

Light and Color Possibilities With LED Street Lighting

Navigating the Technical and Social Issues as a Manufacturer

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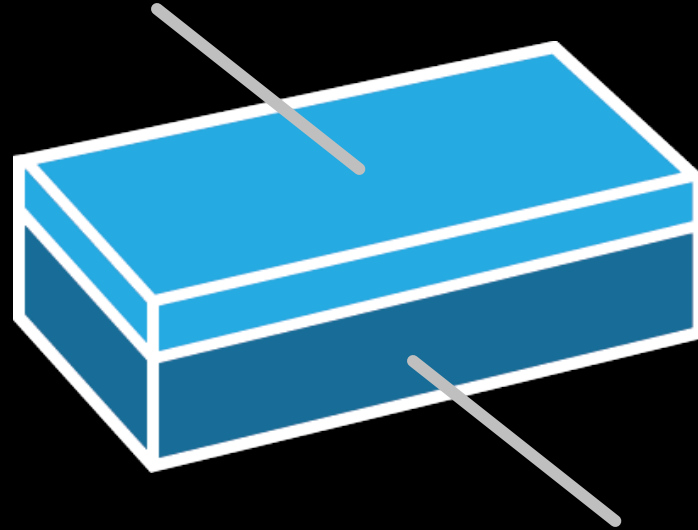
Creating White Light

A glowing white circle with a soft, radial gradient, centered on a black background. Inside the circle, the words "WHITE" and "LIGHT" are stacked vertically in a bold, black, sans-serif font.

