

# High Power Emitters for Illumination Applications

## Application Note

### 1. Introduction

More and more applications are using invisible infrared (IR) light sources with high optical output power levels in the range of Watts. This paper focuses on the benefits using high power infrared products and their special requirements in the application.

In general high power emitters can be driven with DC currents in the range of 1 Ampere whereas most low power products like 5 mm Radials are limited to 100 mA.

As the light output increases with driving current the optical power is raised by a factor of ten compared to standard devices. At the same time much less board space is occupied as fewer devices are needed. On the other hand a careful thermal management is absolutely mandatory because the thermal power dissipation is increasing in the same way as the optical output power. To keep the junction temperature of the chip as low as possible a low thermal resistance is needed and the standard FR4-PCB has to be replaced by a metal core PCB. Like this a high optical efficiency of the IRED can be achieved.

High power emitters as infrared light sources are used in:

#### **Consumer / Industrial:**

- Closed-circuit television (CCTV)
- Biometric access control systems
- Machine vision systems
- Automatic number plate recognition (ANPR)
- Camera based distance systems
- 3D-cameras (gesture recognition, play tables)
- 3DTV (data transmission to shutter glasses)

#### **Automotive:**

- Night Vision
- Sensing systems (pre-crash)
- Driver monitoring

#### **High power emitters**



**Figure 1:** High power product overview.

In Figure 1 the OSRAM IR high power product portfolio is presented. A product selection guide with the main optical parameters is shown in Table 1 (see Chapter 4).

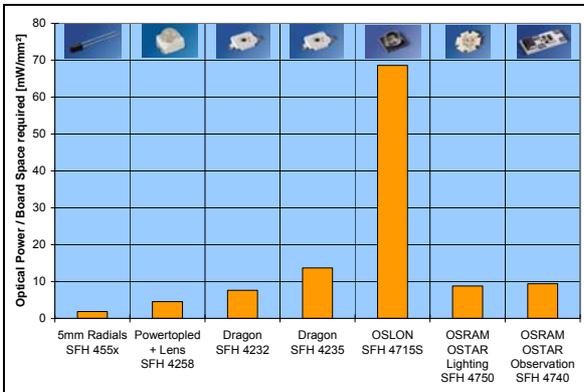
In general two common wavelengths (850 nm and 940 nm) are available. The spectral emission range matches well to the sensitivity range of standard photo diodes, photo transistors or CCD and CMOS cameras with extended IR sensitivity.

The available Diamond Dragons with integrated  $\pm 20^\circ$  silicone lens provide a narrower beam compared to the Platinum Dragons with  $\pm 60^\circ$ . The focussed beam allows an irradiation of objects at higher distances. The OSLON is in between with  $\pm 45^\circ$ .

For applications where space is very limited the 850 nm double stacked emitters (SFH 4235, SFH 4715S), where two vertically stacked pn-junctions are used in one chip, are the right choice. These devices

provide about twice the light density per current and this decreases the number of devices needed to get the same optical performance. As these devices are operated at a higher voltage with the same thermal properties, the increased power dissipation has to be considered.

Multi-chip emitter arrays as the OSRAM OSTAR Lighting (3x2 chip matrix) or OSRAM OSTAR Observation (5x2 chip matrix, see separate application note) provide the highest possible packing density for the light output as the chips are assembled as close as possible. Especially in this case an effective cooling is absolutely mandatory.



**Figure 2:** Maximum optical DC power per required board space for different products.

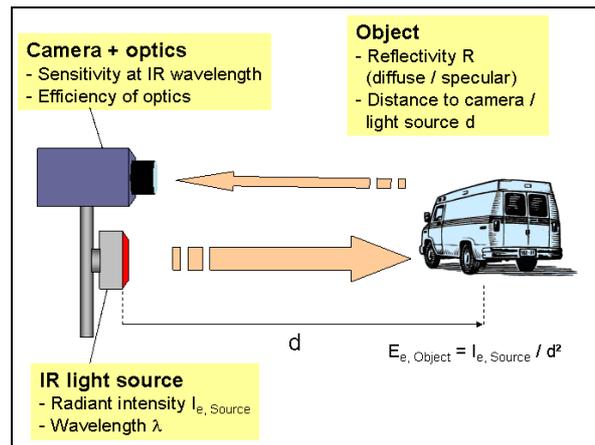
In Figure 2 a comparison of the ratios of the maximum possible optical DC power and the required space on the board is shown. The maximum outline dimensions have been used for calculation, but no thermal requirements have been taken into account. It can be seen very easily that the optical power per required board space can be drastically increased by using high power devices like OSLON, Dragons or OSRAM OSTARs instead of standard 5 mm radial products. With a package size of only 4x4 mm<sup>2</sup> and a stacked emitter chip, the IR OSLON is offering outstanding optical power per board space.

