

LED LIGHTING: ENERGY EFFICIENT & PLANET FRIENDLY



Integrated SSL design for General Lighting

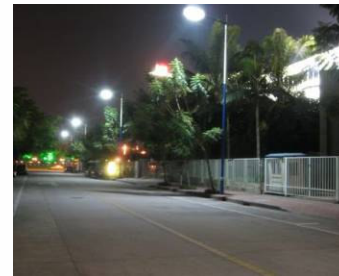
Tony van de Ven

OECC 2009 Hong Kong

CREE 
LED Light

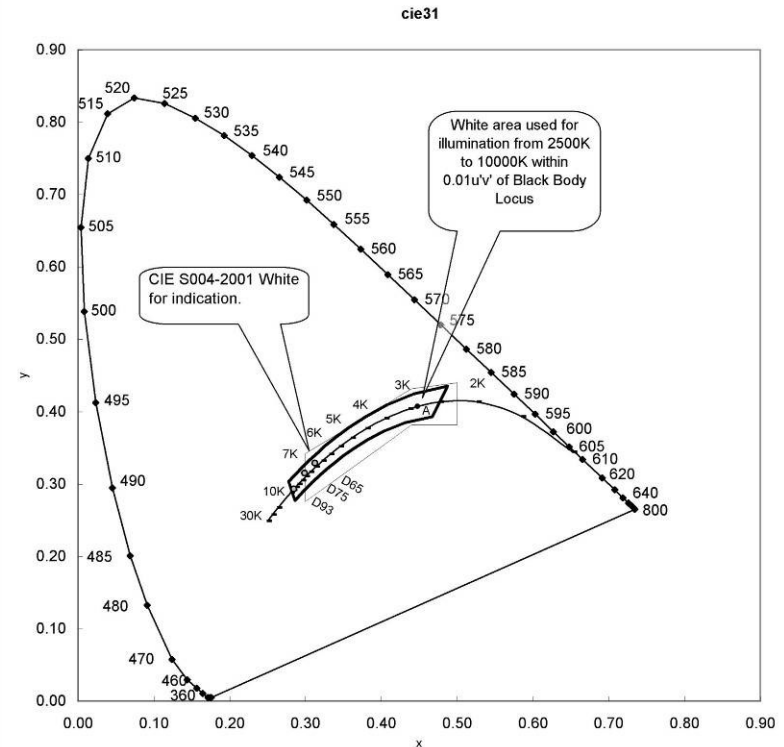
General Lighting

- **General lighting illuminates our homes, offices, restaurants, streets, garages and shops.**
- **General lighting is typically white light and needs to provide -**
 - comfortable light levels,
 - acceptable color rendering,
 - reliable operation,
 - acceptable efficiency
 - economical
- **General lighting presently is provided by non-optimal technologies**
 - Incandescent – very inefficient
 - Fluorescent – mercury toxicity
 - Sodium – very poor color quality
- **Present General lighting uses >20% of all generated electricity**


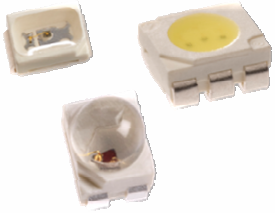
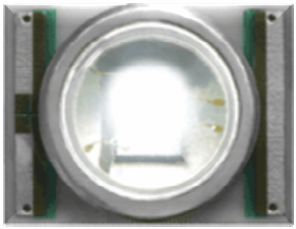


