LEDs for Flash Applications

Application Note

Abstract

This application note introduces two LED types with optimized design and characteristics which are particularly suitable for use as camera flash.
In addition to a short summary of the requirements of flash applications and the advantages of LEDs, some important LED parameters are described with reference to flashlight operating modes.

Introduction

Often, the ambient light available for taking a picture is insufficient, requiring the use of a flash unit as an additional light source.
Traditional flash units consist of a flash tube in which a flash is created by means of a gas discharge. The flash tube contains an inert gas, usually xenon or krypton.
Using a suitable circuit, the battery charges a capacitor to a level of a few hundred volts. This is then stepped up to a secondary voltage in the kV range by means of an ignition coil. This ignition voltage is released in the flash tube, causing the gas to ionize.
The flash arises through recombination and lasts only a fraction of a second. During this time a few hundreds amperes of current flow.
The light emitted from the flash tube exhibits a continuous spectrum similar to that of sunlight (a Planck emitter in the color temperature range of 5500 – 6500K).
Modern flash units contain a sensor, in which the reflected light from the subject is measured by means of a photodiode. The flash is automatically switched off after a predetermined amount of light is sensed.
Due to the increasing brightness of LEDs, the flash tubes previously used in flash units can be replaced by LEDs for use in mobile phones and digital cameras, for example. In comparison to flash tubes, LEDs provide several advantages.

Advantages of LEDs

- high mechanical stability
- small dimensions
- low voltage required to create a flash, compared to that of flash tubes
- simple circuitry
- no charging time – the flash is immediately available
- longer lifetime than conventional flash tubes
- longer flash duration possible, up to continuous mode
- RGB-LED: adjustable color temperature, adaptable spectrum

Flash Requirements

Depending on the application, various demands are placed on the camera flash in order to achieve a correct exposure. This leads to differing requirements which must be fulfilled, however.

1. Conventional Xenon Flash

Xenon photographic flash units are capable of illuminating subjects up to 45 meters away. The coverage range is regulated by the flash power.
Figure 1 shows the discharge curve for a typical conventional flash unit at maximum power.

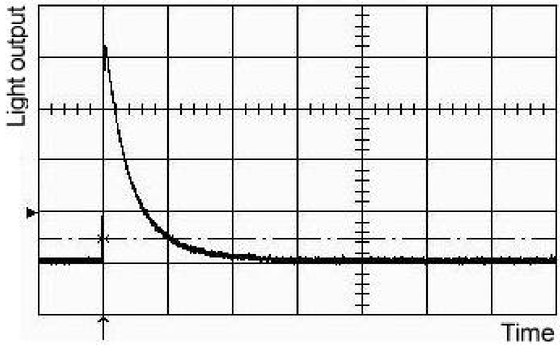


Figure 1: Light output over time of a Xenon flash unit at maximum power

A sharp rise in light intensity is visible, followed by a decay. Depending on the distance between the camera and the subject, a particular quantity of light is required for a proper exposure.
The quantity of light is defined to be the product of the illuminance and the flash duration, which corresponds to the integral of the area under the discharge curve. The quantity of light (flash power) can be controlled by the flash duration. For that purpose, the flash discharge and thus the discharge curve is prematurely interrupted.
Conventional flash units illuminate a subject with an illuminance of approximately E_v=450lx. The flash duration varies from 15µs to 2ms, depending on the coverage range.

Flash unit for conventional applications	
Subject illuminance E_v	> 420lx
Flash duration	15µs – 2ms
Flash coverage	2m – 35m
Lifetime	5,000 flashes
Time between flashes	2s – 5s
Viewing angle	100°
Color temperature	5500K – 6500K

Table 1: Flash unit for conventional applications

The color temperature of the flash ranges between 5500K and 6000K.
The period between two flashes ranges from 2s to 5s. This period is necessary in order to recharge the capacitor.
Conventional flash units have a lifetime of about 5,000 flashes. Afterwards, the brightness is reduced to a level of 90%.
Table 1 summarizes the requirements of a flash unit used for conventional applications.