## 2. General design guidelines for camera systems with an IR light source

Even if the applications can be found in different application segments the basic concept of such illumination systems is quite similar. Reflected or scattered light from an object is detected by a CCD or CMOS camera and generates an analogue or digital signal. A high output signal and low-noise level is needed to ensure a high quality signal that can be further analyzed. Especially if observing an object under changing light conditions (day/night, outdoor application) the signal to noise ratio can drop significantly and additional artificial light is needed to improve the picture quality. For covert observation at night or if glare (e.g. of a car driver) must be avoided invisible IR light is the best choice to use.

### Note:

Although human eyes are considered as insensitive to wavelengths above 800 nm according to the CIE V(λ) curves, it has been shown that a red glow is still perceived in 850 nm IREDs at high power levels. This effect is around 50 – 100 times lower at 940 nm, therefore a higher wavelength should be chosen to minimize the red glow in certain applications.



**Figure 3:** Main parameters that affect the performance of a camera system with artificial light source.

When choosing an additional IR light source for a camera system one has to be aware of several parameters that affect the amount of light hitting the camera chip. In Figure 3 the main parameters are visualized and the question arises, which is the right emitter and how many emitters are required to get a good quality picture of the irradiated scenery.

First of all the object size, its distance to the camera and the desired picture resolution determine the optical properties of the camera system (sensor size, objective) and its field of view (FOV).

Typical distances for some applications are:

*Short Range* ~ up to 5 m

Examples: door admission, machine vision, driver monitoring

*Mid Range* ~5 ...50 m

Examples: building security, pre-crash sensors (up to 20 m), automatic number plate recognition (ANPR)

*Long Range* ~50 ...200 m

Examples: long range observation, parking place observation, spot light, automotive night vision systems

The resulting horizontal field of view  $\alpha$  (FOV) is visualized in Figure 4 and can be calculated as follows:

$$FOV = 2 * \arctan (0.5 * w / f) \quad (1)$$

with the sensor width  $w$  and the focal length  $f$ . This formula can be used to calculate the vertical FOV as well by replacing the sensor width  $w$  by the sensor height  $h$ .

The radiation characteristics of the artificial light source and the FOV of the camera system should match as good as possible. If the beam angle is too small, the object is not fully irradiated and some details can not be observed at the edges. If the radiation characteristic of the light source is too wide

the light reflected from outside the FOV can not be detected by the camera system. If OSRAM components do not show the desired radiation characteristic, an option is to use second party lenses (please see <http://www.ledlightforyou.com> for further information).

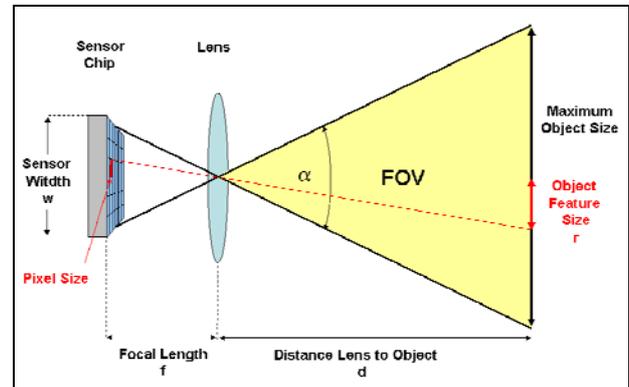


Figure 4: FOV of a camera system.

Please check that the used wavelength of the light source fits to the camera system (including optics and filters used) otherwise the performance will be negatively influenced.

When calculating the irradiance level on the camera chip generated by an IR light source several parameters have to be considered. To show the general dependencies it is assumed that the light source is located close to the camera with negligible angle between optical axis and viewing direction of the camera.

