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The Presidents of the CIE

1913	T. Vauthier	France
1921	E.P. Hyde	USA
1927	C.C. Paterson	United Kingdom
1931	A.R. Meyer	Germany
1935	Ch. Fabry	France
1939	N.A. Halbertsma	Netherlands
1951	W. Harrison	USA
1955	J.W.T. Walsh	United Kingdom
1959	I. Folcker	Sweden
1963	L. Schneider	Germany, Fed. Rep.
1965	I. Folcker	Sweden
1967	D. Vermeulen	Netherlands
1971	W.R. Stevens	United Kingdom
1975	S.K. Guth	USA
1979	J.B. de Boer	Netherlands
1983	G. Wyszecki	Canada
1985	A.M. Marsden	Hong Kong
1987	H. Bodmann	Germany, Fed. Rep.
1991	R.C. Aldworth	United Kingdom
1995	J. Hsia	USA
1999	H.A. Löfberg	Sweden
2003	W. v. Bommel	Netherlands
2007	F. Hengstberger	South Africa
2011	A.R. Webb	United Kingdom
2015	Y. Ohno	USA

Objectives of the CIE

THE INTERNATIONAL COMMISSION ON ILLUMINATION

The International Commission on Illumination (CIE) is an organization devoted to international co-operation and exchange of information among its member countries on all matters relating to the art and science of lighting. Its membership consists of the National Committees in about 40 countries.

The objectives of the CIE are:

1. To provide an international forum for the discussion of all matters relating to the science, technology and art in the fields of light and lighting and for the interchange of information in these fields between countries.
2. To develop basic standards and procedures of metrology in the fields of light and lighting.
3. To provide guidance in the application of principles and procedures in the development of international and national standards in the fields of light and lighting.
4. To prepare and publish standards, reports and other publications concerned with all matters relating to the science, technology and art in the fields of light and lighting.
5. To maintain liaison and technical interaction with other international organizations concerned with matters related to the science, technology, standardization and art in the fields of light and lighting.

The work of the CIE is carried out by Technical Committees, organized in six Divisions. This work covers subjects ranging from fundamental matters to all types of lighting applications. The standards and technical reports developed by these international Divisions of the CIE are accepted throughout the world.

A plenary session is held every four years at which the work of the Divisions and Technical Committees is reported and reviewed, and plans are made for the future. The CIE is recognized as the authority on all aspects of light and lighting. As such it occupies an important position among international organizations.

LA COMMISSION INTERNATIONALE DE L'ECLAIRAGE

La Commission Internationale de l'Eclairage (CIE) est une organisation qui se donne pour but la coopération internationale et l'échange d'informations entre les Pays membres sur toutes les questions relatives à l'art et à la science de l'éclairage. Elle est composée de Comités Nationaux représentant environ 40 pays.

Les objectifs de la CIE sont :

1. De constituer un centre d'étude international pour toute matière relevant de la science, de la technologie et de l'art de la lumière et de l'éclairage et pour l'échange entre pays d'informations dans ces domaines.
2. D'élaborer des normes et des méthodes de base pour la métrologie dans les domaines de la lumière et de l'éclairage.
3. De donner des directives pour l'application des principes et des méthodes d'élaboration de normes internationales et nationales dans les domaines de la lumière et de l'éclairage.
4. De préparer et publier des normes, rapports et autres textes, concernant toutes matières relatives à la science, la technologie et l'art dans les domaines de la lumière et de l'éclairage.
5. De maintenir une liaison et une collaboration technique avec les autres organisations internationales concernées par des sujets relatifs à la science, la technologie, la normalisation et l'art dans les domaines de la lumière et de l'éclairage.

Les travaux de la CIE sont effectués par Comités Techniques, organisés en six Divisions. Les sujets d'études s'étendent des questions fondamentales, à tous les types d'applications de l'éclairage. Les normes et les rapports techniques élaborés par ces Divisions Internationales de la CIE sont reconnus dans le monde entier.

Tous les quatre ans, une Session plénière passe en revue le travail des Divisions et des Comités Techniques, en fait rapport et établit les projets de travaux pour l'avenir. La CIE est reconnue comme la plus haute autorité en ce qui concerne tous les aspects de la lumière et de l'éclairage. Elle occupe comme telle une position importante parmi les organisations internationales.

DIE INTERNATIONALE BELEUCHTUNGSKOMMISSION

Die Internationale Beleuchtungskommission (CIE) ist eine Organisation, die sich der internationalen Zusammenarbeit und dem Austausch von Informationen zwischen ihren Mitgliedsländern bezüglich der Kunst und Wissenschaft der Lichttechnik widmet. Die Mitgliedschaft besteht aus den Nationalen Komitees in rund 40 Ländern.

Die Ziele der CIE sind:

1. Ein internationales Forum für Diskussionen aller Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik und für den Informationsaustausch auf diesen Gebieten zwischen den einzelnen Ländern zu sein.
2. Grundnormen und Verfahren der Messtechnik auf dem Gebiet der Lichttechnik zu entwickeln.
3. Richtlinien für die Anwendung von Prinzipien und Vorgängen in der Entwicklung internationaler und nationaler Normen auf dem Gebiet der Lichttechnik zu erstellen.
4. Normen, Berichte und andere Publikationen zu erstellen und zu veröffentlichen, die alle Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik betreffen.
5. Liaison und technische Zusammenarbeit mit anderen internationalen Organisationen zu unterhalten, die mit Fragen der Wissenschaft, Technik, Normung und Kunst auf dem Gebiet der Lichttechnik zu tun haben.

Die Arbeit der CIE wird durch Technische Komitees geleistet, die in sechs Divisionen organisiert sind. Diese Arbeit betrifft Gebiete mit grundlegendem Inhalt bis zu allen Arten der Lichtanwendung. Die Normen und Technischen Berichte, die von diesen international zusammengesetzten Divisionen ausgearbeitet werden, sind auf der ganzen Welt anerkannt.
Alle vier Jahre findet eine Session statt, in der die Arbeiten der Divisionen berichtet und überprüft werden, sowie neue Pläne für die Zukunft ausgearbeitet werden. Die CIE wird als höchste Autorität für alle Aspekte des Lichtes und der Beleuchtung angesehen. Auf diese Weise unterhält sie eine bedeutende Stellung unter den internationalen Organisationen.

CIE Administrative Bodies 2015-2019

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Division 4	Lighting for Transport (till 2017) Transportation and Exterior Applications	Director:	Ronald B Gibbons (till 2017) Dionyz Gasparovsky
Division 5	Exterior Lighting (closed in 2017)	Director:	Peter Schwarcz (till 2017)
Division 6	Photobiology	Director:	John O'Hagan
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Technical Manager:	Peter Zwick
Office Manager:	Leo Trausnith (till 01/2018) Iona Bichler (01/2018 – 07/2018) Romana Floth

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WELCOME ADDRESSES

Message from the incoming President, Dr Peter Blattner

CIE – THE UMBRELLA ORGANIZATION OF THE NATIONAL LIGHTING ORGANIZATIONS

It is with reverence and humbleness but also with great pleasure that I accept the Presidency of the International Commission on Illumination CIE, this outstanding and honourable organization founded in 1913 by the lighting societies of several countries. In recent years, the lighting industry has gone through a turbulent period. This technological but also structural transformation has a direct impact on the work of the CIE. The LED has largely replaced the "classical" light sources. Accordingly, the CIE has adapted many of its guidelines and recommendations. For physical reasons, however, the luminous efficacy of light sources cannot be increased indefinitely. An important way to increase energy efficiency is the intelligent control of lighting systems. It includes adaptive light sources as well as smart sensors. In this interconnected world, it is important for the CIE to position itself clearly and address issues such as dynamic or adaptive lighting.

The lighting industry has created the term "Human Centric Lighting" to describe the non-visual effects of light on humans induced or supported by the intrinsically photosensitive retinal ganglion cells (iPRGCs). Personally, I prefer the term "integrative lighting", which is used within the CIE and ISO. It represents the versatility of light and lighting, namely the combination of visual and non-visual effects to produce physiological and/or psychological benefits on humans. With the introduction of the International Standard CIE S 026:2018 *CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light* the CIE has created an important basis for the different stakeholders to use the same terms and metrics. Now it is a matter of establishing these metrics in the research community, and thus generate results that can be applied for the benefit of the human being. As an important tool I note the CIE research strategy which takes a forward-looking approach to the major topics on our field.

But the subject of light and lighting does not end with integrative lighting for humans. Optical radiation is used for horticultural lighting or disinfection applications. Besides the clever use of optical radiation, it is also about minimizing negative effects, e.g. through light pollution or photobiological damage. These topics are dealt with in Divisions 4 and 6, and I am convinced that the CIE will set further milestones in this area over the next four years. I am also excited about the further developments in the field of colorimetry. The cone-fundamental-based spectral luminous efficiency functions published in CIE 170-2:2015 will play an important role here. A further milestone will be the publication of the revised International Lighting Vocabulary (ILV, CIE S 017). This comprehensive work has been revised by many CIE experts in close cooperation with IEC TC 34 and IEC TC 1. At this point I would like to thank the CIE Technical Manager Dr Peter Zwick, who chaired the CIE JTC responsible for this work, for his high-quality work for the revision of the ILV, in addition to the other CIE publications that have required his work to bring to publication.

In the area of publications there will be further challenges in the coming years. The call for free access to the publications and proceedings is getting stronger. Certain public research institutions request that the research results which are financed by public funds become publicly available. The CIE is taking a step in this direction by making the individual papers of the CIE session in Washington D.C. freely available. In addition to the free access to expertise, digitization is a challenge and an opportunity for the CIE. It will be important to make use of new forms of digital products including validated calculation tools, apps, databases, machine-readable documents, etc.

However, CIE is not only an international forum for the discussion of all questions relating to the science, technology and art of light and lighting, but above all it is the umbrella organization of national associations in the field of light and lighting. Over the next four years, I would like to significantly intensify cooperation with the National Committees. The most recent example is the translation of the CIE Position Statement on blue light hazards. The

importance of this interaction between the National Committees and the CIE Board was also emphasized during an NC Workshop at the General Assembly in Washington D.C. I intend to meet with each National Committee at least once physically or virtually during my term of office.

Since the major revision of the Code of Procedure and the Statutes, and the establishment of the International Lighting Network (ILN) in 2011, the CIE has gained considerable momentum. I would like to continue this path and make adjustments and extensions only where necessary. For example, the topics in the field of light and lighting are becoming increasingly interdisciplinary, which is why the CIE has created the possibility of horizontal TCs (JTCs). The number of JTCs has increased significantly in the recent past. It is a challenge to manage this JTC structure, and the Code of Procedure may need to be adapted in support of this. The responsibilities and the distribution of functions of the different organs of the Commission could also be more clearly defined. A working group of the Board of Administration will address this issue and will make some proposals to the Board and the General Assembly. Finally, the CIE should continue to strategically network, and the ILN is a good platform to base this on. The CIE Board as recently approved a policy on liaison with external organizations.

The CIE is a fascinating organization. It lives from a high diversity of people and their expertise. I am looking forward to working with all of you, my colleagues in the Board, and the staff of the CIE Central Bureau: the General Secretary Kathryn Nield, the Technical Manager Peter Zwick, and the Office Manager Romana Floth. Last but not least, I hope to meet many CIE experts in person during the coming four years.

