Blue-light hazard risk assessment for white-light sources

Guidance for a practical illuminance based assessment method

baua: Guidance brief

Light from screens and general lighting is almost always photobiologically safe. The use of high-power spotlights e. g. in structural and civil engineering, at events or large storage areas, however, can come along with a blue-light hazard. The associated workplace risk assessment often requires demanding and time-consuming radiance measurements. An alternative method based on illuminance and correlated color temperature is virtually as accurate but much more practical.

Blue-light hazard

Bright light is not only dazzling but can also cause photochemical retinal damage. This health impairment is better known as blue-light hazard (BLH) because spectral components in the blue wavelength range are most detrimental. While light from monitors, mobile devices, or office-typical general lighting does not pose any retinal risk, a BLH can occur for high-power spotlights used at construction sites, in theatres, television studios etc.

Risk assessment

If a BLH can be proven or ruled out unequivocally, e. g. with the help of the manufacturer's data, no measurements are necessary. The risk group (RG) classification according to EN 62471 can serve as a starting point for it: no BLH is expected within exposure durations of 10 000 s or 100 s for RG 0 and RG 1, respectively, but this might be possible for RG 2 and RG 3.

In case of any unclear BLH situation, a risk assessment must be carried out by means of a qualified measurement. Depending on the size α of the lamp's shining front side at the site of immission, either the BLH weighted radiance L_B ($\alpha \geq 11$ mrad) or irradiance E_B ($\alpha < 11$ mrad) is required for a comparison with the associated exposure limit values (ELVs). Assuming a cumulative glance time $t \leq 10\,000$ s at the source, it is expected that no BLH appears for a certain maximum permissible exposure duration t_{max} (MPE duration). Otherwise ($t > 10\,000$ s), the time independent ELVs must not be exceeded at any time during an eight-hour working day.

Practical procedure

Extended sources ($\alpha \geq 11$ mrad)

Radiance L reflects the measured irradiance E in a certain solid angle Ω, $L = E\,\Omega^{-1}$, which is why a so-called acceptance angle γ or field-of-view (FOV) must be taken into account that, however, complicates data acquisition at workplaces. For practical reasons, $\gamma = 11$ mrad or 100 mrad are chosen for risk assessment. Then, L_B can be compared to the ELVs.

Small sources ($\alpha < 11$ mrad)

To check whether the small source criterion is fulfilled, the inner diameter D of the lamp's shining front side and the distance d to the site of immission can be used, $\alpha \approx D\,d^{-1}$.

As measurements of E_B are usually performed with an open FOV, i. e. $\gamma = 180°$, they are quite easy to handle and thus often used for a risk assessment of extended sources, too, via $L_B = E_B\,\Omega^{-1}$ with $\Omega \approx 0.785\,\alpha^2$.

Exposure limit values depending on source size and time base

- **extended source ($\alpha \geq 11$ mrad)**
  $t \leq 10\,000$ s, $L_B\,t_{max} = 1$ MJ m^{-2} sr^{-1}
  $t > 10\,000$ s, $L_B = 100$ W m^{-2} sr^{-1}
- **small source ($\alpha < 11$ mrad)**
  $t \leq 10\,000$ s, $E_B\,t_{max} = 100$ J m^{-2}
  $t > 10\,000$ s, $E_B = 10$ mW m^{-2}

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Alternative approach

If there is no equipment to detect L_B or E_B, an open FOV illuminance (E_v) measurement can be an alternative approach due to its correlation to E_B via the BLH efficacy of luminous radiation, $E_B = K_{B,v}\,E_v$. This conversion factor depends on the correlated color temperature (CCT) and can be approximated for white-light sources, cf. Tab. 1. For known CCT, e.g. from the software based control of the spotlight, its manual or technical data sheet, in conjunction with a measured E_v, the MPE duration (based on $t \leq 10\,000$ s) follows as

$$t_{max} = (K_{B,v}E_v)^{-1} \begin{cases} 100\ \mathrm{J\,m^{-2}} \\ 7.85\ \mathrm{kJ\,m^{-2}} \\ 785\ \mathrm{kJ\,m^{-2}}\,\alpha^2 \end{cases}$$

Line 1 represents the determination of t_{max} in case of small sources ($\alpha < 11$ mrad), the 2nd and 3rd lines those for extended sources ($\alpha \geq 11$ mrad) either with $\gamma = 100$ mrad or 11 mrad.

Tab. 1 CCT (in K) and $K_{B,v}$ (in W klm^{-1})

CCT	$K_{B,v}$	CCT	$K_{B,v}$	CCT	$K_{B,v}$
2 400	0.20	3 800	0.53	5 400	0.87
2 500	0.23	3 900	0.56	5 600	0.91
2 600	0.25	4 000	0.58	5 800	0.94
2 700	0.27	4 100	0.60	6 000	0.98
2 800	0.29	4 200	0.62	6 200	1.01
2 900	0.32	4 300	0.65	6 400	1.04
3 000	0.34	4 400	0.67	6 600	1.07
3 100	0.37	4 500	0.69	6 800	1.10
3 200	0.39	4 600	0.71	7 000	1.13
3 300	0.41	4 700	0.73	7 200	1.16
3 400	0.44	4 800	0.75	7 400	1.18
3 500	0.46	4 900	0.77	7 600	1.21
3 600	0.49	5 000	0.79	7 800	1.23
3 700	0.51	5 200	0.83	8 000	1.26

Example halogen spotlight

A PAR 56 spotlight with a constant CCT of 2 750 K shall be assessed in a distance of 15 m. Its shining front side has an inner diameter of 12 cm; thus, $\alpha = D\,d^{-1} = 8$ mrad and the spotlight can be regarded as a small source. With a measured $E_v = 0.345$ klx and $K_{B,v} = 0.29$ W klm^{-1} from Tab. 1 for 2 800 K (rounding up because of a restrictive choice), line 1 of t_{max} yields 1 000 s.

Example LED spotlight

The inner diameter of its shining front side was measured with $D = 25$ cm. The LED spotlight being tuned to 6 000 K ($K_{B,v} = 0.98$ W klm^{-1}, cf. Tab. 1) shall be assessed in 10 m distance so that $\alpha = D\,d^{-1} = 25$ mrad. Although the employee works in front of the spotlight his visual task can be characterized by a FOV of at least $\gamma \geq 100$ mrad and line 2 of t_{max} must be applied. With a measured illuminance of 4 klx, $t_{max} \approx 2\,000$ s. In contrast, another employee looks temporarily towards the spotlight, hence $\gamma = 11$ mrad will be assumed. Consequently, the MPE duration of 125 s results from line 3 of t_{max}.

Further information

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