Overview of LED Product Safety
A European Perspective

Introduction

Over the past year, safety legislation relating to LED devices has become somewhat more complicated due not only to a change of horizontal product safety standard, but also the impending implementation of the artificial optical radiation directive, concerned with worker exposure. This note provides an overview of the current situation[1] and a guide to the required measurements.

General Product Safety

The safety of products marketed in the European Union is demonstrated by CE conformity marking, which in turn demonstrates compliance with the relevant applicable EU directive (Low voltage directive, General Product Safety Directive, Machinery Directive…).

Rather than including in these directives the technical requirements for compliance, the EU "New Approach" states the legal requirements to be achieved in the form of Essential Health and Safety Requirements (EHSRs).

To facilitate the interpretation of such requirements, the CEN (Comité Européen de Normalisation) or CENELEC (Comité Européen de Normalisation Electrotechnique), create (or adopt) relevant horizontal safety standards, often based on those published by the International Electrotechnical Committee (IEC).

These European Norme (EN) standards are "harmonised" in support of one or more directives, and published by individual EU member states (sometimes with deviations particular to their country). Compliance with these standards are not mandatory but gives presumption of compliance with the essential health and safety requirements.

There may also exist product-specific vertical standards, based on such horizontal standards, to provide manufacturing or user safety requirements

LED Product Safety

In the past, LEDs have been classed as laser type devices and as such have come under the remit of laser standards, such as EN 60825 :2001. With the publication of IEC 60825:2007, and its harmonisation as EN 60825:2007, it is specifically stated that LED devices are no longer covered by this standard, with the exception of those used in communication applications.

Henceforth, LEDs are to be measured against EN 62471:2008, "Photobiological Safety of Lamps and Lamp Systems", a document originally based directly on CIE S009:2002, published by the CIE (Comission Internationale d'Eclairage) and adopted in 2006 by the IEC in IEC 62471:2006.

This standard is due soon to be harmonised into the low voltage directive.

EN62471-1:2008 gives guidance for evaluating the photobiological safety of lamps and lamps systems emitting optical radiation in the range 200-3000nm and provides exposure limits and a framework for classification.

Artificial Optical Radiation Directive (AORD)

Further to Article 16(1) of Directive 89/391/EEC of the 12th June 1989, introducing measures to encourage improvements in the safety and health of workers at work, the European Union has adopted a number of additional directives relating to the working environment. Amongst these are a group relating to Physical Agents, such as vibration, noise, electromagnetic fields, and artificial optical radiation.

This latter is introduced in Directive 2006/25/EC, published in the Official Journal of the European Union on the 27th April 2006, to be brought into force in law by 27th April 2010.

The measures introduced are designed to prevent harm to workers, due to exposure of the skin and eyes to coherent and non-coherent artificial sources in the work place. It is notable that solar radiation is not included in this directive.

[1] *Situation current at publication, May 2009*

In accordance with Directive 89/391/EEC, 2006/25/EC states that the burden of responsibility lies with the employer to ensure that risks be assessed (and effectively reduced or removed) within a proper framework, and that the workforce be aware of such risks.

Further specific guidance is provided within this standard with reference to the scope of the risk assessment, to corrective/ preventative measures should limits be exceeded, to worker information and to training and health surveillance.

The methodology to be applied in the determination of exposure levels should follow IEC standards for laser radiation (IEC 60825) and CIE/CEN standards for non-coherent radiation (EN 62471). It should be noted that in the case of the retinal thermal hazard, the exposure limits here differ from those of the IEC/EN standard.

EN 62471:2008: Required Measurements

This standard considers six hazards relative to exposure to the eye and skin over a period of up to eight hours.

