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LightingEurope Position Paper on Flicker and Stroboscopic Effect
(Temporal Light Artefacts)

Introduction

Different terms exist to describe artefacts that may be perceived by humans due to the fact that the light output of a lighting product varies with time. The general term for this is 'temporal light artefacts' (TLA) which includes two well-known phenomena: 'flicker' and 'stroboscopic effect'.

Formally, TLAs are described as undesired effects in the visual perception of an observer within an environment. The term 'flicker' refers to unacceptable light variation that is directly perceived by an average (or normal) observer. 'Stroboscopic effect' is an effect which may become visible for an average observer when a moving or rotating object is illuminated. Lighting products that exhibit flicker or stroboscopic effect are considered not good quality lighting.

TLAs are not just annoying to humans, but might also have health impacts (see Annex A).

Currently, modulation depth (*MD*) and flicker index (*FI*) are often used to quantify flicker or stroboscopic effect. It has been shown, that both metrics are not able to objectively score the level of flicker or stroboscopic effect as actually perceived by humans. Instead of *MD* and *FI*, for 'flicker' a widely applied and IEC-standardized metric exists, the 'short-term flicker severity' ($P_{\mathrm{st}}^{\mathrm{LM}}$). For the objective assessment of stroboscopic effect, the Stroboscopic Visibility Measure (*SVM*) is available (see Annex B). Adverse effects on optical systems such as high-speed cameras, smart phones, bar-code scanners etc. are not considered in this paper.

TLAs are caused by light modulations which may have several root causes (see Annex C).
TLA requirements impact light quality and are not correlated with energy efficiency.

LightingEurope position on TLA

LightingEurope calls upon the market to use correct terms and metrics to describe flicker and stroboscopic effect:

- To use distinct terms and definitions for the different TLA phenomena flicker and stroboscopic effect
- To use the objective and validated metrics $P_{\mathrm{st}}^{\mathrm{LM}}$ for flicker and *SVM* for stroboscopic effect
- To stop using the metrics 'Modulation Depth' *MD* and 'Flicker index' *FI* to describe 'flicker' and 'stroboscopic effect' for human perception
- To make selective use of the metrics, as 'flicker' and 'stroboscopic effect' phenomena are not relevant for all products or in all applications
- To support research to define acceptance criteria for the TLA metrics in the various applications
- To adopt existing and forthcoming CIE and IEC publications, definitions and metrology for flicker and stroboscopic effect

More details and background information and all references can be found in the Annexes of this position paper.

Annex A: Effects on humans

The effects considered in this position paper are limited to flicker and stroboscopic effects perceived by humans due to the modulation in the light output of lighting equipment.

During the past years the scientific committees IEEE PAR 1789 [1] and EC SCENIHR [2] have assessed the potential health, performance and safety-related effects resulting from flicker and stroboscopic effects. Possible adverse effects on human health are migraine and aggravation of autistic behavior, and even photosensitive epileptic seizure under extreme conditions (e.g. flash lights). Performance and safety-related implications are the incorrect perception of the motion of an object and distraction which may be unacceptable in working environments with machinery.

As a consequence, within Europe the European Commission (EC) has issued Mandate M/519/EN [3] in which the need for new or enhanced performance standards for flicker and stroboscopic effects has been identified as one of the key areas of concern.

Individual people have a different sensitivity for flicker and stroboscopic effect. There are some experiments and studies done showing no effect of age. [5] Therefore we currently assume that sensitivity to TLA is age independent.

Annex B: Metrics and acceptance criteria

Metrics presently often used

Currently, 'Modulation Depth' (*MD*) – also called Percent Flicker - and 'Flicker Index' (*FI*) are often applied to rate the severity of both flicker and stroboscopic effect. These metrics are used without any distinction of the TLA phenomena being considered (flicker and stroboscopic effect). These metrics do not account for critical properties of the wave shape of the light ripple, such as frequency, wave shape and duty cycle:

- Frequency: Flicker becomes visible if the frequency of the light modulations ranges from a few tenths of Hertz (Hz) up to approximately 80 Hz, whereas stroboscopic effects may occur for light modulation frequencies up to 2 kHz [1]. For 'flicker' the maximum sensitivity is around 10 Hz.
- Wave shape: Flicker and stroboscopic effects induced by sinusoidal, saw tooth and rectangular light variations are perceived differently. The aggregation of the different frequency components of the light ripple has impact on perception.
- Duty cycle: In case of rectangular wave shapes, the duty cycle is the percentage of the time that the light level is at a maximum level. This parameter is important for LED lighting.

In conclusion: the metrics *MD* and *FI* should no longer be used to describe 'flicker' and 'stroboscopic effect' for humans.[2]

NEMA TLA Working Group has published a TLA Position Paper [7] mid-2015. In this paper, concern is expressed on IEEE Std 1789-2015 [1]. Firstly, because they apply the metric *MD*, and secondly they have proposed limits that are overly strict for many applications, which could add unnecessary cost to the electronics in LED products. Even incandescent lamps do not fall within the low-risk or no-effect regions in the recommended practices.

Preferred metrics

Instead of *MD* or *FI*, we need other metrics that take frequency, wave shape and duty cycle into account and which are actually able to objectively predict the visibility of flicker and stroboscopic effect by humans.