Defining “White” Light for Illumination

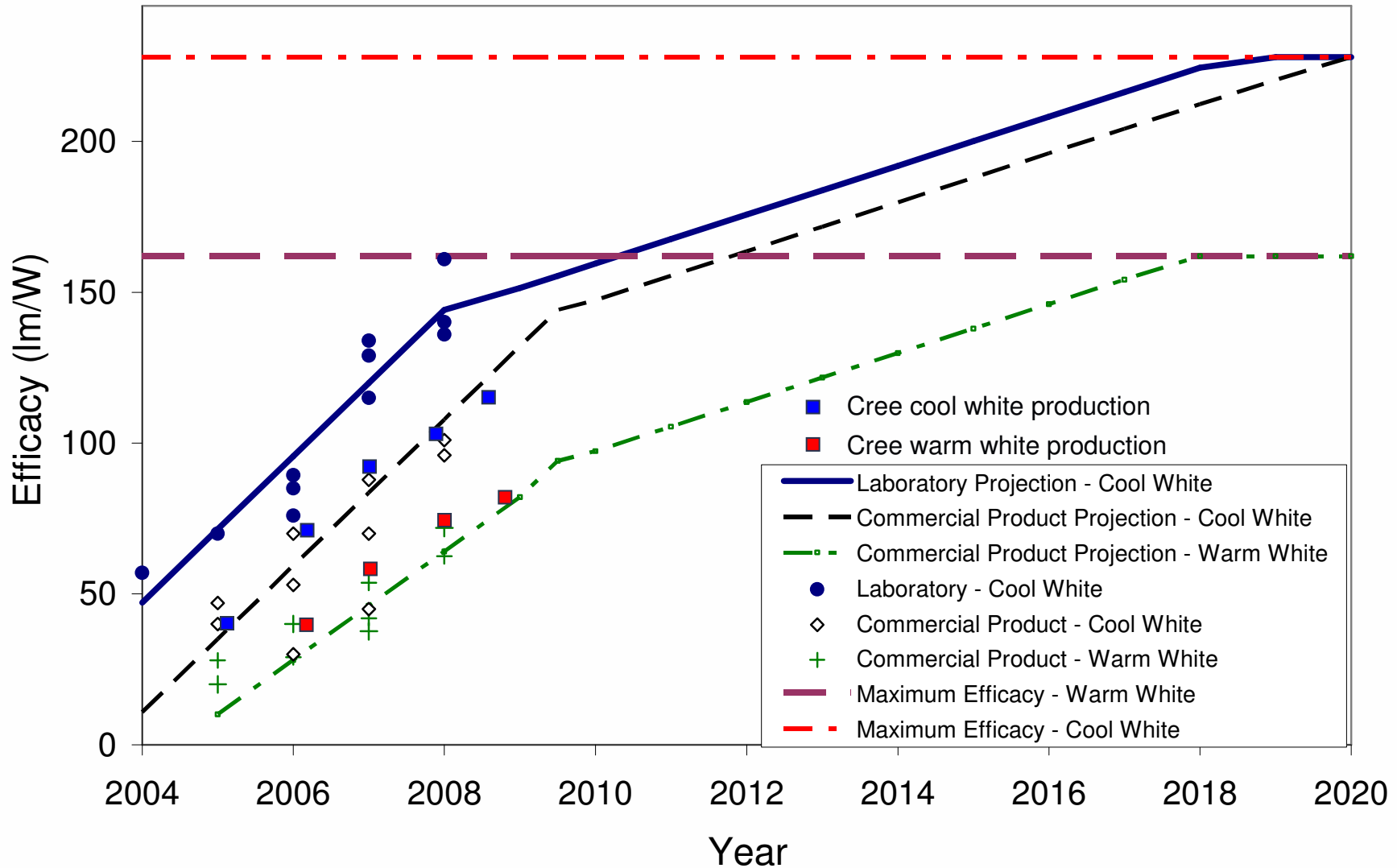
- **Daylight and black body emitter colors naturally appeal and form basis for CRI comparisons**
 - Both have a generally continuous spectrum and are close to BBL
- **Not all illumination is pure white**
 - Lower temperature incandescent sources are yellow or orange in color – called warm white
- **Quality illumination is within 7 step Macadam's of the BBL.**
- **Proposed definition for illumination white color –**
 - Within 0.01 $\Delta u'v'$ of BBL
 - Between 2500K and 10000K CCT



SSL = Solid State lighting = LED Lighting

Round 	60mW 1-5 lumens	Indicators for consumer electronics, some application in large indicators, video screens
SMD 	60mW – 150mW 1 – 10 lumens	Backlights for consumer electronics – mobile phones, LCD screens
Power 	1W to 10W 30L to 1000L	General illumination

SSL Energy Efficiency

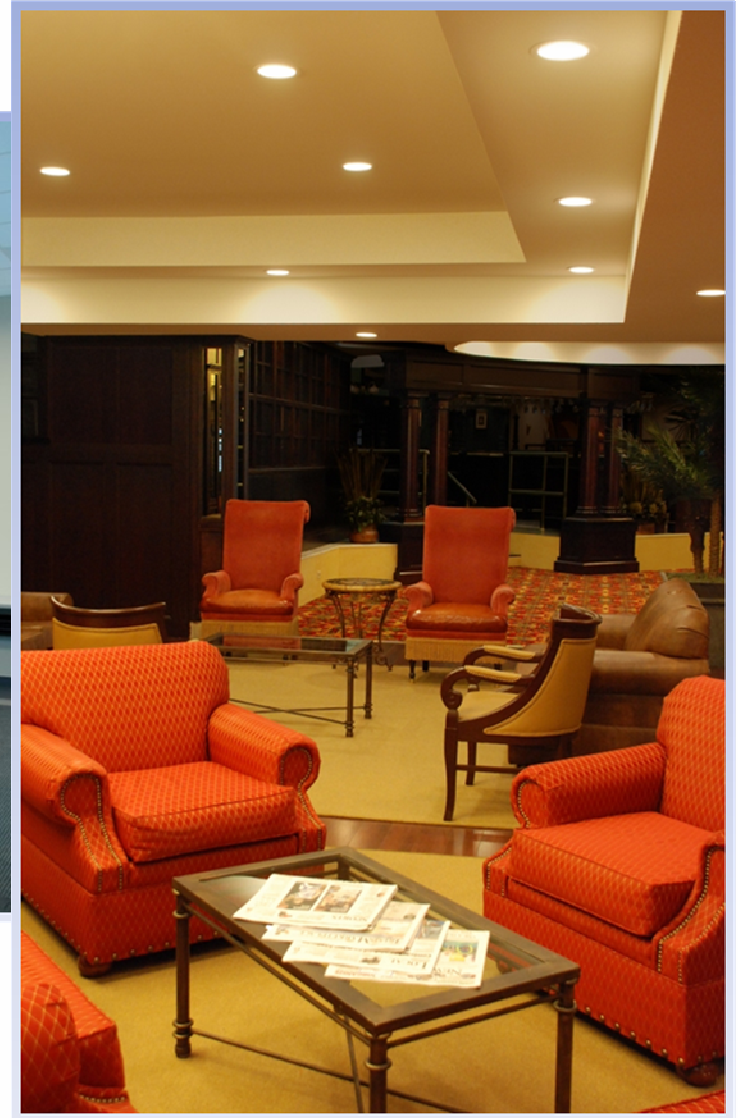


US Department of Energy 2009 Multi-Year Plan for SSL

LED's promise for General Illumination

- ✓ – Quantity of light
- ✓ – Quality of light
- ✓ – Cost of light
- ✓ – Energy consumption
- ✓ – Reliability (Lifetime, MTBF)
- ✓ – Environmental impact

