International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

Institute of Communication & Computer Systems
National Technical University of Athens

CIE Expert Tutorial on the Measurement of Temporal Light Modulation

National Technical University of Athens, Athens, Greece

October 10, 2022
09:30 to 16:00 EEST

Experts from around the world will present a one-day Expert Tutorial on the Measurement of Temporal Light Modulation (TLM). TLM causes visual perception effects such as flicker, phantom array and stroboscopic effects. These effects, collectively called temporal light artefacts (TLA), can have adverse effects on users of lighting products such as decreases in performance and health. Increasingly authorities are enforcing restrictions on TLM, thus necessitating accurate assessment of the effects.

This tutorial will help participants to understand the broader issues surrounding TLM and the underlying concerns about TLA. The tutorial will provide practical advice on measurement of TLM using standards and CIE documents as well as the estimation of measurement uncertainty and conformity assessment. The goal is to provide participants with the knowledge to assess accurately TLM, which in turn is fundamental to the proper assessment of its effects on users.

Who should attend: The tutorial will be of benefit to testing laboratories, lighting companies, equipment manufacturers, researchers, market-surveillance and product-testing authorities, students and anyone else who is interested in all aspects of TLM, as well as researchers undertaking fundamental psychophysical research on TLAs.

What you will learn: Fundamentals of TLM and how it affects us. Best practice advice on how to measure TLM accurately and how to evaluate the measurement equipment. Inside advice on how to calculate the predictors of TLA. Methods of evaluating the uncertainty of measurement and uncertainty in the calculations of the predictors of TLA. How to evaluate products with respect to performance limits.

How to attend: The tutorial is organized as an in-person event, however in case of special circumstances online attendance is possible. For more information please see the event website: https://cie.co.at/news/cie-expert-tutorial-and-symposium-measurement-temporal-light-modulation.

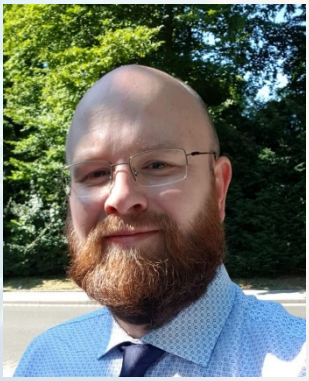
Presenters and presentation titles:

Presenter	Topic
Dr Jennifer A. Veitch (CA)	Fundamentals of TLM and its effects on people
Mr Menno Schakel (DE)	Outline of CIE TN 012:2021
Mr Paul Dekker (NL) Dr Costis Bouroussis (GR)	Measurement of temporal light modulation (TLM)
Dr Małgorzata (Gosia) Perz (NL)	Calculation of predictors of TLAs
Dr Anders Thorseth (DK)	Estimation of measurement and calculation uncertainties
Dr Peter Blattner (CH)	The role of measurement uncertainty in conformity assessment
Mr Tony Bergen (AU)	Round panel discussion

The day following the Tutorial there will be a **CIE Symposium on Advances in Measurement of Temporal Light Modulation**: a one-day scientific symposium featuring contributed papers by experts from around the world. Also accompanying these events there will be:

- CIE Division 2 Annual Meeting and Technical Committee meetings;
- EURAMET MetTLM stakeholder meeting;
- social function

The tutorial team and their presentations:

	Presenter	Presentation title and contents
	**Dr Jennifer A. Veitch** *National Research Council of Canada* Jennifer is a Principal Research Officer in the NRC Construction Research Centre, where she investigates interactions of people and their physical environments, including lighting quality and light source effects on performance, mood, and health. She chaired the *CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems* in 2017, and she continues to investigate the effects of TLM on people. Jennifer is a Fellow of national and international associations in lighting and psychology, and a Senior Member of IEEE. She received the CIE Waldram Gold Pin for Applied Illuminating Engineering in 2011 and the IES Medal Award in 2018. She serves the CIE as its Vice-President Technical and President-elect.	**Fundamentals of TLM and its effects on people** Temporal light modulation (TLM) is a property of light sources and lighting systems that show a cyclic variation in light output. Whereas the TLM of legacy light sources such as incandescent lamps was a property of the technology that was broadly common to all lamps in that family regardless of manufacturer, the TLM of light-emitting diode (LED) lamps and lighting systems is a property of the electronics that control the lamp or lighting system, and varies widely from one product to another even from a single manufacturer. TLM can cause visual, behavioural, neurological problems in observers, and there is some evidence that a subset of the population is more at risk of serious outcomes. This lecture will introduce how TLM occurs in lighting system operation and will demonstrate why it is a problem worthy of our attention.
	**Mr Menno Schakel** *Nichia Europe GmbH, Germany* As a technical marketing engineer for Nichia, Menno focuses on customer's technical requirements, bridging the gap between the customer and Nichia's product research and development teams. Before his current position he has worked as an optical measurement specialist at Philips Lighting (currently Signify) and Lux-TSI. He has been a member of several CIE Division 2 Technical Committees and was chair of TC 2-89 "*Measurement of Temporal Light Modulation of Light Sources and Lighting Systems*", which prepared CIE TN 012:2021.	**Outline of CIE TN 012:2021: Guidance on the Measurement of Temporal Light Modulation of Light Sources and Lighting Systems"** TN 021:2021 is intended to give users guidance and recommendations on the measurement of quantities related to temporal light modulation. This presentation will give a brief outline of these recommendations, when they apply, and also when they might not apply.

