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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 might need to be replaced by a metal core PCB. In doing so a high optical efficiency of the IRED can be achieved.

High power emitters as infrared light sources are used in:

Automotive
- Pre-crash sensors
- Seat occupancy detection
- Night Vision
- Driver Monitoring

Industrial
- Cameras (CCTV)
- Machine vision
- Traffic surveillance

Consumer
- Touch screens
- Gesture sensing
- Eyetracking
- Biometrics (Face recognition, Hand Vein Recognition, Iris scan)

And wherever a high power IR light source is required

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 three common wavelengths (810 nm, 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.

Different beam angles are available within the portfolio. The Power TOPLED SFH 4258 and SFH 4258S with integrated ±15° lens provide a narrower beam compared to the standard Power TOPLED SFH 4250S with

±60°. The focussed beam allows a higher irradiation of objects at higher distances.
Other angles of ±45° / ±75° are available with the OSLON Black SFH 4715A / SFH 4716A.

For applications where space is very limited the 850 nm double stacked emitter SFH 4715AS, where two vertically stacked pn-junctions are used in one chip, is the right choice. This device provides about twice the light density per current and decreases the number of devices needed to get the same optical performance. As this device is operated at a higher voltage with the same thermal properties, the increased power dissipation has to be considered.

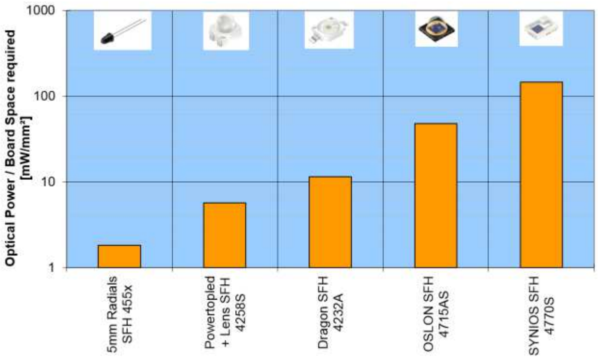


Figure 2: Maximum optical DC power per required board space for different products.

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 SYNIOS or OSLON Black instead of standard 5 mm radial products.
With a package size of only 2x2.75 mm² and a stacked emitter chip, the SYNIOS 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 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.

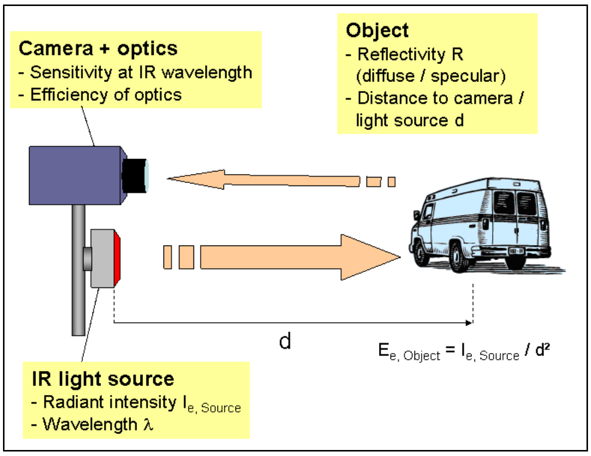


Figure 3: Main parameters that affect the performance of a camera system with artificial light source.

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 10 m
Examples: door admission, machine vision, driver monitoring

Mid Range ~10 …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 horizontal field of view α (FOV) is shown in Figure 4 and can be calculated as follows:

*FOV = 2 * arctan (0.5 * w / f)* (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 cannot be observed at the edges. If the radiation characteristic of the light source is too wide the light reflected from outside the FOV cannot 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 secondary optics suppliers).