**WHITE
LIGHT**

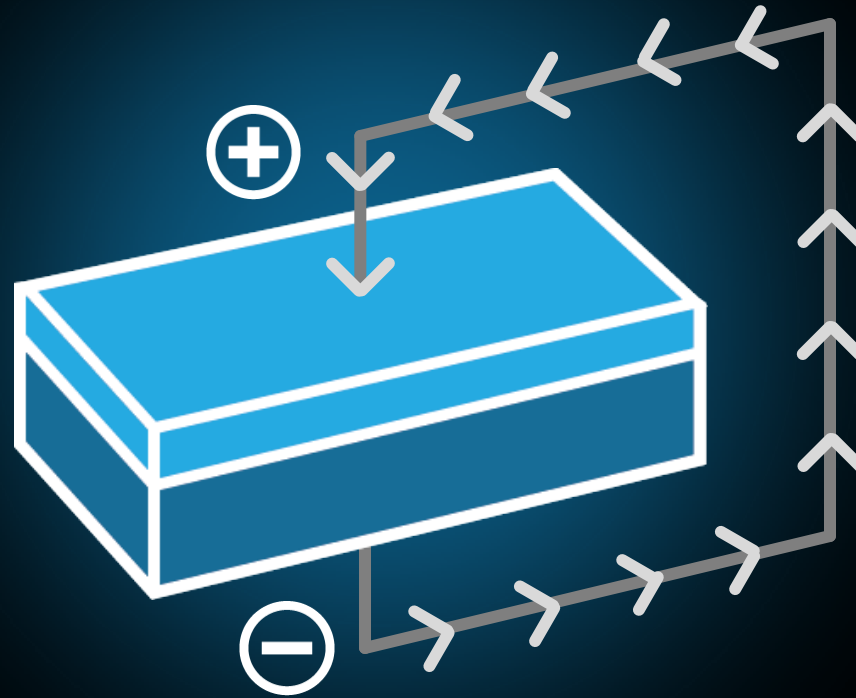
White Light for General Illumination

Epitaxial Layer

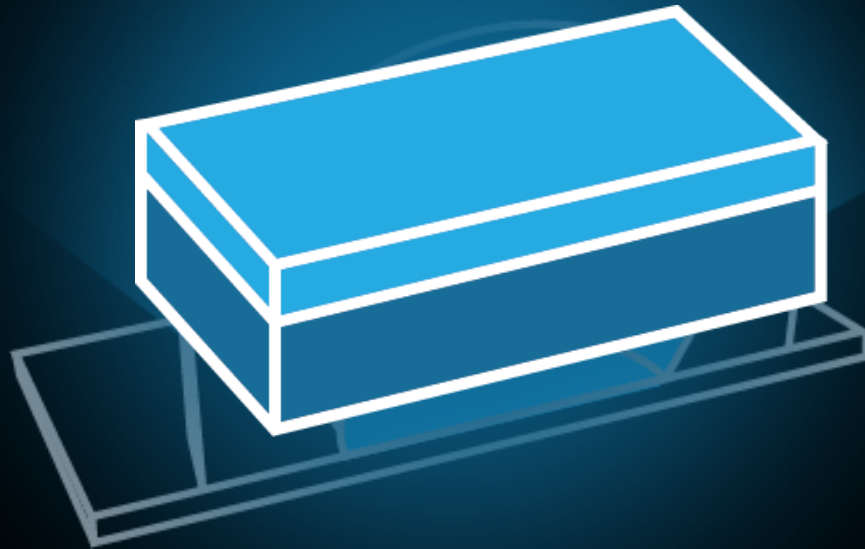


Substrate

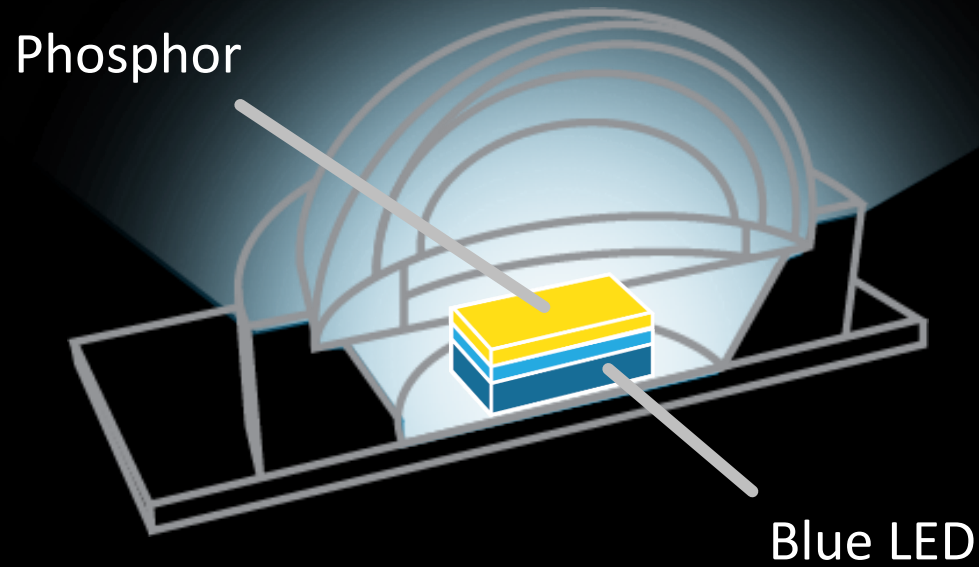
LIGHT EMITTING DIODE



LIGHT EMITTING DIODE

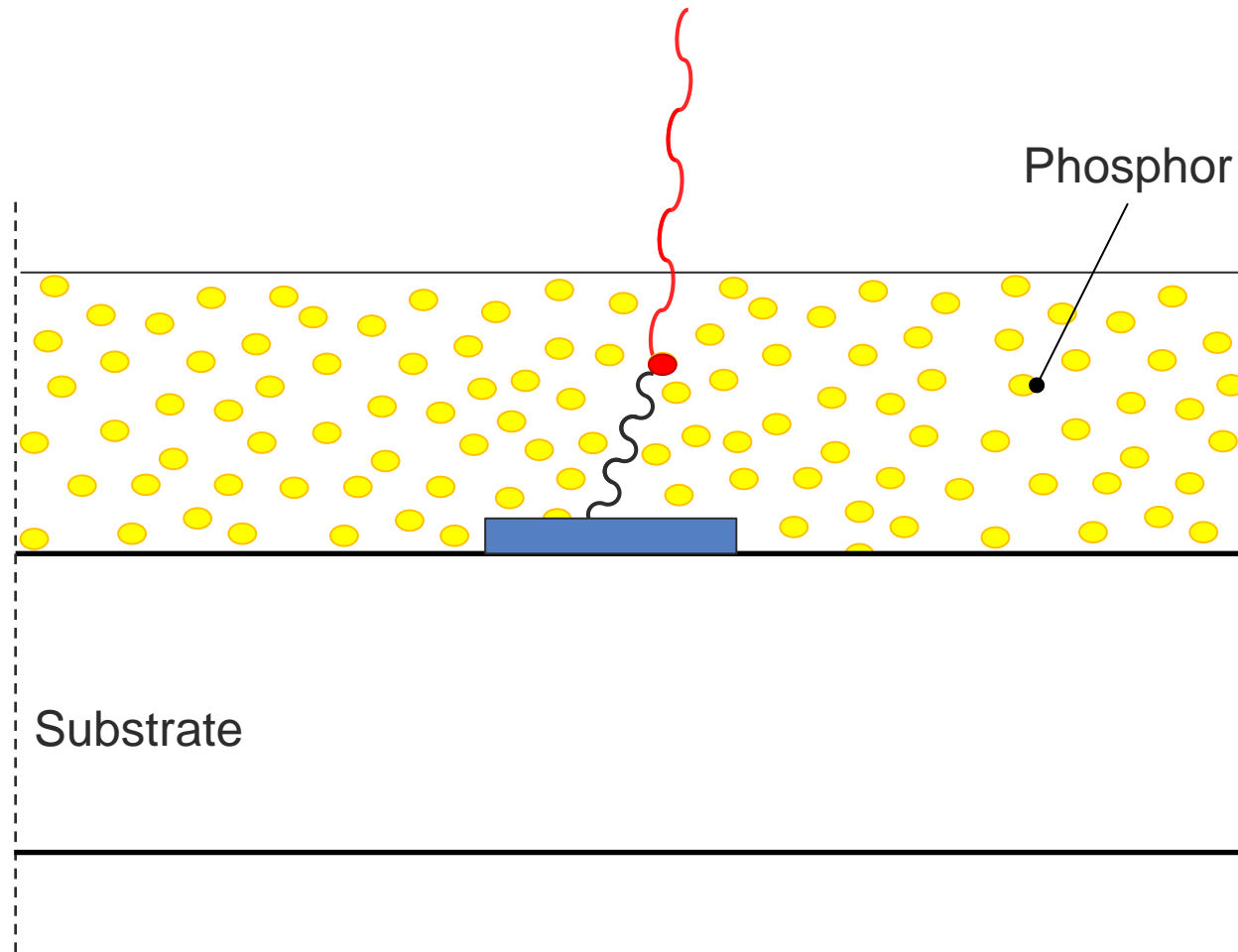


LED Package



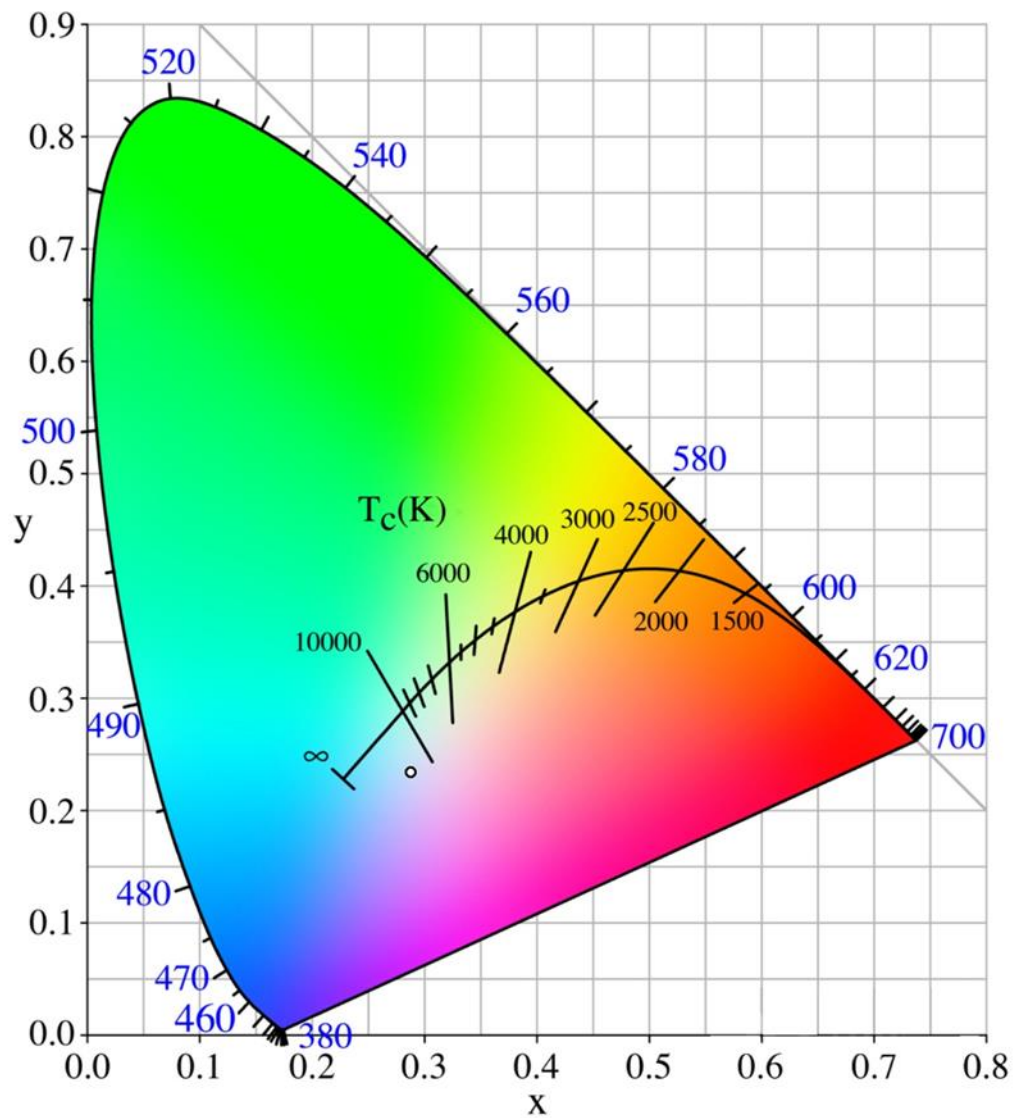
Blue + Phosphor

Generating White Light with LEDs

