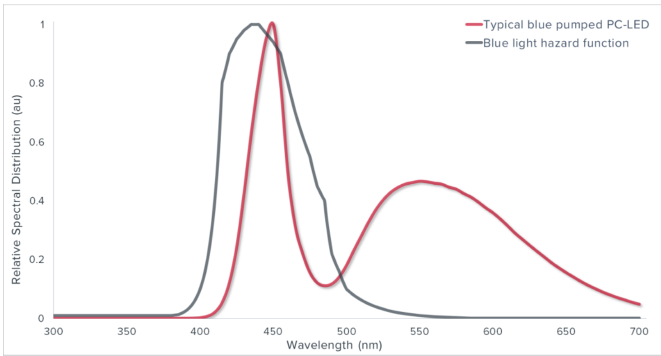
An overview of blue light hazard

Background

Blue light retinal injury is the name given to type II photochemically induced photoretinopathy, caused by absorption of light by the retinal pigmented epithelium and the choroid. Retinal injury includes a blind spot and a loss of vision, although recovery is noted in mild cases. Whilst the spectral sensitivity of this hazard ranges from 300nm to 700nm, the peak sensitivity is between 435-440nm, hence the “blue” appellation. Blue light retinal injury is typically encountered in the accidental viewing of the sun (solar retinitis) or welding arcs. This photochemical injury follows the Bunsen Roscoe law of reciprocity: high level exposure for short duration having the same effect as low level exposure for long duration. Whilst some have suggested that chronic blue light exposure contributes to age-related macular degeneration, this remains an area of research.

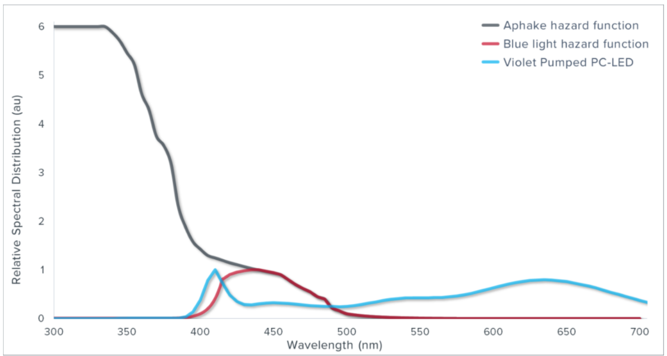
In lighting applications

Blue light retinal injury caused by excessive staring at lamps is extremely rare, the natural aversion response limiting exposure. Concerns for long-term low level exposure exist however, particularly in this era of SSL for which the blue LED pump, present in virtually all white phosphor conversion-LEDs, falls in the blue light hazard danger zone.



Aphakic hazard function

The UV transmittance of the crystalline lens of the eye is much higher in infants than in adults. Whilst some state that by the age of two years, the retina is afforded full protection, others argue that this can take up to ten years. Some have proposed the use of violet pumped PC-LEDs to ostensibly render objects as sunlight. For these sources, the aphakic hazard is greater than the blue light hazard.

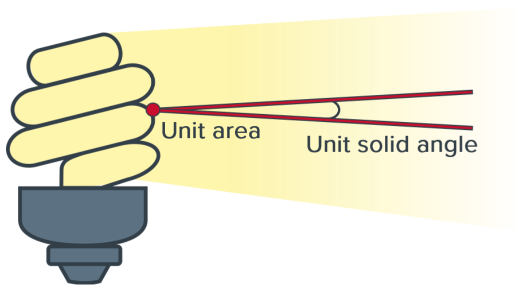


Designing for low blue light

Decreasing blue light radiance can be achieved by reducing either the blue component of the spectrum or the overall radiance produced by the source. The former can be easily achieved by using lower CCT LEDs, whilst reducing the radiance implies avoiding direct viewing of LEDs or operating LEDs at lower current, using more chips to maintain the same luminous output of the luminaire.

What is spatially-averaged radiance?

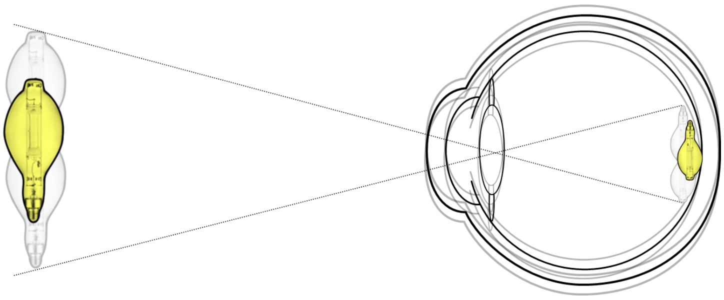
Take the radiance we all know and love...



