In the Matter of:

CERTAIN LIGHT-EMITTING DIODE PRODUCTS, FIXTURES, AND COMPONENTS THEREOF

Inv. No. 337-TA-1213

Jianzhong Jiao, Ph.D.

Honorable Clark S. Cheney

Administrative Law Judge

Asserted claims of the ’819 and ’531 patents

- **’819 Patent:** claims 1, 24-27, 29, 48-50, 52, 57-60, and 65-67
- **’531 Patent:** claims 1, 10-12, and 25-26

Text of the Claim Constructions

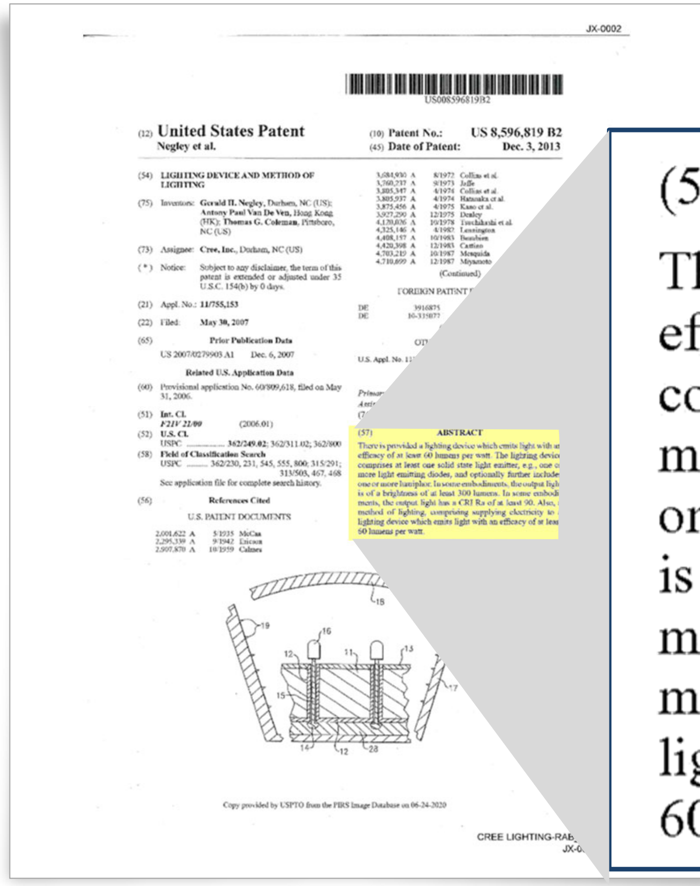
Term	Construction
"said output light being a quantity of light exiting from the lighting device"	Plain and ordinary meaning
"solid state light emitter"	Plain and ordinary meaning
"perceived as white"	"perceived as white by normal human vision"
"perceived as warm white"	"perceived as light having a color temperature between approximately 2700K and 3500K"
"wall plug efficiency"	"brightness (of light emitted by a lighting device) as measured relative to outlet energy (the power input to the lighting device) in lumens per watt."

Level of Ordinary Skill in the Art

"A person of ordinary skill would have had at least a Bachelor of Science degree in materials science, electrical engineering, or an equivalent field of study, along with three or more years of experience working with LED technology and that a more advanced degree reduces the threshold for years of experience in working with LED technology."

The ’819 Patent

’819 Patent – Abstract


JX-0002

(12) United States Patent
Negley et al.

(10) Patent No.: US 8,596,819 B2
(45) Date of Patent: Dec. 3, 2013

(54) LIGHTING DEVICE AND METHOD OF LIGHTING

(57) **ABSTRACT**

There is provided a lighting device which emits light with an efficacy of at least 60 lumens per watt. The lighting device comprises at least one solid state light emitter, e.g., one or more light emitting diodes, and optionally further includes one or more lumiphor. In some embodiments, the output light is of a brightness of at least 300 lumens. In some embodiments, the output light has a CRI Ra of at least 90. Also, a method of lighting, comprising supplying electricity to a lighting device which emits light with an efficacy of at least 60 lumens per watt.

JX-0002

Limitations of the Asserted Claims of ’819 Patent

Limitation	Claims
"at least 60 lumens per watt"	1, 29, 52, 60
"output light is perceived as warm white"	24
"from about 60 to about 70 lumens per watt"	25, 48, 57, 65
"from about 70 to about 80 lumens per watt"	26, 49, 58, 66
"from about 80 to about 85 lumens per watt"	27, 50, 59, 67

’819 Patent – First Embodiment

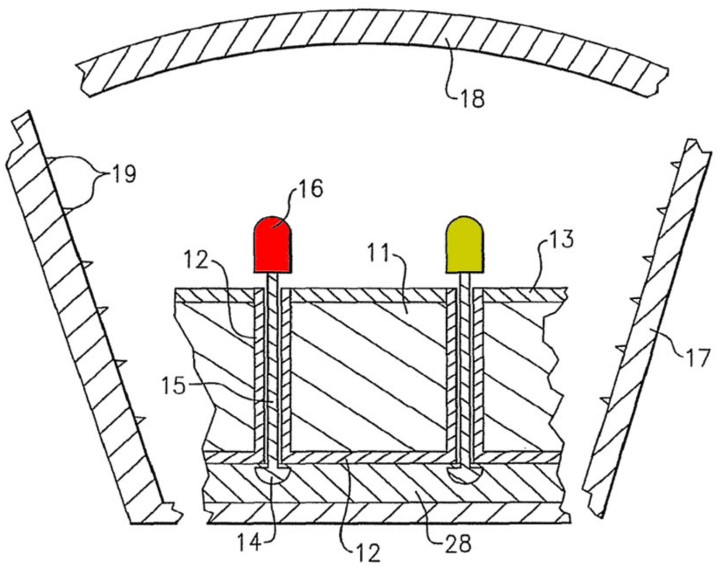


FIG.4

FIG. **4** depicts a first embodiment of a lighting device in accordance with the first aspect of the present invention.

Referring to FIG. **4**, there is shown a lighting device which includes a heat spreading element **11** (formed of aluminum), insulating regions **12** (formed in situ by anodizing surfaces of the aluminum heat spreading element), a highly reflective surface **13** (formed in situ by polishing the surface of the aluminum heat spreading element), conductive traces **14** formed of copper, lead frames **15** formed of silver-plated copper (or silver-plated mild steel), packaged LEDs **16***a*, **16***b* (described in more detail below), a reflective cone **17** (made of MCPET® (marketed by Furukawa, a Japanese corporation) with a diffuse light scattering surface and a diffusing element **18** (the diffusing element **18** performs a light scattering function).

JX-0002.0010, 22 at 15:11-25 (annotated)

’819 Patent – First Embodiment

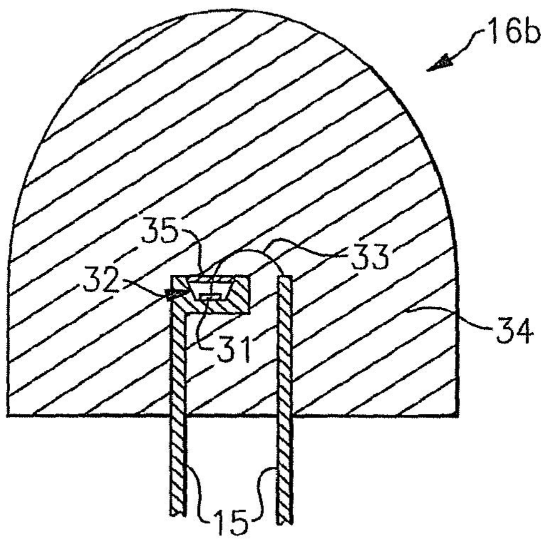
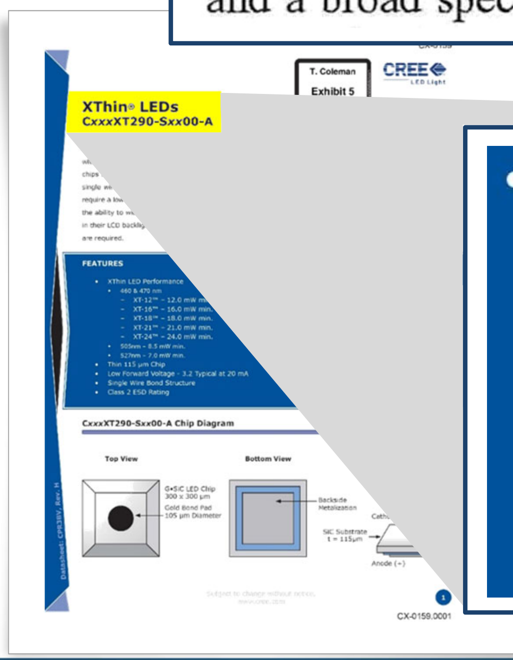


FIG.7

Referring to FIG. **7**, each of the greenish-yellowish emitters **16***b* includes a blue light emitting diode chip **31** (namely, a Cree XT LED (C460XT290) die with a peak wavelength range of from about 450 nm to about 465 nm, and optical power greater than 24 mW), a lead frame **15** having a reflective surface **32**, a copper wire **33**, an encapsulant region **34**, and a broad spectrum emitting lumiphor **35**.



- XThin LED Performance
  - 460 & 470 nm
    - XT-12™ – 12.0 mW min.
    - XT-16™ – 16.0 mW min.
    - XT-18™ – 18.0 mW min.
    - XT-21™ – 21.0 mW min.
    - XT-24™ – 24.0 mW min.

JX-0002.0011, 22 at 16:39-45

RDX-0002.09

’819 Patent – First Embodiment

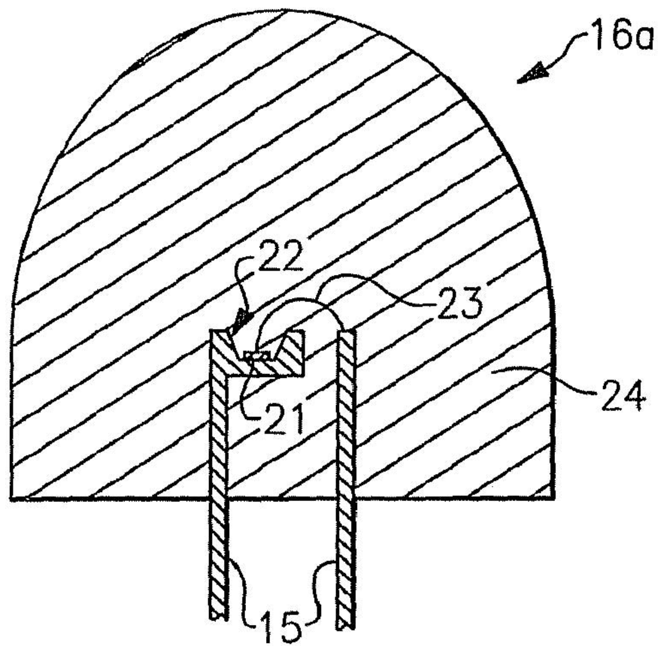


FIG.6

Referring to FIG. **6**, each of the red LEDs **16***a* includes a red light emitting diode chip **21** (from Epistar in Taiwan, measuring 14 mils×14 mils, comprising AlInGaP and having a brightness of not less than 600 mcd), a lead frame **15** having a reflective surface **22**, a copper wire **23**, and an encapsulant region **24**. The reflective surface **22** is made of silver.

JX-0002.0011, 22 at 16:23-28

’819 Patent - First Embodiment (47 red LED + 123 BSY emitters)

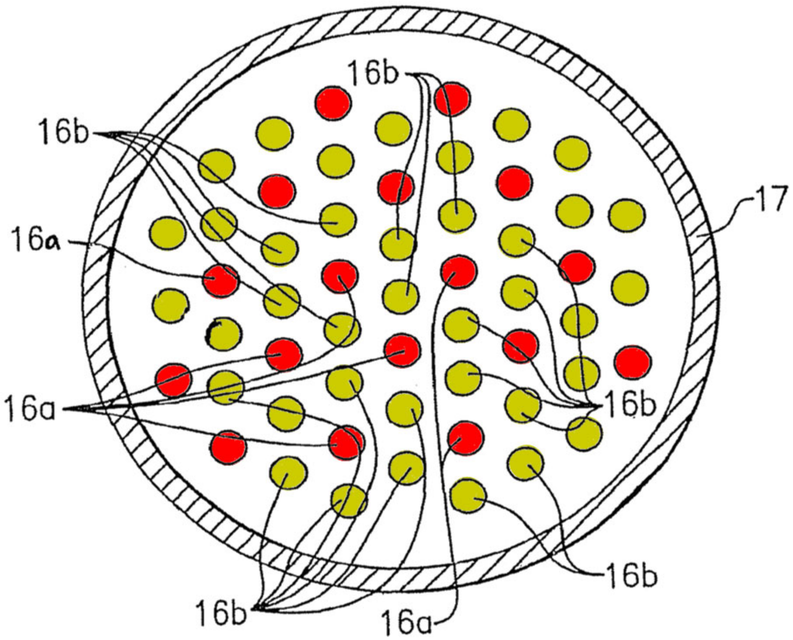


FIG.5

The device depicted in FIG. **4** includes three series strings of LED emitters.

Connected to the first string of LED emitters are a current regulator, forty-seven red LEDs **16***a* (shown in more detail in FIG. **6**), and twenty-one greenish-yellowish emitters **16***b* (each including a blue LED and a broad spectrum emitting lumiphor) (shown in more detail in FIG. **7**).

Connected to the second string of LED emitters are a current regulator, zero red LEDs and fifty-one greenish-yellowish emitters **16***b* (as above).

Connected to the third string of LED emitters are a current regulator, zero red LEDs and fifty-one greenish-yellowish emitters **16***b* (as above).

The current passing through the first string of LED emitters is regulated to be about 20 milliamps.

The current passing through the second string of LED emitters is regulated to be about 20 milliamps.

The current passing through the third string of LED emitters is regulated to be about 20 milliamps.

JX-0002.0010, 15:36-48; 15:55-60; Fig.5 (annotated)

’819 patent – Second Embodiment

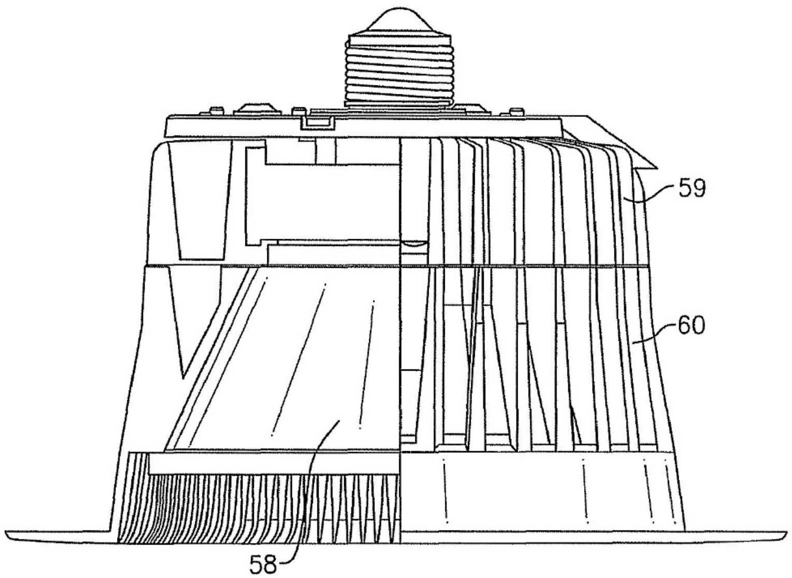


FIG.8

FIGS. **8-11** depict a second embodiment of a lighting device in accordance with the present invention.

The lighting device includes a plurality (e.g., three) series strings of LED emitters.

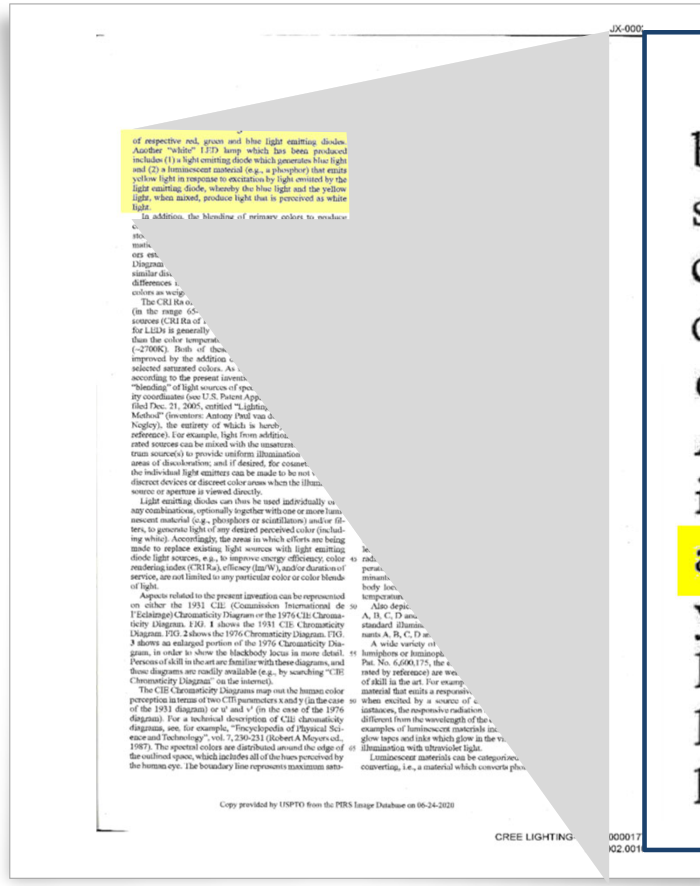
Connected to a first string of LED emitters are a current regulator and a plurality (e.g., six) of greenish-yellowish emitters. Each of the greenish-yellowish emitter includes a blue LED and a lumiphor, the lumiphor comprising YAG doped with Ce, Pr and/or Gd.

Connected to a second string of LED emitters are a current regulator, and a ratio of red LEDs to greenish-yellowish emitters, e.g., zero red LEDs and a plurality (e.g., six) of greenish-yellowish emitters.

Connected to a third string of LED emitters are a current regulator, and a different ratio of red LEDs to greenish-yellowish emitters, e.g., a plurality of red LEDs (e.g., thirty) and zero greenish-yellowish emitters.