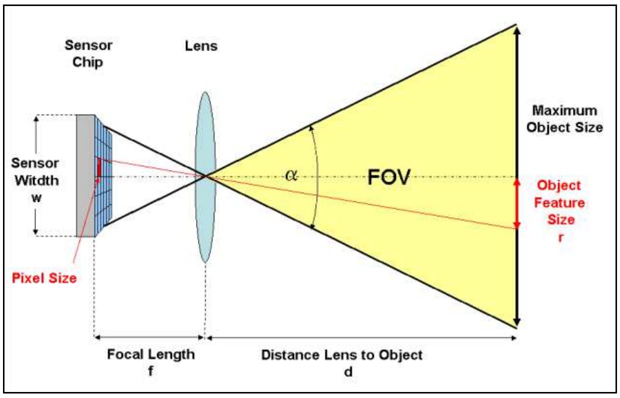


Figure 4: FOV of a camera system.

Please check that the used wavelength of the light source fits to the camera system (including optics and filters) 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, with Lambertian characteristics)
- 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 Ie 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:

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

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 a person needs to be recognized in darkness and at a 7.5 m distance. An artificial IR light source (λ = 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 its 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 7x7 µm² and a fixed focal length lens of 12 mm (f/# = 1.2, T_{optics} = 15%) is used. The reflectivity R of the object shall be 40% and the required E_e at the camera chip is 0.25 µW/cm² (value is assumed for calculation purpose). With this data we can determine how many IRED of a certain kind 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. 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.

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 camera field of view can be calculated with equation (1) and the given camera parameters:
The result is ±11.3° in horizontal and ±8.5° 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 at the 850 nm IRED portfolio one can see that the one which comes close is the SFH 4783.

If you want to use another IRED that has not the exact radiation characteristic of ±10°. 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 to modify the radiation characteristics of an LED like the Golden DRAGON (see http://www.ledlightforyou.com as well).

A suitable lens for the Golden DRAGON SFH 4232A to achieve a ±10° 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 4232A is increased by a factor of 7.6 to 1558 mW/sr at 1 A. Without lens we only get 205 mW/sr.

Step 2: Calculate the number of IREDs

We need to irradiate the sensor with an irradiance of 0.25 µW/cm² in order to obtain a good quality picture.
Using equations (2), (3), (4) and (5) and the given parameters of a single SFH 4232A with lens results in a sensor irradiance of 0.0288 µW/cm². Therefore we need minimum 9 devices (9 x 0.0288 µW/cm² = 0.259 µW/cm²) 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 Golden DRAGON at high DC currents (in this case 1 A) the junction temperature will increase and this causes a reduction in 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 losses 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 DRAGON + lenses to 11. 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 Tj increase of 50 K (using again the TCI = -0.3%/K for calculation) and this has to be assured by a proper thermal design.

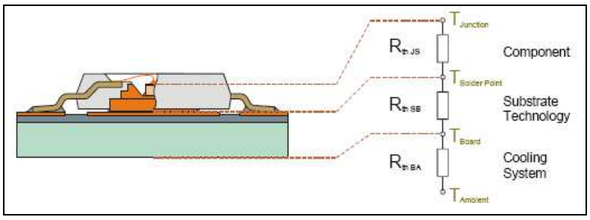


Figure 5: Thermal resistances series configuration.

The total thermal resistance of the system (see Figure 5) can be described by a serial connection of the thermal resistances from LED junction to the solder point $R_{th\,JS}$, the thermal resistance from the solder point to the board $R_{th\,SB}$ and the thermal resistance of the heat sink from the board to the ambient air $R_{th\ BA}$ (cooling system). If N, thermally independent components are used the system 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 the estimation can be done with the maximum values of V_F = 2.1 V and R_{thJS} = 10 K/W (from the datasheet) and assuming no light output. This leads to a dissipated power P_{diss} = $P_{thermal}$ = 11 * 2.1 V * 1 A = 23.1 W.

A typical R_{thSB} 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 0.95 K/W.

In case the optical power is included in the calculation (P_{opt} = 0.65 W, $P_{thermal}$ = P_{diss} - P_{opt}) a heat sink with R_{thBA} = 1.9 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 especially if the design is more complex.

