July 2010

Gigahertz-Optik

Measurement of Light

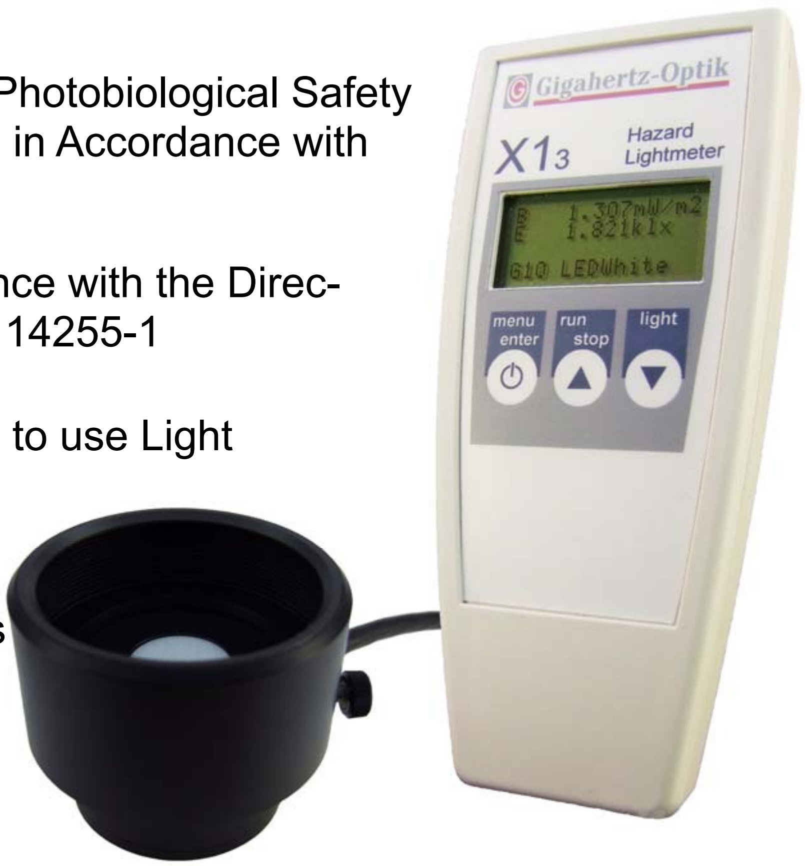
Measurement with Light

Hazard Lightmeter

for Assessment of

UV and BLUE Light Emission and Light Exposure

- Product Classification of the Photobiological Safety of Lamps and Lamp Systems in Accordance with EN 62471
- Workplace safety in Accordance with the Directive 2006/25/EC and DIN EN 14255-1
- Model X13 Portable & Simple to use Light Meter for Constant Radiation
- Model P-9801 High Speed Data Logger for Light Shapes and Pulsed Light Detection



Hazard Lightmeter for Emission & Exposure Values

Dear Colleague:

Optical radiation from artificial and natural light sources can effect a photobiological reaction on human skin and eye with the risk of damage due to overexposure. Regulations including effective limit values are published for equipment safety and occupational safety in the workplaces. Equipment safety requirements that are internationally agreed on, require manufacturer's to classify, design criteria and warning labels for their products, whereas workplace safety is national requiring health protection of employees including published exposure limit values, threat analysis and precautionary measures. The most current regulations are:

Equipment Safety: EN 62471 **Safety of Workplaces:** 2006/25/EC Guideline and DIN EN 14255

Gigahertz-Optik GmbH is a world class manufacturer of high-end filter photometers, colorimeter and radiometers. Effective irradiance meters with ICNIRP / ACGIH UV and Blue Light Hazard spectral sensitivity have been manufactured and calibrated since 1992. The early single sensor design of the hazard meter was later replaced by dual or multi-cell detectors for improved measurement uncertainty but also for simpler operation. To support the 2006/25/EG, DIN EN 62471 and EN 14255-1 standards measurement demands new light meter set-ups for the evaluation of hazard exposure have been developed by Gigahertz-Optik. The simple and inexpensive filter radiometer technology designed by Gigahertz-Optik supports the needs of lamp distributors, light source systems and luminaire manufacturers, institutional and industrial safety engineers, hygienists and others required to perform routine and periodical health hazard optical radiation measurements independently without third party testing laboratories.

Our hazard light meter datasheet not only includes instrument descriptions and technical specifications but also a preliminary guide to the principals of light hazard measurement.

Gigahertz-Optik GmbH

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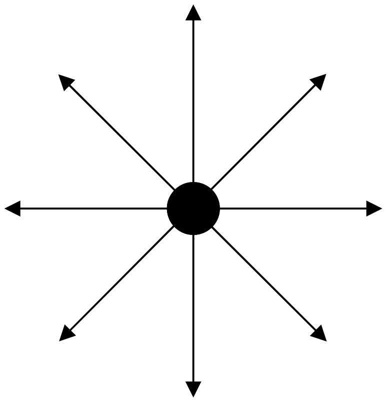
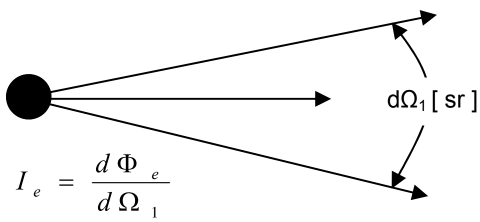
Basics of Light Measurement

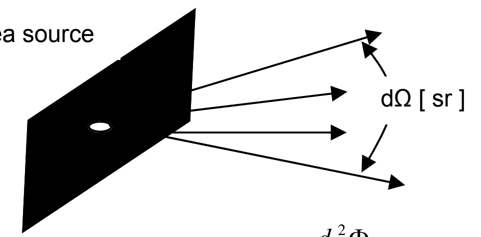


Radiant Power of Φ_e of a Light Source is defined as its total emitted Optical Radiation



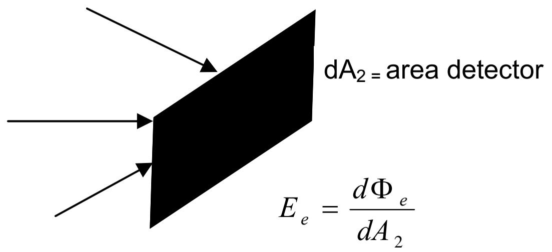
$$I_e = \frac{d\Phi_e}{d\Omega_1}$$

Radiant Intensity is Directional Flux



$$L_e = \frac{d^2\Phi_e}{dA_1 \cdot d\Omega_1}$$

Radiance



$$E_e = \frac{d\Phi_e}{dA_2}$$

Irradiance defined as Incident Radiant Power $d\Phi_e$ per surface area element dA.

Radiant Power Φ_e is the basic radiometric quantity and describes the total amount of electromagnetic radiation emitted by a source. Luminous flux **Φ_v** is the photometric counterpart to radiant power. The unit of radiant power is Watt (W).

Radiant Intensity I_e quantifies the radiant power emitted by a source in a certain direction. In detail, the source's (differential) radiant power $d\Phi_e$ emitted in the direction of the (differential) solid angle element $d\Omega$ is given by

$d\Phi_e = I_e \cdot d\Omega$ and thus $\Phi_e = \int_{4\pi} I_e \, d\Omega$

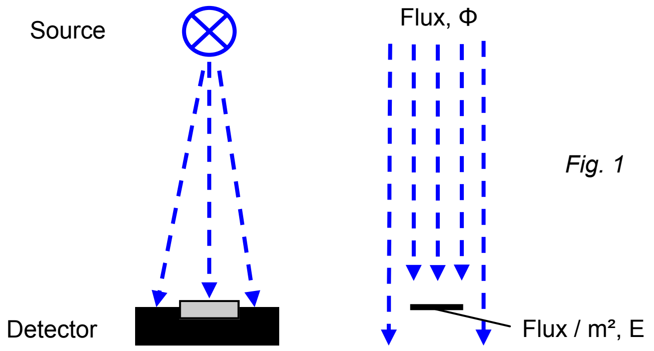
The unit of radiant intensity is Watt per steradian (W/sr)

Radiance L_v and it's photometric equivalent Luminance L_e are the measurement quantities used in applications where the brightness of an object surface needs to be qualified. Luminance can be effected by transmitted light (windows), reflected light (walls) or self emitting sources (monitors).
In detail, the (differential) radiant power $d\Phi_e$ emitted by a (differential) surface element dA in the direction of the (differential) solid angle element $d\Omega$ is given by $d\Phi_e = L_e \cos(\theta) \cdot dA \cdot d\Omega$ with θ denoting the angle between the direction of the solid angle element $d\Omega$ and the normal of the emitting or reflecting surface element dA.
The unit of radiance is W/(m²sr). Radiance is measured at a reference area within the total light emission area. Assuming a uniform light output the radiance measurement can be limited to one point at any position within the radiance area. In case of non-uniform incident light the radiance must be measured at several points to profile the non-uniformity. Averaged radiance with minimum and maximum variation can be evaluated by multiple point measurements.

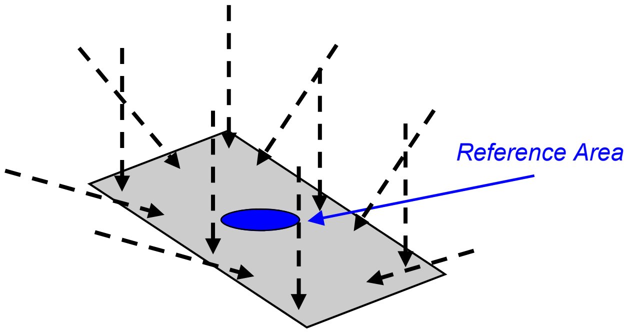
Irradiance E_e Irradiance and it's photometric equivalent illuminance E_v are the most common measurement quantities in applied light measurement applications. It indicates the light incident on object surfaces, e.g. desks, floors and also human skin and eye. Irradiance describes the radiant power per area impinging upon a certain location of an irradiated surface. In detail, the (differential) radiant power $d\Phi_e$ upon the (differential) surface element dA is given by $d\Phi_e = E_e \cdot dA$. Generally, the surface element can be oriented at any angle towards the direction of the beam. Irradiance E_e upon a surface with arbitrary orientation is related to irradiance $E_{e,normal}$ upon a surface perpendicular to the beam by $E_e = E_{e,normal} \cos(\vartheta)$ with ϑ denoting the angle between the beam and the surface's normal. The unit of irradiance is W/m².

Irradiance and Radiance Measurements are required in light hazard measurement applications and therefore described in more detail on the following pages:

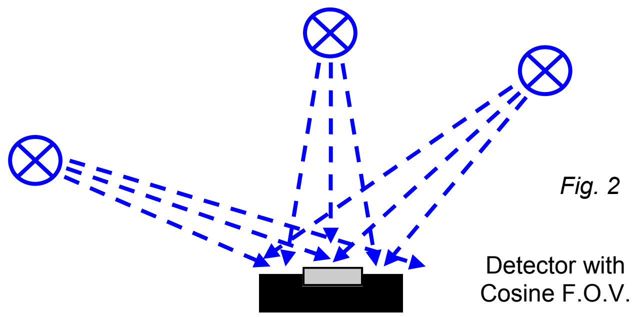
Basics of Light Measurement

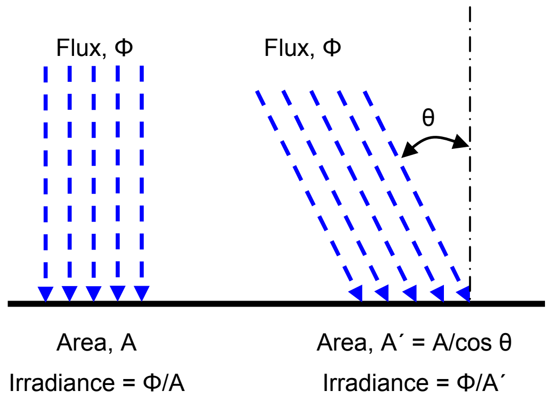


Irradiance Measurement of Single Source



Irradiance is Flux Incident on a Surface





Cosine Law:
Irradiance Decreases with Cosine of Incident Angle

Irradiance Measurement of Multiple Sources with Different Incident Light Angles on Detector

Measurement of Irradiance:

Lighting Conditions:

1. Fig. 1 shows quasi-parallel incident light from a single source or collimated beam light source. Here the irradiance can be measured with a flat field detector with a narrow or wide field of view (F.O.V.) or detector with cosine diffuser perpendicular to incident light axis.
2. Fig. 2 shows diffuse incident light from multiple identical or non-identical light sources requiring a flat field detector with cosine corrected F.O.V. located perpendicular to light axis. Its relative value would be 1 at 0 degrees and 0 at 90 degrees.

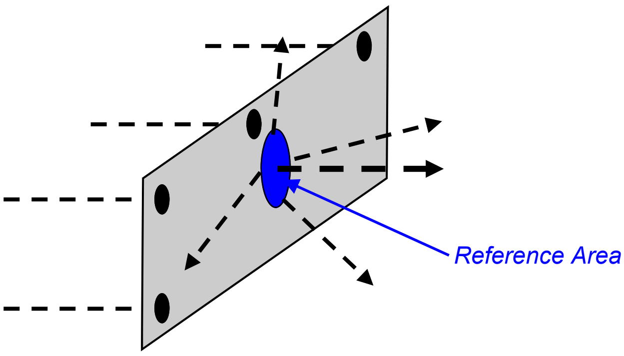
Irradiance is measured in a reference area within the total irradiated area. Assuming a uniform incident light the measurement can be limited to one point at any position within the area of interest. In case of non-uniform incident light the irradiance must be measured at several points to profile the non-uniformity. Averaged irradiance with minimum and maximum variation can be evaluated by multiple point measurements.