OFFICERS' REPORTS

President's Report to the General Assembly

June 16, 2019

Yoshi Ohno, US

This report summarizes major activities and accomplishments of the CIE during the quadrennium 2015 to 2019.

1 Merger of Divisions 4 and 5

The previous Division 4 and Division 5 were merged and a new Division 4 (Transportation and Exterior Applications) and was established at CIE Midterm Meeting in Jeju in 2017, after some years of discussion in CIE BA. The motivation for the merger was that there were more and more overlapping topics in the areas covered by the two Divisions, especially given the impact of LED light sources in various outdoor lighting applications. The border between the two Divisions was becoming less clear and in some cases there were instances of duplication of work. It was decided that this merger was necessary to ensure that the CIE work for outdoor lighting applications was more efficient and coherent. The new Division 4, under leadership of Dionyz Gasparovsky, has been operating successfully since its establishment. See the VPT's report for further information on the activities of Division 4.

2 CIE Research Strategy (August 2016)

CIE published its *Research Strategy* in 2016, which listed the ten topics that were of highest priority as identified by CIE for research needed for future CIE technical reports and standards. There is insufficient research and information on these topics in order for CIE to develop the publications needed in an efficient way. This document promotes that these topics are taken up by universities, research institutes and industry, and as well as ensuring that funding organizations are aware of these needs. This document also helped to communicate to CIE liaison organizations about our plans for future developments, which may be useful for future cooperation.

To encourage researchers to participate and contribute to the work of the CIE along CIE Research Strategy, several letters of support have been provided to researchers and consortia upon request. The consortia covered many requests we have had to date, such as those from EURAMET (See VPT Report for further details).

3 Key publications

Many technical reports and standards have been published by the CIE during this quadrennium. See the VPP report for the details. Among them, CIE issued the following key publications:

- **CIE S 025:2015** Test Method for LED lamps, LED luminaires, and LED modules
  This is the first internationally-agreed test method for LED lighting products, providing the basis for testing and measurement of solid state lighting products internationally. This standard is now used in Europe and by IEC, and gradually being adopted in other countries, but still needs much promotion and support for its uptake. See (4) on our special efforts to promote and assist the industry to adopt this standard in the world.
- **CIE 218:2016** Research Roadmap for Healthful Interior Lighting Applications
  Healthful lighting is considered to be a major direction for future lighting applications. This publication sets the CIE's leadership for research in this area and provides the basis and guidance for future research work to be done on this important topic.
- **CIE 224: 2017** CIE 2017 Colour Fidelity Index for Accurate Scientific Use
  CIE has worked many years to address the problems of CRI. This publication is the first CIE publication on a CIE-defined colour rendering metric since 1974. Although it does not

replace CRI, this publication is a major milestone for developing a set of colour quality metrics to replace CRI for the near future.

- **DIS 017:2016** ILV: International Lighting Vocabulary 2nd Edition
  This revision of ILV, published from JTC 8, was a major work to update this fundamental publication since the last version in 2011. Based on this DIS, work is in progress to publish a joint CIE/IEC ILV version.
- **CIE S 026:2018** CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light
  This standard was published from the work of JTC 9, it provides the basis for metrology of light and optical radiation related to non-visual effects of light, by defining the values for the action spectra for the five photoreceptors including ipRGC. CIE is promoting this new document in many occasions, and also provided the first tutorial – see (4).
- **CIE 018:2019** The Basis of Physical Photometry, 3rd Edition
  This publication, a major revision of CIE 18.2-1983, was published from the work of JTC 2 (CIE CCPR) on May 20, 2019, World Metrology Day, concurrent with historic revision of the SI (International System of Units). This publication brings the CIE definitions in photometry in alignment with the revised SI and provides the link between the reformulated definition of the candela and the new set of CIE spectral luminous efficiency functions including those for mesopic vision (based on CIE 191:2010) as well as for 10° photopic vision (based on CIE 165:2005).

4 Capacity building / Education

We consider it very important to follow up after CIE standards and recommendations are published and to provide education on the topic to the relevant stakeholders and community. CIE has been very active in such activities during the quadrennium. The following tutorial events related to the key publications reported above were organized by relevant CIE Divisions. Those for CIE S 025 included laboratory sessions, which required additional efforts.

- CIE Tutorial and Expert Symposium on the CIE S 025, November 23-26, 2015, PTB Braunschweig, Germany (D2)
- CIE Tutorial and Practical Workshop on LED Lamps and Luminaire Testing to CIE S 025, May 08 – 11, 2017, METAS Bern-Wabern, Switzerland (D2)
- CIE Tutorial and Practical Workshop on LED lamp and Luminaire Testing according to CIE S 025, Nov. 5-7, 2018, Moscow, Russia (D2)
- CIE Workshop on New Vision of Visibility for Roadway Lighting, May, 2018,Berlin; Germany,, (D4)
- CIE Expert Tutorial and Workshop on Research Methods for Human Factors in Lighting, in Copenhagen, August 2018, Copenhagen, Denmark (D3)
- CIE Tutorial on S026:2018, March 14, 2019 to March 15, 2019, Eindhoven, the Netherlands (D6)

We thank very much the NCs and local organizers that hosted these CIE tutorial events, which were all very successful.

5 CIE Conferences

CIE had the following four conferences and a symposium during the quadrennium:

- CIE 2016 Lighting Quality and Energy Efficiency, Melbourne, Australia, March 2016
- CIE 2017 Midterm Meeting, Jeju Island, Republic of Korea, October 2017
- CIE 2018 Topical Conference on Smart Lighting, Taipei, Chinese Taipei, April 2018
- CIE 2019 Quadrennial Conference, Washington DC, United States (to be held in June 2019)

- 4th CIE Expert Symposium on Colour and Visual Appearance and Tutorial, September 2016, Prague, Czech Republic

We thank very much the NCs and local organizers that hosted these conferences and symposia, which made great contributions to the goals of CIE.

CIE decided to disband the LQEE conference series, as the needs were changing, and instead, established a new series “Topical Conference” which is not periodic but need-based, for a more focused topic but wide interest across CIE Divisions. CIE 2018 Taipei was the first one, on the topic of smart lighting.

6 CIE Position Statements

CIE Position Statements (PSs) are developed in response to significant questions and comments from external parties on matters of strong interest to the CIE. A PS reflects CIE’s stance on the specific topic and outline the current and future work of the CIE in the area. CIE started publishing PSs from 2015. To date three PSs have been published, as below, mostly recently one on the blue light hazard. This most recent PS clarifies that blue light hazard is no problem for general use of LED lighting products, while such hazard from LED sources is often overexaggerated by some articles. We are preparing an update of the one for colour quality.

- Position Statement on the Blue Light Hazard (April 23, 2019)
- Position Statement on CRI and Colour Quality Metrics (October 15, 2015)
- Position Statement on Non-Visual Effects of Light - Recommending Proper Light at the Proper Time (June 28, 2015)

7 Research Forum

This new function *Research Forum* entity was approved by the BA in 2017. Research Fora offer the opportunity for researchers to discuss ideas and exchange data on a given scientific or technical topic that is not considered within a current TC or Reportership. It may be a stage to collect research data before a TC or Reportership can be established. We have three Research Fora established so far:

- RF-01 Spectral Imaging
- RF-02 Matters relating to temporal light modulation
- RF-03 on colour rendering properties of white-light sources

8 JTCs increasing

The framework of joint TC (JTC) was established in 2012, and there are currently 17 JTCs, some of which are with other organizations. The following ten JTCs were established from 2015 to 2019. This shows that many technical issues are cross-Divisional, that there is active cooperation between the Divisions and such cases are increasing.

- JTC 08 (D1/D2/D3/D4/D5/D6/D8) Terminology in light and lighting
- JTC 09 (D1/D2/D3/D6) Quantifying ocular radiation input for non-visual photoreceptor stimulation (CIE DIS 026 published and closed)
- JTC 10 (D8/D1) A new colour appearance model for colour management systems: CIECAM16
- JTC 11 (CIE-ISO) Light and Lighting – Maintenance factor – Way of working
- JTC 12 (D1/D2/D8) The measurement of sparkle and graininess

- JTC 13 (D4/D3) Depreciation and Maintenance of Lighting Systems
- JTC 14 (CIE-ISO) Integrative Lighting
- JTC 15 (CIE-ISO) Lighting of Indoor Workplaces
- JTC 16 (D1/D8) Validity of Chromatic Adaptation
- JTC 17 (D1/D2/D8) Gloss measurement and gloss perception: A framework for the definition and standardization of visual cues to gloss

Details on some of these JTCs are reported in VPT's report.

9 Cooperation with ISO/TC 274

ISO/TC 274 was established in 2012, and collaboration between CIE and ISO on application of light and lighting has been intensified since then. The collaboration had been well in place since then under the Working Arrangements (WA) set in 2014. However, due to changes in ISO requirements, the MoU between CIE and ISO has been converted into ISO/CIE Partner Standards Development Organization (PSDO) agreement, and the WA is renamed to "Implementation Guide" (IG) for ISO/TC 274 and the CIE. This resulted in significant work requiring extensive discussions during this quadrennium. An important recent technical development is that a new work item for technical report on "Integrative Lighting" started in ISO, and corresponding JTC 14 (CIE-ISO) was established. The details are reported in the VPS report.

10 Policy on Liaison with External Organizations

Noting the increasing importance to cooperate with external organizations, the BA developed "*Policy on Liaison with External Organizations*" published in May 2019. This document provides guidance on which types of organization (e.g. international, regional, national, standards-developing, professional society, etc.) may have liaison with the CIE (at high level) and what kind of cooperation activities are possible, and will allow the CIE to make fair judgements when there are such requests or wish from external organizations to have official cooperative relationships with the CIE.

11 Liaison activities

The liaison activities with many partner's organizations are reported in General Secretary's Report. Some highlights are below.

- MoU with EURAMET was signed in 2017 "to foster progress in metrology research and the traceability of measurements to the SI units related to colorimetric, photometric, radiometric, photobiological, photochemical and photon-based quantities", and for "potential research topics within European Metrology Programme for Innovation and Research".
- Discussion with Illuminating Engineering Society (IES) to investigate a relationship that would be useful to both organizations, whilst still supporting NC USA.

12 Connecting TC members and National Committees

The CIE BA approved changes to the CIE Code of Procedure (CoP) policy in 2017, to enable connectivity between TC members and respective NCs. As has always been, anyone with relevant expertise can join CIE TCs with no connection to an NC. This is still the case, but the additional text in the CoP provides an **option** that allows a National Committee (NC) to require individuals within their country, who are currently members of a CIE TC or who are seeking membership of a CIE TC, to be a member of their NC. In cases where NCs exercise this option, there are exceptions permitted, for example when experts from other organizations are invited to a TC by the TC Chair.

There were numerous other activities that brought many improvements in CIE and cooperation with partner organizations, the details of which are available in General Secretary's report and VPs' reports. We thank very much all NCs and Associate NCs for their great support for all activities of CIE during this quadrennium and their continuing support for the future.

Quadrennial Report 2015 – 2019 of the Vice-President Technical

Erkki Ikonen, FI

This report describes activities related to CIE Research Strategy, CIE Conferences and CIE Divisions.