2. Flash units for mobile phones

For mobile phones, a minimal subject illuminance of around 30lx is required. For mobile phones of the high end range with an optical resolution of 2 Mpixel or more, the optimum illuminance should be 45lx to 50lx at 1m.
Moreover in most applications, the flash should cover a rectangular field of view, e.g. 60° x 47°. In the center of this field, an illuminance of 50lx should be achieved. The degradation of illuminance in the corner of this field of view should be no more than 40%.
The required flash duration is in the range of up to 400ms. Depending on the processing rate of the mobile phone, the time between flashes is usually about 2.5s, although this can be shorter. The duty cycle of a flash is given by pulse duration divided by the cycle time (pulse duration plus break).

The lifetime of the flash unit is assumed to be greater than 30,000 flashes.

For mobile phone applications, an operating temperature of -10° C to 50° C is required.
In addition to pulse operation, constant operation is also desired, e.g. for movie functionality, with a lifetime of 170h. This permits the LED to function as a torch light, for example. For this application, a luminous intensity of 2cd or greater at about 200mA is required.
The following requirements are placed on a flash unit for use in mobile phones:

Flash unit for use in mobile phones	
Minimal dimensions	Height < 3mm
Subject illuminance	> 30lx
Flash duration	< 400ms
Flash coverage	< 3m
Flash lamp lifetime	> 30,000 flashes
Viewing angle	50° - 75°
Color temperature	5500K – 6500K
Lifetime (constant operation)	> 170h
Luminous intensity (constant operation)	> 2cd

Table 2: Flash unit for use in mobile phones

LEDs for Camera Flash Applications

In the following, two LEDs are presented which can be considered for use as a substitute for flash tubes.

White LEDs are particularly well suited for use as camera flash.
White LEDs are typically based on the principle of color addition, in which the primary color blue (blue semiconductor chip) and the appropriate complimentary color yellow (yellow converter) are used to create white light.
The typical color temperature of white LEDs is in the range of 5500K to 6500K, with a color reproduction index (CRI) of 80.
Figure 2 shows the spectrum of a typical white LED. The dashed line indicates the standard eye response curve V(λ).

In addition to the function of digital image sensors (CCD or CMOS), RGB-LEDs are also suited for use as camera flash.
The radiated white light consists of the three single colors red, green and blue, corresponding to the individual chips employed.

Since OSRAM-OS continually makes improvements to the luminous intensity of LEDs, please check the data sheets of the following LED types for further details and the latest performance data (www.osram-os.com).

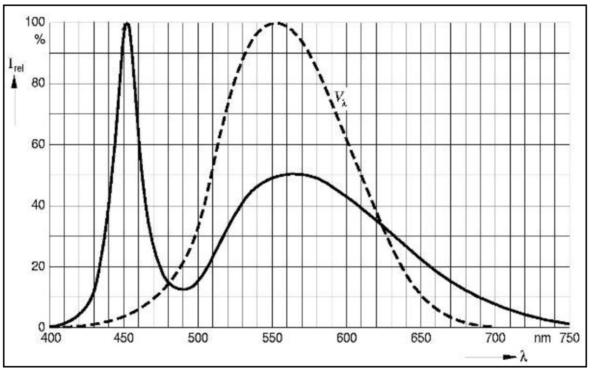


Figure 2: Spectrum of typical white LED

OSLUX™ - LW F65G

The OSLUX™ is especially developed for camera flash applications with high demands on brightness combined with small dimensions (5mm x 5.1mm x 2.7mm).

The LED is based on the newest highly efficient ThinGaN® chip technology and shows excellent color uniformity as a result of the front emitter behavior combined with color conversion at the chip level.
For the target viewing field, this means that there is practically no color variation or separation.
In addition, the package has an integrated lens and is IR-reflow solderable for Pb-free components.
The special lens design provides a uniform rectangular illumination pattern with a viewing angle of 60°/47° (Figure 3). This directs most light to the target viewing field of the camera, adjusted to the picture format.
Compared with other flash LEDs with a typical radial Lambertian radiation pattern, the OSLUX™ LED exhibits only a minor decrease in brightness in the boundary region. Thus, when taking photos, the object is illuminated in a laminar and uniform fashion rather than at a central point. Darker picture contours and/or backgrounds belong to the past.