*Important parameters to be considered are:*

For the object:

- Distance  $d$  between object and light source
- Reflectivity  $R$  (assuming diffuse reflection, Lambertian reflector for calculation purposes)
- Object size

For the camera system:

- focal length  $f$

- F-Number of optics  $f/\#$  ( $f/\# = f/D$ , with  $D =$  diameter of entrance aperture)
- sensor width  $w$
- transmission of optics  $T_{optics}$
- pixel size to calculate the minimum detectable object feature size  $r$  (optional)

For the light source:

- # of IREDS + optics
- Radiant intensity  $I_e$  of the source
- Emission wavelength

*Equations needed for calculations:*

Irradiance at the object position (valid for far field):

$$E_{e, object} = I_{e, source} / d^2 \quad (2)$$

Radiance of the object (considering object is a lambertian reflector):

$$L_{object} = E_{e, object} * R / \pi \quad (3)$$

Magnification:

$$m = f / (d-f) \quad (4)$$

Irradiance at the sensor position [3]:

$$E_{e, sensor} = L_{object} * T_{optics} * \pi / (2 * f/\# * (m+1))^2 \quad (5)$$

Resolved object feature size:

$$r = \text{pixel size} / m = \text{pixel size} * (d-f)/f \quad (6)$$

#### Note:

Each camera system can be optimized by choosing the right parameter settings (e.g. frame rate, integration time, etc.). As there are many different systems available it is not the scope of this application note to handle this topic. Please check with the corresponding camera vendor.

#### Eye Safety Issues

According to the type of application (data transmission or lamp application) either the eye safety standard IEC 60825 or IEC 62471 has to be applied for risk assessment (see Application note "Eye Safety of IREDS used in Lamp Applications"). Be aware when using arrays of continuous driven high power

IREDS (especially with narrow radiation angle) it is possible that the limits of the exempt group can be exceeded.

### 3. Design example for high power emitters: Artificial light source for cameras used in CCTV systems

A common task for CCTV (closed circuit television) systems is to observe objects or people by using cameras with IR illumination.

In this example of a CCTV application it is considered to recognize a person in darkness in 7.5 m distance. An artificial IR light source ( $\lambda = 850$  nm) shall be used to provide a high signal to noise ratio (SNR) at the camera system.

#### Note:

The necessary  $E_e$  value to obtain a certain SNR depends on the spectral sensitivity/quantum efficiency curve of the CCD/CMOS chip and the integration time. Please ask the camera manufacturer for detailed information. An example curve is shown in the appendix.

The available camera contains a 1/3" type sensor with a corresponding sensor width of 4.8 mm and a height of 3.6 mm. The pixel size is  $7 \times 7 \mu\text{m}^2$  and a fixed focal length lens of 12 mm ( $f/\# = 1.2$ ,  $T_{optics} = 15\%$ ) is used. The reflectivity of the object shall be 40% and the required  $E_e$  at the camera chip is  $0.25 \mu\text{W}/\text{cm}^2$  (value is assumed for calculation purpose). With this data it needs to be calculated how many and what kind of IREDS have to be used.

The calculation is carried out in several steps. First the type of IRED is chosen that fits to the observed scenery and the camera system, second the number of IREDS is roughly calculated to have a starting point for the thermal design and in a 3rd step this number is fine tuned taking thermal aspects into account. Finally the system is completed by choosing a suitable power supply and doing prototyping.

**Step 1:** Choose an emitter with a radiation characteristic that fits to the scenery and the field of view (FOV) of the camera system.

The field of view calculation of the camera system can be done by using equation (1) and the given camera parameters:

The result is  $\pm 11.3^\circ$  in horizontal direction and  $\pm 8.5^\circ$  in vertical direction. This corresponds to a horizontal maximum object size of 3 m and a maximum vertical object size of 2.25 m in a distance of 7.5 m. As intended a person can be mapped in full height using this setup.

Looking in the 850 nm IRED portfolio one can see that the radiation characteristics of the devices do not match the FOV requirements. The one which comes close is the SFH 4236, but this has a radiation characteristic of  $\pm 20^\circ$ . Much of the light would not hit the camera chip FOV and would be lost.

Therefore another possibility is to use a second party lens in order to modify the radiation characteristics of a standard Platinum Dragon or an OSRAM OSTAR (see <http://www.ledlightforyou.com> as well).

A suitable lens for the Platinum Dragon SFH 4232 to meet the  $\pm 10^\circ$  FOV requirement is for example the Lisa-SS lens from LEDIL which will be used in this example.

Test measurements show that the radiant intensity of SFH 4232 is increased by a factor of 7.6 to 1400 mW/sr at 1 A. Without lens we only get 180 mW/sr.

**Step 2:** Calculate the number of IREDs

We need to irradiate the sensor with an irradiance of  $0.25 \mu\text{W}/\text{cm}^2$  in order to obtain a good quality picture.