Hazard	**Wavelength Range (nm)**	**Quantity**	**Bioeffect**	
			Eye	**Skin**
Actinic UV skin and eye	200-400 (weighted)	Irradiance	*Cornea*-photokeratitis *Conjunctiva*- conjunctivi-tis *Lens*-cataractogenesis	Erythema Elastosis
UVA eye	315-400	Irradiance	*Lens*-cataractogenesis	
Retinal Blue-light	300-700 (weighted)	Radiance	*Retina*- photoretinitis	
Retinal Blue-light-small source	300-700 (weighted)	Irradiance		
Retinal thermal	380-1400 (weighted)	Radiance	*Retina*- retinal burn	
Retinal thermal- weak visual stimulus	780-1400 (weighted)	Radiance	*Retina*- retinal burn	
Infrared radiation eye	780-3000	Irradiance	*Cornea*- corneal burn *Lens*-cataractogenesis	
Thermal skin	380-3000	Irradiance		Skin burn

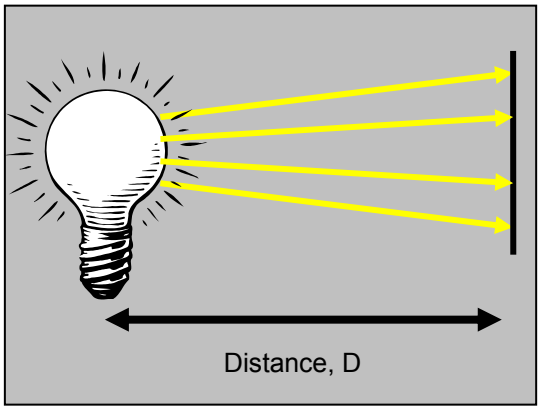
The quantities to be measured and evaluated against exposure limit values, are of irradiance and radiance, as summarised below.

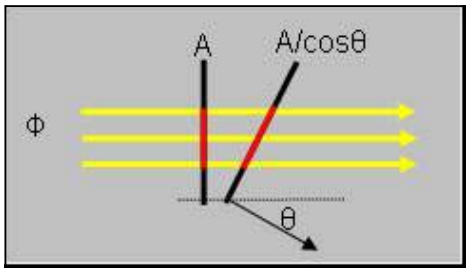
Irradiance

Hazards relating to irradiance are concerned with the quantity of light incident on the skin and eye.

Spectral irradiance is defined as the incident power, from a source at a given distance, per unit area, as a function of wavelength with units of $W.m^{-2}$ nm^{-1}.

Integrated between the correct wavelength limits, and weighted in certain instances against hazard functions, a value of irradiance in $W.m^{-2}$ is obtained, which may be compared with the relevant exposure limit to determine permissible time to exposure before hazard.





The correct measurement of spectral irradiance should include light from the entire hemisphere above the measurement plane.

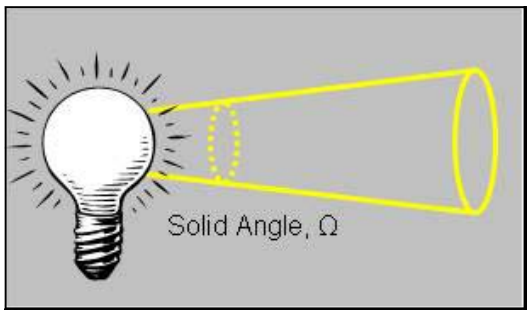
As the angle of incidence moves away from the normal to the measurement plane, the irradiance reduces with the cosine of the angle, since the illuminated area increases by the same factor.

This is termed cosine response; it is important that the cosine input optic mimics this response to measure accurately, the deviation therefrom being characterised by the parameter, f2'.

In practice, with regards to EN 62471, the hemispherical field of view of the measurement is restricted in certain cases to relate to biophysical phenomena.

Radiance

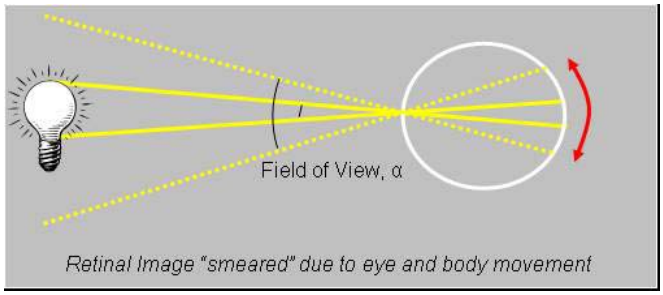
Hazards relating to radiance are concerned with the irradiation of the retina, the eye imaging the source in question thereupon.



Spectral radiance is defined as the power emitted from a source per unit area into unit solid angle with units of $W.sr^{-1}m^{-2}\ nm^{-1}$.