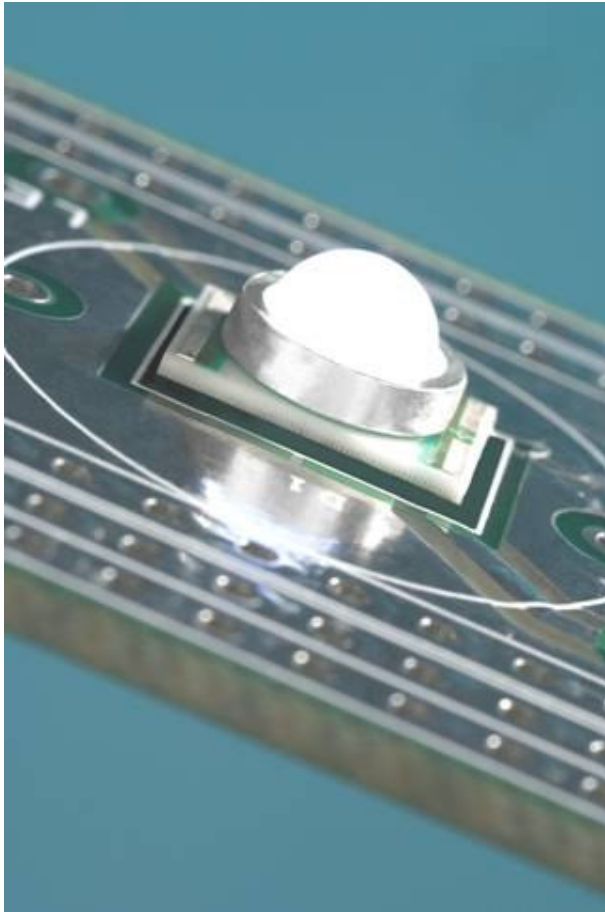
Effective SSL Luminaire Design Starts Here...



LED Luminaire Design Requires a Different Approach

- **It requires an integrated systems approach**
 - LEDs
 - Electronics – power supply & driver
 - Mechanical design
 - Thermal management
 - Optics
- **Total system optimization is critical to maximize performance and meet consumer expectations**

LEDs - Defining Lighting-Class...



Lighting-Class LEDs	
High Output	>80 lm @ 350mA
High Efficacy	> 75 LPW
Stable Color Point	No bin change over lifetime
Long Lifetime	>40k hrs per IESNA LM-80
Isolated Thermal Path	Designed for lighting apps
High Color Rendering Index	>75
Avail in full range of CCT	7000K - 2700K
Binning	Per ANSI 78.377A

- **Key:**
 - **Color point stability**
 - **Lifetime per IESNA LM-80**
 - **Binning per ANSI 78.377A**
 - **Enables DOE SSL Energy Star**

LEDs - Quality Matters



LED Puck



16.5" Linear



22" Linear



LEDs - Color Mixing

- **Generate white light with different colored LEDs**
 - A mix of unsaturated yellow and red
 - Active color management
 - Up to 100 LPW of delivered light
 - 92+ CRI
 - 2700K or 3500K
- **Generate as many of the right photons as you can**



LEDs – Color Mixing for High CRI



Yellow/Green

+

Red

=



LEDs - Color Rendering Index (CRI)

Light Source	CRI (Ra)
Low pressure sodium	< 18
High pressure sodium	25
Warm white fluorescent tube	75
Typical Cool White LED	65-80
Daylight fluorescent tube	79
Ceramic Metal halide	75-85
Typical Warm White LED	70-80
Halogen MR16	95-100
Incandescent	100
Cree True White Technology	92-96

LEDs – Color Rendering Index (CRI)



LED – CRI Ra 92, 36 Watts



CMH – CRI Ra 82, 158 Watts

LEDs - Color Rendering Index (CRI)