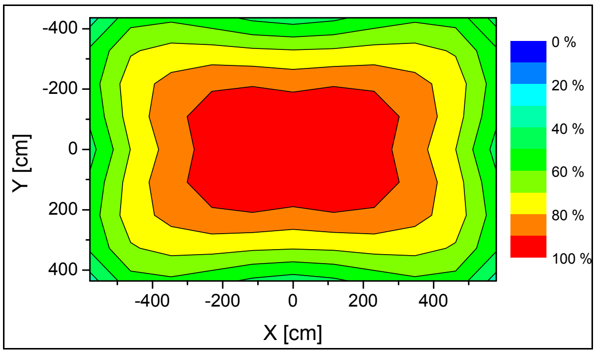
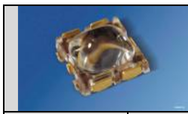


Figure 3: Rectangular Illumination pattern of the OSLUX™ (LW F65G) at 1m distance

With a low forward voltage (U_{ftyp}= 3.8V @ 1000mA), the LW F65G makes electrical control much easier compared to other flash LEDs available on the market.
Furthermore, due to the optimized low thermal resistance, the LW F65G can be driven with a current of up to 1.5A in pulse mode.
To reach the optimal performance of the LEDs, however, thermal management should be considered.
Table 3 shows the optical specifications in relation to the forward current for the LW F65G.



OSLUX™ – LWF65G

I_f	350mA	500mA	700mA	1000mA	1.5A
Φ_v (typ.)	48.5lm	60lm	73lm	81lm	92.5lm
I_v (typ.)	26cd	33cd	40cd	45cd	52cd
$E_{v\ max}$ at 1 m	34.5lx	42.5lx	52lx	58lx	66lx
$E_{v\ avg.}$ at 1m	24lx	30lx	37lx	42lx	47lx
U_f (typ.)	3.2V	3.4V	3.6V	3.8V	4.3V
U_f (max.)	3.8V	4V	4.2V	4.5V	4.9V
Pulse duration [T_a=25°C]	DC	DC	500ms	300ms	50ms

Table 3: Characteristics of the OSLUX™

In Figure 4 and Table 4, the illuminance of the OSLUX™ at different distances is shown.

