



# LED Lighting - State of the Art

**Bob Roller**  
**VP – Business Development**

**March 1, 2013**



# Customer Expectations for LED Lighting

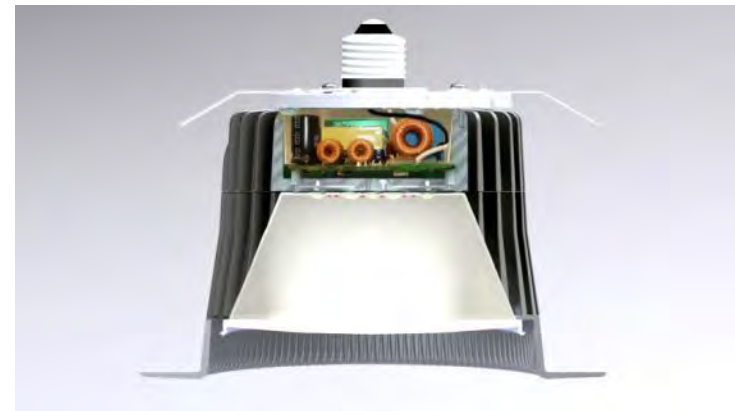
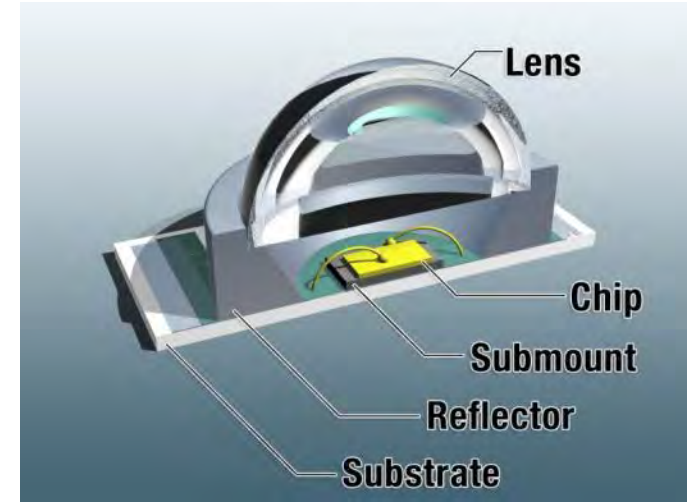
- **Energy Savings**
  - **Good Rule of Thumb – 40% to 60% Savings Typical When Replacing Incumbent High Efficiency Technologies**
    - Metal Halide
    - High Pressure Sodium
    - Fluorescent
  - **Much Higher Savings When Replacing any Type of Incandescent or Halogen Technology**
    - **60% to 90% Energy Reduction Depending Upon the Application**
- **Long Life**
  - **Expectation of at Least 50,000 Operating Hours in Most Applications**

# Thermal Management

- **Goal**
  - **Maximize Light Extraction From LED Package**
  - **Maximize Lumen Maintenance**
    - **Minimize Lumen Depreciation**

# Thermal Management

- Heat kills LEDs
  - Minimal IR, heat must be conducted away
- LED junction temperature must be kept below manufacturer specified levels to achieve long life
- An integrated thermal management approach is required
  - Every thermal interface must be considered and optimized

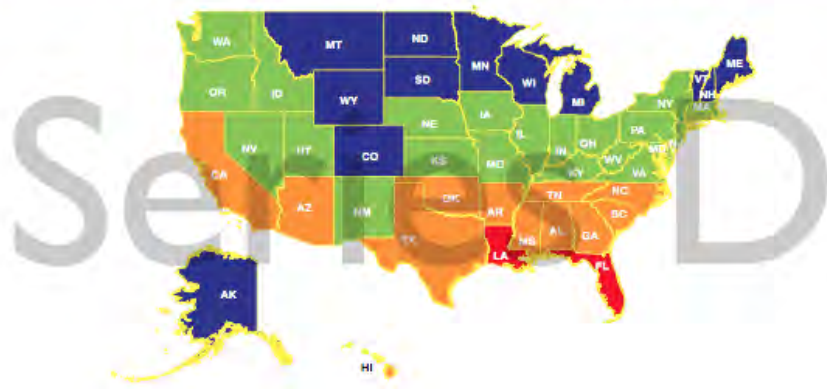


# Step #1 - continued

## Lumen Maintenance Factors Must Be Applied!

BetaLED provides Lumen Maintenance Factors in a user-friendly format in its TD-13 Document.