The radiance of a source is defined as the power emitted per unit area of the luminous surface into unit solid angle. The product of area and solid angle is called the geometric extent, which is at best conserved in any optical system. Radiance can be decreased by filters or diffusers, but not increased by any optical system. It is for this reason that radiance is used to account for light perceived by the eye through its photometric equivalent, luminance.

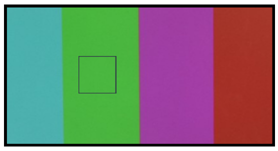
..and add some biophysical considerations

In evaluating hazards to the retina, the irradiance of the retinal image should be considered. With increasing exposure time this image is spread across the retina due to saccades and eye movements. What is of interest is not the radiance of the source but the radiance in the area of the retina irradiated.



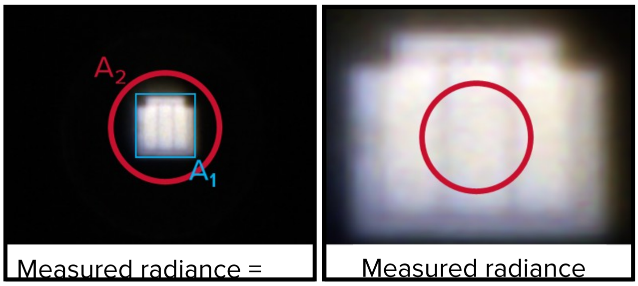
Radiance measurement conditions

In traditional radiometry, the radiance or luminance measurement is made with an optic that permits selecting the measurement field of view, and thereby the area of the source measured. In all cases, the luminous area should be uniform and must extend beyond the field of



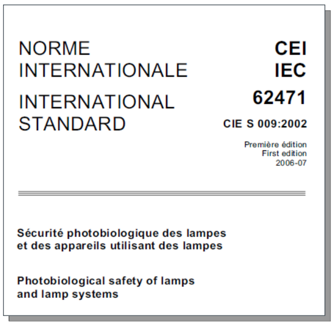
Spatially averaged radiance measurement conditions

On one hand we have a relationship between exposure time and angular subtense of the retinal image, on the other risk groups defined by permissible exposure time. Combining the two, we have measurement conditions defined by risk group, assessing the exposure of the retina. Where the source is smaller than the field of view, a spatially averaged radiance will result.



Comparing IEC 62471 and IEC 60598-1 Results

Since 2008: IEC 62471


NORME INTERNATIONALE CEI
INTERNATIONAL STANDARD IEC
62471
CIE S 009:2002
Première édition
First edition
2006-07

Sécurité photobiologique des lampes et des appareils utilisant des lampes

Photobiological safety of lamps and lamp systems

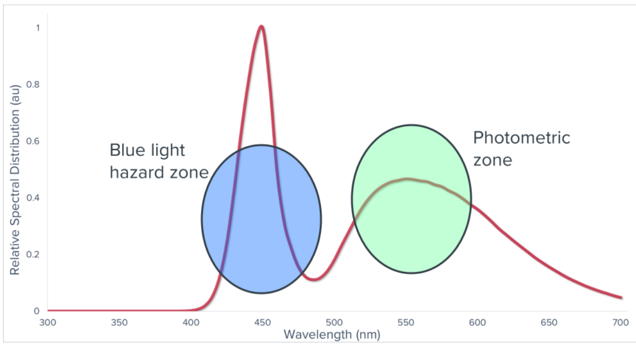
According to IEC 62471, the photobiological safety of lamps and luminaires intended for general lighting service (GLS) applications is evaluated by implementing the GLS classification criterion, namely by reporting at a distance at which the source produces an illuminance of 500 lux, not less than 200mm. Risk groups are assessed in turn, from RG0 until such point that the measured radiance be below the accessible emission limit of that risk group.

The measurement field of view to be used is:-
RG0- 100mrad using alternative (irradiance) technique
RG1- 11mrad with TEL310
RG2- 1.7mrad with TEL310

No Risk at 500lx

It can be demonstrated that at 500 lx, only LEDs having very high CCT (greater than approximately 10,000K) possess the asymmetric spectrum that will exceed the limits of the blue light exempt risk group.

Since such high colour temperature sources are seldom used in SSL applications, one can conclude that few GLS sources will exceed the limits of RG0 even before taking into account the measurement field of view.



The "New" Approach

According to the latest edition of the luminaire standard, IEC 60598-1, implementing IEC TR 62778, assessment should be made to determine whether or not the luminaire under test exceeds the limits of IEC 62471 blue light hazard RG1 at a distance of 200mm. Where this limit is exceeded, the RG1 hazard distance should be determined and reported on marking on the luminaire.

