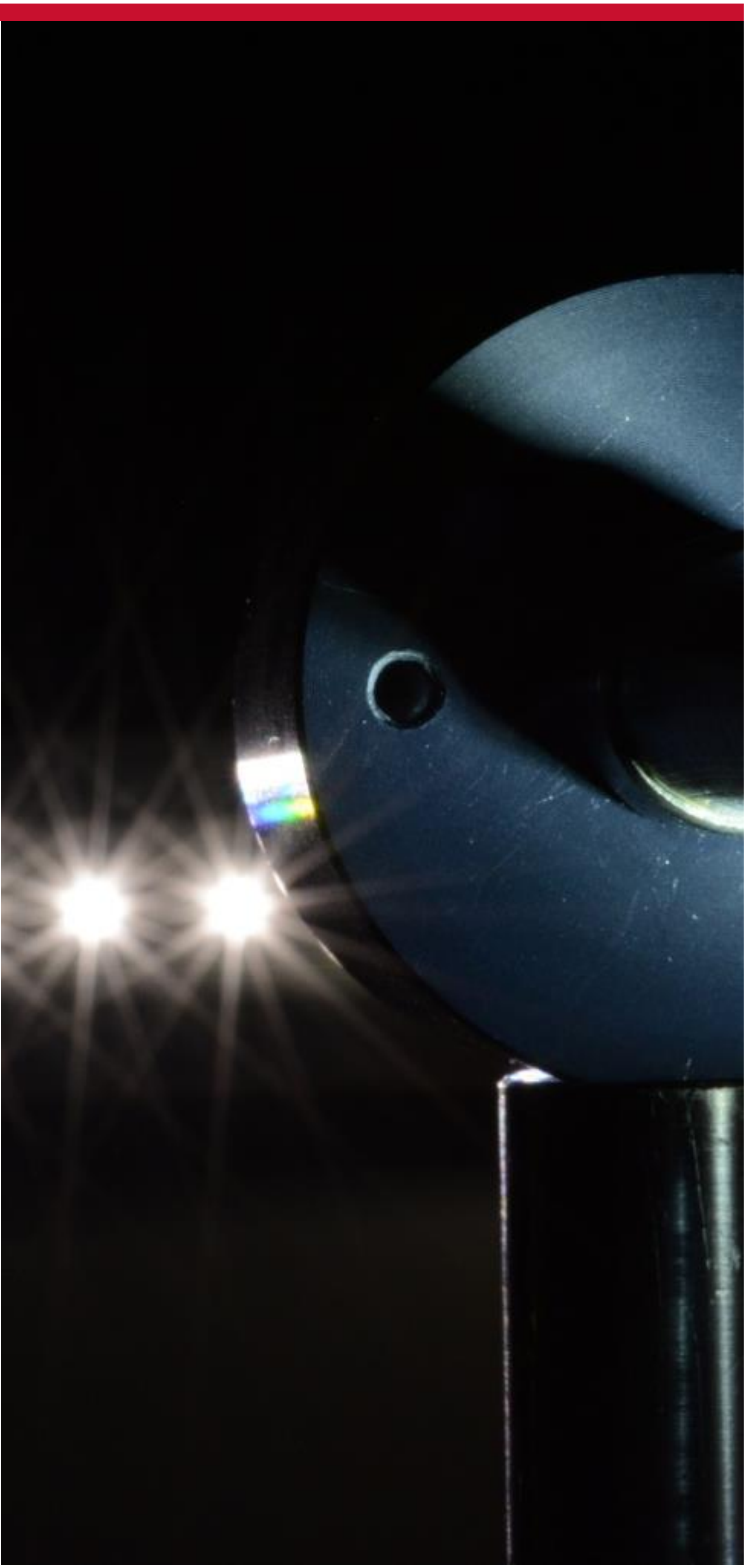


BENTHAM

Photobiological Safety in Lighting Applications

Introduction

Since the publication of EN 62471:2008 “Photobiological Safety of Lamps and Lamp Systems” (harmonised to the low voltage directive 2014/35/EU), the discussion of optical radiation safety has moved from being the preserve of laser or UV lamp manufacturers to become a common discussion point in the lighting industry, particularly in the case of retinal blue light hazard.