Series D  
Recommended BetaLED® Lumen Maintenance Factors (LMF)



**PRODUCTS INCLUDE:**  
STR-LWY, CAN-227, CAN-304, PKG-304, FLD-OL

Zone*	Drive Current (mA)	Initial LMF	25K hr LMF	50K hr LMF	100K hr LMF
-30°C* (-4°F)	350mA	1.11	1.07	1.03	0.96
	525mA	1.11	1.07	1.03	0.94
	700mA	1.11	1.06	1.01	0.92
-10°C* (14°F)	350mA	1.09	1.05	1.01	0.93
	525mA	1.09	1.04	1.00	0.91
	700mA	1.09	1.04	0.99	0.88
5°C (41°F)	350mA	1.05	1.01	0.97	0.88
	525mA	1.05	1.00	0.95	0.86
	700mA	1.05	0.99	0.94	0.83
10°C (50°F)	350mA	1.04	0.99	0.95	0.87
	525mA	1.04	0.99	0.94	0.84
	700mA	1.04	0.98	0.93	0.81
15°C (59°F)	350mA	1.03	0.98	0.94	0.85
	525mA	1.03	0.98	0.93	0.82
	700mA	1.03	0.97	0.91	0.79
20°C (68°F)	350mA	1.01	0.97	0.92	0.83
	525mA	1.01	0.96	0.91	0.81
	700mA	1.01	0.95	0.89	0.77
25°C (77°F)	350mA	1.00	0.96	0.91	0.82
	525mA	1.00	0.95	0.90	0.79
	700mA	1.00	0.94	0.88	0.75

Rev. E Expires: 09/2011

Recommended BetaLED Lumen Maintenance Factors (TD-13) (2 of 6)

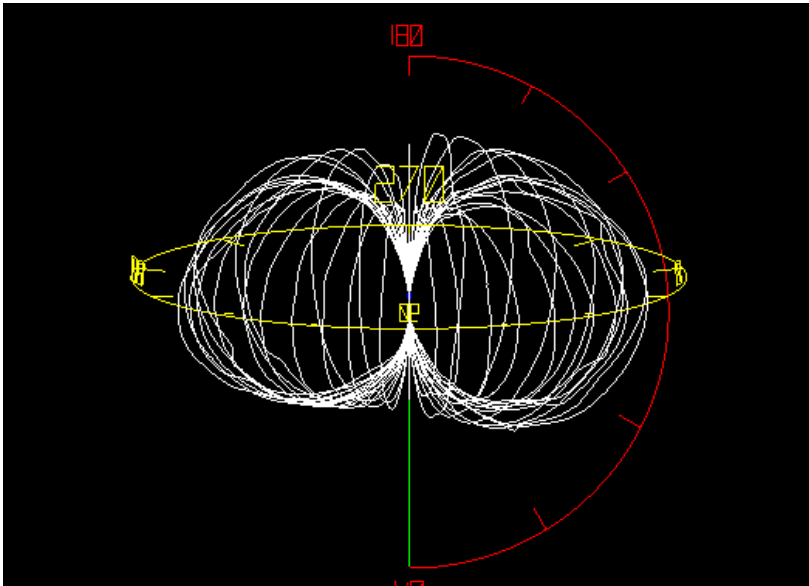
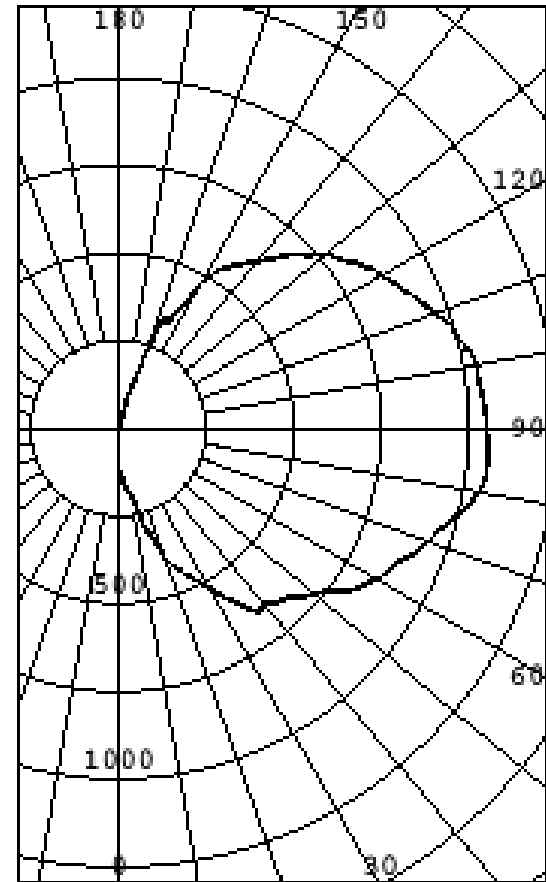