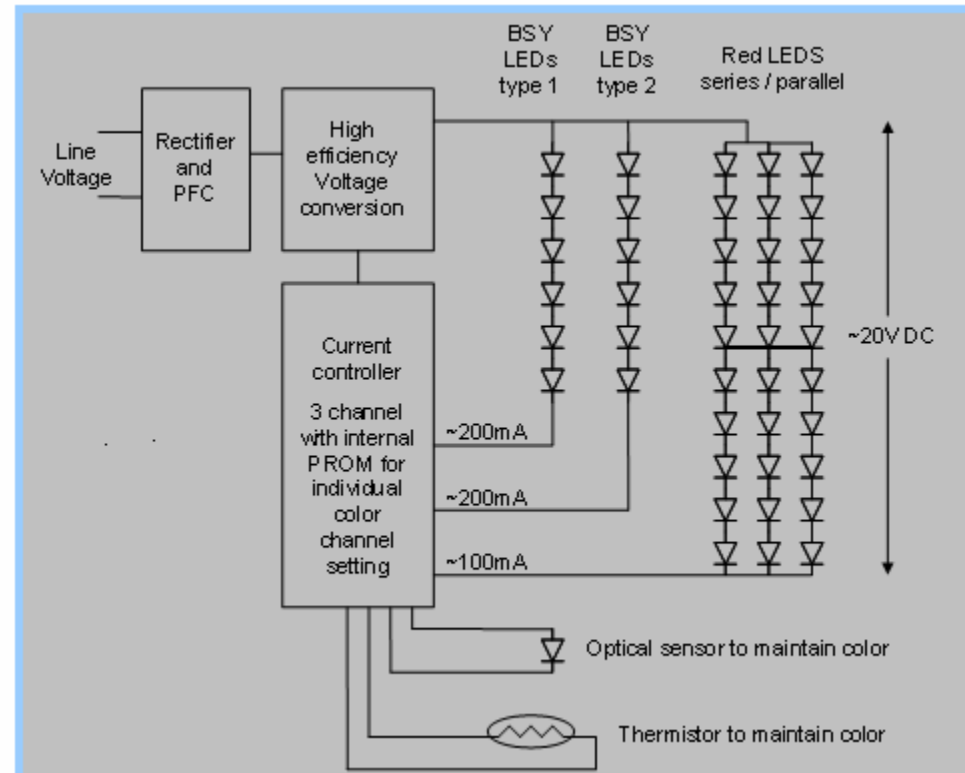


- **Higher CRI = colors show up much better, clearly visible in the color of the cabinets. (CFL Ra 80 vs LED Ra 92)**
- **>200W for CFL vs. 48W for LED**

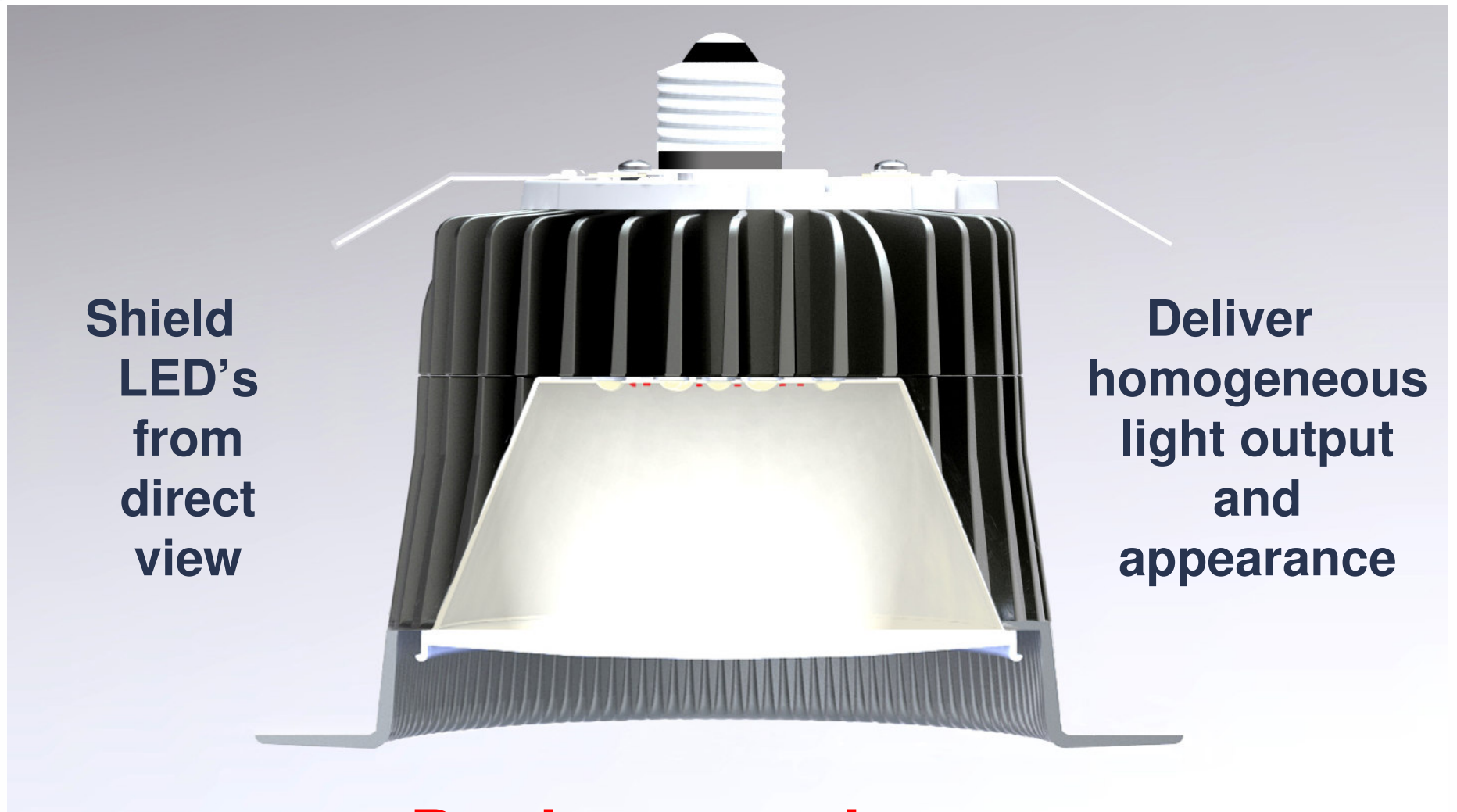
Courtesy of GreenLight Energy Trading LLC

Electronics – Power Supply and Driver

- AC to DC conversion
- Power factor correction
- $>.7$ ideally $>.9$
- LED control (current)
 - Set initial color
 - Actively maintain color over time
 - Maintain color over range of temperatures
 - Change output based upon dimming input
- Meet FCC requirements for EMI
- **Don't waste electrons**