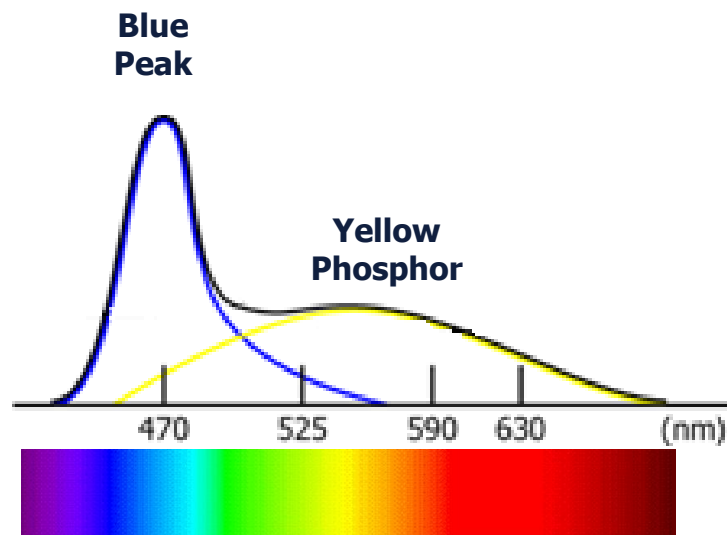
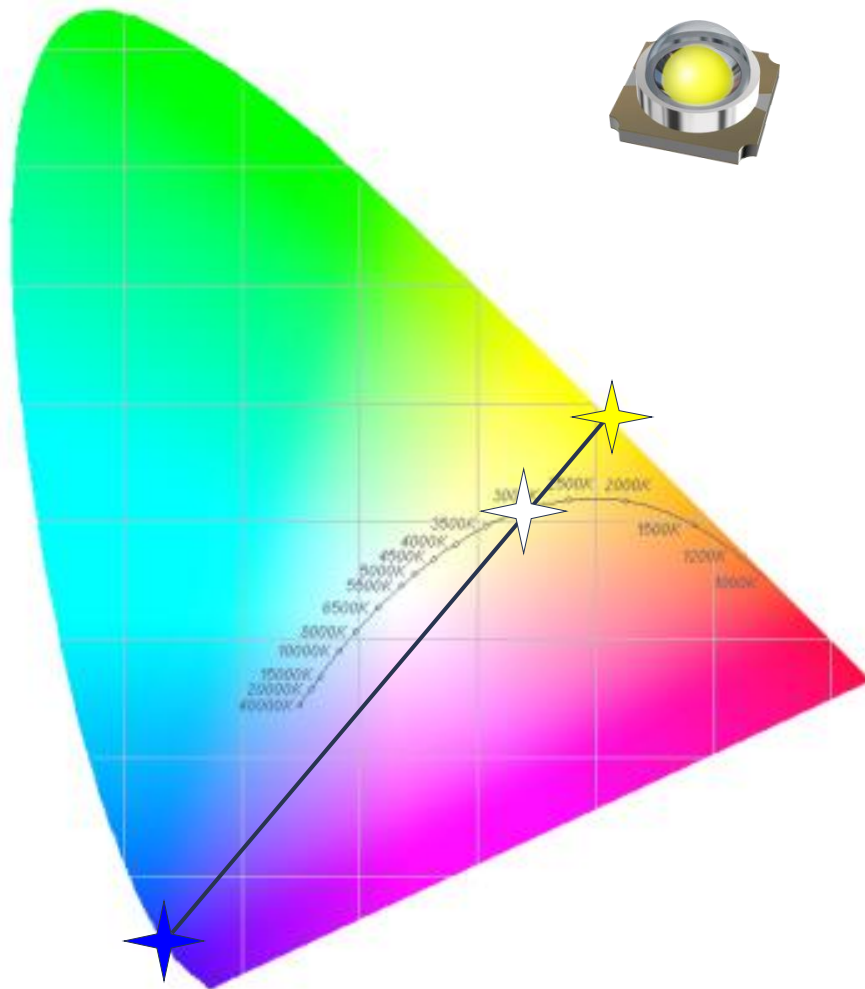
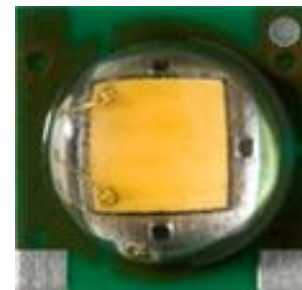
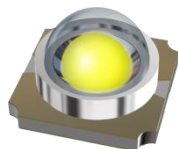


Blue photons emitted from the LED chip strike phosphor particles and are down converted to longer wavelengths.

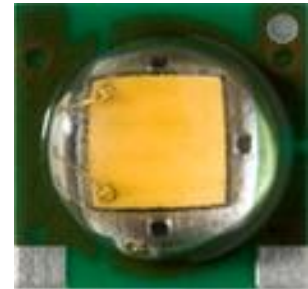
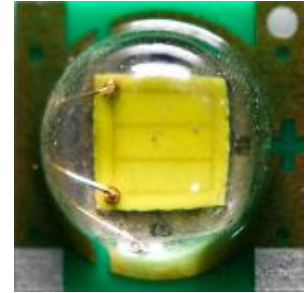
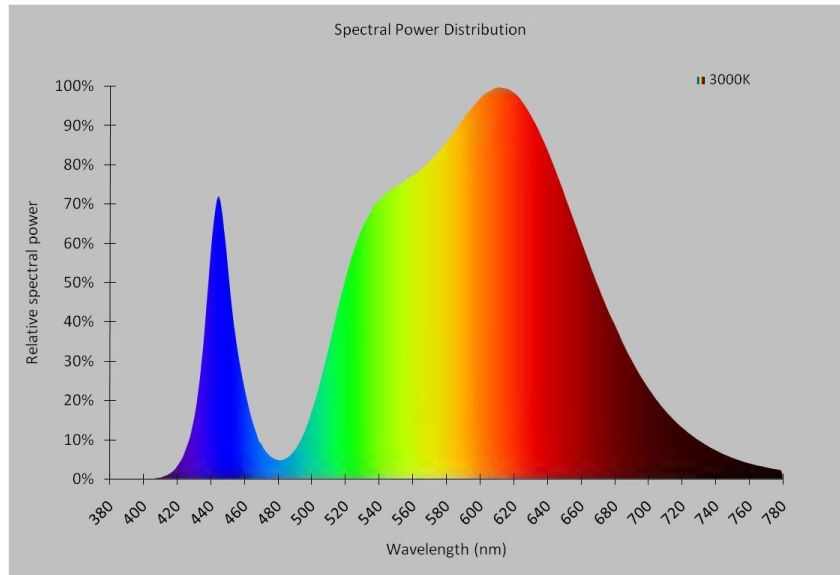
CIE 1931 Color Space