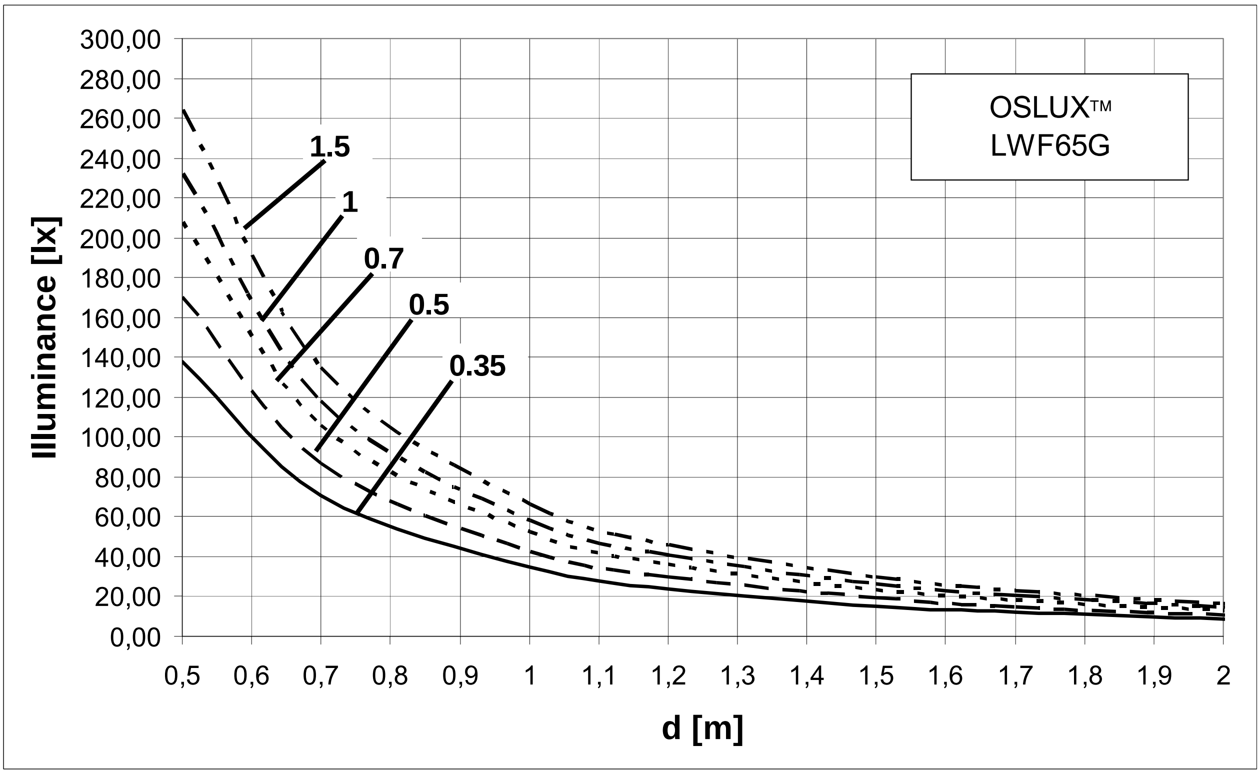


Figure 4: Illuminance of the OSLUX™ for different distances with a typ. brightness of 48lm @ 350mA

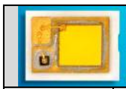
I_f	E_v at 1m	E_v at 1.5m	E_v at 2m	E_v at 3m
350mA	34lx	15lx	8.5lx	3.8lx
500mA	42lx	19lx	11lx	4.7lx
700mA	52lx	23lx	12.5lx	5.8lx
1A	58lx	25.5lx	14.5lx	6.5lx
1.5A	66lx	29.5lx	16.5lx	7.3lx

Table 4: Illuminance of the OSLUX™ at different distances

Without any auxiliary optics, the LW F65G fulfills all required characteristics and exceeds those of other LEDs regarding brightness, uniform color, homogeneous illumination and optical system efficiency.
For use as a camera flash in high performance flash units, therefore, it represents the best choice in this case.

CERAMOS™ - LW C9SP

This LED is a combination of minimized package and also the newest high efficient ThinGaN® chip technology with excellent color homogeneity.
Especially designed for application with extremely limited space the LED exhibits with a dimension of 2.1mm x 1.65mm x 0.75mm a very high luminous brightness. Table 5 shows the optical characteristics of the CERAMOS™ LED.



CERAMOS™ – LWC9SP				
If	350mA	500mA	700mA	1000mA
Φ_v (typ.)	36lm	45lm	54lm	63lm
I_v (typ.)	12cd	15cd	18cd	22cd
$E_{v\ max}$ at 1 m*	27lx	34lx	41lx	48lx
	with OSRAM OS lens			
$E_{v\ avg.}$ at 1 m*	15lx	19lx	22lx	26lx
	with OSRAM OS lens			
U_f (typ.)	3.2V	3.4V	3.6V	3.8V
U_f (max.)	3.7V	4.0V	4.3V	4.8V
Pulse duration [T_a=25°C]	DC	DC	500ms	300ms

Table 5: Characteristics of CERAMOS™

The LW C9SP is suitable for pulse currents up to 1000mA. A typical pulse condition for flashlight application in mobile phones is pulse duration of 400ms at 500mA. The Duty Cycle is D=0.1.

