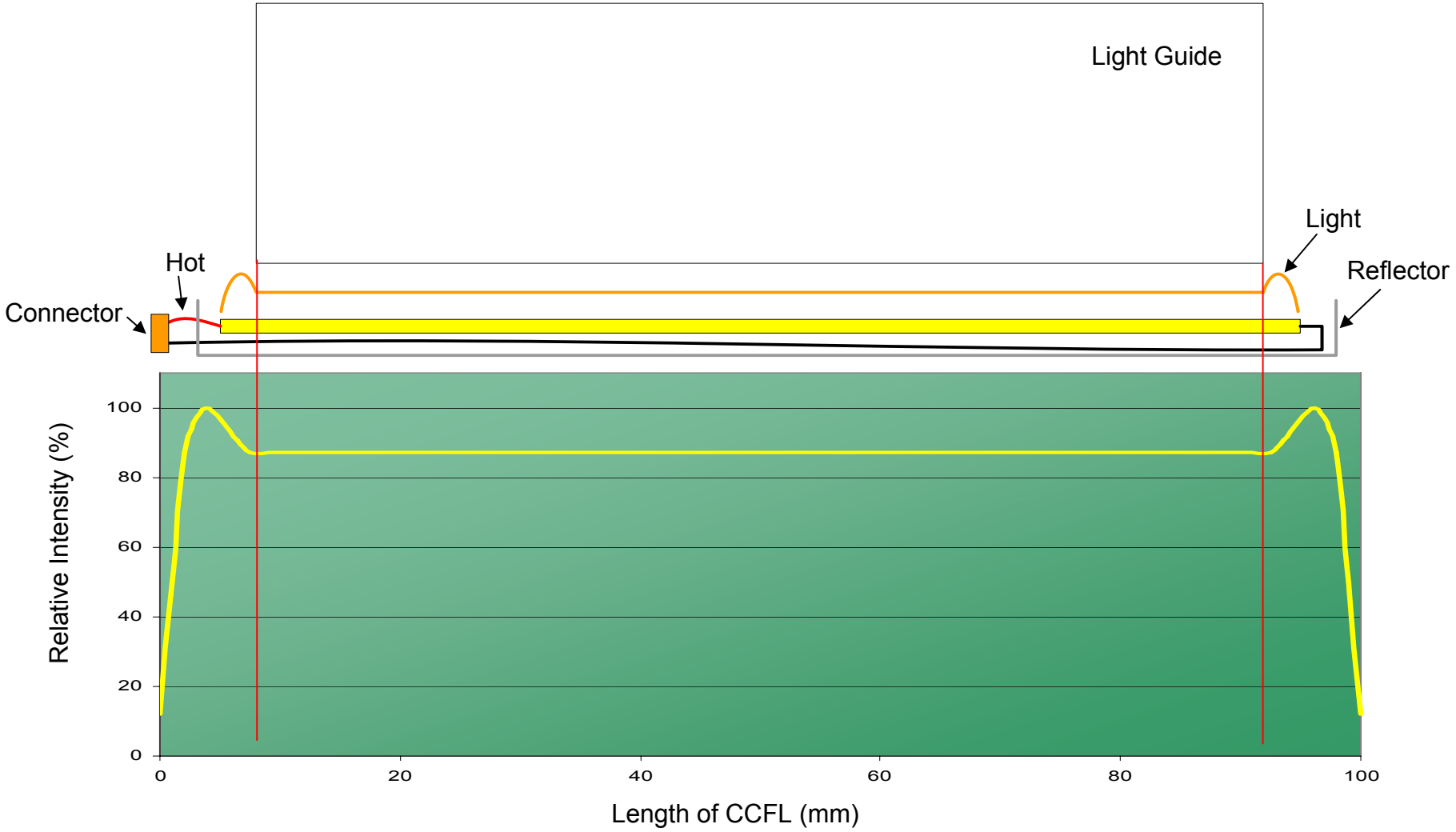
$$\text{Cost of Light} = \frac{[\,p + h\,] / L + [W \times R]}{F} \quad \text{(in \$ / Mlm-hr)}$$

Where p is the lamp price (in cents)
h is the labor cost to replace lamp (in cents) assumed to be 400¢
L is the lamp life (in hours)
F is the lamp flux output (in lumens)
W is the lamp input power (in watts)
R is the energy cost (in cents/kW-hr) assumed to be 10¢

