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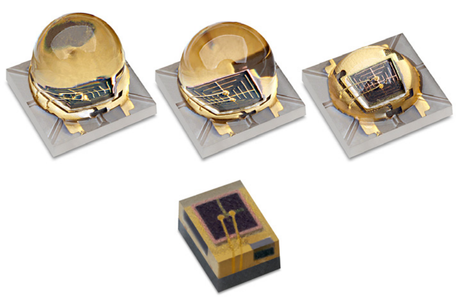
INFRARED

LUXEON IR Family for Facial Recognition

Assembly and Handling Guidelines



Introduction

Biometric identification techniques for the consumer market space have been evolved lately as a security feature. Examples include payment methods and unlocking of smart electronic devices like mobile phones, laptops and tablets, which generally store private and sensitive data.

There are many biometric identification methods like Facial Recognition (FR), iris scanning and fingerprints that are becoming very popular for consumer applications. This application brief covers aspects of facial recognition biometric identification application. It describes the basic application procedure, requirements, advantages and challenges for the application.

The most important aspect for the success of facial recognition is good visibility of the face and the repeatability of the image quality taken in different ambient light scenarios. An infrared (IR) illuminator is critical for the uniform illumination of the face to produce better signal to noise ratio (SNR), which actually translates into an improved user experience. The LUXEON IR Family is a good example of light sources, which are ideal for facial recognition applications that require high efficiency, stable spectral widths with reduced thermal impact, fast switching cycles and low thermal resistance.

Abbreviations used in the document (in order of appearance):

- FR — Facial Recognition
- IR — Infrared
- SNR — Signal to Noise Ratio
- NIR — Near Infrared
- LED — Light Emitting Diode
- FOV — Field of View
- FR module — Facial Recognition module, including IR illuminator & camera
- FWHM — Full Width Half Maximum
- QE — Quantum Efficiency
- LCD — Liquid Crystal Display

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1. Facial Recognition Biometric Identification Application

Most consumer electronic devices (e.g. mobile phones, tablets, computers and personal computers) have pins or passwords to secure private information. Biometric identification techniques make the security layer easier, faster and more secure than the conventional pin or password security. Facial recognition (FR) is one of the key biometric identification techniques available for the consumer market. The main aspect of facial recognition is to determine facial features, for example, determining the size and shape relative to the position of the eyes, nose, cheekbones and jaw. These features and landmarks can be used to check from a library of face images or feature data.

Figure 1. Schematic of facial recognition using a mobile phone.

There are two main types of recognition algorithms:

1. **Geometric:** checks for distinguishing features of the face.
2. **Photometric:** statistical approach that distils an image into values and compares the values with templates to eliminate variances.

2. Hardware for Facial Recognition

For application space of mobile phone and personal computer (unlocking of the device), it is generally assumed that face position will be reasonably aligned in the frame and head tilt will be within acceptable limits. There are many important factors for accurate facial recognition systems, for example, image noise, ambient illumination impact, head position, misalignment and eye glasses.

Better signal to noise ratio and repeatability within different illumination (ambient) conditions are very important. Near Infrared (NIR) imagery gives better results for image capture for facial recognition. Near Infrared imagery is independent of different skin colors and has low visual reflex for eyes, so the user will not get annoyed by the extra illumination or flash for the image capture. Illumination using IR is also helpful to prevent spoofing by showing a picture of the person, instead of a real person, to the camera, because a picture doesn't display in IR due to different wavelengths (colors) present. Similarly, pictures on an LCD display are also not displayed in the IR illumination in the camera capture.

Figure 2 below shows the schematic of the facial recognition system and hardware. A facial recognition NIR imagery system generally consists of:

- Infrared illuminator, including IR light emitting diode (LED) and possible optics for beam shaping
- Camera module with camera sensor, camera optics and spectral band pass filter
- Software for capturing face image, analyzing data and recognizing facial features for facial recognition