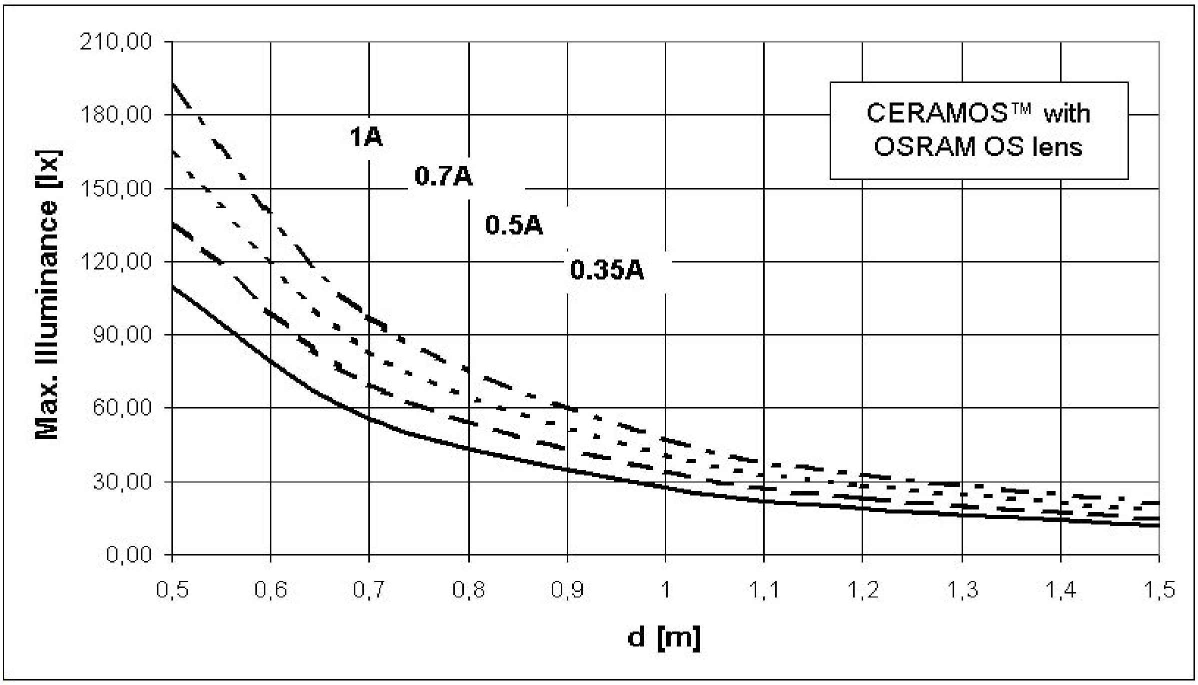


Figure 5: Maximum Illuminance of CERAMOS™ for different distances

Figure 5 shows the illuminance of the CERAMOS™ for different distances. Please notice, that there is the illuminance in the center of the viewing field plotted.
The LW C9SP has solitary a viewing angle of +- 60° with a Lambertian characteristic.

The LED can be easily combined with an e.g. Fresnel lens to focus the light in the center of the viewing field. The lens can be fixed e.g. in the cover of the mobile phone.

For further performance optimization of the CERAMOS™ OSRAM OS has developed a specific Fresnel optic with TIR structures.

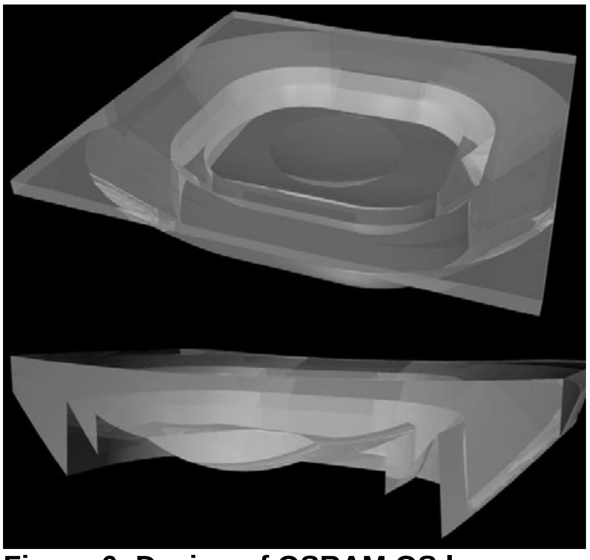


Figure 6: Design of OSRAM OS lens

The geometric dimensions of the external lens are 5mm x 5mm x 1.1mm. The lens shows a high efficiency of ≥ 51% combined with a homogenous light distribution.