The measurement field of view to be used is:-
RG1— 11mrad with TEL310

Pragmatic IEC 62471 RG0 testing

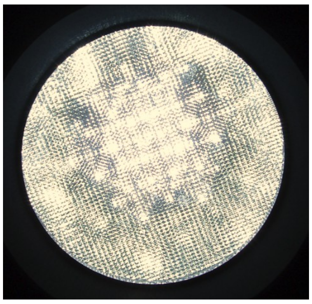
IEC 62471 requires that GLS sources be reported (but not necessarily assessed) at the distance at which they produce an illuminance of 500lx. This offers a simpler analysis of blue light hazard.

Blue light RG0 is tested using the the alternative (irradiance) technique. In testing at the 500 lx distance, an aperture should be placed at the source to limit the emission to 100mrad. The diameter of the aperture (estimated from 0.1x 500 lux distance) is different for every source as is the area to be blocked, and so is not practical to measure.

An alternative is to measure at a convenient distance (200mm recommended) and computing values for 500 lx before reporting. The field of view cannot be taken into account. For sources which extend beyond the 100mrad field of view at the GLS distance, this represents an over-estimation. The same assessment result (classification) is reported but not the same measured radiance.The measurement is greatly simplified and benefits from measuring at an irradiance level much higher than the noise equivalent irradiance of the spectroradiometer.

Comparison of Blue Light Hazard Analyses

Case 1: Extended Source



White LED mid- bay luminaire, fitted with diffuser

- Source diameter = 250mm
- 500 lx distance = 1.5m

Measurement Configurations

Full IEC 62471 assessment

Source extends beyond 100mrad FOV at GLS distance. Place 150mm diameter aperture at source. Measure spectral irradiance at 1.5m with D7 diffuser. Source radiance spatially averaged over 100mrad.

E.g. $L_{100,\,full}$= 35 $W{\cdot}m^{-2}{\cdot}sr^{-1}$

Simple IEC 62471 assessment

Measure spectral irradiance at 200mm in open field of view with D7 diffuser. Scale to 500 lux before re-porting blue light radiance.

