OSRAM
Opto Semiconductors

High-power emitters for illumination applications

Application Note

Valid for:
OSLON® Black (SFH 47XX)
OSLUX® (SFH 47XX)
SYNIOS® P2720 (SFH 477X)
Power TOPLED® (SFH 42XX)

Abstract

More and more applications are using invisible infrared (IR) light sources with high optical output power levels in the range of Watts.

This application note focuses on the benefits using high power infrared products and their special requirements in the application.

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A. High-power emitters

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.

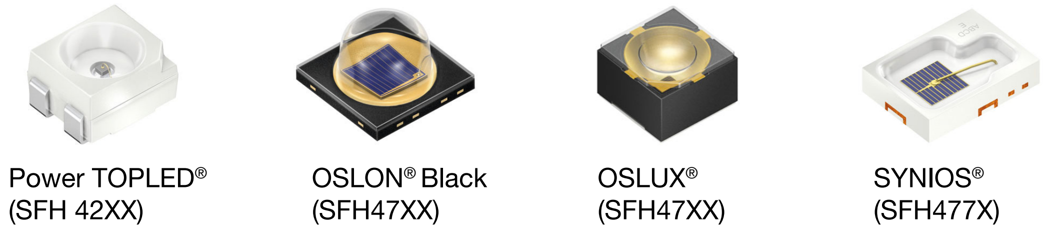
As the light output increases with driving current the optical power is raised by a factor of ten compared to standard devices. At the same time much less board space is occupied as fewer devices are needed. On the other hand a careful thermal management is absolutely mandatory because the thermal power 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. By this a high optical efficiency of the IRED can be achieved.

High power emitters such as infrared light sources are e.g. used in consumer / industrial applications, such as closed-circuit television (CCTV), machine vision systems, traffic surveillance, biometric access control systems, touch screens, gesture sensing ore eye tracking or in automotive applications, such as night vision, pre-crash sensors, seat occupancy detection or driver monitoring.

Product portfolio

In Figure 1 the IR high-power product families from OSRAM Opto Semiconductors are presented. For detailed information please refer to the OSRAM Opto Semiconductors IR high-power product portfolio on the homepage.

Figure 1: High-power product overview



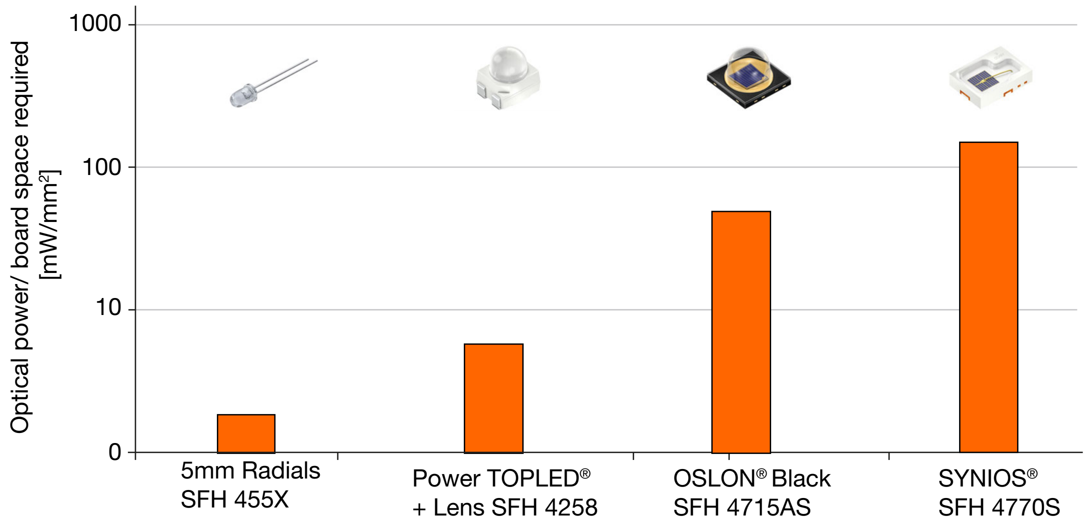
In general, three common wavelengths (810 nm, 850 nm and 940 nm) are available. The spectral emission range matches well to the sensitivity range of standard photo diodes, photo transistors or CCD and CMOS cameras with extended IR sensitivity.

Different beam angles are available within the portfolio. For further information please visit the respective product page on the OSRAM Opto Semiconductors website.

For applications where space is very limited the double stacked emitter versions of the IR OSLON® Black or SYNIOS® family, 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.

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 such as the OSLON® Black or SYNIOS® instead of standard 5 mm radial products. With a package size of only 2 x 2.75 mm² and a stacked emitter chip, the SYNIOS® is offering outstanding optical power per board space.