# Optical Control

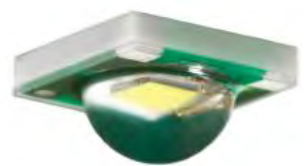
# HID Bare Source Photometry



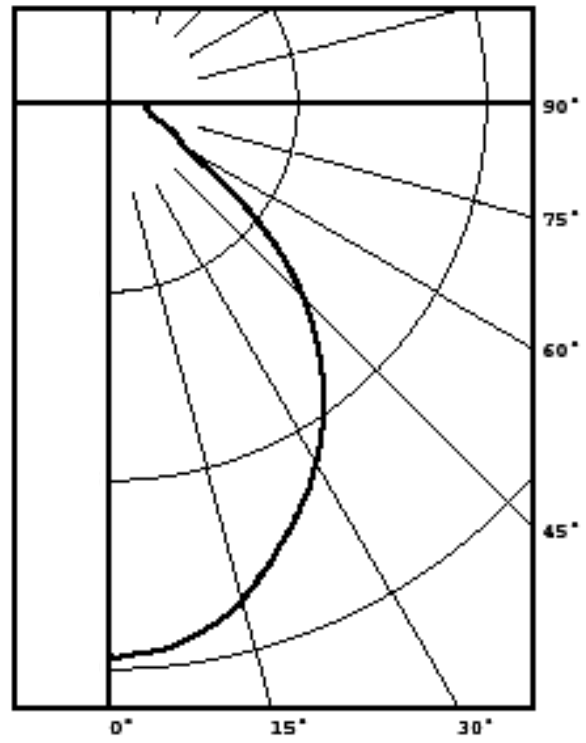
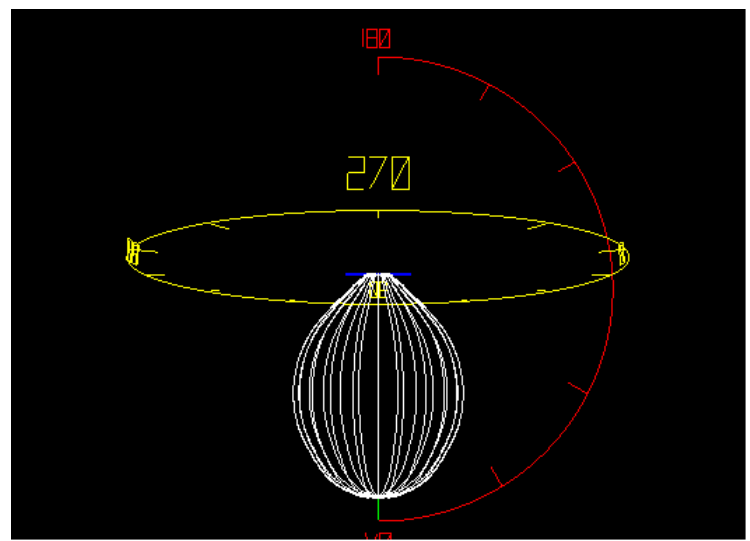
Commercially Available MH Lamp  
Polar Candela Plot



# LED Bare Source Photometry



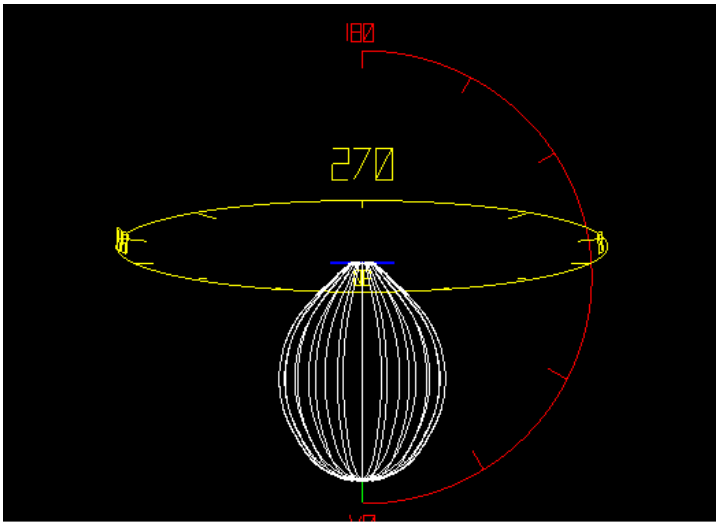
Commercially Available HB  
White LED  
Polar Candela Plot





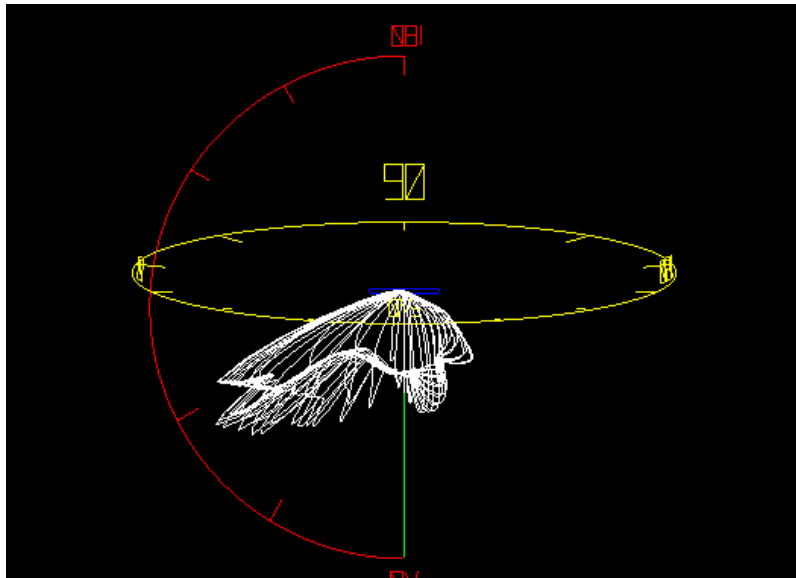
# Optical Control

## Bare LED Package Illustration



# Optical Control

## Illustration of Altered Distribution (Secondary Optic Added)



# Dramatically Improved Uniformity



Optimizing the  
Specification  
Process...