Under the hazard aspect irradiance measurements are used for skin and with limitations for the eye. For eye hazard irradiance measurements are only specified in cases where the light source does not focus onto the retina, e.g. large size sources and radiation not transmitted by the pupil.

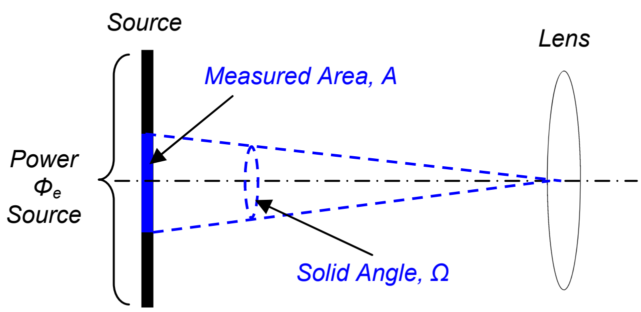
In irradiation measurements with multiple light sources light detectors with cosine corrected field of view are needed.

For several reasons including the physiology of the human eye, all hazard limit values for UV sources are based on sources with a maximum emission angle of 80 degree (1.4 radian). The measurement of light sources with more than 80 degree must be done with detector heads with a limited F.O.V. of 80 degree.

Basics of Light Measurement



Radiance is a measure of the flux density
per unit solid viewing angle.



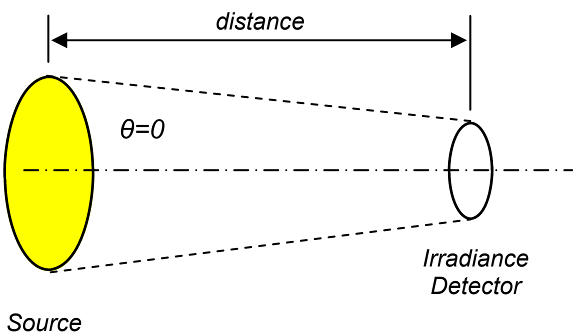
Source Radiance,
Power per Unit Area, per Unit Solid Angle Emitted

Measurement of Radiance with Spot Detector:

Under the hazard effect for the human eye radiance measurements are important for large size sources emitting optical radiation within the spectral emission band of the pupil. Because of this hazard radiance measurements are limited to Blue Light Hazard and Retinal Thermal Hazard.

In its strict definition, radiance is measured using an input optic that measures over a defined are of the source, into a defined solid angle. In applied radiance measurements light detectors with a lens system and specified field of view are used. The smallest image that can be focused on the retina by the eye has a maximum angular extent of 1.7mrad. As exposure time increases this angle increases to a maximum of 100mrad. This is due to eye movement and task-determined movement . This phenomenon is recognized in the hazard measurement standards, that the field-of-view in radiance measurements is relevant to the exposure of the eye, and not the size of the source itself.

Radiance measurements with lens system based light meters are not simple because of detector alignment and focusing reasons. As a result simplified radiance measurements as described on the following pages have been approved.



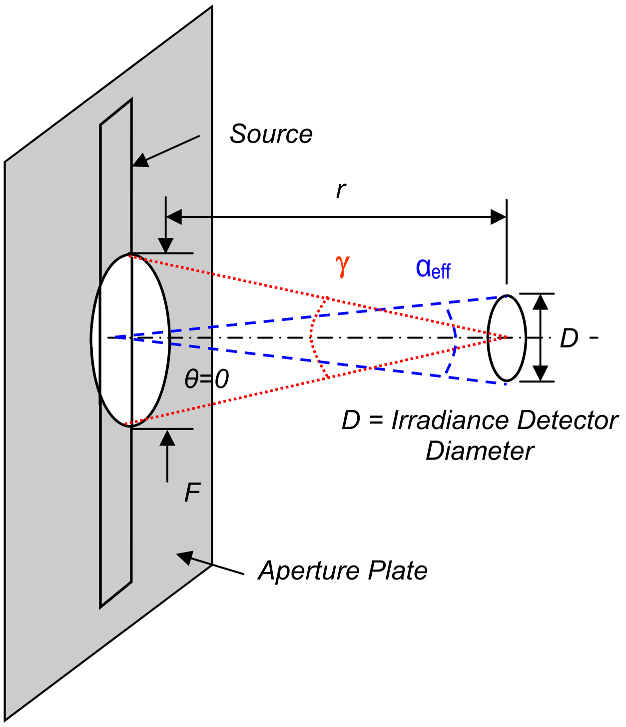
Situation of Radiance Determination

Radiance Measurement with Determined F.O.V. Situation:

The most simple method for evaluation of the radiance limit values is by calculation using the lamp dimensions and distance only.

α is calculated by the averaged size of the source
Ω is calculated by the source area

Basics of Light Measurement



Radiance Measurement with Aperture

Radiance Measurement with Auxiliary Aperture:

The measurement of radiance with a lens system based light meter includes a certain risk of measurement uncertainty due to misalignment and focusing on the measurement object. The precise use of radiance meters requires proper training and experience with the measurement device. Also radiance measurement instruments cost much more than irradiance meters due to their complex front end optics. The main goal of light hazard measurement is to assess any potential optical radiation hazard to avoid personal injury. That gives freedom in performing light measurements with only convergence level to CIE specified light measurement regulations. This is well defined in EN 62471.

Radiance measurement is in principal an irradiance measurement with a well defined field-of-view where the irradiance measurement value is divided by the F.O.V. angle to obtain the radiance value. Using an aperture plate at the source, the radiance meter field-of-view can be simulated. The free aperture diameter *F* and the distance to the irradiance detector measurement aperture *r* define the field of view.

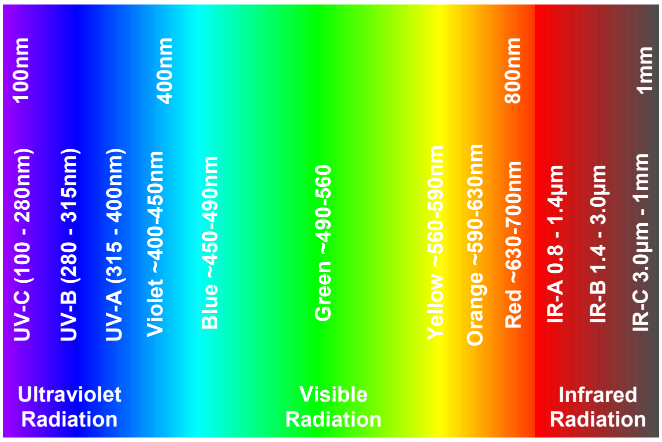
$$\gamma = F / r$$

One precondition is that the distance between source and aperture plate must be kept short for a well defined field-of-view.

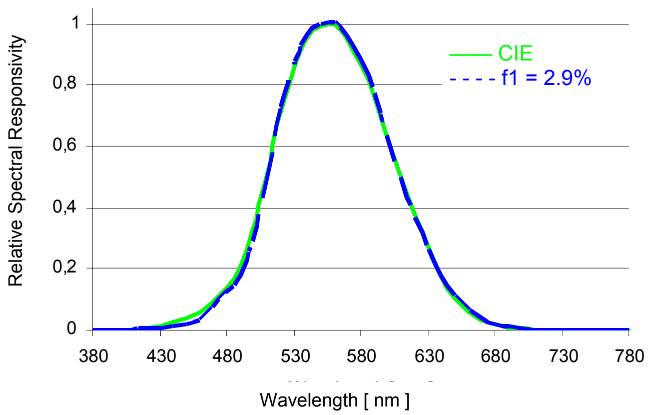
In irradiance measurement applications for the evaluation of radiance hazard light exposure values the diameter of the aperture plate is defined by:

$$\gamma = \alpha_{eff}$$

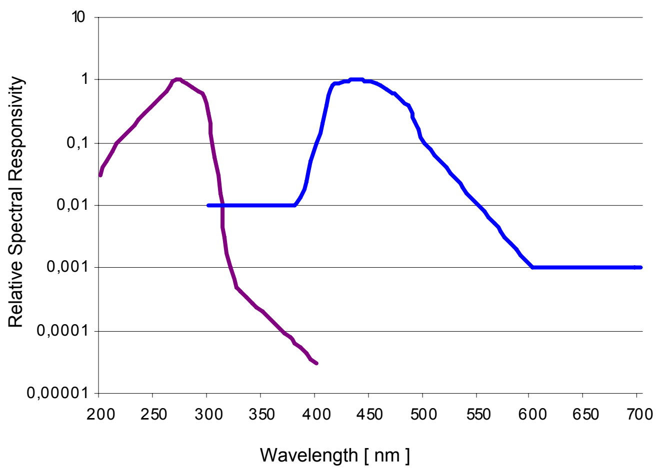
Basics of Light Measurement



Optical Radiation Spectrum



CIE Spectral Sensitivity of the Human Eye V(λ) As Compared to Photometric Detector with very good Spectral Match λ = 380 -780nm



EN 62471 UV and Blue Actinic Sensitivity

Light, the visible part of the electromagnetic radiation spectrum, is the medium through which human beings receive a major portion of environmental information. Evolution has optimized the human eye into a highly sophisticated sensor for electromagnetic radiation. Joint performance between the human eye and visual cortex, a large part of the human brain, dwarfs recent technical and scientific developments in image processing and pattern recognition. In fact a major part of the information flow from external stimuli to our brain is transferred visually.

Photometry deals with the measurement of this visible light energy. The human eye perceives light with different wavelengths as different colors, as long as the variation of wavelength is limited to the range between 400 nm and 800 nm (1 nm = 1 nanometer = 10^{-9} m). Outside this range, the human eye is insensitive to electromagnetic radiation and thus we have no perception of ultraviolet (UV, below 400 nm) and infrared (IR, above 800 nm) radiation.

Radiometry covers the whole spectral range of optical radiation. The term light is commonly incorrectly used for non-visible radiation. As a physical measurement quantity optical radiation is measured without any actinic 'weighting' function. CIE and DIN group optical radiation into spectral ranges, e.g. UV-A, UV-C and IR-A. Optical radiation measurements with an actinic spectral function, e.g. hazard measurements for skin and eye, are performed as effective radiometric measurements. The measurement result or quantity normally indicates what actinic function was followed with the term 'effective' placed in front of the units of measurement. An example would be Effective W/m^2.

Lightmeters for photometric measurements must offer a visible spectral sensitivity correlating to that of the human eye, typically the daylight adapted eye response V(λ). The quality of the V(λ) spectral match to that specified by CIE and DIN is one of the key parameters for photometer specifications. Spectral mismatch error is the key source for measurement uncertainty with light sources other than tungsten lamps normally used in the photometer calibration.

'Lightmeters' for absolute radiometric measurements must offer a wavelength independent sensitivity within the specified spectral range. The spectral mismatch error is one source of measurement uncertainty but can be reduced if the spectral emission distribution of the light source is known.

'Lightmeters' for effective photobiological measurements under the hazard or phototherapy aspect for example must offer a spectral sensitivity weighted according to the specific photobiological process (action spectra). The spectral mismatch error is one source of measurement uncertainty but can be reduced if the spectral distribution of the light source is known.

Basics of Light Hazard Measurement

Health Hazard Effects from Overexposure to Optical Radiation:

Due to absorption of optical radiation in the outer layers of the body and eye optical radiation emitted by artificial light sources effects a photobiological reaction with potential health hazard risk if limit values are exceeded.

Wavelength (nm)		Eye	Skin
100 - 280	UVC	Photokeratitis Photoconjunctivitis	Erythema Skin cancer
280 - 315	UVB	Photokeratitis Photoconjunctivitis Cataracts	Erythema Elastosis (photoageing) Ski cancer
315 - 400	UVA	Photokeratitis Photoconjunctivitis Cataracts Photoretinal damage	Erythema Elastosis (photoageing) Immediate Pigment Darkening Ski cancer
380 - 780	Visible	Photoretinal damage (Blue Light Hazard) Retinal burn	Burn
780 - 1400	IRA	Cataracts Retinal burn	Burn
1400 - 3000	IRB	Cataracts	Burn
3000 - 10^6	IRC	Corneal burn	Burn

Regulations are necessary to ensure **equipment safety** and **safety within the workplaces**. Equipment safety requirements that are internationally agreed on, require manufacturer's to classify, design criteria and warning labels for their products, whereas workplace safety is national requiring health protection of employees including published exposure limit values, threat analysis and precautionary measures. **Equipment Safety:** In Germany fundamental demands on equipment regarding safety and health protection are part of the equipment and product safety law (GPSG). Manufacturer and importer of technical tools and consumer products must ensure that their products are made or qualified in that way that no risk for user and third party exist. The three European Standards Organization (CEN, CENELEC[1) and ETSI) develop product standards and technical specification which guidelines enable the general product safety requirements. Products made or qualified by this standards will be CE labeled and must be accepted by the member states. The GSPG Low Voltage Equipment states that manufacturer and importer must inform the user about the risk of its products following the CIE S009:2002 or IEC 62471:2006 or EN 62471:2008 standards. **Safety in Workplaces:** Workplace orientated safety standards for laser radiation are based on laser and laser accessory classification by the manufacturer or importer as specified in IEC 60825. Following the European Parliament and Council 2006/25/EC guideline employer have to ensure the observing of exposure limit values. The guideline defining the minimum requirements which may be more restricted by member states. It enable a flexible risk evaluation under various condition and situations. IEC 62471:2006 accepted us EN 62471:2008 within the low voltage directive (2006/95/EC) describes the exposure limit values as well as the measurement methodology. Irradiance measurements are mentioned as simpler to perform as compared to radiance measurements that could overtax non-experienced personnel. The standard also describes suitable measurement instruments. The **reference light meter** for hazard classification is the double monochromator spectral radiometer. This is because of the high accuracy demands in spectral resolution and out-of band stray-light suppression. Measurement and calibration laboratories[2), some larger lamp manufacturers, government and military laboratories equipped with these high-grade measurement devices and in-house traceable calibration standards with an experienced staff are able to support these complex and expensive measurements. But what about that manufacturers of lamps and lamp systems and end users not able to invest in that kind of instruments? The expert committee members involved in writing DIN EN 62471 recognized this limitation and recommends spectral broadband (spectral integrating or filtered detector) light meters with some restrictions as an alternative measurement method.