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

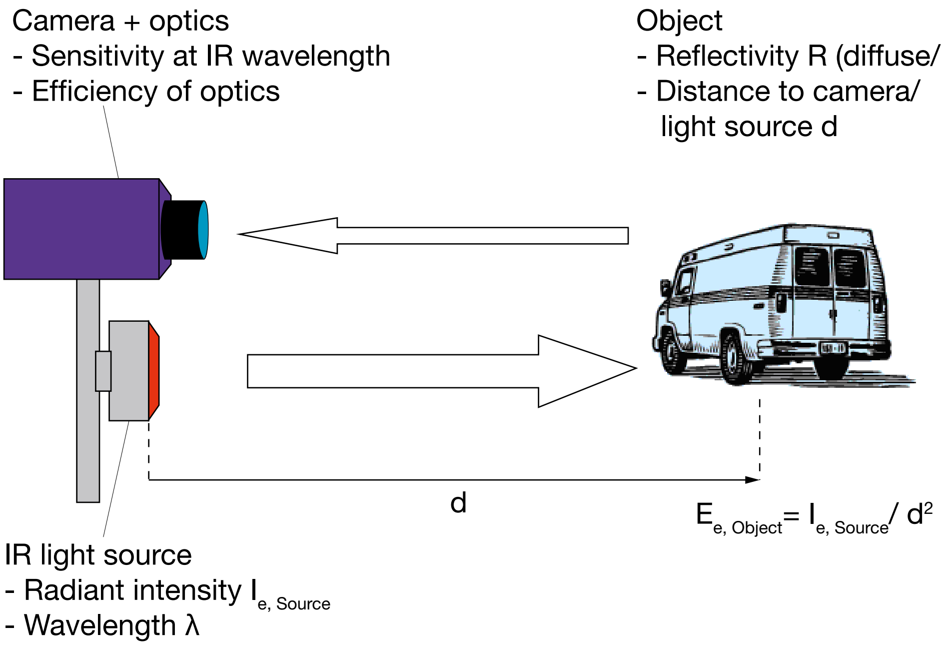


B. General design guidelines for camera systems with an IR light source

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 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

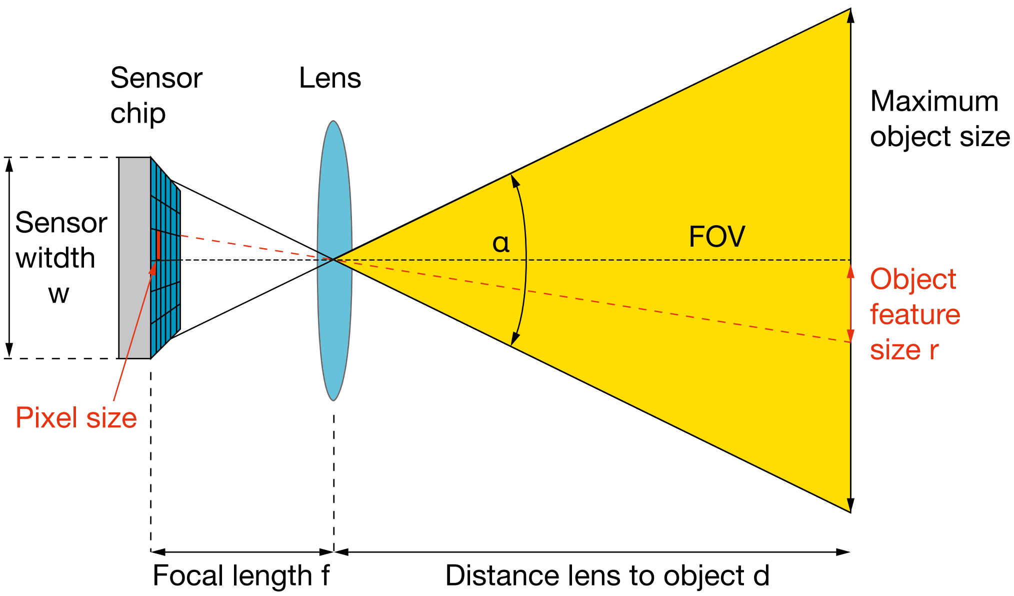
Figure 4 shows the horizontal field of view α (FOV) which can be calculated as follows:

$$FOV = 2 \cdot arc\tan\left(0.5 \cdot \frac{w}{f}\right) \qquad (1)$$

, 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 Opto Semiconductors 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 make sure that the used wavelength of the light source fits 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 a 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:

- Number 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):

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

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

$$L_{object} = E_{e,\,object} \cdot \frac{R}{\pi} \qquad (3)$$

Magnification:

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

Irradiance at the sensor position [3]:

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

Resolved object feature size:

$$r = \text{pixelsize}/m = \text{pixelsize} \cdot (d-f)/f \qquad (6)$$

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 may be exceeded.