For flicker a widely applied and IEC-standardized metric exists: the 'short-term flicker severity' $P_{\mathrm{st}}^{\mathrm{LM}}$ (see IEC TR 61547-1 [4]). For the objective assessment of stroboscopic effect, the 'Stroboscopic Visibility Measure' *SVM* is available [5].

Both the TLA phenomena and the metrics $P_{\mathrm{st}}^{\mathrm{LM}}$ and *SVM* are being reported in a CIE Technical Note which is expected to be published by mid-2016 [6].

Acceptance criteria

Acceptance criteria for the TLA metrics depend upon both the visibility and on the criticality in the application. For example, in a workshop the absence of stroboscopic effects is critical with respect to the safe operation of machinery, while for some other lighting applications stroboscopic effects are rarely an issue. Hence specification of both metrics and their acceptance criteria depends upon the application.

For common applications (home, office) the visibility threshold $P_{\mathrm{st}}^{\mathrm{LM}} \leq 1.0$ may be adequate (see IEC TR 61547-1 [4]). Regarding the *SVM* metric [5] further experience shall be gained throughout the lighting community in the next years.

Several international and regional lighting application standards and industry standards are in the process of proposing requirements to limit flicker and/or stroboscopic effect.

1 The visibility of stroboscopic effect depends also on the speed of the motion of the illuminated objects.

2 The metrics *MD* and *FI* may still be valuable to specify limits to avoid interference of camera's, machine vision applications, bar-code scanners and alike.

Testing

The P_{st}^{LM} and *SVM* metrics can be measured for the lighting equipment under stable operational conditions. However, the tests using the same metrics can also be executed under conditions of mains voltage fluctuations and/or dimming.

IEC TR 61547-1 specifies how lighting equipment should be tested against mains voltage fluctuations that are likely to be present in application. Within IEC a joint ad-hoc working group JAHG17 of IEC TC23 and TC34 is also considering how to specify TLA as part of dimmer compatibility requirements. The number of test points/dimming levels is subject of the work of this standardization project.

In general, we prefer that the equipment should be tested under the conditions that likely occur in practice, i.e. with dimming or with mains voltage fluctuations.

In principle, both metrics can be used to test individual product as well as the TLA performance of installations in actual applications (in-situ). However, the latter in-situ testing is much more prone to measurement uncertainties due to various influence quantities such as ambient light from other light sources or daylight, moving subjects and unstable setups. This is especially true for in-situ testing of flicker performance using P_{st}^{LM} as a waveform of at least one minute must be recorded, and relative light level variations of about a quarter percent are already at the limit. Therefore, TLA measurements should normally be done at product level. TLA performance of an actual application environment of multiple light sources is generally better than the TLA performance of a single light source due to the averaging out of the light modulation from the different light sources.

Annex C: Root causes and visibility

Possible causes for light modulation of lighting equipment that may give rise to flicker or stroboscopic effects [1][6] are:

- Light source technology and its driver topology
- Dimming technology of externally applied dimmers or internal light level regulators
- Dimming level
- Mains voltage fluctuations caused by electrical apparatus connected to the mains or intentionally applied for mains signaling purposes

The resulting light fluctuations may be periodic or non-periodic.

Factors that determine the visibility of TLAs are related to the light, the observer and the environment:

- Frequency and relative magnitude of luminance ripple
- The shape of the light waveform (square, sinusoidal, duty cycle)
- The light level of the lighting equipment
- The illuminated/observed object and its speed of movement
- The sensitivity of the observer, the viewing angle and any changes in direction of view
- The background light level within the environment

Annex D: References

[1] IEEE Std 1789-2015, IEEE Recommended Practices of Modulating Current in High Brightness LEDs for Mitigating Health Risks to Viewers, http://standards.ieee.org/findstds/standard/1789-2015.html

[2] EC SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks), Health Effects of Artificial Light, 19 March 2012: http://ec.europa.eu/health/scientific_committees/consultations/public_consultations/scenihr_consultation_14_en.htm.

[3] Mandate M/519/EN, Mandate addressed to CEN, CENELEC and ETSI to develop standardization in the field of light emitting diodes (LEDs), 12 February 2013: http://ec.europa.eu/enterprise/standards_policy/mandates/database/index.cfm?fuseaction=search.detail&id=527.

[4] IEC/TR 61547-1:2015, Equipment for general lighting purposes. EMC immunity requirements. Part 1: An objective voltage fluctuation immunity test method.

[5] G. Perz et al, Modeling the visibility of the stroboscopic effect occurring in temporally modulated light systems, Lighting Research and Technology published online 13 May 2014: http://lrt.sagepub.com/cgi/reprint/1477153514534945v1.pdf?ijkey=GcQ3UW7Qz2UwqtM&keytype=ref.

[6] CIE Technical Note TN 006:2016, Visual aspects of time-modulated lighting systems, August 2016.

[7] NEMA Position Paper, Temporal Light Artifacts (Flicker and Stroboscopic Effects), 2015-06-15: https://www.nema.org/news/Pages/NEMA-Lighting-Systems-Division-Publishes-Position-Paper-on-Temporal-Light-Artifacts.aspx.

LightingEurope is an industry association of 33 European lighting manufacturers, national associations, and companies producing materials. LightingEurope members represent over 1,000 European companies, a majority of which are SMEs; a total workforce of over 100,000 people in Europe; and an annual turnover estimated to exceed 20 billion euros. LightingEurope is dedicated to promoting efficient lighting practices for the benefit of the global environment, human comfort, and the health and safety of consumers.

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