# Application Efficacy

- Meeting the Maintained Lighting Performance Requirements With:
  - Lower Lighting Power Density
    - Higher Lumens/Watt on the Application Target

...Maintained

Light Loss Factors Must be Applied  
Lowest In-Service Lighting Performance Threshold

# Essential Elements

## A Specification Development Process That:

1. Defines the Required Sustainable Illumination Performance
2. Defines the Required Sustainable (Risk Managed) Economic Performance
  - Life Cycle Cost Analysis Elements/Variables
    - Evaluation Timeframe /Desired Application Life
    - Product Durability Performance Requirements
    - Standards Compliance / Reliability / Warranty
    - Etc.

# Step #1

## **Always!**

Establish the Required Maintained Illumination Performance Requirements

- Lighting Performance Specification
  - Vertical and Horizontal Illumination Requirements
  - Uniformity
  - Color Quality
  - Light trespass
  - **Glare Metrics...**
  - Etc.

Step #1 - continued

# Illumination Performance

## Define the Variables:

- Define the Lighting Application Geometric Target(s)
  - Boundaries
- Luminaire Position Constraints
  - New vs. Retrofit
- Service Life (i.e. Application Life)
  - Years of Expected Near Maintenance Free Operation (i.e. Hours of Operation)
  - Required Economic Assessment Period (5 -15yrs...?)

**Lumen Maintenance Factors Must Be Applied!**



## Step #2 - continued

### Required Product Characteristics "Must Haves"

- Designed to mount on 1.25" IP (1.66" O.D.) and/or 2" IP (2.375" O.D.) horizontal tenon
- Adjustable Horizontal tenon mounting capable of (+/- 5 Degrees) in 2.5° vertical increments
- Finish Color shall be silver
- Luminaire EPA shall not exceed 0.90 / maximum weight not to exceed 30 LBS
- Meets Buy American requirements within the ARRA
- UL Listed for Wet Locations
- RoHS Compliant
- Meets CALTrans 611 Vibration Testing Requirements

## Step #2 - continued

# Required Product Characteristics “Must Haves”

- Driver: UL Listed, Power Factor  $> 90\%$  and THD  $< 20\%$  at full load; Complies with FCC rules and regulations, Title 47 CFR Part 15 Non-Consumer (Class A), 100,000 hours expected life ( $\leq 0.5\%$  failure at 100,000 hours of operation in  $25^{\circ}$  C ambient).
- Integral 10kV Surge Protection
  - Tested in Accordance With IEEE/ANSI C62.41
- Exposed hardware shall be Stainless Steel
- Light Engine must meet IP66 requirements
- Serviceable and upgradable light engine
- Passive thermal management (heat sink)

## Step #2 - continued

### Required Product Characteristics “Must Haves”

- International Dark-Sky Association (IDA) approved
- Suitable to operate in  $-40^{\circ}$  C to  $+40^{\circ}$  C ambient environments
- Minimum 5 year Luminaire Warranty
- Minimum 10 year Finish Warranty
  - Luminaire and finish endurance tested to withstand 5,000 hours of elevated ambient salt fog conditions as defined in ATSM Standard B 117 testing standard
  - Greater than 90% Gloss Retention per ASTM G154 (UV Exposure Test)
- Etc.

## Step #2 - continued

### *Optional* Product Characteristics “*Nice Haves*”

- Manufactured in an ISO9001 facility
- Tool-less Entry
- Minimum 70% recyclable content (by weight)
- Scalable: Luminous increments of no more than???
- Field selectable/adjustable drive current (range???)
- Leveling Indicator
- Power supply quick disconnect harness(s) suitable for mate-and-break under load on power feed
- Minimum XX years LED luminaire manufacturing experience and XX installed LED projects (XX References Required)
- Etc.

# Do **NOT** Specify Product Performance Variables That Directly or Indirectly Affect Illumination Performance

For Example:

- Total Luminaire Efficacy
- Optical Efficiency
- Driver Efficiency
- Specific Lumen Maintenance (i.e. 80% at 50,000 hours)
- A Specific  $L_{70}$  Value (i.e. 50,000 hours)
  - $L_{70}$  Limits are OK
- Specific IES Types (Type I, II, III, IV, V)
- Etc.

# Other Economic Variables Outside the Scope of the Spec

- Energy Costs
- Maintenance Costs
- Cost of Capital
- Etc.

## Essential Elements

### A Specification Development Process That:

1. Defines the Required Sustainable Illumination Performance
2. Defines the Required Sustainable (Risk Managed) Economic Performance
  - Life Cycle Cost Analysis Elements/Variables
    - Evaluation Timeframe /Desired Application Life
    - Product Durability Performance Requirements
    - Standards Compliance / Reliability / Warranty
    - Etc.



