TLS120Xe

Photobiological safety analysis

Introduction

In this report, the optical radiation safety of the TLS120Xe high power tuneable light source is considered with respect to EN 62471: 2008 "Photobiological Safety of Lamps and Lamp Systems" and worker exposure with respect to the EU artificial optical radiation directive, 2006/25/EC.

Overview of TLS120Xe

The TLS120Xe is an ultraviolet- visible- near infrared monochromatic tuneable light source (250 nm – 1100 nm) intended for laboratory use in the physical and life sciences.

Figure 1

TLS120Xe high power tuneable light source

The TLS120Xe houses an ultra-quiet short-arc xenon light source, starter and constant current power supply with a 120mm focal length concave grating monochromator in a single 19" rack (4U) unit.

The arc of a short arc xenon lamp is placed at the primary focal point of an $AlMgF_2$ coated ellipsoidal reflector. At the secondary focal point of the ellipsoidal reflector is located the rectangular entrance slit of a concave grating constant deviation monochromator. A four position filter wheel is located behind the entrance slit, fitted with a shutter and two long pass filters to supress diffraction orders other than the first diffraction order. A 1200 g/m, ruled concave diffraction grating (380 nm blaze wavelength) is mounted on an on-axis rotating turret driven by stepper motor.

The grating spectrally disperses the broadband optical input light and re-focusses the dispersed light onto a rectangular exit slit, transmitting a narrow band of wavelengths defined by the largest width of the entrance and exit slits.

Rotating the diffraction grating allows selection of the transmitted wavelength over the range 280nm to 1100nm or zero order (white light).

A pair of biconvex lenses focus light transmitted through the slit onto the optical fibre/ liquid light guide of choice. An iris diaphragm allows control of the level of illumination.

The bandwidth of the TLS120Xe can be manual set as 5, 10, 20 or 40nm (nominal).

Overview of EN 62471:2008 Standard

EN 62471:2008 provides measurement techniques and a classification scheme for the photobiological safety assessment of electrically powered lamps and lamp systems emitting optical radiation in the wavelength range 200 nm to 3000 nm in consideration of six hazards relative to the exposure of the eye and skin.

EN 62471 Hazards

Hazard Designation	Spectral range	Hazard weighting function
Actinic UV skin & eye	200 nm -400 nm	S(λ)
Near UV eye	315 nm -400 nm	-
Retinal blue light	300 nm -700 nm	B(λ)
Retinal thermal	380 nm -1400 nm	R(λ)
Infrared eye	780 nm -3000 nm	-
Thermal skin	380 nm -3000 nm	-

Table 1

Hazards to skin and eye considered by EN 62471

Implementing exposure limits promulgated by ICNIRP, and taking the maximum permissible exposures times on which the classification system is based, accessible emission limits are derived for each hazard and each risk group.

Hazards are evaluated through consideration of the spectral irradiance and spatially-averaged spectral radiance produced at a distance of 200 mm from the (apparent) source of optical radiation. Due to consideration of eye movement, the assessment of retinal hazards should be performed under the fields of view (FOV) highlighted in table 2.

Retinal Hazards FOVs (rad)

Risk Group	Blue Light	Retinal Thermal
RG0	0.1	0.011
RG1	0.011	-
RG2	0.0017	0.0017

Table 2

Applicable field of view for spatially-averaged radiance measurement

In the case of retinal thermal hazards, where the luminance produced by an apparent source in a 0.011 rad FOV is less than 10 cd.m^{-2} the retinal thermal weak visual stimulus case applies.

In this assessment, all hazards were assessed through measurements of the spectral irradiance produced by the source at defined measurement planes. The alternative technique was used to derive spatially-averaged radiance for the above FOVs. Where the FOV under-fills the apparent source, the effective irradiance is computed on the ratio of areas, assuming an elliptical apparent source.

The apparent source size and location was also determined. The source size is used to determine the average angular subtense, required to evaluate the retinal thermal hazard accessible emission limits.

Since the thermal skin hazard is not considered in the context of the classification system and since hazards are mitigated by the associated pain perceived, this will be no further considered here.

EU Artificial Optical Radiation Directive

As part of directive 89/391/EEC, introducing measures to encourage improvements in the safety and health of workers, the European Union adopted a number of additional directives relating to the working environment. Amongst these additional directives are a group relating to physical agents, such as vibration, noise, electromagnetic fields, and artificial optical radiation; the latter is introduced in the artificial optical radiation directive (AORD) 2006/25/EC.