JX-0002.0012, 23 at 17:57-18:4

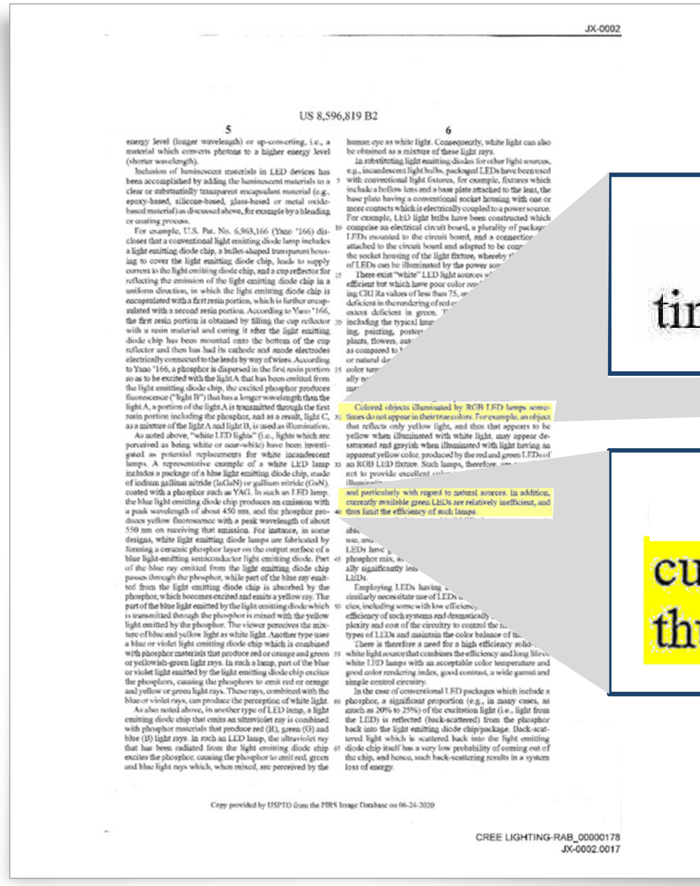
Background Section of ’819 Patent – RGB and PC LED Approaches



Because light that is perceived as white is necessarily a blend of light of two or more colors (or wavelengths), no single light emitting diode junction has been developed that can produce white light. “White” LED lamps have been produced which have a light emitting diode pixel/cluster formed of respective red, green and blue light emitting diodes. Another “white” LED lamp which has been produced includes (1) a light emitting diode which generates blue light and (2) a luminescent material (e.g., a phosphor) that emits yellow light in response to excitation by light emitted by the light emitting diode, whereby the blue light and the yellow light, when mixed, produce light that is perceived as white light.

JX-0002.0015 at 2:63-3:8

Background Section of ’819 Patent – RGB LED Approach

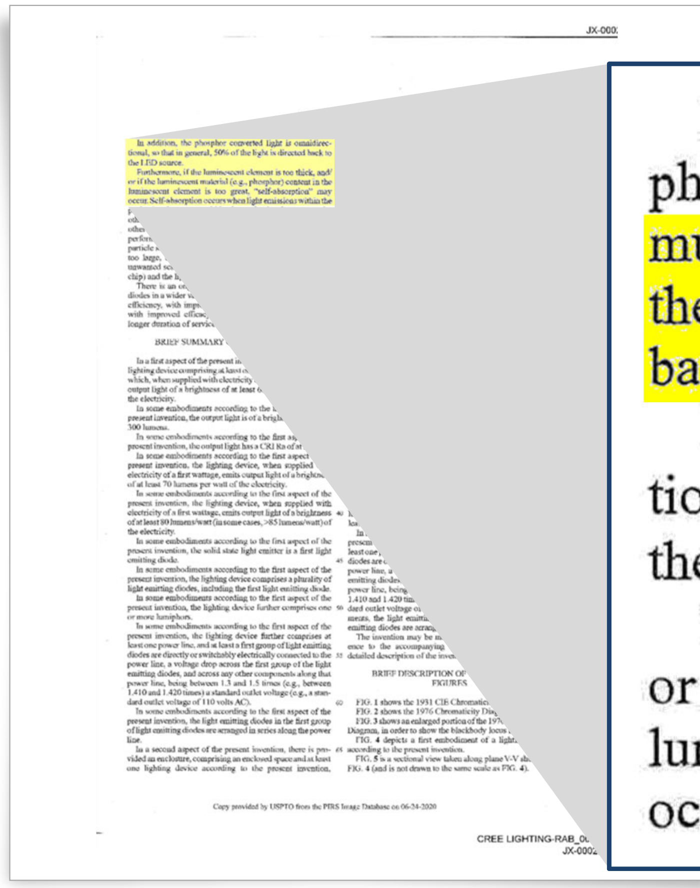


Colored objects illuminated by RGB LED lamps sometimes do not appear in their true colors.

In addition, currently available green LEDs are relatively inefficient, and thus limit the efficiency of such lamps.

JX-0002.0017 at 6:29-30, 38-40

Background Section of ’819 Patent – PC LED Approach



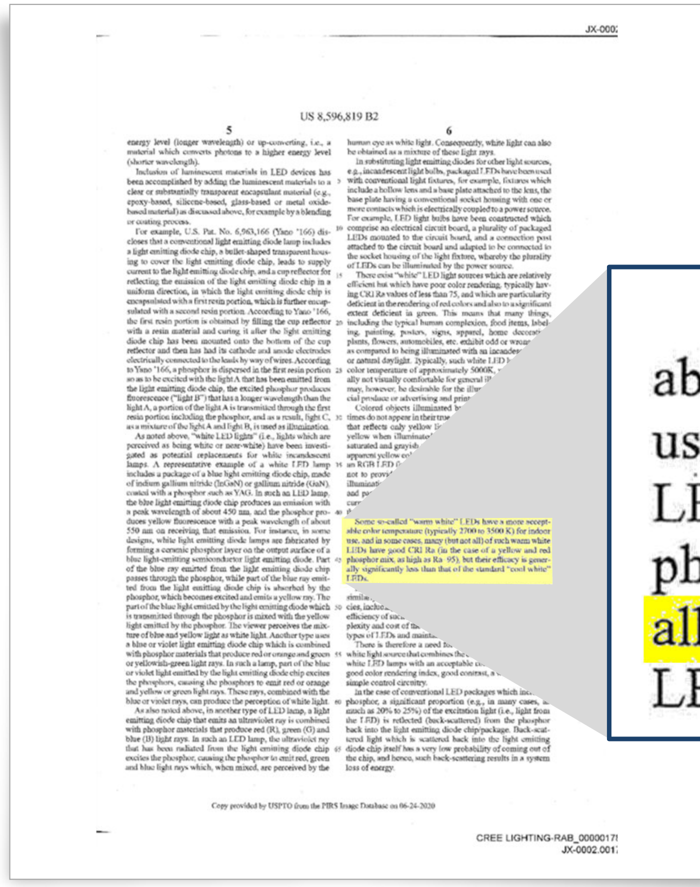
In the case of conventional LED packages which include a phosphor, a significant proportion (e.g., in many cases, as much as 20% to 25%) of the excitation light (i.e., light from the LED) is reflected (back-scattered) from the phosphor back into the light emitting diode chip/package.

In addition, the phosphor converted light is omnidirectional, so that in general, 50% of the light is directed back to the LED source.

Furthermore, if the luminescent element is too thick, and/or if the luminescent material (e.g., phosphor) content in the luminescent element is too great, “self-absorption” may occur.

JX-0002.0017 at 6:59-7:7

Background Section of ’819 Patent – PC LED Approach


JX-0002

US 8,596,819 B2

Copy provided by USPTO from the PIRS Image Database on 06-24-2020

CREE LIGHTING-RAB_0000017

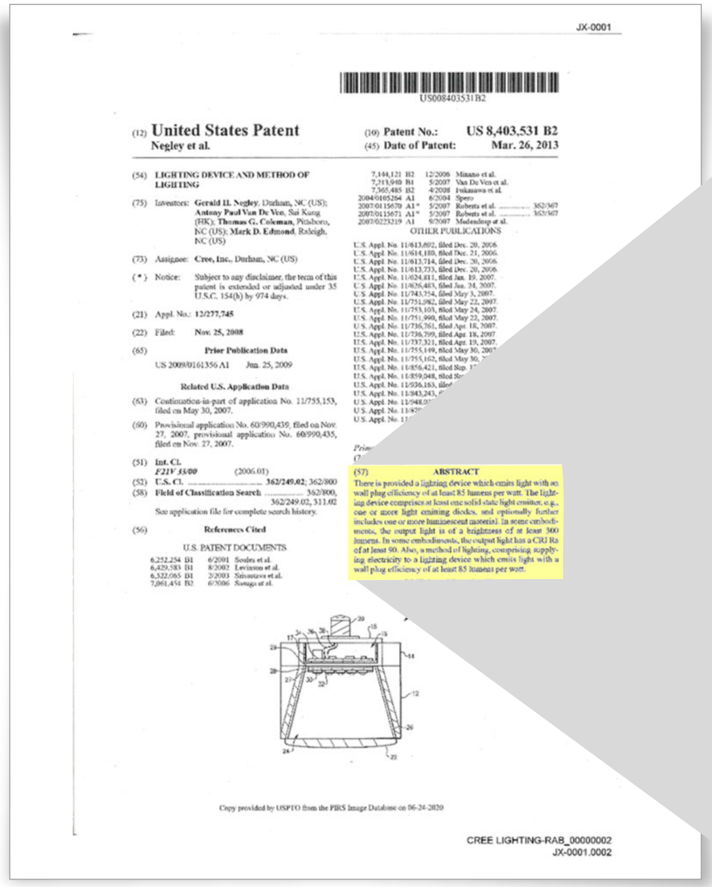
JX-0002.0017

Some so-called “warm white” LEDs have a more acceptable color temperature (typically 2700 to 3500 K) for indoor use, and in some cases, many (but not all) of such warm white LEDs have good CRI Ra (in the case of a yellow and red phosphor mix, as high as Ra=95), but their efficacy is generally significantly less than that of the standard “cool white” LEDs.

JX-0002.0017 at 6:41-47

The ’531 Patent

U.S. Patent 8,403,531 – Abstract



(57) **ABSTRACT**

There is provided a lighting device which emits light with an wall plug efficiency of at least 85 lumens per watt. The lighting device comprises at least one solid state light emitter, e.g., one or more light emitting diodes, and optionally further includes one or more luminescent material. In some embodiments, the output light is of a brightness of at least 300 lumens. In some embodiments, the output light has a CRI Ra of at least 90. Also, a method of lighting, comprising supplying electricity to a lighting device which emits light with a wall plug efficiency of at least 85 lumens per watt.

Limitations of the Asserted Claims of ’531 Patent

Limitation	Claims
"at least 85 lumens per watt"	1
"from about 85 to about 113.5 lumens per watt"	10
"at least 110 lumens per watt"	11
"from about 100 to about 113.5 lumens per watt"	12
"from about 85 to about 100 lumens per watt"	25
"from about 85 to about 110 lumens per watt"	26

’531 Patent – Only Disclosed Embodiment

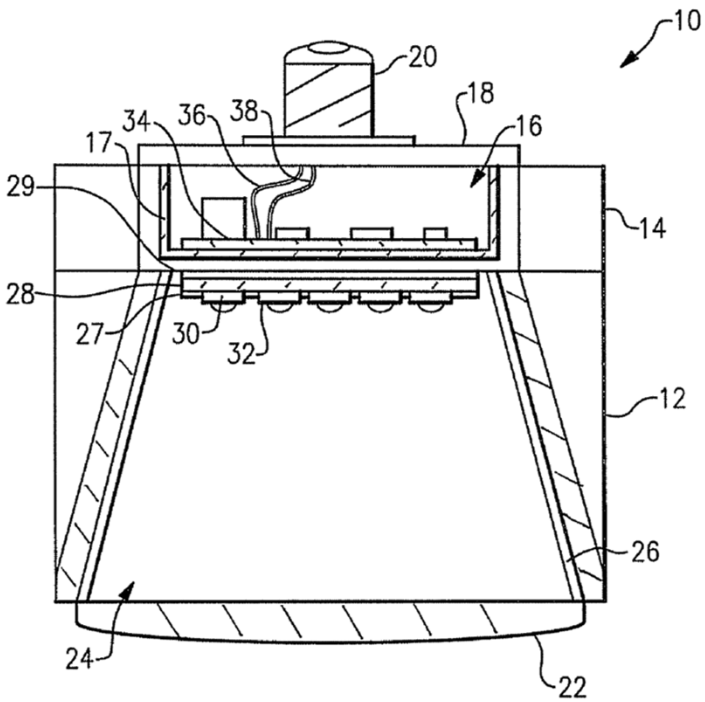


FIG.1

The light sources are LEDs. The LEDs include non-white, non-saturated phosphor converted LEDs **30** and saturated LEDs **32**. The LEDs provided light output as described in U.S. Pat. No. 7,213,940, the entirety of which is hereby incorporated herein in its entirety. In this particular embodiment, 21 phosphor converted LEDs **30** and 11 saturated LEDs **32** are utilized. The phosphor converted LEDs **30** are Cree X Lamps from Cree, Inc., Durham, N.C. and the saturated LEDs **32** are from OSRAM/Sylvania. The brightness of the parts are sufficiently high to achieve the desired light output and wall plug efficiency. The saturated LEDs **32** are OSRAM Golden Dragon parts to which lenses are attached to improve light extraction. In particular, an optical adhesive is used to attach lenses, such as the lenses from Cree XRE parts, to the Golden Dragons.

JX-0001.0004, 20 at 21:17-31

’531 Patent – Only Disclosed Embodiment

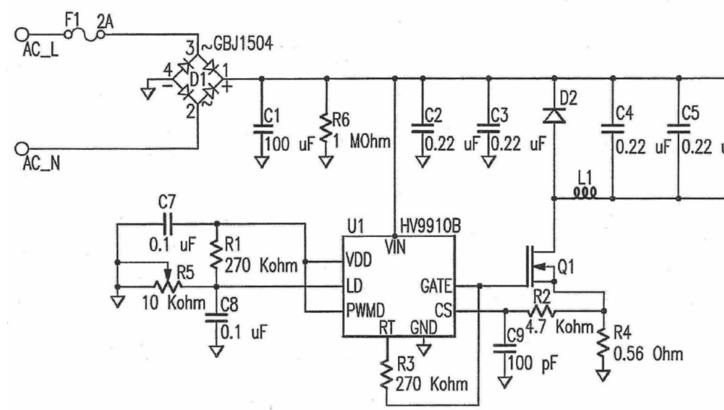
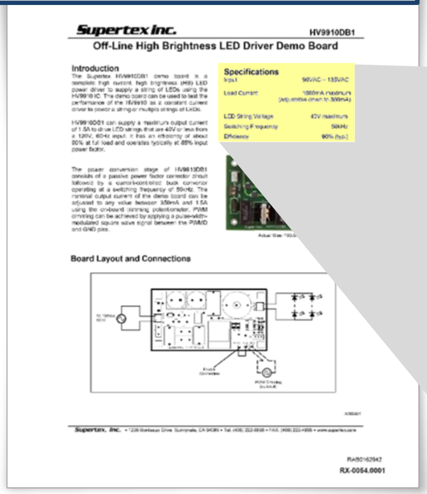


FIG.2

The power supply **34** is connected to the Edison connector **20** through wires **36** and **38**. A schematic of the power supply **34** is provided in FIG. **2**. In FIG. **2**, the string of LEDs is connected between pins **1** and **2** of J**1**. With regard to specific parts, the values in the present embodiment are provided in FIG. **2** for the majority of parts. With regard to parts without values, the diode D**2** is a MURS140 from Digikey, the inductor L**1** is 3.9 mH and the transistor Q**1** is an nFET FQP3N30-ND from Digikey. The HV9910B is a universal high brightness LED driver from Supertex, Inc, Sunnyvale, Calif. The variable resistance R**5** is provided to adjust the current through the LED string connected across J**1**.



Specifications

Input	90VAC – 135VAC
Load Current	1500mA maximum (adjustable down to 350mA)
LED String Voltage	40V maximum
Switching Frequency	50kHz
Efficiency	90% (typ.)

JX-0001.0005, 20 at 21:52-63

RDX-0002.021

’531 Patent – Only Disclosed Embodiment

Input voltage: 120 Volts (V) AC, 60 Hz
Lamp current: 0.1158 Amperes (A)
LED Lamp Input Electrical Power: 5.802 Watts (W)
Total Luminous Flux: 658.7 lumens (lm)
Wall plug efficiency: 113.5 lm/W
CIE 1931 chromaticity coordinates: x 0.4511, y 0.402
Correlated Color Temperature: 2760K
CRI: 91.2
Ambient temperature: 26° C.

The device of FIGS. **1** and **2** was tested by NIST and resulted in the Following performance:

The optical performance of the system was measured internally at LED Lighting Fixtures, Inc. (Morrisville, N.C.) as about a 4.5% loss in that about 95.5% of the light generated by the light sources was extracted from the lamp. The power supply efficiency was measured internally at LED Lighting Fixtures, Inc. as about 93.5% in that 93.5% of the power supplied to the lamp was supplied to the load.

