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Photobiological Risk from the Spectral Emission of Human Centric LED Luminaires – Case Study

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Abstract

People spend most of their time indoors. That is a good reason for implementation Human Centric Lighting solutions in offices. Such solutions can lead to increased productivity and motivation to employees. The spectral composition of light, the timing of the different light scenes and the duration of light exposure play important role for the non-visual effects of light that occur in humans. Moreover, research has shown that these effects may depend on the environment, specifics of the activity, and personal characteristics of people.

The use of LED Luminaires makes the implementation of Human Centric Lighting easy and possible. The LEDs as light sources, however can lead to blue light hazard risk that should be estimated. The human eye is adapted to function in a media of optical radiation that ensures not only vision, but also important physiological functions. The emission of LED luminaires is in wide spectrum, especially in the blue part, and it can be both favorable and harmful. The current paper represents an experimental research of the possibility of blue light hazard in a real human centric lighting system..

Index Terms: Photobiological safety, human centric LED luminaires

1 Introduction

It is the century of the LED lighting and since it is a young technology it has a lot of advantages, drawbacks and issues to be considered. One of the first things that not specialists think when they hear about LED lighting is that is a little bit more expensive, but much more efficient and they are sometimes absolutely unaware of problems as Temporal Lighting Artefacts or Photobiological Risk from blue light. According to the European Standard EN 62471:2009 "Photobiological safety of lamps and lamp systems" for estimation of a source of optical radiation, which emits in a large spectral range, it is necessary to estimate the spectral distribution of its radiance in points where humans are present, according to the size of the projection of the light source for the spectral range, where retinal damage is possible and the change of the radiation in certain geometry of the lighting installations with the change of the distance to the source [1].

The conditions at which the radiometric measurement of the spectral distribution and the intensity of the light sources depend on the geometry of the lighting installation, the size of the light sources (apprised by α_{eff}) and the exposition time according to their application. The dimension α_{eff} (effective angular subtense), rad depends on the projection of the visible part of the light source on the eye of the observer or in the measurement point. This dimension is a full angle, not a half – fig. 1.

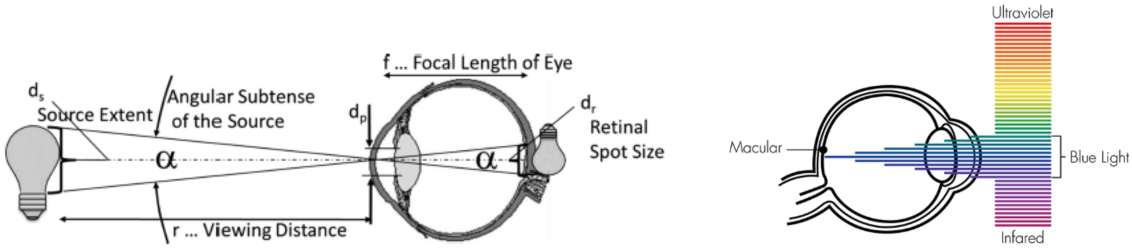

Fig.1 Determination of the effective angular subtense of a source of optical radiation [2,3]

A source, whose projection on the retina is so big that the biological influence in radial direction from the center of the image towards the surrounding biological tissue is negligible compared to the biological influence in the direction of the central axis, is considered a large source of optical radiation – fig. 2. In this case the spectral radiance of the light source L_e $(W_e/sr)/m^2$ is important.

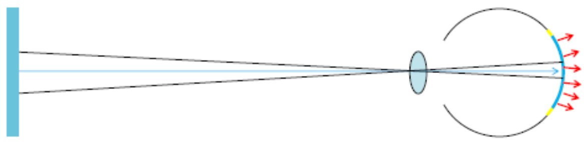

Fig.2 Projection of the light source on the retina and biological impact of a large light source.

For determination of the angular subtense of a light source and the measurement geometry, at which the intensity of the optical radiation is taken, the size of the light source should be known as well as the distance to the irradiated surface and the visual field of the observer.