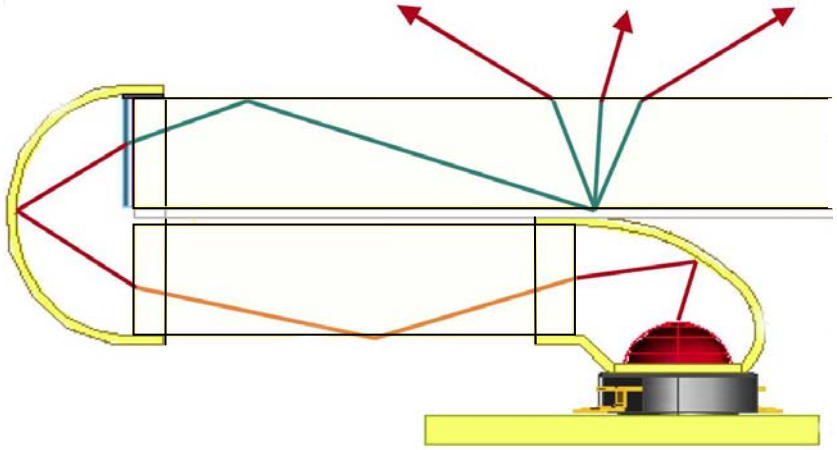
Luminous Efficiency
Improvement Trends

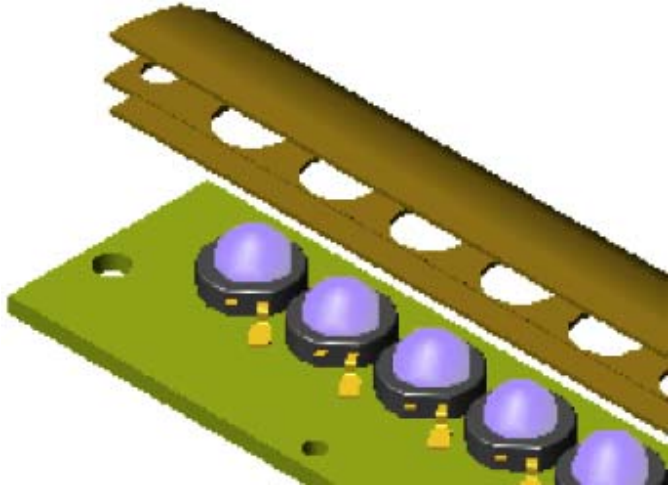


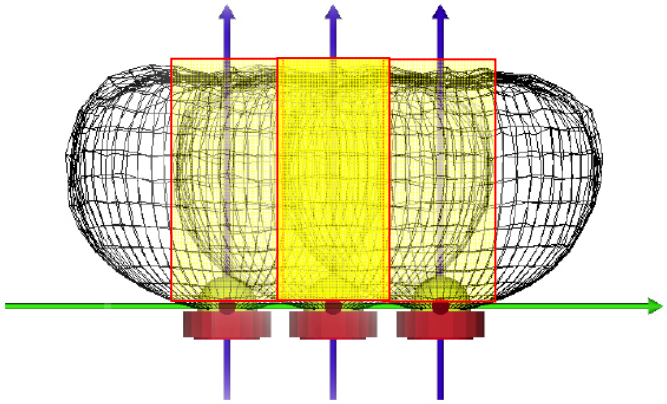
CCFL – Light Intensity



LED – On The Side

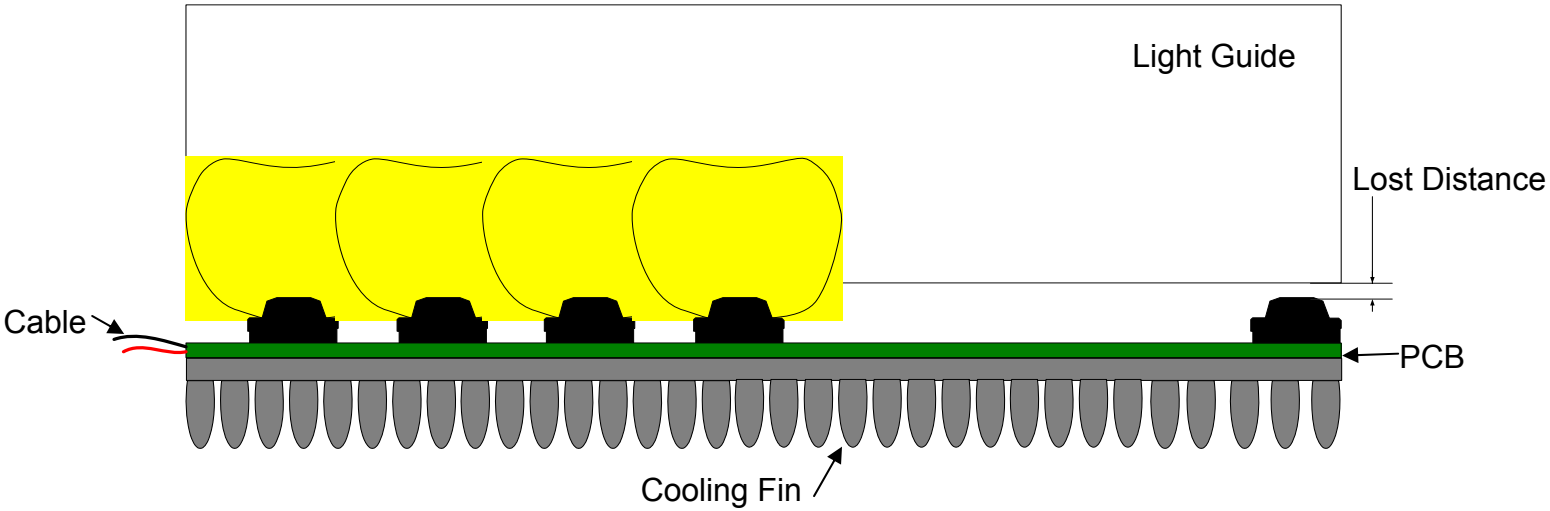


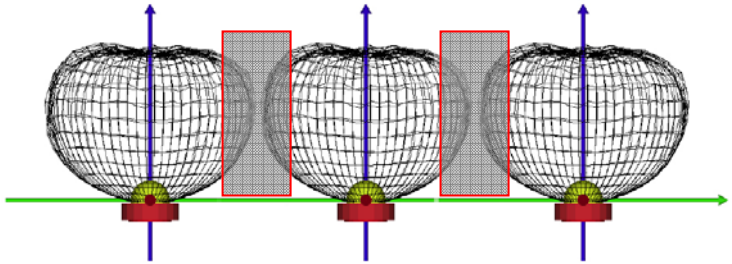




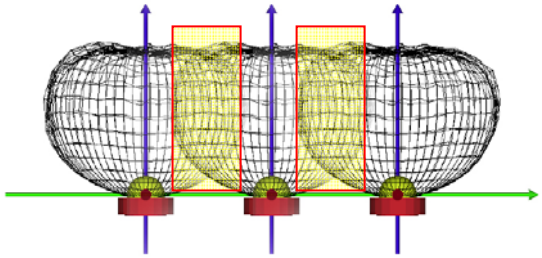