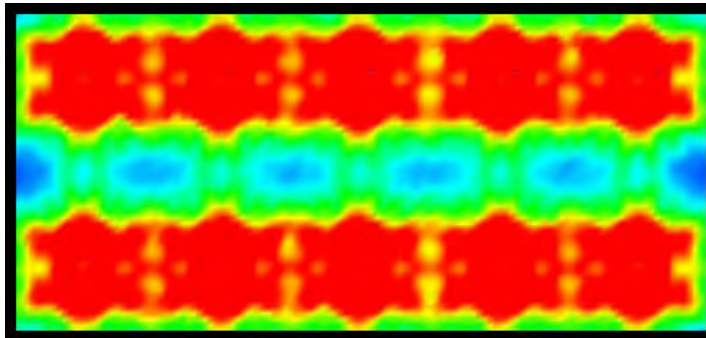
# LED Exterior Lighting Applications



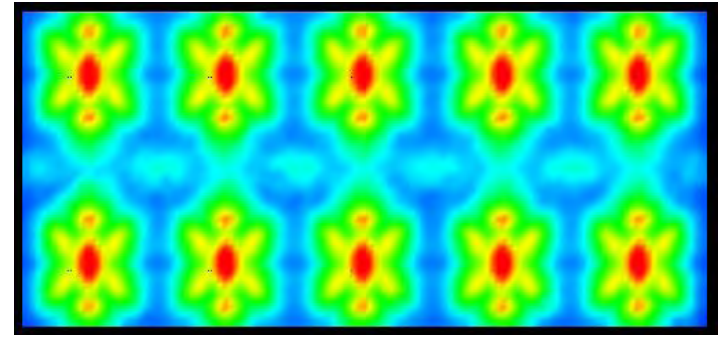
# How Does LED Performance Compare to Incumbent Lighting Technologies?

# LED Comparison to Incumbent Technologies

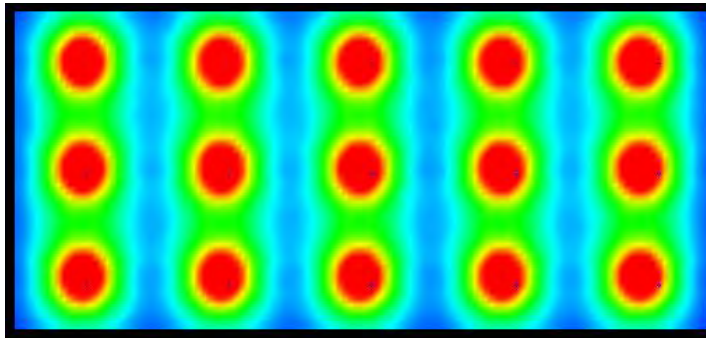
## Pseudo Color Renderings



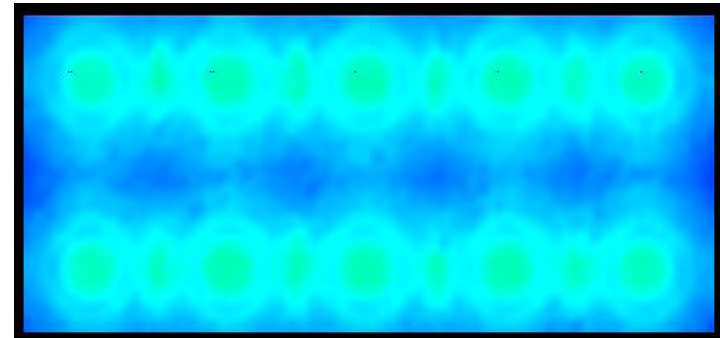
High Pressure Sodium



Metal Halide



Induction



LED

# LED Comparison to Incumbent Technologies

## Luminaire Schedule

Technology	Number of Poles	Number of Fixtures	Arrangement	Lamp Lumens	LLF	Total Watts
High Pressure Sodium	10	20	Back to Back @ 90°	51000	.88	9200
Induction	15	60	4 per pole	11000	.70	8820
Metal Halide	10	20	Back to Back @ 90°	33100	.67	9100
LED	10	20	Back to Back @ 90°	10178	.91	<b>2780</b>

# LED Comparison to Incumbent Technologies

## Illuminance Calculation Results

Technology	Units	Average	Max Fc	Min Fc	Avg/Min Ratio	Max/Min Ratio
HPS	Fc	4.34	9.1	0.5	8.68	18.20
Induction	Fc	2.52	7.5	0.5	5.04	15.00
MH	Fc	2.13	5.9	0.5	3.55	9.83
LED	Fc	1.13	1.6	0.6	<b>2.26</b>	<b>3.2</b>

LED Light Levels calculated at Grade using predicted lumens after 50K hours assuming a 10° C average night time temperature.

MH and HPS light levels calculated at grade using mean lumens.

Induction light levels calculated at grade using lumens at 60 K hours.

# The Bottom Line

- **70% less energy than HPS**
- **68% less energy than Induction**
- **69% less energy than Metal Halide**

**AND...**

**A Superior Lighting Project with an Average to Minimum Ratio of only 2.26**



# Cub Foods Parking Lot, Minneapolis, MN



# George Mason University, Fairfax, VA





# North Star Commuter Rail, Minneapolis, MN



# Floodlighting Application



# Security Lighting Application



# Petroleum Station Canopy Application



HID

BetaLED

30% Energy Savings

# Petroleum Canopy, Hamburg, Germany



# West Palm Beach Airport, Florida



# LED Parking Structure Duke University



# Parking Structure, Duke University





# Milwaukee Technical College - Wisconsin



# Street Lighting, Los Angeles, CA



# LED Products For Interior Lighting Applications



# Innovation

- LR6 has been in the market 2 years longer than any other credible LED downlight
  - Millions sold
  - Tremendous amounts of data gathered
  - **Lessons learned....**