CIE Research Strategy

The Research Strategy was published in July 2016 at the CIE website. It lists research topics that are judged by the CIE as needing immediate attention. The CIE calls on national and international research funders to create opportunities that will enable the research community to address these topics.

1) Recommendations for Healthful Lighting and Non-Visual Effects of Light
2) Colour Quality of Light Sources Related to Perception and Preference
3) Integrated Glare Metric for Various Lighting Applications
4) New Calibration Sources and Illuminants for Photometry, Colorimetry, and Radiometry
5) Adaptive, Intelligent and Dynamic Lighting
6) Application of New CIE 2006 Colorimetry
7) Visual Appearance: Perception, Measurement and Metrics
8) Support for Tailored Lighting Recommendations
9) Metrology for Advanced Photometric and Radiometric Devices
10) Reproduction and Measurement of 3D Objects

Examples of funding organizations that have responded positively to CIE needs:

European Metrology Research Programme – 5 projects

- Future photometry based on solid-state lighting products (topic 4)
- Pavement surface characterization for smart and efficient road lighting (topic 5)
- Towards documentary standards for BRDF based quantities (topic 7)
- New quantities for the measurement of appearance (topic 7)
- Self-calibrating photodiodes for the radiometric linkage to fundamental constants (topic 9)

National Science Foundation (China) – 2 projects

- Assessing white perception (topic 2)
- Assessing colour difference of 3D objects (topics 7 and 10)

Furthermore, the CIE Research Strategy has been an important tool for liaison work with ISO and IEC.

CIE Conferences

CIE has organized four major conferences during 2016-2019:

- CIE 2016 "Lighting Quality and Energy Efficiency", Melbourne, Australia, March 3 – 5, 2016,
- CIE 2017 Midterm Meeting, Jeju Island, Republic of Korea, October 20 – 28, 2017

- CIE 2018 Topical Conference on Smart Lighting, Taipei, Chinese Taipei, April 24 – 28, 2018
- CIE 2019 Quadrennial Conference, Washington DC, United States, June 16 – 19, 2019

The International Scientific Committees (ISC) of these conferences were chaired by the VPT. The tasks of the ISC include:

- Define the outline of the event schedules
- Agree on the list of topics of the conference
- Find invited speakers
- Define the conference workshops
- Prepare call for papers and abstract submission instructions
- Prepare instructions for abstract review
- Form the review panel of abstracts
- Analyse the review results
- Prepare the scientific conference program

Highlights of the work of CIE Divisions during 2015-2019 as reported by the Division Directors

Division 1

At the CIE D1 meeting held in Manchester, UK, in 2015, CIE Division 1 director has been changed from Ronnier Luo to Youngshin Kwak. During Kwak's first term, CIE D1 had four division meetings – one in each year: 9th September 2016 in Prague, Czech Republic, 27th October 2017 in Jeju, Republic of Korea, 28th April 2018 in Taipei, Chinese Taipei, and 21st June 2019 in Washington D.C., USA.

Between 2015 and 2019, CIE Division 1 has published 6 technical reports and 2 technical notes and as of April 2019, in CIE Division 1, there are 4 TCs for vision section, 6 TCs for colour section and 4 JTCs lead by D1 aiming to publish TRs.

During 2015-2019 (Youngshin Kwak's first term as DD1), CIE Division 1 management team put their effort on reorganizing the TCs that do not comply with the code of procedure continuing the previous DMT's work and promoting the CIE research strategy to D1 experts. As a result, more efficient and focused CIE D1 activities are expected.

In the coming Kwak's second term as DD1, CIE Division 1 will focus on actively outreaching other relevant academic and industrial societies to conduct the timely CIE TR/TS development following the academic and industrial demands.

Publication list during 2015-2019:

1) CIE 230:2019 Validity of Formulae for Predicting Small Colour Differences
2) CIE 015:2018 Colorimetry, 4th Edition
3) CIE 228:2018 Grey-Scale Calculation for Self-Luminous Devices
4) CIE TN 007:2017 Interim Recommendation for Practical Application of the CIE System for Mesopic Photometry in Outdoor Lighting
5) CIE 224:2017 CIE 2017 Colour Fidelity Index for accurate scientific use
6) CIE TN 006:2016 Visual Aspects of Time-Modulated Lighting Systems – Definitions and Measurement Models
7) CIE 217:2016 Recommended Method for Evaluating the Performance of Colour-Difference Formulae

8) CIE 170-2:2015 Fundamental Chromaticity Diagram with Physiological Axes–Part 2: Spectral Luminous Efficiency Functions and Chromaticity Diagrams

Division 2

In the year 2015, CIE Division 2 has published a key document: CIE S 025 is the first international test standard for LED lamps, luminaires and modules. This standard has been adopted by many countries and regions. In Europe the harmonized standard EN 13032-4, which is fully equivalent to CIE S 025 is the required test method for any LED lighting product that is put on the market. One fundamental difference to other standards is that CIE S025 requires explicitly the uncertainty evaluations of all measurands. As these evaluations are not easy, CIE division 2 has organized several tutorials involving more than 15 lecturers. The tutorials took place in Braunschweig (2015), Bern (2017) and Moscow (2018). A supplement to CIE S025 (test method for OLED luminaires and light sources) has been published as draft international standard recently. In addition to this standard, Division 2 has published several other important technical reports including test methods for high power LEDs and high speed testing of LEDs, both presently converted into international standards. Furthermore CIE 2-69 (the first international classification system for illuminance and luminance meter) and 2-51 (dealing with the characterization of array-spectroradiometer) are ready for publishing.

During the period 2015 to 2019, Division 2 has established 12 new TCs. To prioritize the work, 4 TCs were designated as "urgent TCs" getting special attention and support by the division management team. The 4 TCs are

- TC 2-83 CIE Standard on test methods for OLED light sources,
- TC 2-86 Glare Measurement by Imaging Luminance Measurement Device (ILMD),
- TC 2-88 Standard Reference Solar Spectra for Industrial Applications, and
- TC 2-89 Measurement of Temporal Light Modulation of Light Sources and Lighting Systems.

This new concept is very promising as all four TCs are making good progress.

CIE Division 2 was involved in the revision of the International System of Units. The SI-brochure was reviewed by many CIE experts and key contributions were given in particular to Appendix 3 dealing with quantities and units for photobiological and photochemical effects. In addition, the fundamental document "Principles Governing Photometry" was revised by JTC 2, a joint technical committee between CIE and the Consultative Committee for Photometry and Radiometry (CCPR) and published on May 20, 2019, the date on which the revised SI was introduced.

Finally, CIE Division 2 has contributed on the definition of several research topics within the CIE Research Strategy. These research topics were taken up by diverse research programs and several research projects are addressing the topics defined by the strategy. As an example the European research project PhotoLED has contributed significantly to TC 2-90 (LED Reference Spectrum for Photometer Calibration). The collaboration between CIE and the research community is highly beneficial for both communities and further collaborations are strongly desired to address the challenges induced by the present technological changes.

Division 3

During this quadrennium, Division 3 completed and published the following technical reports and standards, either independently or in joint technical committees:

- ISO/CIE TS 22012:2019(E) Light and Lighting — Maintenance Factor Determination — Way of Working
- ISO/CIE 20086:2019(E) Light and Lighting — Energy Performance of Lighting in Buildings
- CIE TN 008:2017 Final Report CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems

- CIE 227:2017 Lighting for Older People and People with Visual Impairment in Buildings
- CIE 222:2017 Decision Scheme for Lighting Controls in Non-Residential Buildings
- CIE 218:2016 Research Roadmap for Healthful Interior Lighting Applications

The watchword for the work of Division 3 is collaboration. Nearly all of the technical work in this division takes place together with another CIE Division or with ISO/TC 274. Partnerships characterize the two Division 3 events in this quadrennium:

- In February 2017, with financial support from the lighting industry and the Government of Canada, and with involvement from all CIE Divisions, we led the CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems. This was the first such gathering of researchers, industry, standards development organizations, and regulators, to discuss the requirements for consensus documents in this important, but complex, area.
- In August 2018, Division 3 organized the CIE Expert Tutorial and Workshop on Research Methods for Human Factors in Lighting, in Copenhagen, Denmark. This event was linked to the forthcoming publication of a special issue of LEUKOS – The Journal of the IES on Lighting Research Methods. CIE in partnership with the Illuminating Engineering Society and publisher Taylor and Francis has made all the articles in this special issue open access, as a contribution towards furthering the strength of the evidence base for recommendations and standards in light and lighting and towards the development of the next generation of lighting researchers.

Division 4

Application problems of outdoor lighting have been formerly covered by two CIE Divisions 4 and 5. Dealing with similar problems, having overlap in many particular issues and having many double nominated representatives opened the question of merger to enhance the working effectiveness. The merger took place in the CIE Midterm Meeting in 2017 and the new CIE Division 4 has been established “to study and prepare guides for the design of exterior lighting and light signalling”, as defined in the terms of reference. The Division 4 now covers all outdoor lighting applications such as road lighting, lighting for transportation, sports lighting, lighting of outdoor workplaces, architectural and urban lighting and masterplanning, environmental aspects of outdoor lighting etc., including fundamental problems as such as mesopic vision and maintenance factor. New Division Management Team has been commenced in 2017 with Dionyz Gasparovsky as Division Director, Steve Fotios, Raoul Lorphèvre and Sermin Onaygil as Associate Division Directors, Maurice Donners as Division Secretary and Nigel Parry as Division Editor.

During the period, three Technical Reports have been published:

- CIE 083:2019 Guide for the Lighting of Sports Events for Colour Television and Film Systems, 3rd Edition
- CIE 140:2019 Road Lighting Calculations, 2nd Edition
- CIE 150:2017 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations, 2nd Edition

The Division collaborated on publication of three International Standards and three Technical Notes:

- ISO/CIE 8995-3:2018(E) Lighting of Work Places – Part 3: Lighting Requirements for Safety and Security of Outdoor Work Places
- ISO/CIE TS 22012:2019(E) Light and Lighting — Maintenance Factor Determination — Way of Working
- CIE S 017-SP1:2015 ILV: International Lighting Vocabulary –Supplement 1: Light Emitting Diodes (LEDs) and LED Assemblies – Terms and Definitions
- CIE TN 005:2016 Specifying Product Performance for Mesopic Applications

- CIE TN 004:2016 The Use of Terms and Units in Photometry – Implementation of the CIE System for Mesopic Photometry
- CIE TN 007:2017 Interim Recommendation for Practical Application of the CIE System for Mesopic Photometry in Outdoor Lighting

Currently the Division 4 incorporates 15 Technical Committees, 10 Reporterships, participates in 2 Joint Technical Committees and has 9 Liaison Officers with other organizations.

The Division 4 holds face-to-face meeting every year and since Manchester 2015 the meetings were held in Melbourne 2016, Jeju 2017, Berlin 2018 and the annual meeting in Washington 2019 is in preparation. Division officers and representatives actively participate in preparation of CIE conferences and events. Topical conference in Taipei on smart lighting was a highlight in 2018. Workshop on New Vision of Visibility for Roadway Lighting was organized in Berlin 2018. Division Director D. Gasparovsky represented Division 4 in Street Lighting and Smart Controls Conference in Sydney 2019 with a presentation on Adaptive Road Lighting.