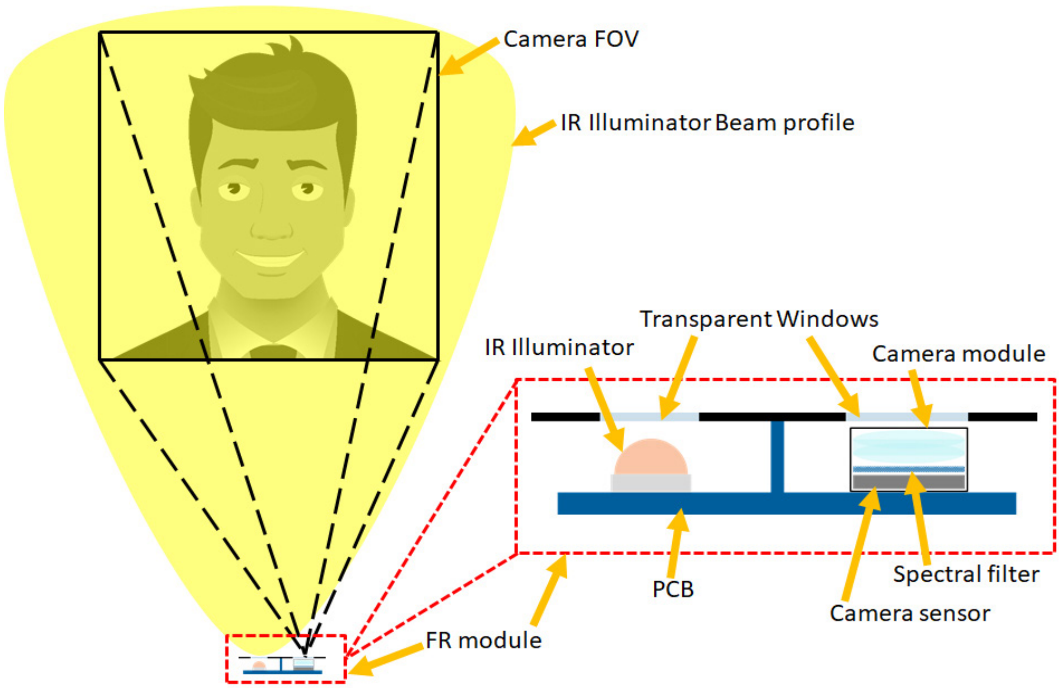


Figure 2. Schematic of the facial recognition module and hardware.

A narrow spectral width of the IR illuminator helps to use narrow band pass filter for the camera, which improves the signal to noise ratio (SNR) for even the brightest ambient environments. Wavelengths of 850nm and 940nm have become industry standard for NIR imagery for facial recognition systems due to negligible eye reflex and the trade-off between the desired 'low red glow' and 'good sensitivity of commercially available Si based camera sensors.' As the wavelength increases, the red glow of an IR emitter decreases, but at the same time sensitivity of a Si based camera sensor decreases.

3. System Considerations

3.1 Field of View (FOV)

For a better face image for recognition, the full face should be illuminated with uniform irradiance levels. Field of view is the area of interest that covers the face for recognition, and 'average application distance' is the average distance from the face to the FR module (includes camera and IR illuminator).

Table 1. Typical distances and field of view for various facial recognition applications.

APPLICATION	AVERAGE DISTANCE	FOV
Mobile Phones	30cm–50cm	45° x 45°
Laptops	50cm–80cm	40° x 40°
Desktops/Webcams	50cm–100cm	40° x 40°

The IR illuminator should provide good uniformity within this FOV so that all features of the face can be captured with minimum possible noise and errors. The FOV of laptops and desktops should be chosen with consideration that a person generally sits at larger distance (compared to a mobile phone) from the device and within a larger space. Also, the face may not be exactly aligned on axis with the FR module.

As the distance (face to FR module) increases:

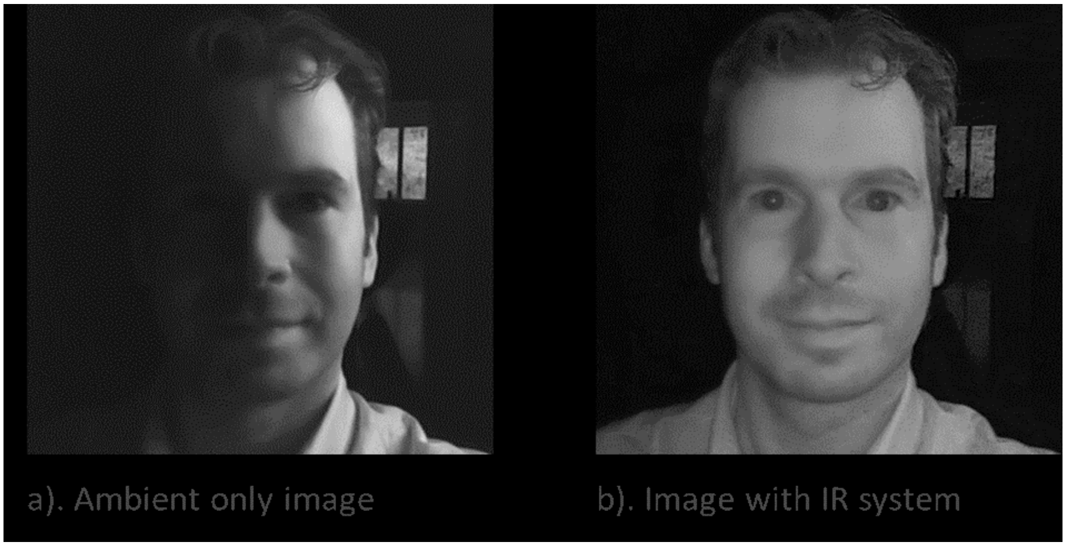
- The absolute irradiance levels decreases
- Effective uniformity on face remains same or increases

3.2 Picture Quality

A 'good quality picture' is required to recognize the face by distinguishing facial features clearly. To capture all the facial features clearly, several factors are important:

- In order to recognize the face, the facial recognition algorithm needs to be able to distinguish between facial features (e.g. nose, eyes, etc.) and noise. For this to be possible, a high signal to noise ratio (SNR) is required. High SNR can be achieved by illuminating the camera sensor as much as possible, avoiding overexposure of the camera sensor.
- Because a face can be imaged anywhere in the FOV of the camera, it is important to have a good SNR throughout the camera FOV. Ideally, the radiant intensity in the corner of the FOV needs to be at least as high as the center of the FOV. Usually, corners of the FOV are imaged with lower efficiency compared to the center, for example, by camera vignetting and illumination projection on a plane. It is, therefore, good practice to illuminate the corners of the FOV more intensely than the center of the FOV.
- In addition to have a uniform SNR of the camera images, a uniform illumination of the sensor is important for feature recognition in the face recognition algorithm. Sharp illumination features like rings, dark/bright patches and sharp drop-off of the illumination, may be confused with features on the face by the algorithm. This could lead to a false recognition.
- A poor illumination setup can also cause shadows on the face, for example if the illuminator is spaced at some distance from the camera, the nose may have a shadow. It is therefore preferred to have the illuminator close to the camera. Alternatively, two illuminators could be used, symmetrically placed on either side of the camera.

The ambient illumination condition can impact reproducibility of the facial features. Figure 3a below shows an example of the impact of ambient light on the picture captured; a shadow effect, due to the ambient light, is clearly visible. Figure 3b shows the advantage of NIR illumination, which removes the shadow from the ambient lighting. This increases reproducibility of face pictures in different ambient lighting conditions.



Figures 3a and 3b. Example of the advantage NIR illumination.
3a. Camera image without ambient light suppression showing non-uniformly lit face.
3b. Camera image with ambient light suppression showing mostly IR light from IR illuminator.

3.3 Choosing Wavelength and Spectral Filter for Camera

Infrared LEDs usually have spectrum with typical spectrum full width half maximum (FWHM) of around 35nm to 50nm, which Figure 4 below illustrates.

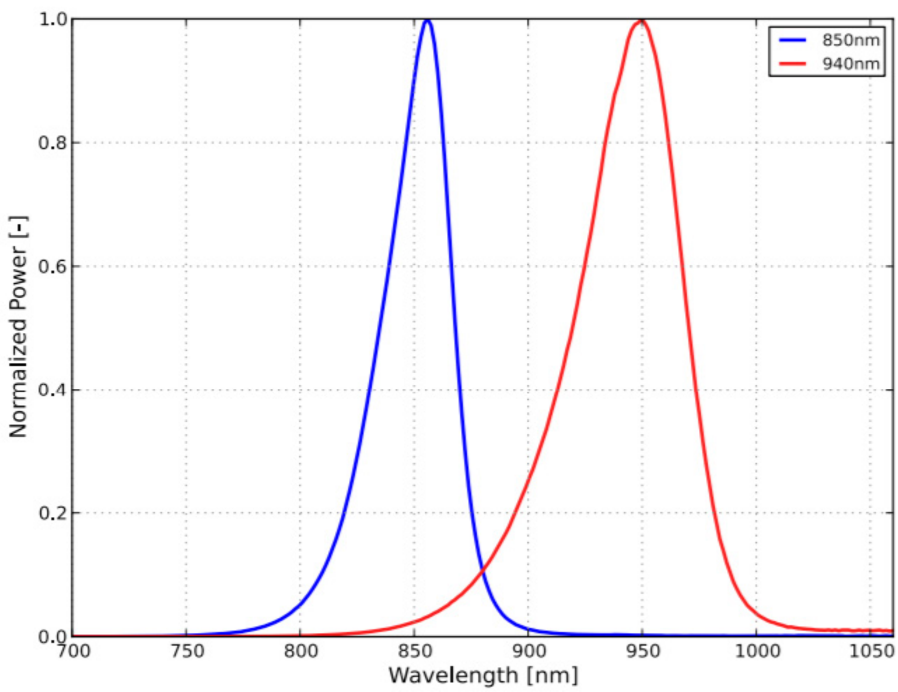
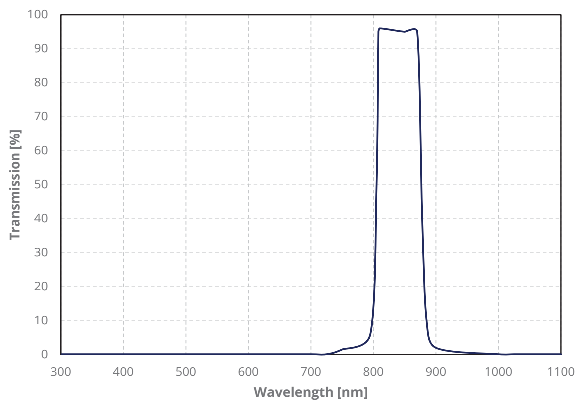


Figure 4. Spectral Power Distribution (SPD) of the LUXEON IR products.

