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TECHNICAL NOTE

Final Report

CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems

CIE TN 008:2017

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Summary

Contemporary lighting systems vary widely in the degree to which their light output shows temporal variations (temporal light modulation, TLM). TLM is known to affect human visual perception, neurobiology, and performance, sometimes in adverse ways. Many standards development organizations, regulators, and certification bodies have been active in seeking to address these issues. Some researchers are actively studying the effects of TLM. However, current activities are uncoordinated and risk being inefficient. The CIE, with the support of Natural Resources Canada – Office of Energy Efficiency, the National Electrical Manufacturers' Association, Philips Lighting, BC Hydro, and the National Research Council of Canada, convened a stakeholder workshop in Ottawa, Canada, February 8–9, 2017, to provide an impetus towards improved collaboration. The objective of this meeting was to develop a roadmap of research, recommendations, and standards activities related to temporal light modulation from lighting systems that are needed in order to speed up the process of developing international standards in an efficient way while preventing overlap and duplicate effort. The scope of the meeting was limited to developing the roadmap, establishing collaborations, and dividing the work amongst participants. The meeting was not intended to establish the content details for future standards documents. This report summarizes the current state of knowledge and standardisation concerning TLM, identifies gaps, and sets out the roadmap developed by the workshop participants. The roadmap leads, through collaborative effort, to evidence-based international standards intended to limit undesirable TLM from lighting products and systems. Lighting systems that meet these standards will thereby support the needs of lighting end-users, which will facilitate the market acceptance of new technologies and the achievement of energy-efficient targets.

1 Introduction

1.1 Background

The technological change in light sources and lighting systems since 2000 is unprecedented, with the luminous efficacy of individual solid-state lighting (SSL) packages moving rapidly towards what is thought to be a practical maximum on the order of 300 lumens per electrical watt (lm/W). In this period of rapid product development, it is not surprising that there is diversity among products in the driver designs for the electronics of these new light sources, resulting in wide variations in the temporal patterns of their light output (Poplawski et al. 2011). These temporal variations are known colloquially as flicker, and more precisely as temporal light modulation (TLM). In addition to the driver designs of the light source itself, dimming controls can add TLM even to light sources that do not exhibit TLM when operated at 100 % output. Many light-emitting diode (LED) systems use pulse-width modulation (PWM) dimming (100 % modulation at one frequency with varying duty cycles).

Temporal light modulation, whether from the design of the driver or through dimming control, can have adverse effects on visual function and health (Wilkins et al. 2010). Therefore, it is advisable for standards to be developed that will limit the possibility that new light sources and controls will produce light output with undesirable TLM characteristics. There is a liability risk for industry in possibly introducing products to market that may cause harm to consumers, and risks to public health for those who might experience these consequences.

The first industry recommendation on limiting light source flicker for the purpose of reducing the risk to viewers was IEEE 1789-2015, which was released in June 2015 (IEEE Power Electronics Society 2015). It has proved to be controversial, as several industry associations have issued press releases in response to it (e.g. National Electrical Manufacturers Association (NEMA) Lighting Systems Division 2015). Partly as a result of the publication of IEEE 1789-2015, and partly because of the general interest in TLM, several organizations, including CIE, have activities under way to address various aspects of the issue, including metrology, visual effects, and health effects. Some of these organizations write standards or recommendations, either at the national or international level; others generate information and research results.

CIE has recently published Technical Note TN 006:2016 (CIE 2016a) as an interim output of its Technical Committee (TC) 1-83 “Visual aspects of time-modulated lighting systems”. This

document establishes definitions and proposes a measurement model for quantifying TLM for the purposes of predicting temporal light artefacts. TC 1-83 will proceed to complete its terms of reference to propose a predictive model based on data collected using this measurement model. In parallel, CIE Division 2 has a Reportership, DR 2-52, titled “Flicker measurement and flicker index study on solid state lighting”.

All of this activity is healthy, but there is a possibility that different bodies may produce competing recommendations. The limited number of international experts in this field may be taxed to serve on the various committees and boards attempting to address light source flicker. A co-ordinated, harmonized approach would reduce duplication and speed the development of a reduced set of documents covering metrics, measurement, and criteria for protecting public health. CIE convened a stakeholder workshop, held in Ottawa, Canada, February 8–9, 2017, to open discussions towards such an approach. This document is the report of that workshop.

1.2 Workshop scope

The objective of this meeting was to develop a roadmap of research, recommendations, and standards activities related to temporal light modulation from lighting systems that are needed in order to speed up the process of developing international standards in an efficient way while preventing overlap and duplicate effort. The scope of the meeting was limited to developing the roadmap, establishing collaborations, and dividing the work amongst participants. The meeting was not intended to establish the content details for future standards documents.

