Partial Flux - Measurement Reliability of Lensed LEDs

Application Note

Introduction

The majority of LED manufacturers use units of luminous intensity (cd) for the measurement and classification of LED brightness. For numerous LED types, this procedure is reliable and reproducible. However, for LEDs with narrow emission angle characteristics, this method is insufficient. This application note describes the procedures for measuring luminous intensity, partial flux and luminous flux, along with the advantages and disadvantages relating to LED design.

Luminous Intensity Measurement

Luminous intensity is measured in the units of cd. The luminous intensity Iv is calculated from the luminous flux $d\phi_V$, which passes through a solid angle $d\Omega$:

$$I_v = \frac{d\Phi_v}{d\Omega} \qquad \left(cd = \frac{lm}{sr} \right) \quad \text{(Formula 1)}$$

Osram Opto Semiconductors follows the recommendations of the International Commission on Illumination (CIE) for luminous intensity measurements of LEDs as described in Publication 127-1997, in which the detector is positioned a distance of 100 mm from the tip of the LED to be measured (see Figure 1). The light-sensitive surface must be round and possess an area of 1 cm². This geometry results in a solid angle of 0.01 sr (Steradiant) through which the luminous intensity is measured.
In the 2D projection, the solid angle of 0.01 sr corresponds to an aperture angle of ±3.2° (see Figure 2).

In order for luminous intensity to be measured in a reproducible manner, the distribution of luminous intensity within the solid angle must remain constant.

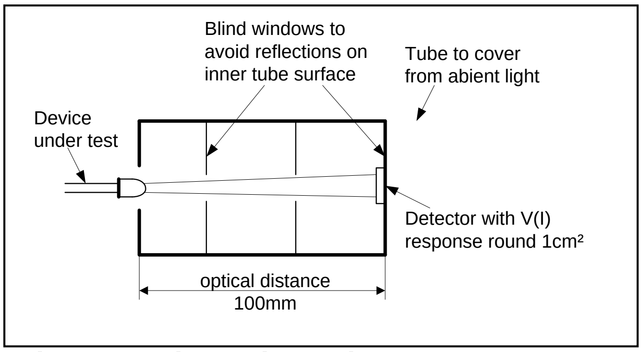

Fig. 1: Luminous intensity measurement

Factors which can negatively influence a luminous intensity measurement include:

- Component tolerances (e.g.: variations in the emission angle, squint angle)
- Positioning tolerance during measurement (e.g.: tipping the component during contact)

The tolerances described above can be neglected for components with a large emission angle (e.g.: 120°) and without primary optics, for example, TOPLED, Power TOPLED, SIDELED and MiniTOPLED.

For components with a narrow emission angle (< ±20°), the described measurement difficulties can arise. The tolerances can prevent reproducible measurements from being carried out for these LEDs. The nature of this problem is not dependent on the construction or manufacturer of the LED. The tolerance is most pronounced for radial components whose leads are inserted through the board. Because of their mounting technique, SMT LEDs provide an advantage in this area.

Luminous Flux Measurement

In contrast to the luminous intensity measurement which is used to measure the intensity of light passing through a narrow angle, the luminous flux measurement is used to measure the total power of light emitted in all directions. The unit of measurement for luminous flux is the Lumen (lm). From a technical standpoint, this measurement can be carried out in two different ways: either by means of a goniometer or by utilizing a so-called integrating sphere.

With a goniometer, the light intensity is recorded as a function of the emission angle. By using the inverse of Formula 1, the luminous flux can be ascertained:

$$\Phi_v = \int_{4\pi} I_v d\Omega \qquad (lm) \quad \text{(Formula 2)}$$

Although this method provides the most precise measurement of the luminous flux emitted from an LED, it is extremely time-consuming, and is therefore not well suited for production environments.

When measuring luminous flux by means of an integrating sphere, the device under test is placed inside a hollow sphere which inner surface is coated with a high-grade diffuse material. The multiple reflections of light created by the inner surface of the sphere serve to create a distribution of illumination which is proportional to the luminous flux emitted from the LED. By recording the illumination intensity present at an opening in the sphere, the entire luminous flux can be measured. The difficulty in measuring luminous flux with this procedure arises from the type-specific calibration which is necessary, along with the requirement that the device under test must be completely enclosed within the sphere. Type-specific calibration of the integrating sphere implies that in order to carry out accurate measurements, a reference light source must be used which corresponds to the form and emission characteristics of the device under test.

If this requirement were to be extended to the production environment, a large number of calibrations would be necessary for the various types of LEDs. The logistical problems which arise are not in keeping with the cost effectiveness gained through the mass production of LEDs. The positional requirements for such a measurement also impact the highly-automated cost-effective production of LEDs. Together, these two difficulties lead to enormous expenditures which are required to carry out a "true" flux measurement under production conditions, and can only be implemented in an extremely limited number of cases such as the new high power LEDs (Dragon).