1) *GENELEC member are the national electrotechnical committees of Belgium, Bulgaria, Denmark, Germany, Estonia, Finland, France, Greece, Ireland, Iceland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Austria, Poland, Portugal, Romania, Sweden, Switzerland, Slovakia, Slovenia, Spain, Czech Republic, Hungary, United Kingdom and Cyprus*
2) *Gigahertz-Optik's Calibration Laboratory for Optical Radiation Measurement Quantities DIN EN ISO/IEC 17025 accredited for Spectral Sensitivity and Spectral Irradiance (DKD-K-10601-03 since 1993-06-22) is one of the few industrial suppliers accredited by a national laboratory globally.*
3) *UV-Network ISSN 1456-2537 UVNEWS The official newsletter of Thematic Network for Ultraviolet Measurement Issue6 /November 2000 pages A-10f*

Basics of Light Hazard Measurement

Hazard	Risk for	λ Range (nm)	Quantity
UV-A,B,C	Eye&Skin	200-400	Irradiance ICNIRP weighted
UV-A	Eye	315-400	Irradiance
Blue Light	Eye	300-700	Radiance for large sources, B(λ) weighted
Blue Light	Eye	300-700	Irradiance for small sources, B(λ) weighted
Retinal Thermal	Eye	380-1400	Radiance, weighted
RT - weak visual stimulus	Eye	780-1400	Radiance, weighted
IR Radiation	Eye	780-3000	Irradiance
IR Radiation	Skin	380-3000	Irradiance

EN 62471:2009 Specified Measurements

Hazard	λ Range nm	Exposure [s]	Limiting Aperture	Limit Value E continue
	nm	s	Rad(deg)	$W \cdot m^{-2}$
UV Actinic Skin & Eye	200-400	<30000	1.4(80)	30/*t*
Eye UV-A	315-400	≤ 1000 > 1000	1.4(80)	10000/*t* 10
B(λ) small source	300-700	≤ 100 > 100	<0.011	100/*t* 1.0
			F.O.V. rad	L continue $W \cdot m^{-2} \cdot sr^{-1}$
B(λ) Retina	300-700	0.25 - 10 10 - 100 100 - 10000 ≥ 10000	$0.011 \cdot \sqrt{(t/10)}$ 0.011 $0.001\ 1 \cdot \sqrt{t}$ 0.1	$10^6/t$ $10^6/t$ $10^6/t$ *100*
Thermal Limit Values are not listed				

EN 62471:2009 Limit Values for Skin, Cornea and Retina

Hazard	Symbol	Emission Limit Values			Unit
		risk free	low risk	mean risk	
Actinic UV	E_s	0.001	0.003	0.03	$W \cdot m^{-2}$
UV-A	E_{UVA}	10	33	100	$W \cdot m^{-2}$
B(λ) small source	B(λ)	1.0 *)	1.0	400	$W \cdot m^{-2}$
B(λ)	B(λ)	100	10 000	4 000 000	$W \cdot m^{-2} \cdot sr^{-1}$

- *) the definition of a small source is a source with angle spreading of α<0.011 radiant. The field of view for averaging during the measurement is 0.1 radiant at 10000s
- Thermal Limit Values are not listed

EN 62471:2009 Risk Group Limit Values of CW Lamps

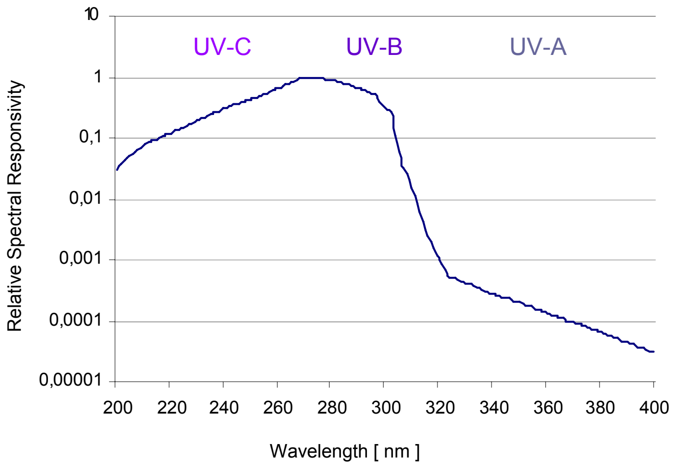
In the European Union product safety is assured by a **CE Conformity Marking**. With this product marking manufacturers and importers confirm compliance with relevant applicable EU directives such as General Product Safety Directive, Low Voltage Directive and so on. Technical requirements for compliance to these general directives are achieved in the Form of Essential Health and Safety Requirements (EHSRs). The CENELE (European Committee for Electrotechnical Standardization) create relevant safety standards often based on those published by the International Electrotechnical Committee (IEC). These European Norm (EN) are standardized to support one or more directives and published by individual EU members states, sometimes with deviations particular to their country. These standards are not mandatory but give the presumption of compliance with the essential health and safety requirements. **The classification of lamps** is part of EN 62471 to enable risk group classification and definition of distances at which photobiological risk values effect lamp radiation. Because of different risk aspects a classification scheme is provided:

- Limit emission values in E or L for general purpose lamps should be specified at a distance with a illuminance value of 500lx at a distance not shorter than 200mm.
- Limit emission values for all other lamps including flash lamps should be specified at a distance of 200mm

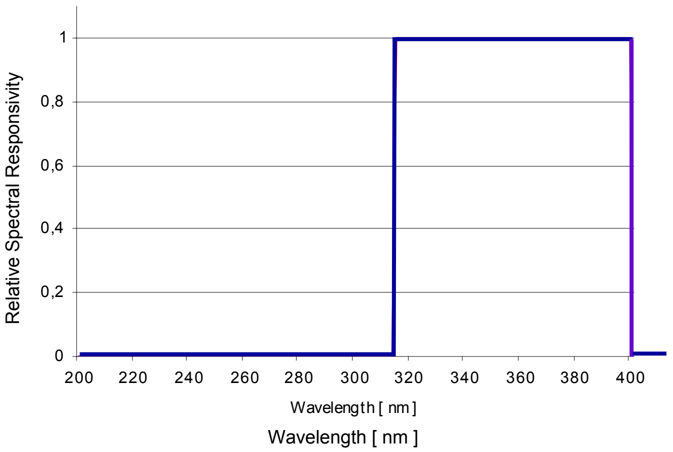
This scheme for lamps can also be used for lamp systems or other systems employing lamps. The classification scheme only points out the potential risk not the risk due to abuse and overexposure time.

The matter of Artificial Optical Radiation Hazard 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 by law by the 27th April 2010. The goal is to prevent harm to workers due to exposure of the skin and eyes to coherent and non-coherent artificial sources in the work place. The burden of responsibility lies with the employer to ensure that risks be assessed and if needed effectively reduced and that the workforce be aware of that risks. The methodology in the determination of exposure levels is not specified but should follow IEC/CEI standard for non-coherent radiation such us EN62471. Within Europe the limit values are already specified in directive 2006/25/EG and should be used instead of IEC 62471:2006. Limit values for workplaces should be measured at the place of exposure.

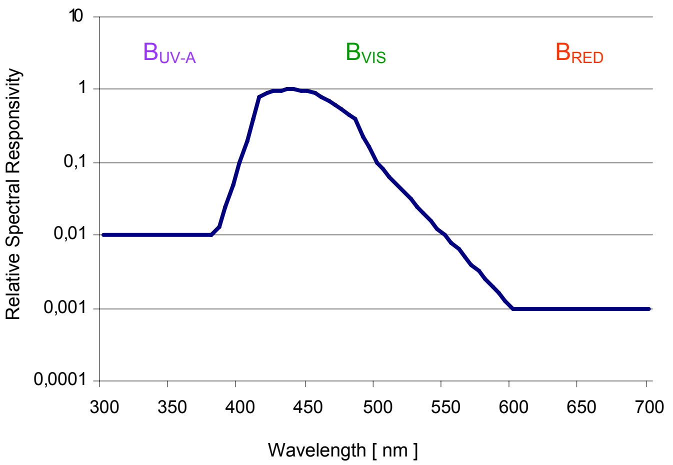
Basics of Light Hazard Measurement



$S_{UV}(\lambda)$ for Skin and Eye



UV-$A_{315\text{-}400nm}$ for Eye



$B(\lambda)$ for Retina

Light hazard measurements are measurements of the light emission of light sources for **correlation** with the hazard exposure limit values specified in EN 62471. To enable the comparison the measurements must be done in the corresponding measurement quantities, within the specified wavelength ranges and with the spectral weighting function specified. For UV hazard and BLUE Light hazard measurements two different measurement quantities and thee different spectral weighting functions are recommended.

Spectral Sensitivity Functions (DIN EN 62471:2009-02 and EN 62471:2008):

$S_{UV}(\lambda)$ spectral weighting function for actinic UV radiation for UV hazard measurements. In other standards and international guides it is known as the ACGIH and later ICNIRP spectral effectiveness function. The limit values specified are for irradiation of unprotected skin and eye during an eight hour period. Continuous irradiation longer than eight hours must not be considered. The limit value is 30 $J \cdot m^{-2}$.

UV-$A_{315\text{-}400nm}$ function is specified for near UV hazard measurements. The limit value specified for the non protected eye for less than 1000s is 10000 $J \cdot m^{-2}$. For irradiation periods longer than 1000s the UV-A irradiance E_{UVA} must be below 10 $W \cdot m^{-2}$.

$B(\lambda)$ spectral weighting function for photochemical retinal damage is specified for blue light hazard measurements. The limit values are specified in different ways for small or large size light sources. For small size sources the actinic irradiance needs to be measured - for large size sources the actinic radiant intensity. The limit values are shown in the table on page 4.

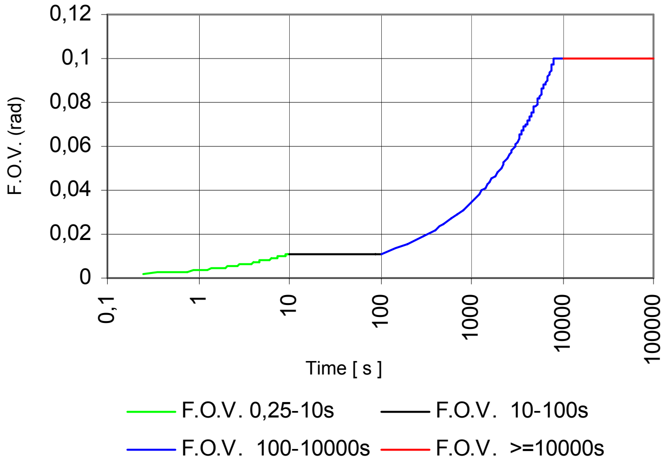
Preparation for a Light Hazard Measurement:

Before any actual measurements take place some decisions for classification of the light source must be made. This includes **technical aspects,** e.g. source has no UV emission, source has no strong IR emission and **application aspects,** e.g. source is designed for general lighting purposes (GLP) or for other applications. This classification will indicate the necessary range of measurements and the measurement strategy.

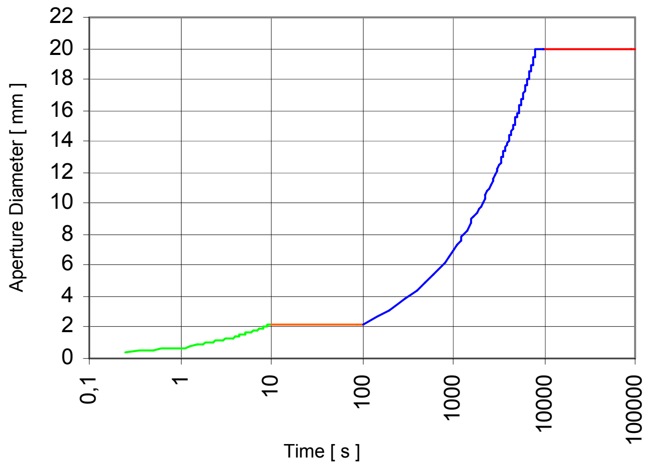
The emission spectrum of the light source indicates if UV Hazard or Blue Light Hazard or both needs to be measured. For GLP lamps it is recommended to evaluate a source at a distance that produces an illuminance of 500lx. In practice the measurement distance may be several meters. In all other cases the measurement should be performed at a 200mm distance.

Determining the F.O.V. and the F.O.V. dependent aperture size for radiance measurements using an aperture are described on the following page.

Basics of Light Hazard Measurement



F.O.V. as Function of Exposure Time



Aperture Diameter as Function of Exposure Time
r = 200 mm

Determining F.O.V. for Radiance Measurements:

The smallest image that can be focused on the retina by the eye has a maximum angular extent of 1.7mrad. With increasing exposure time this is increased to a maximum of 100mrad. This is due to eye movement and task-determined movement . This phenomenon, that the field-of-view in radiance measurements is relevant to the exposure of the eye, and not the size of the source itself is recognized in the hazard measurement guidelines.