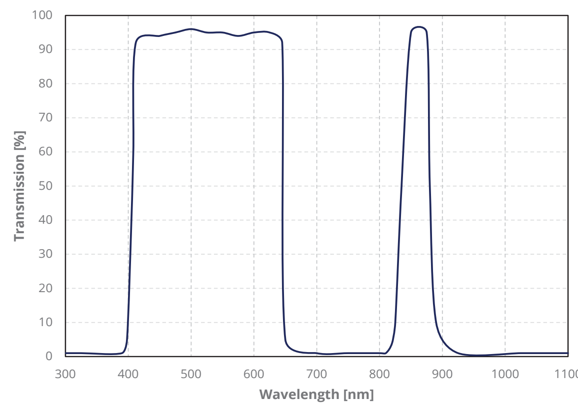
Having narrow spectral width is an advantage, because after combining with a narrow band pass filter with the camera, most of the ambient light can be cut off from the picture, which leads to better reproducibility of good quality images and, therefore, a better user experience.

LUXEON IR emitters are quite useful for resolving the issue of the ambient light impact on image quality. There are two ways of resolving this problem:

1. Using a separate IR camera that has a narrow pass filter around the peak wavelength of the illuminator
2. Using a normal (visible spectrum) front facing camera on the phone with a dual band pass filter, which allows it to pass the visible spectrum, as well as a narrow spectral band around the wavelength of the IR illuminator (e.g. 850nm)



a). Band pass filter (850nm)



b). Dual Band pass filter visible +850nm

Figures 5a and 5b. Transmission characteristics of spectral filter for cameras.
5a. Infrared camera only single band pass filter.
5b. Visible light camera dual band pass filter (transparent for IR and visible around 850nm).

In order to reduce the ambient light impact, two images are captured, one with 'IR illuminator ON + ambient' (Image 1), the second with 'ambient only' (Image 2). Image 2 is then subtracted from image 1 to retrieve the 'Signal' as illustrated in Figure 6 (below).

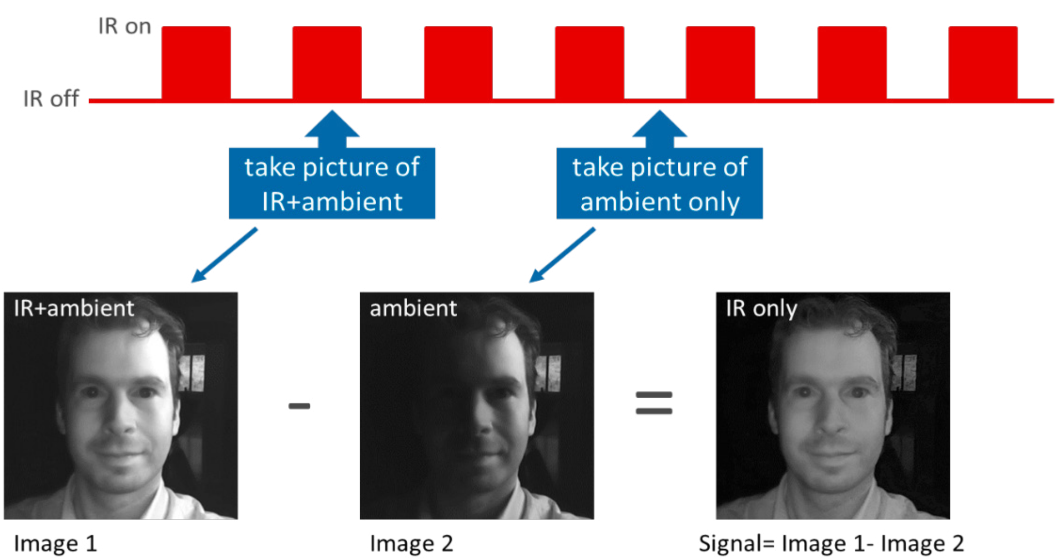


Figure 6. Example of reducing the ambient light impact.

This technique also works outdoors in normal sunlit conditions, but for really bright sunlit conditions. Although, it may still be difficult to retrieve the signal. To improve the image quality (signal), the spectrum of the illuminator should be quite narrow, along with the narrow band pass filter, to cut away ambient light as much as possible.

As the peak wavelength and width of the spectrum of the LED changes with the temperature, the spectral performance of the LED at application conditions should be taken into account when selecting the filter. There are two important aspects:

- The choice of position of the band pass filter depends on the peak wavelength position of the LED at operating conditions
- The width of the filter should be chosen to maximize the direct IR to ambient light ratio falling on the sensor, including camera sensitivity in all operating conditions. This depends on the ambient spectra, IR spectra and the band width of the band pass filter (see Figure 7)

Spectral behavior of the LUXEON IR emitters at different operating conditions is described in the LUXEON IR Family datasheets.

Figure 7 below is an example of choosing the width of the band pass filter for an application where ambient light is solar light. The position and width of the band pass filter is selected such that the ratio of IR to ambient light is at maximum. The band pass filter may block IR illuminator spectrum to where the ambient spectrum also has high proportion, which improves the overall IR to ambient ratio.