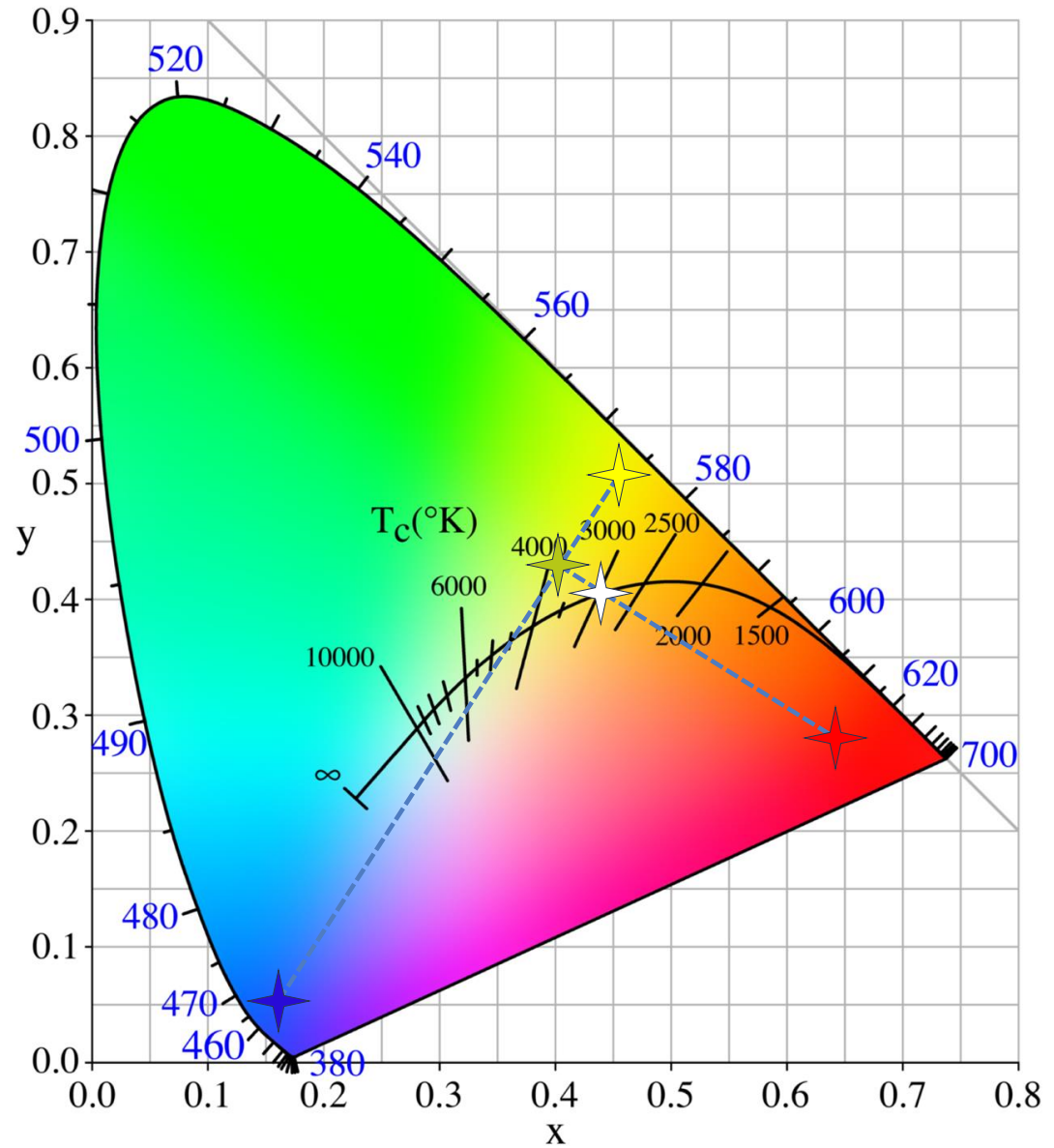
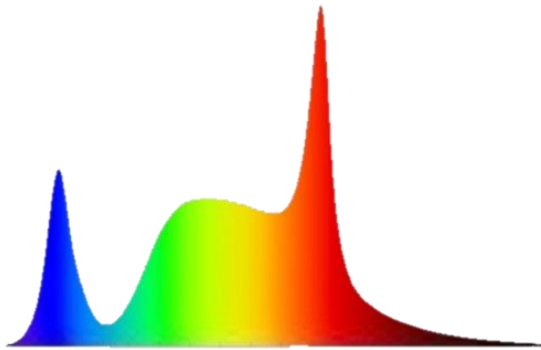
Blue + Yellow Phosphor

