Product Document

Published by
ams OSRAM Group

Application Note No. AN084

OSRAM
Opto Semiconductors

Projection with LED light sources

Application Note

Valid for:
OSRAM OSTAR® Projection Compact
OSRAM OSTAR® Projection Cube
OSRAM OSTAR® Projection Power

Abstract

This application note provides insights into the use of LED light sources for projection applications.

It presents an overview of LED projection systems and their benefits, along with a summary of OSRAM Opto Semiconductors LEDs suitable for these applications.

Furthermore, it addresses fundamental design issues related to the use of LEDs in projection modules.

Author: Bartling Hanna / Morgott Stefan

Table of contents

A. LEDs for projection

Following a sharp increase in visible LED performance in the last few years, LEDs are increasingly being considered in the design of projection systems for the use as a light source.

In addition to their robustness and longevity, saturated colors, low power requirements and high integration capabilities are among the benefits that are expanding the use of LEDs in this new application area.

OSRAM Opto Semiconductors products based on thin-film technology are best suited for this application since they can make efficient use of the emitted light due to their surface emission characteristics.

In order to obtain higher efficiency and enhanced durability in the application, certain design considerations should be observed, such as matching the LED light source to the optical system and the use of proper thermal management, as described in this application note.

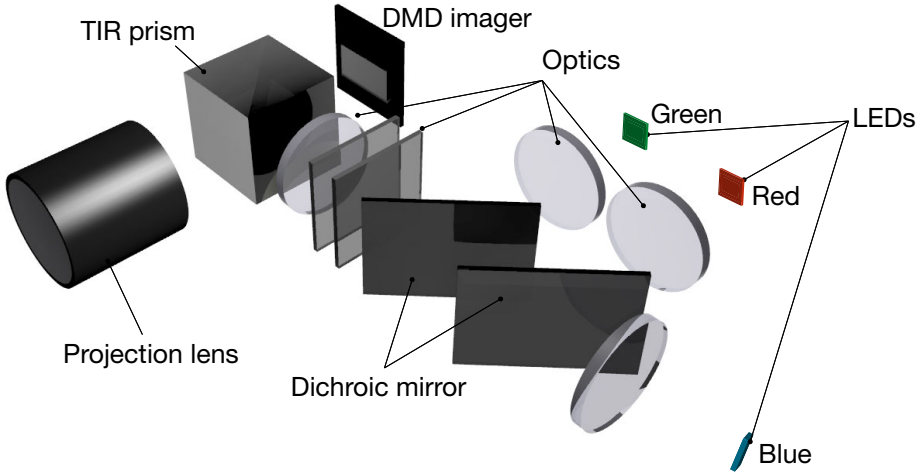
B. Projection concepts using LEDs as light sources

Basic concept

Basically, each projection system can be divided into three main functional components: the light source, the imager and the image projection.

The light source module enables the generation and shaping of the light to illuminate the imager. In addition to the light source itself, it normally comprises the light collection optics and prisms as well as the optical components required for homogenization and, in some cases, the polarization of the light prior to image generation. The imager module is the active component that generates the image from the incoming light. Figure 1 schematically shows a DMD projection system.

Figure 1: 1-chip DMD projection system



Currently there are three types of imagers that are widely used, namely DMDs (Digital Mirror Devices), transmissive LCDs (Liquid Crystal Displays) panels and LCoS (Liquid Crystal on Silicon). The imager is a key system component since most of the optical limitations are influenced by its properties (dimensions, polarization, acceptance angle, etc.).

In addition, there is a system component which ensures is the projection and magnification of the generated image using projection optics. As this does not particularly alter the requirements of the light source, it will not be considered further in this application note.

Comparison of optical configuration

In general, various concepts are possible for the projection setup, depending on the specific application. Each setup has its own advantages and disadvantages. The three possible setup are described in detail below:

- 3-channel setup
- 2-channel setup
- 1-channel setup

3-channel setup. For the 3-channel setup three discrete LED devices are incorporated within the system. The advantages of this setup are the maximum lumen per etendue per color achievable as well as a good color uniformity. Sufficient cooling enables higher LED power. Disadvantages may be the larger engine size and the long bill of material (BOM). In addition, many components are required.

