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LIGHTING QUALITY WITH LEDS

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Abstract

CIE Technical Committee 3-50 *Lighting Quality Measures for Interior Lighting with LED Lighting Systems* looked into available research results that underlines the suitability or discard the applicability of existing measures to evaluate lighting quality of interior lighting with LED lighting systems. The work has been summarized in the CIE report 205:2013 “Review of lighting quality measures for interior lighting with LED lighting systems”. The document gives recommendations in the use of quality measures for LED lighting solutions, including background information, research results and literature references, as well as an indication of the relevant parameters to look into. To that, it gives an indication of needed research to ensure quality lighting in all situations with LED systems.

This paper will focus on two reviewed quality criteria. A summary of the conclusions by CIE TC 3-50 as well as recent research activities with respect to these quality metrics are presented.

Keywords: LED, Lighting Quality, Indoor Applications, Interior Lighting, Review

1 Introduction

Light Emitting Diodes (LEDs) have shown a rapid evolution in the last few years and replacing conventional light sources in luminaires for general, functional, lighting in indoor applications. Even though the application of LED replacement lamps and LED luminaires will likely increase energy efficiency, the resulting lighting conditions are not always rated positively by the users. A reason for this might be that quality measures are applied, which are derived from research with and referring to the use of diffuse fluorescent lighting. As LEDs have different characteristics, such as a small size, a relatively high brightness and a different spectral power distribution, it seemed to be required to validate the applicability of the existing quality measures in situations with LED lighting solutions. CIE TC 3-50 *Lighting Quality Measures for Interior Lighting with LED Lighting Systems* looked into available research results that underline the suitability or discard the applicability of existing measures to evaluate lighting quality of interior lighting with LED lighting systems. The work has been summarized in the report “Review of lighting quality measures for interior lighting with LED lighting systems” (CIE 2013).

2 Review of Quality Measures

The quality measures included in the review conducted by CIE TC 3-50 were derived from a number of relevant publications, such as CIE conference proceedings and reports, European and US handbooks, guidelines and standards (e.g. CIE 1998, CIE 2002a, CIE 2002b, CEN 2011, IESNA 2000, IESNA 2004, IESNA 2008, McGowan 2009 2009).

A distinction has been made between quality criteria and recommendations. Quality criteria focus on visual performance and avoiding visual discomfort, to ensure performance and safety. Recommendations go beyond task performance and safety aspects and generally aim at a higher lighting quality.

The following quality criteria were considered:

- Task visibility: uniformity of task illumination, reflected glare, veiling reflections and shadows
- Visual comfort: discomfort glare, overhead glare, luminance ratios, visual fatigue and eyestrain
- Flicker and stroboscopic effects

To that, the following recommended measures for quality of interior lighting were reviewed:

- Modelling of faces and objects
- Colour rendering, light colour preference, object colour appearance
- Appearance of spaces: room surface brightness, distribution of light on surfaces
- Consistency of colour and luminous flux over time and space

Literature on research looking into these quality measures was studied to identify the gaps and weaknesses in existing measures to assess the quality of interior lighting with LED lighting systems. This paper will address two quality aspects: discomfort glare and flicker, relevant to secure visual performance and avoid visual discomfort. The complete review can be found in the report of CIE TC 3-50 (CIE 2013).

3 Lighting Quality: Discomfort Glare

The Technical Committee identified that the appearance of the LED lighting solution is one of the major topics that affects the applicability of existing quality measures. Whereas style, size, integration into architecture and appropriateness of appearance is as relevant as it was for conventional lighting solutions, a non-uniform luminance distribution or patterns of bright spots within the luminaire`s exit window can induce a feeling of restlessness, which might impact well-being, visual fatigue and performance. The author is not aware of research dealing with this topic up until today. Yet, a larger number of studies looked into the effect of non-uniformity on perceived discomfort glare, which are described in the report of CIE TC 3-50 (CIE 2013).

The review of research* on discomfort glare from non-uniform stimuli indicates that LED lighting solutions with a non-uniform luminance distribution cannot be evaluated with the Unified Glare Rating (CIE 1995) or the Visual Comfort Probability (IESNA 2000), typically employed to assess discomfort glare from conventional indoor lighting solutions. In general, the non-uniform stimuli induce more glare than conventional, fluorescent lighting solutions of the same size, with the same average luminance. Based on the available research on metrics to asses discomfort glare from LED lighting solutions, CIE TC 3-50 concluded that the UGR and VCP should not be used for non-uniform light sources.