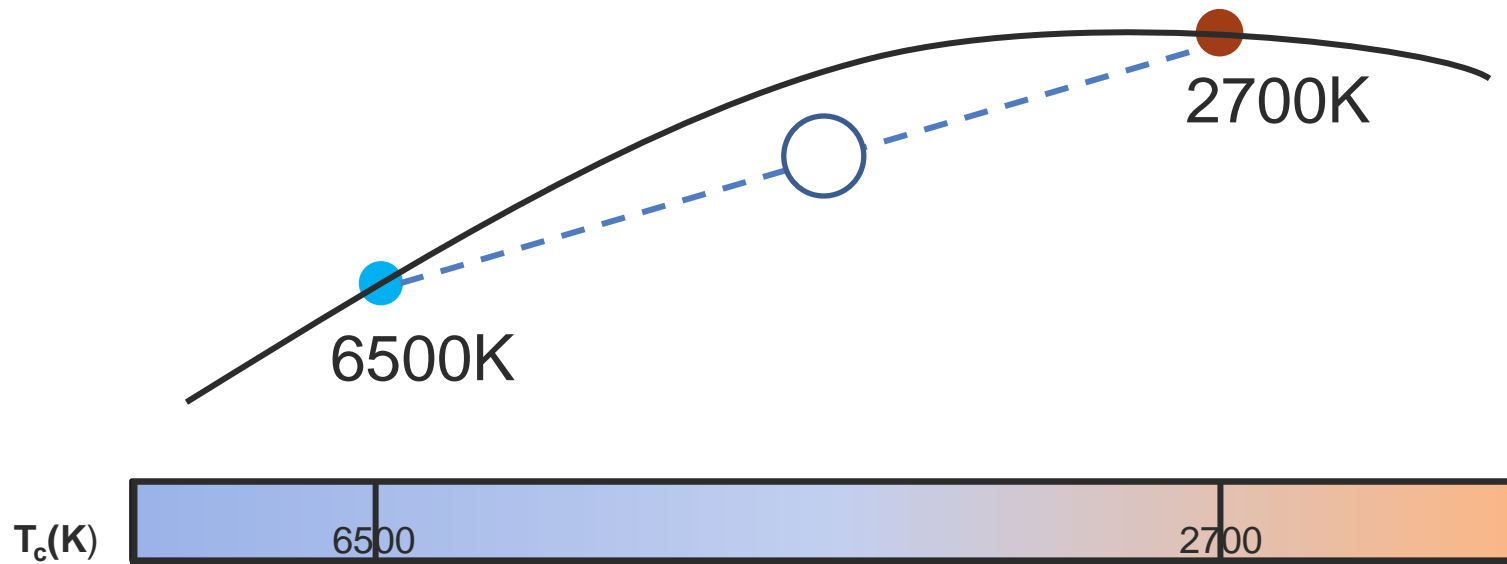


Phosphor Converted LEDs

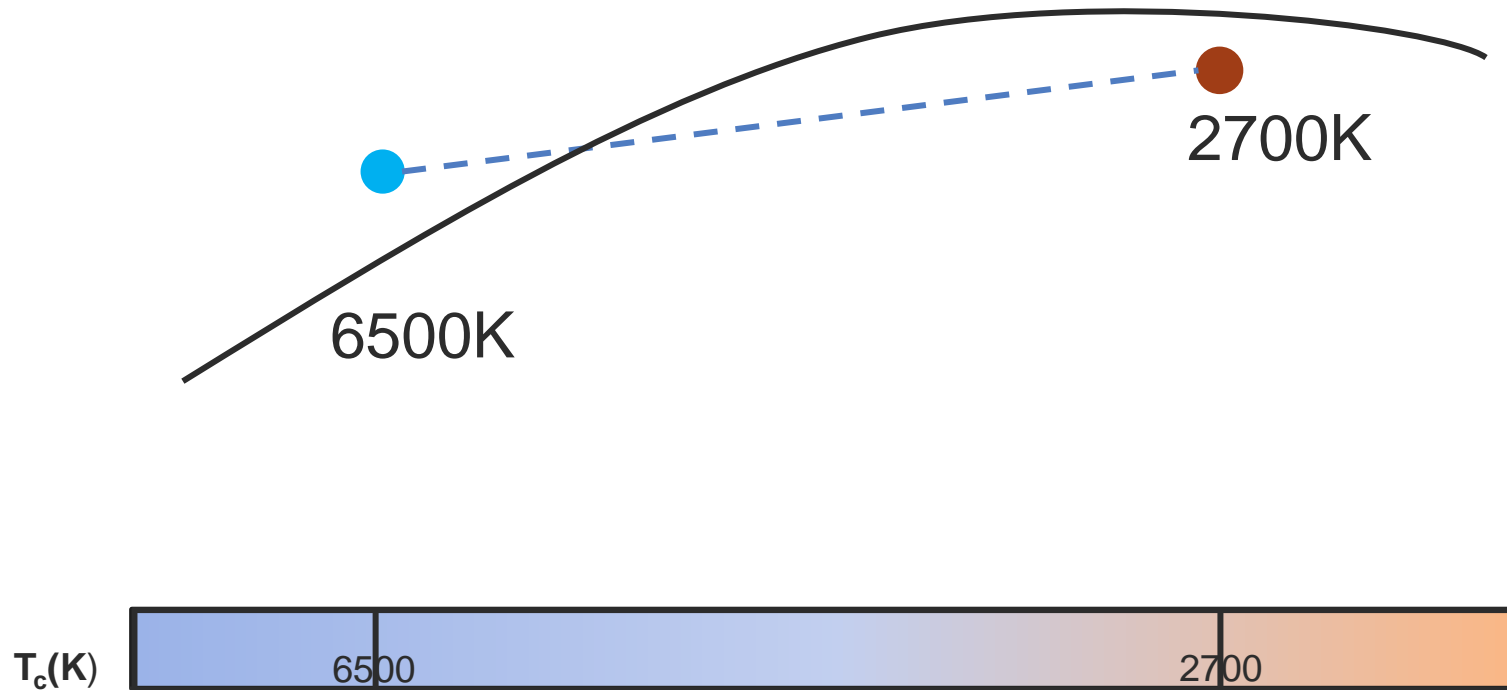


Precise Color Tuning



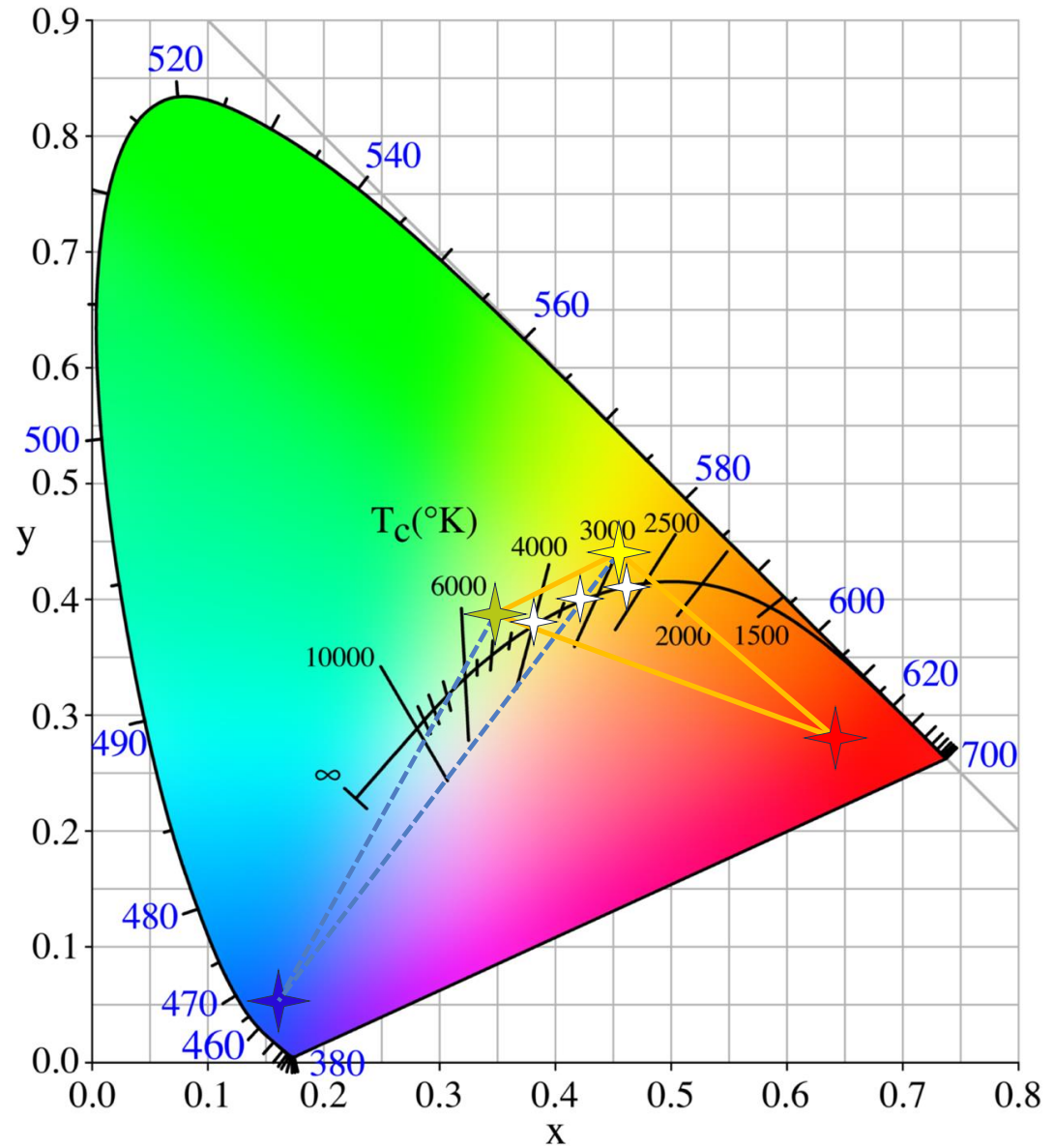


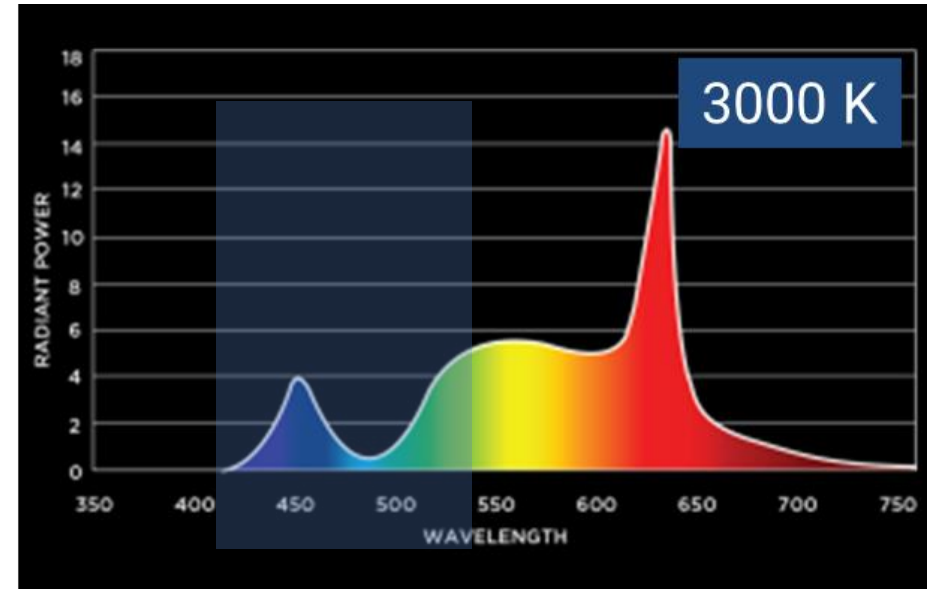
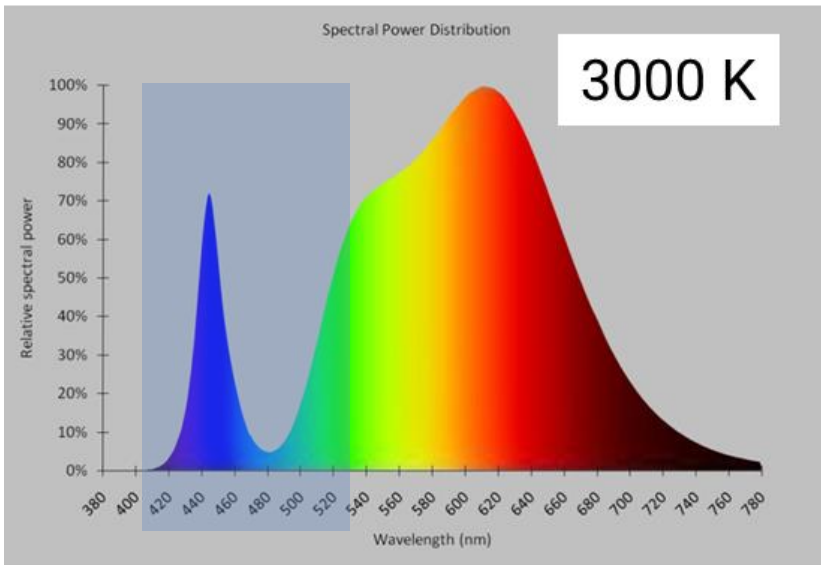
Credit: Finelite



Credit: Finelite

Precise Color Tuning





Approximate Stokes Loss Improvements

2008 to Present

<u>CCT</u>	<u>2008</u>
5700k	1.00
4000k	0.71
3000k	0.42