The 3-channel setup is recommended for business solutions which require high intensities/brightness and are not limited in size.

2-channel setup. For the 2-channel setup two discrete LED devices — one a dual-color package — are used in the projection system. The main advantages of this setup are the reduced engine size and the reduced BOM in comparison to the 3-channel setup. For this version only one dichroic filter element is needed, instead of two for the 3-channel version. Disadvantages of the setup may be that the colors in this 2-in-1 package have a limited etendue and in addition, color homogenization is required.

The 2-channel setup is commonly used in compact solutions as it is an excellent compromise between brightness and system size.

1-channel setup. For the 1-channel setup only one multi-color LED device is used. In this case, the main advantages are the further reduced engine factor and BOM. In addition, no dichroic filter is needed at all. On the other hand, only low lumen per etendue for each color can be achieved and color homogenization is required.

The 1-channel system is commonly used for embedded solutions, where the system size is the most critical factor.

Etendue

Unlike conventional high pressure lamps used for projection that are often considered to be a point light source, LEDs must be considered as a two-dimensional light source, and thus the law of etendue applies accordingly:

$E_{LED} \leq E_{system}$, whereby E is the etendue of the LED respectively the system.

The etendue E describes the required phase space of the area and the solid angle that is required in order to guarantee the loss-free transfer of light from one point to another within the optical system. The etendue thus characterizes each optical element in the system and can be specified for every component.

$$E_{LED} = \pi \cdot n^2 \cdot A_{LED} \cdot \sin^2(\varphi_{LED})$$

$$E_{system} = \pi \cdot A_P \cdot \sin^2(\varphi_{system})$$

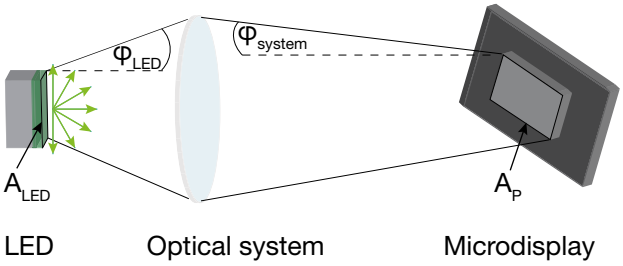
When designing an LED projection system it is therefore particularly important that the etendue of the light source is properly matched to that of the system. By

means of the etendue, it is possible to determine the efficiency of the light source in the system. The application of etendue is shown in Figure 2.

This is a limiting property of LEDs because the light etendue of a source cannot be reduced without loss. Due to the law of etendue, there is a maximum emitting area of the LED surface (A_{LED}) for a given imager (e.g. microdisplay) and optical system (lens) above which no additional light can be coupled into the system.

This is a key issue in the design of an optical unit for projection systems which employ an LED as a light source and imply that the etendue of the system (primarily the imager) should match the etendue of the LED.