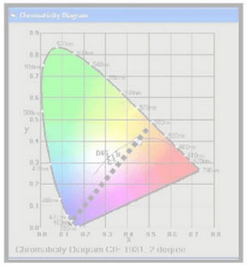
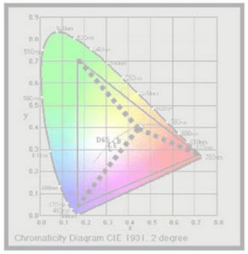
JX-0001.0020 at 21:64-22:14

Conventional RGB and PC LED Approaches

Conventional LED Warm White

- Blue dice with Phosphor conversion
  - Adding Red Phosphor and Green Phosphor
    - Low Efficacy (15 LPW to 35LPW) at the component Level due to phosphor quantum efficiency and stokes loss
    - Good CRI Ra 80 - 95

- RGB
  - Tunable CCT with "warm white"
    - ~ 40 LPW primarily due to low efficiency of Green LEDs
    - Low CRI

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Good CRI Ra 80 - 95
nable CCT with "warm ite"
~ 40 LPW primarily due to low efficiency of Green LEDs
Low CRI
tional methods - Low efficacy or poor CRI

Conventional methods - Low efficacy or poor CRI

A Different Approach – "BSY+R"

A different approach

Combine phosphor yellow LEDs and red LEDs – "BSY+R"

Phosphor Yellow LED Lamps

– a unique area in color space (CIE 1931 (x,y) chart)

– an "unconventional color" using "conventional phosphor conversion"

"BSY+R" Technology

–Yellow phosphor Lamps in conjunction with conventional, saturated red LEDs

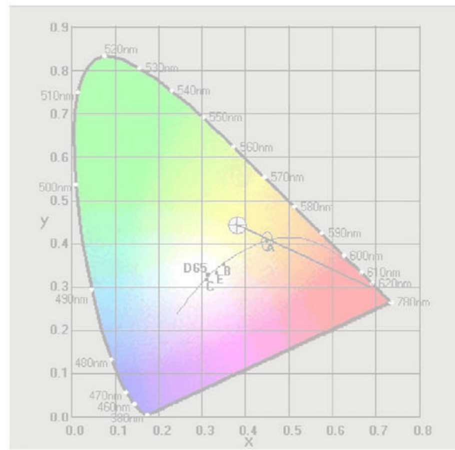
Using BSY lamps of various colors and "pulling" to the Black body locus with RED gives superior efficacy and color

BSY Phosphor yellow + red →

High Efficacy

High Color Quality warm white

Combine phosphor yellow LEDs and red LEDs – "BSY+R"



BSY+R - High efficacy and high CRI

Confidential and Proprietary

RX-0090.0004

Conventional vs. "BSY+R" Approaches

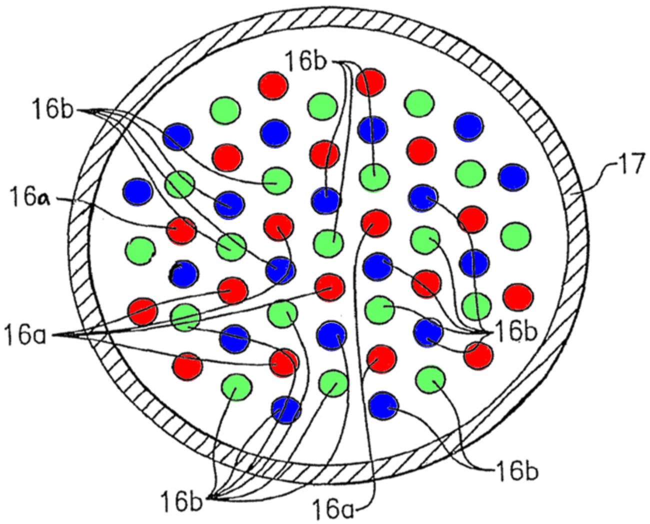
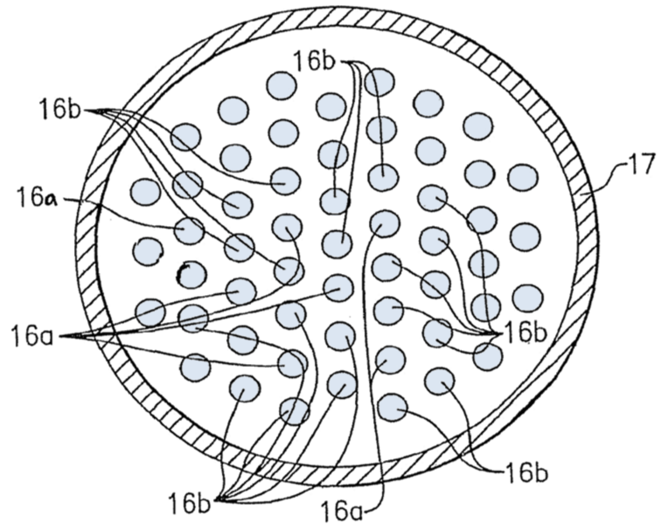
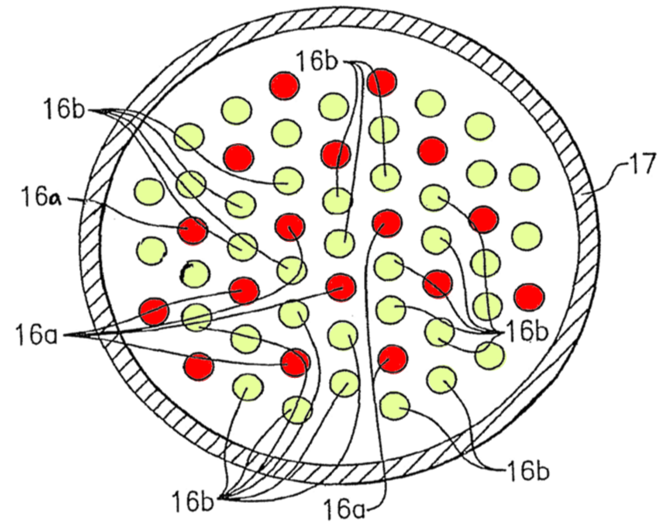
Prior Art – RGB [Mixture of red, green and blue dots]	Prior Art – PC LED [All white dots]	BSY+R [Combined red dots and greenish-yellowish dots]
		

FIG.5

FIG.5

FIG.5

JX-0002.0010 (annotated)

At Least One LED or Solid State Light Emitter

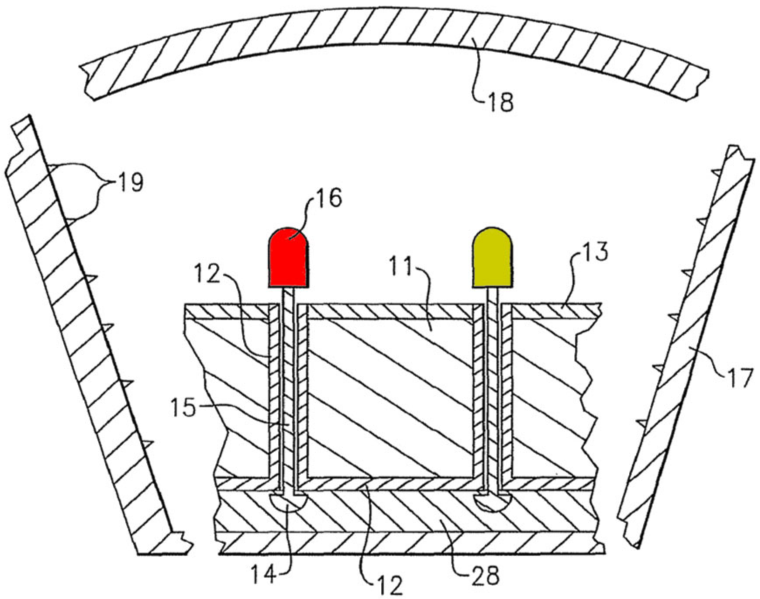


FIG.4

1. A lighting device comprising at least one solid state light emitter, said lighting device, when supplied with electricity of a first wattage, emitting output light having a wall plug efficiency of at least 85 lumens per watt of said electricity.

1. A lighting device comprising at least one light emitting diode,
said lighting device, when supplied with electricity of a first wattage, emitting output light with a wall plug efficiency of at least 60 lumens per watt of said electricity.

DOE Roadmap

RX-0726

Light Emitting Diodes (LEDs) for General Illumination

AN OIDA TECHNOLOGY ROADMAP UPDATE 2002

Full Edition Including Tutorial Source Material

November 2002

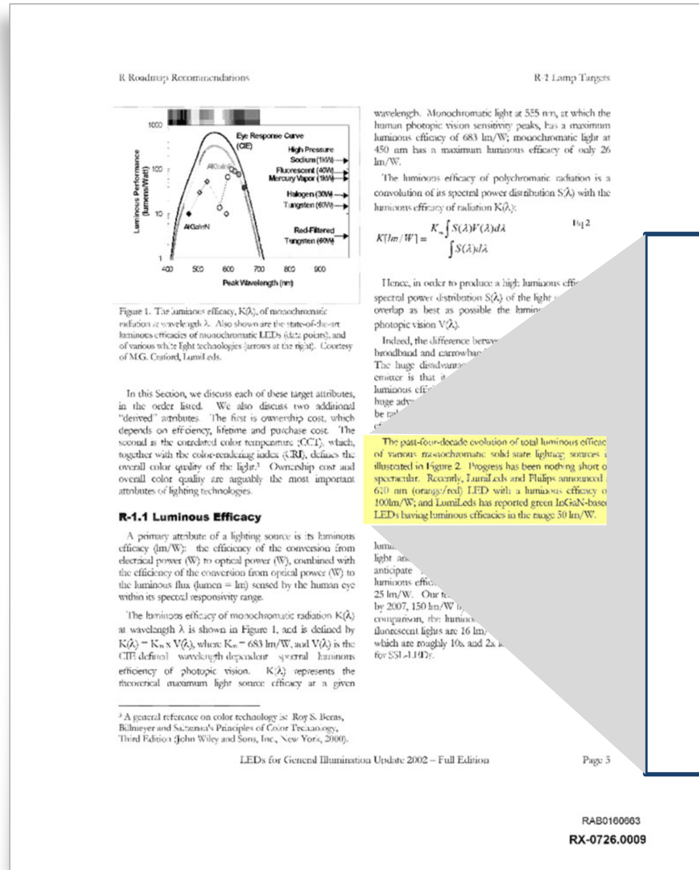
Sponsored by: Optoelectronics Industry Development Associatio[n]
National Electrical Manufacturers Association (NEMA)
Department of Energy – Office of Building Technology, State a[nd] Community Programs

Edited by: Jeff Y. Tsao, Sandia National Laboratories

Published by: OIDA OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

RAB0160655
RX-0726.0001

DOE Roadmap



R Roadmap Recommendations — R-1 Lamp Targets

Figure 1. The luminous efficacy, K(λ), of monochromatic radiation at wavelength λ. Also shown are the state-of-the-art luminous efficacies of monochromatic LEDs (data points), and of various white light technologies (arrows at the right). Courtesy of M.G. Craford, LumiLeds.

In this Section, we discuss each of these target attributes, in the order listed. We also discuss two additional "derived" attributes. The first is ownership cost, which depends on efficiency, lifetime and purchase cost. The second is the correlated color temperature (CCT), which, together with the color-rendering index (CRI), defines the overall color quality of the light.[3] Ownership cost and overall color quality are arguably the most important attributes of lighting technologies.

R-1.1 Luminous Efficacy

A primary attribute of a lighting source is its luminous efficacy (lm/W): the efficiency of the conversion from electrical power (W) to optical power (W), combined with the efficiency of the conversion from optical power (W) to the luminous flux (lumen = lm) sensed by the human eye within its spectral responsivity range.

The luminous efficacy of monochromatic radiation K(λ) at wavelength λ is shown in Figure 1, and is defined by K(λ) = K_m x V(λ), where K_m = 683 lm/W, and V(λ) is the CIE defined wavelength dependent spectral luminous efficiency of photopic vision. K(λ) represents the theoretical maximum light source efficacy at a given wavelength. Monochromatic light at 555 nm, at which the human photopic vision sensitivity peaks, has a maximum luminous efficacy of 683 lm/W; monochromatic light at 450 nm has a maximum luminous efficacy of only 26 lm/W.

The luminous efficacy of polychromatic radiation is a convolution of its spectral power distribution S(λ) with the luminous efficacy of radiation K(λ):

$$K[lm/W] = \frac{K_m \int S(\lambda)V(\lambda)d\lambda}{\int S(\lambda)d\lambda} \quad \text{Eq 2}$$

Hence, in order to produce a high luminous effic… spectral power distribution S(λ) of the light … overlap as best as possible the lumin… photopic vision V(λ).

Indeed, the difference betwe… broadband and narrowban… The huge disadvanta… emitter is that it… luminous effi… huge adv… be tai…

The past-four-decade evolution of total luminous efficac[y] of various monochromatic solid state lighting sources i[s] illustrated in Figure 2. Progress has been nothing short o[f] spectacular. Recently, LumiLeds and Philips announced [a] 610 nm (orange/red) LED with a luminous efficacy o[f] 100lm/W; and LumiLeds has reported green InGaN-base[d] LEDs having luminous efficacies in the range 50 lm/W.

lumi… light an… anticipate… luminous effic… 25 lm/W. Our t… by 2007, 150 lm/W … comparison, the lumino… fluorescent lights are 16 lm… which are roughly 10x and 2x … for SSL-LEDs.

[3] A general reference on color technology is: Roy S. Berns, Billmeyer and Saltzman's Principles of Color Technology, Third Edition (John Wiley and Sons, Inc., New York, 2000).

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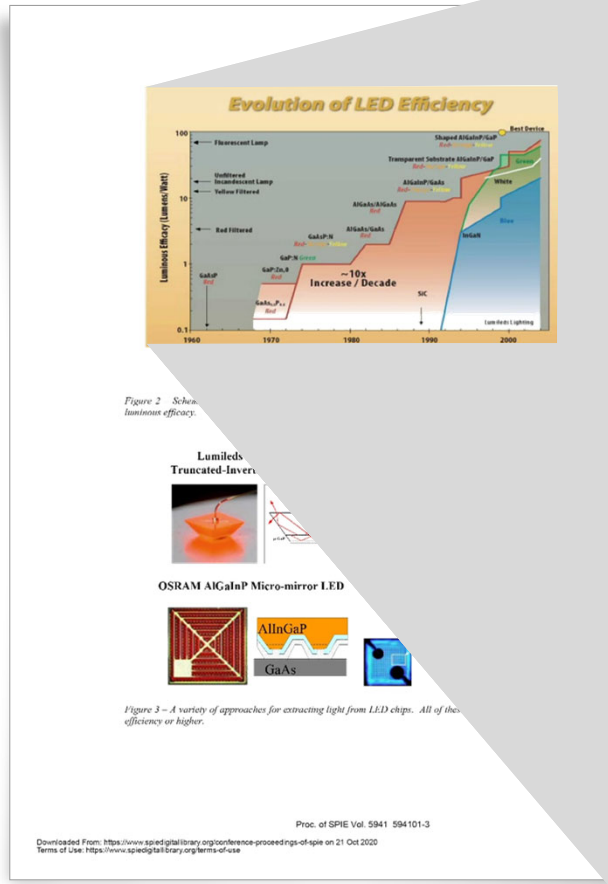
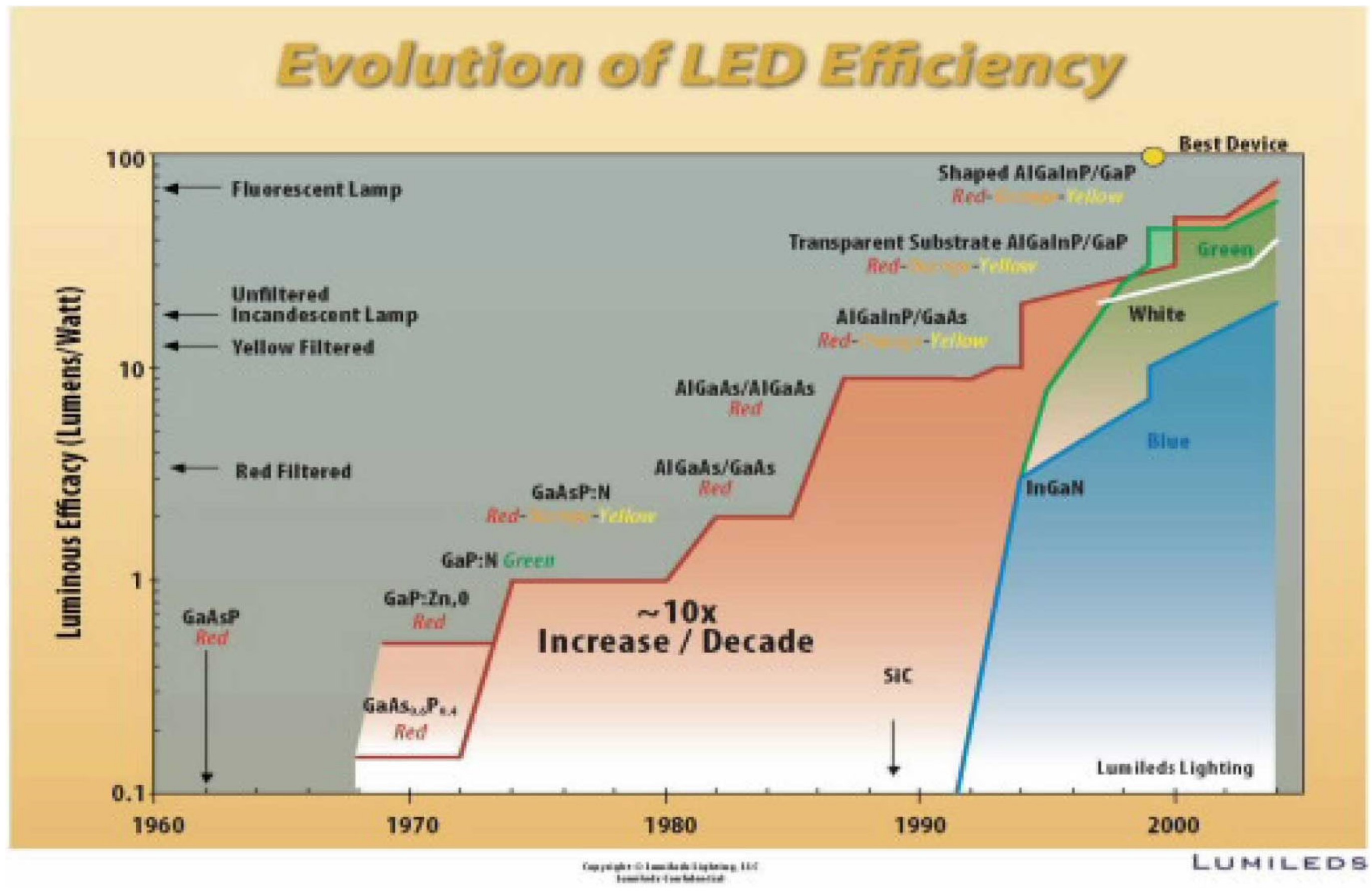
RX-0726.0009

The past-four-decade evolution of total luminous efficacy of various monochromatic solid-state lighting sources is illustrated in Figure 2. Progress has been nothing short of spectacular. Recently, LumiLeds and Philips announced a 610 nm (orange/red) LED with a luminous efficacy of 100lm/W; and LumiLeds has reported green InGaN-based LEDs having luminous efficacies in the range 50 lm/W.