Determining Aperture Diameter for Radiance Measurements :

Radiance measurement is in principal an irradiance measurement with a well defined field-of-view where the irradiance measurement value is divided by the F.O.V. angle to obtain the radiance value. Using an aperture plate at the source, the radiance meter field-of-view can be simulated. The free aperture diameter *F* and the distance to the irradiance detector measurement aperture *r* define the field of view.

$$\gamma = F / r$$

One precondition is that the distance between source and aperture plate must be kept short for a well defined field-of-view.

In irradiance measurement applications for the evaluation of radiance hazard light exposure values the diameter of the aperture plate is defined by:

$$\gamma = \alpha_{eff}$$

On the following pages examples of certain types of light hazard measurement are described.

Basics of Light Hazard Measurement

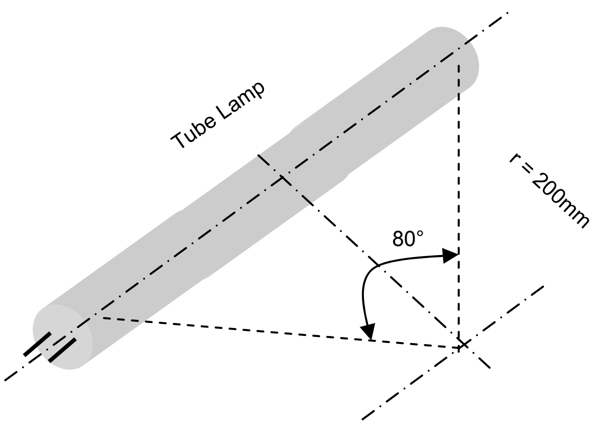
Light Hazard Assessment Example 1:

High Intensity Industrial Tube Lamp

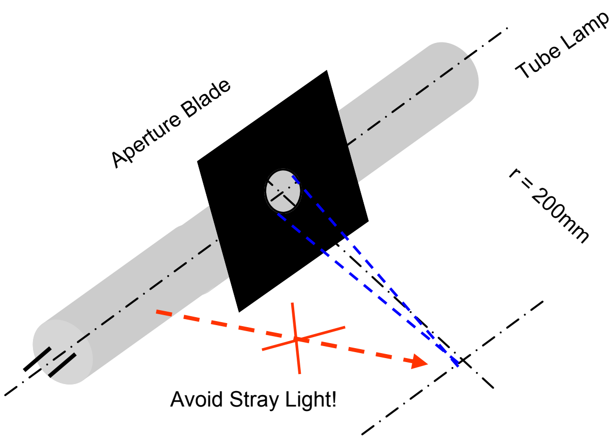
First Step: Assumption

1. UV tube lamp for industrial applications
2. Measurement distance r specified at 200mm
3. UV source therefore S_{UV} evaluation required
4. UV-A emission therefore B(λ) evaluation required

Second Step: S_{UV} Skin and Eye Risk Evaluation (picture 1)



Picture 1: S_{UV} and UV-A Irradiance Measurement Situation



Picture 2: B(λ) Radiance Measurement Situation

Measurement of S_{UV} actinic irradiance for Skin and Eye protection with XD-45HUV detector head in r = 200mm distance to tube. Measurement value in W/m².

- If the measurement value is < 1mW/m² the source can be specified as risk free.
- If the measurement value is > 1mW/m² the maximum safe exposure time in seconds must be specified [30J/m²/(SUV value in W/m²)]

Third Step: UV-A Eye Risk Evaluation (picture 1)

Measurement of UV-A irradiance for Eye protection with XD-45HUV detector head in r = 200mm distance. Measurement value in W/m².

- If the measurement value is < 10W/m² the source can be specified as risk free
- If the measurement value is > 10W/m² the maximum safe exposure time in seconds must be specified [10000J/m²/(UV-A value in W/m²)]

Fourth Step: *B(λ) Retinal Risk Evaluation (picture 2)*

- Large source therefore measurement in radiance values
- F.O.V. selected with 0.1rad for risk free sources with ≥10000s exposure time
- The diameter of the aperture is calculated by the measurement distance r and the specified F.O.V. with D = 200 x 0.1 = 20mm$^{\varnothing}$

Measurement of the B(λ) actinic irradiance with XD-45HB detector head and 200mm length XD-45-HB-SRT steradian tube adapter with 20mm aperture cap. Measurement value in W/m².

The radiance L is calculated by E and Ω:
Ω = A (area of the aperture) / r^2 (measurement distance)
Which is Ω = 0.000314m² / 0.04m² = 0.00785sr

The radiance L = E (value in W/m²) / 0.00785

- If the value ≤100 $W \cdot m^{-2} \cdot sr^{-1}$ the source can be specified as risk free
- If the measurement value is >100 $W \cdot m^{-2} \cdot sr^{-1}$ the maximum safe exposure time in seconds must be specified. The evaluation of the 10 to 100 second exposure time condition can be supported by a measurement with the 11mrad aperture adapter cap of the SRT200 tube. The values for 0.25 - 10 and 100 - 10000 second exposure are calculated by the calculated F.O.V. with use of the estimated source size.

Basics of Light Hazard Measurement

Light Hazard Assessment Example 2:

Lamp with four Fluorescence Tubes for General Lighting

First Step: Assumption

1. Sources with four 57cm x 2cm 18W tube lamps within a 60x60cm housing with reflectors, no diffuser
2. Non-uniform light source = single lamp determination
3. No relevant IR radiation emission
4. Source for general lighting application only. Distance for lamp risk classification following the 500lx distance guideline

Second Step: Measurement Distance Evaluation

Measurement of illuminance E with detector head XD-45HB to evaluate the measurement distance in front of the light source at 500lx illuminance level.

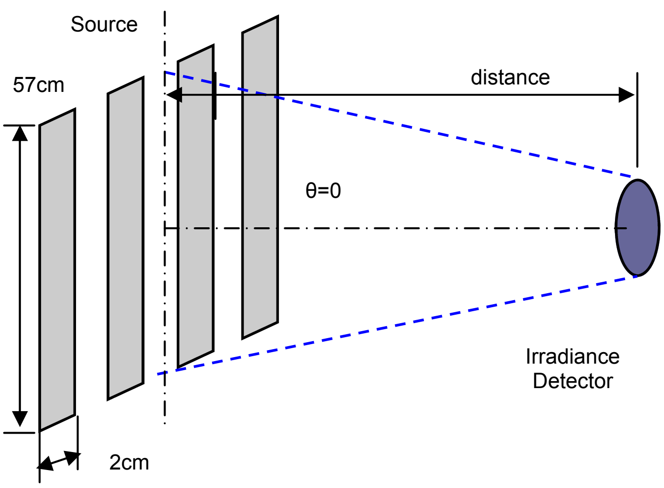
Third Step: S_{UV} Skin and Eye Risk Evaluation

Measurement of S_{UV} actinic irradiance for Skin and Eye protection with XD-45HUV detector head. Measurement value in W/m².

- If the measurement value is < 1mW/m² the source can be specified as risk free.
- If the measurement value is > 1mW/m² the maximum safe exposure time in seconds must be specified (30J/m²/SUV value in W/m²)

Fourth Step: UV-A Eye Risk Evaluation

Measurement of UV-A irradiance for Eye protection with XD-45HUV detector head. Measurement value in W/m².



Picture 1: B(λ) Radiance Determination Situation

- If the measurement value is < 10W/m² the source can be specified as risk free
- If the measurement value is > 10W/m² the maximum safe exposure time in seconds must be specified (10000J/m²/UV-A value in W/m²)

Fith Step: B(λ) classification

Evaluation of the measurement distance detector to source at 500lx by the measurement of E in lx with detector head XD-45HB

Source size definition:
Averaged source size: (57cm+2cm) / 2 = 29.5cm
r = specified for 500lx illuminance level (example r = 1m)
α = 0.295rad
α ≥ 0.011 = large size source = L measurement

Measurement of B(λ) actinic *irradiance E with detector head XD-45HB at the 500lx reference plane. Measurement value in W/m².*

Calculation of the B(λ) actinic radiance L by E measurement value and calculated Ω

Ω = A (area of single source) / r^2 (measurement distance)
Which is Ω = 0.114m² / 1m² = 0.114sr

The radiance L = E (value in W/m²) / 0.114sr

- If the value ≤100 $W \cdot m^{-2} \cdot sr^{-1}$ the source can be specified as risk free
- If the measurement value is >100 $W \cdot m^{-2} \cdot sr^{-1}$ the maximum safe exposure time in seconds must be specified. The evaluation of the 10 to 100 second exposure time condition can be supported by a measurement with the 11mrad aperture adapter cap of the SRT200 tube. The values for 0.25 - 10 and 100 - 10000 second exposure are calculated by the calculated F.O.V. with use of the estimated source size.

Basics of Light Hazard Measurement

Light Hazard Assessment Example 3:

LED Spot for General Lighting

First Step: Assumption

1. Source set-up with white blue stimulated phosphor LEDs with no UV emission and therefore no need for UV hazard measurement
2. Uniform light source definition
3. Source for general lighting applications. Blue light hazard measurement following 500lx distance guideline

Second Step: B(λ) classification

Evaluation of the measurement distance detector to source at 500lx by the measurement of E in lx with detector head XD-45HB

Source size definition:

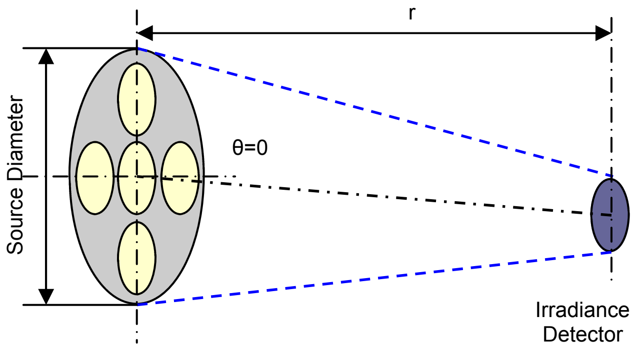
Source size: 80mm$^{\varnothing}$
r = specified at 500lx illuminance level (example r = 1m)
α = 0.08rad
α ≥ 0.011 = large size source = L measurement

Measurement of B(λ) actinic *irradiance E with detector head XD-45HB at the 500lx reference plane. Measurement value in W/m².*

Calculation of the B(λ) actinic radiance L by E measurement value and calculated Ω

Ω = A (area of the source) / r^2 (measurement distance)
Which is Ω = 0.005m² / 1m² = 0.005sr

The radiance L = E (value in W/m²) / 0.005sr



Picture 1: B(λ) Radiance Determination Situation

- If the value ≤100 $W \cdot m^{-2} \cdot sr^{-1}$ the source can be specified as risk free
- If the measurement value is >100 $W \cdot m^{-2} \cdot sr^{-1}$ the maximum safe exposure time in seconds must be specified. The evaluation of the 10 to 100 second exposure time condition can be supported by a measurement with the 11mrad aperture adapter cap of the SRT200 tube. The values for 0.25 - 10 and 100 - 10000 second exposure are calculated by the calculated F.O.V. with use of the estimated source size.

Basics of Light Hazard Measurement

Light Hazard Assessment Example 4:

LED Spot Light for Industrial Applications

First Step: Assumption

1. Sources with blue LEDs with no UV emission and therefore no need for UV hazard measurement
2. Source for industrial applications. Blue light hazard measurement following the 200mm distance guideline.
3. Single LED spots visible therefore no uniform light source definition
4. Blue light hazard measurement focusing on the single LED (hot) spots

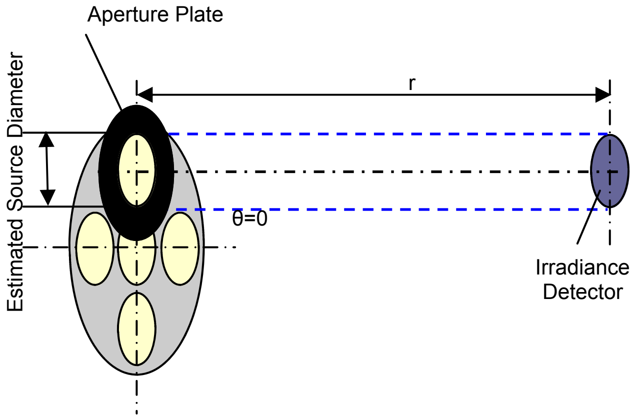
Second Step: Small or Large Source Definition:

Source size: ca. 10mm$^{\varnothing}$
r = 200mm
α = 0.05rad
α ≥ 0.011 = large size source = L measurement

Third Step: B(λ) classification

Measurement of the B(λ) actinic irradiance with XD-45HB detector head and 200mm length XD-45-HB-SRT steradian tube adapter with 20mm aperture cap. The hot spots must be centered and fall completely within the 20mm measurement apertur. The hot spot with most intensive irradiance value is taken for the risk evaluation. Measurement value in W/m².