Moreover the design of the lens offers a flexible adaptation (additional structures) to new requirements.

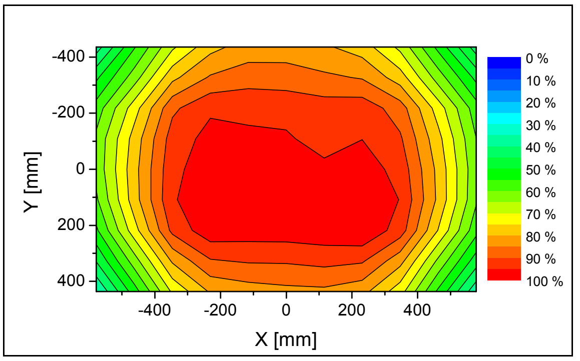


Figure 7: Illumination pattern of the CERAMOS™ (LW C9SP) with OSRAM OS lens at 1m distance

LED Characteristics Related to Flash Operation

Switching Time

White LEDs contain semiconductor chips based on InGaN technology. The switching time of InGaN dies is a few ns. The yellow converter switches approximately a factor of 10 later.
After this time, the light appears white to the eye.
Since the switching time of the converter is a factor of 10^6 shorter than that of the flash duration, the switching time of the converter need not be considered. Thus, it can be assumed that during the entire duration of the flash, white light is measured by the detector.

Flash Duration

The quantity of light produced by a flash is determined from the product of the flash duration and illuminance E_v. With a higher illuminance of the LED, a shorter flash duration is required for a sufficient exposure. In order to reduce blurring, the flash duration should be kept as short as possible.

Radiation Characteristics

The viewing angle of an LED is defined as the angle at which the light intensity falls to 50% of its maximum value. The previously described LEDs without lenses have a viewing angle of 120° (Figure 8).

The radiation characteristics correspond to a Lambertian emitter. In other words, the light density is independent of the angle of observation.

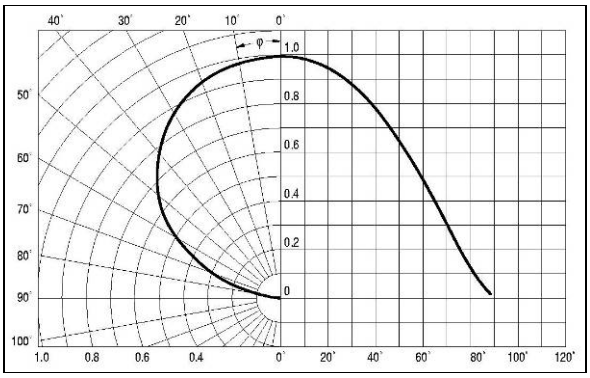


Figure 8: Radiation characteristic, 120° viewing angle

The illuminance E_v of an LED is indirectly related to the square of the distance (photometric distance law). That is, for a doubling of the distance, the illuminance is reduced to one fourth of the output value.

Additional optics (e.g. a lens) may be used to reduce the viewing angle and therefore increase the light intensity along the forward axis.

Luminous Flux

Figure 9 shows the relation of luminous flux Φ_v to the forward current I_f.
Due to the physical behavior of the semiconductor diode, the luminous flux of an LED does not increase or decrease linearly with the forward current applied, as can be seen in the diagram.
The temperature dependent brightness characteristic is shown in Figure 10.
If the luminous flux at a specified value is to be doubled, for example, the forward current must be increased by an additional factor.