Driven by the desire to circumvent issues encountered in applying EN 62471, a new approach to the evaluation of the photobiological safety of luminaires is now in place.

According to the latest edition of the luminaire standard EN 60598-1: 2015, the photobiological safety assessment of luminaires takes into account two hazards, depending on source type:

1. Actinic UV hazard to the skin and eye
2. Retinal blue light hazard

The former has been part of the luminaire standard since 2002, ensuring suitable shielding of discharge sources to prevent UV leakage. The consideration of retinal blue light hazard is assessed in application of IEC TR 62778, “Application of IEC 62471 for the assessment of blue light hazard to light sources and luminaires”.

One Technical Report, Two Points of View

A significant motivation in the writing of IEC TR 62778 was the reduction of the measurement burden for luminaire manufacturers. This is achieved in two manners, firstly by providing conditions under which the risk group classification of a primary light source (lamp, LED chip or module) may be transferred to a luminaire and secondly in presenting a choice of assessment methodologies, two of which are based on commonly available data.

This technical report should therefore be considered from two distinct points of view: that of the primary light source and that of the luminaire.

Table 1: Overview of IEC TR 62778 assessment results

Primary Light Source		Luminaire	
Assessment Result	**Definition**	**Assessment Result**	**Definition**
RG1 unlimited	Does not exceed limit of the blue light hazard RG1 in any case[†]	RG1	Does not exceed limit of the blue light hazard RG1
E_{thr}	Illuminance at which upper limit of RG1 found	d_{thr}	Distance from luminaire at which E_{thr} found

One Technical Report, Three Assessment Methods

Three techniques are proposed for the assessment of blue light hazard, an overview of which is presented, in order of required inputs, below.

Table 2: Overview of IEC TR 62778 assessment techniques

	Method A	Method B	Method C
Input(s)	CCT	CCT	Spectral radiance/ irradiance (300-780 nm)
Result(s)	E_{thr}	RG1 (unlimited) E_{thr}	RG1 (unlimited) E'_{thr}
Comment	Includes safety factor	Includes safety factor	

An overview of blue light hazard

Background

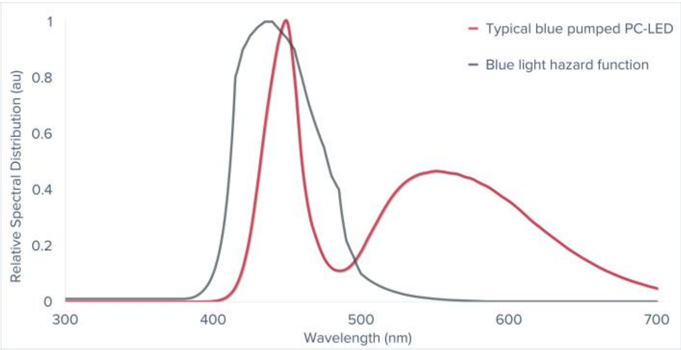
Blue light retinal injury is the name given to type II photochemically induced photoretinopathy, caused by absorption of light by the retinal pigmented epithelium and the choroid. Retinal injury includes a blind spot and a loss of vision, although recovery is noted in mild cases.

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

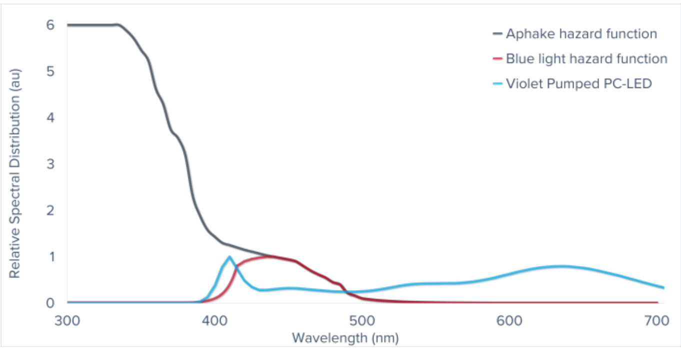
Blue light retinal injury caused by excessive staring at lamps is extremely rare, the natural aversion response limiting exposure. Concerns for long-term low level exposure exist however, particularly in this era of SSL for which the blue LED pump, present in virtually all white phosphor conversion-LEDs,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



Graph 1: Relative spectral distribution of a blue pumped PC-LED against the blue light hazard function

Aphakic hazard function

The UV transmittance of the crystalline lens of the eye is much higher in infants than in adults. Whilst ICNIRP states that by the age of two years[1], the retina is afforded full protection, others argue that this can take up to ten years[2]. 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.