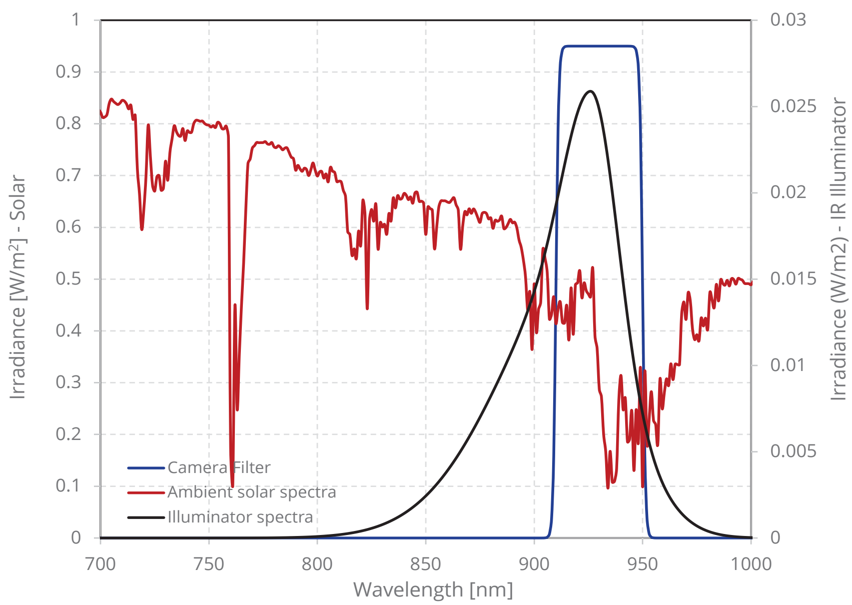


Figure 7. Example of a camera band filter matching illuminator spectrum and ambient solar spectrum.

3.4 Camera Sensitivity

Quantum Efficiency (QE) of a digital camera related to “incident photon to converted electron ratio” means how sensitive the camera sensor is in sensing incident light. The QE of the existing mobile camera sensors decreases as the wavelength of the IR light increases. Lower QE means the camera is less sensitive to the light falling on it.

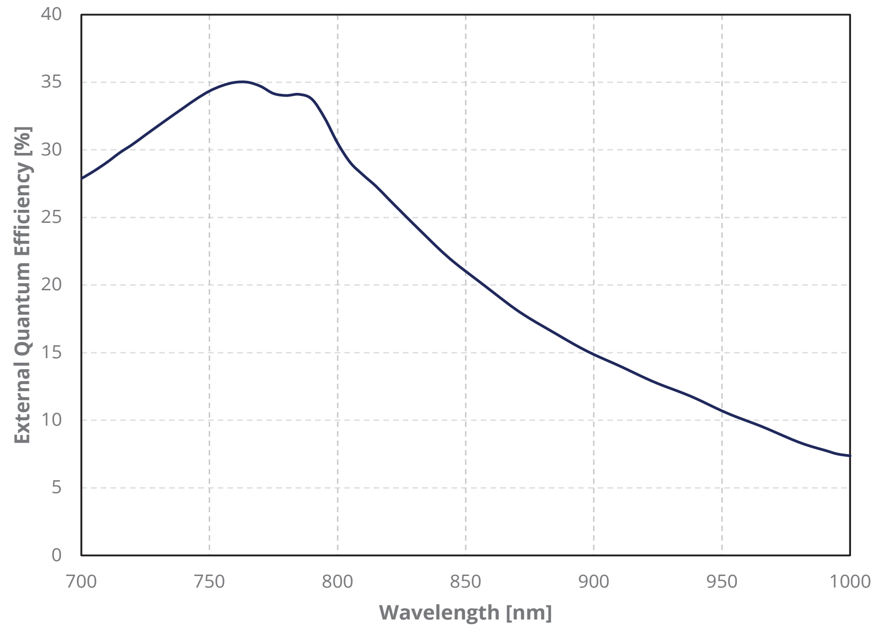


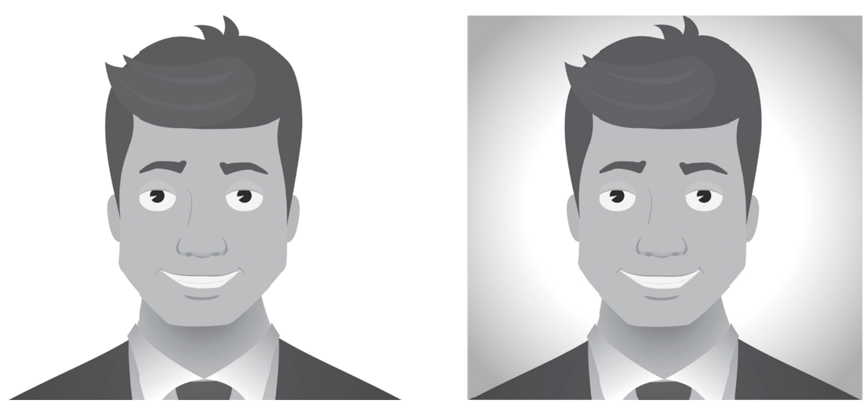
Figure 8. Example of a spectral sensitivity curve for a Si based camera sensor.