In Figure 6 a possible design is shown. It is using 11 SFH 4232 A + 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).

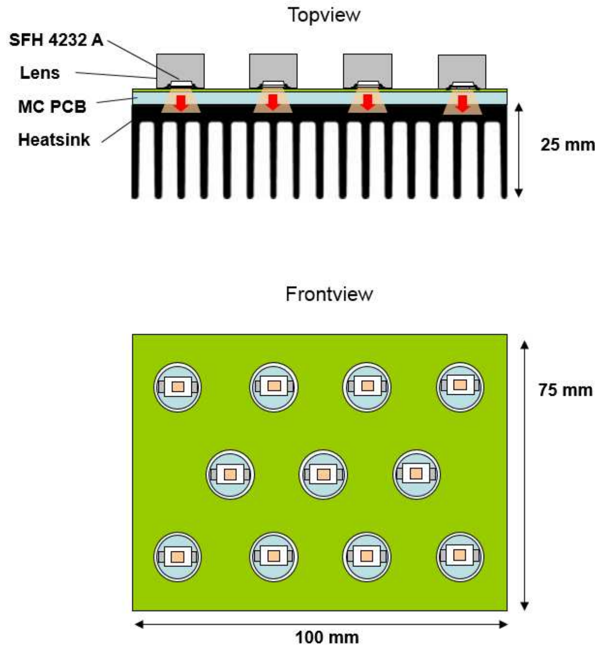


Figure 6: Design example.

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 a 20% light loss here). In this case R_{thBA} needs to be improved to 1.8 K/W. With 8 SFH 4235 and a 30% light loss an R_{thBA} of 3 K/W is needed.

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

The power supply has to provide a minimum power of 23.1 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

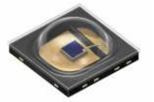
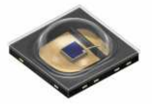
Table 1 presents a short product selection guide which highlights products and product families of OSRAM that are suitable for IR illumination applications.

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.

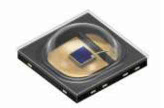
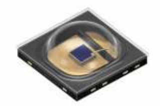
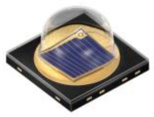
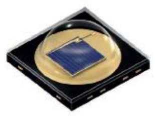
Product Selection Guide

Short Range ~up to 10m

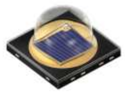
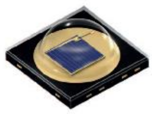
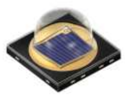
Part Number	Photograph	Wavelength	Package	Typ. Radiant Intensity, I_e / Half-Angle, φ
SFH 4250*		850 nm	Power Top LED	20 mW/sr (100 mA) ± 60°
SFH 4250S*		850 nm	Power Top LED	30 mW/sr (100 mA) ± 60°
SFH 4258*		850 nm	Power Top LED	110 mW/sr (100 mA) ± 15°
SFH 4258S		850 nm	Power Top LED	185 mW/sr (100 mA) ± 15°
SFH 4259*		850 nm	Power Top LED	55 mW/sr (100 mA) ± 25°
SFH 4259S		850 nm	Power Top LED	85 mW/sr (100 mA) ± 25°
SFH 4240*		940 nm	Power Top LED	18 mW/sr (100 mA) ± 60°
SFH 4248*		940 nm	Power Top LED	100 mW/sr (100 mA) ± 15°
SFH 4249*		940 nm	Power Top LED	50 mW/sr (100 mA) ± 25°

SFH 4711A		850 nm	OSLON Black	145 mW/sr (500 mA) ± 45°
SFH 4714A		850 nm	OSLON Black	140 mW/sr (1 A) ± 75°
SFH 4780S		810 nm	OSLUX	2900 mW/sr (1 A) ± 10°
SFH 4783		850 nm	DRAGON Dome	2300 mW/sr (1 A) ± 12°