Graph 2: Relative spectral distribution of a violet pumped PC-LED against the blue light hazard, and aphake hazard function

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. However, 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.

[1] ICNIRP Guidelines on Limits of Exposure to Incoherent Visible and Infrared Radiation, Health Physics 105(1):74-96, 2013

[2] F. Behar-Cohen et al., Light-emitting diodes (LED) for domestic lighting: Any risks for the eye?, Progress in Retinal and Eye Research 30, 2011

Method A

In IEC TR 62778, a table is reported of illuminance values, as a function of CCT (≤ 8000K), below which RG1 will result. Consulting the table for a source of known CCT, one can adopt the reported illuminance value as E_{thr}.

This value may be reported in the data sheet of a primary light source and converted to d_{thr} for a luminaire.

Where the latter process yields d_{thr} ≤200mm, below the assessment distance, then RG1 should be reported. This method includes a safety factor of two and cannot produce a transferable risk group classification.

Method B

In IEC TR 62778, a table is reported of luminance values, as a function of CCT (≤ 8000K), below which RG1 will result. In addition to knowledge of the CCT of the source, a measurement of luminance ($cd{\bullet}m^{-2}$) is required. The field of view (FOV) of measurement employed in determining luminance should not extend beyond the luminous area of the source.

Where the measured luminance of a primary light source is below that reported in the table, "RG1 unlimited" applies whilst for luminaires, "RG1". This method includes a safety factor of two. Where the measured luminance exceeds the tabulated values, one should consider methods A or C.

Method C

The direct spectroradiometric measurement is called for here, yielding the most accurate assessment result.

On the level of the primary light source, where the luminous area of the source fully overfills the 2.2mm diameter circle defining the 11mrad FOV at 200mm and the measured radiance is below the limit of RG1, the product can be assessed as RG1 unlimited, otherwise E_{thr} should be reported.

Where a primary light source under-fills this measurement FOV, a measurement of spectral irradiance is called for to report E_{thr}.

The requirement for the different measurement type to determine E_{thr} is not necessary and shall be removed in future. In the case of luminaires, an assessment is directly performed in the 11mrad FOV at 200mm.

Where the measured radiance is below the limit of RG1, the product can be assessed as RG1, otherwise d_{thr} should be reported.

Computation of E_{thr}

The threshold illuminance, E_{thr}, at which RG1 is found, may be computed by considering the irradiance-based emission limit for this RG1 measurement in an 11mrad FOV.

The product of the blue light hazard RG1 emission limit radiance (10000 $W{\bullet}m^{-2}{\bullet}sr^{-1}$) and the solid angle corresponding to an 11mrad FOV ($9.50332{\bullet}10^{-5}$ steradians) yields the blue light irradiance emission limit of 1 $W{\bullet}m^{-2}$.

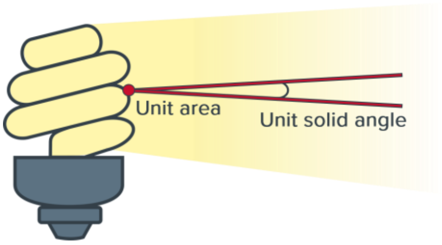
The ratio of luminance ($cd{\bullet}m^{-2}$) to blue light radiance ($W{\bullet}m^{-2}{\bullet}sr^{-1}$) being equal to that of threshold illuminance, E_{thr}, to blue light irradiance emission limit (1 $W{\bullet}m^{-2}$), E_{thr} (lux) can be easily obtained from the spectral radiance measurement, 300-780nm.

Determination of d_{thr}

Given the threshold illuminance, the low measurement burden path recommended by IEC TR 62778 is to use existing goniophotometric data on the luminaire to determine the peak luminous intensity and use the inverse square law to compute d_{thr}.