Optical Mixing



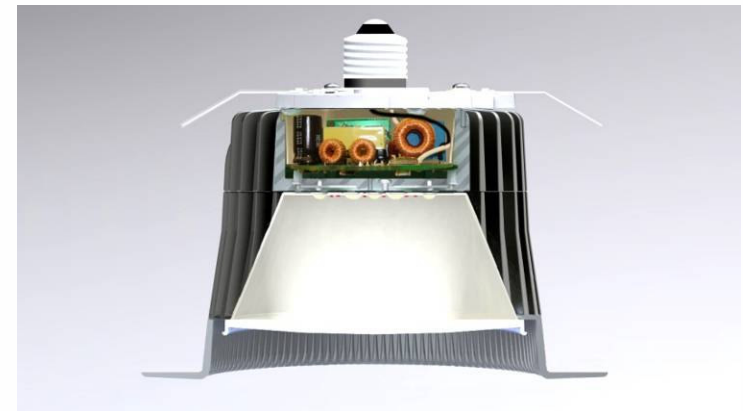
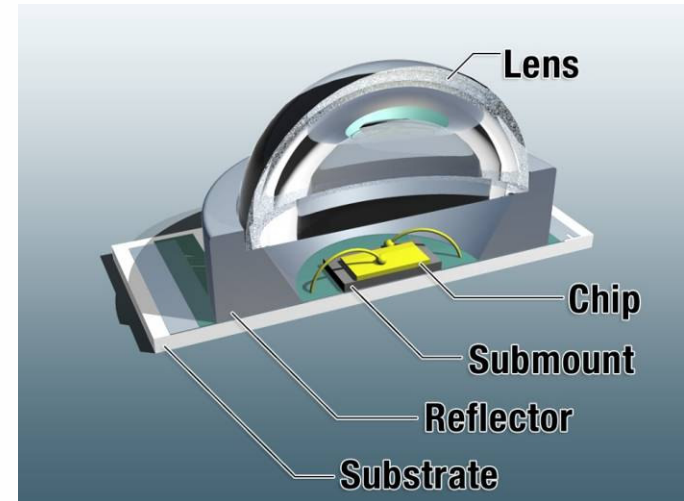
Shield
LED's
from
direct
view

Deliver
homogeneous
light output
and
appearance

Don't waste photons

Thermal Management

- **Heat kills LEDs**
 - Heat must be conducted away
- **LED junction temperature critical to lifetime**
- **Thermal management is part of the system**
 - From the LED chip to the environment
 - Every thermal interface must be considered and optimized
- **Don't waste LED potential**



Summary

- **Systems Solution for High Efficacy and Long-Life requires optimization in**
 - **Optical**
 - **Optimization of overall optical system... photons can only be lost or wasted (typical optical efficiency ~80%)**
 - **Electrical**
 - **Efficacy is from the wall-plug. (typical power supply efficiency ~ 80%)**
 - **Thermal**
 - **Adequate thermal design is the key to “long life product” (well designed system has a thermal roll-off of ~7%)**
- **System Efficacy = Optical efficiency x Power Supply Efficiency x LED Thermal roll off. (~ 60% of LED component Efficacy)**

TEN KEY QUESTIONS....

1. What are the delivered lumens and efficacy?
2. Is the fixture Energy Star qualified? Is there a category?
3. Can you supply an IESNA LM-79 photometric report and IES file from an independent lab for your fixture?
4. Has your LED supplier provided an IESNA LM-80 test report?
5. What is the operating temperature range and what is the maximum junction temperature (T_j) of the LEDs in the range?
6. What is the expected L_{70} lifetime of your fixture? How did you calculate it?
7. Which LED supplier did you choose and why?
8. Is the chromaticity of the fixture in the ANSI C78.377A color space and is it stable over time? How do you know?
9. Does the color of the light output vary from fixture to fixture?
10. Is your fixture lead-free, mercury-free and RoHS compliant?

A 4" Architectural Downlight

- **For New Construction**
- **Architectural Appearance**
 - Smooth aperture appearance
 - Light source more deeply recessed
 - Moderate or deep shield angles
- **The Best Performance From a Small Aperture**
 - Up to 540 Delivered Lumens
 - Nominal Input Power = 11W
 - 94 CRI (2700K) 91 CRI (3500K)
 - 50,000 Hour Life
 - Active Color Management



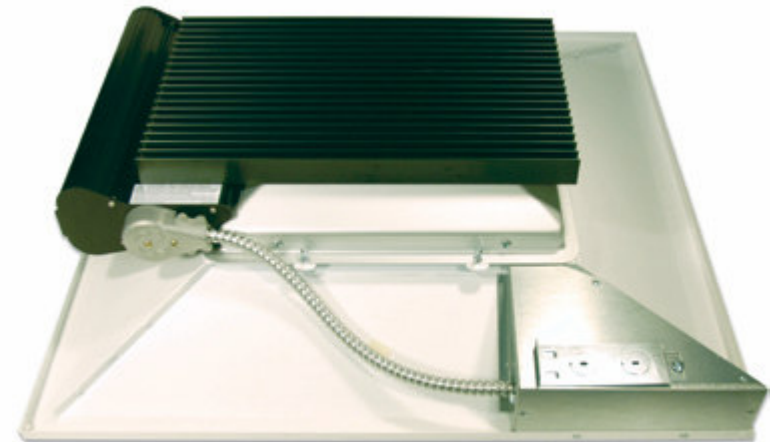
The Unique Challenges

- LR4
 - Electronics
 - LED count
 - Optical
 - Increased Recess
 - Surface area of lens
 - Thermal
 - Deeper recess of LEDs
 - Separate trim