RX-0726 at Pg. 5

DOE Roadmap/Craford Article





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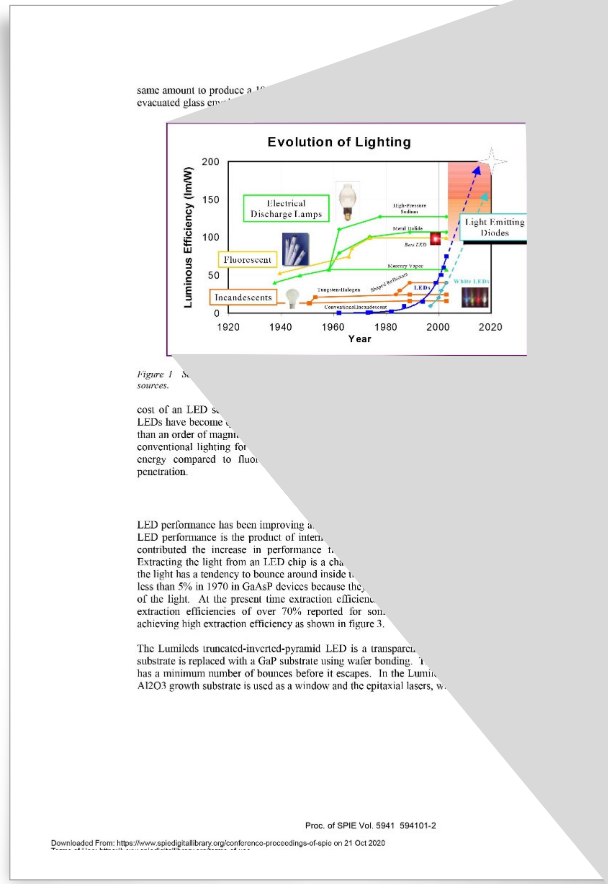
DOE Roadmap/Craford Article



same amount to produce a 1…
evacuated glass env…

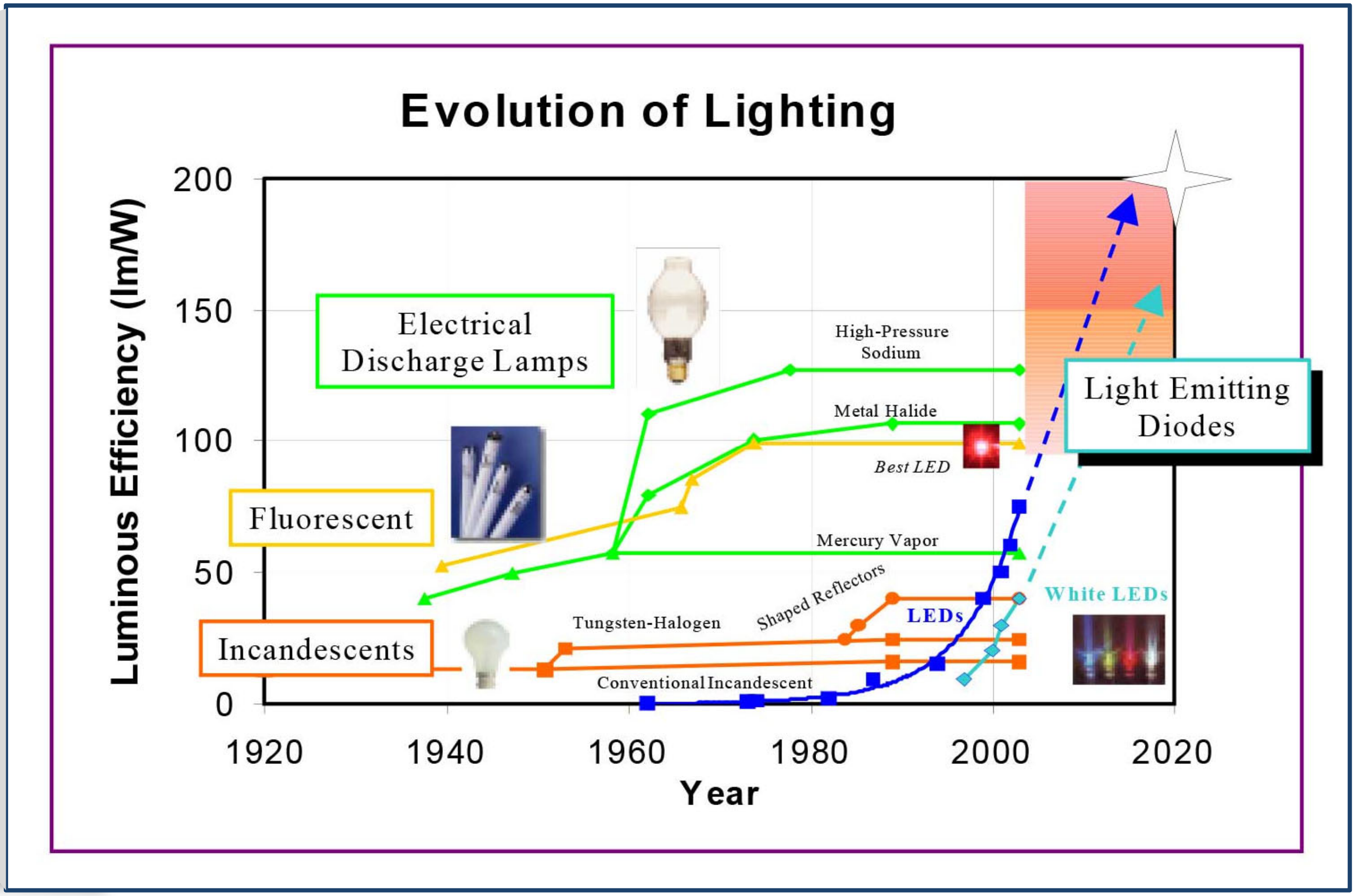
Figure 1 S…
sources.

cost of an LED s…
LEDs have become …
than an order of magn…
conventional lighting for…
energy compared to fluo…
penetration.

LED performance has been improving a…
LED performance is the product of intern…
contributed the increase in performance t…
Extracting the light from an LED chip is a cha…
the light has a tendency to bounce around inside t…
less than 5% in 1970 in GaAsP devices because the…
of the light. At the present time extraction efficienc…
extraction efficiencies of over 70% reported for son…
achieving high extraction efficiency as shown in figure 3.

The Lumileds truncated-inverted-pyramid LED is a transparen…
substrate is replaced with a GaP substrate using wafer bonding. T…
has a minimum number of bounces before it escapes. In the Lumi…
Al2O3 growth substrate is used as a window and the epitaxial lasers, w…

Proc. of SPIE Vol. 5941 594101-2



RX-0756.0003

RDX-0002.030

Timeline – January 2006 CSA Test

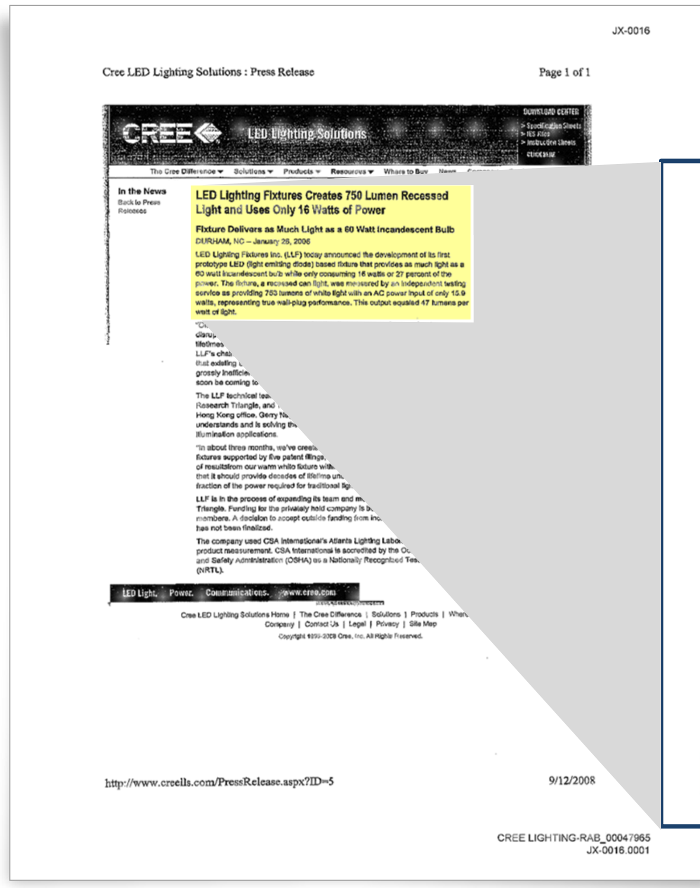
Test Data Collected

1. Total Lamp Operation Time = 20 minutes
2. Input Voltage = 117.01 V, 60Hz
3. Input Current = 323 mA
4. Input Power = 15.9 W
5. Ambient Temperature Inside Sphere = 25.4 °C
6. Luminous Flux = 753 Lumens
7. Radiant Flux = 2579 mW
8. Correlated Color Temperature = 5887 K
9. CRI = 84.46
10. X = 0.3237
11. Y = 0.3409
12. Efficacy (calculated) = 47.36 lumen/watt

Test Data Collected

1. Total Lamp Operation Time = 55 minutes
2. Input Voltage = 117.01 V, 60Hz
3. Input Current = 342 mA
4. Input Power = 16.7 W
5. Ambient Temperature Inside Sphere = 25.7 °C
6. Luminous Flux = 552.2 Lumens
7. Radiant Flux = 1837 mW
8. Correlated Color Temperature = 3557K
9. CRI = 94.28
10. X = 0.4079
11. Y = 0.4055
12. Efficacy (calculated) = 33.07 lumen/watt

Timeline – January 2006 Press Release


JX-0016

Cree LED Lighting Solutions : Press Release   Page 1 of 1

LED Lighting Fixtures Creates 750 Lumen Recessed Light and Uses Only 16 Watts of Power

Fixture Delivers as Much Light as a 60 Watt Incandescent Bulb

http://www.creells.com/PressRelease.aspx?ID=5   9/12/2008

CREE LIGHTING-RAB_00047965
JX-0016.0001

LED Lighting Fixtures Creates 750 Lumen Recessed Light and Uses Only 16 Watts of Power

Fixture Delivers as Much Light as a 60 Watt Incandescent Bulb

DURHAM, NC – January 26, 2006

LED Lighting Fixtures Inc. (LLF) today announced the development of its first prototype LED (light emitting diode) based fixture that provides as much light as a 60 watt incandescent bulb while only consuming 16 watts or 27 percent of the power. The fixture, a recessed can light, was measured by an independent testing service as providing 753 lumens of white light with an AC power input of only 15.9 watts, representing true wall-plug performance. This output equaled 47 lumens per watt of light.

JX-0016

Timeline – February 2006 CSA Test

Report Number: 1765845 Project Number: 1765845-1		Date Issued: February 16, 2006 Page 4 of 12

General Input and Output Measurements
No Standard

Test Method Applied

The LED lamp was mounted into the integrating sphere in the lamp base up orientation
Lampholder jig. Proper Baffling of the lamp was visually verified around the la
the horizontal plane of the opening in the sphere for the measurement sa
then energized at rated input voltage and frequency (measurement t
binding posts). The lamp was allowed to stabilize before an
made. The LED lamp was considered photometrically
minimum time period of 15 minutes and stable
of the LM-66 Standard. The photometric
integrating sphere with an auxiliary
a power analyzer. Measurem
The temperature was m
testing was meas
plane as th
was

Test Data Collected

1. Total Lamp Operation Time = 15 minutes
2. Input Voltage = 117.05 V, 60Hz
3. Input Current = 271.9 mA
4. Input Power = 13.089 W
5. Input Power Factor = 0.411
6. Ambient Temperature Inside Sphere = 25.1 °C
7. Luminous Flux = 700.3 Lumens
8. Radiant Flux = 2135 mW
9. Correlated Color Temperature = 2904 K
10. CRI = 92.81
11. X = 0.4425
12. Y = 0.4038
13. Efficacy (calculated) = 53.50 lumen/watt

Test Equ

1. 926
2. A46
3. AC100
4. DAS1100
5. LPS200
6. PA101
7. TI1100

Test Data Collected

1. Total Lamp Operation Time = 15 minutes
2. Input Voltage = 117.05 V, 60Hz
3. Input Current = 271.9 mA
4. Input Power = 13.089 W
5. Input Power Factor = 0.411
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10. CRI = 92.81
11. X = 0.4425
12. Y = 0.4038
13. Efficacy (calculated) = 53.50 lumen/watt

RX-0738

Timeline – February 2006 Press Release

LED Lighting Fixtures, Inc. Announces Record Performance

Warm White Fixture Emits 700 Lumens using 13 Watts of Household Power

DURHAM, N.C., Feb. 16 /PRNewswire/

LED Lighting Fixtures, Inc. (LLF) today announced performance results from its most recent recessed can fixture. The fixture was tested by an independent lab as providing 700 lumens of white light at a color temperature of 2900 Kelvin, with a color rendering index (CRI) of 93. Total power supplied to the fixture from a residential voltage, AC power source was 13 watts. The fixture efficiency equaled approximately 54 lumens per watt of warm white light.

Timeline – April 2006 CSA Tests

Test Data Collected At 110V, 60Hz Input

1. Total Lamp Operation Time = 35 minutes
2. Input Voltage = 110.03 V, 60Hz
3. Input Current = 169.4 mA
4. Input Power = 7.446 W
5. Input Power Factor = 0.4
6. Ambient Temperature Inside Sphere = 24.8 °C
7. Luminous Flux = 594.1 Lumens
8. Radiant Flux = 864.8 mW
9. Correlated Color Temperature = 3124 K
10. CRI = 92.24
11. X = 0.4227
12. Y = 0.3888
13. Efficacy (calculated) = 79.79 lumen/watt

Test Data Collected At 115V, 60Hz Input

14. Total Lamp Operation Time = 112 minutes
15. Input Voltage = 115.03 V, 60Hz
16. Input Current = 213.2 mA
17. Input Power = 9.737 W
18. Input Power Factor = 0.399
19. Ambient Temperature Inside Sphere = 25.5 °C
20. Luminous Flux = 707.9 Lumens
21. Radiant Flux = 1030 mW
22. Correlated Color Temperature = 3189 K
23. CRI = 91.66
24. X = 0.4184
25. Y = 0.3866
26. Efficacy (calculated) = 72.70 lumen/watt

JX-0014.0009

Timeline – April 2006 Press Release for April 2006 CSA Test Results (115V)

Test Data Collected At 115V, 60Hz Input

14. Total Lamp Operation Time = 112 minutes
15. Input Voltage = 115.03 V, 60Hz
16. Input Current = 213.2 mA
17. Input Power = 9.737 W
18. Input Power Factor = 0.399
19. Ambient Temperature Inside Sphere = 25.5 °C
20. Luminous Flux = 707.9 Lumens
21. Radiant Flux = 1030 mW
22. Correlated Color Temperature = 3189 K
23. CRI = 91.66
24. X = 0.4184
25. Y = 0.3866
26. Efficacy (calculated) = 72.70 lumen/watt

Latest prototype fixture operates using 15 percent of the power of standard 65-watt incandescent bulbs

Morrisville, N.C., April 24, 2006

LED Lighting Fixtures, Inc. (LLF) announced today that independent third-party testing has confirmed that the company's recessed luminaire has an efficacy of 73 lumens per watt, a staggering gain in efficacy of 35 percent over test results of its predecessor just two short months ago. This advance paves the way for wider acceptance of light-emitting diode (LED) technology in the U.S. lighting market, estimated at $12 billion.

In recent testing conducted at CSA International's Lighting Laboratory in Atlanta, LLF's fixtures continuously produced more than 700 lumens using less than 10 watts from a wall-plug AC source. This result was significantly higher than the company's 54 lumens per watt achieved in February. Color temperature was measured at 3200 Kelvin, with a color rendering index of 92. LLF's proprietary white light technology allows for a wide range of desired color temperatures. The company used LEDs supplied by Cree, Inc.

Timeline – May 2006 Press Release for April 2006 CSA Test Results (110V)

Test Data Collected At 110V, 60Hz Input

1. Total Lamp Operation Time = 35 minutes
2. Input Voltage = 110.03 V, 60Hz
3. Input Current = 169.4 mA
4. Input Power = 7.446 W
5. Input Power Factor = 0.4
6. Ambient Temperature Inside Sphere = 24.8 °C
7. Luminous Flux = 594.1 Lumens
8. Radiant Flux = 864.8 mW
9. Correlated Color Temperature = 3124 K
10. CRI = 92.24
11. X = 0.4227
12. Y = 0.3888
13. Efficacy (calculated) = 79.79 lumen/watt

LED Lighting Fixtures, Inc. Sets World Record at 80 Lumens per Watt for Warm White Fixture

Company to Demonstrate Initial Products to Target Customers During Lighting Conference

LAS VEGAS, May 30 /PRNewswire/ -- LED Lighting Fixtures Inc. (LLF) today announced another record in solid state fixture performance at 80 lumens per watt from its most recent recessed downlight. This product was tested by an independent lab as providing 600 lumens of warm white light at a color temperature of 3100 Kelvin, with a color rendering index (CRI) of 92. Total power supplied to the fixture from a residential voltage AC power source was 7.5 watts. The company used LEDs supplied by Cree, Inc. (Nasdaq: CREE). These results reflect a ten percent increase in efficiency from the company's previous record of 73 lumens per watt announced on April 24, 2006.

JX-0014.0099, RX-0051.002

Timeline - May 5, 2006 Project List

Project Name	Description	Purpose	Str	CCT	Lumens	Watts	L/W	CRI	CSA	Location
T1 - cool white	**Nichia lamps + Cotco RED**	**First press release**		**5500**	**753**	**16**	**47**		**yes**	**USA office**
T1 - warm white	Nichia lamps (dipped) + Cotco RED			2800					yes	USA office
T2	**XT+ cotco red**	**Second press release**	**4**	**2800**	**700**	**13**	**54**	**93**	**yes**	**USA office**
L1		Customer demonstration in small volumetric fixture		3400						USA office
L1-1		Light engine for 2' x 4' fixtures for Lightfair		3400			70			
D1	18 x Xlamp CW ring type McPET reflector hat	Photo used in early company presentations	1	5500	600		30			Tony's house
D2	18 x SS WW, ring type cone reflector	Not completed	1	2800						USA office
D3-1	**3 strings, 117 x XT31, 55 x EPI 600mcd 616nm AlInGaP**	**Third press release**	**3**	**3200**	**700**	**10**	**73**	**92**	**yes**	**USA conference room**
D3-2	Per D3-1- denser packing, improved color mixing	mark II	3	3400	700		70			
D3-3	Per D3-1- improved housing	Lightfair demos	3	3400	700		70			
D4	4 string, XT33 + Osram 616 reds	Lightfair press release	4	3400	700		90			

Company Confidential

5/5/2006

Timeline – May 22, 2006 Email

RX-0743C

Message

From: Gerald Negley [gerry_negley@ledlightingfixtures.com]
Sent: 5/22/2006 7:06:25 PM
To: Cynthia Merrell [cindy_merrell@ledlightingfixtures.com]
CC: mike_rogers@cree.com; Neal Hunter [hnf313@aol.com]; tonyvdv@ledlightingfixtures.com
Subject: RE: No LPW record at this time

From: Gerald Negley [mailto:gerry_negley@ledlightingfixtures.com]

Subject: No LPW record at this time

The 80 LPW number is real and a bench mark -- but does use a lower curent density (standard industry trick) to acheive. I must also tell you that we were trying to use this same "trick" to get to 90 lpw.............. but the samples just fell short.....way short.

Let's see the opinions of others.

Knowing that each succesive gain that we will release is getting dramatically tougher................. I think we should consider showing this result as we are approaching the onset of Zeno's dichotomy paradox!

