Are LED-based screens and lamps suddenly hazardous?

Assessment of the blue light hazard

Being somewhat theoretical, the current international standard IEC 62471 for photobiological safety has been supplemented by a practical Technical Report IEC TR 62778. The latter explains how IEC 62741 is to be used for simple assessment of the blue light hazard of lamps and luminaires with visible radiation.

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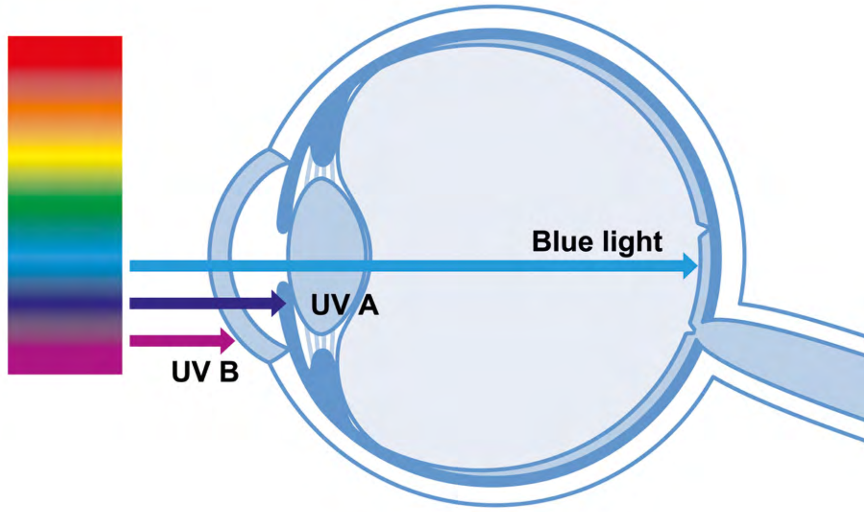

Figure 1: While UV radiation is absorbed by the cornea, blue light enters the eye and penetrates to the retina.

TECHNICAL **ARTICLE**

Instrument Systems
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The fast-growing importance of modern solid-state lighting (SSL) in our daily environment raises critical safety concerns such as photobiological safety, in particular blue light hazard (BLH). The current international standard IEC 62471 contains guidelines for assessing the photobiological safety of lamps and lamp systems. However, to ensure reliable assessment, it places extremely high demands on measuring instruments and procedures.

The standard specifies two health risks that can be caused by visible light. Intensive light may result in burning of the retina – a risk that is easily avoided by normal aversive behavior. Blue light between 400 and 500 nm, however, causes photochemical damage to the retina (Figure 1). This so-called blue light hazard may lead to degeneration of the macula and is difficult for normal users to assess. For effective blue light hazard assessment, the standard specifies a weighting function by which the spectral measurement data must be multiplied. The function covers the wavelength range between 300 and 700 nm with a maximum of 435 to 440 nm.

The characteristic blue peaks of LEDs raise the question of risk from SSL sources. IEC 62471 subdivides light sources into four risk groups from 0 to 3 (Table 1) depending on the radiance L_B evaluated with the blue light hazard function and the calculated maximum exposure time t_{max}. In addition, IEC Technical Report 62778 specifies how the standard for BLH assessment of lamps and luminaires with visible radiation is to be applied. Throughout the world efforts are currently being undertaken to elevate this report to the level of a new standard. The goal is a detailed description of measuring procedures for BLH assessment that are accessible to a broader public.

Light sources in risk groups RG 0 and RG 1 are deemed safe and do not require a safety label. Risk group RG 3 is extremely unlikely for SSL. The task to be solved is thus as follows: to determine whether the source exceeds the emission limit for RG 1 at a distance of 200 mm and a field of view of 11 mrad (Figure 2 shows the specifications to be verified). A spectral irradiance measurement should be performed for sources that are larger than the field of view of 11 mrad (equal to a measurement spot with a diameter of 2.2 mm). A spectral irradiance measurement is otherwise recommended for small sources. If the radiation density (or irradiance) weighted by the blue light hazard function exceeds the limit value for RG 1, the threshold illuminance level E_{thr} as the border between RG 1 and RG 2 should additionally be specified and stated in the data sheet for LED components or lamps. When E_{thr} is known, the threshold distance d_{thr} can be determined for the final product.