C. 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 horizontal camera FOV of ± 40° needs to be realized at 20 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 the integration time. Please contact 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 5.07 mm and a height of 3.38 mm. The pixel size is 2.2 x 2.2 µm² and a fixed focal length lens of 2.8 mm (f/# = 1.2, T_{optics} = 15 %) is used. With this data the right amount and kind of IREDs for the system can be calculated.

The calculation is carried out in several steps. Firstly, the type of IRED is chosen regarding to the observed scenery and the camera system. Secondly, the number of IREDs is roughly calculated to have a starting point for the thermal design. This number is then fine-tuned in the next step, taking the thermal aspects into account. The design is then finalized by choosing a suitable power supply and building a prototype.

Step 1: Choose an emitter.

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 ± 42° in horizontal direction and ± 31° in vertical direction. This corresponds to a horizontal maximum object size of 36 m and a maximum vertical object size of 24 m in a distance of 20 m. Looking in the 850 nm IRED portfolio one can see that the one which comes close is the SFH 4715AS with its FWHM of ± 45°.

Step 2: Calculate the number of IREDs.

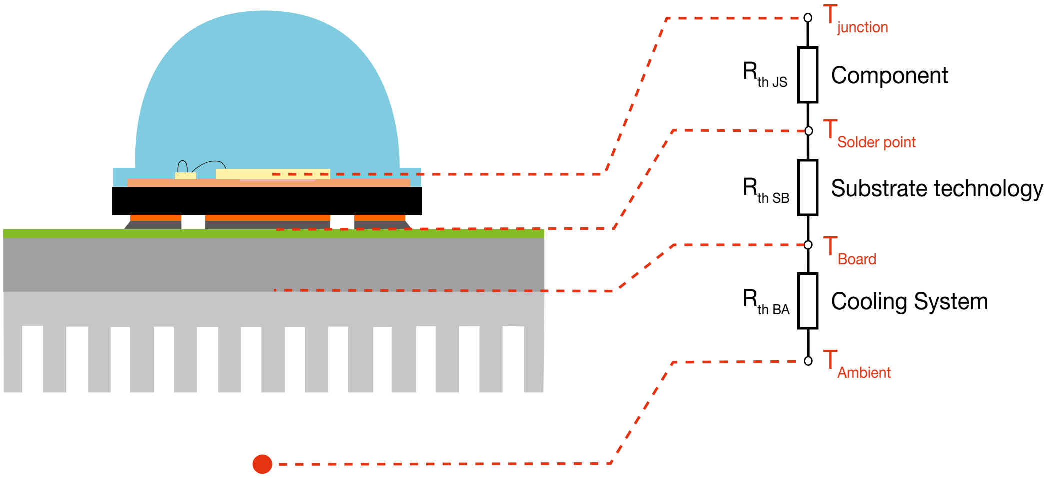
We need to irradiate the sensor with an irradiance of 0.25 μW/cm² in order to obtain a good quality picture. Using equations (2), (3), (4) and (5) and the given parameters of a single SFH 4715AS (at 1.5 A) results in a sensor irradiance of 0.073 μW/cm². Therefore we need minimum 4 (3.4) devices (4 x 0.073 μW/cm² = 0.292 μW/cm²) to achieve the target value, assuming ideal overlap of the radiation characteristics in the center.

Note: At the half angle ± φ 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 OSLON® Black at high DC currents (in this case 1.5 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 % in order to still work with 4 SFH 4715AS. 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 T_{CI} = - 0.3 %/K for calculation) and this has to be assured by a proper thermal design.

Figure 5: Thermal resistance 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, 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:

$$R_{th\ total} = \frac{1}{N} \cdot (R_{th\ JS} + R_{th\ SB}) + R_{th\ BA} \qquad (7)$$

For more details please see application note "Thermal management of light sources based on SMT LEDs".

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

$$\Delta T_{JA} = R_{th\ total}\ x\ P_{thermal} \qquad (8)$$

As an estimation the calculation can be done with the typical values of V_F = 3.35 V (1.5 A) and $R_{th\ JS}$ = 6 K/W (real, typ) (from the data sheet). This leads to a dissipated power P_{diss} = $P_{thermal}$ = 4 * 3.35 V * 1.5 A * (1-0.40) = 12 W (optical power included).

A typical $R_{th\ SB}$ for a good metal core PCB is 6.0 K/W.