overexposed Area

LED – Light Intensity



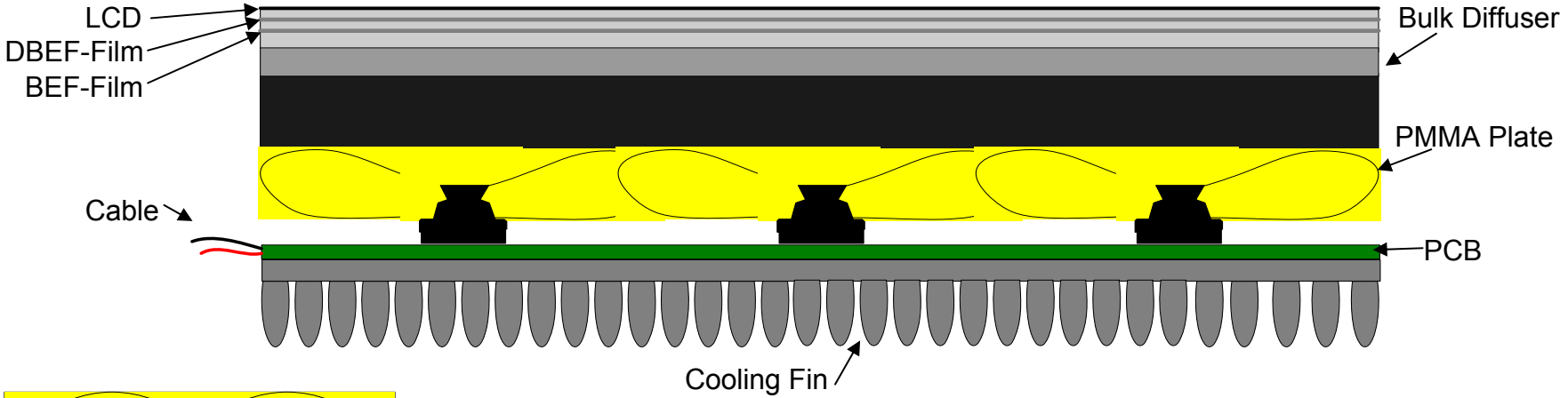


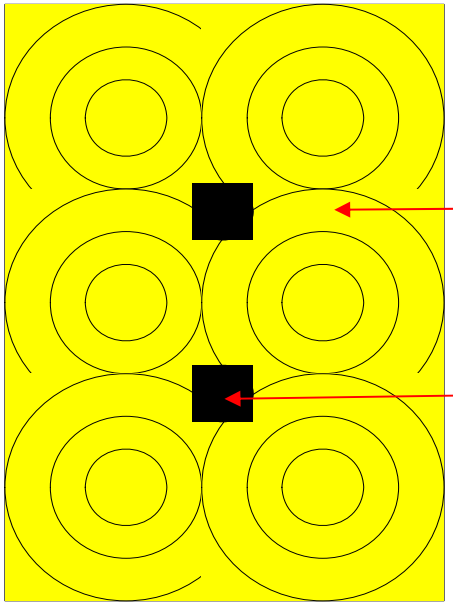
underexposed Area

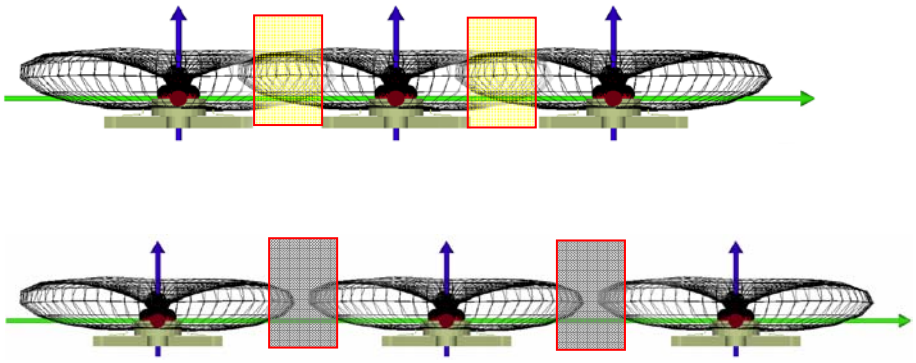


overexposed Area

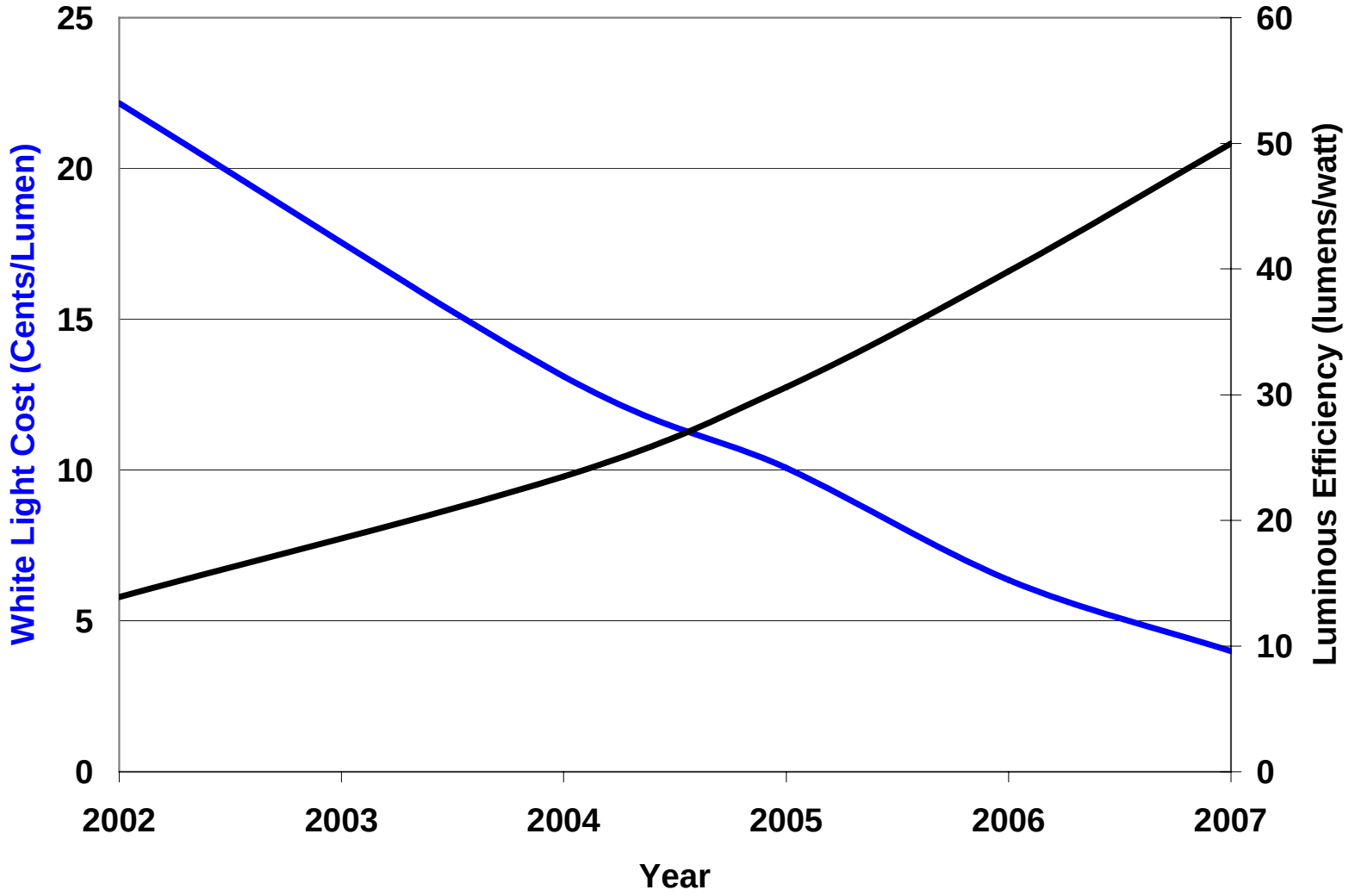
LED – Backside







White LED Trends



Advantage vs Disadvantage

Issue	CCFL	LED	Note