Using equations (2), (3), (4) and (5) and the given parameters of a single SFH 4232 + lens results at the sensor in an irradiance of  $0.0253 \mu\text{W}/\text{cm}^2$ . Therefore we need minimum 10 devices ( $10 \times 0.0253 \mu\text{W}/\text{cm}^2 = 0.253 \mu\text{W}/\text{cm}^2$ ) to achieve the target value, assuming ideal overlap of the radiation characteristics in the centre.

**Note:**

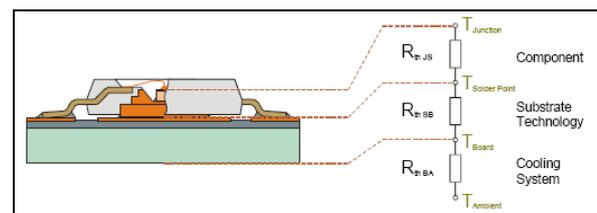
At the half angle  $\pm \varphi$  of a given radiation characteristic the radiant intensity drops to 50% of the peak value and leads to an inhomogeneous irradiation of an extended object.

**Step 3:** Thermal design of the light source

When driving the Platinum Dragon at high DC currents (in this case 1 A) the junction temperature will increase and this causes a reduction of the optical power (see temperature coefficient in datasheet: TCI =  $-0.3\%/K$ ). To keep this decrease as low as possible an efficient cooling of the system is mandatory. In any case there will be light power loss and this has to be considered in the design of the light source and consequently the number of IREDs has to be increased.

In this example the thermal optical power loss shall not exceed 15% and this increases the number of Dragons + lenses to 12. If further losses have to be taken into account (e.g. due to losses at the housing) the number has to be adapted again.

A 15% light decrease corresponds to a junction temperature  $T_j$  increase of 50 K (using again the TCI =  $-0.3\%/K$  for calculation) and this has to be assured by a proper thermal design.



**Figure 5:** Thermal resistances series configuration.

The total thermal resistance of the system (see Figure 5) can be described by a serial connection of the thermal resistances from junction to solder point  $R_{th,JS}$ , the thermal resistance from solder point to board  $R_{th,SB}$  and the thermal resistance of the heat sink from the board to the ambient  $R_{th,BA}$  (cooling

system). If N components are used in the system that are thermally independent from each other, this can be described by a parallel connection of the N  $R_{th JB}$  connected in series to the  $R_{th BA}$  of the heat sink:

$$R_{th total} = 1/N * (R_{th JS} + R_{th SB}) + R_{th BA} \quad (7)$$

For more details please see application note "Thermal Management of Golden DRAGON LED".

The temperature increase from junction to ambient can be calculated by using the thermal power  $P_{thermal}$

$$\Delta T_{JA} = R_{th total} * P_{thermal}. \quad (8)$$

As worst case estimation the calculation can be done with the maximum values of  $V_F = 1.8 V$  and  $R_{th JS} = 9 K/W$  (from datasheet) and assuming no light output. This leads to a dissipated power  $P_{diss} = P_{thermal} = 12 * 1.8 V * 1 A = 21.6 W$ .

A typical  $R_{th SB}$  for a good metal core PCB is 3.4 K/W.

Using equations (7) and (8) one gets

$$R_{th BA} = \Delta T_{JA} / P_{thermal} - 1/N * (R_{th JS} + R_{th SB}) \quad (9)$$

which gives a thermal resistance for the heat sink of 1.29 K/W.

In case the optical power is included in the calculation ( $P_{opt} = 0.53 W$ ,  $P_{thermal} = P_{diss} - P_{opt}$ ) a heat sink with  $R_{th BA} = 2 K/W$  would be sufficient.

**Note:**

This calculation is a rough estimation to dimension the needed heat sink only. More accurate are commercial available thermal analysis programmes (e.g. FloTHERM®) especially if the design is more complex.

In Figure 6 a possible design is shown. It is using 12 SFH 4232 + Lisa SS Lens mounted on a metal core PCB and a standard heat

sink (e.g. from Fischer Elektronik, SK 508 75 mm,  $R_{th} = 2 K/W$ ).