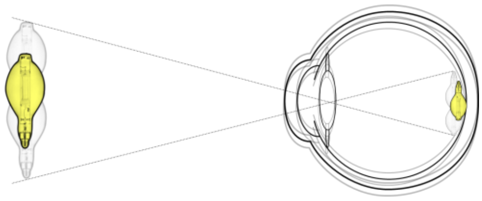
In the absence of goniophotometric data, an illuminance meter can be used directly to determine the position at which E_{thr} is found.

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 should be evaluated is not the radiance of the source, but the irradiance of the retinal image.

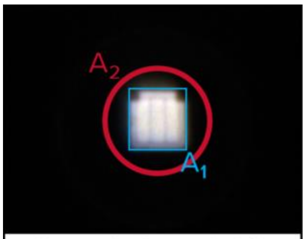


Radiance measurement conditions

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 view.

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.



Measured radiance = $L.A_1/A_2$


Measured radiance = L

The bottom line
For RG1 with a time basis of 10,000s, measurements of spatially averaged radiance should be made in an 11mrad field of view (FOV). Measurement at 200mm will encompass a circular area of 2.2mm diameter, no matter how large the luminaire to be measured.

This approach whilst simple, does not however take into account the fact that the measurement should be evaluated in an 11mrad FOV. If the luminaire under test subtends >11mrad at d_{thr} it follows that emission from the source outside the 11mrad FOV contributed to the measurement of illuminance used to find the location of E_{thr}, leading to an over-estimate of d_{thr}. As an example of this, see figure 1. From a measurement at 200mm, E_{thr} was determined from the ratio of luminance to blue light radiance and d_{thr} determined using a luxmeter.

Evaluation of the 11mrad FOV at d_{thr} (depicted in yellow) shows that the source extends beyond the FOV. The assessment is overly conservative. Whilst in certain circumstances this may present no application-related issues, it can have an impact in the marketing of the product since one will naturally tend to those sources having a shorter d_{thr}, perceived as being “safer”.

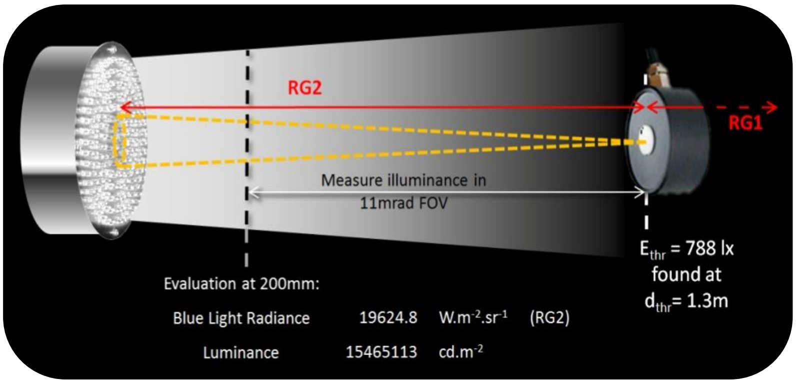


Figure 1: Example showing over-estimation of d_{thr}.

Refined determination of d_{thr}

In IEC TR 62778, guidance is provided to address the case where a luminaire comprised of an array of LEDs subtends >11mrad at the initial estimate of d_{thr}, as shown in figure 2. Given that the luminaire extends beyond an 11mrad FOV (figure 2, upper), this binary approach considers the threshold distance of a single emitter and determines whether or not other emitters fall into the 11mrad FOV at that distance (figure 2, lower).

Practically, this approach requires that all other emitters in the luminaire be extinguished or covered, which in many instances is neither easily realisable nor practical. Figure 2 was realised thanks to Photoshop!

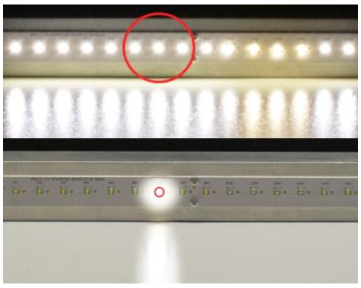


Figure 2: Binary approach to refine d_{thr} of luminaires comprised of an array of LEDs.

Given that the LED technology of today generates a maximum blue light radiance between four and eight times the RG1 limit we can estimate how much the area over which the 11mrad FOV must increase to generate a spatially averaged blue light radiance equal to the RG1 limit.