Figure 2: Etendue match

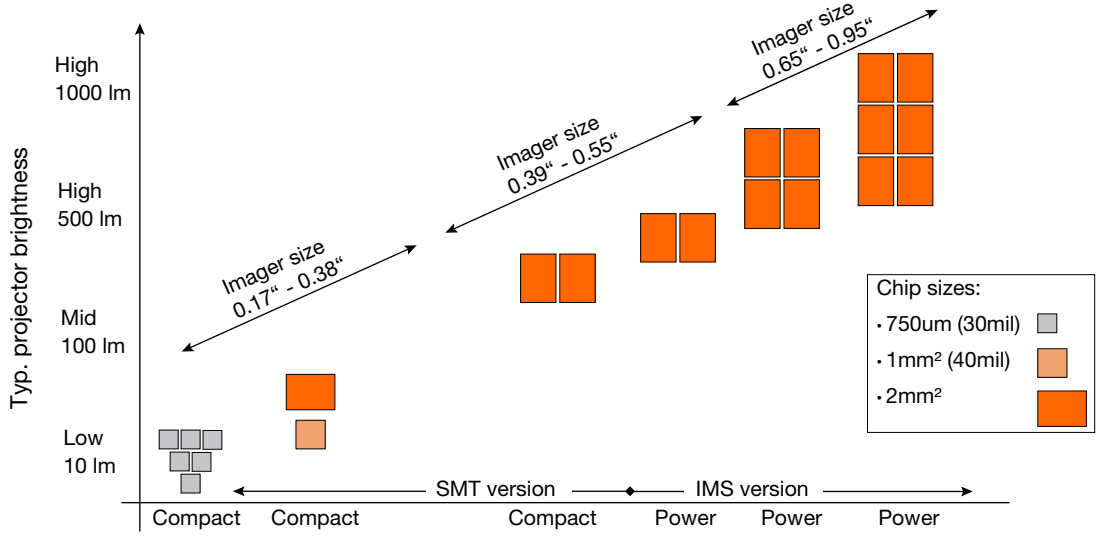


This results in the following conclusion: The greater the luminance of the light source, the smaller the optical system can be designed at the same level of efficiency.

Grouping of suitable chip size

As previously described, the matching of the etendue of the system and of the LED is essential for an efficient projection system. Thus, OSRAM Opto Semiconductors provides LEDs with various light emitting areas to match a huge variety of projector systems. Recommendations for finding a suitable chip size are given in Figure 3.

Figure 3: Suitable chip sizes for typical projection brightnesses



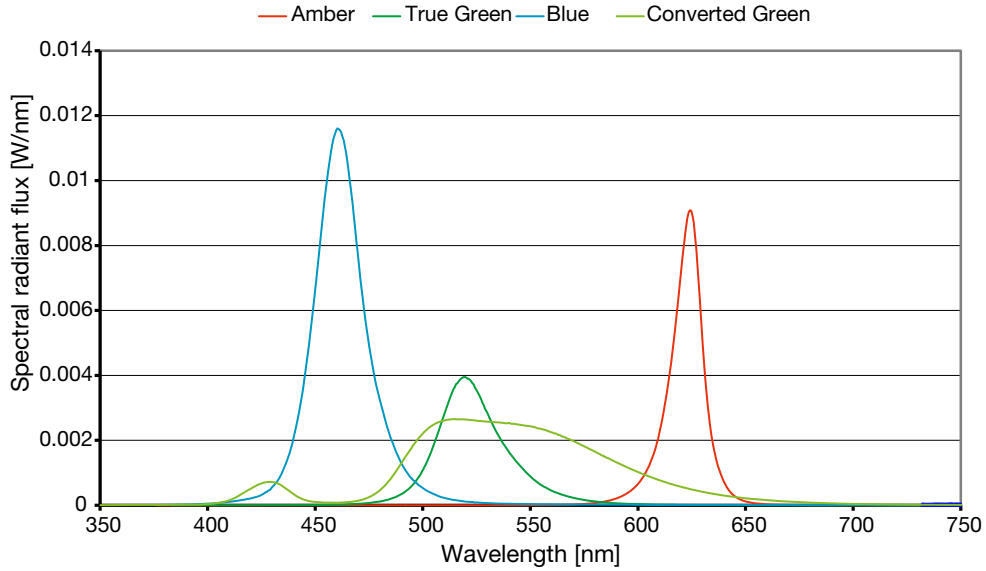
Converted Green

Green LED light can either be obtained directly (Direct Green) or via conversion (Converted Green/Pure Green). Direct Green or True Green LEDs from OSRAM Opto Semiconductors contain an InGaN LED chip. In contrast, Converted Green / Pure Green (CG / P) LEDs consist of a blue InGaN chip together with an additional phosphor layer.

Comparing the CG/P and the Direct Green (True Green) the CG/P has a 60 % higher luminous flux and a wider spectral width of 100 nm (in comparison to 33 nm for Direct Green LEDs) and still fulfills the Rec.709 (sRGB) color gamut standard.

Figure 7 shows the spectral power density curves of 750 µm chips at 350 mA and 25 °C for the colors Blue, Amber, True Green and Converted Green.