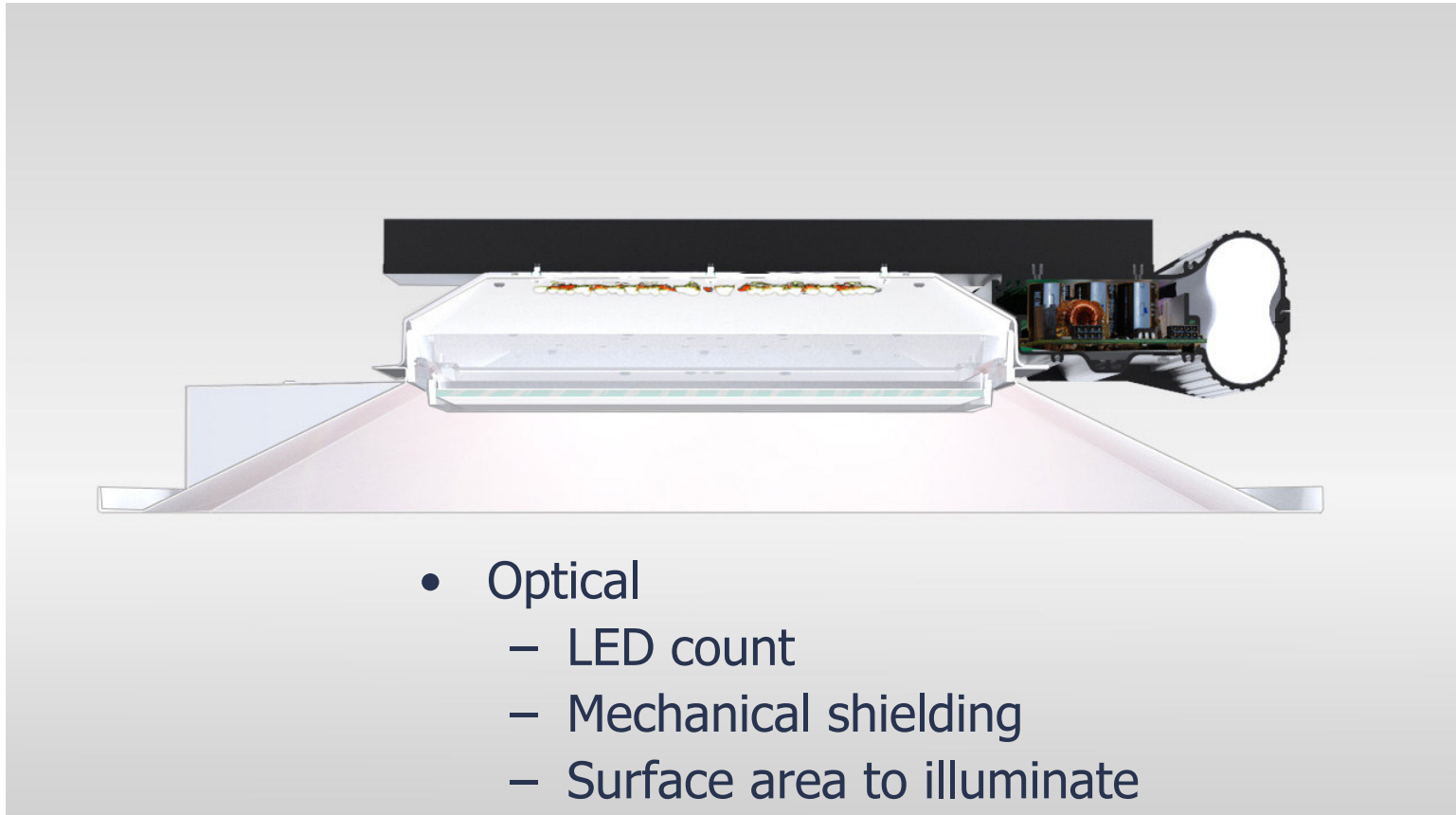
LR24 – Architectural Lay-in

- **Performance**
 - 48W → 3200 Lumens
 - 40FC on 8'x8' spacing
 - 92 CRI
 - 3500K CCT
 - Designed for 50,000 hour life
- **Comfortable Appearance**
 - Optimized distribution illuminates walls and vertical surfaces
- **Serviceable Light Engine Module**
 - 120-277V Input
 - Dimmable with 0-10VDC controls
- **Direct replacement of the most popular troffers used today**



The Unique Challenges – LR24

- Thermal
 - Operating environment
 - Height restrictions
- Electrical
 - LED count
 - Operating range
 - Dimming control



Thousands of Installations

- **Retrofit and new construction**
- **Energy savings:**
 - **20% ~ 40% energy savings over CFL**
 - **60% ~ 80% energy savings over incandescent and halogen**



Thousands of Installations



Thousands of Installations



Residential Installation



Conference Room Installation



Restaurant Installation



Cree LR6

What About Directional Lighting?