The workshop scope was expressed as follows:

Temporal light modulation from lighting systems can affect people and equipment. Effects on equipment (e.g. interference with optical systems such as barcode readers and cameras) were out of scope. Effects on people were in scope for this workshop. Possible effects on people include the following:

- Visual perception effects (temporal light artefacts, TLA): flicker, stroboscopic effect, and phantom array
- Performance effects: eye movements changes, changes in visual performance, changes in cognitive task performance
- Neurobiological effects: headache, eyestrain, migraine, epilepsy, etc.

The workshop aimed to align efforts in standardisation and research within its scope, to identify overlap and knowledge gaps, to identify possible mismatches between research and standardisation projects, and to develop a roadmap for collaboration and co-operation leading to a useful set of appropriate standards in this domain. At the conclusion of the workshop, the goal was to achieve agreement on both the work that is needed and on who will undertake the various activities needed to fulfil the roadmap. Annex A shows the workshop agenda.

1.3 Workshop participants



Front row: Carl Bloomfield; John O'Hagan; Jennifer Veitch; Yoshi Ohno; Howard Wolfman; Naomi Miller; Terry McGowan. Second row: Robert Nachtrieb; Andrew Watson. Third row: Youngshin Kwak; Kathryn Nield; Joanne Zwinkels; Brad Lehman. Fourth row: Sandra Mancini; Li Qian (Cherry); Arnold Wilkins. Fifth row: Alex Baker; He Yang (Crane); Annette Steinbusch. Back row: Chan Su Lee; Jim Gaines; Aaron Miller; Dan Rogers; Malgorzata Perz; Norbert Wittig; Reinhard Lecheler; Christophe Martinsons

Figure 1 – Workshop participants

The organizing committee developed a list of nearly 50 invitees, comprising representatives of standards development organizations (SDOs), industry associations, researchers who are or were recently active in studying TLM, and regulators. The SDOs included were at both the regional and international levels, as were the industry associations. Every effort was made to include participation from all regions of the globe; despite this, there were no invitations issued to organizations representing South America or Africa. Some organizations chose to be represented by people who were also attending on behalf of another organization, and a few individuals were unable to attend because of illness. There were twenty-seven participants, all of whom were present for the entire workshop. The workshop was aided by a professional facilitator, Mr. Alain Rabeau of the Intersol Group, a consultancy based in Ottawa, Canada. Ms Sandra Mancini of the National Research Council of Canada assisted with recording and arrangements.

Participants were responsible for funding their travel and accommodation costs. There was no registration fee for the workshop; the sponsors' contributions covered the meeting and associated costs.

Table 1 lists the workshop participants and their affiliations. Where more than one affiliation is listed, the first is the primary affiliation for which the individual was a representative at the workshop. The second (and in one case, third) affiliation listed is the individual's employer, where that is different from the primary affiliation, to provide context for each individual's contributions to the workshop.

Table 1 – Workshop participants and affiliations

Name	Organization(s)	Country
Yoshi Ohno	CIE – President National Institute for Standards & Technology	USA
Kathryn Nield	CIE – General Secretary	Austria
Youngshin Kwak	CIE – Director, Division 1 Ulsan National Institute of Science and Technology	Republic of Korea
Joanne Zwinkels	CIE – Associate Director, Division 2 NRC Measurement Science & Standards	Canada
Jennifer Veitch	CIE – Director, Division 3 NRC Construction	Canada
John O'Hagan	CIE – Director, Division 6 Public Health England	United Kingdom
Pierre Gallant	Natural Resources Canada – Office of Energy Efficiency	Canada
Annette Steinbusch	LightingEurope Philips Lighting	Netherlands
Rob Nachtrieb	IEC/TC 23, IEC/TC 34, IEC/TC 23/SC 23B/JAHG 17 NEMA Lutron Electronics	USA
Jim Gaines	NEMA Philips Lighting	USA
Brad Lehman	IEEE P1789 Northeastern University	USA
Howard Wolfman	IEEE Power Electronics Society Study Group Lumispec Consulting	USA
Arnold Wilkins	University of Essex	United Kingdom
Malgorzata (Gosia) Perz	CIE TC 1-83 Philips Lighting	Netherlands
Norbert Wittig	IEC/TC 34/WG 5 Panasonic Europe	Germany
Naomi Miller	Illuminating Engineering Society [North America] Pacific Northwest National Laboratory	USA
Li (Cherry) Qian	China Lighting Standardization Committee TC 224 SC3 Everfine	China
Dan Rogers	Environmental Protection Agency / ENERGY STAR ICF International	USA
Reinhard Lecheler	ZVEI OSRAM	Germany
He (Crane) Yang	International SSL Alliance	China
Alex Baker	International SSL Alliance Lumileds	USA
Terry McGowan	American Lighting Association	USA
Andrew Watson	Apple	USA
Chan Su Lee	Yeungnam University	Republic of Korea
Aaron Miller	CSA Group	USA
Carl Bloomfield	Intertek	USA
Christophe Martinsons	IEA 4E SSL Annex Centre Scientifique et Technique du Bâtiment	France