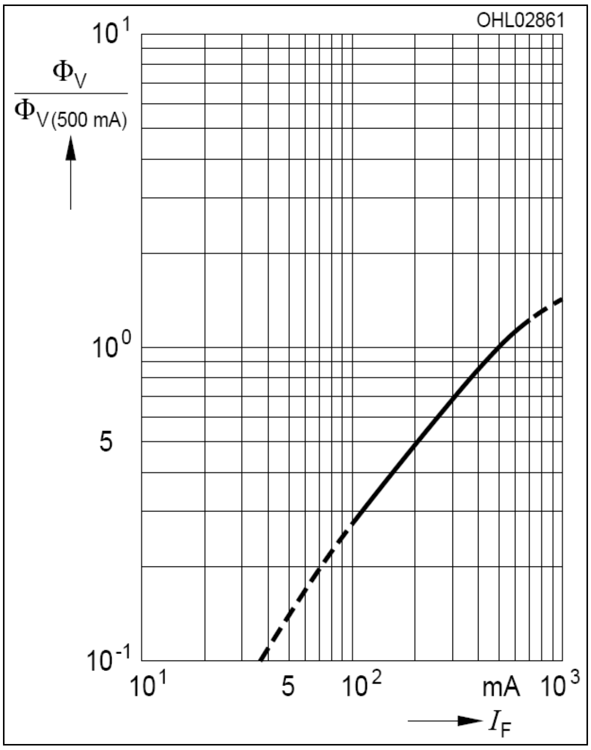


Figure 9: Relative luminous flux vs. current (e.g. CERAMOS™)

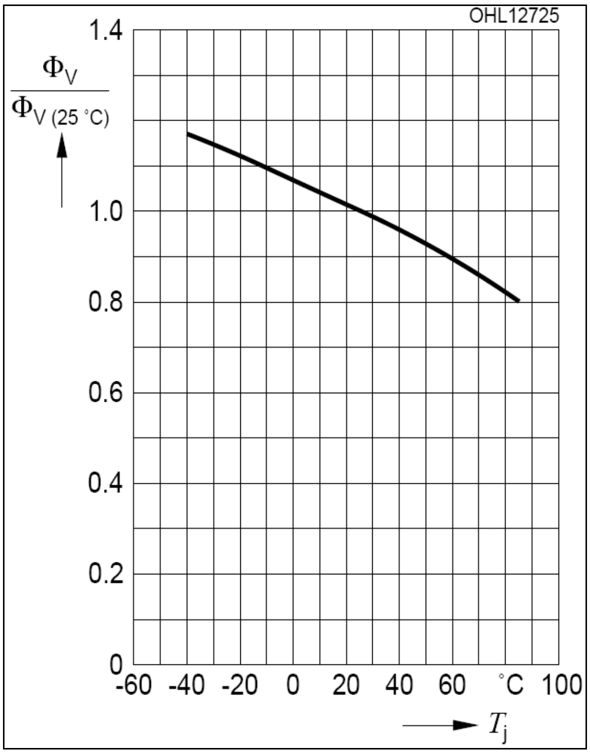


Figure 10: Relative luminous flux vs. temperature (e.g. CERAMOS™)

At higher temperatures, less light is produced by the LED. With an increase in temperature by 35°C, for example, the brightness is reduced by 10%.

Color Coordinates

For most areas of photography, the color reproduction of white LEDs (typ. 80) is sufficient. Within the professional sector, a higher color reproduction index is required.
For these applications, the use of several different single-color, or multi color LEDs, as well as white LEDs with multiband converters is recommended.
By enhancing the chromatic spectrum, the color reproduction can be significantly improved.

The forward current of standard white LEDs influences the chromaticity coordinate, however. This relation can be seen in Figure 11. With increased forward current, the chromaticity coordinate shifts further into the blue range.