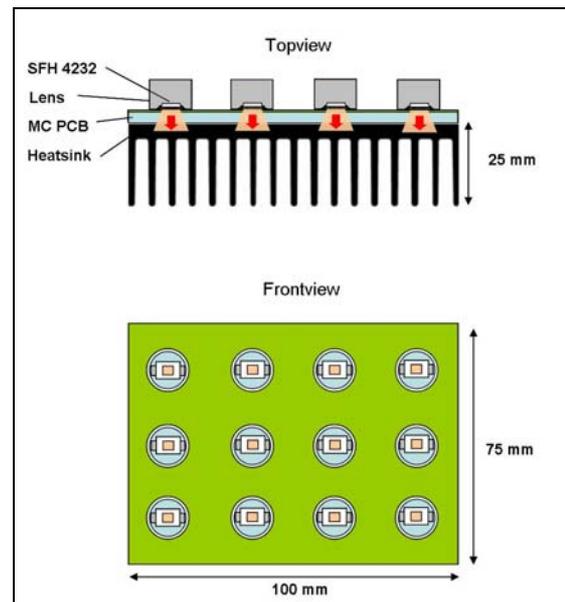


Figure 6: Design example.

**Note:**

As an alternative device the Platinum Dragon SFH 4235 (with a double Nanostack) can be used. Doing the same calculation (using the maximum  $V_F = 3.4 V @ 1A$ , optical power output included), this results in 7 devices needed to get the same optical performance as before (but assuming 20% light loss here). In this case  $R_{th BA}$  needs to be improved to 1.8 K/W. With 8 SFH 4235 and 30% light loss an  $R_{th BA}$  of 3 K/W would be needed.

**Step 4:** Select a suitable power supply and circuit design.

The power supply has to provide a minimum power of 21.6 W at a maximum current of 1 A.

For circuit design (series or matrix circuit) see Appnote: "Comparison of LED Circuits"

**Step 5:** Verify design by test measurements

- Check FOV: Is target homogenous irradiated? Dark areas at the edges?
- Check SNR of camera system with defined reflectors

## 4. Product Selection Guide

Table 1 presents a short product selection guide which highlights products and product families of OSRAM that are suitable for IR illumination applications.

Please note that this guide provides just a general overview. For more detailed information and the latest products and updates please visit [www.osram-os.com](http://www.osram-os.com).

## 5. Literature

[1] OSRAM-OS: <http://www.osram-os.com>

[2] LFFY-Network: <http://www.ledlightforyou.com>

[3] Dalsa Application Notes, Practical Radiometry

[http://www.couriertronics.com/docs/notes/lighting\\_application\\_notes/Practical\\_Radiometry.pdf](http://www.couriertronics.com/docs/notes/lighting_application_notes/Practical_Radiometry.pdf)

[4] www link:

[http://www.cctv-information.co.uk/i/Infra\\_Red\\_Illumination#Camera\\_sensitivity](http://www.cctv-information.co.uk/i/Infra_Red_Illumination#Camera_sensitivity)

[5] Photonfocus AG, Application Note AN008 12/2004 V1.1 "Photometry versus Radiometry"

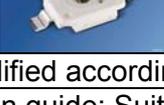
[http://www.photonfocus.com/upload/application\\_notes/AN008\\_e\\_V1\\_1\\_PhotometryVersusRadiometry.pdf](http://www.photonfocus.com/upload/application_notes/AN008_e_V1_1_PhotometryVersusRadiometry.pdf)

Product Selection Guide				
Short Range ~up to 5m				
Part Number	Photograph	Wavelength	Package	Typ. Radiant Intensity, $I_e /$ Half-Angle, $\varphi$
SFH 4740 <sup>*)</sup>		850 nm	OSRAM OSTAR <sup>®</sup> Observation	1400 mW/sr (1 A) ± 60°
SFH 4750		850 nm	OSRAM OSTAR <sup>®</sup> Lighting	1000 mW/sr (1 A) ± 70°
SFH 4751		940 nm	OSRAM OSTAR <sup>®</sup> Lighting	900 mW/sr (1 A) ± 70°
SFH 4236 <sup>*)</sup>		850 nm	DRAGON LED	630 mW/sr (1 A) ± 20°
SFH 4239 <sup>*)</sup>		940 nm	DRAGON LED	550 mW/sr (1 A) ± 20°
SFH 4715S <sup>*)</sup>		850 nm	OSLON LED	500 mW/sr (1 A) ± 45°
SFH 4232 <sup>*)</sup>		850 nm	DRAGON LED	180 mW/sr (1 A) ± 60°
SFH 4235 <sup>*)</sup>		850 nm	DRAGON LED	320 mW/sr (1 A) ± 60°

SFH 4233 <sup>*)</sup>		940 nm	DRAGON LED	170 mW/sr (1 A) ± 60°
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### Mid Range ~5...50m