# Cree TrueWhite<sup>®</sup> Technology

- **A unique way to generate white light with LEDs**
  - Proprietary mix of unsaturated yellow (blue + phosphor) and red
  - Color management (thermistor)
- **High CRI and high Efficacy**
  - 110 LPW at 90 CRI
  - 80 LPW at 94 CRI
- **Each product is optimized before shipment by sophisticated tuning equip.**
- **Color maintained over time and temperature**
  - Thermistor (all)
  - Optical sensor (some)



# Cree TrueWhite® Technology

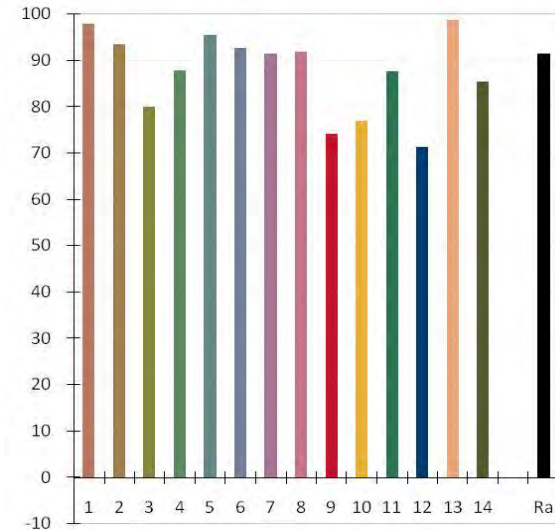
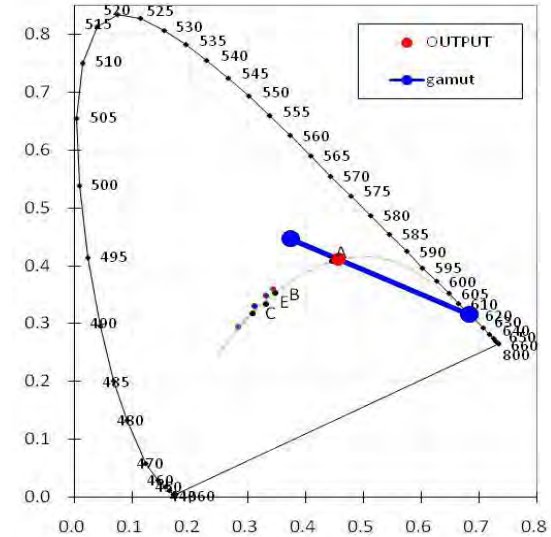
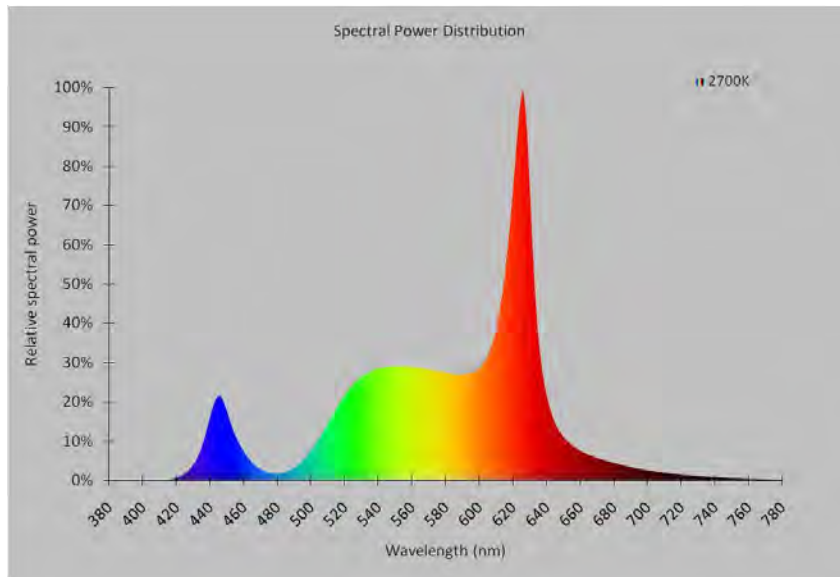


Yellow/Green + Red =



# Color Quality: Cree TrueWhite

- **Non-white PC LED (BSY) and add red LED**
  - Very good efficacy (100LPW)
  - Most suitable for WW CCT ~2700K
  - High CRI (>90 Ra)
  - Some control requirements
  - Color mixing at fixture level