- **Until now, there has been no efficient light source with excellent color**
- **Incandescent is preferred**
 - Color is great
 - Efficiency is bad
 - Energy codes prevent traditional usage
- **Ceramic Metal Halide has limitations**
 - Red renders poorly
 - Cost is high
 - Longevity is average
 - Surface brightness is uncomfortable
- **Is it possible to combine the best of both with LED technology?**



Subtle Lights, Popping Merchandise



SSL PAR38



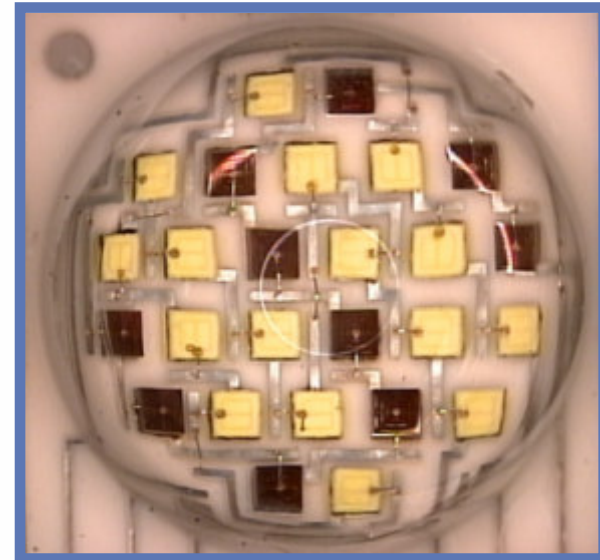
Performance Summary

- Utilizes Cree TrueWhite™ technology
- CRI = 92
- CCT = 2700K
- Active Color Management
- CBCP = 4000
- Beam Angle = 20°
- Maximum Input Power = 12W
- 42 lumens per watt minimum
- Dimmable to 20%
- Designed to last 50,000 hours in open fixtures
- Designed to last 35,000 hours in non-IC recessed downlights

The Combination of High Efficiency and Vibrant Color is Possible with Two Technology Breakthroughs