Figure 4: Spectral power density curves



C. OSRAM LEDs for projection applications

All the OSRAM Opto Semiconductors LEDs presented in this section are based on efficient thin film technology with almost pure surface emission and high current capability. They exhibit Lambertian radiation characteristics, providing illumination within a limited space, independent of the viewing angle. Besides the pure colors of amber, blue and true green, some LEDs are also available in conversion technology with Converted Green (CG) or Ultra White (UW).

Depending on the imager size used and the application-specific brightness level requirement, the LEDs are designed as single chip or multi chip array. The chip sizes used vary from about 750 µm to 2 mm² to fulfill the various power classes.

Tables 1 thru 4 show an overview of the LED types of OSRAM Opto Semiconductors particularly suited for projection applications.

All the packages have been optimized for heat dissipation and efficient light output with minimal degradation over their lifetime in typical applications.

OSRAM OSTAR® Projection Compact

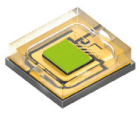
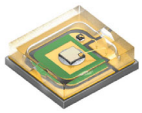
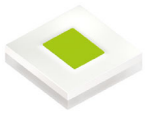
The package of the OSRAM OSTAR® Projection Compact product family is based on a ceramic substrate on which the chips are attached and contacted.

For the LE x Qxxx LED types, the chips and the wire bonding are covered by means of the attachment of a glass window. This basically provides protection against physical contact, and does not hermetically seal the component from the environment. The electrical contacts are designed as bottom-only terminations.

In addition, a new package type without a glass window is available. The Kx CSLxxx LED types consist of a white molded ceramic package. The chips are covered by a ceramic (conversion) layer which ensures that the emitting surface is on the top of the package.

Available as a single chip or multi chip LED (up to 3) and with various chip sizes, the OSRAM OSTAR® Projection Compact group is suitable and established for embedded and compact solutions. The LEDs are available in the colors Amber, Red, True Green, Green, Converted green/Pure Green, Blue and White (Table 1).

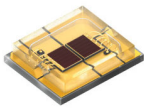
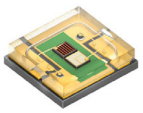
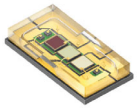
Table 1: OSRAM OSTAR® Projection Compact

	1-chip package			
LED type	LE × Q8WP	LE x Q8WM	Kx CSLNM1.xx	Kx CSLPM1.xx
				
Package size	3.9 × 3.7 × 1.2 mm³		3.0 × 3.0 × 0.75 mm³	
Chip size	2 mm²	750 µm	1 mm²	2 mm²
Max. pulse current	8 A (6 A for A, R)	1.2 A	4 A (3.3 A for R)	8 A
Typ. dom. wavelength / color coordinate	A: 617 nm R: 625 nm CG: 0.32/0.64 T: 530 nm B: 459 nm	T: 530 nm	R: 617 nm P: 0.32/0.64 B: 455 nm W: 0.32/0.33	P: 0.32/0.64 W: 0.32/0.33
Brightness	A: 200 lm[1] R: 160 lm[1] CG: 650 lm[1] T: 340 lm[1] B: 1,900 mW[1]	T: 90 lm[2]	R: 140 lm[3] P: 450 lm[3] B: 1,200 mW[3] W: 325 lm[3]	P: 680 lm[1] W: 515 lm[1]

A = Amber, B = Blue, T = True Green, CG / P = Converted Green

[1]typ. @ I_f=1.4 A, [2]typ. @ I_f=350 mA, [3]typ. @ I_f=1 A

Table 2: OSRAM OSTAR® Projection Compact

	2-chip		3-chip
LED type	LE × Q7WP	LE BR Q7WM	LE RTB N7WM
			
Package size	5.8 × 4.7 × 1.2 mm³	3.9 × 3.7 × 1.1 mm³	5.3 × 2.7 × 0.9 mm³
Chip size	2 × 2 mm²	2 × 750 µm	3 × 750 µm
Max. pulse current	6 A /chip	1 A	1 A
Typ. dom. wavelength / color coordinate	A: 617 nm CG: 0.32/0.64 B: 460 nm	A: 617 nm B: 465 nm	A: 617 nm T: 525 nm B: 465 nm
Brightness	A: 400 lm[1] CG: 1,300 lm[1] B: 3,800 mW[1]	A: 55 lm[2] B: 350 mW[2]	A: 55 lm[2] T: 90 lm[2] B: 350 mW[2]