Urgent problems of outdoor lighting demanding the attention of researchers have been identified and prioritized to establish a road map for new items. Part of the priority topics contributed to the CIE Research Strategy 2016. In 2019 the Division's research priority topics are being updated.

Division 6

Publications

- CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light
- CIE 221:2016 Infrared Cataract
- CIE 219:2016 Maintaining Summer Levels of 25(OH)D during Winter by Minimal Exposure to Sunbeds: Requirements and Weighing the Advantages and Disadvantages
- ISO/CIE 28077:2016(E) Photocarcinogenesis action spectrum (non-melanoma skin cancers)
- CIE TN 003:2015 Report on the First International Workshop on Circadian and Neurophysiological Photometry, 2013

Events

CIE Tutorial on S026:2018, March 14, 2019 to March 15, 2019, Eindhoven, the Netherlands

Division 6 also participated in:

- May 16, 2018 International Day of Light, Paris. UNESCO Officially announced May 16 as the International Day of Light
- CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems, February 8th and 9th, 2017, National Research Council of Canada, 1200 Montreal Road, Ottawa, Ontario

Division 8

Division 8 has stepped into a new field which is an important topic in the current industry – 3D printing technology and characterization of surface. We also try to contribute to the imaging industry in terms of High Dynamic Range and Wide Colour Gamut imaging. We proactively look for connections with other divisions. We have formed 5 new JTC and TCs, joined 3 JTCs, started 4 DRs to look for future topics, one RF to follow up the previous work at TC 8-07 and published one TR in the past four year.

TCs, JTC, and RF formed:

- TC 8-14 Specification of Spatio-Chromatic Complexity
- TC 8-15 Archival Colour Imaging
- JTC 10 A new colour appearance model for colour management systems: CIECAM16
- TC 8-17 Methods for Evaluating Colour Difference between 3D Colour Objects
- TC 8-16 Consistency of colour appearance within a single reproduction medium
- RF8-01 Spectral Imaging

JTCs joined:

- JTC 12 The Measurement of Sparkle and Graininess
- JTC 16 Validity of Chromatic Adaptation
- JTC 17 Gloss Measurement And Gloss Perception: A Framework for The Definition and Standardization of Visual Cues to Gloss

DRs started:

- DR 8-14 Office Lighting for Imaging
- DR 8-15 A survey on Quality Metrics on Stereoscopic Imaging
- DR 8-16 Material Adjustment Transforms
- DR 8-17 Literature Survey on Uniform Colour Space for Imaging Applications including Wide Colour Gamut and High Dynamic Range Images

Publication:

- CIE 223:2017 Multispectral Image Formats

Quadrennial Report 2015 – 2019 of the Vice-President Publications

Ronnier Luo, GB/CN

1. Publication 2018 Sales Report

There were 8 publications in 2018 including 4 technical reports, 1 proceeding and 2 international standards (one being the draft of the final standard).

Fig. 1 shows the income from publications from Year 2008 and Figure 2 summarizes the number of publications sold from 2008. It can be seen that there was an increase in both income and number of publications by 15 % compared with 2017. The best-selling publications were 015:2018 (4th Edition) *Colorimetry*, and 224:2017 *Colour fidelity index*, respectively.

From Figure 1, it can be seen that the majority of sales from the Webshop are from individuals not using the discount code. These individuals are advised to our NCs for follow-up, in case they might be interested in participating in CIE work or have some reason are members and have not used the discount code.

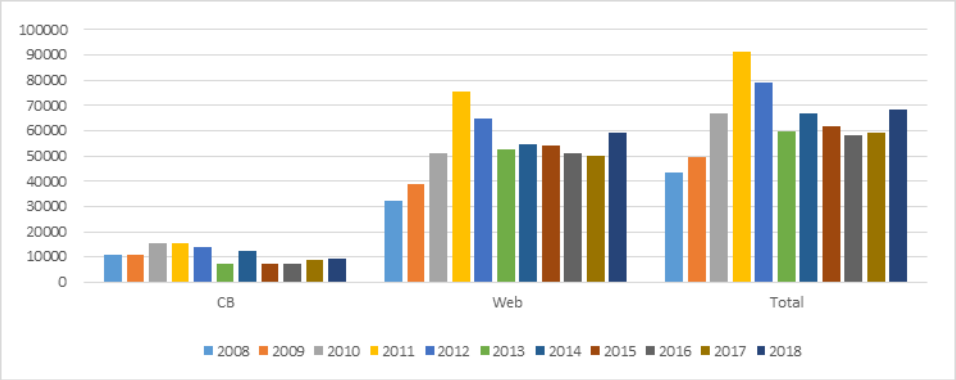


Figure 1 – Income from publications from Year 2008

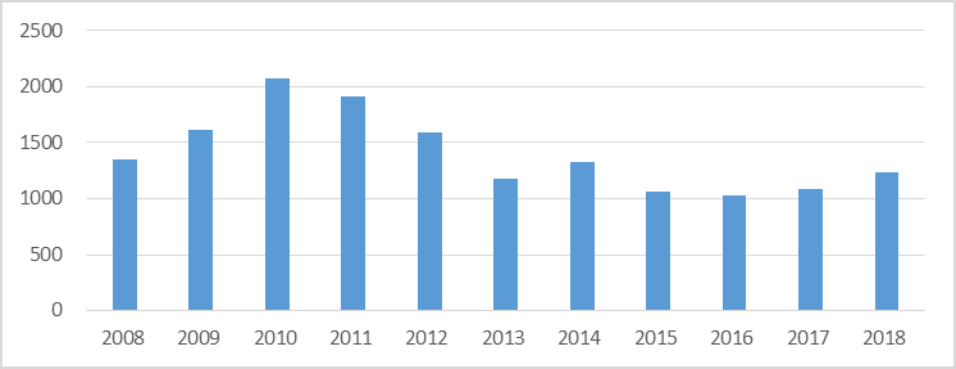


Figure 2 – Number of publications sold from Year 2008

Figure 3 shows the income by top 17 countries. The top 6 purchasing countries were US, DE, JP, FR, GB, CN. It is to be noted that sales in some regions are below what would be

expected, for example China, where perhaps the translation of CIE publications into Chinese might be helpful.

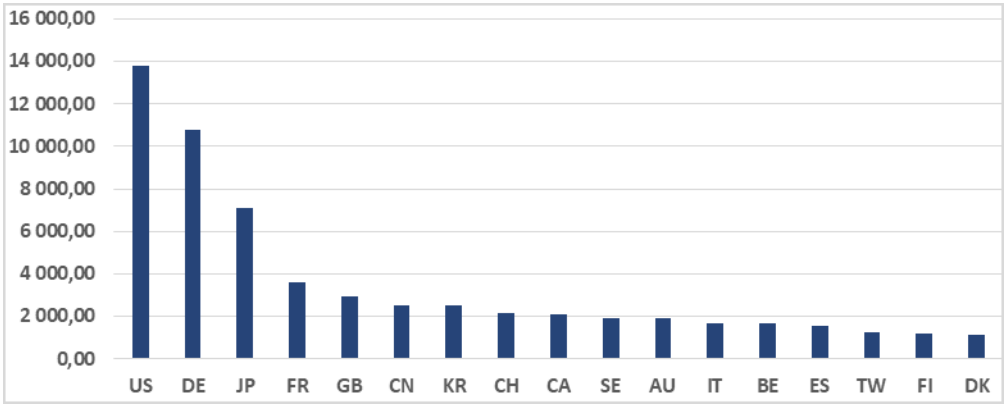


Figure 3 – Income by top 17 countries in 2018

2. Updates on CIE Publication Distribution

The inclusion of Digital Object Identifiers (DOI) has been implemented for CIE publications, such as Technical Reports (TR), and CIE Conference and Symposium Proceedings.

The CIE continues to arrange for some high quality papers from CIE proceeding papers, tutorial workshops to be jointly published in leading journals in the lighting field. A CIE/Leukos special issue has been published on Lighting Research Methods, which includes presentations given at the CIE Expert Tutorial and Workshop on Research Methods for Human Factors in Lighting', Denmark, August 2018.

Since 2017 individual proceeding papers have been made available for purchase from the CIE Webshop. In addition CIE CB can make available on request individual papers from older proceedings (for a modest fee similar to those charged by libraries for interloan services). Abstract booklets are available for the majority of CIE conferences, these being a reference point for seeking out specific individual papers.

A decision was made by the CIE Board of Administration to make the individual papers submitted for presentation at CIE 2019 Open Access (OA). At this point this is a trial and no fee has been charged to the authors to enable their papers to be OA paper. The uptake of the papers will be reviewed to assess its usefulness (see later).

3. Publication strategy

3.1 To Achieve Top Quality Publication of CIE Work

It is our goal that all the publications to be published in a timely manner and that they should clearly address the application point. It should have a good coverage of the historical background, a summary of state of the art technology and a clear recommendation. For the proceeding papers to be sold well, all papers should be concise and have good value to cover new research results for at least one year until the publication of full scientific paper.

To promote the high quality proceeding papers, we have already implemented with DOI number for each paper, and selective Open Access papers and jointed publication in the high quality journals, such as Leukos, LRT, etc. All the efforts should increase the attraction to the academic community to attend CIE conferences. The above services automatically raise the visibility and attract high flyers to the CIE activities.

CIE conference has generated consensus as the top quality conference in lighting engineering. It is important to attract more postgraduate students, who are the future of CIE members.

3.2 To Promote Sales

The NCs are encouraged to play a more proactive role to promote sales via in their countries. This includes ensuring that members of their NCs have access to the publication discount code (giving a 66,7 % discount).

As to sales from CIE CB to NCs, note that only a few NCs take advantage of purchasing publications from CIE CB at the 80 % discount, for either re-selling in their country or for holding their own libraries. This is might be because it is possibly more efficient for NCs to rely on sales from the Webshop for distribution in their countries, from which the NCs derive income as credit notes (distributed to NCs every quarter – this being about 35 % of the royalties derived from the Webshop sales).

CIE CB has on its “subscription list” 10 NCs that purchase a copy of each new CIE publication. CIE also has a few NCs that purchase publications for selling in their countries, of these one NC is very active and there are 2 or 3 others that send requests to CIE CB on a less frequent basis.

Due to the overhead costs of selling publications from CIE CB and to enable NCs to purchase secure pdfs of CIE publications, a trial has recently been established whereby subscribers are sent a 80 % voucher to purchase new publications from the Webshop, likewise our regular customers are also sent vouchers in response to their requests. This trial has been in place since March 2019 and is currently under review. One issue noted to date is for those NCs who need to pay by Bank Transfer, rather than credit card, there is a significant burden of the $40 bank transfer fee imposed by Techstreet on all such payments, regardless of the size of the bank transfer.

NCs are also reminded that upon agreement with CIE Central Bureau they can make available in their country versions of CIE publications translated into their language. The distribution of these requires that a copy of the original English version is distributed with the translation. The request to translate is to be made for each and every publication that an NC intends to translate. More information about this can be found in the CIE Translation Policy.

3.3 Open Access

Open Access (OA) is relatively new to us. As noted above that from 2016 individual papers of symposia and conferences have been made available from the Webshop, at a modest price of €25 for non CIE members. The total income for 2108 was about €500. The BA made the decision to trial OA in late 2018. It is noted that researchers may have funding for preparing papers in OA publications, and the CIE should review the current situation as in the current situation no fees have been charged to enable OA, this being funded directly from CIE resources. It should also be noted that the CIE co-funded the OA of the papers from the CIE Tutorial held in Copenhagen in 2018 that were published in Leukos.