The visual field is defined as a solid angle γ, sr, under which the radiance of the source is perceived by the detector of the measuring instrument – radiometer or spectrophotometer. Under sudden conditions a planar angle γ, rad can also be used.

The European standard EN 62471:2008 describes two standard measurement procedures:

1. Measurement of the irradiance and radiance of the light sources at a distance, at which the light source assures illuminance of 500 lx, but not shorter than 200 mm – used for general lighting;

2. Measurement of the irradiance and radiance of the light sources at a distance of 200mm and guaranteed visual field – for the rest of the cases.

These conditions, however concern some considerations when sudden applications are investigated and can lead to different interpretations of the experimental setup which can corrupt the measurement results. Useful information and clarification about the application of EN 62471:2008 for estimation of the blue light hazard from light sources and luminaires are given in IEC/TR 62778: 2012 [4].

2 Radiometrical Measurement of the Spectral Distribution of the Radiant Intensity of LED Lighting Products and Assessment of Their Blue Light Hazard

The measurement, described in the current paper has been made in a laboratory in the Technical University of Sofia, where the lighting system has been renovated and a human – centric lighting has been installed. The experiment has been carried out by means of spectroradiometer Stellar BLACK-Comet, which can measure radiation with wavelength from 200 nm to 1100 nm. The experiment is made in compliance with EN 62471:2008 and the recommendations in IEC/TR 62778:2012.

The lighting system under consideration consists of six ceiling mounted Human – Centric LED Luminaires with the following dimensions: l=1.175m, w=0.575m. All the luminaires have a plastic diffuser completely covering the light sources. LEDs have emissions in the blue part of the spectrum and in the current publication deals with the hazard that may arise from exposure to visible or ultraviolet wavelengths. It is expected that the ultraviolet wavelengths are attenuated by the plastic diffuser [6].

Spectral irradiance data is measured at a distance of 1.8 m from the luminaire, looking directly at it. The source has an average dimension of 0.875 m. Therefore $\alpha = 0.486$ rad. The source has a surface area of 0.676 m^2. Therefore $\Omega = 0.68$ sr. Therefore $\Omega_B = 0.209$ sr [1,2,6]. According the standard EN 62471 the maximum angular subtense value for all retinal hazards must not exceed 0.1 rad due to the pupil diameter physiological limitations. This means that if the luminance of this source is high, as it is expected only a part of the source size will be the effective angular subtense α_{eff} and used for determination of the blue light hazard. For achieving of this measuring conditions and $\gamma=\alpha_{eff\ max}=0.1$ rad a non transmitting aperture is used. Thus the dimensions of the emitting area of the luminaire are limited to D=0.18m, therefore $\alpha = 0.1$ rad.

Schematic representation of the experimental setup is given on Fig. 3.

Detailed radiometric data for white light sources is required only if the luminance of the source L exceeds 10^4 cd/m^2 [1,2]. The preliminary assessment with measurement of the source luminance at distance 1.8 m and with the subtended angle, defined by the actual average dimension of the luminaire without the use of aperture, showed luminance exceeding 10^4 cd/m^2.

a) b) c)

Fig.3 Representation of the experimental set up

After generating in Sketchup the 3D model is inserted in the lighting design program Dialux EVO. An illustration of the created model after adding additional surfaces with real reflection charachteristics is shown on fig. 5.

The measurements were performed for the set of the correlated color temperatures for which the human-centric lighting installation is designed. The experimental data obtained by means of the spectroradiometer represent the surface density of the radiant flux that has fallen on the photoelement of the radiometer W/m^2, or its irradiance. The measured spectral power distribution for the set of CCTs and the blue light weighted function B(λ) in relative unites are shown on fig. 4.