A = Amber, B = Blue, T = True Green, CG = Converted Green
[1]typ. @ I_f=1.4 A per chip, [2]typ. @ I_f=350 mA

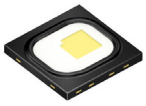
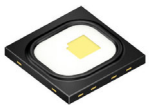
OSRAM OSTAR® Projection Cube

The OSRAM OSTAR® Projection Cube is only available in the color Converted Green and with two different chip sizes.

The package of the OSRAM OSTAR® Projection Cube consists of a molded epoxy with a metal lead frame on which the semiconductor chip is mounted and electrically connected. The chip and wire bond is finally encapsulated with a white embedding material. The electrical contacts are located on the bottom surface of the LED, whereas the exposed cathode serves as thermal pad.

The LED is used for projection applications especially in mobile devices (Table 3).

Table 3: OSRAM OSTAR® Projection Cube

	1-chip package	
LED type	LCG H9RN	LCG H9RM
		
Package size	3.8 × 3.8 × 0.5 mm³	
Chip size	1 mm²	750 µm
Max. pulse current	1.5 A	1 A
Typ. color coordinate	CG: 0.32/0.64	CG: 0.32/0.64
Brightness	340 lm[1]	170 lm[2]

CG = Converted Green; [1]typ. @ I_f=700 mA, [2]typ. @ I_f=350 mA

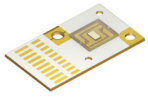
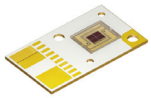
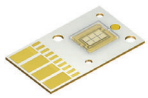
OSRAM OSTAR® Projection Power

The OSRAM OSTAR® Projection Power was developed to match optical requirements in the home, industry and office segment (business solutions).

The high-power LEDs are available in various configuration levels with two, four or six chips. The basis for the LED is a multi-chip technology in combination with a copper carrier board (Isolated Metal Substrate (IMS)). The semiconductor chips (size 2 mm²) are mounted accordingly and wired as a light source on a board covered with a glass window. The IMS-PCB acts as a heat spreader, providing a large surface area for efficient thermal contact to the system heat sink.

The OSRAM OSTAR® Projection Power is available as a monochrome module with the colors amber, converted green and blue (Table 4).

Table 4: OSRAM OSTAR® Projection Power

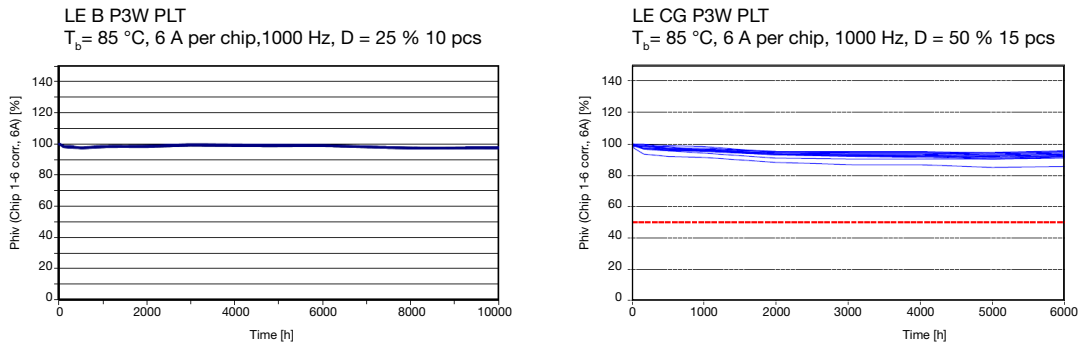
	2-chip	4-chip	6-chip
LED type	LE × P1W/A	LE × P2W/A	LE × P3W/A 01
			