*Calculation of the B(*λ) actinic radiance L by E measurement value and calculated Ω



Picture 1: B(λ) Radiance Determination Situation

Ω = A (area of the source) / r^2 (measurement distance)
Which is Ω = 0.0001m² / 0.04m² = 0.0025sr
A = 0.01m diameter (estimated)
r = 0.2m

The radiance L = E (value in W/m²) / 0.0025sr

- If the value ≤100 $W\cdot m^{-2}\cdot sr^{-1}$ the source can be specified as risk free
- If the measurement value is >100 $W\cdot m^{-2}\cdot sr^{-1}$ the maximum safe exposure time in seconds must be specified. The evaluation of the 10 to 100 second exposure time condition can be supported by a measurement with the 11mrad aperture adapter cap of the SRT200 tube. The values for 0.25 - 10 and 100 - 10000 second exposure are calculated by the calculated F.O.V. with use of the estimated source size.

Simplified Method:

Measurement Distance	200mm
Measurement Aperture	20mm diameter
Maximum Field of View	0.1rad
Minimum F.O.V. for L Measurements	0.011rad
Estimated Source Diameter	**L=E*factor**
2.2mm	1.05E+04
3mm	5.66E+03
4mm	3.18E+03
5mm	2.04E+03
8mm	7.96E+02
10mm	5.09E+02
15mm	2.26E+02
20mm	1.27E+02

If the irradiance is measured with the XD-45-HB-SRT steradian adapter with 20mm aperture cap the maximum field of view is limited to 100mrad. Smaller diameter sources effect a field of view between 100mrad to 11mrad. The following tabular enables the quick L calculation by the estimated source diameter.

The limit values for small sources with <11mrad (2.2mm diameter in 200mm distance) are specified in irradiance E values (small source)! The 2.2mm diameter aperture cap of the XD-45-HB-SRT steradian tube adapter supports irradiance measurements of small size sources.

Basics of Light Hazard Measurement

Light Hazard Assessment Example 5:

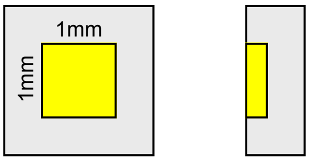
Single LED Chip without Lens

First Step: Assumption

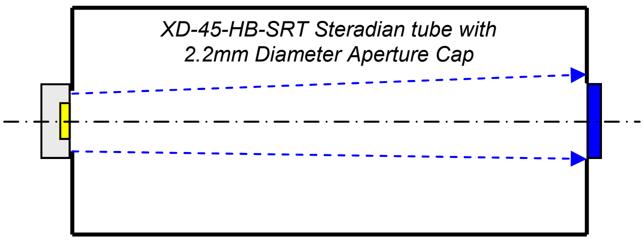
1. Sources with white blue stimulated phosphor LEDs with no UV emission and therefore no need for UV hazard measurement
2. Blue light hazard measurement following the 200mm distance stated

Second Step: Small or Large Source Definition:

Source size: ca. 1x1mm
r = 200mm
α = 0.005rad
α ≤ 0.011 = small size source = E measurement



Picture 1: LED Size



Picture 2: B(λ) Irradiance Measurement Set-up

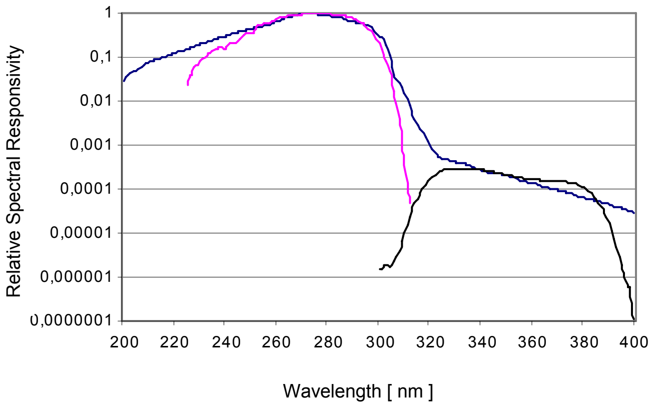
Third Step: B(λ) classification

Measurement of the B(λ) actinic irradiance with XD-45HB detector head and 200mm length XD-45-HB-SRT steradian tube adapter with 2.2mm aperture cap. The hot spots must be centered and fall completely within the 2.2mm measurement aperture.

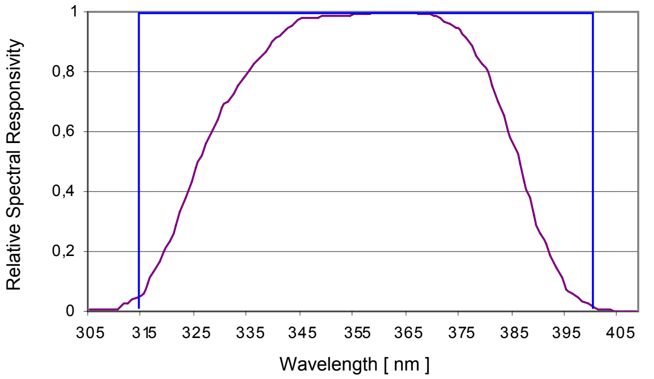
- If the value ≤1W·m^{-2} the source can be specified as risk free for exposure time longer than 100 seconds
- If the exposure time is shorter than 100 seconds the maximum irradiance value is specified as 100(W/m²)/100s

Product Description: XD-45-HUV UV-Hazard Detector Head

XD-45-HUV Detector with 80° FOV Adapter



$S_{UV}(\lambda)$ *EN62471 Spectrum*
UV-CB and UV-A Sensor Responsivity Spectrum



UV-A *EN62471 Spectrum*
UV-A Sensor Responsivity Spectrum

The XD-45-HUV irradiance detector is specially designed for the evaluation of light exposure hazard values for artificial light sources. The three sensor design of this unique device covers the requirements for skin and eye risk assessment.

The ICNIRP spectral sensitivity required for skin and eye risk evaluation is formed using two filtered sensors. This prevents the typical cross-talk and limited sensitivity dynamic between the UV-A, UV-B and UV-C spectral ranges of a single filtered sensor solution. Also, a UV-A sensor for the evaluation of UV-$A_{315\text{-}400nm}$ human eye risk is integrated. All three detector heads are mounted behind the 20mm diameter cosine diffuser. For measurements of eye dependent irradiance values a front adapter is supplied to limit the detector field-of-view to 80 degrees.

Calibration of the detector ICNIRP (W/m²) and UV-A (W/m²) sensitivity is performed by the Gigahertz-Optik GmbH calibration laboratory for optical radiation measurements quantities. As with all light detectors supplied by Gigahertz-Optik the calibration of the detector sensitivity includes the relative spectral sensitivity data. Having this data available allows the measurement uncertainty of each individual sensor to be calculated for light sources different than the reference lamp used for calibration. This includes a wide range of UV rich lamps as well as simulated UV LED sources. In measurements where the type of light source is known, source specific calibration correction factors are supplied to improve the measurement uncertainty.

Specifications:

$S_{UV}(\lambda)$ effective irradiance measurement range:
0.5mW/m² to 10W/m² (max. resolution 0.05mW/m²)

S_{UV}(200-320nm) cell effective measurement range:
0.5mW/m² to 10000W/m² (max. resolution 0.05µW/m²)

S_{UV}(320-400nm) cell effective measurement range:
0.5µW/m² to 10W/m² (max. resolution 0.05µW/m²)

UV-$A_{315\text{-}400nm}$ irradiance measurement range:
0.2mW/m² to 10000W/m² (max. resolution 0,02mW/m²)

Remarks:

- Specifications stated for X1_3 meter plus detector
- The maximum measureable irradiance and illuminance value may be limited by heat radiated by the source under test

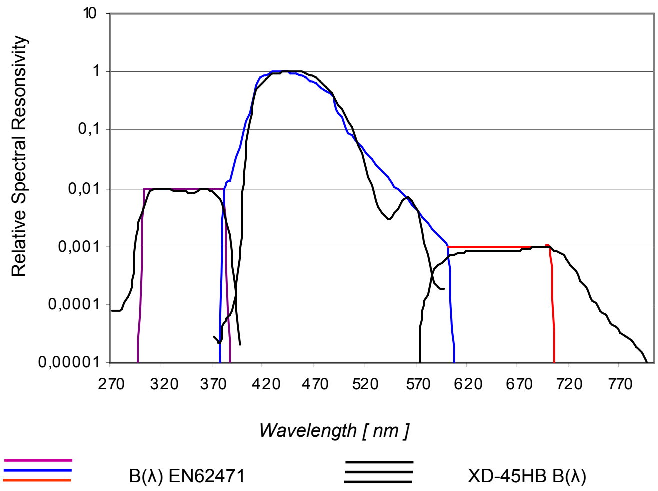
XD-45-HB BLUE-Light Hazard Detector Head

XD-45-HB

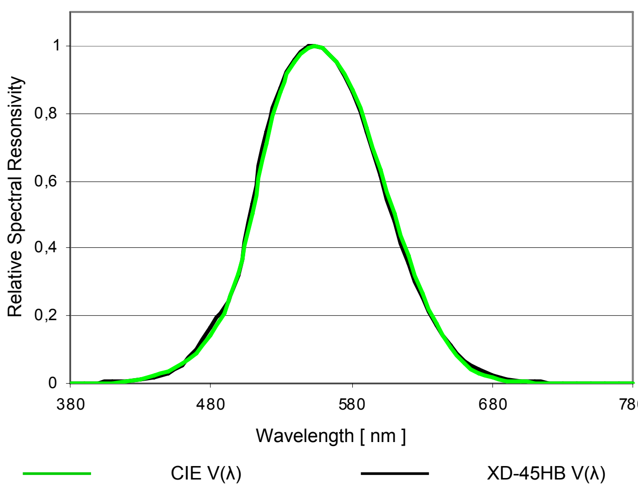
The XD-45-HB irradiance detector is specially designed for the evaluation of Blue light exposure hazard values for artificial light sources. The four sensor design of this unique device covers the requirements for eye risk assessment.

The Blue Light Hazard spectral sensitivity required for eye risk evaluation is formed by three filtered sensors for the $BLUE_{UA300-400}$, $BLUE_{400-600}$ and $BLUE_{RED600-700}$ spectral ranges. The EN 62471 conformal B(λ) detector is useful for evaluation of any type light source that contains UV-A and deep red light components. Also, a V(λ) photometric sensor for the evaluation of illuminance in lx is integrated to establish the 500lx reference distance protocol for the illuminance and/or radiance qualification. All four filtered sensors are mounted behind the 20mm diameter cosine diffuser.

Calibration of the B(λ) (W/m²) and $E_{v\ (lx)}$ detector sensitivity is performed by the Gigahertz-Optik GmbH calibration laboratory for optical radiation measurements quantities. As with all light detectors supplied by Gigahertz-Optik calibration of the detectors sensitivity includes the relative spectral sensitivity data. Having this data available allows the measurement uncertainty of each individual sensor to be calculated for light sources different than that of the reference lamp used for calibration. This includes a wide range of lamps as well as simulated LED sources. In measurements where the type of light source is known, source specific calibration correction factors are supplied to improve the measurement uncertainty.



XD-45-HB B(λ) Detector Spectral Responsivity



XD-45-HB V(λ) Detector Spectral Responsivity

Specifications:

B(λ) effective irradiance measurement range:
0.02mW/m² to 100W/m² (max. resolution 2µW/m²)

B(300-380nm) cell effective measurement range:
2µW/m² to 100W/m² (max. resolution 0.2µW/m²)

B(380-600nm) cell effective measurement range:
20µW/m² to 1000W/m² (max. resolution 2µW/m²)

B(600-700nm) cell effective measurement range:
0.05µW/m² to 2W/m² (max. resolution 0.005µW/m²)

V(λ) illuminance measurement range:
0.2lx to 1000000lx (max. resolution 0,02lx)

Remarks:

- Specifications stated for X1_3 meter plus detector
- The maximum measureable irradiance and illuminance value may be limited by heat radiated by the source under test

XD-45-HB-SRT200 100mrad/11mrad F.O.V. & Distance Adapter

Adapter assembled to XD-45-HB Detector Head

The XD-45-HB-SRT200 adapter is an unique tool for product qualification measurements of blue light hazard at the recommended distance of 200mm. The adapter which can simply and precisely assembled to the front of the XD-45-HB detector head offers two exchangeable aperture plates to form a 100mrad (20mm diameter) and 11mrad (2.2mm diameter) field of view as stated in EN 62471:2009 limit values (see table on page 8). The adapter is made out of light weight plastic with internal baffles and low reflection coating to reduce side wall stray light. The XD-45-HB-SRT200 adapter is an optionally available detector accessory component. No extra calibration is required.

X1₃ Optometer

XD-45-HUV
XD-45-HB

Detector Selection

Average
LED white
Xenon Low Pressure
CFL Daylight

Source Selection

SU nnnn W/m2
UVA nnnn W/m2

S: Xe Low Pressure

UV-Hazard Display

B nnnn W/m2
E nnnn lx

S: CFL Daylight

Blue-Hazard Display

Gigahertz-Optik X1 meter introduced in 2001 is one of the most compact and ergonomically styled multi-channel light meters available. It's simple operation and reasonable price make it the basic meter in many Gigahertz-Optik and other OEM light measurement applications.

To support light hazard measurements in the ultraviolet, blue and visible spectral range Gigahertz-Optik offers different detector heads each in multiple sensor design. The Gigahertz-Optik X1₃ (X-One-Three) Optometer is the read-out meter for these multi-cell detectors in stationary and mobile applications with CW operated light sources. The key features of the X1₃ optometer are:

- Four channel electronics for multi-cell detectors
- Wide dynamic range (0.1pA to 200µA amplifier)
- Low noise for high sensitivity (0.1pA resolution)
- Auto ranging gain control
- Range dependent gain calibration for high linearity over the full measurement range (DKD traceable)
- Four column alphanumeric display
- Powerful microprocessor operation
- Large data storage memory
- Simple to use menu supported operation
- Ergonomic hand-held meter design
- Battery or USB power operation
- USB interface

Quick Operation Guide:

After switching on the meter the main menu is opened by pressing the *menu* button. Depending on the measurement application the UV Hazard or Blue Light Hazard detector, connected to the meter, is selected by its model number. The detector calibration data is activated by the *enter* key and the display is automatically set to the correlating measurement values. If the light source characteristics in the application are not known an average calibration factor is used. A light source emission spectrum dependent measurement uncertainty is factored into the average instruments uncertainty. If the light source can be indisputably identified a light source dependent calibration correction factor can be selected from a library in the menu to reduce measurement uncertainty. The instrument is then ready for actual measurements.