Using equations (7) and (8) on gets:

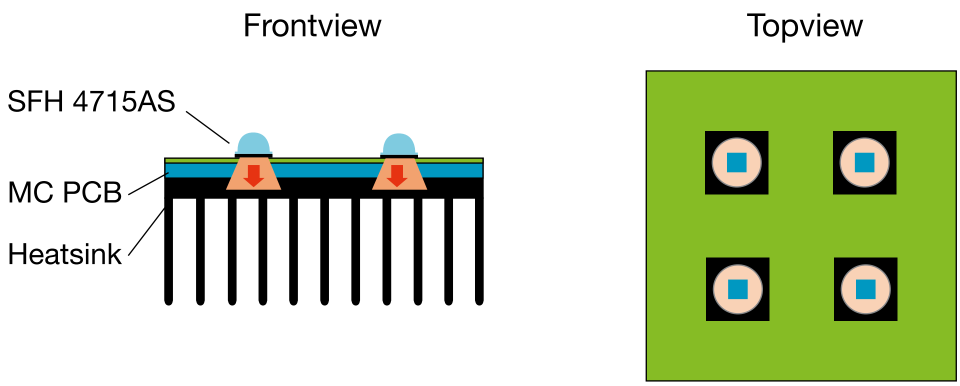
$$R_{th\ BA} = \frac{\Delta T_{JA}}{P_{thermal}} - \frac{1}{N} \cdot (R_{th\ JS} + R_{th\ SB}) \qquad (9)$$

, which gives a thermal resistance for the heat sink of 1.16 K/W.

Note: This calculation is a rough estimation to dimension the needed heat sink only. More accurate are commercial available thermal analysis programs especially if the design is more complex.

In Figure 6 a possible design is shown. It is using 4 SFH 4715AS mounted on a metal core PCB and a standard heat sink (e.g. from Fischer Elektronik).

Figure 6: Design example



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

The power supply has to provide a minimum power of 4 * 3.35 V * 1.5 A = 20.1 W at a maximum current of 1.5 A.

For circuit design (series or matrix circuit) see application note "Comparison of LED circuits".

Step 5: Verify design by test measurements. •

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

D. Product selection guide

For detailed information and the latest products and uodates on the IR high-power product families (OSLON® Black, OSLUX®, SYNIOS® P2720 and Power TOPLED® please visit the OSRAM Opto Semiconductors IR high-power product portfolio on the OSRAM Opto Semiconductors homepage.

Please contact your local sales office to get technical assistance during the selection of the product and the design-in phase.

E. References

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

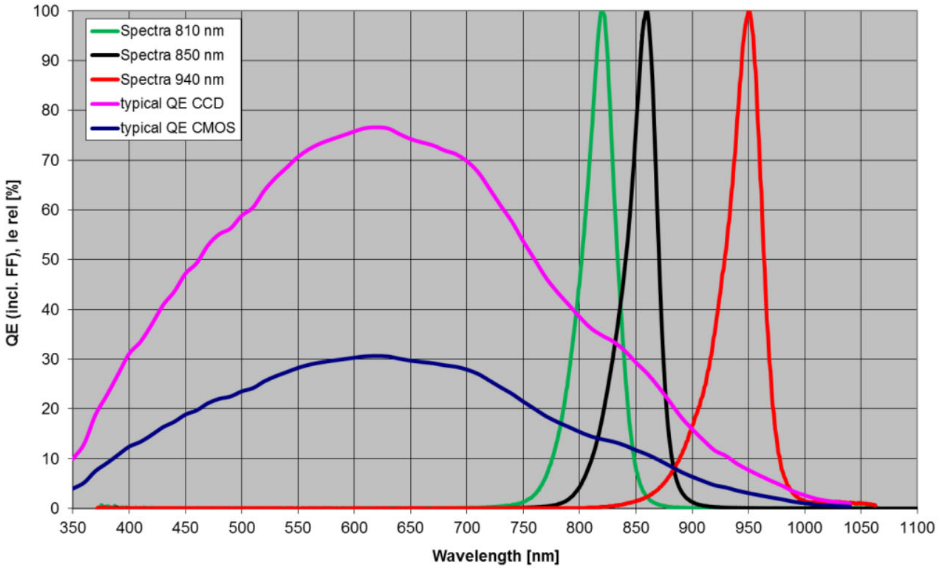
[2] LLFY-Network: http://www.ledlightforyou.com

[3] Dalsa Application Notes, Practical Radiometry http://www.couriertronics.com/docs/notes/lighting_application_notes/Practical_Radiometry.pdf

[4] CCT information, The CCT Advisory Service: http://www.cctv-information.co.uk/i/Infra_Red_Illumination#Camera_sensitivity

F. Appendix

Figure 7: Typical quantum efficiency curves for CCD and CMOS cameras and typical emission spectra of 810, 850 and 940 nm emitters



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www.ledlightforyou.com

ABOUT OSRAM OPTO SEMICONDUCTORS

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