Chip size	2 × 2 mm²	4 × 2 mm²	6 × 2 mm²
Max. pulse current	12 A (A), 16 A (B, CG)	24 A (A), 32 A (B, CG)	36 A (A), 48 A (B, CG)
Typ. dom. wavelength / color coordinate	A: 617 nm B: 453 nm CG: 0.32/0.64	A: 617 nm B: 453 nm CG: 0.32/0.64	A: 617 nm B: 459 nm CG: 0.32/0.64
LED type	A: 1,400 lm[1] B: 12 W[1] CG: 4,000 lm[1]	A: 2,800 lm[2] B: 24 W[2] CG: 8,000 lm[2]	A: 4,200 lm[3] B: 36 W[3] CG: 12,000 lm[3]

A = Amber, B = Blue, CG = Converted Green,
[1]typ. @ I_f=12 A, [2]typ. @ I_f=24 A, [3]typ. @ I_f=36 A

D. Reliability and lifetime

Long-term studies were performed to investigate the lifetime degradation of the OSRAM OSTAR® Projection Power under both standard and harsh conditions. Figure 5 shows the lifetime degradation for the Converted Green and the Blue chip exemples. For the Blue chip the intensity is still above 95 % after 1000 h. For the Converted Green chip the intensity loss is more pronounced but still does not fall under 80 % after 6000 h.

Figure 5: Lifetime degradation of the OSRAM OSTAR® Projection Power



E. High temperature operation

However, the junction temperature does not only influence the lifetime however. Figure 6 shows that the luminous flux and efficiency are also dependent on the junction temperature. This is especially the case for Amber LEDs as these are based on an InGaAlP semiconductor material system, whereas Green and Blue are based on InGaN.

Figure 6: Relative luminous flux versus junction temperature

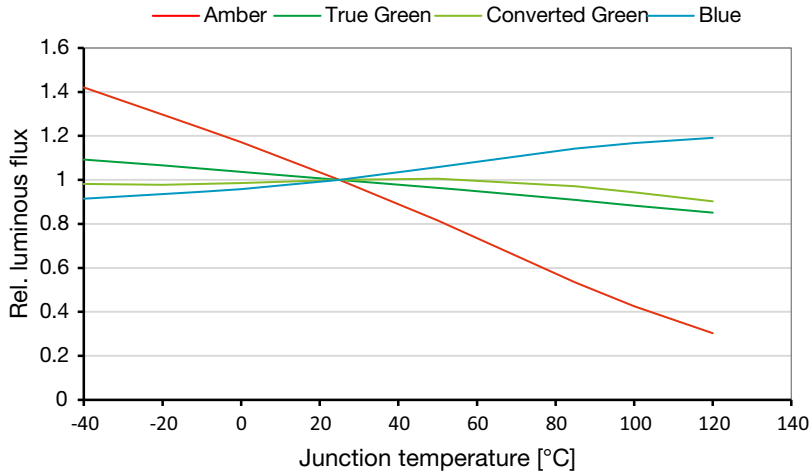
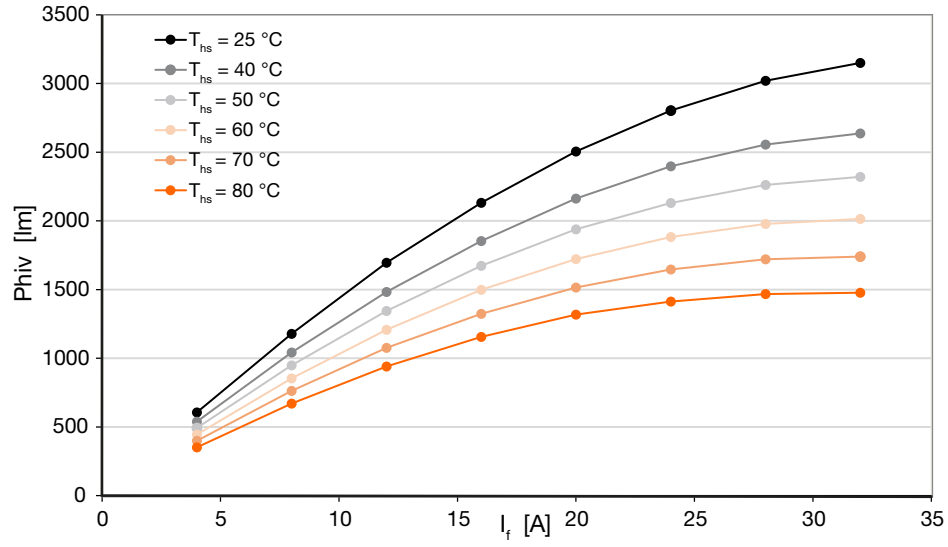