# OFFICES





# OFFICES



# OFFICES



# CONFERENCE CENTER





# FIRST LOOK...Computer Lab Before (2400W)





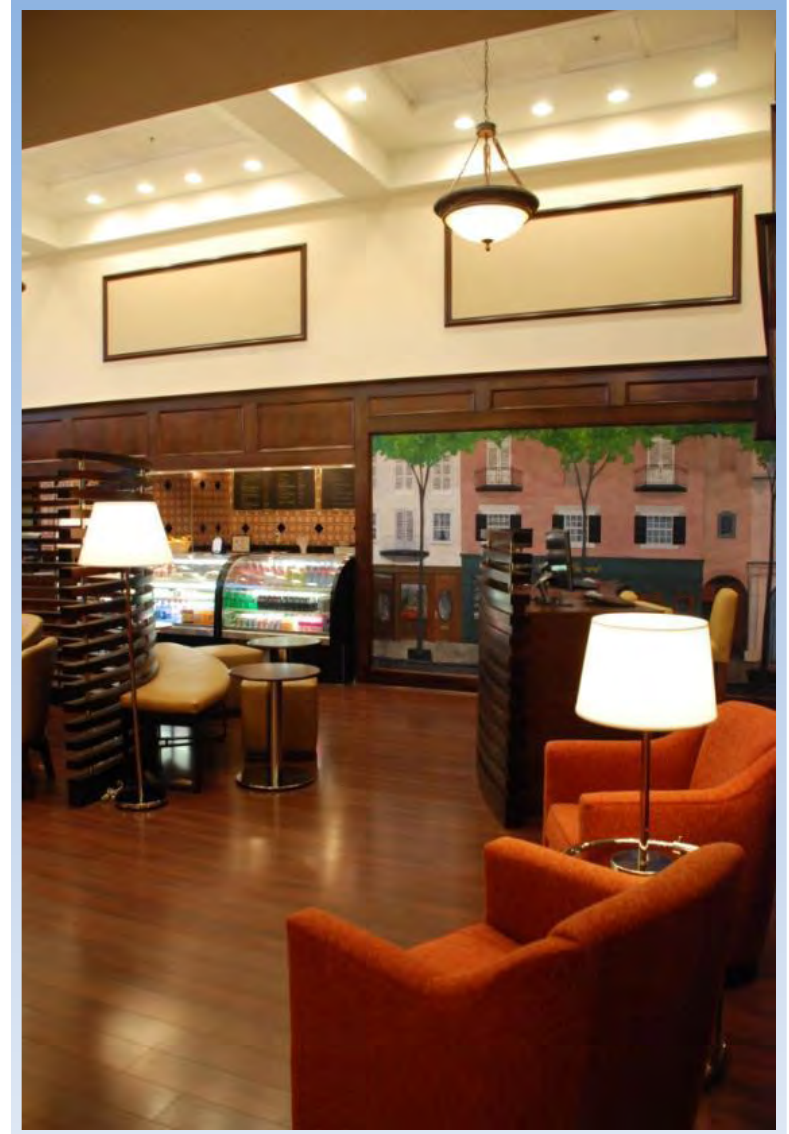
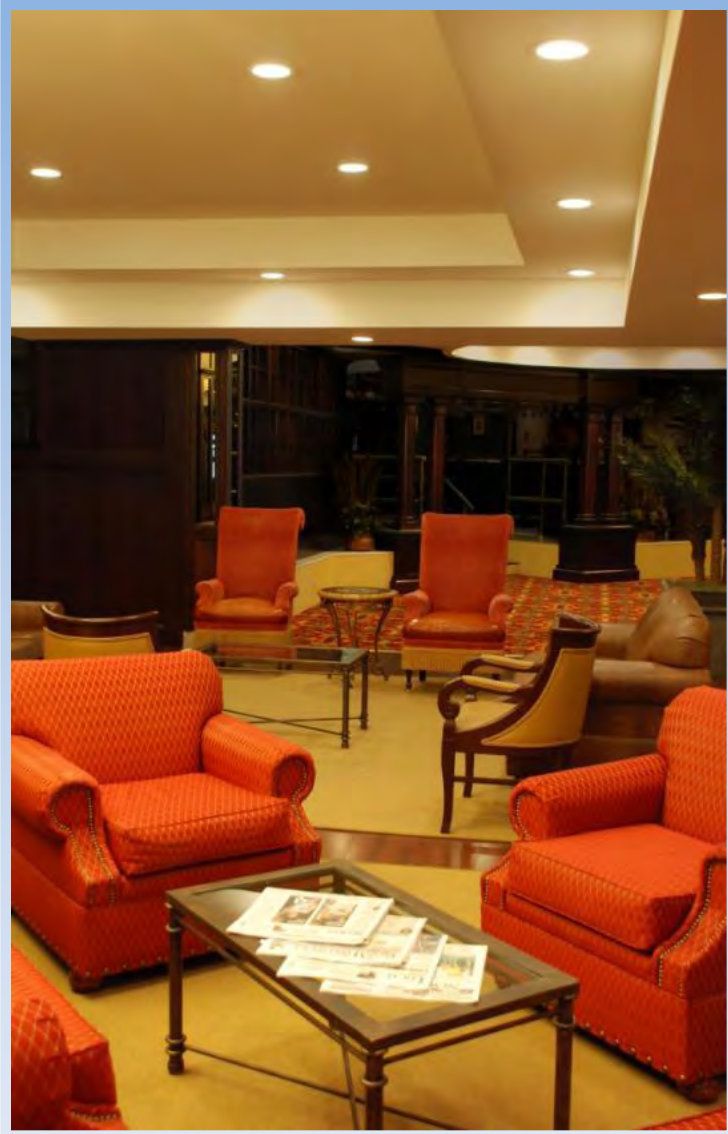
# FIRST LOOK – Computer Lab After (640W)



HOTELS



# Hotel Installations



# THEATERS





est. 2010 *The place for Smiles* Fox Chapel, PA

RESTROOMS

le Our  
community!