\\ WHICH MEASURING PROCEDURE IS SUITABLE?

Correct risk assessment is a challenging task for the experimenter and starts with the selection of suitable test equipment. Nowadays, the measuring instrument of choice is often an array spectrometer instead of the difficult-to-handle double monochromator suggested in standard IEC 62471. High-end array spectrometers must also have advanced stray light correction methods

Table 1 \\ Risk groups for blue light hazard to the retina

Number of risk group	Name of risk group	L_B limit value / [W/m²sr]	Corresponding t_{max}
RG 0	Exception	≤ 100	> 10,000 s
RG 1	Low risk	100 - 10,000	100 - 10.000 s
RG 2	Moderate risk	10,000 - 4,000,000	0.25 - 100 s
RG 3	High risk	> 4,000,000	< 0.25 s

Quelle: IEC

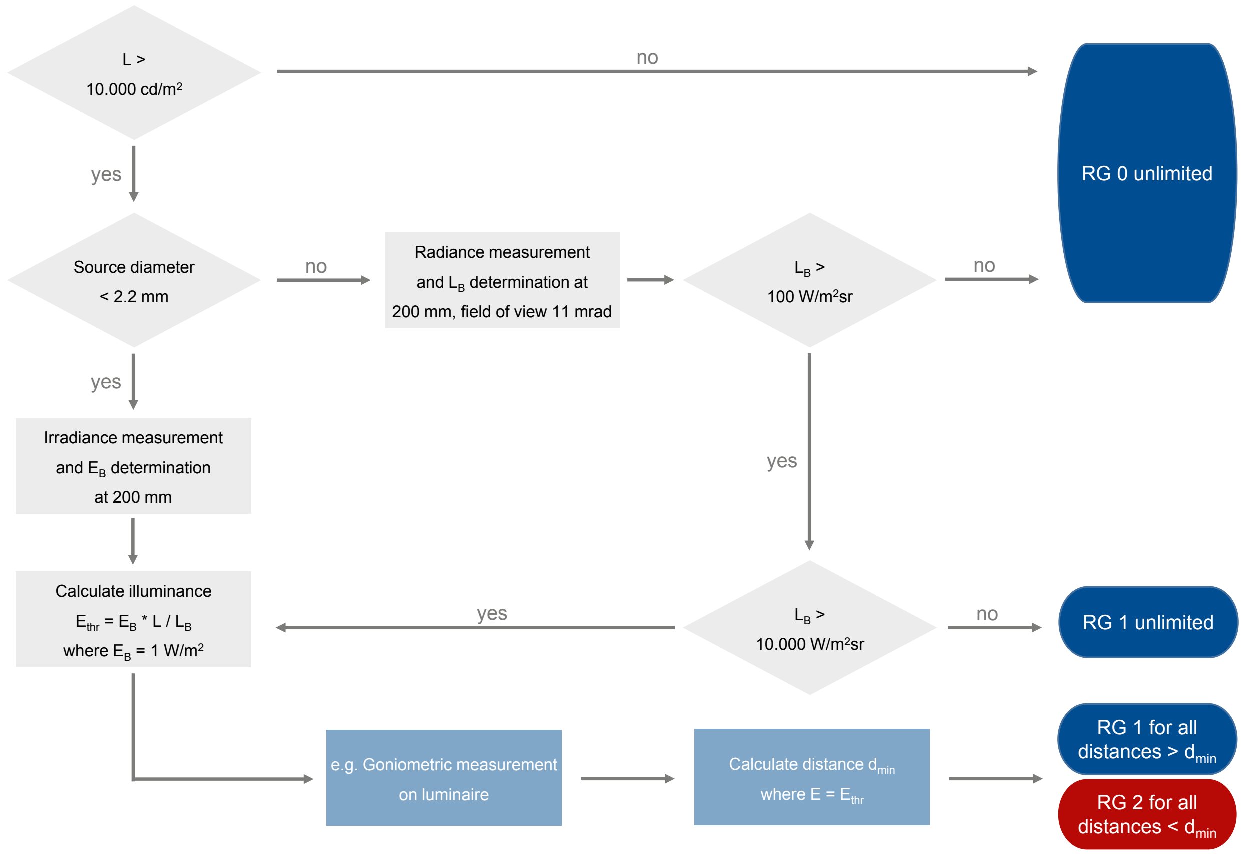

Figure 2: Evaluation guidelines for blue light hazard as a flow diagram based on Technical Report IEC TR 62778.

in order to achieve the required high measuring dynamics. This is particularly important in the less sensitive blue range. Carefully designed test adapters are required to ensure correct and reproducible test geometry. Equipped with these instruments, test labs that are accredited to ISO 17025 can reliably determine the risk class of lighting products.

