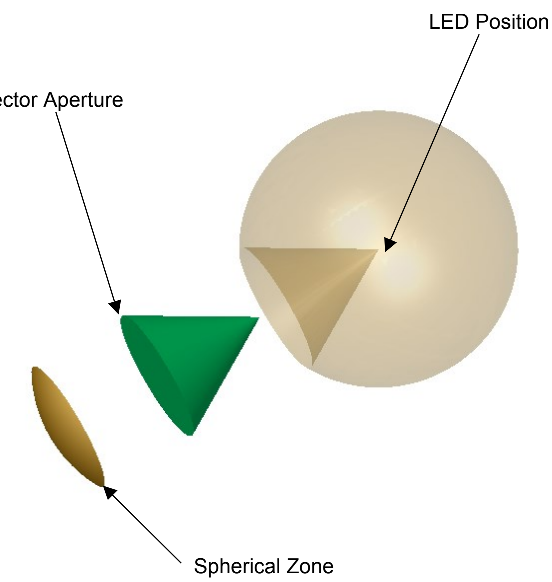
Converting Radiant Intensity in Units of mW/cm² to mW/sr

Application Bulletin 222

Radiant intensity is commonly measured in units of power per steradian and power per area. The SI standard is power per steradian. Optek's standard is power per area. Many customers will design their application around power per steradian so there is a need for a conversion between both standards.

To derive the conversion, an understanding of solid angles and how it relates to the SI intensity measurement needs to be presented. Imagine the LED and a detector placed in front of it with circular aperture. Place an imaginary sphere around the LED with the radius defined by the distance from the LED to the detector aperture. Place a cone in the sphere and locate it with respect to the LED and the detector aperture. The portion of the sphere bounded by the aperture is a spherical zone. Refer to the exploded view of the measurement diagram below.



The cone represents the measurement solid angle (ω). The SI unit for solid angles is the steradian (sr). A steradian is defined as the solid angle for which the spherical area bounded by the solid angle is equal to the square of the sphere's radius. The surface area of a sphere is calculated by the following formula.

$$A_S = 4 \pi R^2$$

A sphere contains 4π steradians. This is analogous to a circle containing 2π radians. The solid angle is calculated by multiplying 4π by the ratio of the zone's area to the sphere's area.

With this information, the conversion of mW/cm2 to mW/sr can be derived .

$$R = \sqrt{d^2+(D/2)^2}$$

(D=Diameter of aperture)

The area of the sphere (AS) is

$$AS = 4 \pi R2$$

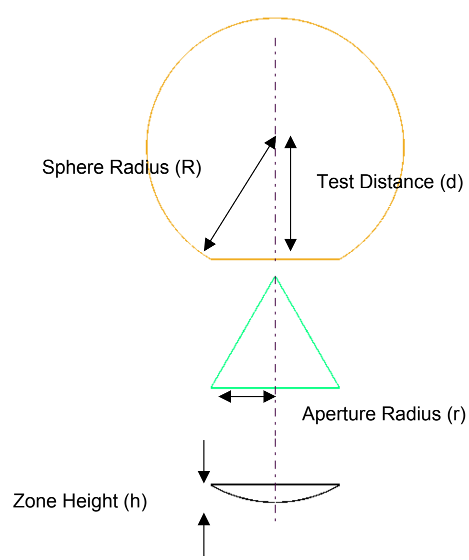
The area of the zone (AZ) is

$$AZ = 2 \pi R h$$

(h = R-d)

The area of the detector (AD) is

$$AD = \pi r2$$



The solid angle of the cone (w) is calculated by the following:

$$\omega = \frac{4\,\pi\,A_Z}{A_S} = \frac{4\,\pi\,(2\,\pi\,R\,h)}{4\,\pi\,R^2} = \frac{2\,\pi\,h}{R}$$

The conversion of mW/cm^2 to mW/sr is derived below.

$$\underset{\text{Units(mW/sr)}}{E_{e,\,sr}\,\omega} = \text{Power} = \underset{\text{Units(mW/cm}^2\text{)}}{E_{e,\,area}\,A_D}$$

$$E_{e,\,sr}\,\omega = E_{e,\,area}\,A_D$$

$$E_{e,\,sr} = \frac{E_{e,\,area}\,A_D}{\omega}$$

Optek measures the radiant intensity of the OP265 and OP266 with a 2.06 mm apertured detector placed 14.99 mm away from the LED. The apertured area of the detector is 3.333 mm^2 or .03333 cm^2. The distance from the LED to the detector's aperture edge is 15.025 mm. The height of the zone is .035 mm. The solid angle formed by the LED and detector is calculated below.

$$\omega = \frac{2\,\pi\,(.035)}{15.025} = .015\text{ sr}$$

For this measurement set up, the conversion is 2.255 (mW/sr)/(mW/cm^2).

Many customers will measure the intensity using different aperture sizes and test distances. Because the detector will capture only a portion of the non-uniform image projected from the LED, the power measured will not be proportional to the aperture size. This will cause the intensity measurement to vary. Therefore it is very important to consider the measurement setup when comparing intensities.

TT Electronics | Optek Technology
1645 Wallace Drive, Suite 130, Carrollton, TX, USA 75006 |Ph: +1 972-323-2300
www.ttelectronics.com | sensors@ttelectronics.com

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Conversion Table for Optek LEDs

Product	Test Distance	Aperture Diameter	Solid Angle	Conversion Factor
	cm	cm	sr	Cm^2/sr
OP123	1.270	0.079	0.003	1.614
OP124	1.270	0.079	0.003	1.614
OP140	1.660	0.457	0.059	2.795
OP145	1.660	0.457	0.059	2.795
OP165	1.499	0.206	0.015	2.255
OP166	1.499	0.206	0.015	2.255
OP168	1.016	0.206	0.032	1.040
OP169	1.660	0.457	0.059	2.795
OP223	1.270	0.079	0.003	1.614
OP224	1.270	0.079	0.003	1.614
OP231	3.630	0.635	0.024	13.252
OP232	3.630	0.635	0.024	13.252
OP233	3.630	0.635	0.024	13.252
OP231W	1.184	0.635	0.214	1.477
OP232W	1.184	0.635	0.214	1.477
OP233W	1.184	0.635	0.214	1.477
OP240	1.660	0.457	0.059	2.795
OP245	1.660	0.457	0.059	2.795
OP265	1.499	0.206	0.015	2.255
OP266	1.499	0.206	0.015	2.255
OP268	1.016	0.206	0.032	1.040
OP269	1.660	0.457	0.059	2.795
OP290	1.270	0.635	0.188	1.688
OP291	1.270	0.635	0.188	1.688
OP292	1.270	0.635	0.188	1.688
OP293	1.070	0.635	0.260	1.220
OP298	1.070	0.635	0.260	1.220
OP294	1.270	0.635	0.188	1.688
OP299	1.270	0.635	0.188	1.688
OP295	3.630	0.635	0.024	13.252
OP296	3.630	0.635	0.024	13.252
OP297	3.630	0.635	0.024	13.252

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