3.5 Vignetting

Vignetting is the reduction of an image's brightness toward the periphery compared to the image center. This can be due to:

- **Mechanical vignetting:** light path obstructed by mechanical parts of the system
- **Optical vignetting:** light path obstructed or shaded by stacked optical elements and affecting off-axis incident light
- **Natural vignetting:** always present and is related to the illumination falloff due to the effective projection of the incoming light on the off-axis points. The falloff is approximated by Cosine fourth law of illumination falloff
- **Pixel vignetting:** it is due to the angle–dependence of the digital sensors

Vignetting causes a picture's corners to be less bright and can potentially reduce the quality of the image. This makes corner irradiance an important parameter for picture quality. If corner irradiance is much lower than center irradiance level, then adding up the effect of vignetting leads to really dark corners in the captured image and poor picture quality. Increasing corner irradiance improves the picture quality (SNR). Figure 9 below illustrates both scenarios.



a). Image without vignetting b). Image with vignetting effect

Figure 9. Schematic of vignetting effect.

4. Illuminator Aspects

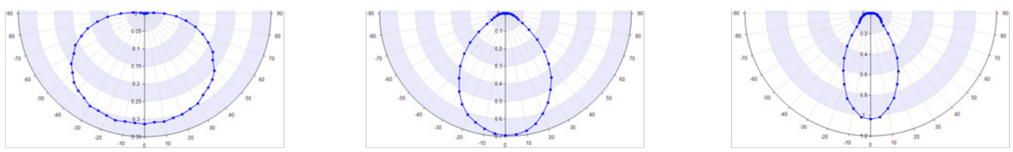
4.1 Optics and Beam Angle

A basic LED generally has a very wide beam profile, which generally provides very high uniformity on the scene but very low irradiance levels, because a lot of light resides outside of the target. Due to the field of view for the facial recognition application not being very wide, reshaping the original LED beam can improve the effective levels (irradiance) map on the target (within the FOV):

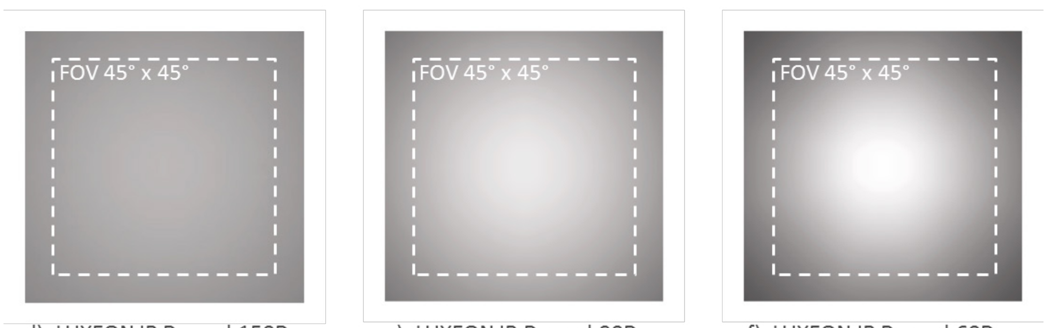
- Center or maximum irradiance level (W/cm2)
- Corner irradiance level (W/cm2)
- Uniform irradiance on target plane

The reshaping of the beam can be done by using primary or secondary optics with the LED. Primary optics refers to the optics integrated within the LED package, for example, the special shape of the dome of the LED. Figure 10 below shows the examples of the projected radiation patterns using primary optics.

Figure 10 below also shows the intensity plots (normalized by LED flux) of the, a) LUXEON IR Domed 150Deg, b) LUXEON IR Domed 90Deg, c) LUXEON IR Domed 60Deg; d), e) and f) are irradiance on the target (45° x 45° FOV) by a), b) and c), respectively.



a). LUXEON IR Domed 150Deg   b). LUXEON IR Domed 90Deg   c). LUXEON IR Domed 60Deg

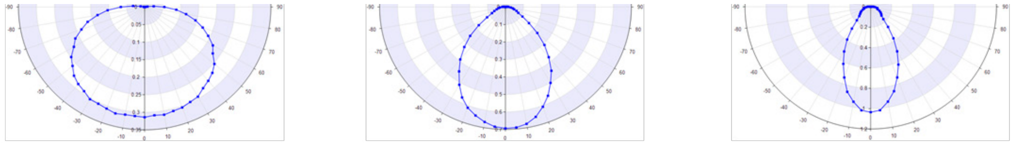


d). LUXEON IR Domed 150Deg   e). LUXEON IR Domed 90Deg   f). LUXEON IR Domed 60Deg

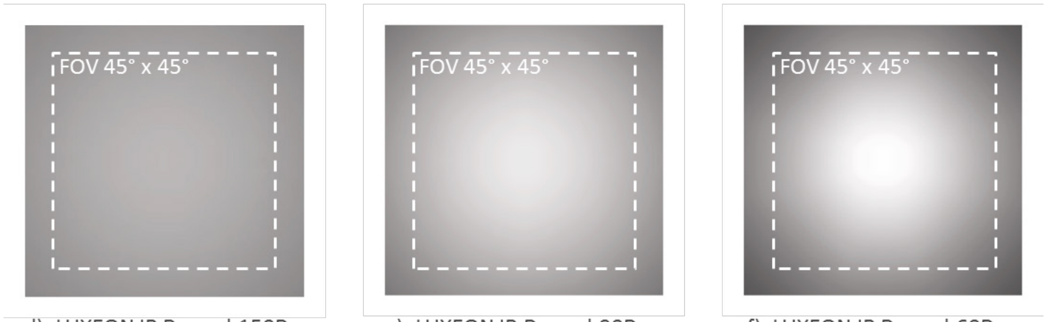
Figure 10. Radiation profiles and their performance on target (window height = 3mm).