Size	+ +	- -	
Homogeneous of Luminance	+	-	
Dimmable	-	+ +	
Lifetime@-30°C	- -	+ +	very good for automotive
Lifetime@0°C	+	+ +	
Lifetime@+25°C	+ +	+	
Lifetime@+60°C	+ +	- -	
Lifetime@+85°C	+ +	- - -	very bad for automotive
Environmental	- -	+	CCFL mercury is very low
Color Stabilization	+ +	+	
Brightness Stabilization	+	+	
Lost Temperature	+ +	-	For the same brightness
EMI	-	+	
Driving Voltage	- -	+	
Useable for Ex-Protected Area	-	+ +	
Medicine Application	+	+ +	
Price of System	+ +	-	approx. +20%

LED-Converter vs Resistor

Examples for three HBLEDs with resistor

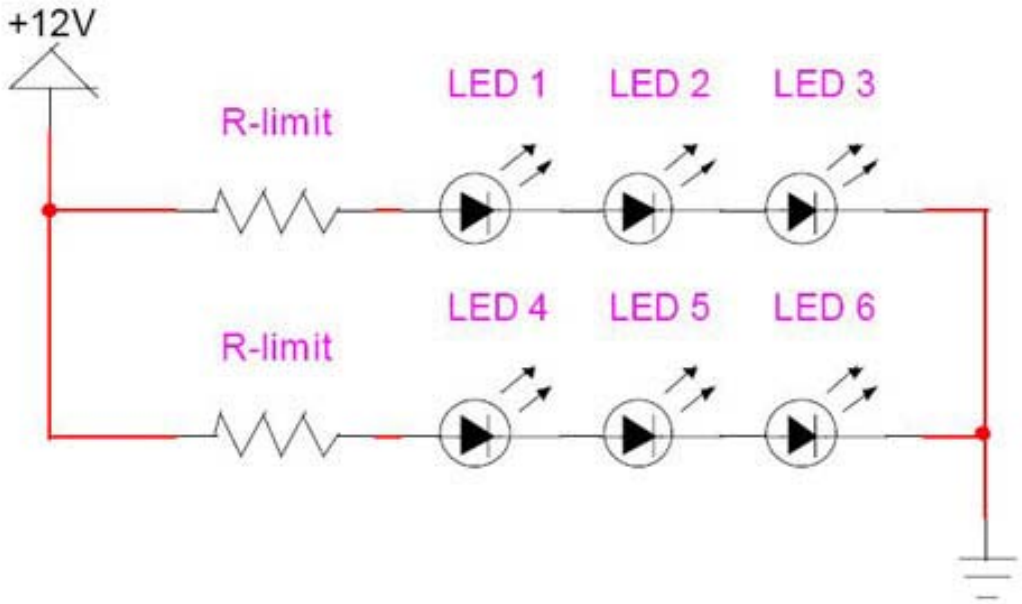
R-limit = (Vin - (3 * Vfwd)) / Ifwd
= (12V - (3 * 3.0V)) / 0.5A
= 6 ohms