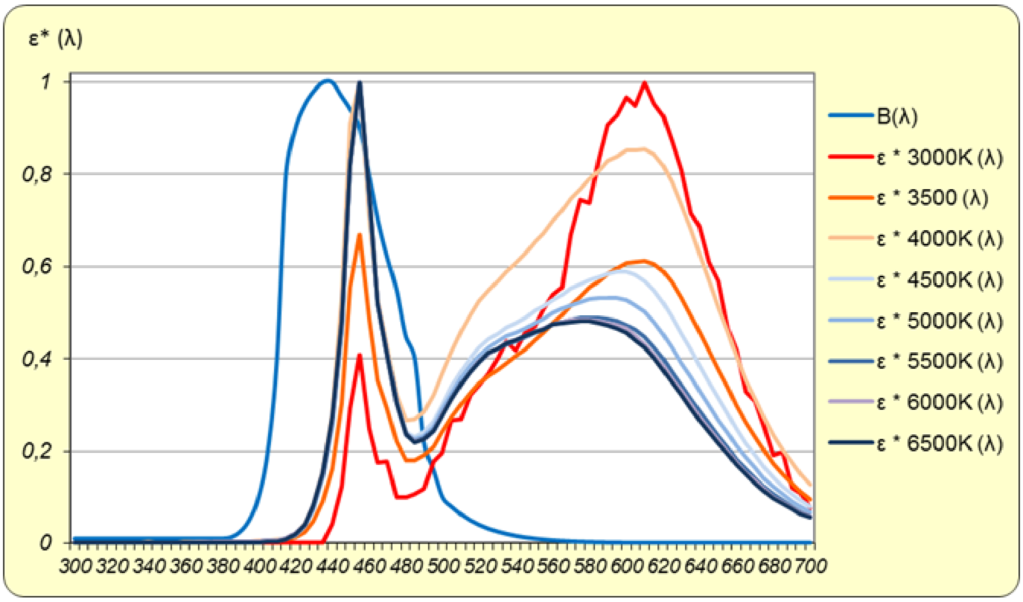

Fig.4 Measured spectral power distribution for the set of CCTs and the blue light weighted function B(λ).

For all measurements are determined the blue light hazard efficiencies of radiation, according EN 62471:2008. The results are represented on fig. 5.

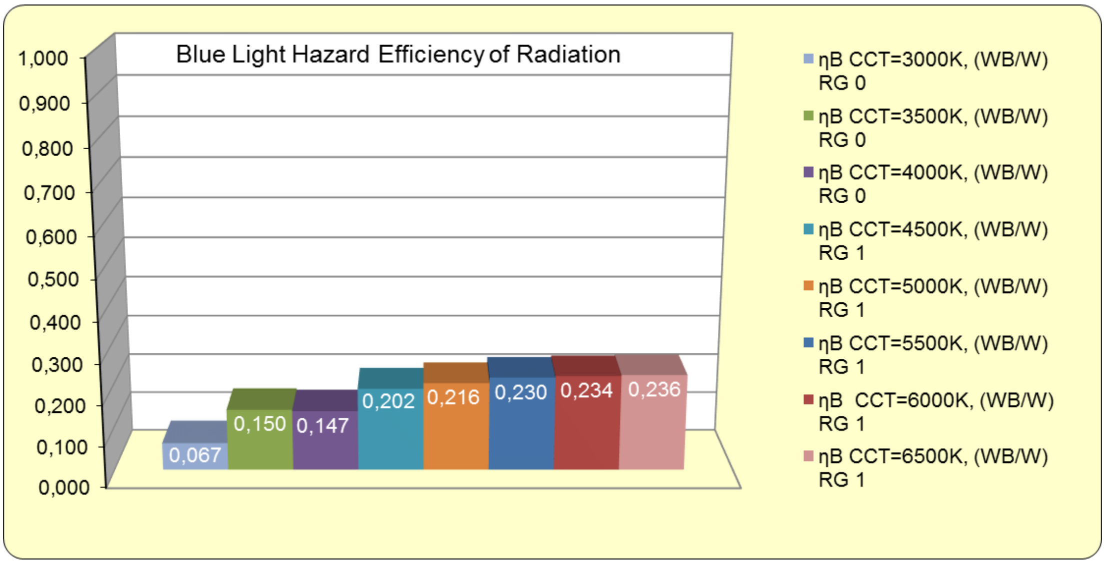

Fig.5 Blue light hazard efficiencies for the different CCTs of the luminaires

The blue light weighted effective radiance L_B, W/(m^2.sr), for the different CCTs are calculated from:

$$L_B = \sum_{300}^{700} L_e(\lambda).B(\lambda).\Delta\lambda, \qquad (1)$$

where $L_e(\lambda)$ is the effective spectral radiance, W_e/(m^2.sr.nm); B(λ) is the blue light hazard weighting function and Δλ is the bandwidth, nm.

The source radiance L_e is defined from the measured irradiance E_e and the angle of the measurement field of view Ω, sr:

$$L_e = \frac{E_e}{\Omega} \qquad (2)$$

The data from the blue light hazard risk evaluation and the determined risk groups [1,2,4,5] are represented in table 1.

Quantity	CCT 3000K	CCT 3500K	CCT 4000K	CCT 4500K	CCT 5000K	CCT 5500K	CCT 6000K	CCT 6500K
Effective irradiance, W/m^2	16,68	98,53	129,62	119,47	123,54	127,76	132,78	159,98
Illuminance (Photopic weighted effective irradiance), lx (lm/m^2)	229,47	1259,59	1627,79	1509,99	1560,06	1606,36	1674,09	1712,26
Luminance of the source L, cd/m^2	29216,59	160376,55	207256,54	192258,52	198633,15	204528,07	213151,34	218011,56
Blue light weighted effective radiance L_B, W/(m^2.sr)	5,57	74,02	95,11	120,95	133,63	146,99	155,28	159,98
Maximum L_B for the risk group classification, W/(m^2.sr)	≤100	≤100	≤100	>100 ≤10000	>100 ≤10000	>100 ≤10000	>100 ≤10000	>100 ≤10000
t_{max}, s	179430	13510	10514	8268	7484	6803	6440	6251
Risk Group	0 (EXEMPT)	0 (EXEMPT)	0 (EXEMPT)	1(LOW RISK)	1(LOW RISK)	1(LOW RISK)	1(LOW RISK)	1(LOW RISK)

Table 1 Blue light hazard evaluation for human-centric lighting installation at different set of CCTs

3 Conclusions

The received results show that the highest CCT in which the lighting situation could be categorized as exempt risk group is 4000 K. The lighting situations with higher CCTs exceed the limitations of the exempt group and are included in risk group 1 (low risk).

The most important thing in risk assessment of retinal injuries is the lighting design geometry and the type of performed visual tasks. It is suitable to be made appropriate measurements of the lighting installations in which the luminaires are implemented. The different applications may lead to different assessment results. It is important to be taken into account the eye movements of the observers for the performed visual tasks. In situations with laboratory visual tasks a constant eye direction is not typical. Moreover a situation in which the observer is looking directly at the light emitting surface is not expected. Appropriate assessment for human-centric lighting installations could be performed with taking into account the human eye possibilities and the subtended angle for color recognition in measurement geometry with direction of the central axis of the observer’s eye not perpendicular to the emitting surface. Another point of observation is that in this situation there will be more than one retinal images and their angular subtenses will differ depending on the working place and the typical axes of eye fixation direction. It would be useful as well to be taken into account the lighting distribution of the used luminaires.

4 References

[1] EN 62471:2008, Photobiological safety of lamps and lamp systems Light and lighting - Sports lighting, 2008.

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[6] Radiation Protection Division, Health Protection Agency, A Non-Binding Guide to the Artificial Optical Radiation Directive 2006/25/EC, 2007