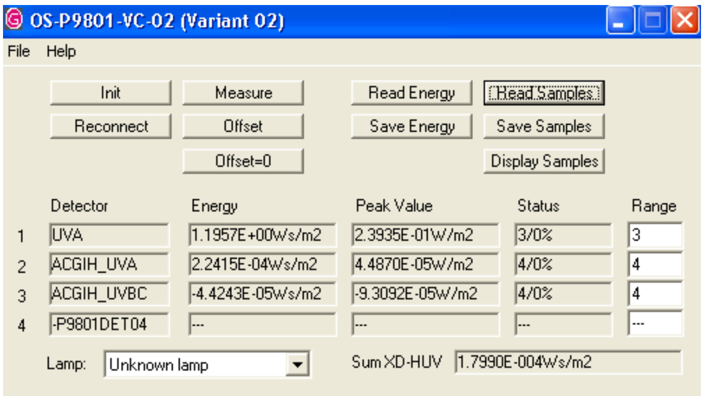
Specifications:	
Detector Input	Current to voltage converter amplifier plus x10 voltage amplifier. Seven decades gain range in steps from 200.0pA to 200µA. Automatic gain range selection. 12 bit ADC (up to 14 bit in long averaging mode)
Signal Processing	A/D converter with 1ms time interval. Longer integration up to 1s buy multiple measurements with averaging
Detector Connector	9 pin MDSM9-socket (type –4)
Parameter Settings	Menu supported. Retention of last setting. Three function buttons
Display	14.3 x 35.8mm, 97x32 pixel LCD graphic display with four columns each with 14 characters. LED back lighted
USB Port Settings	USB HID, USB DLL supplied on CD
Operating Temperature	10 to 40 °C (50 to 104 ° F) (75 % rel. H, non-condensing). Storage Temperature: 0 to 50°C (32 to 122 °F)
Dimensions/Weight	145 x 63 x 30 mm / 150 g (5.7 x 2.5 x 1.2 in / 0.33 lb)
Power supply	2 x battery size AA (2.2 to 3.2 V); USB operation bus powered

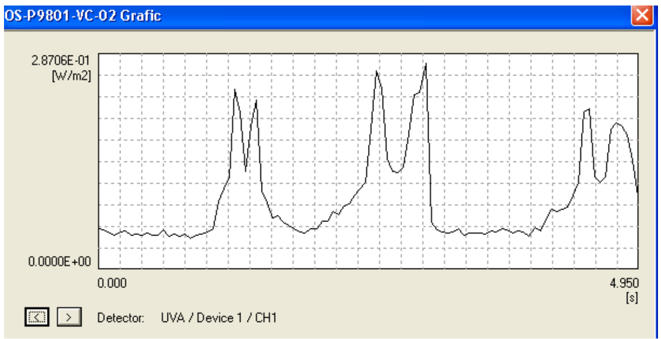
P-9801-V03 Optometer

Gigahertz-Optik P-9801 meter introduced in 1998 is one of the most powerful multi-channel light meters available. It's real 8-channel design for simultaneous signal reading, fast microprocessor with data logging function and metal shield housing make it to an reference meter in many industrial and research measurement applications.

The Gigahertz-Optik P-9801-V03 Optometer is designed as the read-out meter for the XD-45-HUV and XD-45-HB multi-cell detectors in cw and data-logger mode. The key features of the P-9801-V03 optometer are:

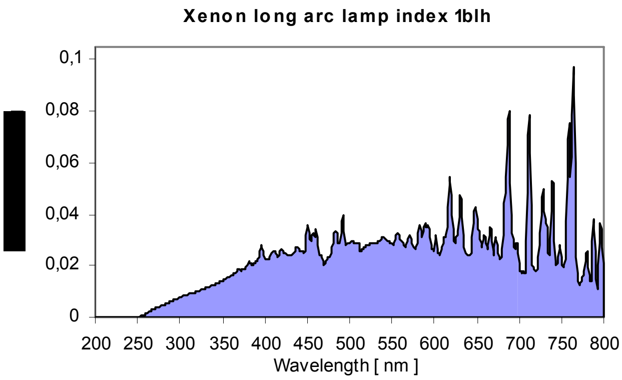
- Eight channel electronics for simultaneous reading of XD-45-HUV and XD-45-HB
- Wide dynamic range 0.1pA to 2mA amplifier
- Low noise for high sensitivity (0.1pA resolution)
- 1ms rise time (except 0E-9 und 10E-8 range)
- 1ms sampling rate data logger for fast pulse shape detection with 5957 samples/channel storage
- Auto ranging and manual gain control
- Range dependent gain calibration with DKD traceability
- Eight column alphanumeric display
- Low DC voltage power operation
- RS232 and IEEE488 interface
- Optional PC software supplied for the measurement set-up, read-out of data logger, calculation of energy and peak values, numerical and graphical display of the measurement and calculated values.

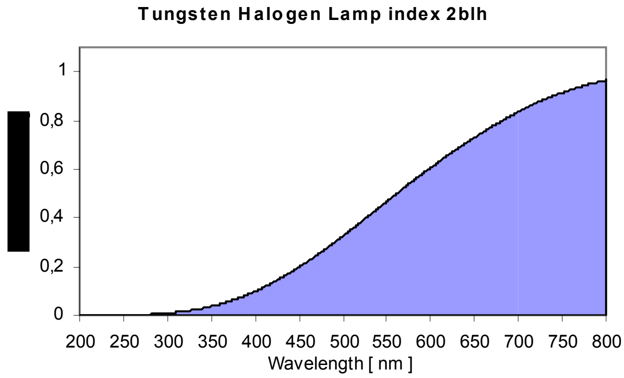


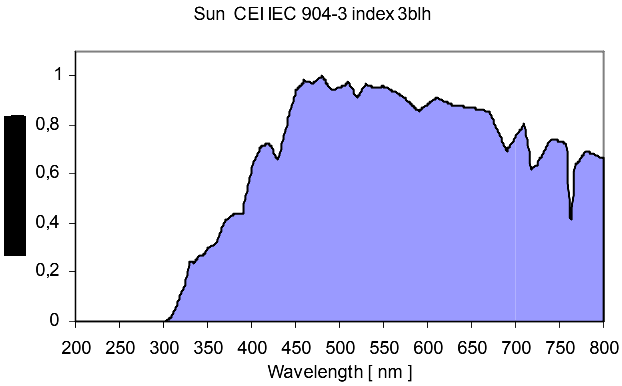


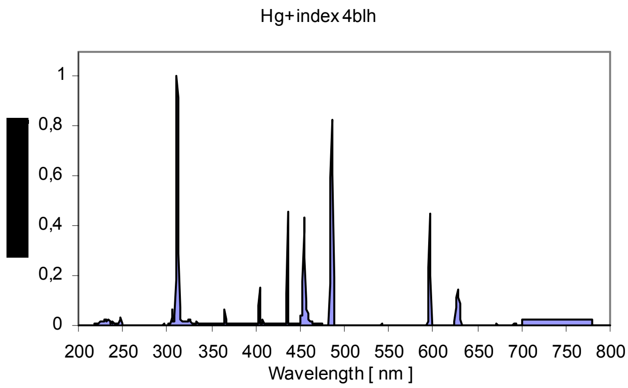
Specifications:	
Detector Input	Eight photocurrent to voltage converter amplifiers with following voltage to voltage amplifiers (x10). 8 decade stepped gain ranges with max. gain signal values from 2.000 mA to 200.0 pA . Manual or automatic range switching. Eight 12 bit ADC with up to 14 bits at longer integration times. Rise time except 10E-9 und 10E-8 range
Signal Processing	A/D converter with 40 µs time interval. Longer integration (1 ms to 10 s) through averaging of multiple measurements.
Detector Connector	8 BNC sockets . Detector heads with BNC connector (type –1).
Data Logger	Sampling rate 0.1s to 6000s or fast sampling settable from 1ms to 100ms; Max. 5957 sample memory / channel
Trigger Input	Measurements can be triggered (started) by external event using Trigger Input
Display	LCD display, LED background illumination (switchable), 160x80 pixels
Operating Temperature	+5 to +40 ˚C (+41 to +104°F)
Dimensions/Weight	280 mm x 250 mm x 70 mm; 1 kg (11 in x 9.8 in x 2.8 in; 2.2 lb)
Serial Port Settings	RS232 (9600 baud, 8 data bits, 1 stop bit, no parity) 5 pin cylindrical TRIAD01 connector..
Power supply	6.5 - 7.5 VDC / 1A; cavity plug 5.5/2.5 mm, Plug-in AC power supply unit 230 V/50 Hz; 7.5 VDC/1 A; cavity plug 5.5/2.5 mm, inner conductor positive.
Electromagnetic Compatibility	Electromagnetic compatibility is assessed in accordance with EN 61326-1 Class B (noise emission for "living areas", noise immunity for "continuous supervised operation"
RS232	RS232, adjustable baudrate 600 - 57600.
IEEE488	IEEE488 with settable device address; optional checksum calculation; for debugging purposes, received commands (Hexadecimal/ASCII) or measurement results can be displayed in parallel to remote operation

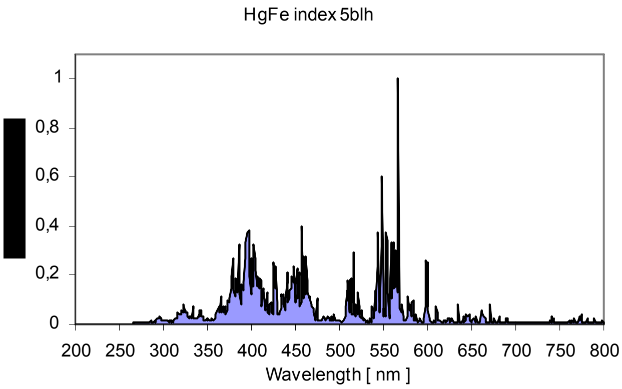
Technical Source Library with a(Z) Correction Values for XD-45-HB