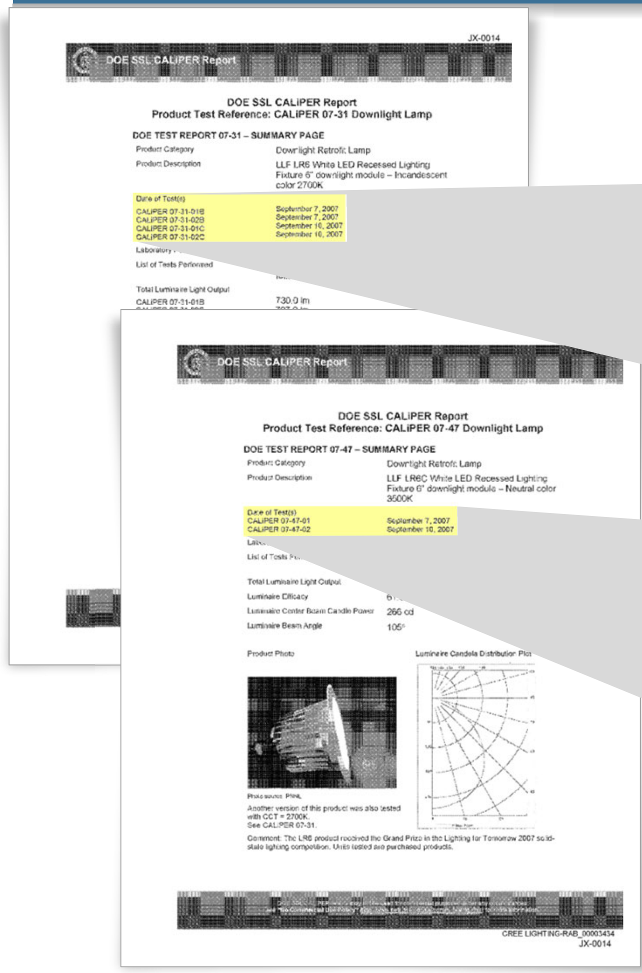
Working on the numbers -- but it looks like we will fall way short of the 90 LPW performance goal...... or even my predicted minimum of 85 LPW.

Our best mesured number to date is 79.79 LPW (600 lumens) as measured by CSA about a month ago. So far, this attempt is at 640 lumens (77 LPW).

RX-0743C.0001

RX-0743

Timeline – September 2007 CALiPER Tests


JX-0014

DOE SSL CALiPER Report

DOE SSL CALiPER Report
Product Test Reference: CALiPER 07-31 Downlight Lamp

DOE TEST REPORT 07-31 – SUMMARY PAGE

Product Category	Downlight Retrofit Lamp
Product Description	LLF LR6 White LED Recessed Lighting Fixture 6" downlight module – Incandescent color 2700K
Date of Test(s)	
CALiPER 07-31-01B	September 7, 2007
CALiPER 07-31-02B	September 7, 2007
CALiPER 07-31-01C	September 10, 2007
CALiPER 07-31-02C	September 10, 2007
Laboratory	
List of Tests Performed	
Total Luminaire Light Output	
CALiPER 07-31-01B	730.0 lm

DOE SSL CALiPER Report

DOE SSL CALiPER Report
Product Test Reference: CALiPER 07-47 Downlight Lamp

DOE TEST REPORT 07-47 – SUMMARY PAGE

Product Category	Downlight Retrofit Lamp
Product Description	LLF LR6C White LED Recessed Lighting Fixture 6" downlight module – Neutral color 3500K
Date of Test(s)	
CALiPER 07-47-01	September 7, 2007
CALiPER 07-47-02	September 10, 2007
List of Tests Performed	
Total Luminaire Light Output	
Luminaire Efficacy	
Luminaire Center Beam Candle Power	266 cd
Luminaire Beam Angle	105°

Product Photo

Luminaire Candela Distribution Plot

Photo source: PNNL

Another version of this product was also tested with CCT = 2700K.
See CALiPER 07-31.

Comment: The LR6 product received the Grand Prize in the Lighting for Tomorrow 2007 solid-state lighting competition. Units tested are purchased products.

CREE LIGHTING-RAB_00003434
JX-0014

JX-0014.0021-22

DOE SSL CALiPER Report
Product Test Reference: CALiPER 07-31 Downlight Lamp

Date of Test(s)

CALiPER 07-31-01B	September 7, 2007
CALiPER 07-31-02B	September 7, 2007
CALiPER 07-31-01C	September 10, 2007
CALiPER 07-31-02C	September 10, 2007

DOE SSL CALiPER Report
Product Test Reference: CALiPER 07-47 Downlight Lamp

Date of Test(s)

CALiPER 07-47-01	September 7, 2007
CALiPER 07-47-02	September 10, 2007

Acquisition Notes — Purchased from a Distributor 8/2007

LED Lamp/Package References (Product literature; 7/2007; www.llfinc.com)

RDX-0002.040

Timeline – September 2007 CALiPER Test Data

Test	"Wall Plug Efficiency"
CALiPER 07-31-01B	59.9 LPW
CALiPER 07-31-01C	62.4 LPW
CALiPER 07-31-02B	60.1 LPW
CALiPER 07-31-02C	62.4 LPW
CALiPER 07-47-01	61.3 LPW
CALiPER 07-47-02	62.4 LPW

Timeline – November 2007 NIST Test and Press Release

The device of FIGS. **1** and **2** was tested by NIST and resulted in the Following performance:

Input voltage: 120 Volts (V) AC, 60 Hz
Lamp current: 0.1158 Amperes (A)
LED Lamp Input Electrical Power: 5.802 Watts (W)
Total Luminous Flux: 658.7 lumens (lm)
Wall plug efficiency: 113.5 lm/W
CIE 1931 chromaticity coordinates: x 0.4511, y 0.402
Correlated Color Temperature: 2760K
CRI: 91.2
Ambient temperature: 26° C.

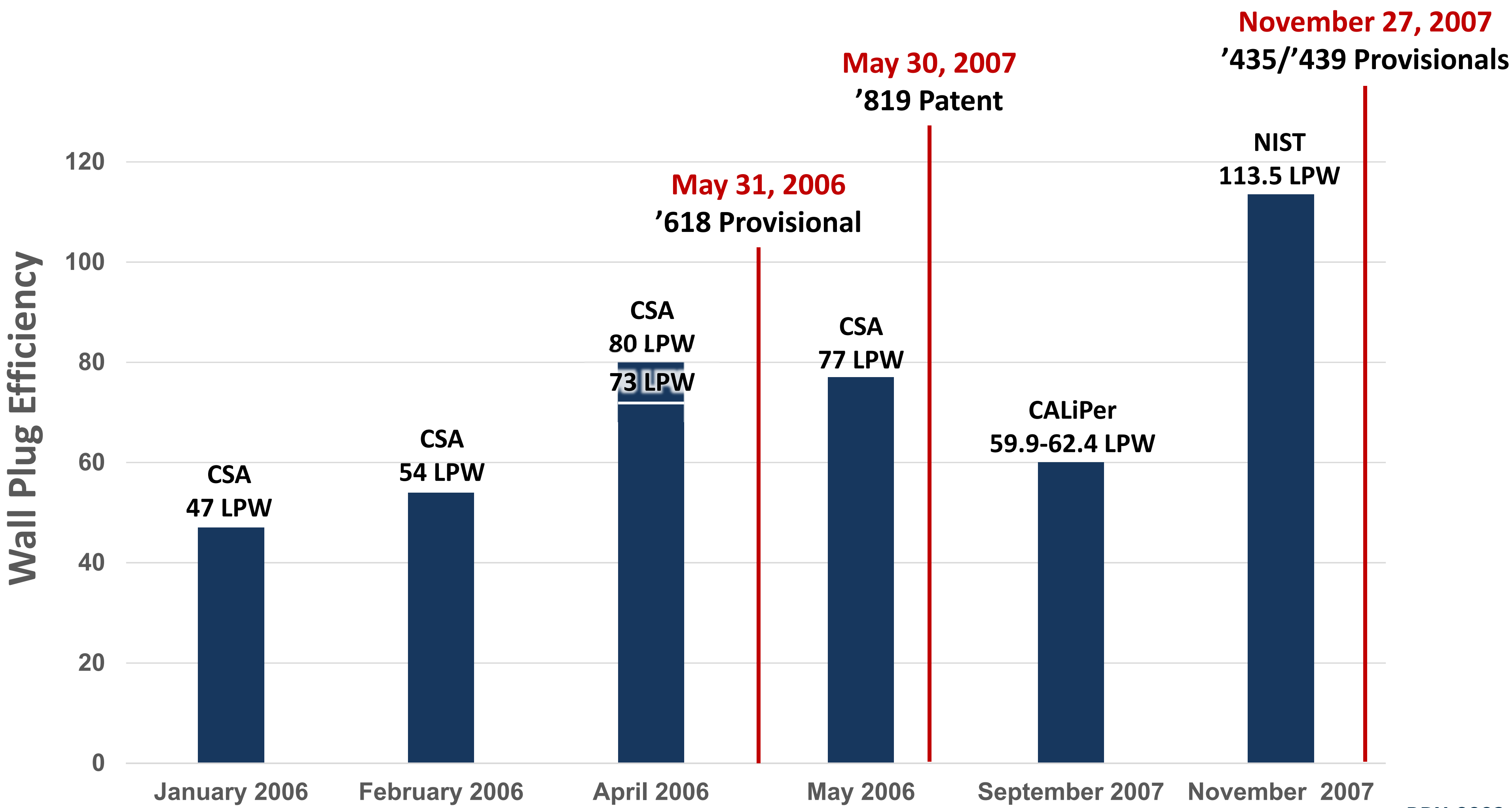
New Lamp from LED Lighting Fixtures Shatters World Record for Energy Efficiency

LLF's High CRI Warm-white Lamp Consumes Less Than 6 Watts and Could Replace the Conventional 65 Watt Lightbulb

Morrisville, NC, November 28, 2007 - LED Lighting Fixtures, Inc. (LLF), which developed and markets the only viable indoor light fixture for general illumination from LED light sources, announced today the results from its prototype PAR 38 self-ballasted lamp. LLF's LRP-38 lamp set a new standard for energy efficient lighting by producing 659 lumens at a mere 5.8 watts of wall-plug power, resulting in 113.6 delivered lumens per watt. The LLF lamp would use less than 9% and 30% of the energy consumed by incandescent and fluorescent sources, respectively. Using LLF's proprietary technology platform, the lamp emitted a warm incandescent-like color of 2760 Kelvin with a superb color rendering index of 91.2 and does not contain any toxic mercury. Steady state testing was conducted by the National Institute of Standards and Technology (NIST) in Washington, DC.

JX-0001.0020 at 21:64-22:7, RX-0658.0002

Timeline – LLF Test Results



RDX-0002.043

Enablement

Wands Factors

1. The breadth of the claims
2. The nature of the invention
3. The state of the prior art
4. The level of one of ordinary skill
5. The level of predictability in the art
6. The amount of direction provided by the inventor
7. The existence of working examples
8. The quantity of experimentation needed to make or use the invention based on the content of the disclosure

April 2006 CSA Prototype Is Not First Embodiment

Project Name	Description	Purpose	Str	CCT	Lumens	Watts	L/W	CRI	CSA	Location
D3-1	3 strings, 117 x XT31, 55 x EPI 600mcd 616nm AlInGaP	Third press release	3	3200	700	10	73	92	yes	USA conference room

Referring to FIG. **7**, each of the greenish-yellowish emitters **16*b*** includes a blue light emitting diode chip **31** (namely, a Cree XT LED (C460XT290) die with a peak wavelength range of from about 450 nm to about 465 nm, and optical power greater than 24 mW), a lead frame **15** having a reflective surface **32**, a copper wire **33**, an encapsulant region **34**, and a broad spectrum emitting lumiphor **35**.

The current passing through the first string of LED emitters is regulated to be about 20 milliamps.

The current passing through the second string of LED emitters is regulated to be about 20 milliamps.

The current passing through the third string of LED emitters is regulated to be about 20 milliamps.

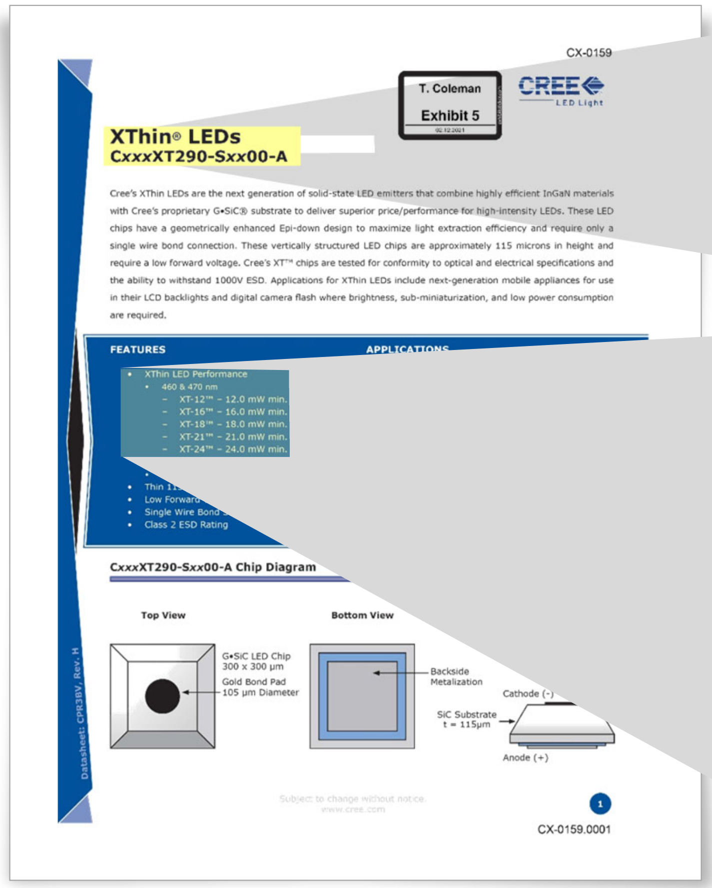
JX-0002.0010, 21

XThin® LEDs
CxxxXT290-Sxx00-A

– XT-24™ – 24.0 mW min.

RDX-0002.046

C460XT290


CX-0159

T. Coleman
Exhibit 5

CREE LED Light

XThin® LEDs
CxxxXT290-Sxx00-A

Cree's XThin LEDs are the next generation of solid-state LED emitters that combine highly efficient InGaN materials with Cree's proprietary G•SiC® substrate to deliver superior price/performance for high-intensity LEDs. These LED chips have a geometrically enhanced Epi-down design to maximize light extraction efficiency and require only a single wire bond connection. These vertically structured LED chips are approximately 115 microns in height and require a low forward voltage. Cree's XT™ chips are tested for conformity to optical and electrical specifications and the ability to withstand 1000V ESD. Applications for XThin LEDs include next-generation mobile appliances for use in their LCD backlights and digital camera flash where brightness, sub-miniaturization, and low power consumption are required.

FEATURES

- XThin LED Performance
  - 460 & 470 nm
    - XT-12™ – 12.0 mW min.
    - XT-16™ – 16.0 mW min.
    - XT-18™ – 18.0 mW min.
    - XT-21™ – 21.0 mW min.
    - XT-24™ – 24.0 mW min.
- Thin 11
- Low Forward
- Single Wire Bond
- Class 2 ESD Rating

APPLICATIONS

CxxxXT290-Sxx00-A Chip Diagram

Datasheet: CPR3BV, Rev. H

1

CX-0159.0001

XThin® LEDs
CxxxXT290-Sxx00-A

- XThin LED Performance
  - 460 & 470 nm
    - XT-12™ – 12.0 mW min.
    - XT-16™ – 16.0 mW min.
    - XT-18™ – 18.0 mW min.
    - XT-21™ – 21.0 mW min.
    - XT-24™ – 24.0 mW min.

Components Used in April 2006 Prototype

Project Name	Description	Purpose	Str	CCT	Lumens	Watts	L/W	CRI	CSA	Location
D3-1	3 strings, 117 x XT31, 55 x EPI 600mcd 616nm AlInGaP	Third press release	3	3200	700	10	73	92	yes	USA conference room

Test Data Collected At 115V, 60Hz Input

14. Total Lamp Operation Time = 112 minutes
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16. Input Current = 213.2 mA
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18. Input Power Factor = 0.399
19. Ambient Temperature Inside Sphere = 25.5 °C
20. Luminous Flux = 707.9 Lumens
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24. X = 0.4184
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RX-0750, JX-0014.0099, JX-0017

February 2006 CSA Test

Model	**LLF-T3**
Report	1765845
Project Number	1765845-1
Date Issued	2/16/2006
Efficacy	53.50

SF	time	chip	phos %	dispence	x	y	rows	col qty	L tot	L	vf tot	vf	Amps	watts	L/W	cct/dom	CRI
3-2		XT24 465	7.5%	dome	0.2931	0.3182	1	5	18.944	3.789	15.00	3	0.02	0.300	63.1	7842	76
1-7	10:00	XT24 465	10.0%	dome	0.3575	0.4309	1	5	20.797	4.159	15.05	3.01	0.01999	0.301	69.1	4863	66
1-2	8:00	XT24 465	10.0%	dome	0.3763	0.4675	1	5	20.465	4.093	15.00	3	0.02	0.300	68.2	4556	62
1-4		XT24 465	12.0%	dome	0.4159	0.5260	1	5	19.781	3.956	15.15	3.03	0.02	0.303	65.3	4074	53
3-3		XT24 465	7.5%	flat	0.2181	0.1977	1	5	14.168	2.834	15.00	3	0.02	0.300	47.2	20000	0
1-3		XT24 465	10.0%	flat	0.3251	0.3775	1	5	19.060	3.812	15.00	3	0.02	0.300	63.5	5769	71
1-5		XT24 465	12.0%	flat	0.3319	0.3904	1	5	19.447	3.889	15.15	3.03	0.02	0.303	64.2	5528	70
1-1	8:00	XT27 455	10%	dome	0.3956	0.4793	1	8	35.24	4.404	25.76	3.22	0.0200	0.516	68.3	4225	61
1-3	9:10	XT27 455	10%	flat	0.3552	0.4018	2	18	156.3	4.341	57.70	3.21	0.04072	2.350	66.5	4836	67
1-4	9:30	XT27 455	10%	dome	0.3896	0.4602	2	18	161.6	4.489	57.63	3.20	0.04023	2.318	69.7	4257	64
1-5	9:45	XT27 455	10%	dome	0.3857	0.4535	2	18	165.6	4.599	57.84	3.21	0.04032	2.332	71.0	4308	64
1-6	10:00	R8Y12W6			0.4427	0.4087	2	22	96.744	2.199	37.45	1.70	0.04016	1.504	64.3	2941	92
1-7	10:15	R8Y12W6			0.4443	0.4099	2	22	94.698	2.152	37.10	1.69	0.04056	1.505	62.9	2924	92
1-8	10:22	R6Y12W6			0.4288	0.4139	2	20	90.336	2.258	34.88	1.74	0.04009	1.398	64.6	3217	88
1-9	10:35	R10Y12W6			0.4552	0.4044	2	24	98.46	2.051	39.19	1.63	0.04014	1.573	62.6	2716	93
1-10	12:45	R10Y12W6			0.4543	0.4021	2	24	100.282	2.089	39.13	1.63	0.04109	1.608	62.4	2711	93
3-1		14mil 616						5	8.714	1.743	10.63	2.126	0.02	0.213	41	613	0
1-1		14mil 625						5	6.955	1.391	10.41	2.082	0.02	0.208	33	620	0