The IEC 62471 suggests two principle measuring procedures for BLH assessment: a direct spectral radiance measurement with an optical system and an alternative method for irradiance measurement with a precisely defined field of vision.

\\ DIRECT SPECTRAL RADIANCE MEASUREMENT

Spectral radiance can be directly measured with an optical telescopic probe in combination with a spectral radiance-calibrated array spectrometer. A telescopic optical probe with an alignment camera enables easier positioning and faster determination of BLH for light sources that do not emit radiation below 360 nm, as the lens for the UV radiation is not permeable. In order to satisfy the requirements of IEC 62471, an additional measurement with another lens suitable for the UV range may therefore be necessary to prove the absence of UV radiation. On the other hand, IEC TR 62778 and the proposed new standard only cover visible radiation.

\\ ALTERNATIVE METHOD

An alternative method proposed in standard IEC 62471 is the measurement of irradiation intensity with a precisely defined field of view. In this case, the measured irradiance is divided by the solid angle to determine radiation density. The test equipment for the alternative method may comprise a stray light-corrected array spectrometer, an irradiance-calibrated PTFE integrating sphere and a tube containing the required apertures for the calculation of radiation density (Figure 3). The length of the 200 mm tube and the two apertures with a diameter of 20 or 2.2 mm define the angle of 100 or 11 mrad. This system covers the entire spectral range of the weighting function for BLH from 300 bis 700 nm, as suggested in standard IEC 62471.

Figure 3: Implementation of the alternative method with the PTFE integrating sphere and a tube with all the necessary apertures for BLH measurements.

\\ WHAT DIFFERENCES DO THE READINGS REVEAL?

Both methods were realized, the measurements were performed on samples and LED packages (Figure 4a) and LED retrofits (Figure 4b) and assigned to the risk groups (Table 2). The standard method was used to weight the measured spectral radiance with the blue light hazard function, and in order to determine L_B and t_{max} = 106 / L_B it was integrated in the range between 300 and 700 nm. The risk assessment process was performed according to Table 1. In the alternative method the spectral irradiance measured was first of all divided by the solid angle defined with the aperture used and the process continued analogous to the above.

The deviations in the results for L_B are relatively small, although each method has a different setup and calibration. The strived for result is, however, assignment to the correct risk group. This is not critical for most sources, as a risk group covers several orders of magnitude. Deviations of merely a few percent play a role only if the source exceeds the limit to risk group 2. But even in this case a threshold illuminance level E_{thr} and a threshold distance d_{thr} should be calculated that does not prove to be critical for most applications.

\\ MORE METHODS WITH THE EMERGING STANDARD

In addition to the measurement of radiance or irradiance, IEC TR 62778 contains observations for risk group classification on the basis of CCT (correlated color temperature) and luminance or irradiance of the source, and these are further developed in the proposed standard. Put simply: the more light in the blue range a source emits, the higher the CCT and the greater the hazard caused by blue light. Luminance and CCT can be measured, e.g. with a filter-based imaging colorimeter.

Table 2 \\ Measurement results for standard and alternative methods for the samples in Figure 2

LED Package	L_B [W/m²sr]	t_{max} [s]	Evaluation
Standard method	1989.8	503	RG 1
Alternative method	1949.9	513	RG 1
Difference	-20 %		

LED Retrofit	L_B [W/m²sr]	t_{max} [s]	Evaluation
Standard method	5829.9	172	RG 1
Alternative method	5497.9	182	RG 1
Difference	-5.7 %		