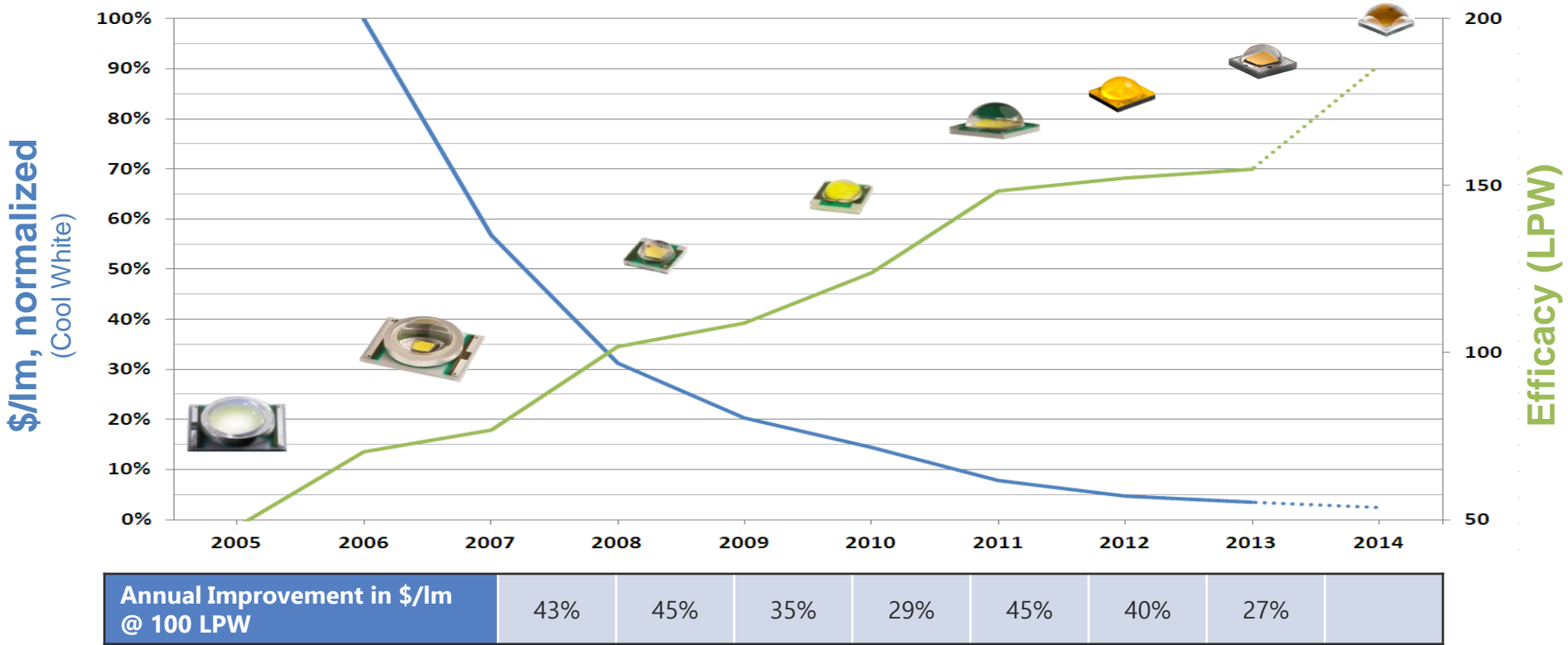
Approximate Stokes Loss Improvements

2008 to Present

18

<u>CCT</u>	<u>2008</u>	<u>2012</u>	<u>2016</u>
5700k	1.00	1.00	1.00
4000k	0.71	0.94	0.98
3000k	0.42	0.77	0.83

Packaged LED Value Evolution



Thermal Management Value Opportunities Have Changed



Extruded Aluminum
Thermal Conductivity = ~ 250 W/m-K

More LEDs With Same Total Power..

More Light...

Less Heat...

More Cost???