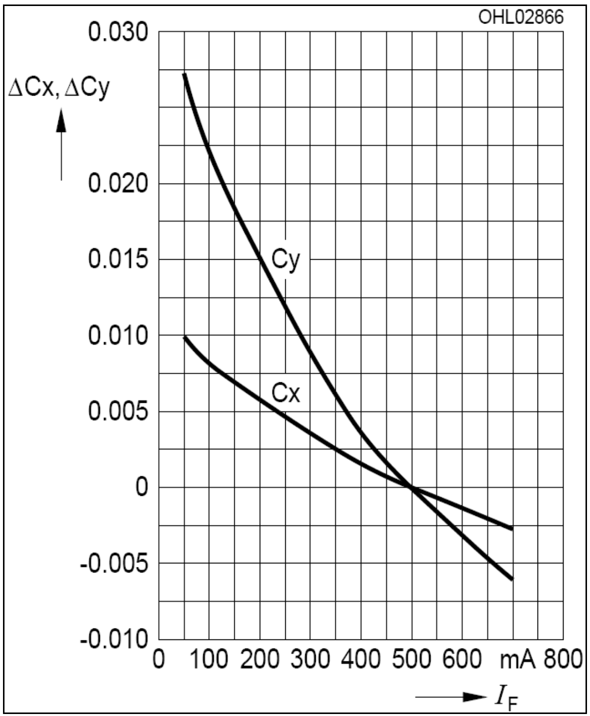


Figure 11: Chromaticity coordinate shift vs. forward current (e.g. CERAMOS™)

Conclusion/Summary

In general, the requirements for the use of an LED as a camera flash can already be fulfilled and/or exceeded by current LED technology, especially for applications in mobile phones.
Furthermore, in contrast to conventional flash tubes, LEDs exhibit significant advantages such as improved shock resistance, small dimensions, low energy requirements, and a higher lifetime. In addition, no charging time is required for the LED flash.

For best optical and electrical performance of LED flashlights, the typical properties of the semiconductor chips such as thermal behavior and effects should be taken into account.

The presented LEDs, OSLUX™ and CERAMOS™ are exceptionally suited for use as a camera flash.
Especially developed and optimized for this application, the OSLUX™ fulfills the requirements regarding brightness (50lx @ 1000mA), color homogeneity and uniform illumination and is adapted to the display format ($\Delta_{center-edge}$ 30%, $\Delta_{center-corner}$ 40%) and thus exceeds other available LEDs on the market. With the rectangular shape the illumination pattern is perfectly adapted to the field of view of the mobile phone cameras.
With its integrated lens, it exhibits the best optical performance as well as system efficiency.

Depending on the requirements of the application, the CERAMOS™ is also suitable for a use as camera flash. Due to its individual advantages, e.g. smaller space requirements, highest luminance and the possibility to generate individual illumination patterns with auxiliary optics it fulfills many requirements for a wide range of applications (e.g. mobile and video).

Table 6 shows a summary of the LED types presented along with a comparison of important parameters.

Besides their use in flash units, the LEDs are also well suited as a flash lamp for video cameras. The advantage in this case is that the flashes can be synchronized to the video frames; the flash only occurs during frame capture. Between frames, the flash is turned off. Compared to common video lamps for video cameras, this results in a lower energy usage.
The further development of LEDs will lead to higher efficiency and more light output. At the same time, the required forward current and the dimensions can be reduced.

LED Types	Illuminance at 1m	Pulse Current (max.)	Dimensions	Illumination pattern	Secondary Optics
OSLUX™ LW F65G	66lx	1.5A	5x5.1x2.6mm	Rectangular 60°/47°	Not necessary
CERAMOS™ LW CS9P	48lx* * with OSRAM OS lens	1A	2.1x1.65x0.75mm	Lambertian	Necessary

Table 6: Comparison of the two LED types introduced

Appendix

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

Links for LED Flash lamp Drivers

austriamicrosystems	www.austriamicrosystems.com
National Semiconductor	www.national.com
ON Semiconductor	www.onsemi.com
Supertex	www.supertex.com
Texas Instruments	www.ti.com

Author: Monika Rose, Andreas Stich, Alexander Wilm

About Osram Opto Semiconductors

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