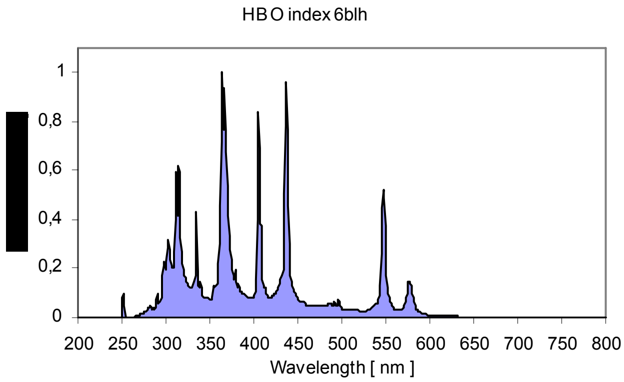


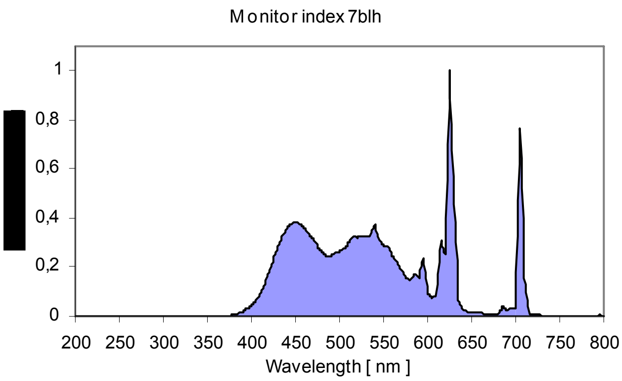


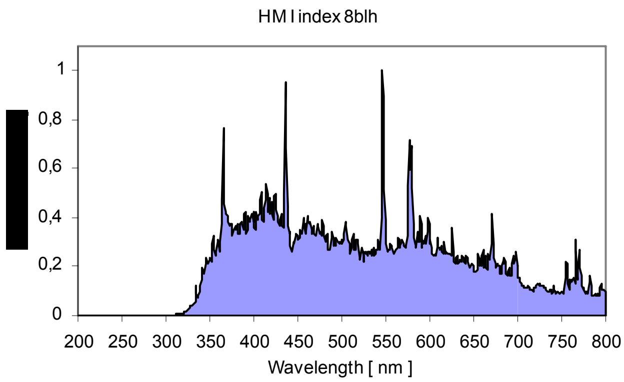




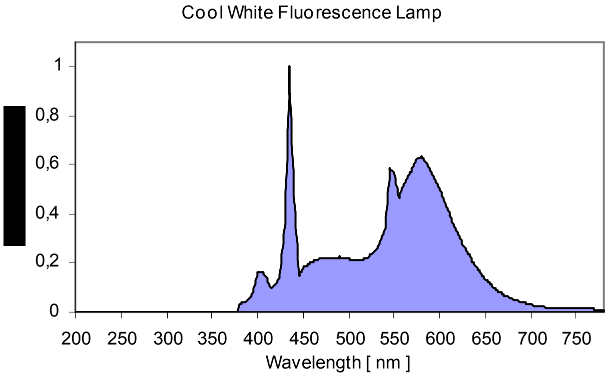


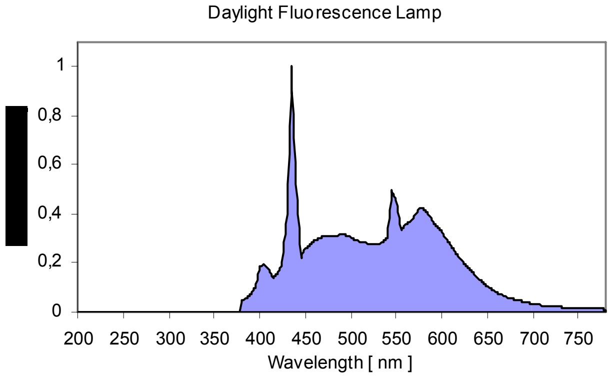


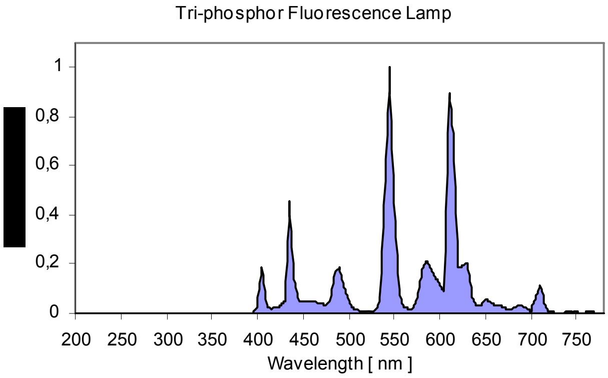


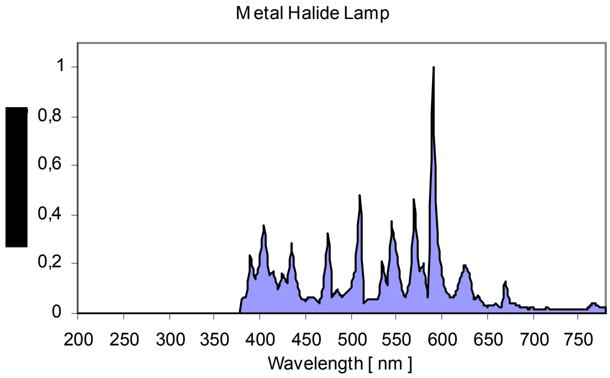


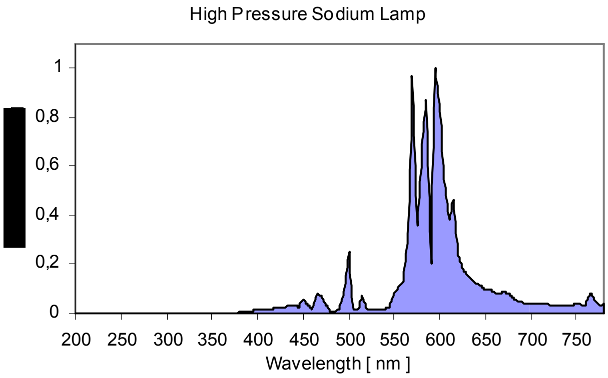
General Lighting Source Library with a(Z) Correction Values for XD-45-HB

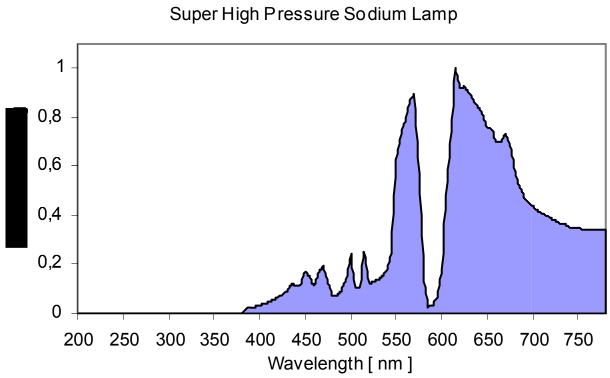


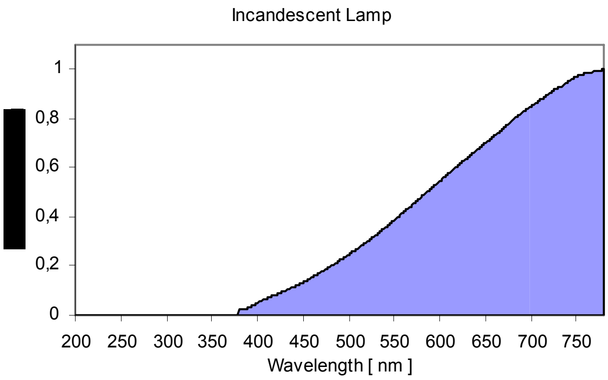


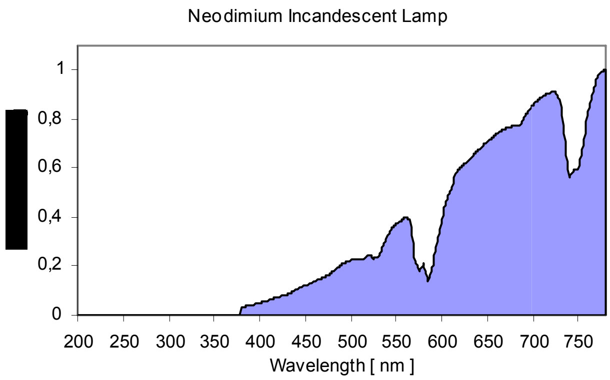








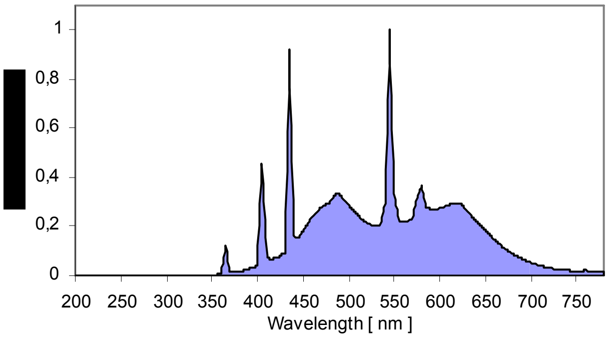




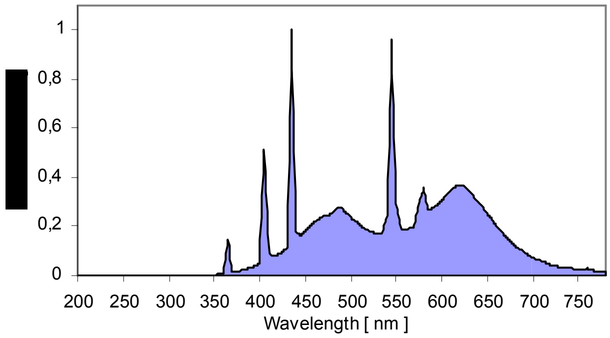
Hazard Lightmeter for Emission & Exposure Values