Secondary optics are optics that are used as an additional component with the LED to better match application requirements. In Figure 11 below, b) and c) are using secondary optics and are optimized for different application conditions.

Figure 11 below also shows the intensity plots (normalized by LED flux) of, a) LUXEON IR Compact, b) LUXEON IR Compact + Optics1, c) LUXEON IR Compact + Optics2; d), e) and f) are irradiance on the target (45° x 45° FOV) by a), b) and c), respectively.



a). LUXEON IR Domed 150Deg b). LUXEON IR Domed 90Deg c). LUXEON IR Domed 60Deg



d). LUXEON IR Domed 150Deg e). LUXEON IR Domed 90Deg f). LUXEON IR Domed 60Deg

Figure 11. Radiation profiles and their performance on target (window height = 2mm).

4.2 Height of the IR Illuminator and Window Size Effect

For facial recognition modules, the height of the IR illuminator is mostly restricted by the available space, which restricts what kind of optical solution can be used in the system. Figure 12 below shows two examples of height restriction, 2mm and 3mm.

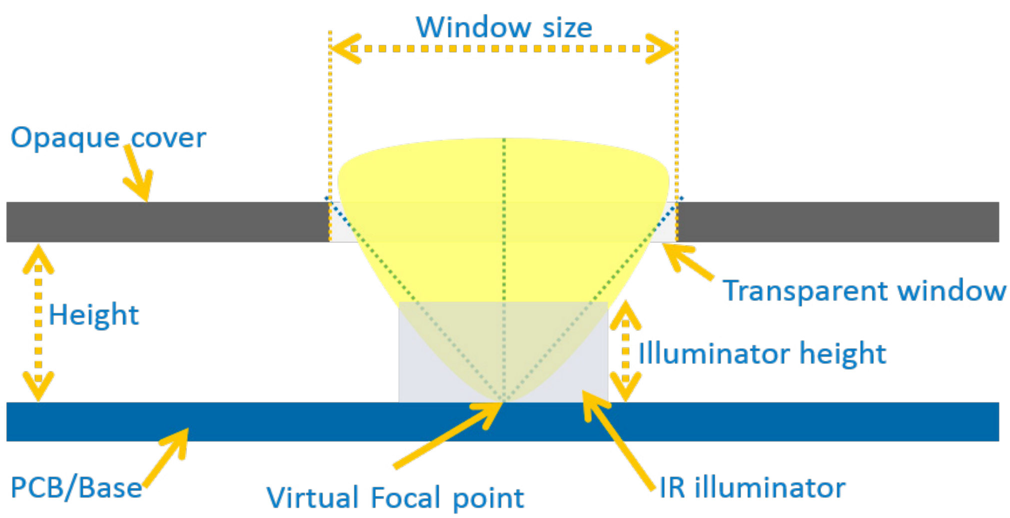


Figure 12. Schematic of IR illuminator within the facial recognition module.

Figure 13 shows the effect of the window size on corner irradiance levels for FOV 45° x 45° with a window height of 3mm and mechanically fitting solutions within that height. Examples below are normalized with output power of the IR illuminator corresponding to input current of 1A.