Figure 7 shows the saturation of luminous flux with respect to operating current for a red emitting OSRAM OSTAR® Projection LED driven at a fixed duty cycle (25 %) for various board temperatures. Increasing the driving current above a certain point leads to a so-called "rollover" effect — in such a case, an increase in current density leads to a reduction of the luminous flux. In other words, the increased input power is no longer converted into light but warms up the LED instead. By optimizing the thermal design, this saturation point can be shifted to higher current density levels, which allows the more efficient operation of the LED.

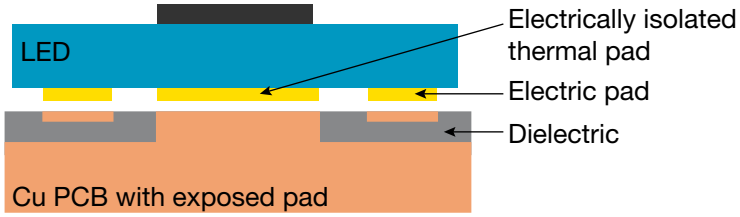
Figure 7: Luminous flux versus driving current (LE A P2W, duty cycle = 25 %, pulse repetition rate 1000 Hz)



F. PCB for high power LEDs

Efficient thermal management is important for high-current LEDs, such as the OSRAM OSTAR® Projection Compact. To enable efficient heat dissipation from the device to the PCB, especially for these high-current LEDs, OSRAM Opto Semiconductors recommends the use of metal core PCBs (MC-PCBs) with Cu pedestals (see Figure 8). The exposed copper pad directly located under the electrically isolated thermal pad enables the efficient dissipation of the heat created in the LED chip.

Figure 8: Schematic view of a Cu PCB with exposed pad



When reflow soldering the LED device onto the PCB, special care must be taken regarding the temperature profile. The difference in the coefficient of thermal expansion (CTE) between dielectric and copper can introduce stress into the device e.g. resulting in banding or cracking of the ceramic substrate. To reduce the stress to the LED the solder pad design, the thickness of the dielectric and the CTE as well as the reflow solder temperature profile must be carefully evaluated.

In contrast to the OSRAM OSTAR® Compact and Cube family, the OSRAM OSTAR® Projection Power already includes an MC-PCB for optimal heat dissipation. The MC-PCB acts as a heat spreader, providing a large surface area for an efficient thermal contact to a heat sink. For further information please refer to the application note “Thermal management of OSRAM OSTAR® Projection light source”.

G. Design suggestions

To support our customers in the setup of a projection system, OSRAM Opto Semiconductors gives some suggestions for suitable LED and DMD (digital micromirror device) combinations, depending on the size of the application. Further information on digital light processing products (DLPs) such as DMDs can be found for example at Texas Instruments Inc.

Table 5: Overview of OSRAM OSTAR® LEDs and suitable DMDs

Solution	DMD diagonal	Projector brightness	LED type
Embedded solutions	0.2“ nHD	up to 30 lm	OSRAM OSTAR® Projection Compact LE BR Q7WM LE T Q8WM LE BR Q7WM LE RTB N7WM OSRAM OSTAR® Projection Cube LCG H9RM
	0.2“ WVGA 0.23“ qHD 0.23“ 720p	up to 150 lm	OSRAM OSTAR® Projection Compact KR CSLNM1.23 KP CSLNM1.F1 KB CSLNM1.14
Compact solutions	0.3“ 720P	up to 300 lm	OSRAM OSTAR® Projection Compact LE A Q8WP LE B Q8WP KP CSLPM1
	0.33“ 1080P	up to 300 lm	OSRAM OSTAR® Projection Compact LE A Q8WP LE B Q8WP KP CSLPM1
		up to 450 lm	LE A Q7WP LE CG Q7WP LE B Q7WP
	0.45“ WXGA	up to 500 lm	OSRAM OSTAR® Projection Compact LE A Q7WP LE CG Q7WP LE B Q7WP OSRAM OSTAR® Projection Power LE A P1W LE CG P1A LE B P1W
	0.47” 1080P 0.47” 4K UHD	up to 1000 lm	OSRAM OSTAR® Projection Power LE A P1W LE CG P1A LE B P1W