General Lighting Source Library with a(Z) Correction Values for XD-45-HB

L36W12-950max

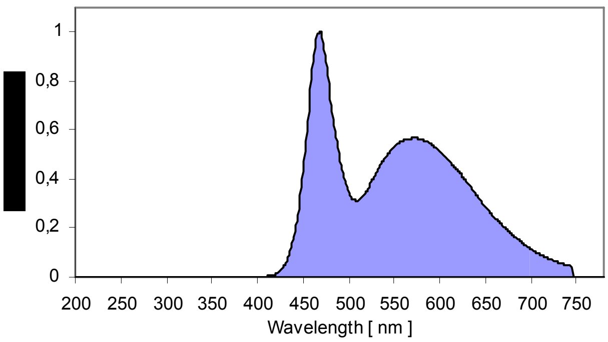


L36W12-76max

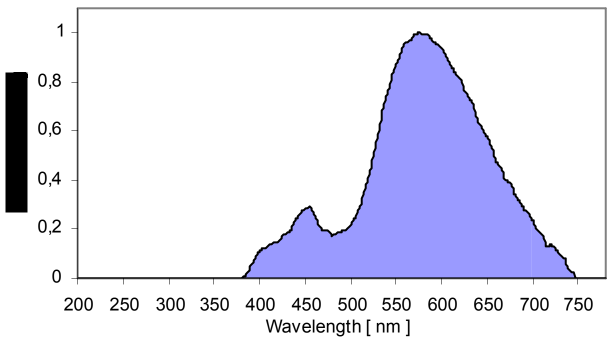


White LED Library with a(Z) Correction Values for XD-45-HB

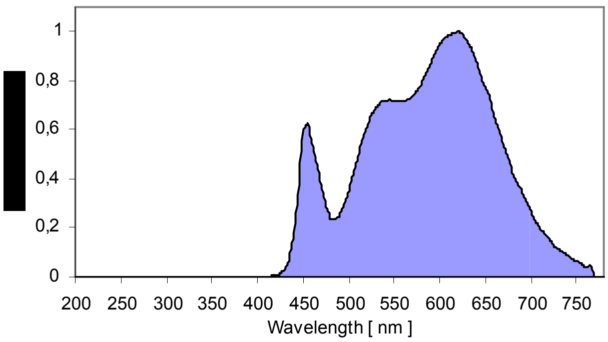
LED-white CRI Ra=84



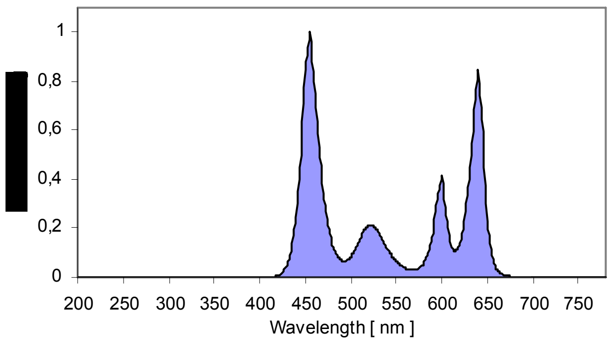
Warm White



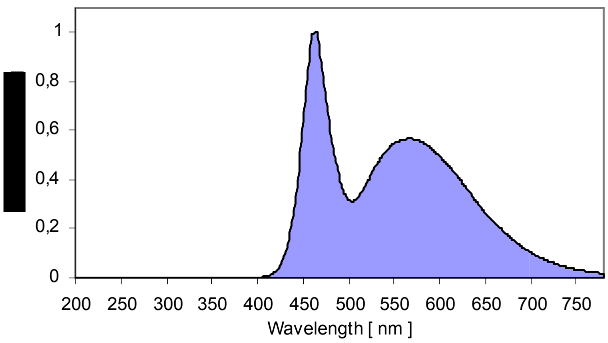
N42180-5



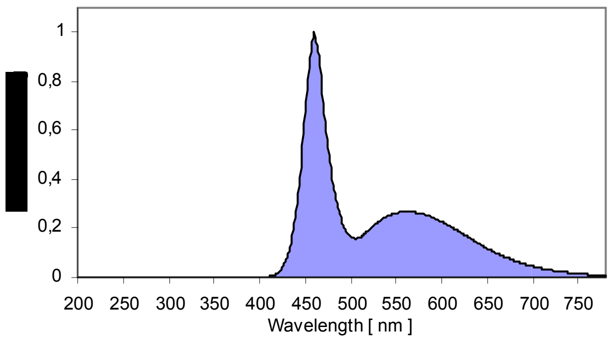
RGBY



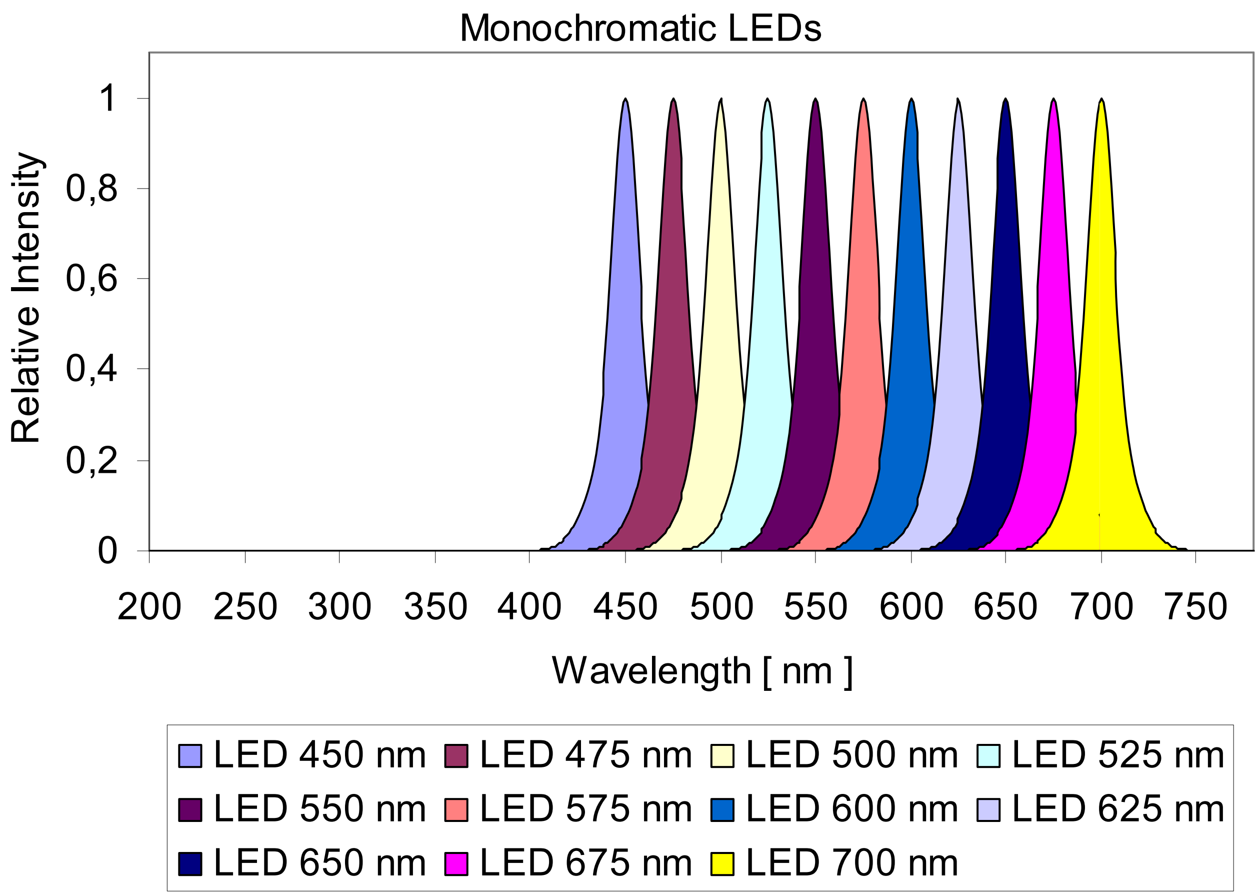
LED-white 3



LED-white 7

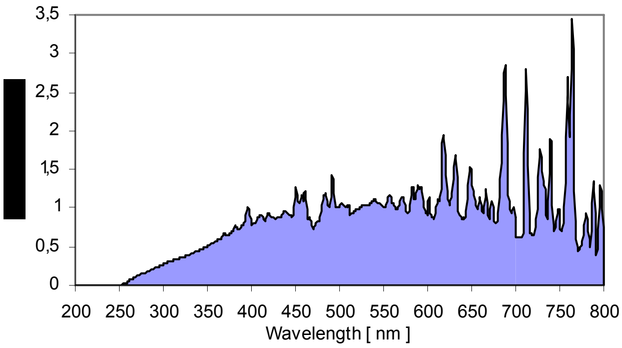


LED Library with a(Z) Correction Values for XD-45-HB

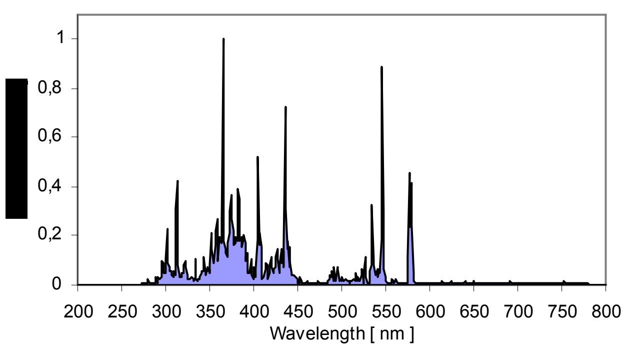


UV Sources Library with a(Z) Correction Values for XD-45-HUV

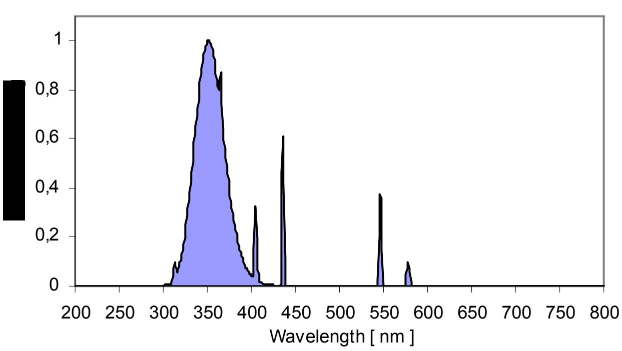
Xenon long arc lamp index 1



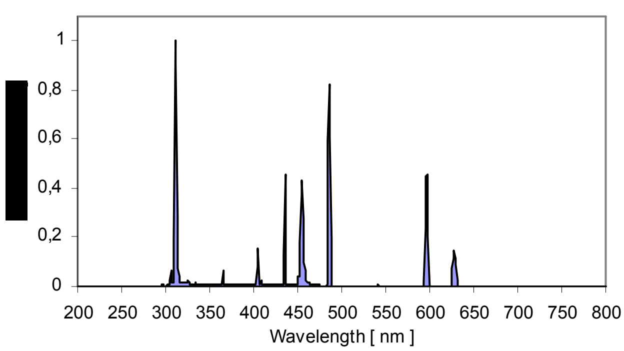
HM I lamp index 2



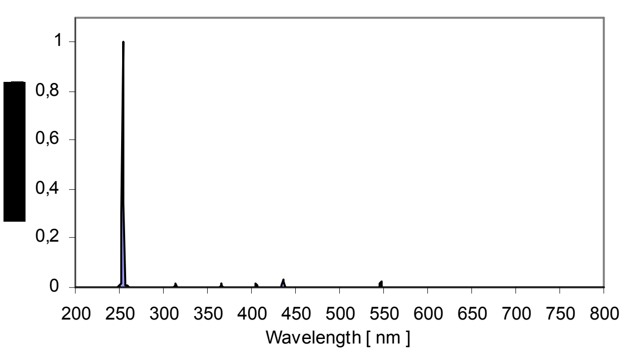
Tanning Lamp UVA index 3



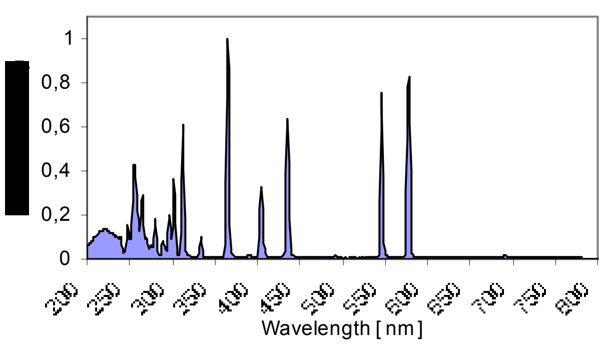
Dermatological used lamp UVB index 4



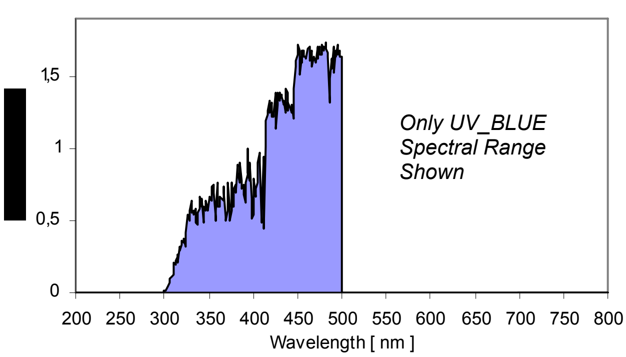
Hg lamp low pressure index 5



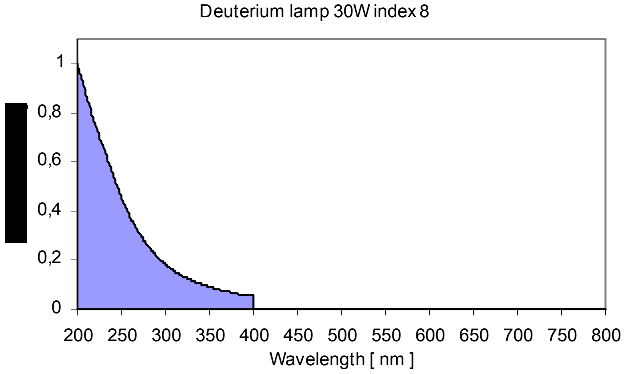
Hg lamp medium pressure index 6



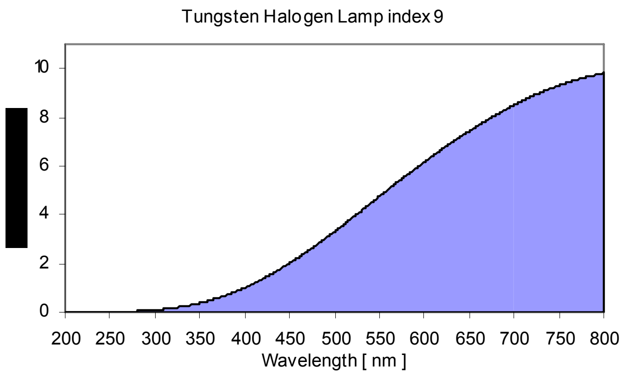
Sun 5th July 97 Thessaloniki 18°SZA (or use AM 1.5) index 7

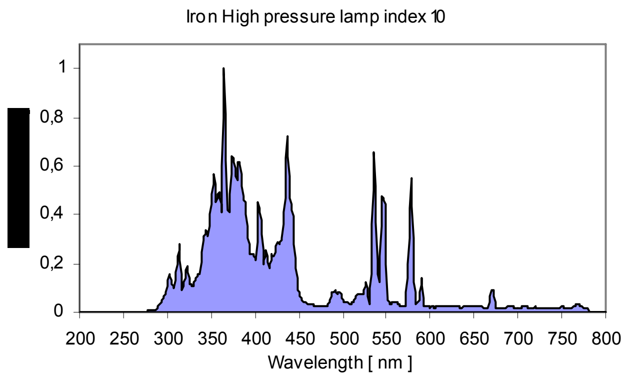


Deuterium lamp 30W index 8

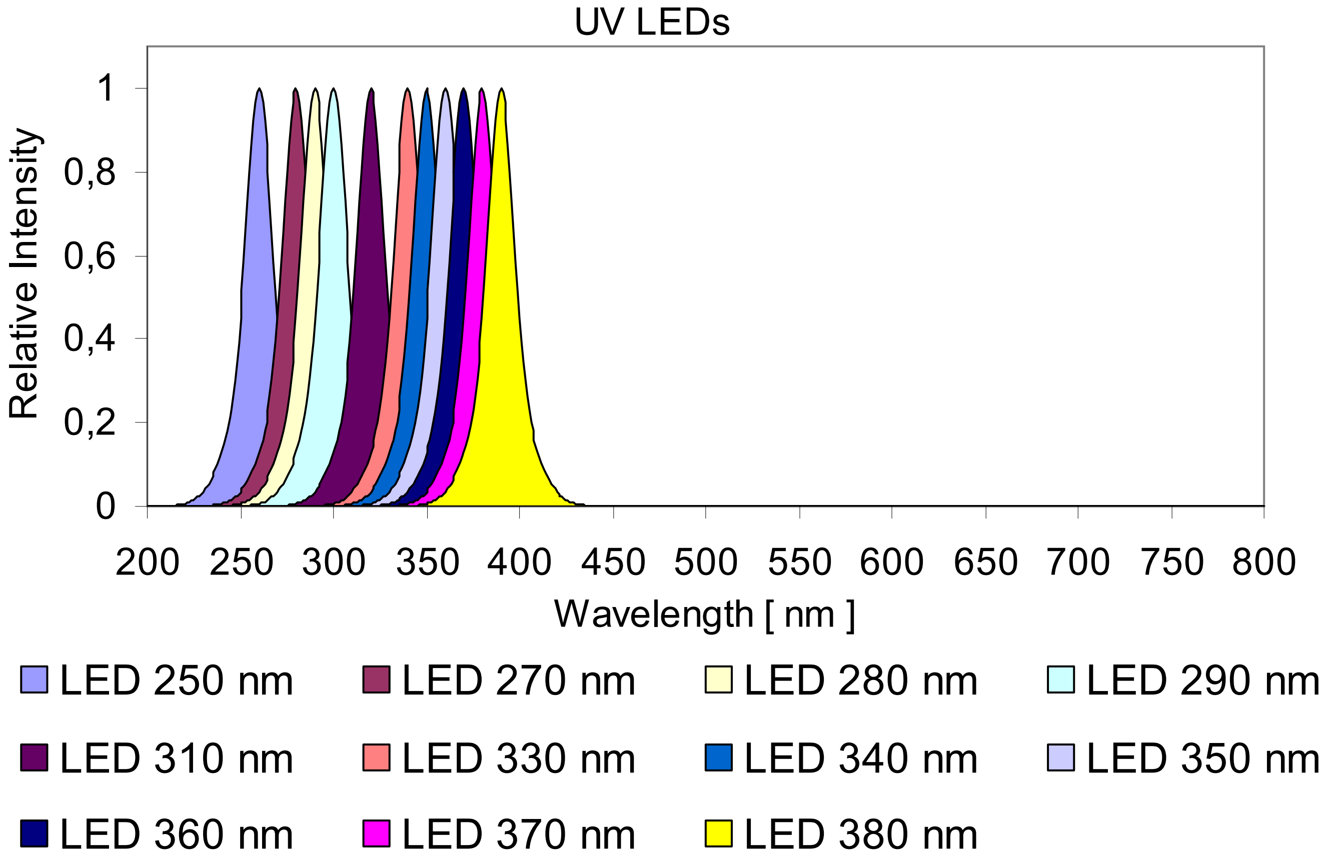


UV Sources Library with a(Z) Correction Values for XD-45-HUV





UV LEDs Library with a(Z) Correction Values for XD-45-HUV



Gigahertz-Optik

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UV Hazard Light Meter
Light Transmission Spectrophotometers
Integrating Spheres for Light Measurements
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Barium Sulfate Paint
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