Quadrennial Report 2015 – 2019 of the Vice-President Standards

Ad de Visser, NL

This report covers activities in “standardization” during the second half of the quadrennium 2015-2019, with contributions from TCs, JTCs, Divisions, CB and VPS.

	Content		Annexes
1	Formal collaboration agreement with ISO and its TC 274	1	Published standards; Ongoing standards work
2	Standardization Strategy and Policy	2	Standards developing organizations in liaison with CIE
3	Contributions to the drafting or revision of CIE Policies, that also relate to standardization	3	Information on the Coordination Committee; Information on ISO/TC 274/JAG
4	External positions	4	Status of memberships in CIE and ISO/TC 274, March 2019
5	Request for attention from the General Assembly		
6	Acknowledgement		

The CIE is a scientific organization, and the CIE is a standards developing organization (SDO) as well, as such recognized by ISO, IEC and the CIPM. The CIE has formal collaboration agreements in standardization with ISO, IEC, the CIPM and CEN.

1. Formal collaboration agreement with ISO and its TC 274

The CIE has had a Memorandum of Understanding (MoU) with ISO and IEC since 1986. ISO recognized the CIE as an international standards developing organization since in 1989. Since 2011/2012 this collaboration has been intensified. End of 2012, ISO established technical committee ISO/TC 274, focussing on application of light and lighting, in specific cases complementary to the work items of the CIE, originally intended to coordinate the (fast-track) adoption of CIE International Standards as ISO/CIE standards and to maintain the ISO/CIE dual logo application standards. A set of Working Arrangements (WA) on the cooperation with ISO/TC 274 was defined in 2014 and a Coordination Committee (CoCo) commenced at the end of 2014.

While working with these arrangements, it appeared that fine-tuning of the WA was necessary. The main reasons were that the composition of the CoCo had been changed and that some provisions of the WA were conflicting with or not allowing the previously expected possible interpretations of the internal rules of especially ISO, but also of CIE, which internal rules are also annually updated. This resulted in a revision of the WA in 2016/2017. Already before the WA was formally approved and since its 9th meeting 2017-04-24, the CoCo has been working according to the revised WA, to the satisfaction of the participants.

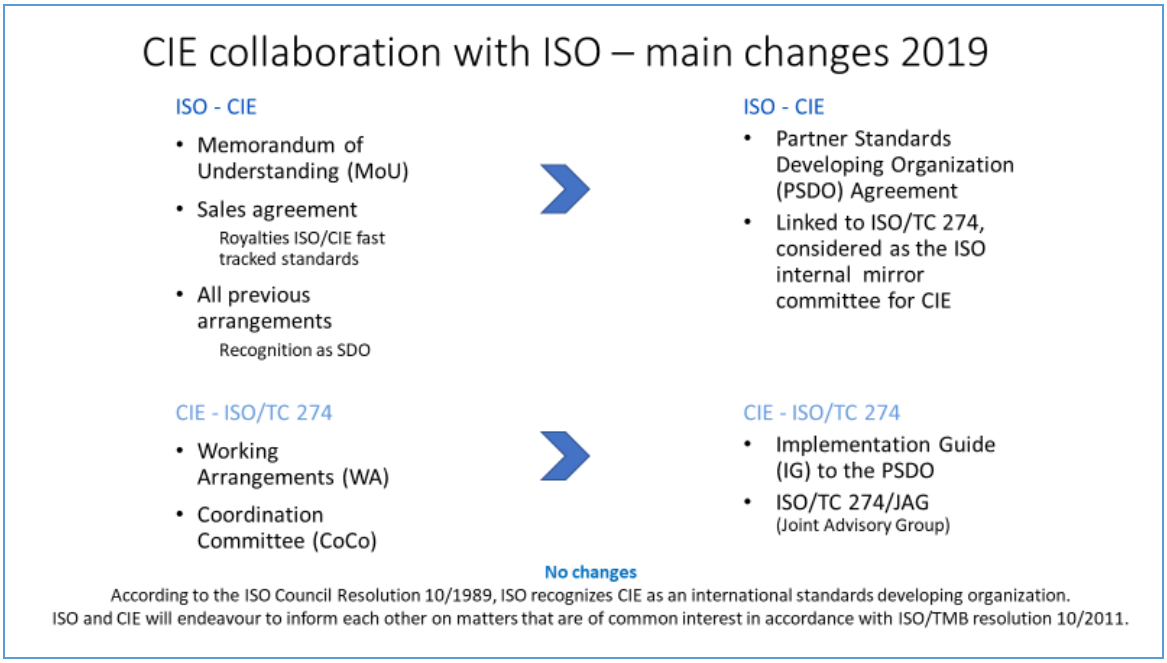
An attempt to update the MoU resulted in a conversion of the MoU into a ISO/CIE Partner Standards Development Organization (PSDO) agreement, whereby the updated WA was renamed into "Implementation Guide" (IG) for ISO/TC 274 and CIE, and annexed to the

PSDO. The sales agreement of dual logo publications from 1998 was modernized and merged with the PSDO. This project was running from 2017 onwards and may be concluded in2019.

The IG was agreed by ISO/TC 274 in September 2017, document ISO-TC274_N0352, and tentatively agreed by the CIE/BA in October 2017, awaiting the final draft PSDO for approval. The PSDO including the IG was finally adopted by the CIE/BA on 2019-02-14, and it is expected to be approved by the ISO/Council at their meeting June 11 – 12, 2019.

A publicly available version of the PSDO and the IG will be published on the CIE web pages; this is the official version of the PSDO minus provisions on copyright, exploitation and commercial arrangements, and on the termination of agreement. The IG can also be found as annex to the Strategic Business Plan (SBP) of ISO/TC 274.

The CoCo was abolished when the ISO/TC 274/JAG was established at the start of 2019.



These projects to revise the MoU, sales agreements and the ISO/TC 274 WA were not planned at the beginning of the 2015-2019 term and required considerable effort from VPS, GS and the CIE team of PRES, DD2, DD3, DD6 and TM.

2. Standardization Strategy and Policy

CIE has a broad scope covering all topics pertaining to light and lighting. Parts of its scope overlap with the scopes of other organizations that have a wider scope in another field of expertise. Introduction of new technologies, new entrants in light and lighting or trends in society sometimes result in new organizations or in existing organizations changing their scope overlapping with the scope of the CIE, particularly when it is perceived that there are no organizations already established to work in this scope.

CIE needs to ensure its leadership as both an SDO and a scientific organization, in particular in regards to standardization in the fundamentals of light and lighting.

A proposal for a Standardization Strategy and Policy was submitted to the BA meeting on 2019-06-15 for discussion and – if the BA is ready for it – approval. The proposal also contains an introduction to the Divisions and amendments to the Code of Procedure.

3. Contributions to the drafting or revision of CIE Policies that also relate to standardization

The BA has adopted a *CIE Policy on Liaison with External Organizations* in its meeting on 2019-02-14. VPS supported the BA Task Group that prepared the proposal since *External Organizations* may be SDOs, and to ensure that new collaboration agreements are not inconsistent with existing ones with SDOs. There should also be stricter conditions to collaboration when it concerns the joint development of normative documents.

The *CIE Policy on Intellectual Property* was revised and also here, input was provided from the standardization side, since collaboration with SDOs implies agreement with IP provisions of the particular organization. In addition, normative documents contain requirements and experts applying the standards should be able to comply with the requirements without IP restrictions or at reasonable terms of the IP owner.

CIE policies are published in the CIE web pages, organizational documents.

4. External positions

Contacts with other ISO TCs and other organizations were/are maintained by the CB.

A CIE BA Member is the convenor of the Coordination Committee (CoCo) and its successor ISO/TC 274/JAG.

From that position as convenor, he/she is also ISO/TC 274 chair, and from the latter position ISO/TC 274/CAG convenor.

This was/is/will be the GS during 2012-2015; VPS during 2015-2019; BA Secretary during 2019-2021.

The close relationship with ISO, which includes joint development, requires active involvement of the CIE Divisions, in particular of DIV 3 and DIV 4, for application standards, and of DIV 1 and Div 2, for both fundamental and application standards - this relationship needing a considerable effort from CB.

The co-convenors of ISO/TC 274/ JWGs 1, 3, 4 and 5 are the TC chair persons of JTCs 6, 11, 14 and 15 respectivley.

5. Request for attention from the General Assembly

Overlap membership CIE and ISO/TC 274

In the case of joint development of a standard or another normative document by CIE and ISO/TC 274, or in the case of (systematic) review of an existing ISO/CIE technical publication, there is parallel voting in both organizations. It would be beneficial to the content of the document and the arrangements of the voting process if the local CIE and ISO communities would be connected.

Local connection of communities could also be beneficial to research. Subsidies are sometimes provided by national or other authorities to develop a standard in an area that needs regulation, which may require research beforehand. CIE affiliates in countries where NCs are not connected to the NSBs may miss such opportunities.

NC voting on standards

According to the Statutes article 7.2, NCs shall approve the publication of standards.

> *"... the Commission shall publish technical documents. These include "CIE Standards" which require the approval of both the Board of Administration and the National*

Committees and other publications which require the approval of the Board of Administration only."

Currently, this requires an additional enquiry and approval stage (DIS, FDIS). This takes time, and in general the participation and response from NCs is very low. In addition, Division Members (DMs), representing their NCs, have already voted in the DIV ballot; they also often prepare the position of their NC. This raises the question about the need to continue with the NC voting.

To shorten and rationalize approval procedures, two options are possible:

- Parallel balloting of NCs with DIV and BA in the enquiry/approval stage; this requires changing the statutes, which requires time and money.
- Skip the (additional) NC enquiry/approval stage; this may be possible under the condition of a certain interpretation of the Statues, approved by the GA.
  "The GA agrees that the approval of standards by the NCs is given by their DMs and no additional approval by the NCs is necessary."

The position of the GA on the above is appreciated.

6. Acknowledgement

Before being elected as VPS I had been asked what I would hope to have achieved in the term 2015-2019.

My target was:

"A well running operation of standards development in CIE and in ISO/TC 274; not only along official CIE procedures, ISO procedures and the working agreement between CIE and ISO, but also in good cooperation between and within organizations.
CIE procedures will be updated and a mode of operation in CIE and its Divisions should grow as well as the communication and cooperation with ISO/TC 274.
How this is precisely being achieved is too early to say……."

I leave the evaluation to you, the reader, but I believe the job is done, though there was not enough attention to other SDOs such as IEC. May be this is something for the next VPS.

The portfolio of VPS requires very close cooperation with the GS and the TM. This report was reviewed by the GS, Kathy Nield, and the TM, Peter Zwick. Many thanks.

This is my last report as VPS, I did enjoy it, and wish my successor John O'Hagan lots of success and fun.

Annexes

ANNEX 1

Published standards

Current International Standards and Draft International Standards are listed on the CIE website.