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<td>Mr Paul Dekker
VSL, The Netherlands

Paul is senior metrologist at VSL, the National Metrology Institute of the Netherlands. He is currently coordinating a project on Metrology for Temporal Light Modulation within the European Metrology Programme for Innovation and Research. Paul represents the Netherlands in CIE Division 2 and is a member of CIE TC 2-89 "Measurement of temporal light modulation of light sources and lighting systems".</td>
<td rowspan="2">Measurement of temporal light modulation (TLM)

The presentation will analyse and discuss measurement of temporal light modulation in a holistic way. This will include the preparation of the device under test, the different types of the measurement setups, the most common instrument types and their properties and characteristics. It will present all the steps in the measurement procedure including key aspects of sampling, filtering and acquiring of the modulated light. Facilities for the characterization of the measurement devices will be also presented.

During the presentation, it is planned that some demonstration measurements will be performed live (subject to confirmation).</td>
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<td>Dr Constantinos Bouroussis
National Technical University of Athens, Greece

Constantinos (Costis) is research associate at Lighting Laboratory of the National Technical University of Athens, and an independent consultant. His main areas of interest include lighting technology, photometry and radiometry, imaging sensors, machine vision, and unmanned aerial systems.

Costis represents Greece in CIE Division 2 as country member, is the Chair of TC 2-95 “Measurement of obtrusive light and sky glow” and member of several CIE TCs.</td>
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Dr Małgorzata Perz
Signify Research, The Netherlands

Gosia is a scientist at Signify Research, Lighting Applications department. Her interest as well as her expertise lie in studying the various aspects of the visual perception (spectral, spatial and temporal) and in translating experimental results into design rules and guidelines to ensure optimal light quality of different products.

For its final few years, Gosia chaired TC 1-83 (the first chair was Dragan Sekulovski) "Visual aspects of time-modulated lighting systems", and their work has recently been published as Technical Report, CIE 249:2022.

Calculation of predictors of TLAs

Methods/models used to predict the visual response are typically built on psychophysical measurements of observers' sensitivities. Two such methods, used to predict the visibility of temporal light artefacts (TLAs), are formulated in the CIE 249:2022, a recently published Technical Report of TC 1-83. One is defined in frequency- and other in time-domain.

Two specific implementations of these methods are further defined, translating the input TLM into visibility measures: the SVM for the stroboscopic effect and the IEC light flickermeter (for flicker, of course).

In this presentation it will be first briefly explained how to interpret results from psychophysical measurements and what their effect on the visibility measures is. The computational steps of the frequency- and time-domain methods will be presented followed by demos of the recommended visibility measures: SVM and P_{st}^{LM}.

Dr Anders Thorseth
Technical University of Denmark

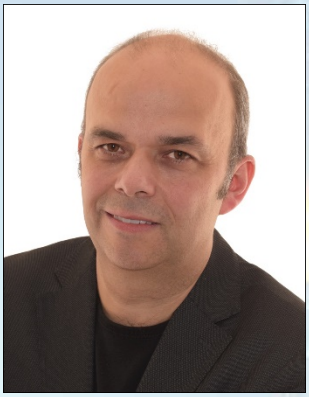
Anders is Project Manager at Technical University of Denmark at the Department of Electrical and Photonics Engineering. His interests are photometric and radiometric measurements of light and lighting, developing new methods and establishing standards for global harmonization.

Anders chaired TC 2-93 for the revision of the International Standard ISO/CIE 23539 "Photometry – The CIE system of physical photometry" and is now chairing TC 2-97 for the revision of the International Standard CIE S 025 "Test Method for LED Lamps, LED Luminaires and LED Modules".

Estimation of measurement and calculation uncertainties

Temporal light modulation (TLM) presents new challenges for the lighting measurement community. New complicated TLM signals and strict regulatory requirements show the need to estimate measurement uncertainties.

The talk will present current and developing recommendations for reducing and estimating uncertainties of TLM measurements and how this affects the calculation of TLA metrics. Furthermore, challenges regarding reproducibility and traceability. Aspects of uncertainties related to both laboratory and field measurements will be covered.

	**Dr Peter Blattner** *Federal Institute of Metrology (METAS), Switzerland* Peter Blattner holds a PhD in applied optics from the University of Neuchâtel, Switzerland. He is currently head of the optics laboratory at the Swiss Institute of Metrology (METAS). From 2007 to 2011, he was Chairman of the Technical Committee on Photometry and Radiometry of the European Association of Metrology Institutes (EURAMET TC-PR). From 2011 to 2019, he was Director of Division 2 (Measurement of Light and Radiation) of the CIE. In 2015, he received the CIE Wyszecki Gold Pin award for outstanding contributions to fundamental research. Peter Blattner is the current CIE President, for the period 2019 to 2023.	**The role of measurement uncertainty in conformity assessment.** The aim of measurements is very often to be able to make conformity statements, for example whether a certain product meets the legal or normative requirements. However, as every measurement has a certain uncertainty, it becomes more difficult to make conformity statements. Part 6 of the Guide to the Expression of Uncertainty in Measurement GUM (i.e. JCGM 106:2012,) provides the mathematical basis for quantifying the consequences of conformity statements. This also involves being able to carry out risk assessments.
	**Mr Tony Bergen** *Photometric Solutions International, Australia* Tony is a physicist who has been working in the field of photometry and radiometry for nearly 25 years. He is Technical Director of Photometric Solutions International, an Australian company that designs and manufactures testing and measurement equipment, and Managing Director of the Australian Photometry and Radiometry Laboratory. Tony also serves as President of CIE Australia and Director of CIE Division 2, and is chair of TC 2-78 The Goniophotometry of Lamps and Luminaires.	**Round Panel Discussion** The experts who have presented the lectures will reconvene for an open discussion session. Participants can ask questions to the lecturers in an open and interactive session. This will be an opportunity to follow up questions which could not be answered in detail earlier and to explore key concepts on the subject matter.