TEST REPORT

Performance Comparison of Two LED Downlight Designs

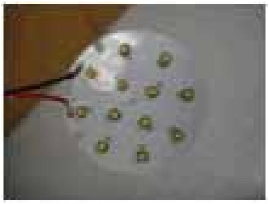
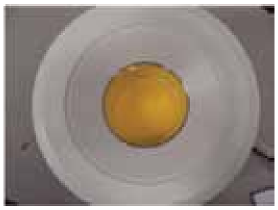
ChromaLit™ Remote Phosphor Lighting System vs. Conventional White LED System

Abstract

Conventionally, LED downlights implement white LEDs that are constructed of a blue LED device coated with phosphor. In the application, these LEDs are arranged in combination with a diffuser optic in order to perform with uniform luminance. This architecture is compared with a downlight designed with a ChromaLit™ remote phosphor light source converting the light emitted by an array of blue LEDs in a reflective mixing chamber. The blue LEDs in each system are controlled to be equivalent and both systems are designed to produce light of 3000K correlated color temperature (CCT) and 80CRI. The light output and luminous efficacy of both systems is compared under room temperature conditions with elevated system temperature during steady state operation.

Description of Test

Two LED downlight systems are assembled as shown in the table below. For the ChromaLit™ system, an array of blue LEDs emitting at 455nm wavelength is mounted on a printed circuit board (PCB) which is mounted to a heat sink. Also attached to the PCB are a diffuse reflective sheet (White97™ film from WhiteOptics) that closely surrounds the LED elements and a tapered walled mixing chamber, also coated with reflective film. The reflective sheet used in this system has diffuse reflectivity of 97%.

ChromaLit™ Remote Phosphor Lighting System	Conventional White LED Lighting System
 	 
Blue LEDs mounted on PCB inside mixing chamber coated with reflective film	White LEDs mounted on PCB with white diffuser element covering
	
Remote Phosphor system with ChromaLit™ source shown and secondary reflector	Complete White LED system with secondary reflector

For the white LED system, white LEDs (constructed of blue LEDs coated with phosphor), are mounted on a PCB in a specular reflector. The blue LEDs at the core of the white LEDs are controlled in this study to have the same quantum efficiency ($W_{rad\text{-}output}/W_{electrical\text{-}input}$) as the blue LEDs used in the ChromaLit™ system. In order to generate the equivalent source luminance as the naturally diffuse remote phosphor system, a diffuser element is applied to the white LED system. Both systems have secondary optics applied to make a complete lighting system. The efficiencies of the ChromaLit™ remote phosphor system elements and their consequent contribution to system throughput are given in the table below within uncertainty.

Efficiencies of ChromaLit™ Remote Phosphor System Elements Tested	
Quantum Efficiency of blue LEDs[1]	41%
Mixing Chamber Efficiency[2]	95%
ChromaLit™ Remote Phosphor Conversion Efficacy (3000K)[3]	180 lm/Wrad
Secondary Optic Efficiency[4]	90%

Notes:
1. At 500mA for both LEDs tested. LEDs continue to improve efficacy performance enabling higher performance systems. See manufacturer datasheet for latest specifications.
2. Mixing chamber efficiency sensitive to reflectivity of interior surfaces. See ChromaLit™ application note for latest recommendations.
3. ChromaLit™ conversion efficacy continues to improve. See datasheet for latest specifications.
4. Not all lighting systems require secondary optic. Efficiencies vary.
5. 3% uncertainty in measurements.

For the light output testing, each lighting system is mounted in a downward emitting direction within an integrating sphere of 1.5 meters diameter shown in the image at right. Luminous output and electrical power are measured after 90 minutes of thermal stabilization time.

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Results of Remote Phosphor Luminaire Measurement

System Type	LED Type	LED Manufacturer	System Lumens	System Power (Wdc)	System Efficacy (lm/W)
ChromaLit™ Remote Phosphor	LUXEON® Rebel Royal Blue	Philips Lumileds	1126	18.6	60.4
	XLamp® XP-E Royal Blue	CREE	1105	19.1	58.0
White LED with Diffuser	LUXEON® Rebel White	Philips Lumileds	838	18.8	44.6
	XLamp® XP-E White	CREE	837	19.0	44.2

Discussion & Conclusions

As seen in the above, a 35% increase in efficacy is demonstrated by the ChromaLit™ remote phosphor lighting system using LUXEON® Rebel Royal Blue LEDs and a 31% increase is observed using CREE XPE Royal Blue LEDs. These results are compared to the performance demonstrated by systems that integrate an array of white LEDs, coating a blue chip with phosphor, with a down-stream diffuser. The increased efficacy is attributed in largest part to increased extraction of light from the blue LED and the white converted light. The mixing chamber structure in combination with the ChromaLit™ conversion element is substantially more effective at recycling upstream converted white light than a phosphor coating on the chip. In addition, the elimination of scattering losses from the diffuser element contributes significantly to the overall increase in system efficacy. Finally, the ChromaLit™ remote phosphor architecture results in lower temperatures both at the remote phosphor and the blue LED chip junction, increasing the efficacy of both elements and in turn contributing to system performance.

Lighting system performance of ChromaLit™ remote phosphor lighting systems may be improved further to the results shown here. The first area of investigation is blue LED selection. Quantum efficiency for LEDs continues to improve and this drives efficacy for the lighting system since more blue light is produced for the ChromaLit™ source to convert. In addition, the conversion efficacy of the ChromaLit™ source itself continues to improve. Finally, the efficiency of the mixing chamber may be improved with materials of higher reflectivity over as wide a spectral range as possible. The combination of improvement in all these areas can combine to enable general and specialty lighting systems of very high efficacy and high light quality.