P-limit = $Ifwd^2$ * R-limit
= 0.5^2 * 6
= **1.5 Watts**

P LEDs = 3 * Vfwd * Ifwd
= 3 * 3.0V * 0.5A
= **4.5 Watts**

Efficiency = PLEDs / (PLEDs + Plimit
= 4.5W/ (4.5W + 1.5W)
= **75%** *Not too impressive!*

Ifwd = (Vin - (3 * Vfwd)) / Rseries
= (11.4V - (3 * 3.0V) / 6 ohms
= 0.4 Amps



Delta **Vin = +/-5% variation** of the +12V power supply will yield a **+/- 20% variation in LED** current — and therefore in LED brightness and life time. Of course, this variation could be reduced by increasing the voltage across the dropping resistor, but this would make the electrical efficiency only worse.

Power Systems

LED-Converter vs Resistor

Examples for three HBLEDs with Converter

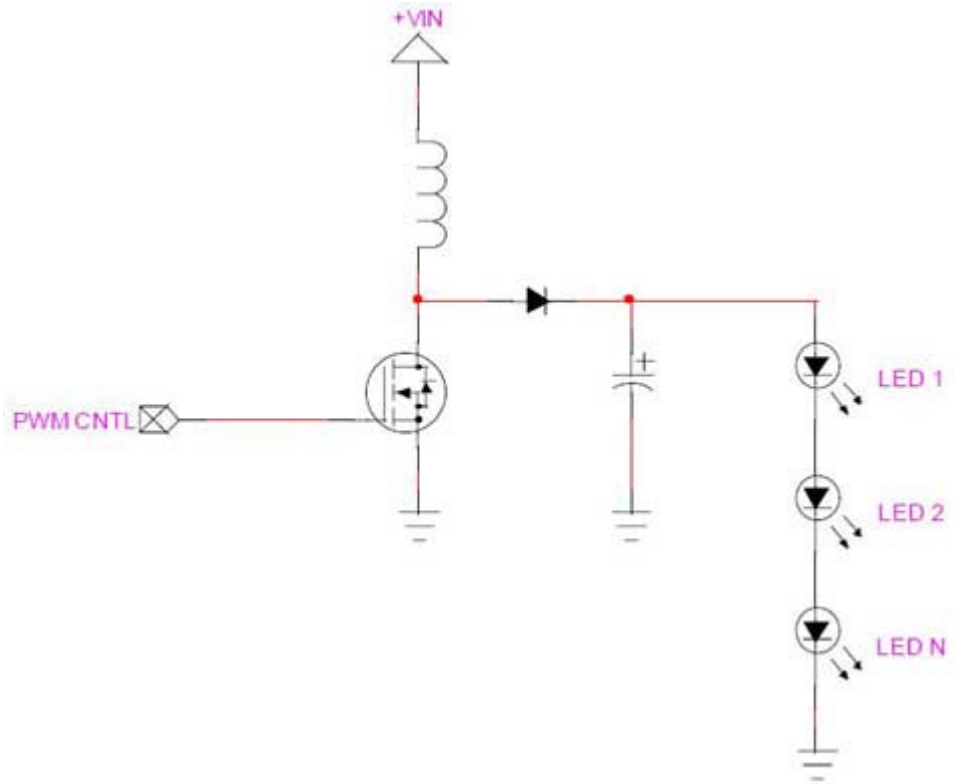
R-limit = (Vin - (3 * Vfwd)) / Ifwd
= (12V - (3 * 3.0V)) / 0.5A
= 6 ohms