Due to their robust characteristics and ever increasing brightness, LEDs are continually found in new applications. Along with the capture of new applications, new demands are placed on the LEDs. In order to be able to better address the demands, Osram Opto Semiconductors has developed a new measurement technique for LEDs with narrow emission angles. The partial flux measurement technique takes into consideration the numerous applications for narrow-angle LEDs while smoothing out the tolerances created by errors during measurement.

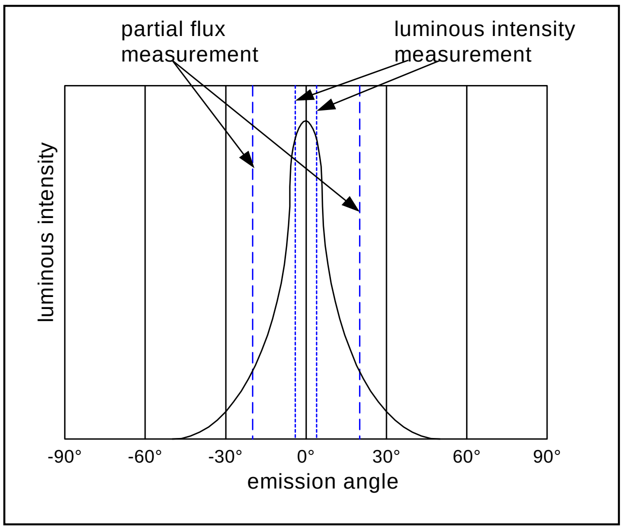

Fig. 2: Comparison of luminous intensity and partial flux measurement

Partial Flux Measurement

In comparison to luminous intensity measurements, the partial flux measurement extends the solid angle used for the measurement from 0.01 sr to approximately 0.38 sr; the aperture angle is thus increased from ±3.2° to ±20° (see Figure 2).

In order to achieve the partial flux measurement geometry described above, the tip of the LED to be measured is positioned at a distance of 19.2 mm from the measurement opening of an integrating sphere. The measurement opening has a diameter of 14 mm, which results in the desired measurement angle of ±20°. This allows only the luminous flux from the LED which lies within the acceptance angle created by the integrating sphere to be applied to the detector.

This angular range significantly increases the measurement reproducibility for LEDs with narrow emission angles. In addition, the new measurement geometry is better suited for current applications employing narrow-angled LEDs than that used for classical LED luminous intensity measurements. For these new applications, a secondary optic with a limited aperture angle is often used, but which always is greater than the ±3.2° angle used for luminous intensity measurements.

In order to emphasize the new nature of the partial flux measurements as well as avoid possible confusion between the units of measurement for luminous flux, luminous intensity and partial flux measurements, partial flux measurements are expressed in terms of illumination. The unit of measurement, as a result, is the Lux (lx).

$$E_v = \frac{d\Phi_v}{dA} \qquad \left(lx = \frac{lm}{m^2} \right) \quad \text{(Formula 3)}$$

Tolerance Considerations – Luminous Intensity and Partial Flux Measurements

The following section addresses errors in measurement for narrow-angled LEDs.
Figures 3 and 4 show the influence of measurement techniques on mechanical tolerances. This can arise, for example, from squinting of the device, or from the positional accuracy of the device.
For intensity measurements, a deviation of 4° leads to an error of 7.2%. In comparison, the error introduced with the partial flux measurement is only 1.4%. The reproducibility of the measurement is significantly improved.

Figure 5 shows 3 emission patterns which each result in a flux of 1 lm. In spite of the identical luminous flux, the luminous intensity at 0° varies from 1.9 cd to 2.6 cd; this corresponds to a variance of 31%. Here, the partial flux measurement proves much more stable, exhibiting only a variance of 14.2% . Since a majority of applications for narrow-angle LEDs utilize almost the entire width of the angular emission characteristic, the advantages of the partial flux measurement are clearly visible in comparison to Iv measurements for narrow-angle LEDs. The observation of measurement accuracy is shown in Table 1.

Why isn't a flux measurement just carried out? A flux measurement requires that the component is completely enclosed in an integrating sphere. For a majority of LED housings, this is very difficult to implement in mass production, due to their construction. If the LED is not completely enclosed, compromises will be introduced, and the flux will not be measured in its entirety. In the strictest sense, this should not be declared as a flux measurement. Furthermore, the entire diffused light from a component is measured. For narrow-angled LEDs, the diffused light is normally not significant.