Prior Art Invalidity

The Fini/Nakamura Technical Report

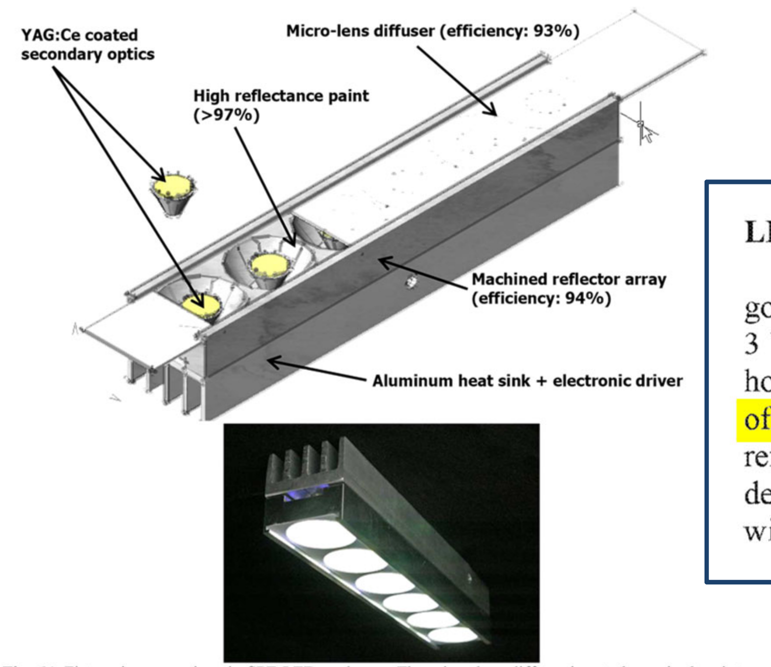
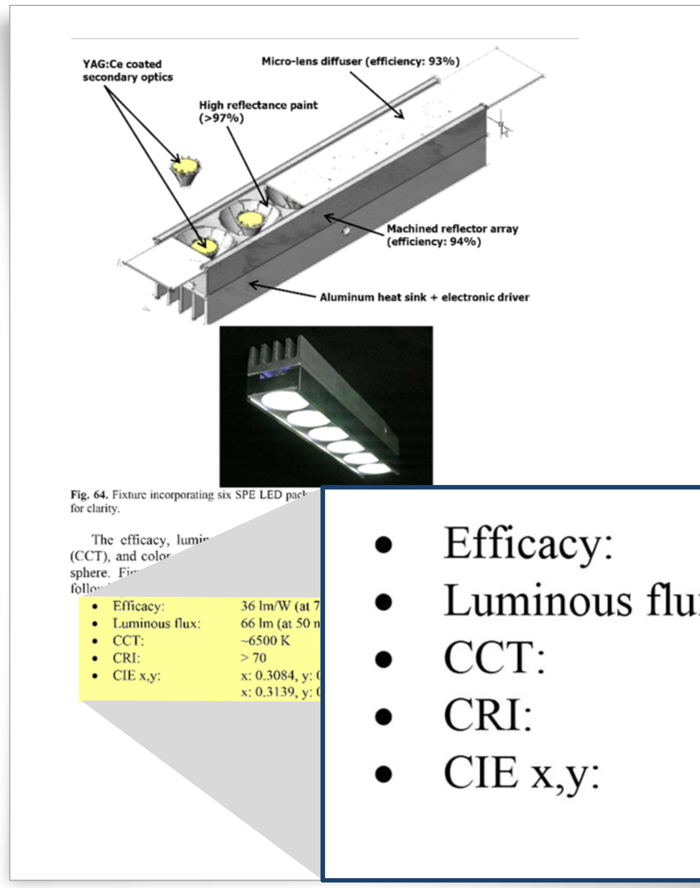


Fig. 64. Fixture incorporating six SPE LED packages. The micro-lens diffuser is not shown in the picture for clarity.

LED fixture using SPE packages

Multiple SPE LEDs were packaged into a fixture and its performance was measured. The goal was to create an efficient and reliable white light source package using the SPE concept. Six 3 W blue LEDs were fitted with YAG:Ce-coated secondary optics and mounted inside a fixture housing with an aluminum heat sink and electronic driver (Fig. 64). The fixture array consisted of a machined reflector with 94% efficiency and a micro-lens diffuser with 93% efficiency. The reflector and micro-lens diffuser combined increase mix uniformity and direct light output in the desired direction. The interior mounting space for the SPE LEDs (*i.e.*, the reflector) was painted with a high-reflectance paint (>97%).

The Fini/Nakamura Technical Report



•	Efficacy:	36 lm/W (at 700 mA) to 78 lm/W (at 50 mA)
•	Luminous flux:	66 lm (at 50 mA) to 541 lm (at 700 mA)
•	CCT:	~6500 K
•	CRI:	> 70
•	CIE x,y:	x: 0.3084, y: 0.3414 without diffuser and x: 0.3139, y: 0.3513 with diffuser (at 700 mA in both cases)

JX-0150.0065

The Fini/Nakamura Technical Report

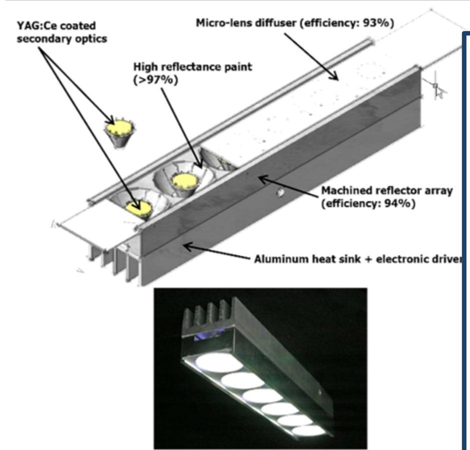


Fig. 64. Fixture incorporating six SPE LED packages. The micro-lens diffuser is not shown in for clarity.

The efficacy, luminous flux, chromaticity coordinates (*x*,*y*), correlated c (CCT), and color rendering index (CRI) of the SPE fixture were measured wi sphere. Figures 65 and 66 illustrate the performance results. The fixture c following:

- Efficacy: 36 lm/W (at 700 mA) to 78 lm/W (at 50 mA)
- Luminous flux: 66 lm (at 50 mA) to 541 lm (at 700 mA)
- CCT: ~6500 K
- CRI: > 70
- CIE x,y: x: 0.3084, y: 0.3414 without diffuser and x: 0.3139, y: 0.3513 with diffuser (at 700 mA in b

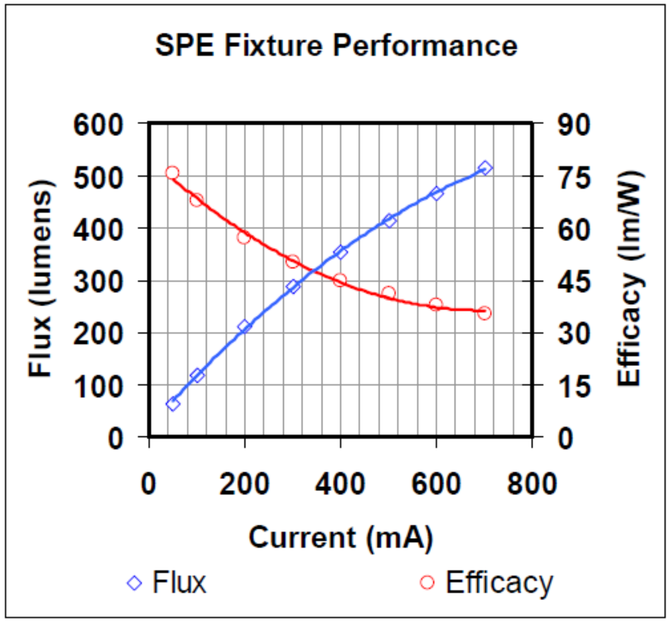


Fig. 65. Measured efficacy and flux for the SPE fixture.

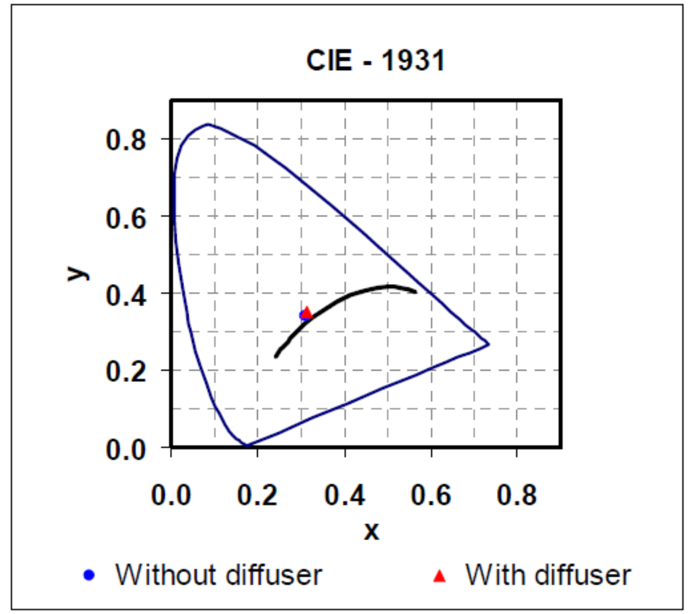


Fig. 66. Chromaticity coordinates of the SPE fixture with and without the micro-lens diffuser.

JX-0150.0066

RDX-0002.053

The Fini/Nakamura Technical Report

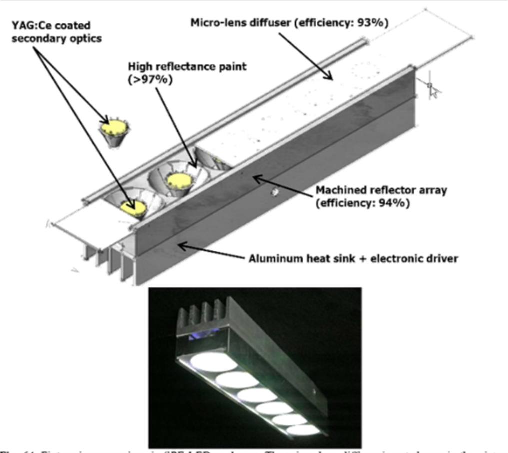


Fig. 64. Fixture incorporating six SPE LED packages. The micro-lens diffuser is not shown in the picture for clarity.

The efficacy, luminous flux, chromaticity coordinates (*x*,*y*), correlated color temperature (CCT), and color rendering index (CRI) of the SPE fixture were measured with an integrating sphere. Figures 65 and 66 illustrate the performance results. The fixture demonstrated the following:

- Efficacy: 36 lm/W (at 700 mA) to 78 lm/W (at 50 mA)
- Luminous flux: 66 lm (at 50 mA) to 541 lm (at 700 mA)
- CCT: ~6500 K
- CRI: > 70
- CIE x,y: x: 0.3084, y: 0.3414 without diffuser and x: 0.3139, y: 0.3513 with diffuser (at 700 mA in both cases)

JX-0150.0065-66, JX-0002.0025 at 22:1-8

59. A method as recited in claim **52**, wherein said lighting device emits output light having a wall plug efficiency in the range of from about 80 to about 85 lumens per watt of said electricity.

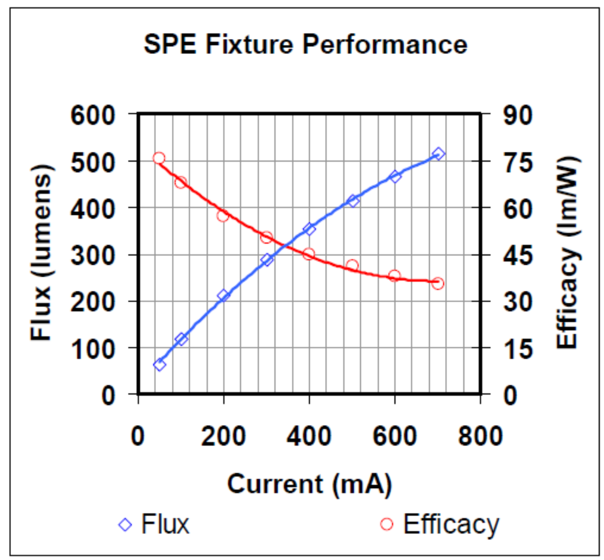


Fig. 65. Measured efficacy and flux for the SPE fixture.

RDX-0002.054

The Fini/Nakamura Technical Report

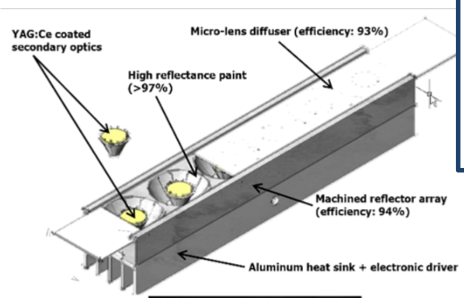


Fig. 64. Fixture incorporating six SPE LED packages. The micro-lens diffuser is not shown in the picture for clarity.

The efficacy, luminous flux, chromaticity coordinates (*x*,*y*), correlated color temperature (CCT), and color rendering index (CRI) of the SPE fixture were measured with an integrating sphere. Figures 65 and 66 illustrate the performance results. The fixture demonstrated the following:

- Efficacy: 36 lm/W (at 700 mA) to 78 lm/W (at 50 mA)
- Luminous flux: 66 lm (at 50 mA) to 541 lm (at 700 mA)
- CCT: ~6500 K
- CRI: > 70
- CIE x,y: x: 0.3084, y: 0.3414 without diffuser and x: 0.3139, y: 0.3513 with diffuser (at 700 mA in both cases)

65

24. A lighting device as recited in claim **1**, wherein said output light is perceived as warm white.

Term	Construction
"perceived as warm white"	"perceived as light having a color temperature between approximately 2700K and 3500K"

JX-0150.0066, JX-0002.0024 at 20:1-2

Narendran PSS Article

phys. stat. sol. (a) **202**, No. 6, R60–R62 (2005) / **DOI** 10.1002/pssa.200510015

pss +++rapid research letters+++
www.pss-rapid.com

Extracting phosphor-scattered photons to improve white LED efficiency

N. Narendran*, **Y. Gu, J. P. Freyssinier-Nova, and Y. Zhu**

Lighting Research Center, Rensselaer Polytechnic Institute, 21 Union Street, Troy, New York 12180, USA

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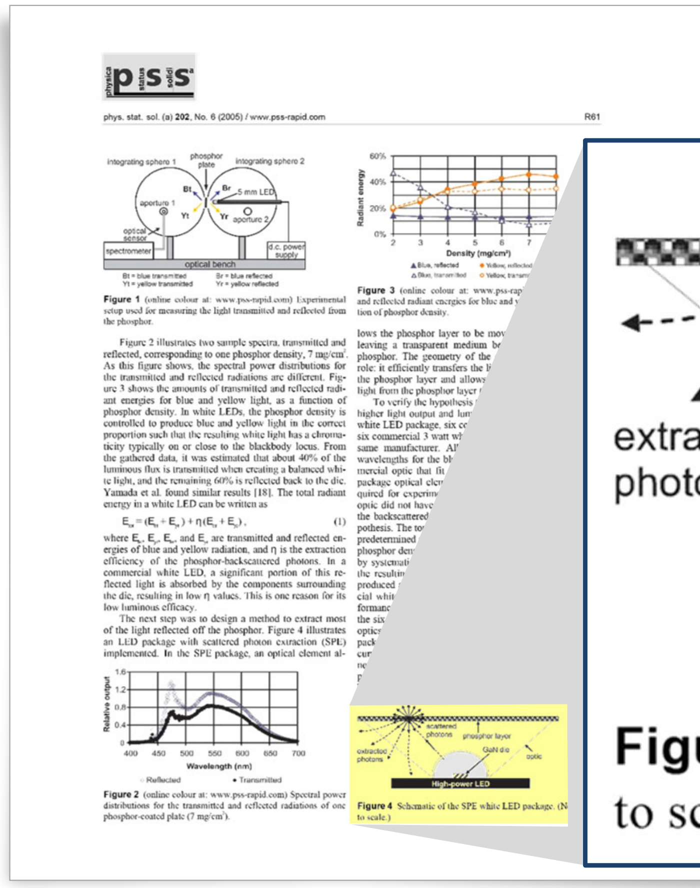
Published online 6 April 2005

PACS 42.72.Bj, 85.60.Bt, 85.60.Jb

* Corresponding author: e-mail narenn2@rpi.edu

Scattered Photon Extraction



pss physica status solidi

phys. stat. sol. (a) 202, No. 6 (2005) / www.pss-rapid.com R61

Figure 1 (online colour at: www.pss-rapid.com) Experimental setup used for measuring the light transmitted and reflected from the phosphor.

Figure 2 illustrates two sample spectra, transmitted and reflected, corresponding to one phosphor density, 7 mg/cm^2. As this figure shows, the spectral power distributions for the transmitted and reflected radiations are different. Figure 3 shows the amounts of transmitted and reflected radiant energies for blue and yellow light, as a function of phosphor density. In white LEDs, the phosphor density is controlled to produce blue and yellow light in the correct proportion such that the resulting white light has a chromaticity typically on or close to the blackbody locus. From the gathered data, it was estimated that about 40% of the luminous flux is transmitted when creating a balanced white light, and the remaining 60% is reflected back to the die. Yamada et al. found similar results [18]. The total radiant energy in a white LED can be written as

$$E_{tw} = (E_{bt} + E_{yt}) + \eta (E_{br} + E_{yr}) , \quad (1)$$

where E_{bt}, E_{yt}, E_{br}, and E_{yr} are transmitted and reflected energies of blue and yellow radiation, and η is the extraction efficiency of the phosphor-backscattered photons. In a commercial white LED, a significant portion of this reflected light is absorbed by the components surrounding the die, resulting in low η values. This is one reason for its low luminous efficacy.