RESTAURANTS

8,500 hours

Gift Cards



# RETAIL



# Residential Installations



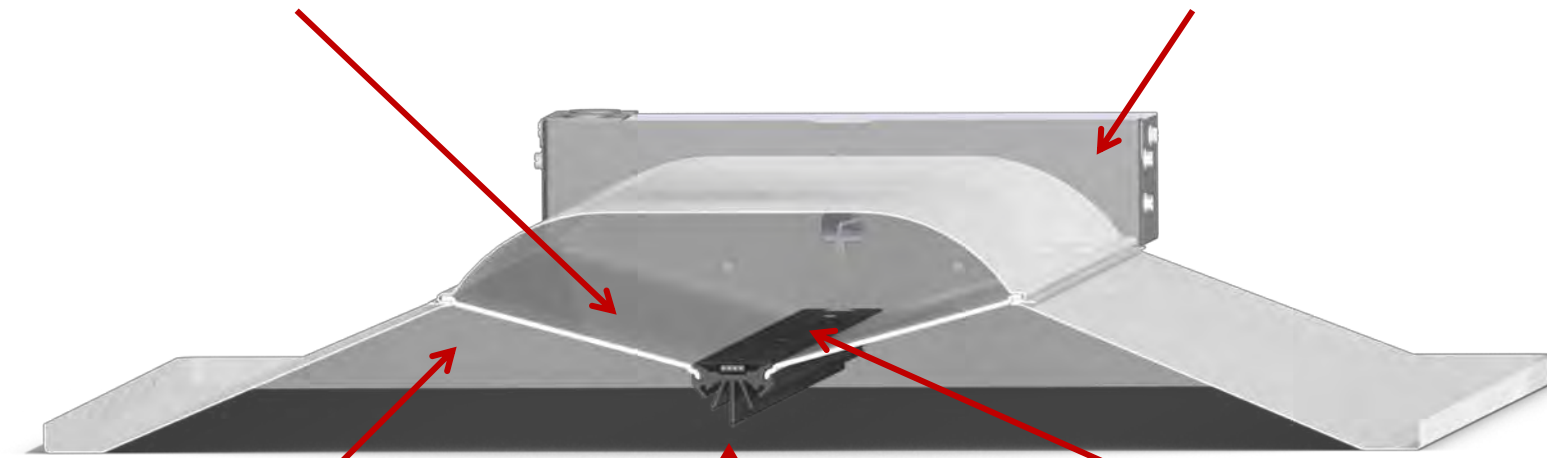
# CR24: systems level approach

## High Efficiency Mixing Chamber

Uniform, low brightness lens

## Next Generation Driver

Reduced Cost, Increased Efficiency



## One Piece Reflector

Creates Quiet Ceiling

## Cree TrueWhite® Technology

Beautiful Consistent Color

## Room-side Heat Sink

Maximized cooling effectiveness

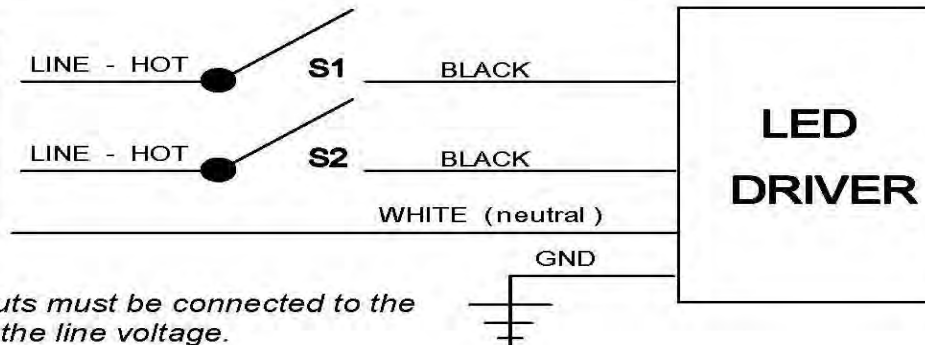
# Controls Options

- ◆ **S = Step Dimming 50% - Standard / Available Now**

The “S” option is for Step Dimming 50%. This option allows the luminaire to deliver either 100% light output (both switches ON), 50% light output (either switch ON and the other OFF) or 0% light output (both switches in the OFF position). It could also be named *Step Switching 50%*, because it does not actually require a dimmer, just (2) common, every day toggle switches or occupancy

## WIRING DIAGRAM:

Power Output	Position	
	S1	S2
100%	On	On
50%	On	Off
50%	Off	On
0%	Off	Off



**Note:** Line (HOT) inputs must be connected to the same phase of the line voltage.

- ◆ **10V = 0-10V dimming optional**

# Power Supply

## Power Supply efficiency

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- **12W product with a 75% efficient power supply generates 3W worth of heat in the power supply compartment**
- **12W product with an 88% efficient power supply generates 1.5W worth of heat in the power supply compartment**



**The power supply is just as important to the life of the fixture as the LEDs**

# Thank You



## Questions, Comments???