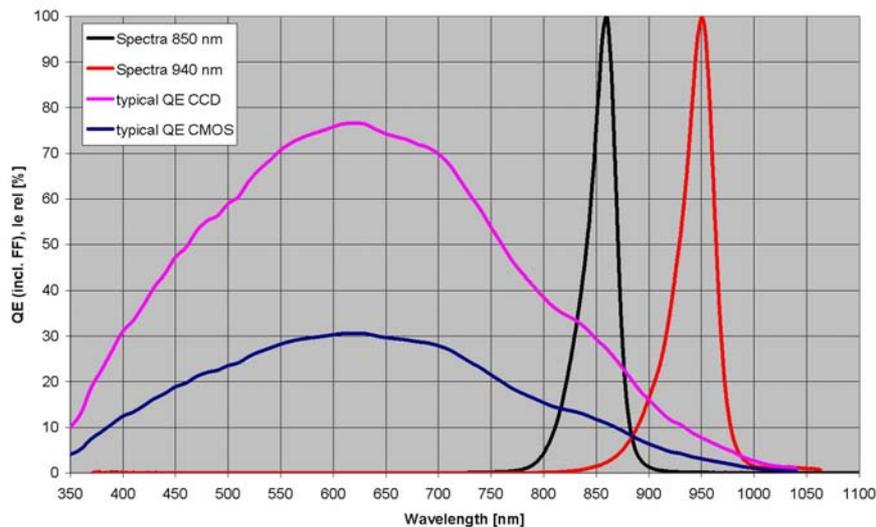
Part Number	Photograph	Wavelength	Package	Typ. Radiant Intensity, $I_e$ / Half-Angle, $\varphi$
SFH 4740 <sup>*)</sup> + ext. lens		850 nm	OSRAM OSTAR® Observation	Depending on ext. lens
SFH 4750 + ext. lens		850 nm	OSRAM OSTAR® Lighting	Depending on ext. lens
SFH 4751 + ext. lens		940 nm	OSRAM OSTAR® Lighting	Depending on ext. lens
SFH 4236 <sup>*)</sup>		850 nm	DRAGON LED	630 mW/sr (1 A) ± 20°
SFH 4239 <sup>*)</sup>		940 nm	DRAGON LED	550 mW/sr (1 A) ± 20°
SFH 4715S <sup>*)</sup> + ext. lens		850 nm	OSLON LED	Depending on ext. lens
SFH 4232 <sup>*)</sup> + ext. lens		850 nm	DRAGON LED	Depending on ext. lens
SFH 4235 <sup>*)</sup> + ext. lens		850 nm	DRAGON LED	Depending on ext. lens
SFH 4233 <sup>*)</sup> + ext. lens		940 nm	DRAGON LED	Depending on ext. lens

<b>Long Range ~50m...200m</b>				
<b>Part Number</b>	<b>Photograph</b>	<b>Wavelength</b>	<b>Package</b>	<b>Typ. Radiant Intensity, <math>I_e</math>/ Half-Angle, <math>\varphi</math></b>
SFH 4740 <sup>*)</sup> + narrow angle ext. lens		850 nm	OSRAM OSTAR® Observation	Depending on ext. lens
SFH 4750 + narrow angle ext. lens		850 nm	OSRAM OSTAR® Lighting	Depending on ext. lens
SFH 4751 + narrow angle ext. lens		940 nm	OSRAM OSTAR® Lighting	Depending on ext. lens
SFH 4715S <sup>*)</sup> + narrow angle ext. lens		850 nm	OSLON LED	Depending on ext. lens
SFH 4232 <sup>*)</sup> + narrow angle ext. lens		850 nm	DRAGON LED	Depending on ext. lens
SFH 4235 <sup>*)</sup> + narrow angle ext. lens		850 nm	DRAGON LED	Depending on ext. lens
SFH 4233 <sup>*)</sup> + narrow angle ext. lens		940 nm	DRAGON LED	Depending on ext. lens

<sup>\*)</sup> automotive qualified according to AEC-Q101

**Table 1:** Selection guide: Suitable OSRAM emitters for illumination applications.

## Appendix



**Figure A1:** Typical quantum efficiency curves for CCD and CMOS cameras and typical emission spectra of 850 and 940nm emitters.



**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](http://www.ledlightforyou.com)

Author: Dr. Claus Jäger

#### **ABOUT OSRAM OPTO SEMICONDUCTORS**

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