Integrated between the correct wavelength limits, and weighted against hazard functions, a value of radiance in $W.sr^{-1}m^{-2}$ is obtained, which may be compared with the relevant exposure limit to determine permissible time to exposure before hazard.

In its strict definition, radiance is measured using an input optic that measures over a defined area of the source, into a defined solid angle. It follows that the measurement instrument view is smaller than, or is overfilled by the source.



The smallest image that can be focussed on the retina by the eye is taken to have angular extent 1.7mrad. With increasing exposire time, due to eye movement and task-determined movement, this image is smeared on the retina, covering the area of an effectively larger field of view, taken as a maximum of 100mrad.

In the context of the photobiological safety of lamps, the measurement of radiance is performed in a manner that reflects this phenomenon; a field of view relevant to the exposure of the eye, and not the size of the source is used. This quantity is more accurately termed "physiological radiance", since the measured radiance may be lower than the true source radiance.

Radiance may be measured by either a lens and aperture, or a solely-aperture-based approach, to restrict the field of view of measurement to one relating to retinal exposure as a function of time.

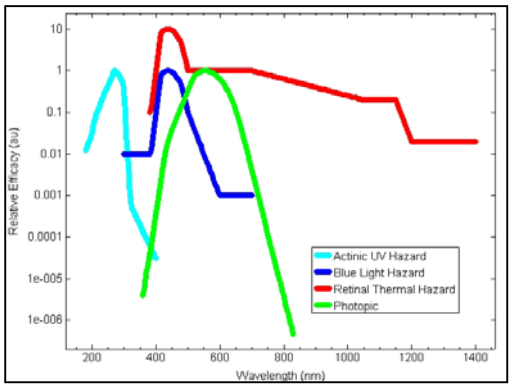
Source Angular Subtense

In the case of the retinal thermal hazard, a knowledge of the source angular subtense (to which retinal image size is proportional) is required to evaluate the hazard since, as the retinal image becomes larger, the axial heat flow reduces, making damage more likely.

Where a source incorporates no optics, the source angular subtense is that of the physical source.

Where a source incorporates lenses and reflectors, the apparent source may be at a location other than that of the physical source; an imaging-based technique is required in the evaluation thereof.

Hazard Weighting Functions
There are four weighting functions used in this standard, three relating to specific photobiological hazards, and the fourth, photopic eye response, used in the evaluation of the luminous effiicacy of the source in question.



Multiplying or weighing, the source spectral irradiance/ radiance spectrum by the action curve determines what portion of the spectrum contributes or not to the function considered.

Classification
Sources are classified into the following four groups according to hazard, based on permissible exposure time before hazard exceeded:-

Risk Group	Philosophical Basis
Exempt	No photobiological hazard
Group 1	No photobiological hazard under normal behavioural limitations
Group 2	Does not pose a hazard due to aversion response to bright light or thermal discomfort
Group 3	Hazardous even for momentary exposure

In all measurements of irradiance, the hazard exposure limit value is divided by the measured irradiance to determine the permissible exposure time, which is then compared with the limits of each risk group.

In the case of measurements of radiance, the field of view corresponding to the maximum permissible time to exposure of a given class is used as the measurement condition, and pass/ fail of the criteria for the given class determined.

Measurement Conditions
The procedure to classify a given source against EN62471:2008, or to determine worker exposure in terms of the AORD is an involved process.

When proceeding to evaluate a source against AORD, the measurement distance should be commensurate with worker exposure; against EN62471:2008, it is first necessary to class the device as either one designed for general lighting service (GLS), or for all other applications.

In the case of GLS devices, the source should be evaluated at a distance that produces an illuminance of 500lux. In practice, the measurement distance may be a number of metres. In all other cases, the measurement should be performed at 200mm.

The measurement of radiance in particular represents a challenge in that within a given field of view, a single device may not pose any hazards, whilst multiple sources may do so.

A further complication is the fact that there is little correspondence between measurements of a bare source and measurements of the same source in a luminaire, making measurements in both instances a potential requirement.

IEC 62471-2
Not formally adopted by CENELEC, IEC 62471-2, "Photobiological safety of lamps and lamp systems – Part 2:Guidance on manufacturing requirements relating to non-laser optical radiation safety" provides further guidance on the measurement and labelling of sources and is a useful supplement to EN 62471:2008.