CIE International Standards

CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light

CIE Draft International Standard

DIS 025-SP1/E:2019 Test Method for OLED Luminaires and OLED Light Sources

Dual logo International Standards

ISO/CIE 8995-3:2018 Lighting of work places - Part 3: Lighting requirements for safety and security of outdoor work places

ISO/CIE 20086:2019 Light and lighting -- Energy performance of lighting in buildings

ISO/CIE TS 22012:2019 Light and lighting -- Maintenance factor determination -- Way of working

Ongoing standards work

CIE

CIE International Standard

TC 2-67 Photometry of Lighting and Light-Signalling Devices for Road Vehicles

TC 2-83 CIE Standard on test methods for OLED light sources
To amend CIE S 025:2015

TC 2-92 International Standard Format for the Electronic Transfer of Luminaire Optical Data Collaboration with ISO/TC 274, route 2 (CIE lead, ISO/TC 274 participation without voting right)

JTC 9 Quantifying ocular radiation input for non-visual photoreceptor stimulation
Published: CIE S 026/E:2018

ISO/CIE International Standard

TC 2-82 Revision of CIE S 014-2: Colorimetry — Part 2: CIE Standard Illuminants for Colorimetry to include Illuminant D50
Note: approval stage: ISO/CIE DIS 11664-2, parallel voting in ISO and CIE

TC 4-60 Road Traffic Lights – Photometric Properties of Roundel Signals:
To revise ISO 16508:1999/CIE S 006.1-1998.
Note: Collaboration with ISO/TC 274, route 2 (CIE lead, ISO/TC 274 participation without voting right)

Technical Report

TC 2-88 Standard Reference Solar Spectra for Industrial Applications

CIE/ISO

JTC 6 (CIE-ISO/TC 274): Energy Performance of Lighting in Buildings
Published: ISO/CIE DIS 20086
NEW: ISO 10916:2014 Calculation of the impact of daylight utilization on the net and final energy demand for lighting
Note 1: Revision by ISO/TC 274/JWG 1 with CIE JTC 6
Note 2: Transferred from ISO/TC 163/SC 2

JTC 11 (CIE-ISO/TC 274) Light and Lighting – Maintenance factor – Way of working
Published: ISO/CIE TS 22012:2019

JTC 14 (CIE-ISO) Integrative Lighting
ISO/WD TR 21783

JTC 15 (CIE-ISO) Lighting of Indoor Workplaces
To revise ISO/CIE 8995-1 in response to its systematic review

Systematic review (SR)

CIE **administrative responsibility**

Minor revisions by CIE Technical Manager

ISO/CIE DIS 11664-1 Colorimetry -- Part 1: CIE standard colorimetric observers
FDIS ballot deadline 2019-04-23

ISO/CIE DIS 11664-3 Colorimetry -- Part 3: CIE tristimulus values
FDIS ballot deadline 2019-04-23

ISO/CIE DIS 11664-4 Colorimetry -- Part 4: CIE 1976 L*a*b* Colour space
FDIS ballot deadline 2019-05-07

ISO/CIE DIS 17166 Erythema reference action spectrum and standard erythema dose
FDIS ballot deadline 2019-04-08

Open SR ballots

ISO/CIE 11664-6:2014 Colorimetry — Part 6: CIEDE2000 Colour-difference formula
deadline 2019-05-18

ISO/CIE 23603:2005 Standard Method of assessing the spectral quality of daylight simulators for visual appraisal and measurement of colour
deadline 2019-05-18

ISO/CIE 23539:2005 The system of physical photometry
deadline 2019-05-18

Planned SR ballot

ISO/CIE 19476:2014 Characterization of the performance of illuminance meters and luminance meters
deadline 2019-09-10

ISO/TC 274 **administrative responsibility**

NEW

ISO 10916:2014 Calculation of the impact of daylight utilization on the net and final energy demand for lighting
Note 1: Revision by ISO/TC 274/JWG 1 with CIE JTC 6
Note 2: Transferred from ISO/TC 163/SC 2

CIE/IEC

JTC 5 (CIE-IEC) (IEC: TC 76 and TC 34)
Review of IEC 62471/CIE S 009: Photobiological Safety of Lamps and Lamp Systems

JTC 8: Terminology in light and lighting
Includes coordination with IEC on questions related to the incorporation of ILV terms and definitions into IEC 60050-845 “International Electrotechnical Vocabulary. Lighting”, coordination with ISO/TC 12 on questions related to the incorporation of ILV terms and definitions into ISO 80000-7 “Quantities and units – Part 7: Light and radiation” and any further terminology issues within CIE
Status April 2019: harmonization with IEC 60050-845
Expected: parallel voting on CIE FDIS 017 and IEC 60050-845

CIE/CCPR

JTC 2 (CIE-CCPR) Principles Governing Photometry

ANNEX 2

Standards developing organizations in liaison with CIE

This concerns ISO, IEC, CIPM and CEN. Memoranda of Understanding can be found on the CIE website.

ISO

ISO and CIE agreed to avoid duplication of work. CIE develops the fundamental and basic standards in all domains covered by its scope. ISO/TC 274 develops application standards, based upon fundamental and basic publications of the CIE and/or common practice or other application publications, in lighting situations of all domains covered by its scope.

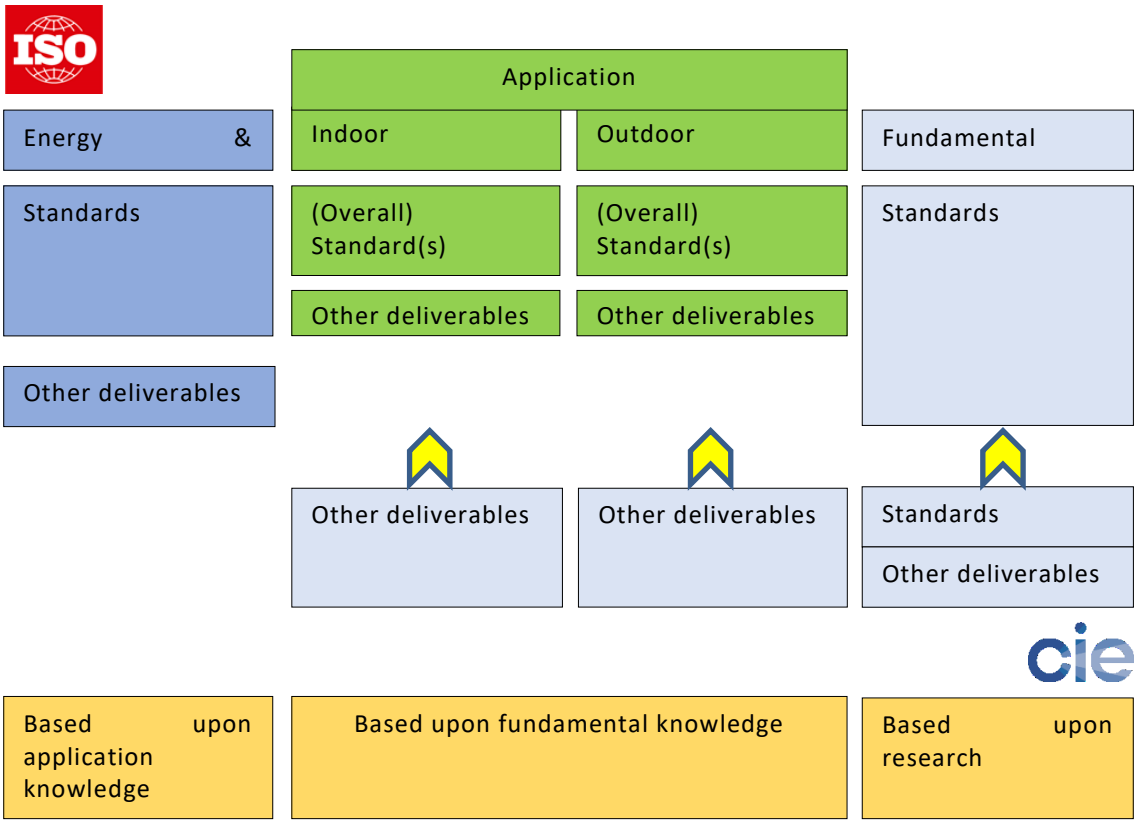


Figure 1 – Visualization of the cooperation between ISO/TC 274 and CIE (see also ISO/TC 274 SBP):

See annex 1 for publications and joint work.

The GS in cooperation with the Divisions regularly updates the list of ISO TCs that the CIE is in liaison with. See also link and link.

There is also an ongoing cooperation with ISO/TC 12 (Quantities and units) in the work on the revision of all parts of ISO 80000, especially Part 7, carried out by ISO/TC 12/WG 19. This work, related to the work of CIE JTC 8, led to harmonization of definitions that are both in ISO 80000-7 and in the ILV.

IEC

The main cooperation projects between CIE and IEC were in the field of terminology, harmonization of the vocabularies, biological safety and new, horticultural lighting. It concerns

mainly IEC/TC 34 (Lamps and related equipment), IEC/TC 1 (Terminology), and IEC/TC 76 (Optical radiation safety and laser equipment). Harmonization efforts in terminology between IEC/TC 34 and CIE were successful and will lead to a revised ILV and a revised subject area 845 of the IEV (IEC 60050-845). See also annex 1 "*Ongoing standards work"*.

CIE is always invited to participate in its Standards Management Board (SMB) meetings.

CIPM

A CIE delegation witnessed a historic moment by attending and participating in the 26th General Conference on Weights and Measures (CGPM) in Paris, in November 2019. At this meeting, the CIE President gave a presentation in balance to the presentation of the Consultative Committee for Photometry and Radiometry (CCPR). It was during this meeting that the CGPM approved a resolution to revise the definitions of the International System of Units, the SI. The revised SI comes into force formally on May 20, 2019 (World Metrology Day).

CIE has contributed to a revised version of Appendix 3 of the new SI-Brochure dealing with units for photochemical and photobiological quantities: https://www.bipm.org/utils/en/pdf/si-revised-brochure/Draft-Appendix3-2018.pdf

CEN

There was little interaction with CEN in the past two years, maybe indirect, because the increasing work program of ISO/TC 274, where CIE is involved, is now and then overlapping with CEN activities. The CIE is invited to the plenary meetings of CEN/TC 169.

The CIE GS requested assistance from the CIE Divisions to appoint liaisons to CEN/TC 169 WGs.

- CEN/TC 169/WG 1 Basic terms and criteria
- CEN/TC 169/WG 2 Lighting of work places
- CEN/TC 169/WG 3 Emergency lighting in buildings
- CEN/TC 169/WG 4 Sports lighting
- CEN/TC 169/WG 6 Tunnel lighting
- CEN/TC 169/WG 7 Photometry
- CEN/TC 169/WG 8 Photobiology
- CEN/TC 169/WG 9 Energy performance of buildings
- CEN/TC 169/WG 11 Daylight
- CEN/TC 169/WG 12 Joint Working Group with CEN/TC 226 - Road lighting
- CEN/TC 169/WG 13 Non-visual effects of light on human beings
- CEN/TC 169/WG 14 ErP Lighting Mandate Management Group

Liaisons to be reviewed:

- CEN/TC 226 Road Equipment
- CEN/TC 139 Paints and varnishes

CIE is also involved in STAIR (STAndards, Innovation and Research) to ensure the CIE research strategies are included in the standardization research strategies of CEN and Euramet as well as in EMPIR.