The measures introduced are designed to prevent harm to workers, particularly to the eyes and skin, due to exposure to coherent and non-coherent artificial sources in the work place.

Measurement methods follow those employed in EN 62471, however consideration of actual worker exposure may lead to the modification of the measurement distance to reflect realistic exposure scenarios.

This analysis will extend the EN 62471 assessment to consider worst case hazards to the skin and front surfaces of the eye for exposure at the closest point of human access (CPHA).

Measurement Equipment

A DIFF_D7 cosine-corrected transmission diffuser ensured the collection of light emitted by the TLS120Xe over the correct geometry to evaluate spectral irradiance. Light was transmitted to a spectrometer using a fused silica fibre bundle. A 190mm focal length crossed Czerny-Turner monochromator, associated with a DH_Si silicon photodiode- coupled to a 487 pico-ammeter- was used to analyse the transmitted spectrum over the range 250 nm -1100 nm. The bandwidth of the instrument was set to 1 nm.

A CL6-H, 150 W quartz halogen standard of spectral irradiance, with calibration traceable to PTB, Germany, was used to calibrate the spectroradiometer in spectral irradiance.

A PSL Profiler CMOS-camera based beam profiler was used to determine the apparent source size and location.

EN 62471 Assessment Results

The TLS120Xe was set up with 10 nm bandwidth, and output iris diaphragm fully opened.

The PSL Profiler was set to image a plane 200 mm distant and the relative separation between the profiler and the TLS120Xe output port was varied to find the smallest retinal image. This was found to be the image formed by the pair of fibre-coupling biconvex lenses, located 12 mm from the end face of the output port, the CPHA, as shown in figure 2.

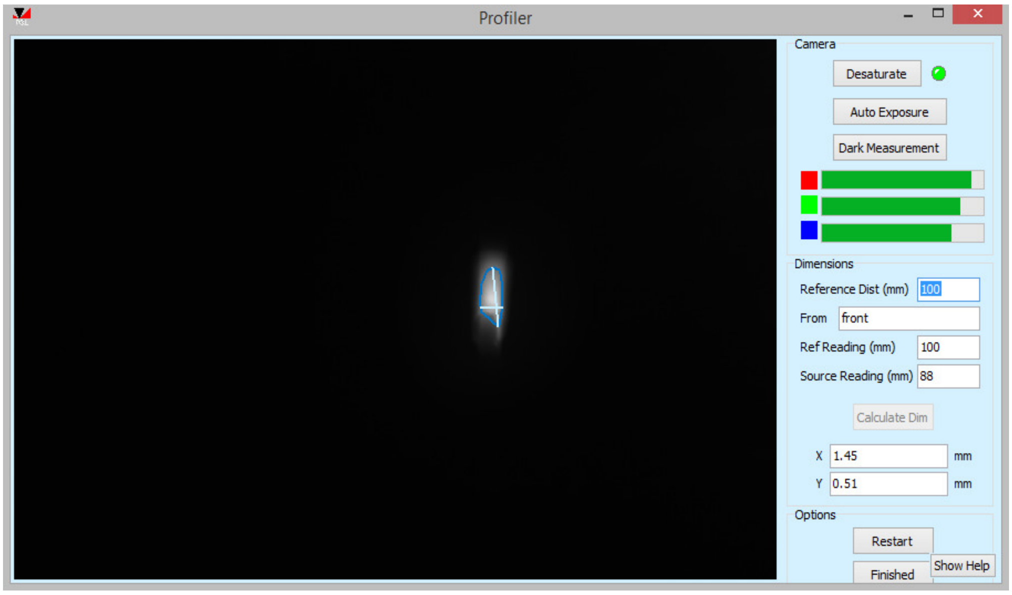

Figure 2

Apparent source size and location determination with PSL Profiler

The spectral irradiance produced at the CPHA was measured over the spectral range 250 nm-1100nm when the TLS120Xe was set to transit white light and 40nm centred on each nominal set wavelength when the TLS120Xe was set to transit monochromatic light. The monochromatic output was assessed in the range 250 nm-1100 nm in steps of 5 nm.

The spectral irradiance produced at 200 mm from the apparent source (188 mm from the CPHA) was also measured over the spectral range 250 nm-1100 nm when the TLS120Xe was set to transit white light.