Mid Range ~10…50m (with secondary optics)

Part Number	Photograph	Wavelength	Package	Typ. Radiant Intensity, I_e / Half-Angle, φ
SFH 4713A		850 nm	OSLON Black	Depending on ext. lens
SFH 4714A		850 nm	OSLON Black	Depending on ext. lens
SFH 4715A		850 nm	OSLON Black	Depending on ext. lens
SFH 4716A		850 nm	OSLON Black	Depending on ext. lens
SFH 4232A		850 nm	Golden DRAGON	Depending on ext. lens
SFH 4770S		850 nm	SYNIOS	Depending on ext. lens
SFH 4783		850 nm	DRAGON Dome	2300 mW/sr (1 A) ± 12°

Long Range ~50m…200m (with secondary optics)

Part Number	Photograph	Wavelength	Package	Typ. Radiant Intensity, I_e / Half-Angle, φ
SFH 4715AS*		850 nm	OSLON Black	Depending on ext. lens
SFH 4716AS*		850 nm	OSLON Black	Depending on ext. lens
SFH 4770S		850 nm	SYNIOS	Depending on ext. lens
SFH 4725AS*		940 nm	OSLON Black	Depending on ext. lens

*) automotive qualified according to AEC-Q101 Rev.C

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

5. Literature

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

[2] LLFY-Network: http://www.ledlightforyou.com

[3] Dalsa Application Notes, Practical Radiometry
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

[5] Photonfocus AG, Application Note AN008 12/2004 V1.1 “Photometry versus Radiometry”
http://cdn.metricmarketing.ca/www.machinevision.ca/files/Applications/AN008_e_V1_1_PhotometryVersusRadiometry.pdf?this=that

Appendix

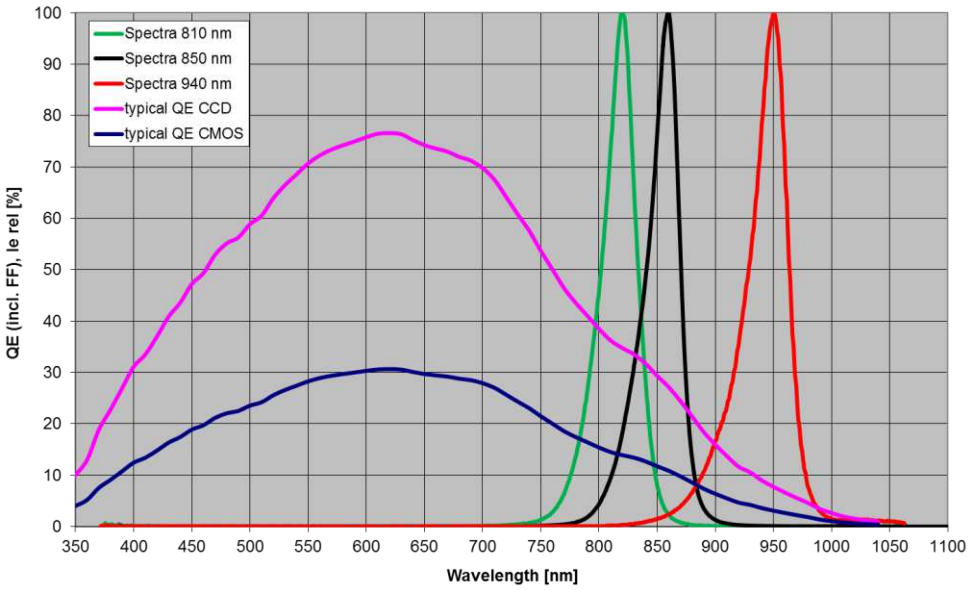


Figure A1: Typical quantum efficiency curves for CCD and CMOS cameras and typical emission spectra of 810, 850 and 940nm emitters.

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

Date	Revision History
09.2011	Release application note
02.2016	Updated portfolio and recalculated examples

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