ANNEX 3

Information on the Coordination Committee and ISO/TC 274/JAG

Coordination Committee 2014-2018 12 meetings

ISO/TC 274/JAG 2019-..... 1 meeting to date of this report

Scope

To support the execution of the Working Arrangement/ Implementation Guide between ISO/TC 274 and CIE, as annexed to the ISO/TC 274 Strategic Business Plan (SBP) and to the PSDO between CIE and ISO.

The main tasks of this advisory group are:

- to recommend one of the routes for collaboration for all work items of ISO/TC 274 and CIE in the field of light and lighting standardization;
- to recommend the administrative responsibility ("lead") for the work item (ISO/TC 274 or CIE);
- to advise on a change of route of collaboration or a change of deliverable;
- to review the results of systematic review ballots and to recommend on the maintenance of the publications;
- to advise on CIE International Standards to be published as ISO/CIE standards through the ISO "fast track procedure";
- to recommend on the conversion of a Technical Specification (TS) or a Publicly Available Specification (PAS) to an International Standard (IS), or the withdrawal of a deliverable;
- to provide recommendations on general topics related to cooperation between parties involved in ISO/TC 274/JAG;
- to consider work items in overlapping areas with other standardization committees.

Membership

The JAG is a closed group, this means only nominated experts and liaison representatives from ISO/TC 274, CIE and IEC/TC 34 (as guest) can participate. Experts related to a specific topic may be invited as guests by the CoCo/JAG secretariat only. Only the liaison representative from ISO/TC 274 and from CIE are eligible to conclude on a recommendation.

The secretariat is formed by:

- A Convenor, who shall be a CIE Board of Administration member
- A Secretary/Manager, who shall be from the National Standards Body holding the secretariat of ISO/TC 274

Agenda structure

1) New work items Under Consideration (NUCs
2) Systematic Reviews
3) Overlapping areas and cooperation
4) Information exchange and general topics
5) Strategic items

ANNEX 4

Status of memberships in CIE and ISO/TC 274, March 2019

Country	CIE National Committee	CIE Associate National Committee	ISO Participating Country (P)	ISO Observing Country (O)	ISO (P,O) No CIE
Armenia				X	O
Australia	X				
Austria	X		X		
Belgium	X		X		
Bulgaria	X				
Brazil	X				
Canada	X		X		
China	X		X		
Colombia				X	O
Cyprus				X	O
Czech Republic	X			X	
Denmark	X		X		
Ecuador				X	O
Estonia				X	O
Finland	X		X		
France	X		X		
Germany	X		X		
Greece	X				
Hong Kong	X				
Hungary	X		X		
India	X				
Iran, Islamic Republic of			X		P
Italy			X		P
Israel	X				
Japan	X		X		
Kazakhstan				X	O
Korea, Republic of	X		X		
Malaysia	X		X		
The Netherlands	X		X		
New Zealand	X			X	
Norway	X		X		
Poland	X			X	
Romania	X			X	
Russian Federation	X		X		
Saudi Arabia		X			
Serbia	X			X	
Singapore		X		X	
Slovenia, Republic of	X				
Slovak Republic	X		X		
South Africa	X			X	
Spain	X			X	
Sri Lanka				X	O
Sweden	X		X		
Switzerland	X		X		
Tanzania			X		P
Turkey	X				
Chinese Taipei		X			
United Arab Emirates				X	O
United Kingdom/ Great Britain	X		X		
USA	X				
TOTAL	**36**	**3**	**22**	**16**	**3 P, 9 O**

Quadrennial Report 2015 – 2019 of the Treasurer

Richard Distl, DE

This report summarizes the financial performance of the CIE in the past four years and discusses its current financial status. Additionally, the report provides an overview of financial related activities in the past term.

It is advised to refer to the separate document "GA1911/BA1933 CIE FY 2018 Draft Financial Report - Letter to NCs" and the respective Excel sheet for a detailed discussion of the FY 2018 financial statements, and to the document "GA1810 CIE FY 2019 Consolidated Budget - Letter to NCs" and the respective Excel sheet for a detailed discussion of the FY 2019 budget.

Discussion of the consolidated P&L statements of the past term

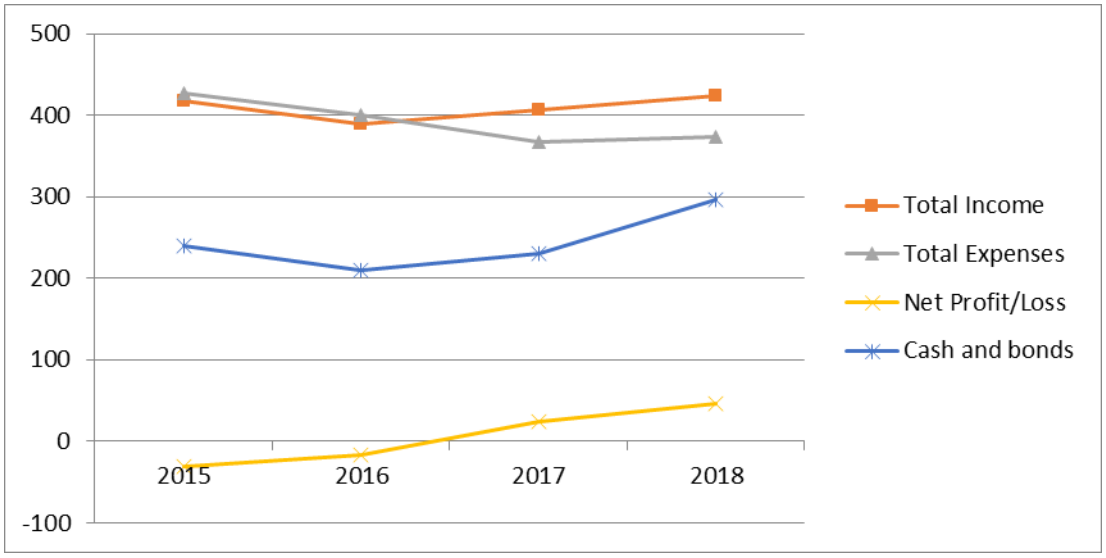
The table below shows major account items for the years 2015 to 2018 and the 2019 budget (all values are in kEuro).

					Budget Plan
Year	**2015**	**2016**	**2017**	**2018**	**2019**
Revenue from Sales	164	112	122	130	105
Membership Dues	253	275	287	294	313
Other revenue	0	3	-3	0	0
Total Income	**417**	**389**	**406**	**424**	**418**
Cost of sales	19	5	13	3	14
Gross Profit	**397**	**385**	**393**	**421**	**404**
Personnel costs	271	255	262	246	245
Depreciation	11	49	12	11	11
Operating cost	144	96	93	116	117
Total Expenses	**427**	**400**	**367**	**373**	**373**
EBIT	**-29**	**-16**	**26**	**48**	**31**
Financial profit, loss	1	1	0	0	0
Tax	-3	-2	-2	-2	-2
Net Profit/Loss	**-30**	**-17**	**24**	**46**	**29**
Cash and bonds	**240**	**210**	**230**	**297**	**>300**
Equity	**339**	**322**	**345**	**392**	**421**

Important account items are discussed as follows:

- Revenue from sales varies from year to year depending on conference activities and the release of new CIE documents
- Membership dues increased continuously as a result of the NC dues increase which will fade out in 2019
- Cost of sales is directly related to conference activities and fluctuates accordingly
- Personnel cost has stabilized after completing the restructuring of the position of the OM
- Depreciation was fairly constant except in 2016 where a large amount of past receivables had to be written off
- Operating cost now seems to have settled at some 115 kEuro after an exceptional large amount of Legal and Consulting Cost in 2015 and very strict cost savings in 2016 and 2017

In summary, Total Income has increased over the past years thanks to the increase of the NC dues in that period, while Total Expenses decreased due to cost savings in various areas. Both contributions resulted in a continuous improvement of Net Profit/Loss in the current term. In the end, CIE could return to profitability after several years of losses.



Discussion of the financial status of the CIE and its outlook

As a result of the financial performance in the past term, CIE finally came back to meet the prudent reserves level of 300 kEuro in Cash and Bonds after passing the lowest value of 210 kEuro in 2016.

The budget for 2019 continuous this positive trend of fostering a healthy and stable financial status of the CIE going forward.

Summary of finance related activities

Major activities in that area included:

Establisment of a quarterly reporting to the BA

- Provide key figures on Profit & Loss, Cash & Equity
- Based on Excel sheet with columns for comparison to the previous year and pro-rata temporis budget
- Column with forecast for remaining quarters to calculate an updated budget and variation of that to the original budget
- Accompanying letter with comments by the Treasurer to interpret the impact of financial figures

<u>Implementation of a new accounting system</u>

- In the past consolidation of Profit & Loss of the two entities „CIE Commission“ and „CIE Scientific Services GmbH“ has been done manually by the CB using Excel sheets
- Establishment of an automated consolidation of both entities by the external accounting firm using their software and data base. Balance Sheet accounts are consolidated as well, thus, information on equity status is given too
- Implementation of a proper process between CB, accounting firm and Treasurer
- Accurate and on-time determination of the profitability and financial status of the whole organization

<u>Sub-Task Group established to define Terms of Reference of the CIE Finance Committee</u>

- Input from BA members collected by Treasurer
- Meeting held in Vienna in June 2016 to discuss the input and related documents
- Next step was to draft a charter describing the role and responsibilities of the Finance Committee and its members for discussion and approval by the BA and NCs
- Due to severe time constraints the Treasurer was not able to dedicate additional time to this subject in the present term. Documents and status will be handed over to the new Treasurer

Finally, I'd like to thank the GS and CB staff for their hard and efficient work and supporting me to fulfill my duty as Treasurer. I also like to thank the members of the BA and the NCs for their trust in my and the CB's work in the past term. In particular, the effect of the agreed NC dues increase has proven to be an important part for bringing CIE back to a financially healthy and stable organization.

Quadrennial Report 2015 – 2019 of the General Secretary

Kathryn Nield, AT

This report will focus on matters at CIE Central Bureau that have been enacted upon as a result of initiatives of the CIE Board of Administration and the needs of the National Committees and the many volunteers who contribute to the work of the CIE, since the previous report circulated for the midterm meeting of the GA, held on Jeju Island, Republic of Korea, October 17, 2017.

Infrastructure and Resources

Communication with CIE NCs was a key topic of discussion during the 2017 GA, with a request for CIE to make available resources such as the CIE Brochure, which was prepared in the early 2000s. Although further work on this particular resource has not been progresses other actions have been completed to ensure that CIE NCs have resources available to support promotion of CIE in their country. These include:

- CIE Website
  The new website was launched in 2018. The new website give more visibility for CIE news items, including the promotion of CIE NC events and other news of NCs as provided.
- Use of Social Media
  CIE CB makes announcements of interest to the wider community via LinkedIn and Twitter. Upon request CIE will promote the events and activities of the NCs
- Additional WebEx Licenses
  WebEx is being well used to facilitate the work of the TCs and Divisions. WebEx meetings can also be arranged for NC meetings upon request.
- Preparation of LED Professional Review articles has been coordinated by CIE CB, with significant input from the BA and other CIE experts. These articles are available on the CIE website and can be used by NC websites to further promote the organization.

CIE CB routinely supports NCs with requests on administrative matters:

- Updates to CIE databases due to changes in NC's personnel (CIE Roster and Collaboration Tools access rights).
- Support on dues payments
- Generation of credit notes for NCs, due to publication sales and supportive members.
- Access to and support in the use of Collaboration Tools and WebEx
- Arranging and hosting WebEx meetings to support CIE procedures, such as systematic reviews of CIE publications, and for the use of NC meetings.