Recently, Xia et al. (2011) and Hara and Hasegawa (2012) indicated that the UGR can be modified to address discomfort glare from non-uniform light sources. Geerdinck et al. (2013) stated that this seems to be suitable for luminance contrasts within the exit window up to 1:10, but the UGR does not correlate well with the subjective assessments of luminaires with a more non-uniform luminance distribution. Geerdinck et al. (2013) indicate that peak luminance, luminance contrasts and spatial luminance distribution play an important role in the glare assessment and need to be considered in the construction of a new glare index. To that, the LED spacing and arrangement seem to be of importance (review in CIE 2013).

Division 3 of the CIE has set up a new Technical Committee addressing discomfort glare by luminaires with a non-uniform source luminance. The TC will identify the non-uniformity parameters that influence the glare rating, define the limits to the validity of UGR and propose a preliminary correction to the UGR that takes into account non-uniformity of glare sources.

* published until Fall 2012

4 Lighting Quality: Flicker and Stroboscopic Effects

Looking into quality of interior lighting with LED lighting systems, photometric flicker is a relevant quality parameter; a large variety of photometric flicker is observed in LED products (Paget 2011; Poplawski and Miller 2013) and flicker affects performance and well-being (IEEE 2010). In this context, flicker is defined as “the rapid variation in light source intensity” (IESNA 2000) and reflected in the modulation of luminous flux and the detection of stroboscopic effects.

Drivers of LEDs can produce photometric flicker, and dimming of LEDs can reinforce light modulation. A minimum driver output frequency of 100 or 120 Hz to avoid perceptible flicker seems to be insufficient to ensure lighting quality (review in Poplawski and Miller 2013). Based on the available research on metrics to asses flicker from LED lighting solutions, CIE TC 3-50 concludes that flicker and stroboscopic effects are not addressed appropriately by current quality criteria, such as flicker frequency and flicker percentage.

Bullough et al. (2012; Alliance for Solid-State Illumination Systems and Technologies (ASSIST) 2012) propose a function of flicker frequency and percent flicker to predict the detection and acceptability of stroboscopic effects, based on experiments under worst-case conditions. Further research is required to assess the applicability of this approach in typical applications. Minimum recommendations for flicker criteria as well as guidelines for applications in which flicker is a relevant quality criteria can be found in Poplawski and Miller 2013). CIE TC 1-83 *Visual Aspects of Time-Modulated Lighting Systems* and the IEEE PAR1789 committee are also investigating stroboscopic effects.

5 Outlook and Future Research

The small size of LEDs offers design freedom. It is to be expected that LEDs are not only used in conventional luminaires, but will be, for example, embedded in furniture or room surfaces. This can result in an atypical positioning of the light source, which in return can affect visual comfort in a room. Discomfort glare from a source at the line of sight is typically greater than from the same source positioned above the line of sight, especially when dealing with non-uniform stimuli. Research looking into discomfort glare from non-uniform vertical artificial light sources (e.g. Takahashi et al. 2007, Kasahara et al. 2006) or larger vertical artificial light sources (e.g. Osterhaus 1996, Sendrup 2001) is available, but the research is inconclusive. Further studies are necessarily.

The LED features directional light, small size and high brightness, in their combination uncharacteristic for interior lighting, led to the review of existing quality measures by CIE TC 3-50. Considering the development of larger and commercial OLEDs, it seems to be appropriate to review the quality measures with respect to OLED applications as well. OLEDs have light emitting surfaces with a more uniform luminance distribution, realizing a very diffuse lighting contribution to the room. This lighting condition is deviating from the one realised by conventional, fluorescent lighting as well. The use of OLEDs will affect room appearance. Research indicates that an increase of room surfaces’ luminance positively affects room appearance (e.g. Loe et al. 1994, Houser et al. 2002, Veitch and Newsham 2006). At the same time, too diffuse lighting can cause a low degree of modelling, resulting a in a monotonous visual environment (e.g. Newsham et al. 2004, Fostervold and Nersveen 2008). Direction of light, modeling and shadows are important aspects of lighting quality, which all need further research to define an appropriate metric and determine minimum, as well as maximum requirements (CIE 2013, Knoop 2014).

6 Summary

The work of TC 3-50 has been summarized in the report “Review of lighting quality measures for interior lighting with LED lighting systems”. The document gives recommendations in the use of quality measures for LED lighting solutions, including background information, research results and literature references, as well as an indication of the relevant parameters to look into. It gives an indication of needed research to ensure quality lighting in all situations with LED systems. Focussing on two quality measures in this paper, discomfort glare and flicker, research continued and is expected to lead to suitable metrics in the near future. Quality

aspects related to future applications of LEDs and OLEDs need to be considered. Available research needs to be reviewed and new research activities need to be started up, to provide the lighting community with additional recommendations on the use of criteria to evaluate lighting quality of interior lighting using new technologies.

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