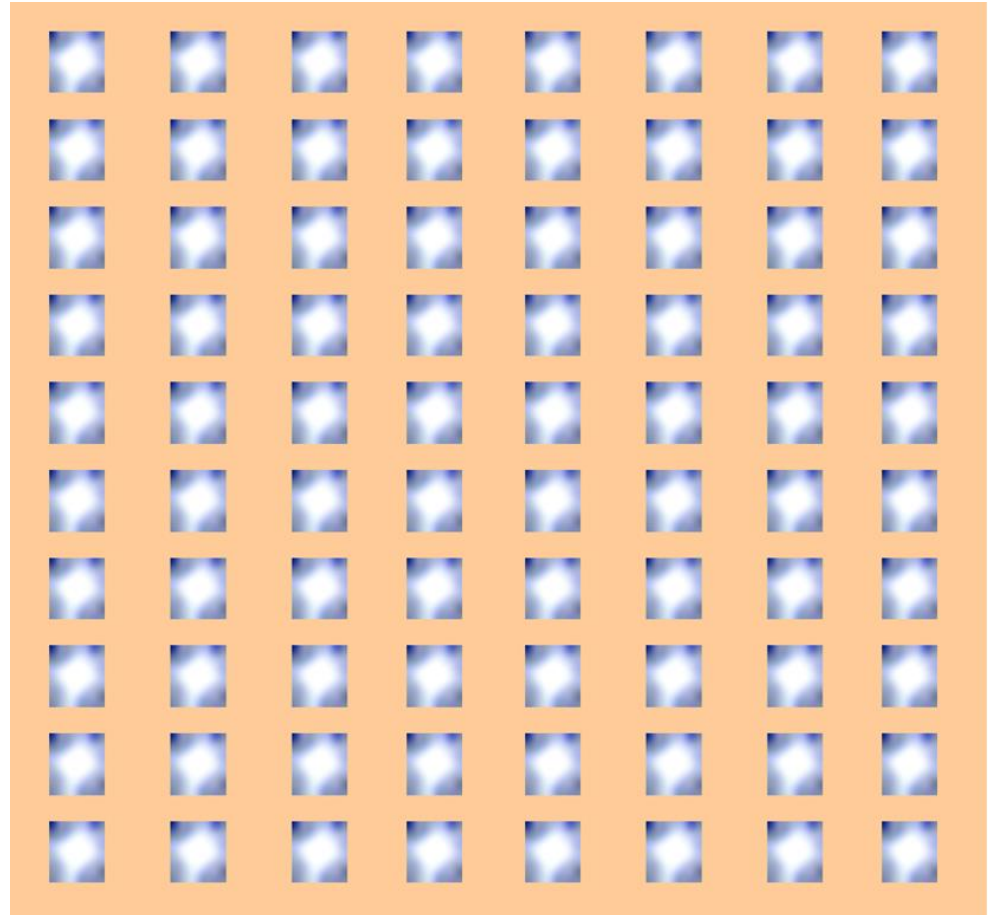
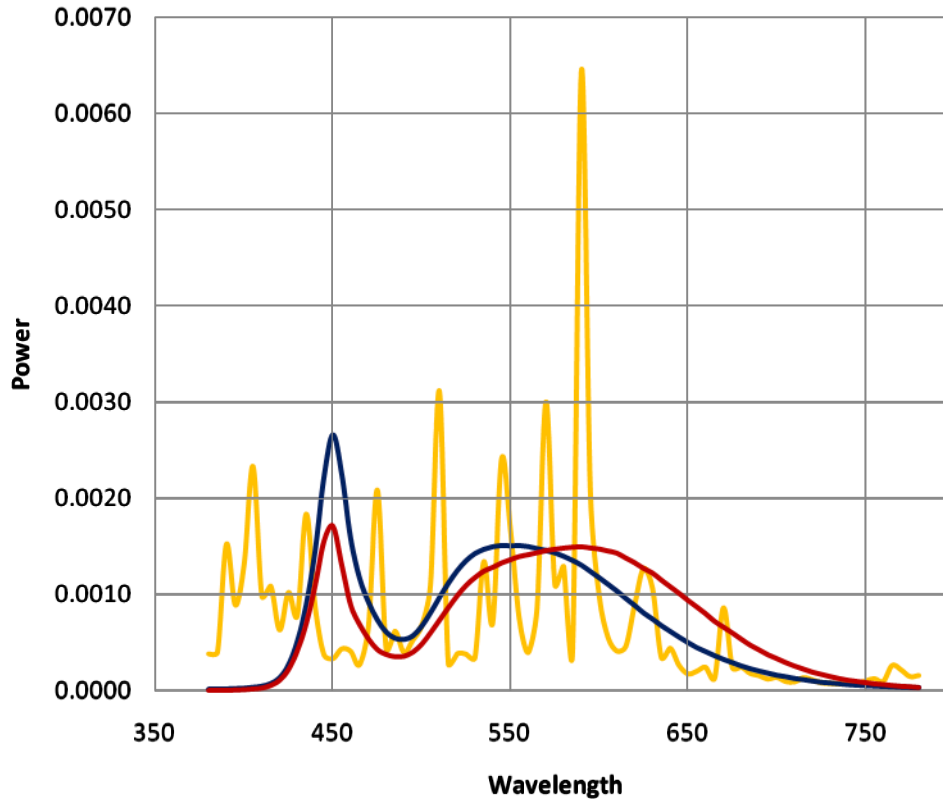






Photo Courtesy: LABSL

SPD Comparison at same Light level



- 6000K LED
- 4000K LED
- Metal Halide 4000K

Lamp Type	% Energy <500nm
Metal Halide	34%
6000K LED	31%
4000K LED	20%

Controlling Blue Wavelengths – Cambridge, MA

- Lumen values derived from city's 2013 inventory
- Blue content calculated by PNNL
- System operates at 70% output at startup; dimmed by 50% (i.e., to 35% of full) after midnight