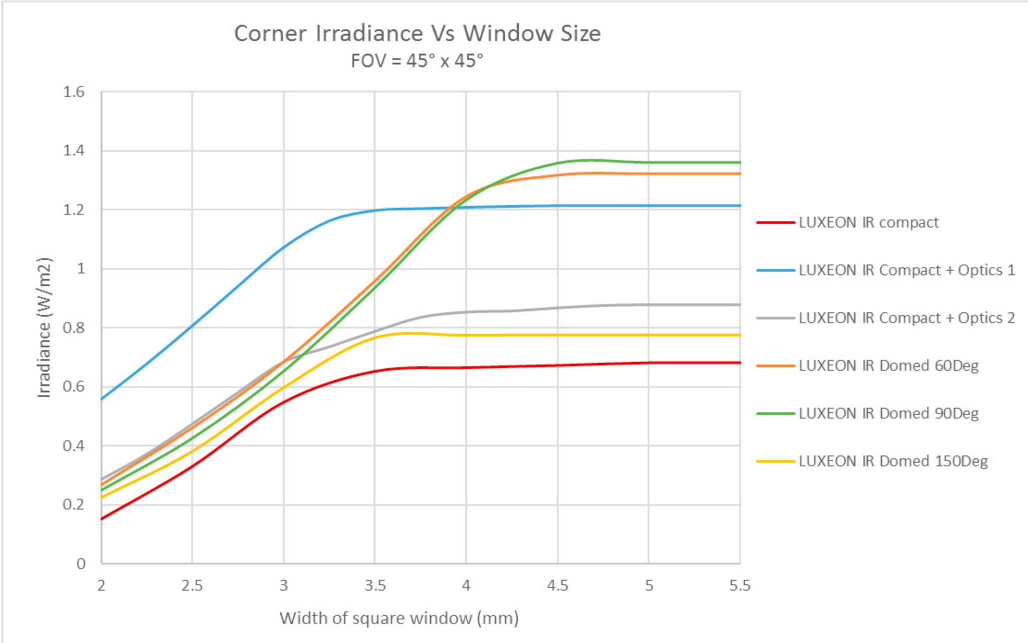


Figure 13. Impact of window size on corner irradiance with window height of 3mm.

Figure 14 shows a similar effect of window size on corner irradiance with mechanically fitting solutions for a window height of 2mm.

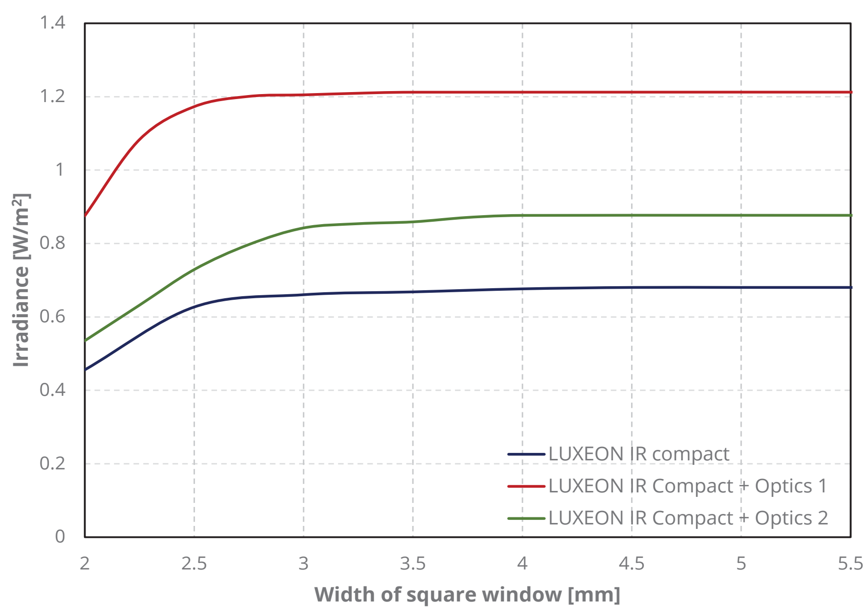


Figure 14. Impact of window size on corner irradiance with window height of 2mm.

From Figures 13 and 14, it is easy to decide which illuminator will fit better depending on the window height and window size. For example, with window height of 3mm:

- For a square window size of 3.5mm X 3.5mm, LUXEON IR Compact + Optics1 is the best performing
- For a square window size of 4.5mm X 4.5mm, LUXEON IR Domed 90Deg is the best performing

5. Eye Safety

All LUXEON IR Domed and LUXEON IR Compact products are inherently eye safe. For LED light lamps, the major parameters for safety are:

- **Retinal exposure:** LUXEON IR products are in the 'Exempt' group (no hazard) according to IEC-62471-1 (at max drive currents in DC and pulse mode conditions)
- **Corneal exposure:** LUXEON IR products are in the 'Exempt' group (no hazard) according to IEC-62471-1 (at max drive currents in DC and pulse mode conditions)

For other conditions (e.g. multiple emitters, secondary optics, etc.) please refer to the application guideline for eye safety with LUXEON IR emitters.

6. Summary

The IR illuminator is a critical part of the facial recognition module. For a good facial recognition system, illuminating the face well with high and uniform illuminance is very important; higher corner irradiance levels are required to compensate vignetting effects. This increases the signal to noise ratio to ensure that facial features can be detected successfully. LUXEON IR products are optimized to provide high central and corner irradiance to make sure the reproducibility of the face images by suppressing the ambient light impact. Narrow spectral width of these products helps filter ambient light efficiently. LUXEON IR products have high power, narrow spectral band width and are eye safe which makes them ideal for facial recognition systems.

About Lumileds

Companies developing automotive, mobile, IoT and illumination lighting applications need a partner who can collaborate with them to push the boundaries of light. With over 100 years of inventions and industry firsts, Lumileds is a global lighting solutions company that helps customers around the world deliver differentiated solutions to gain and maintain a competitive edge. As the inventor of Xenon technology, a pioneer in halogen lighting and the leader in high performance LEDs, Lumileds builds innovation, quality and reliability into its technology, products and every customer engagement. Together with its customers, Lumileds is making the world better, safer, more beautiful—with light.

To learn more about our lighting solutions, visit lumileds.com.

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