P-limit = $Ifwd^2$ * R-limit
= 0.5^2 * 6
= **1.5 Watts**

P LEDs = 3 * Vfwd * Ifwd
= 3 * 3.0V * 0.5A
= **4.5 Watts**

Efficiency = Converter
= >**89%** *impressive!*

Ifwd = (Vin - (3 * Vfwd)) / Rseries
= (11.4V - (3 * 3.0V) / 6 ohms
= 0.4 Amps

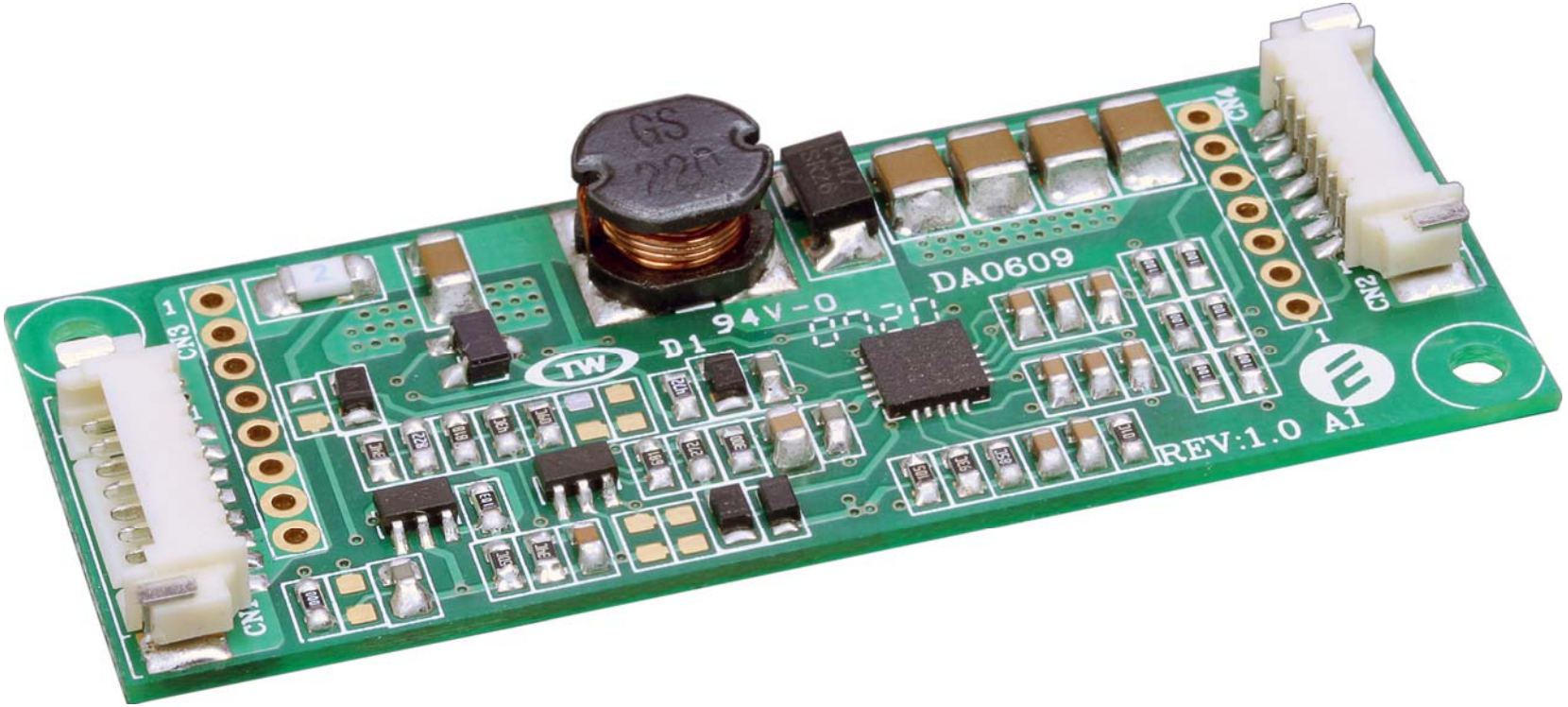


Delta **Vin = +/-5% variation** of the +12V power supply will yield a **+/- 0% variation in LED** current !!