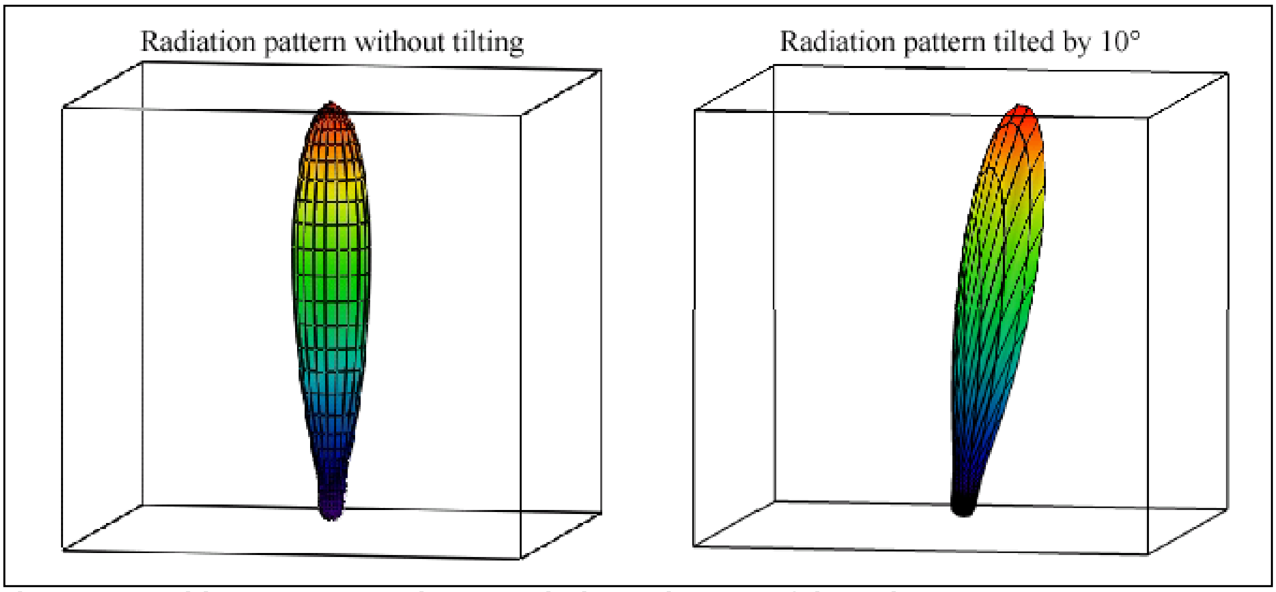

Figure 3: Positional accuracy (e.g.: squinting, alignment failures)