E.g. $L_{100,\,simple}$= 97 $W{\cdot}m^{-2}{\cdot}sr^{-1}$

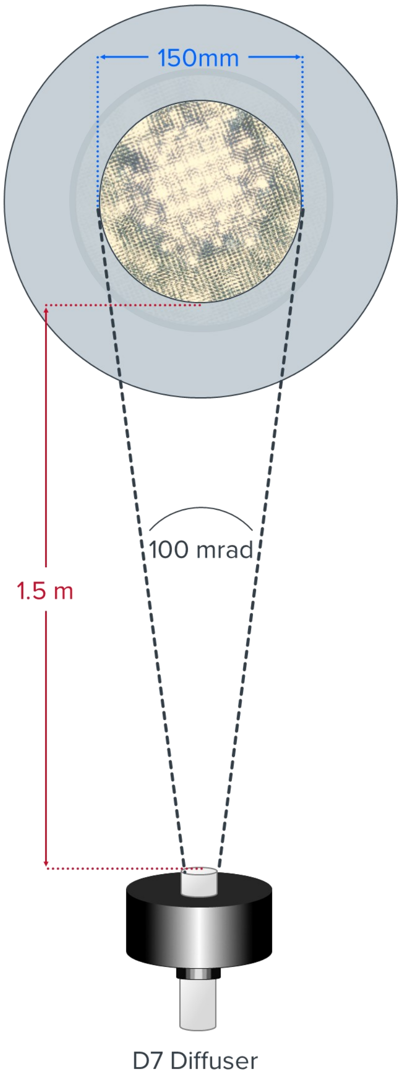
$L_{100,\,simple} > L_{100,\,full}$

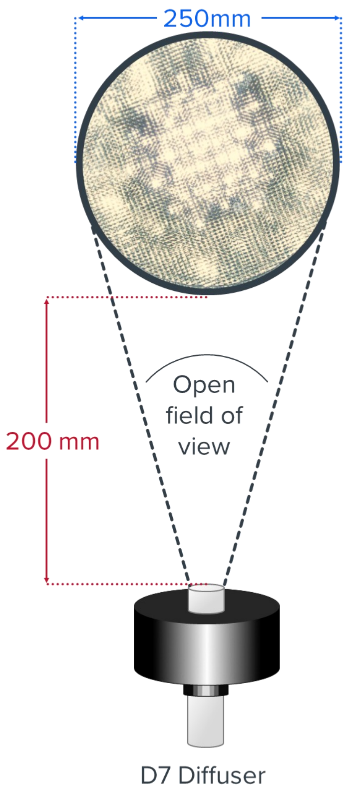
IEC 62778 Assessment

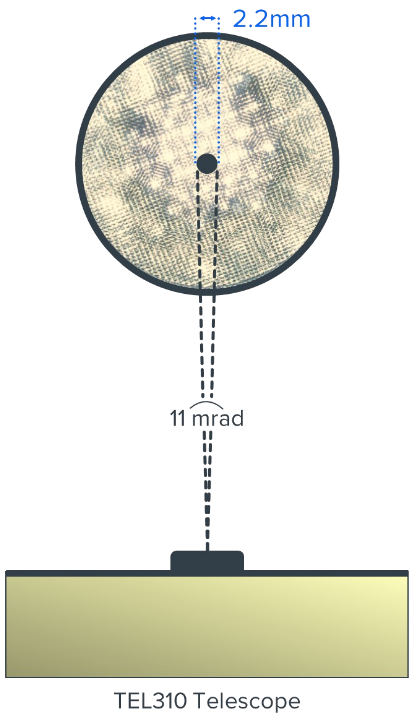
Measure spectral radiance at 200mm in 11mrad field of view with TEL310 telescope. Maximum radiance over 11mrad found.

E.g. L_{11}= 3000 $W{\cdot}m^{-2}{\cdot}sr^{-1}$

$L_{11} \geq L_{100,\,full}$

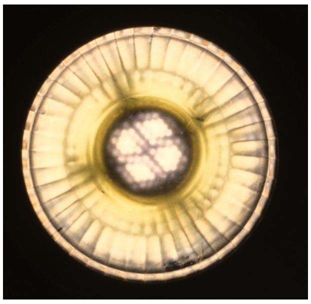






Comparison of Blue Light Hazard Analyses

Case 2: Compact Source



White LED MR16 lamp

- Source diameter = 80mm
- 500 lx distance = 1m

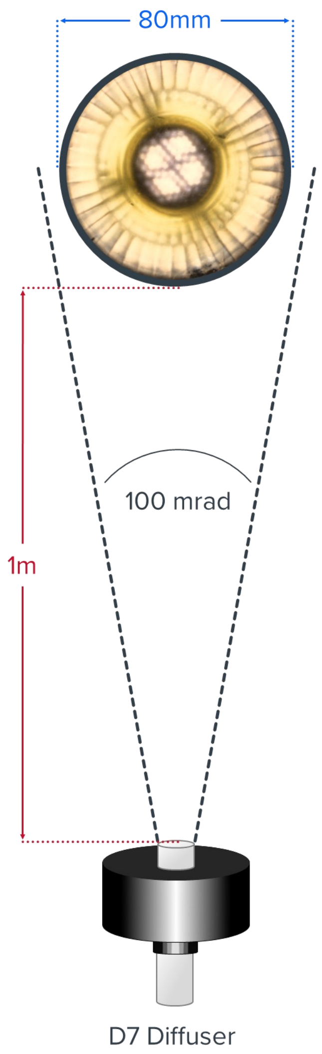
Measurement Configurations

Full IEC 62471 assessment

Source smaller than 100mrad FOV at GLS distance. No need for aperture.

Measure spectral irradiance at 1m with D7 diffuser. Source radiance spatially averaged over 100mrad.

E.g. $L_{100,\ full}$= 55 W·m^{-2}·sr^{-1}

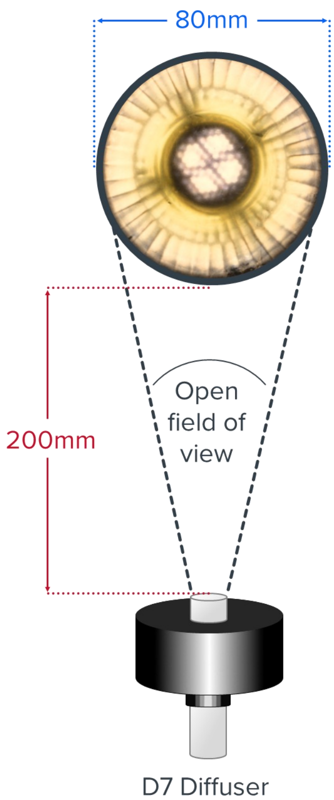


Simple IEC 62471 assessment

Measure spectral irradiance at 200mm in open field of view with D7 diffuser. Scale to 500 lux before reporting blue light radiance.

E.g. L100 mrad, simple= 55 W·m^{-2}·sr^{-1}

$L_{100,\ simple}$ = $L_{100,\ full}$



IEC 62778 Assessment

Measure spectral radiance at 200mm in 11mrad field of view with TEL310 telescope. Maximum radiance over 11mrad found.

E.g. L_{11}= 6000 W·m^{-2}·sr^{-1}

$L_{11} \geq L_{100,\ full}$