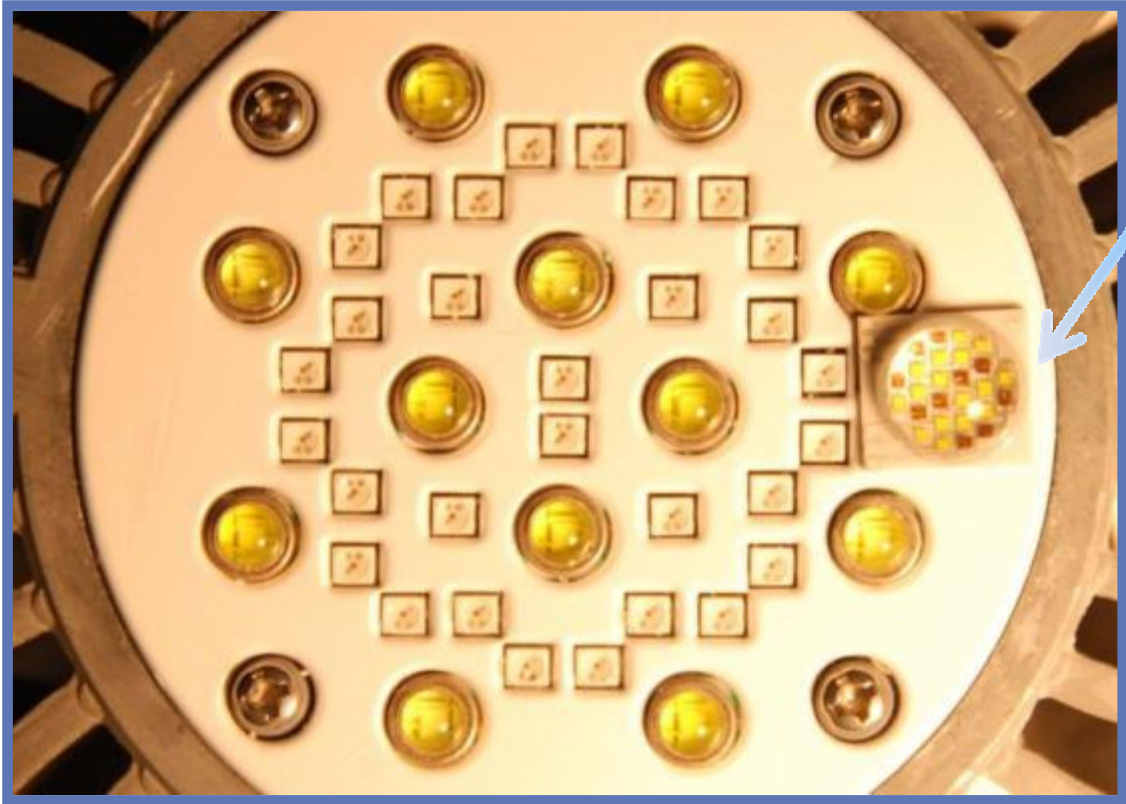


High CRI Color
Mixing



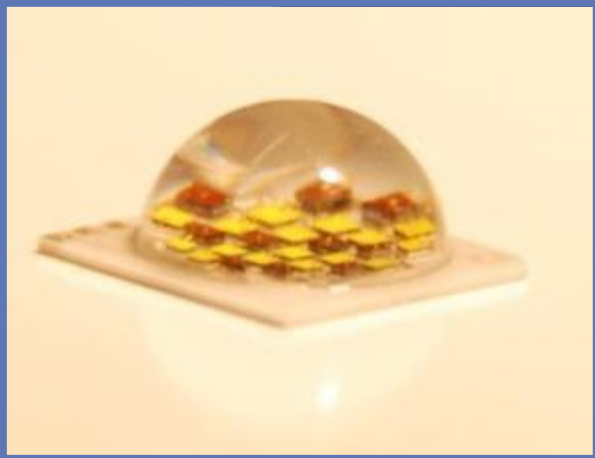
A New Multi-Chip
Light Source

Small Multi-chip Light Source



This one component can replace the 42 components in this light engine

Small Multi-chip Light Source



Enables the Lamp Design



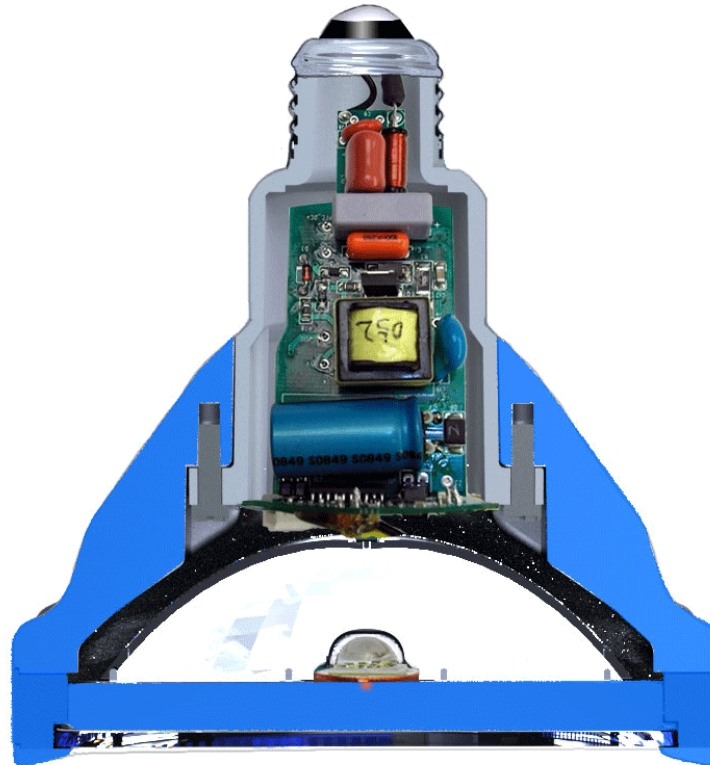
The reflector directs the majority of flux back to a sophisticated reflector, precisely formed to deliver light into a tightly focused beam of high quality light.

A Diffuser Mixes the Colors and Heat is Conducted Away From the Component with a Heat Pipe



Heat pipe technology is very effective, robust and commonly used in laptop computers

LRP 38 Thermal Dispersion



Color Management System Keeps Color Consistent Over Time and Temperature

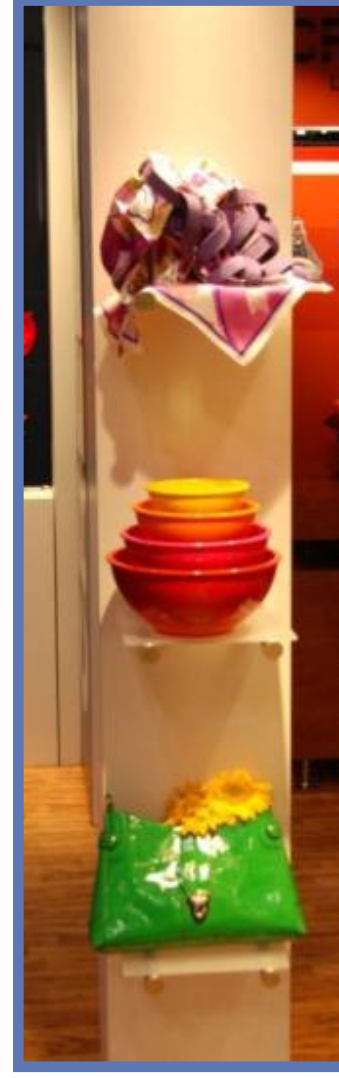
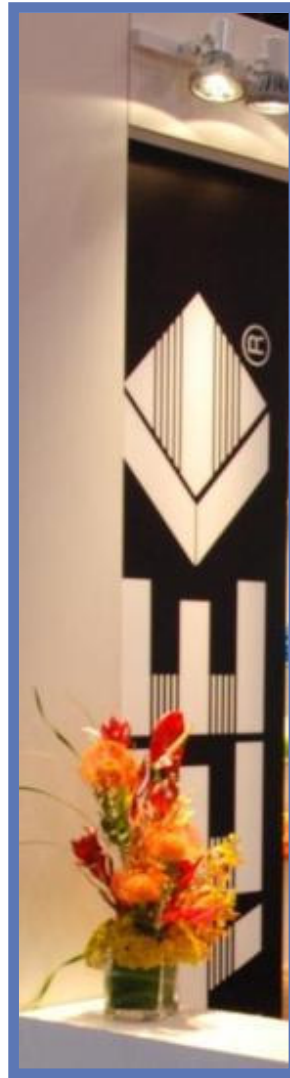


Enables a New Approach to Lamp Design



- This allows the delivery of high intensity, high CRI, high efficacy light from extended distances.
- It is the first light to deliver focused, high efficiency, high CRI light for creating **EMPHASIS**
 - Perishable Goods Displays
 - Department Stores
 - Furniture Stores
 - Specialty Shops
 - Produce Departments
 - Architectural Accent Lighting
 - Museums
 - Anywhere high quality, focused light is required

Beautiful Color, Strong Emphasis, Smooth Beam



Conclusion

- **Using a bottoms-up approach to SSL design taking into account the unique thermal and optical characteristics of LED and combining them in a integrated system provides the outstanding performance in general lighting.**
- **SSL out performs all other lighting technologies and continues to get even better.**
- **SSL luminaires are available already and being used in thousands of general lighting applications.**

LED LIGHTING: ENERGY EFFICIENT & PLANET FRIENDLY



Thank-you.



CREE  [®]
LED Lighting