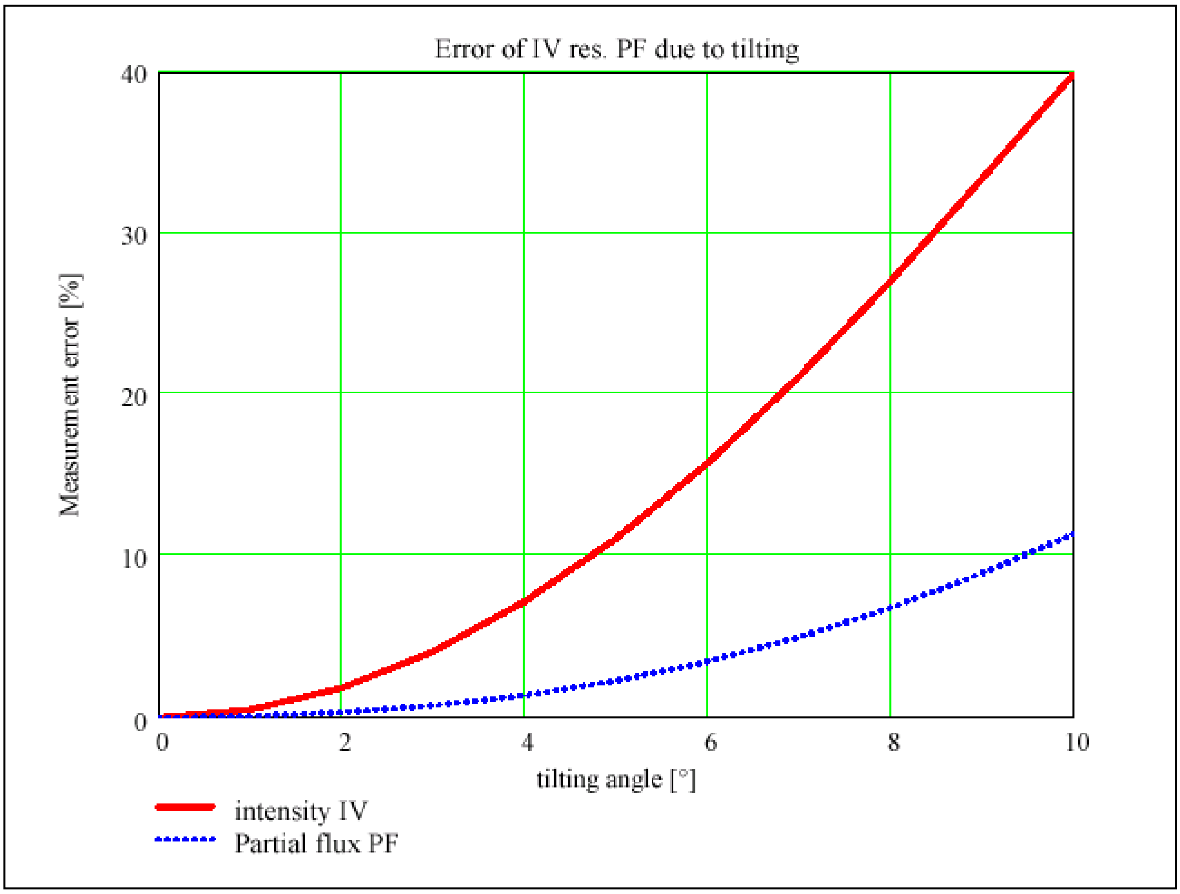

Figure 4: Error analysis – positional accuracy

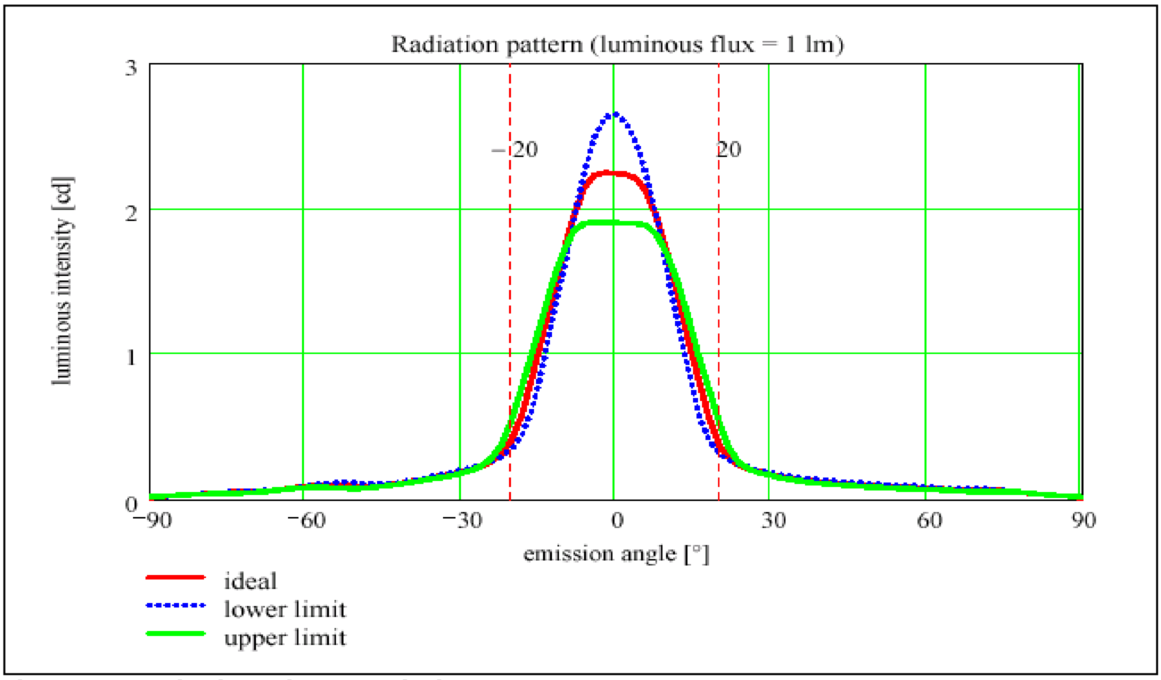

Figure 5: Emission characteristics

	narrow	*ideal*	*broad*	*deviation*
Luminous Flux (2π):	$\Phi_{lo} = 1.00\,lm$	$\Phi_{id} = 1.00\,lm$	$\Phi_{hi} = 1.00\,lm$	*(normalized)*
Luminous Intensity I_V:	$I_{V.lo} = 2.60\,cd$	$I_{V.id} = 2.25\,cd$	$I_{V.hi} = 1.91\,cd$	$\Delta I_V = 31.0\,\%$
Partial Flux:	$PF_{lo} = 2.7\,klx$	$PF_{id} = 3.0\,klx$	$PF_{hi} = 3.1\,klx$	$\Delta PF = 14.2\,\%$

Table 1: Measurement accuracy of emission characteristics Figure 5

Summary

The three measurement techniques described – luminous intensity, partial flux measurement and flux measurement each have their legitimacy. Due to the design and emission characteristics of narrow-angle LEDs, the partial flux measurement technique provides considerable advantages. By means of this development process, Osram Opto Semiconductors employs a measurement technique which is well suited for mass production and whose reproducibility is considerably greater than that provided by luminous intensity measurements.

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