Power Systems

LED-Converter

Power Systems Converter

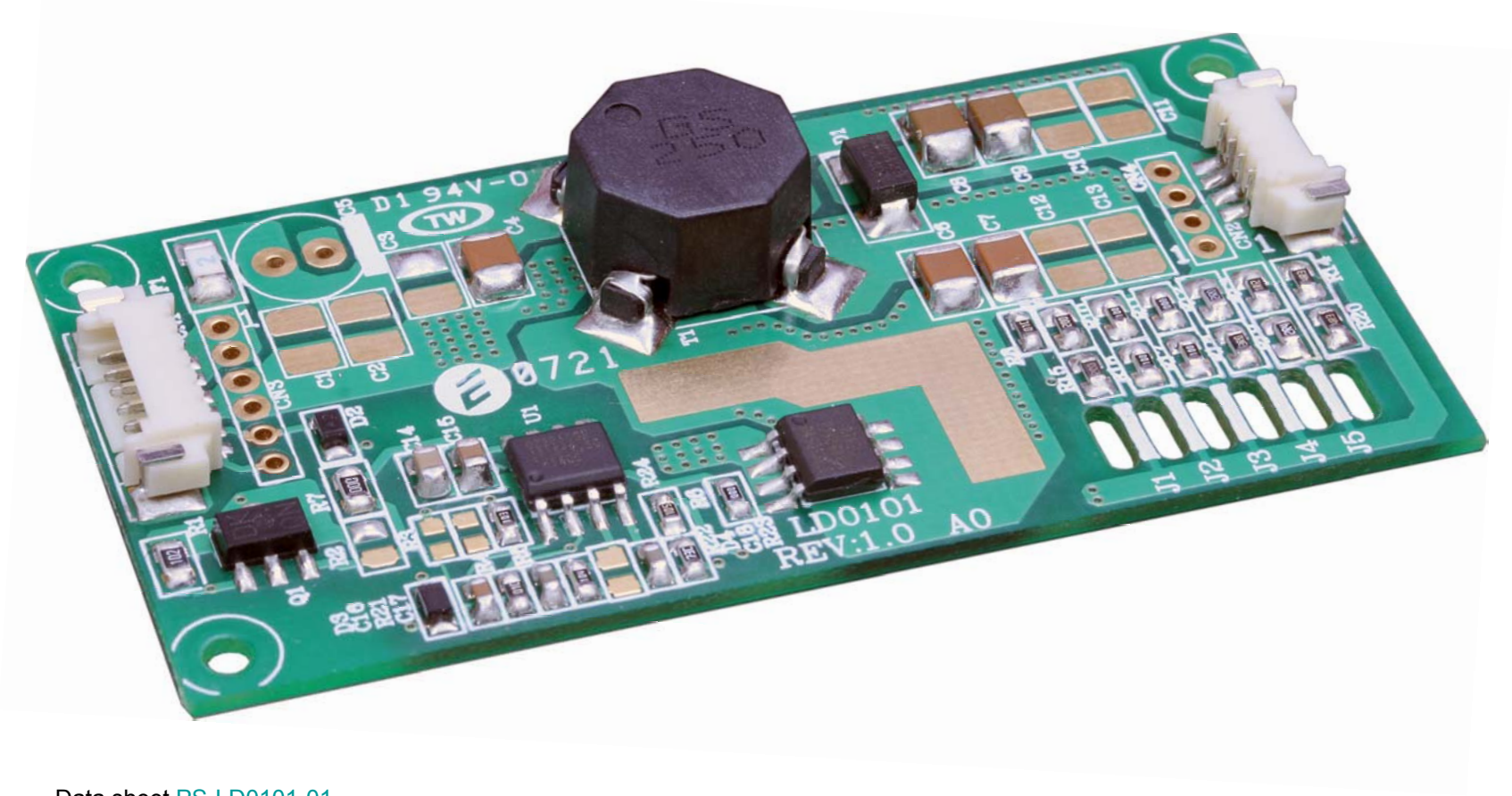


Data sheet PS-LD0609-01

Power Systems

LED-Converter

Power Systems Converter



Data sheet PS-LD0101-01

Advantage vs Disadvantage

VS

LED and CCFL will life in harmony together.
Both technologies have advantages and disadvantages.
Our all customer need to decide what they need and want.
Our job is to explain them the technologies.

Good success.