The next step was to design a method to extract most of the light reflected off the phosphor. Figure 4 illustrates an LED package with scattered photon extraction (SPE) implemented. In the SPE package, an optical element al-

Figure 2 (online colour at: www.pss-rapid.com) Spectral power distributions for the transmitted and reflected radiations of one phosphor-coated plate (7 mg/cm^2).

Figure 3 (online colour at: www.pss-rap... and reflected radiant energies for blue and y... tion of phosphor density.

Figure 4 Schematic of the SPE white LED package. (N... to scale.)

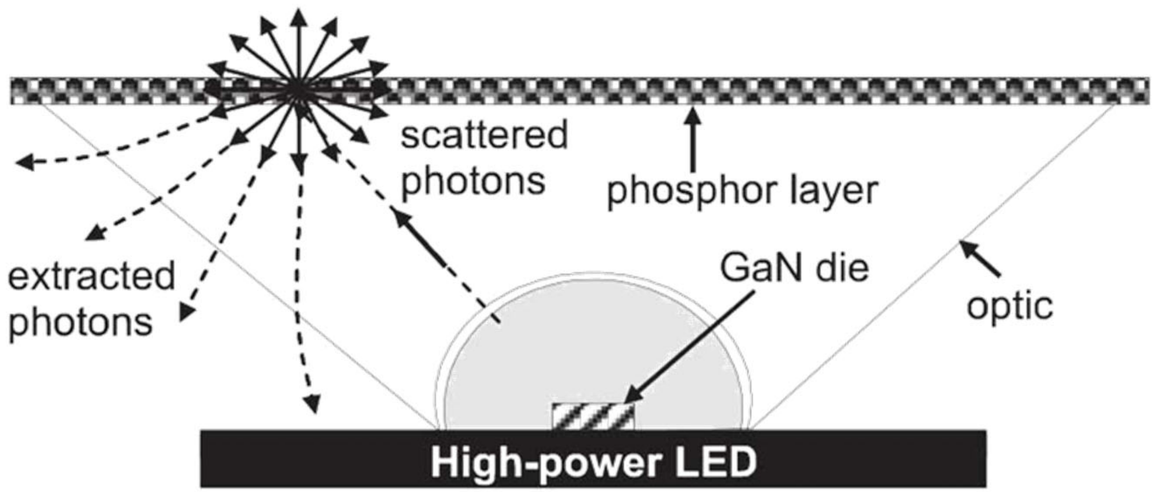
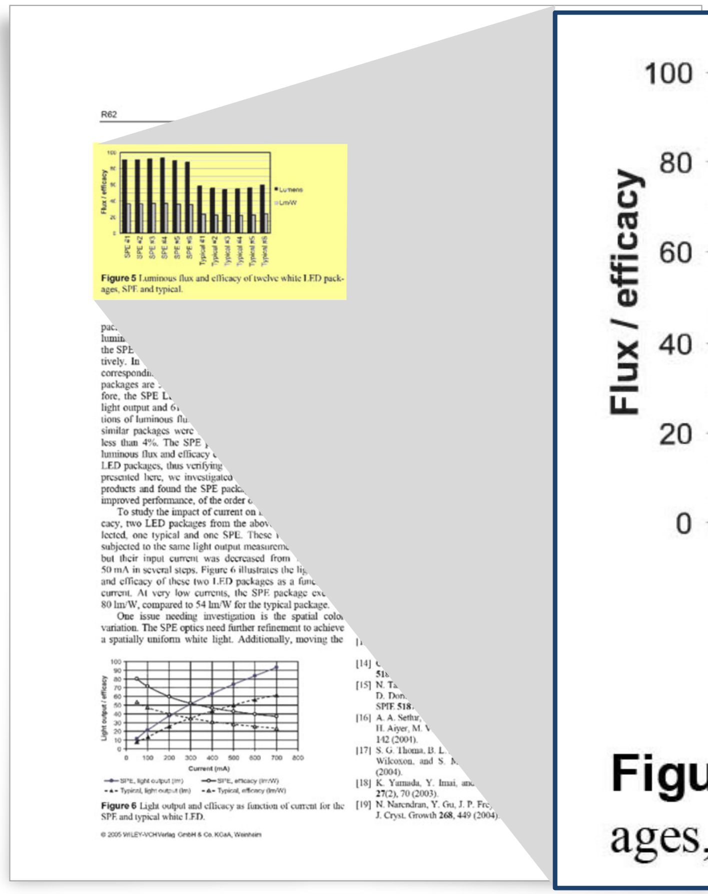


Figure 4 Schematic of the SPE white LED package. (Not drawn to scale.)

RX-0040.0002

Scattered Photon Extraction



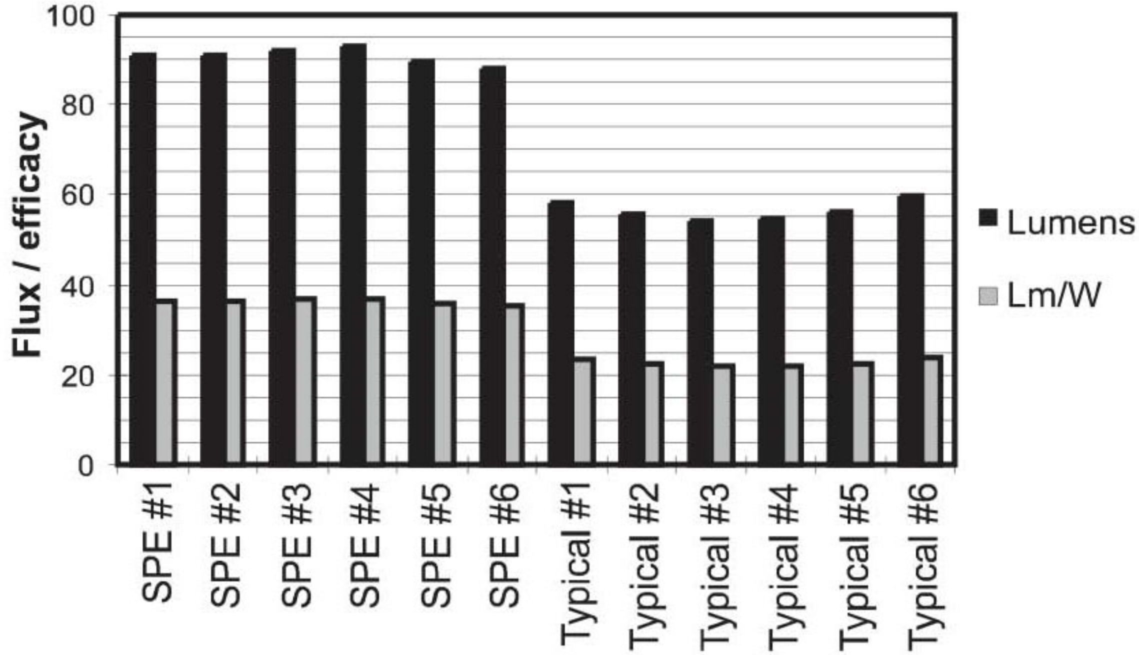
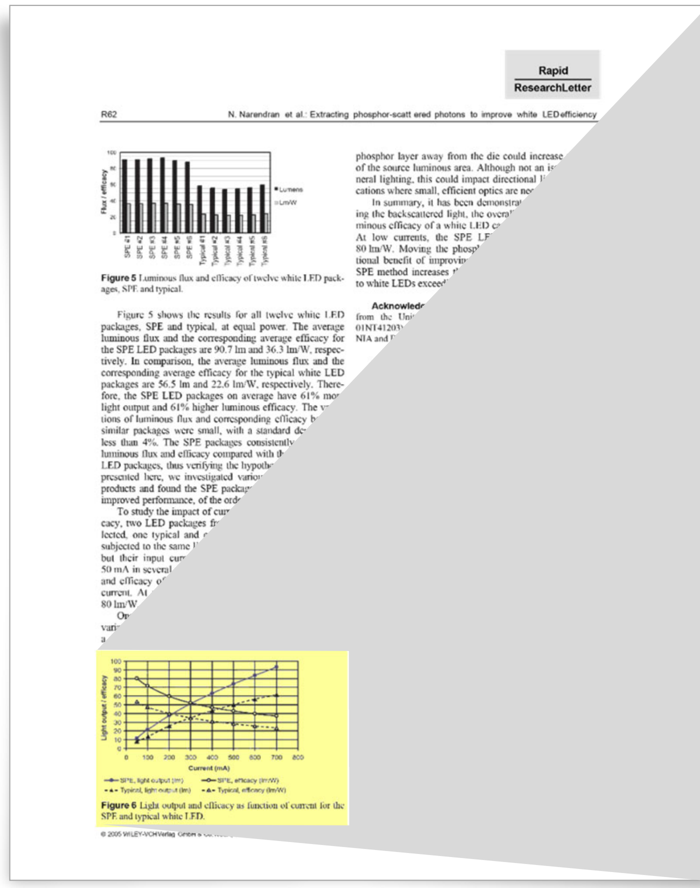


Figure 5 Luminous flux and efficacy of twelve white LED packages, SPE and typical.

RX-0040.0003

Scattered Photon Extraction



Rapid ResearchLetter

Figure 5 Luminous flux and efficacy of twelve white LED packages, SPE and typical.

Figure 5 shows the results for all twelve white LED packages, SPE and typical, at equal power. The average luminous flux and the corresponding average efficacy for the SPE LED packages are 90.7 lm and 36.3 lm/W, respectively. In comparison, the average luminous flux and the corresponding average efficacy for the typical white LED packages are 56.5 lm and 22.6 lm/W, respectively. Therefore, the SPE LED packages on average have 61% mor[illegible] light output and 61% higher luminous efficacy. The v[illegible] tions of luminous flux and corresponding efficacy b[illegible] similar packages were small, with a standard de[illegible] less than 4%. The SPE packages consistently [illegible] luminous flux and efficacy compared with th[illegible] LED packages, thus verifying the hypoth[illegible] presented here, we investigated vario[illegible] products and found the SPE packag[illegible] improved performance, of the ord[illegible]

To study the impact of cur[illegible] cacy, two LED packages fr[illegible] lected, one typical and [illegible] subjected to the same [illegible] but their input cur[illegible] 50 mA in several [illegible] and efficacy o[illegible] current. At [illegible] 80 lm/W[illegible]

phosphor layer away from the die could increase [illegible] of the source luminous area. Although not an is[illegible] neral lighting, this could impact directional l[illegible] cations where small, efficient optics are ne[illegible]

In summary, it has been demonstra[illegible] ing the backscattered light, the overa[illegible] minous efficacy of a white LED c[illegible] At low currents, the SPE LE[illegible] 80 lm/W. Moving the phosp[illegible] tional benefit of improvin[illegible] SPE method increases t[illegible] to white LEDs excee[illegible]

Acknowled[illegible] from the Uni[illegible] 01NT41203[illegible] NIA and [illegible]

Figure 6 Light output and efficacy as function of current for the SPE and typical white LED.

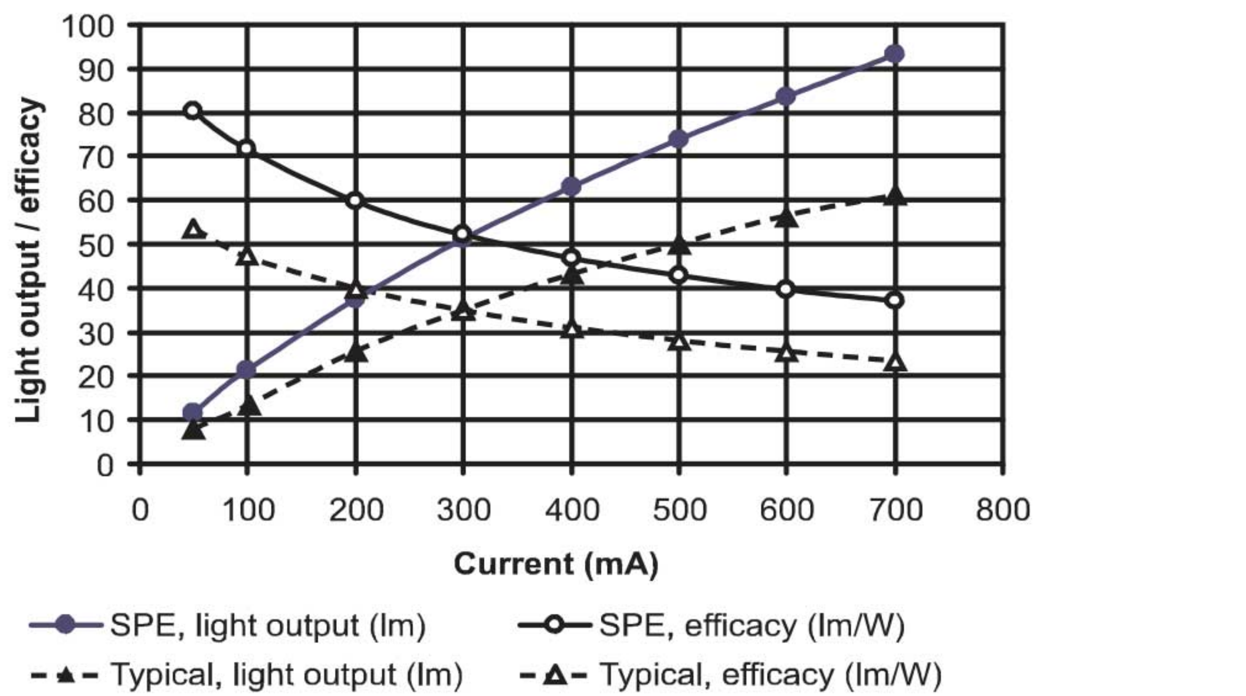


Figure 6 Light output and efficacy as function of current for the SPE and typical white LED.

RX-0040.0003

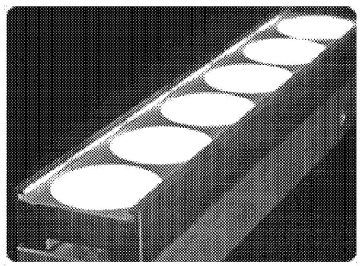
SPE Press Release

RX-0039

PHYS.ORG

Breakthrough Technology Accelerates Solid-State Lighting

11 April 2005



A research group, led by Dr. Narendran, developed a method to extract the backscattered photons by moving the phosphor away from the semiconductor and shaping the LED lens geometry. When combined, these changes allow the photons that would typically be absorbed inside the LED to escape as visible light. The new technology is patent pending.

"Demonstration of this new 'remote phosphor' concept by Rensselaer's Lighting Research Center is an exciting development for solid-state lighting,"

The Fini/Nakamura Technical Report

RX-0032

FINAL TECHNICAL PROGRESS REPORT
For Award Period 10/1/01 – 4/30/05

DoE Award #**DE-FC26-01NT41203**
"High-Efficiency Nitride-Based Solid-State Lighting"

JULY 30, 2005

Authors: Dr. Paul T. Fini, Prof. Shuji Nakamura

University of California, Santa Barbara
Materials Dept., Bldg. 503, Rm. 1355
Santa Barbara, CA 93106-5050

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RAB0160095
RX-0032.0001

JX-0150.0001

FINAL TECHNICAL PROGRESS REPORT
For Award Period 10/1/01 – 4/30/05

DoE Award #**DE-FC26-01NT41203**
"High-Efficiency Nitride-Based Solid-State Lighting"

JULY 30, 2005

Authors: Dr. Paul T. Fini, Prof. Shuji Nakamura

RDX-0002.061

Ibbetson Report

therefore slightly more efficient, package but it isn't suitable for practical use as it cannot effectively dissipate the heat generated by the LED.) The far-field radiation pattern of a typical TO-39 header lamp is shown in figure 14. Of particular note is the near perfect lambertian emission pattern, a result of the micro-lens LED design, which is considered particularly desirable for optical design purposes.

Year 3 Milestone Lamp Demonstrator

At the end of Year 3, we demonstrated high flux white lamp modules with output as high as 1040 lumens at an efficacy of 87 lumens per watt when operated at a drive current of 350 mA per chip (~ 50 A/cm^2). Figure 15 shows a picture of the finished module. The array of emitters was mounted to a metal core printed circuit board attached to a finned metal heat sink for efficient heat dissipation. As far as possible, the modules utilized materials (e.g. solder, phosphor, clear encapsulant) developed for Cree's XLamp products since they have demonstrated proven reliability under high flux operating conditions. The modules' total emitting area was kept within a 4" diameter circle, i.e. the same footprint as a PAR 38 incandescent light source.

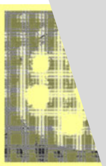


Figure 15: Experin... lamp module consistin... individual emitters on... circuit board.

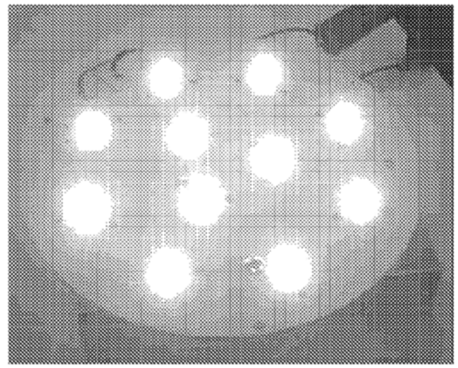


Figure 15: Experimental high flux lamp module consisting of an array of individual emitters on a metal core circuit board.

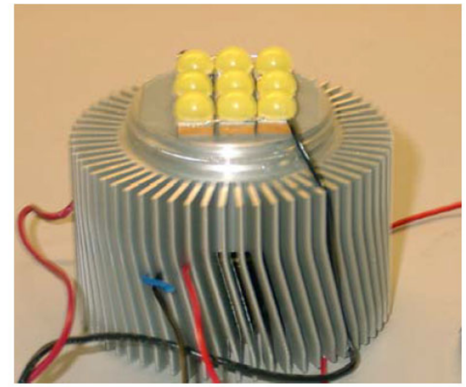


Figure 12. A prototype, 1000 lumens solid-state lamp indicative of the state-of-the-art at the start of the project.

Figure 15 shows a picture of the finished module. The array of emitters was mounted to a metal core printed circuit board attached to a finned metal heat sink for efficient heat dissipation. As far as possible, the modules utilized materials (e.g. solder, phosphor, clear encapsulant) developed for Cree's XLamp products since they have demonstrated proven reliability under high flux operating conditions. The modules' total emitting area was kept within a 4" diameter circle, i.e. the same footprint as a PAR 38 incandescent light source.

Ibbetson Report

Metric	Array Results		
Diode Current Density (A/cm²)	50	75	100
Array Input (W)	12.0	21.5	29.6
Light Output (lumens)	1040	1600	1960
Efficacy (lm/W)	87	74	66
CCT (K)	5850	5900	5950

Table 2: High flux lamp module performance at the target diode current density of 52 A/cm^2. Array #2 has higher efficacy but lower total luminous output.