In the case of omni-directional sources, it is estimated that the true d_{thr} will not exceed 600mm whilst for directional sources d_{thr} may be great, but then the greater d_{thr}, the more likely the source fall fully within the 11mrad FOV.

A measurement-based approach is recommended, starting with the computation of d_{thr} according to the technical report, and evaluation of whether or not the source extends beyond 11mrad. If the source extends beyond 11mrad, the measurement should be repeated at greater distances, in steps of 200mm until such point that the measured blue light radiance is below the RG1 limit.

Reporting Assessment Results

The assessment result for the primary light source should be reported in the accompanying datasheet alongside the current at which the assessment was performed whilst that of the luminaire should be reported in the product literature of the luminaire. Where d_{thr} results, a label warning not to stare at the source within d_{thr} should be placed on the luminaire and in the installation instructions.

Don't Fall Into the Exempt Risk Group Trap

Introduction

Whilst the lighting industry has responded quickly to the change of the standards landscape since the initial publication of EN 62471 in 2008, the same cannot be said about the government and other agencies around the world that specify contracts and tenders.

Don't lose out by speaking the wrong standards language!

EN 62471 & GLS

According to EN 62471, the risk group assessment of luminaires should be determined in application of the GLS condition, reporting (but not necessarily measuring) at the distance at which the luminaire produces an illuminance of 500lx. This results in a risk group zero (RG0) classification for essentially all "white" lighting products. For the main part this chimed well with the desire for "low risk" products. For the most risk averse (and marketing departments), the "exempt" nomenclature was adopted to avoid the unmentionable word "risk", although qualified by a big fat zero. If you see a tender with an RG0 or exempt requirement, be aware that the standard referred to is EN 62471, not EN 60598-1.

The Solution

The assessment result at 500lx can be conveniently calculated from your IEC TR 62778 measurement results at 200mm. Simply multiply your blue light radiance result ($W{\bullet}m^{-2}{\bullet}sr^{-1}$) by the ratio (63662/ luminance ($cd{\bullet}m^{-2}$)). If the result is below 100 $W{\bullet}m^{-2}{\bullet}sr^{-1}$, then the assessment result is exempt at 500lx according to EN 62471. You could be forgiven for missing this last step. Providing the luminaire CCT is less than 12500K (a fairly safe assumption here) then your source cannot produce a blue light radiance at 500lx to cause concern. If you cannot beat them, join them and avoid the exempt risk group trap.

Conclusion

The implementation of IEC TR 62778 and the new approach to the evaluation of the photobiological safety of sources intended for lighting applications will in many instances lead to a simpler assessment.

In others, where a refinement of d_{thr} is sought, additional interpretation will be required, and yet interpretation in standardisation can be problematic. This highlights the need for a sounder metrological approach to the determination of this parameter. Revision of IEC TR 62778 is underway as a new international standard, IEC 63109. In TC 34, we are working hard to ensure that a simple and robust approach to photobiological safety testing is provided to the lighting industry.

Written by Leslie Lyons, head of marketing of Bentham Instruments Limited, UK, and a member of BSI and IEC committees TC 76, optical radiation safety and laser equipment and the WG6 photobiological safety panel of IEC TC 34/SC 34A - lamps.

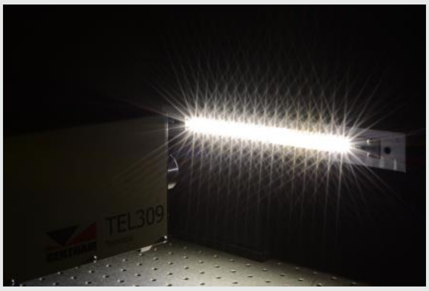
Related Systems

ISR300-PSL

Luminaire Blue Light Hazard Spectroradiometer

The ISR300-PSL is a key tool in the accurate evaluation of blue light hazard across all classes of lighting products. Design your products for compliance and provide accurate safety information to your clients.

- Direct approach to blue light hazard testing
- Assess all classes of lighting product
- No dark room or knowledge of standards required
- Avoid negative perception of hazard over-estimation



Standards

IEC/EN 60598-1 | IEC TR 62778

Measurements

Spectral radiance

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