The ratio of the integrated (and, where applicable, weighted) irradiance for each hazard at 200 mm to that at 0 mm was used to compute the scaling factors to transform the spectral irradiance at 0 mm to that at 200 mm for the set wavelengths in the range 250 nm-1100 nm.

For each hazard, the highest accessible emission was determined and reported in table 3 alongside the TLS120Xe operating condition.

The angular subtense of the apparent source was determined to be 4.90×10^{-3} rad.

EN62471 Assessment: 10nm Bandwidth Setting

Hazard	Measured Value	TLS120Xe Setting	Risk Group	Emission Limit
Actinic UV ($W.m^{-2}$)	$1.9x10^{-1}$	280 nm	RG3	-
Near UV ($W.m^{-2}$)	$8.1x10^{-1}$	320 nm	RG0	$1x10^{1}$
Blue light ($W.m^{-2}.sr^{-1}$)	$1.1x10^{5}$	White	RG2	$4x10^{6}$
Retinal thermal ($W.m^{-2}.sr^{-1}$)	$3.8x10^{5}$	White	RG0	$5.7x10^{6}$
Infrared eye ($W.m^{-2}$)	$2.5x10^{1}$	White	RG0	$1x10^{2}$

Table 3

EN 62471 assessment of TLS120Xe set to 10nm bandwidth

The worst-case bandwidth setting of the TLS120Xe being 40nm, the 10nm bandwidth data was used to estimate values at that bandwidth.

The angular subtense of the apparent source at 40nm bandwidth was estimated to be 8.73x10-3 rad.

EN62471 Assessment: 40nm Bandwidth Setting

Hazard	Measured Value	TLS120Xe Setting	Risk Group	Emission Limit
Actinic UV ($W.m^{-2}$)	$3.1x10^{0}$	280 nm	RG3	-
Near UV ($W.m^{-2}$)	$1.3x10^{1}$	320 nm	RG1	$3.3x10^{1}$
Blue light ($W.m^{-2}.sr^{-1}$)	$1.18x10^{5}$	White	RG2	$4x10^{6}$
Retinal thermal ($W.m^{-2}.sr^{-1}$)	$3.8x10^{5}$	White	RG0	$3.2x10^{6}$
Infrared eye ($W.m^{-2}$)	$4.0x10^{2}$	White	RG1	$5.7x10^{2}$

Table 4

EN 62471 assessment of TLS120Xe set to maximum 40nm bandwidth

AORD Assessment Results

A worst-case exposure analysis extends only to hazards to the skin and anterior surfaces of the eye, given the minimum accommodation distance of the retina of approximately 200 mm.

These hazards were assessed at the CPHA, an unrealistic exposure scenario. Results, provided for information, follow.

Table 5

Artificial optical radiation directive extended assessment of TLS120Xe

AORD Assessment 10nm BW

Hazard	Measured Value	TLS120Xe Setting	Risk Group	Emission Limit
Actinic UV (W.m^{-2})	2.4x10^{4}	280nm	RG3	-
Near UV (W.m^{-2})	8.9x10^{4}	320nm	RG3	-
Infrared eye (W.m^{-2})	2.6x10^{6}	White	RG3	-

Labelling & Safety Information

Given the classification of the TLS120Xe with predominant risks for the UV and blue light hazard, the following label is recommended to be placed near to the output port.

Figure 3

Recommended label for TLS120Xe output port

Further information should be provided in the user manual, according to table 6.

Table 6

Warning and user information relating to the optical radiation safety of the TLS120Xe

Optical Radiation Safety Information

Hazard Designation	Warning	User Information
Actinic UV skin & eye	WARNING. UV emitted from this product.	Avoid eye and skin exposure to unshielded product
Near UV eye	NOTICE UV emitted from this product.	Minimise exposure to eyes. Use appropriate shielding
Retinal blue light	CAUTION. Possibly hazardous optical radiation emitted from this product.	Do not stare at operating lamp. May be harmful to the eyes.
Retinal thermal	-	-
Infrared eye	NOTICE IR emitted from this product.	Use appropriate shielding or eye protection.-

Uncertainty

The uncertainty in the spectral irradiance measurement is estimated to not exceed 10% whilst that of the spectral radiance derivation is estimated not to exceed 25%.

Conclusions

The TLS120Xe poses a moderate risk to the eye and high risk to the skin under direct exposure to the source. In use, the TLS120Xe is designed to be associated with a fibre optic, bundle or liquid light guide to transport light to an experiment. Risks will be reduced significantly in this case, with correct shielding no residual risk will exist.

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