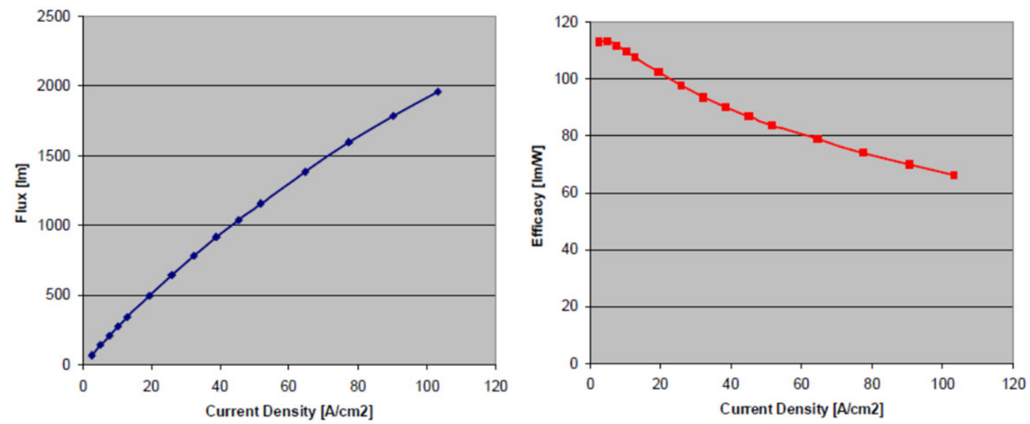
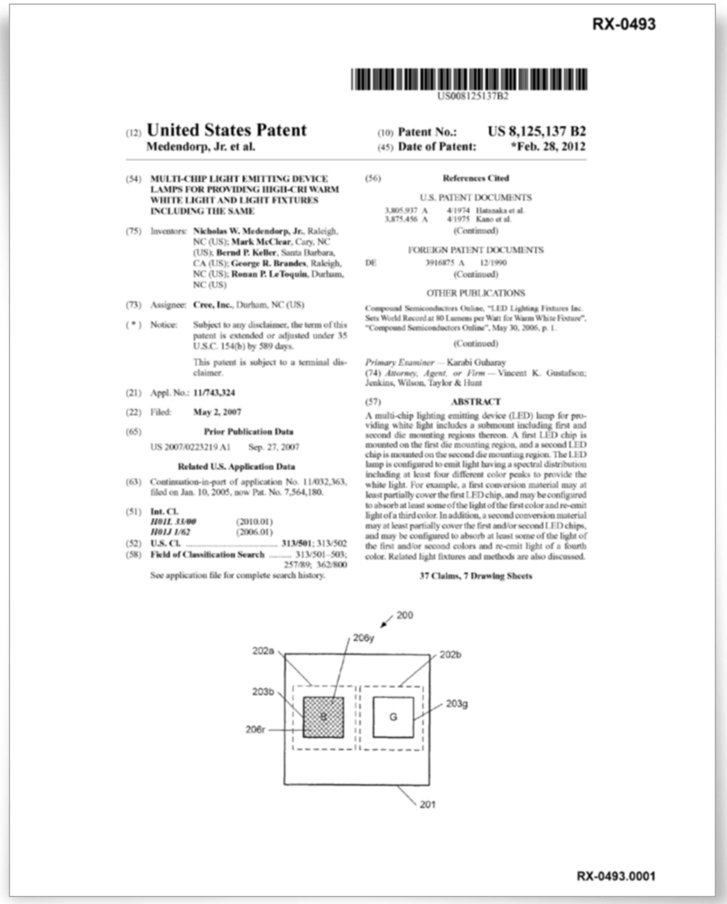


Figure 16: High flux lamp module (a) output and (b) efficacy as a function of current density.

Medendorp



RX-0493

US008125137B2

(12) **United States Patent**
Medendorp, Jr. et al.

(10) **Patent No.:** **US 8,125,137 B2**
(45) **Date of Patent:** ***Feb. 28, 2012**

(54) **MULTI-CHIP LIGHT EMITTING DEVICE LAMPS FOR PROVIDING HIGH-CRI WARM WHITE LIGHT AND LIGHT FIXTURES INCLUDING THE SAME**

(75) Inventors: **Nicholas W. Medendorp, Jr.**, Raleigh, NC (US); **Mark McClear**, Cary, NC (US); **Bernd P. Keller**, Santa Barbara, CA (US); **George R. Brandes**, Raleigh, NC (US); **Ronan P. LeToquin**, Durham, NC (US)

(73) Assignee: **Cree, Inc.**, Durham, NC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 589 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/743,324**

(22) Filed: **May 2, 2007**

(65) **Prior Publication Data**

US 2007/0223219 A1 Sep. 27, 2007

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/032,363, filed on Jan. 10, 2005, now Pat. No. 7,564,180.

(51) **Int. Cl.**
H01L 33/00 (2010.01)
H01J 1/62 (2006.01)

(52) **U.S. Cl.** **313/501**; 313/502

(58) **Field of Classification Search** 313/501–503; 257/89; 362/800

See application file for complete search history.

(56) **References Cited**

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(Continued)

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(Continued)

OTHER PUBLICATIONS

Compound Semiconductors Online, "LED Lighting Fixtures Inc. Sets World Record at 80 Lumens per Watt for Warm White Fixture", "Compound Semiconductors Online", May 30, 2006, p. 1.

(Continued)

Primary Examiner — Karabi Guharay
(74) *Attorney, Agent, or Firm* — Vincent K. Gustafson; Jenkins, Wilson, Taylor & Hunt

(57) **ABSTRACT**

A multi-chip lighting emitting device (LED) lamp for providing white light includes a submount including first and second die mounting regions thereon. A first LED chip is mounted on the first die mounting region, and a second LED chip is mounted on the second die mounting region. The LED lamp is configured to emit light having a spectral distribution including at least four different color peaks to provide the white light. For example, a first conversion material may at least partially cover the first LED chip, and may be configured to absorb at least some of the light of the first color and re-emit light of a third color. In addition, a second conversion material may at least partially cover the first and/or second LED chips, and may be configured to absorb at least some of the light of the first and/or second colors and re-emit light of a fourth color. Related light fixtures and methods are also discussed.

37 Claims, 7 Drawing Sheets

RX-0493.0001

LED light fixtures according to some embodiments of the present invention, such as the LED light fixtures **100***a* and/or **10***b*, may provide a number of features and/or benefits. For example, LED light fixtures including multiple multi-chip lamps according to some embodiments of the present invention may provide a relatively high luminous efficacy (as expressed in lumens per watt) for a given CRI. More particularly, conventional light fixtures may offer 10-20 lumens per watt for a CRI of 90, while LED light fixtures according to some embodiments of the present invention may offer 60-85 lumens per watt for the same CRI. In addition, LED light

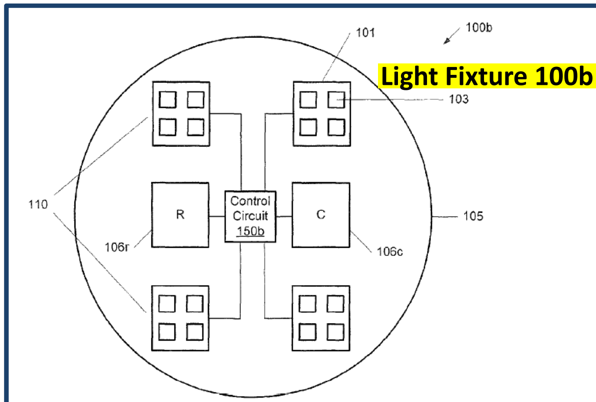
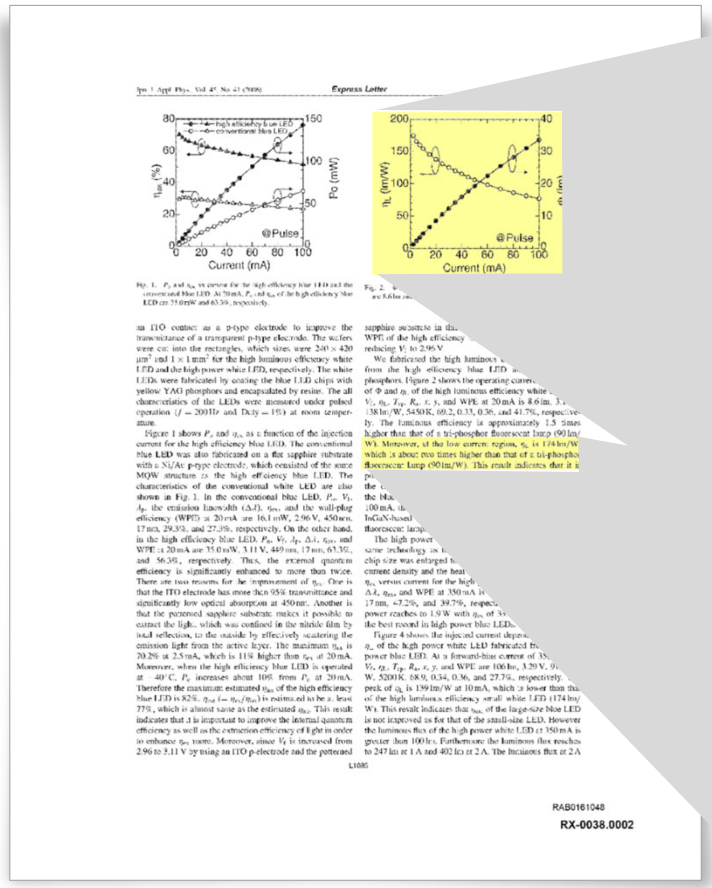


FIG. 1B

RX-0493.0001, 9:35-45, Fig. 1B (annotated)

Narukawa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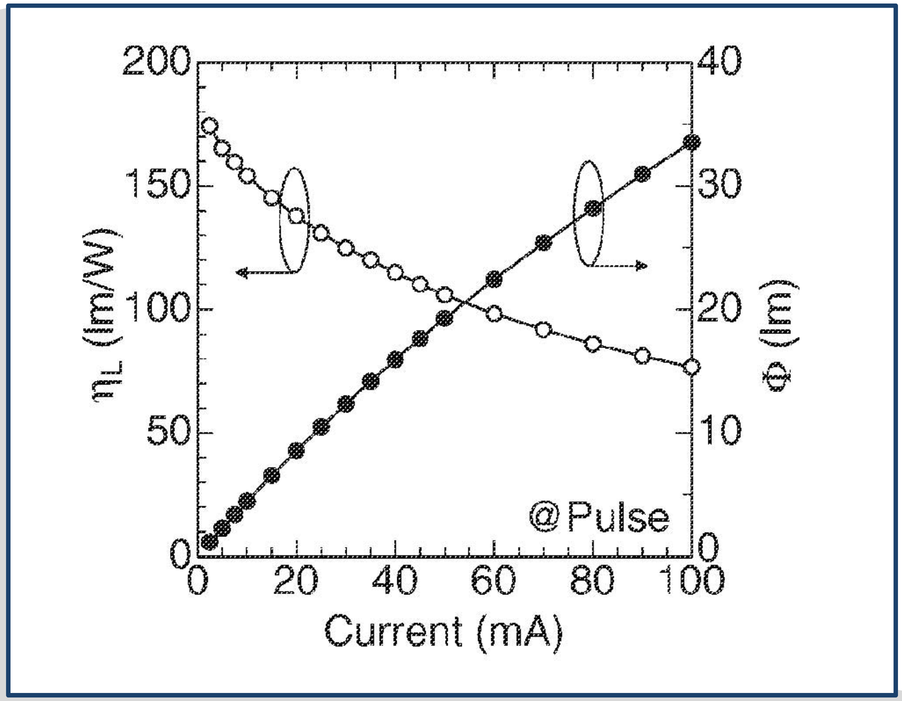


Moreover, at the low current region, η_L is 174 lm/W, which is about two times higher than that of a tri-phosphor fluorescent lamp (90 lm/W).

RX-0038.0002

Lys Driver Efficiency

US 7,737,643 B2

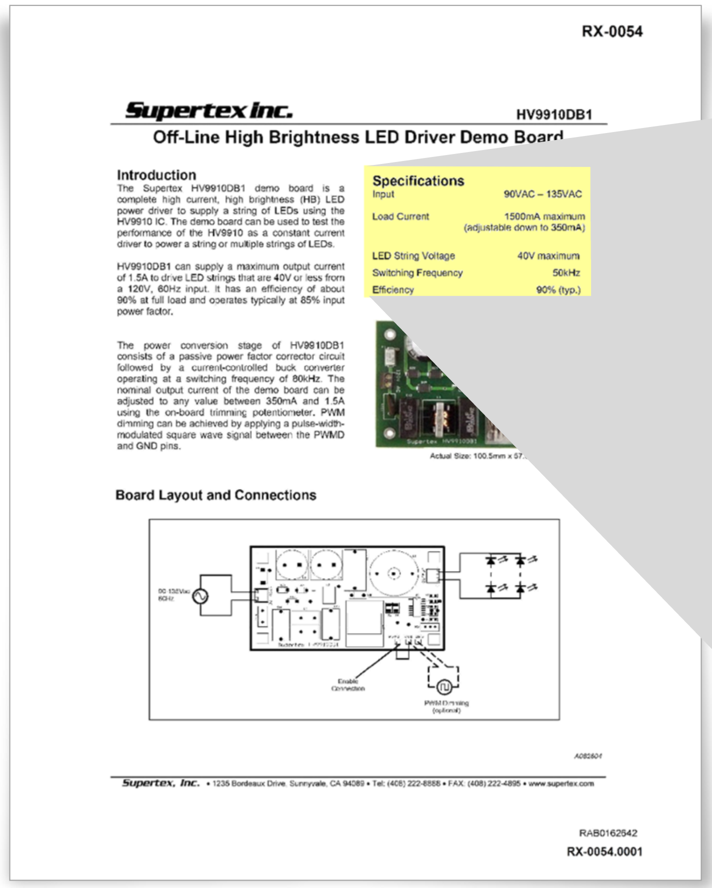
RAB0162432

RX-0024.0061

Applicants have recognized and appreciated that for some power supply applications and some types of loads, commercially available conventional switching power supplies based on DC-DC converters may not be best configured to facilitate a flexible and/or efficient provision of power to a load. For example, although the power conversion efficiency of many conventional switching supplies is on the order of approximately 80% (from A.C. line voltage to a regulated DC voltage output), particular configurations and/or control requirements of different loads may significantly reduce the overall power conversion efficiency of a system that includes a DC-DC converter and a load, wherein the load itself may include various control circuitry.

RX-0024.0060, 61

Supertex Driver Efficiency



RX-0054

Supertex inc. HV9910DB1

Off-Line High Brightness LED Driver Demo Board

Introduction

The Supertex HV9910DB1 demo board is a complete high current, high brightness (HB) LED power driver to supply a string of LEDs using the HV9910 IC. The demo board can be used to test the performance of the HV9910 as a constant current driver to power a string or multiple strings of LEDs.

HV9910DB1 can supply a maximum output current of 1.5A to drive LED strings that are 40V or less from a 120V, 60Hz input. It has an efficiency of about 90% at full load and operates typically at 85% input power factor.

The power conversion stage of HV9910DB1 consists of a passive power factor corrector circuit followed by a current-controlled buck converter operating at a switching frequency of 80kHz. The nominal output current of the demo board can be adjusted to any value between 350mA and 1.5A using the on-board trimming potentiometer. PWM dimming can be achieved by applying a pulse-width-modulated square wave signal between the PWMD and GND pins.

Specifications

Input	90VAC – 135VAC
Load Current	1500mA maximum (adjustable down to 350mA)
LED String Voltage	40V maximum
Switching Frequency	50kHz
Efficiency	90% (typ.)

Actual Size: 100.5mm x 57.

Board Layout and Connections

A082604

RAB0162642

RX-0054.0001

Specifications

Input	90VAC – 135VAC
Load Current	1500mA maximum (adjustable down to 350mA)
LED String Voltage	40V maximum
Switching Frequency	50kHz
Efficiency	90% (typ.)

RX-0054.0001

McClear Letter

JX-0157

EXHIBIT
vollers 3

Cree, Inc.
4600 Silicon Drive
Durham, NC 27703

Dear Richard:

One point of feedback on the subject document from an LED supplier's perspective:

For the most part, the document is a fine effort, and it appears that the targets for the indoor fixtures are reasonable and well thought out.

The one question/comment we had was on the Category B fixtures cited on p.9. On that page, 50, 60, and 70LPW targets are cited for each of three chromaticity ranges. We think this is about 20-25% beyond any currently known technological solution when all the losses (electrical, thermal, optical) are comprehended.

Part of the ENERGY STAR criteria must certainly be to stretch the technology, so in that respect, this may be entirely appropriate. If these goals stay as the targets, we expect that the first fixtures to meet this might not be available for two or more years, however.

Rough calculation for 6500K CCT:

Best LED commercially available:	85LPW @350mA
Derating for thermal losses:	10% (90% of 25 degree C rating)
Derating for driver/electrical losses:	15% (85% efficient)
Optical losses in fixture:	Varies greatly from 10% to more than 30%

S
th
ro
a lu
this

Again
goal.
60/50/4
should h
expect th

Thanks fo

Sincerely,

Mark McClea
Director, Busi
Cree, Inc.
4600 Silicon Dr
Durham, NC 27
(919) 287-7768
mark_mcclear@cr

Rough calculation for 6500K CCT:

Best LED commercially available:	85LPW @350mA
Derating for thermal losses:	10% (90% of 25 degree C rating)
Derating for driver/electrical losses:	15% (85% efficient)
Optical losses in fixture:	Varies greatly from 10% to more than 30%

JX-0157.0060-61

Negley Presentation on Light Fixture Efficiency

Beyond the LED

High Efficacy Fixtures Require a Systems Solution

- **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 of (~ 60% of LED component Efficacy)

CREE

Known and Conventional Claim Limitations

JX-0001

US 8,403,531 B2

1. A lighting device comprising at least one solid state light emitter, said lighting device, when supplied with electricity of a first wattage, emitting output light having a wall plug efficiency of at least 85 lumens per watt of said electricity.

CREE LIGHTING-RAB_00000021
JX-0001.0021

JX-0002

US 8,596,819 B2

52. A lighting device comprising at least a first light emitting diode,

said lighting device, when supplied with AC electricity of a first wattage, emitting output light having a wall plug efficiency of at least 60 lumens per watt of said electricity, said output light being a quantity of light exiting from the lighting device, said output light being perceived as white light.

CREE LIGHTING-RAB_00000186
JX-0002.0025

JX-0001.0021 at 23:11-14, JX-0002.0025 at 21:23-30