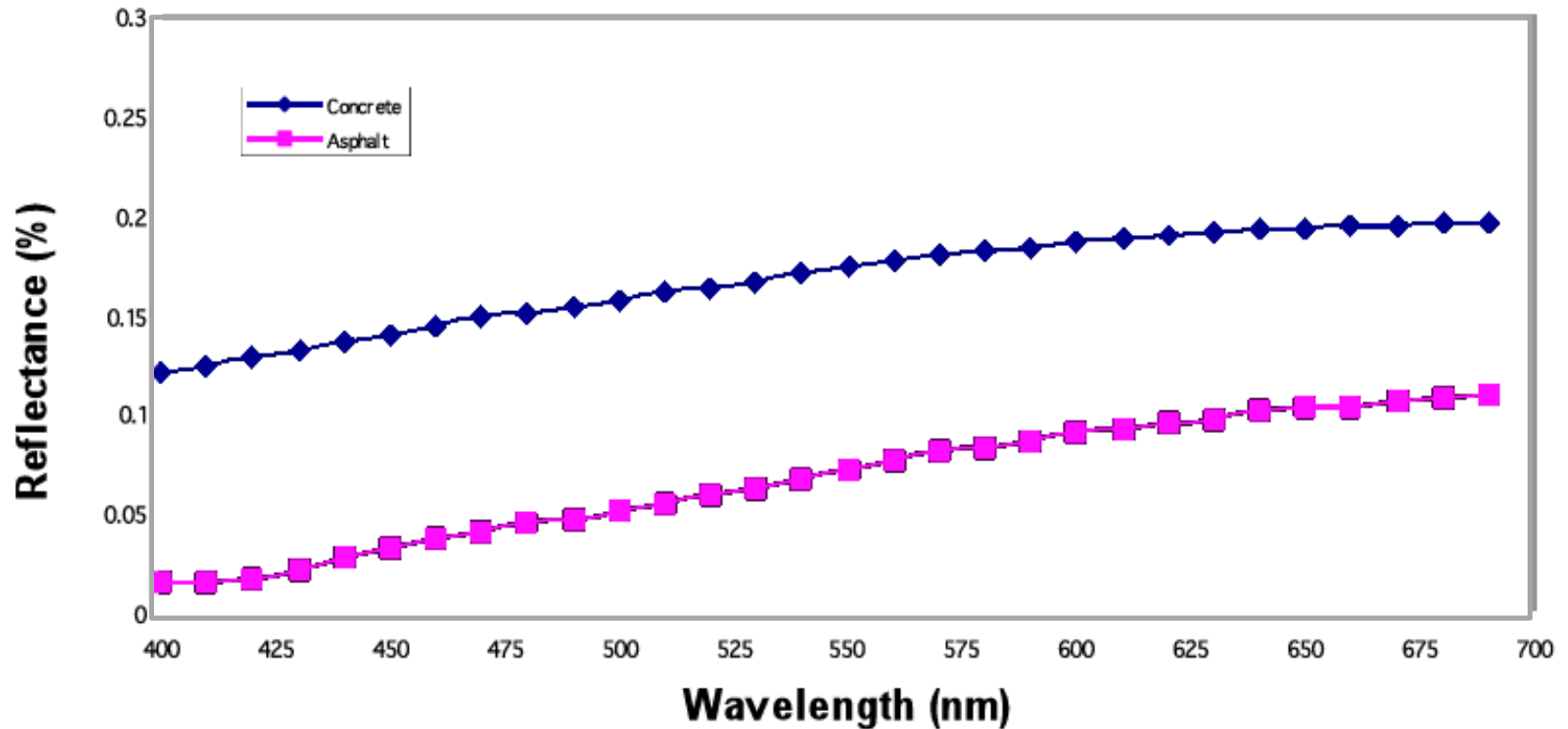


Cambridge, MA Blue Light Impacts from LED Conversion	Initial Output (million lumens)			Blue * percent of radiant power	"Blue" Lumens (millions)		
	Full system as installed	At dusk startup	After midnight		at full power	at dusk	after midnight
Pre-Conversion HPS	54	54	54	10%	5.4	5.4	5.4
Post-Conversion 4000K LED	32	22.4	11.2	32%	10.2	7.2	3.6
Percent Change	-41%	-59%	-79%	N/A	90%	33%	-34%

*includes 405 to 530 nm



Reflectance vs Wavelength







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Lighting cities with cheap, glaring LEDs is a dim move | New ...

<https://www.newscientist.com/.../dn26383-lighting-cities-wi...> ▾ New Scientist ▾

Oct 15, 2014 - Energy-efficient LED street lights can be garishly bright. (Image: Mario ... Not just in our houses, but increasingly outside too. LED street lights ...

Seattle's new LED-lit streets: Blinded by the lights ... - Seattle

crosscut.com/2013/03/streetlights-seattle-led/ ▾ Crosscut.com ▾

Mar 18, 2013 - The first good news: Seattle is leading the nation into a bright new future of energy-efficient, cost-saving LED street lighting — a future limned ...

LED Streetlights in Brooklyn Are Saving Energy but ...

www.nytimes.com/.../new-led-streetlights-shine-too-b... ▾ The New York Times ▾

Mar 23, 2015 - The future is bright on the streets of New York. For Jolanta Benal and her neighbors in Windsor Terrace, Brooklyn, it is far too bright.

Berkeley residents weigh in on new LED streetlights ...

www.berkeleyside.com/.../berkeley-residents-weigh-in-on-n... ▾ Berkeleyside ▾

Aug 6, 2014 - The city began its investigation into the possibility of LED streetlights in 2012 with a council ... Way too bright," added a user named symbiotic.

New bright LEDS that replaced street lamps angering ... - NYC

pix11.com/.../new-bright-leds-that-replaced-street-lamps-angering-... ▾ WPIX ▾

Apr 27, 2015 - Residents say new LED streetlights are blinding, make night feel like daytime ... resident Kris King said the lights are way too bright at night.

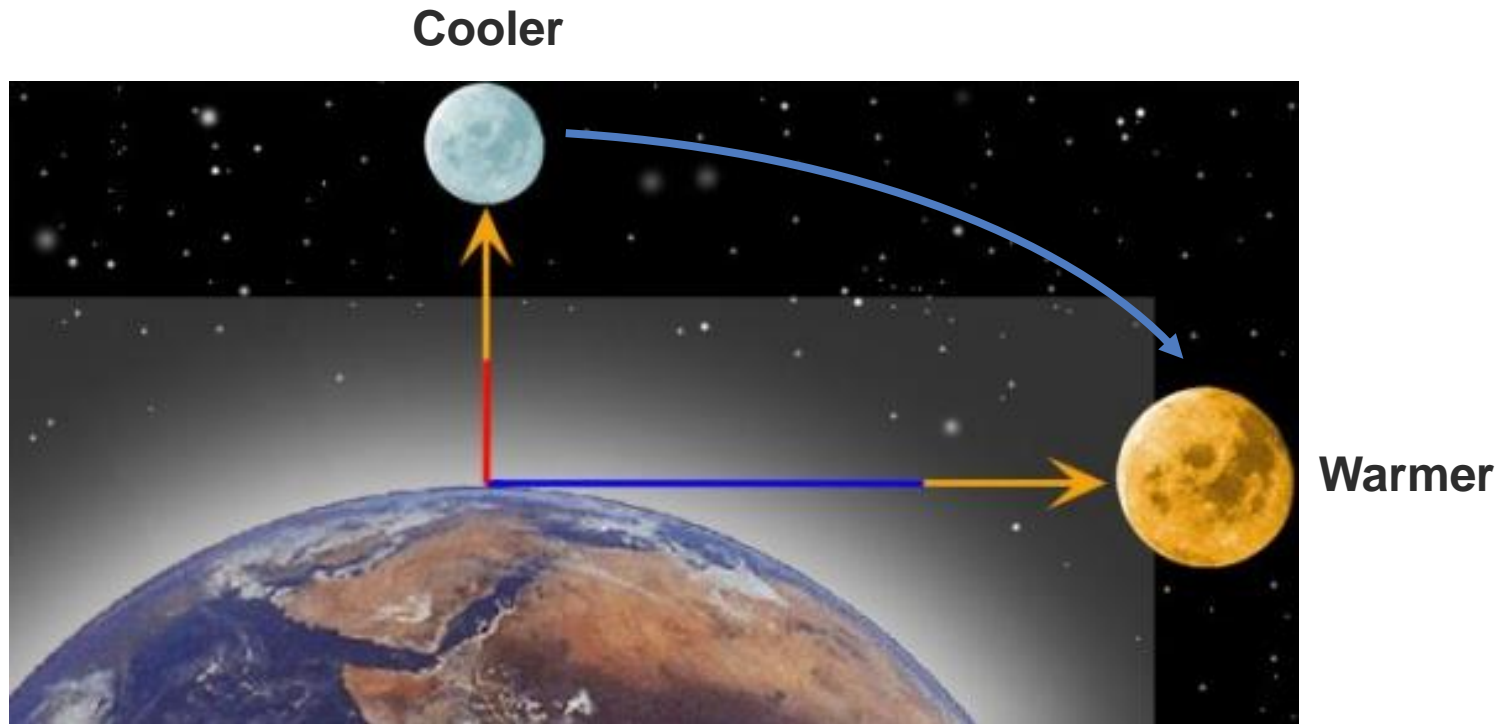
“Natural” Light at Night?



Fire Light to Moonlight



Color Temperature of the Moon



Preferred Choices



“Select a color temperature that complements the environment”

**Thank You for Your
Kind Attention**

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