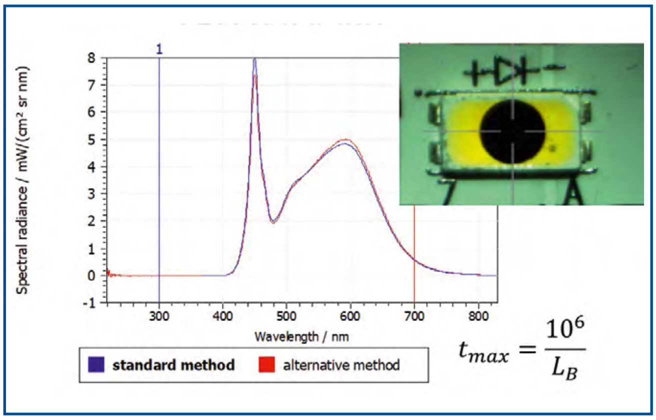

Figure 4a: Measurement spot with a diameter of 2.2 mm on an LED package and spectra, measured by the standard and alternative methods.

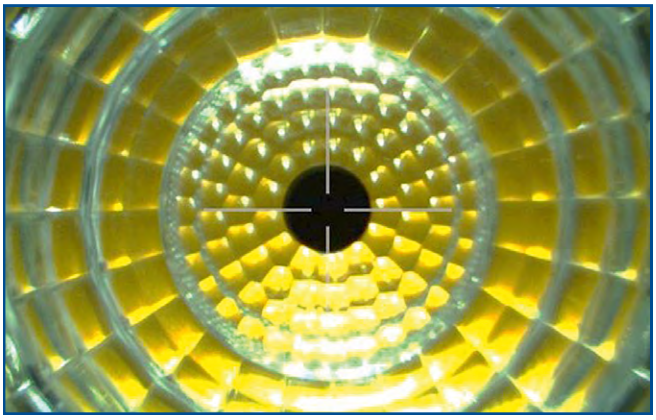

Figure 4b: Measurement spot with a diameter of 2.2 mm on an LED retrofit lamp.

A further suggestion for the proposed standard requires a luminance distribution and relative spectrum for the calculation of the L_B. The fastest measurement of luminance distribution can be achieved with a luminance camera. Additionally, a relative spectrum can be measured with a spectrometer and any desired optical probe.

Only data sheet specifications for CCT and luminance, where appropriate, can be provisionally used to exclude a risk group greater than RG 1 or to provide a rough estimate of E_{thr}. However, the simpler the method is, the greater the anticipated overestimation of the hazard, because higher safety factors must be added to ensure that no risk is overlooked.

\\ CONCLUSION

Measurement of blue light hazard is a difficult task, as radiance measurement itself is extremely complex and heavily dependent on the geometry of the setup. Direct spectral radiance measurement is limited to sources without radiation below 360 nm, as no suitable lenses exist. Positioning of the measurement spot is, however, very convenient, and the measurement itself extremely fast. The greatest challenge for the alternative method is the accurate and reproducible positioning of a small aperture of 2.2 mm, with which an angle of 11 mrad at a distance of 200 mm is defined for most measurements. In comparison, the PTFE integrating sphere is more sensitive in the UV range, and covers the total spectral range for BLH from 300 to 700 nm.

More methods that are available to a broader public are permitted in the newly emerging standard based on IEC TR 62778. However, these simpler methods must contain additional safety factors to avoid underestimation of the BLH risk. The results may thus vary, depending on the measured source and method used. However, the result of the BLH assessment is not the exact absolute value, but the correct risk group that covers several orders of magnitude. Only when the reading is on the boundary between the two risk classes is it important to measure as accurately and reproducibly as possible. Whenever possible, the results of direct spectral radiance measurements or the alternative evaluation method proposed in standard IEC 62471 should be used instead of simplified measurements or approximations, as suggested in the new standard.

\\ NO MAJOR RISKS FOR USERS

The risk classes for various types of display and SSL sources, lamps and luminaires have been evaluated in a number of studies. It has been shown that consumer screens and lamps on an LED basis incur no substantial risk to users than conventional sources. Most luminaires with not directly visible LEDs were assigned to risk group 0. Only luminaires with directly visible LEDs were classified in RG 1 or in a few cases in RG 2, which – like conventional sources – are regarded as safe in normal use and turning behavior. High-risk group 3, which is also hazardous for short exposure times below 0.25 s, is extremely improbable for light sources in general lighting and for consumer displays.

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