Table 5: Overview of OSRAM OSTAR® LEDs and suitable DMDs

Solution	DMD diagonal	Projector brightness	LED type
Business solutions	0.48“ WUXGA 0.47“ 1080P 0.48“ 4K UHD 0.55“ XGA	up to 1000 lm	OSRAM OSTAR® Projection Power LE A P1W LE CG P1A LE B P1W
	0.65“ WXGA 0.65“ 1080P	up to 1300 lm	OSRAM OSTAR® Projection Power LE A P2W LE CG P2A LE B P2W
	0.66“ 4K UHD 0.9“ WQXGA	up to 2500 lm	OSRAM OSTAR® Projection Power LE A P3W 01 LE CG P3A 01 LE B P3W 01
	0.95“ 1080p	up to 2800 lm	OSRAM OSTAR® Projection Power LE A P3W 01 LE CG P3A 01 LE B P3W 01

Don't forget: LED Light for you is your place to be whenever you are looking for information or worldwide partners for your LED Lighting project.

www.ledlightforyou.com

ABOUT OSRAM OPTO SEMICONDUCTORS

OSRAM, Munich, Germany is one of the two leading light manufacturers in the world. Its subsidiary, OSRAM Opto Semiconductors GmbH in Regensburg (Germany), offers its customers solutions based on semiconductor technology for lighting, sensor and visualization applications. OSRAM Opto Semiconductors has production sites in Regensburg (Germany), Penang (Malaysia) and Wuxi (China). Its headquarters for North America is in Sunnyvale (USA), and for Asia in Hong Kong. OSRAM Opto Semiconductors also has sales offices throughout the world. For more information go to www.osram-os.com.

DISCLAIMER

PLEASE CAREFULLY READ THE BELOW TERMS AND CONDITIONS BEFORE USING THE INFORMATION SHOWN HEREIN. IF YOU DO NOT AGREE WITH ANY OF THESE TERMS AND CONDITIONS, DO NOT USE THE INFORMATION.

The information provided in this general information document was formulated using the utmost care; however, it is provided by OSRAM Opto Semiconductors GmbH on an “as is” basis. Thus, OSRAM Opto Semiconductors GmbH does not expressly or implicitly assume any warranty or liability whatsoever in relation to this information, including – but not limited to – warranties for correctness, completeness, marketability, fitness for any specific purpose, title, or non-infringement of rights. In no event shall OSRAM Opto Semiconductors GmbH be liable – regardless of the legal theory – for any direct, indirect, special, incidental, exemplary, consequential, or punitive damages arising from the use of this information. This limitation shall apply even if OSRAM Opto Semiconductors GmbH has been advised of possible damages. As some jurisdictions do not allow the exclusion of certain warranties or limitations of liabilities, the above limitations and exclusions might not apply. In such cases, the liability of OSRAM Opto Semiconductors GmbH is limited to the greatest extent permitted in law.

OSRAM Opto Semiconductors GmbH may change the provided information at any time without giving notice to users and is not obliged to provide any maintenance or support related to the provided information. The provided information is based on special conditions, which means that the possibility of changes cannot be precluded.

Any rights not expressly granted herein are reserved. Other than the right to use the information provided in this document, no other rights are granted nor shall any obligations requiring the granting of further rights be inferred. Any and all rights and licenses regarding patents and patent applications are expressly excluded.

It is prohibited to reproduce, transfer, distribute, or store all or part of the content of this document in any form without the prior written permission of OSRAM Opto Semiconductors GmbH unless required to do so in accordance with applicable law.

OSRAM Opto Semiconductors GmbH

Head office:

Leibnizstr. 4
93055 Regensburg
Germany
www.osram-os.com