One key work activity that CIE CB is engaged in is the sales of CIE publications direct to NCs. These sales have a discount of 80 %, one purpose of these sales from CIE CB is for NCs to then sell the publications in their country. Generally only a few NCs purchase publications in this way and in order to streamline these sales and to enable NCs access to secure pdfs arrangements have now been made for these purchase to be made via the CIE Webshop.

Looking ahead, with the accrual of some modest financial reserves there is more opportunity for CIE to develop materials for the use of the organization as a whole, these including the generation of articles on CIE activities and the long awaited updated CIE Brochure.

Liaison

CIE has liaison both at a technical level and at an organization level with various stakeholders, including those that have written agreement with the CIE and those without.

Over the past two years considerable CIE CB effort has been put into supporting the work with ISO. This work arises from the special relationship between CIE and ISO/TC 274 as well as due to existing liaison with other ISO/TCs who have some need for material developed by the CIE. Currently, in the latter category there are 29 such ISO /TCs, and this number is increasing as the need for standardization of use of lighting technologies in many “daily activities”

Annex
CIE Update of Activities January 2018 – May 2019

Technical Reports:

- CIE 228:2018 Grey-Scale Calculation for Self-Luminous Devices
- CIE 229:2018 Groundwork for Measurement of Effective Intensity of Flashing Lights
- CIE 198-SP2:2018 Determination of Measurement Uncertainties in Photometry Supplement 2: Spectral measurements and derivative quantities
- CIE 015:2018 Colorimetry, 4th Edition
- CIE 230:2019 Validity of Formulae for Predicting Small Colour Differences
- CIE 140:2019 Road Lighting Calculations, 2nd Edition
- CIE 083:2019 Guide for the Lighting of Sports Events for Colour Television and
- Film Systems, 3rd Edition
- ISO/CIE TS 22012:2019 Light and Lighting — Maintenance Factor Determination — Way of Working
- CIE 018:2019 The Basis of Physical Photometry, 3rd Edition

International Standards:

- ISO/CIE 8995-3:2018 Lighting of work places - Part 3: Lighting requirements for safety and security of outdoor work places
- CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light
- ISO/CIE 20086:2019 Light and Lighting — Energy Performance of Lighting in Buildings

Draft International Standards:

- CIE DIS 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light
- CIE DIS 025-SP1 /E:2019 Test Method for OLED Luminaires and OLED Light Sources

Proceedings:

- CIE x044:2017 Proceedings of the Conference at the CIE Midterm Meeting 2017, 23 – 25 October 2017, Jeju, Republic of Korea
- CIE x045:2018 Proceedings of CIE 2018 ”Topical Conference on Smart Lighting”, 26 – 27 April 2018, Taipei, Chinese Taipei

Position Statements:

- April 2019 CIE Position Statement on the Blue light Hazard
  Translated into several languages by CIE NCs
  republished in Colour Research and Science by Wiley

LED Professional Review Articles:

- LpR 65 Tailored Lighting recommendations
- LpR 66 Colour Quality of Light Sources Related to Perception and Preference
- LpR 67 Metrology for Advanced Photometric and Radiometric Devices
- LpR 68 CIE Considers the “Good and Bad” of Light

- LpR 69 Adaptive, Dynamic and Intelligent Lighting
- LpR 70 Visual Appearance: Perception, Measurement and Metrics
- LpR 71 “Glare” is to Light as “Noise” is to Sound – CIE Research Roadmap on Glare
- LpR 73 Horticultural Lighting - The Root to International Standards

Documents currently in CIE approval process (status of 2019-05-13)

- TC 2-51 Calibration, Characterization and Use of Array Spectroradiometers)
- TC 2-82 Revision of S 014-2
- TC 4-56 Masterplanning Urban Lighting
- JTC 2 Principles Governing Photometry
- JTC 7 Discomfort Caused by Glare from Luminaires with Non-Uniform Source Luminance
- DR 2-75 The use of “Accuracy” and related terms in the specifications of testing and measurement equipment (Technical Note)

Systematic Reviews of CIE/ISO International Standards (2019)

- ISO/CIE 11664-6:2014 Colorimetry Part 6: CIEDE2000 Colour-difference formula TC 2-90 LED Reference Spectrum for Photometer Calibration – deadline 2019-05-20
- ISO/CIE 23603:2005 Standard Method of assessing the spectral quality of daylight simulators for visual appraisal and measurement of colour – deadline 2019-05-20
- ISO/CIE 11664-6:2014 Colorimetry Part 6: CIEDE2000 Colour-difference formula TC 2-90 LED Reference Spectrum for Photometer Calibration – deadline 2019-05-20
- ISO/CIE 23539:2005 The system of physical photometry – deadline 2019-05-20
- ISO/CIE 19476:2014 Characterization of the performance of illuminance meters and luminance meters – deadline 2019-09-10

New Technical Committees

- TC 2-89 Measurement of Temporal Light Modulation of Light Sources and Lighting Systems
- TC 2-90 LED Reference Spectrum for Photometer Calibration
- TC 2-91 Optical Measurement Methods of LED Packages and LED Arrays
- TC 2-92 International Standard Format for the Electronic Transfer of Luminaire Optical Data
- TC 4-58 Obtrusive Light from Colourful and Dynamic Lighting and its Limitation
- TC 4-59 Guide for Lighting Urban Elements
- TC 4-60 Road Traffic Lights – Photometric Properties of Roundel Signals
- JTC 12 (D1/D2/D8) The measurement of sparkle and graininess
- JTC 13 (D4/D3) Depreciation and Maintenance of Lighting Systems
- JTC 14 (CIE-ISO) Integrative Lighting
- JTC 15 (CIE-ISO) Lighting of Indoor Workplaces – Revision of ISO/CIE 8995-1
- JTC 16 (D1/D8) Validity of Chromatic Adaptation
- JTC 17 (D1/D2/D8) Gloss measurement and gloss perception: A framework for the definition and standardization of visual cues to gloss

Research Fora

- RF-01 Spectral Imaging

- RF-02 Matters relating to temporal light modulation
- RF-03 Evaluating the current status of colour science and identifying needed research to support the development of a comprehensive method for measuring and specifying colour rendering properties of white-light sources

Terminology work

CIE JTC 8 Terminology in Light and Lighting

- Revision of current version of the ILV (CIE S 017:2011), considering
  - coordination with IEC regarding harmonization with IEC 60050-845 (Subject Area 845 of the IEV)
  - coordination with ISO regarding harmonization with ISO 80000-7 (Peter Zwick member of ISO/TC 12/WG 19)

ILV/IEV work (status of 2018-11-01):

- December 2016:
  CIE DIS 017/E:2016: ILV: International Lighting Vocabulary, 2nd Edition
  published and circulated to CIE NCs/BA/Divisions for enquiry
- September 2017:
  Submission of revised DIS to IEC/TC 1 for translation and preparation of CDV
- Currently:
  IEC/TC 1 ballot on CDV of IEC 60050-845 (Subject Area 845 of IEV) – deadline 2018-11-16
- Planned:
  - Parallel IEC/TC 1 ballot on IEC/FDIS 60050-845 and CIE ballot on CIE FDIS 017
  - Parallel publication of new editions of IEC 60050-845 / CIE S 017

External Representation

- IEC/TC 34/PR 63105 (Lighting Systems Vocabulary) Meeting, Sydney, Australia, February 2018, Division 2 Secretary.
- IEC/SMB Meeting, Vienna, Austria, February 12, 2018, General Secretary
- Frankfurt Light and Building, Frankfurt, Germany, March, 20, 2018, General Secretary, CIE Technical Manager.
- International Day of Light, inaugural event, Paris May 16 2018, President-elect, Division Director 6, General Secretary, NC France President, NC Czech Republic President.
- ISO/TC 274 Plenary Meeting, Toronto, Canada, Vice President Standards, General Secretary, CIE Technical Manager.
- ISO/TC 274 several virtual meetings of the Chair Advisory Group (CAG), Coordination Committee (CoCo), Vice President Standards, General Secretary, CIE Technical Manager, Division 3 Director, Division 4 Director, various CIE experts.
- International Astronomical Union (IAU) -CIE Joint Workshop, Vienna, Austria, August 24, 2018, President-elect, Division Director 4, General Secretary.
- CEN/TC 169 Plenary Meeting, Ghent, Belgium, October, 10 – 11, 2018, General Secretary
- Light Europe Conference, Davos, Switzerland, October 2018, Technical Manager
- 26th Meeting of the CGPM (General Conference for Weights and Measures), November 13 – 16, 2018, Paris, France, President, President-elect, Division 2 Secretary, General Secretary.
- Underwriters Laboratory, virtual meetings to discuss matters pertaining to UL developing a document on recommended practise for circadian lighting, December 2018, BA members and GS.
- IEC SMB Meeting, Montreux, Switzerland, February 19, 2019, General Secretary.
- ISO Central Secretariat to finalize matters of the PSDO between ISO and CIE, Geneva, Switzerland, February 20, General Secretary and Vice President Standards
- GLASE, DLC, ASABE, virtual meetings to connect with experts in the field of horticultural lighting, March 2018, DD6 and GS
- IPWEA 4th International Street Lighting+Smart Controls Conference – Sydney, Australia, April 2 – 4, 2019, DD4
- IEC/TC 24 Advisory Group 4, Horticultural Lighting, Beijing, China, April 25, 2019, CIE Technical Manager.
- International Day of Light, Discussion Panel on Lighting and Education, Trieste, Italy, May 16, 2019, DD6.
- Lichttechnische Gesellschaft Österreichs (LTG) Austrian Lighting Society, Conference, May 21 – 22, 2019, Spielberg, Austria, President-elect/DD2.
- ISO/TC 274 Plenary meeting, JAG, CAG, JWGs 4 and 5, May 20 – 24, 2019, Stockholm, Sweden, GS and TM.
- Commenting on documents and work item proposals of external organizations, General Secretary, Technical Manager, DMTs.
- LED Professional Review articles –DDs, BA, and other technical experts, co-ordinated by the General Secretary.

Past CIE Events

- CIE 2017, Midterm Meeting, Jeju Island Korea, October 21 – 28, 2017,385 participants, 200 abstracts submitted.
- CIE 2018, CIE Topical Conference on Smart Lighting, Taipei, Chinese Taipei, April 24 – 28, 2018, 200 participants, 115 abstracts submitted.
- CIE Visibility Workshop, Berlin, Germany, May 22 – 23, 2018, 63 participants.
- CIE Expert Workshop on Research Methods for Human Factors in Lighting, Copenhagen, Denmark, August 13 – 14, 97 participants
- CIE Tutorial and Practical Workshop on CIE S 025: LED lamps, LED luminaires and LED modules, Moscow, Russia, November 5 – 7, 2018, 34 participants
- CIE Expert Tutorial on CIE S 026, Eindhoven, The Netherlands, March 14 -15, 2019, 53 participants from 18 countries.

Current and Future CIE Events

- CIE 2019 CIE 29th Quadrennial Session
  Washington, United States of America, June14–22, 2019, 353 abstracts submitted.
- 5th CIE Symposium on Colour and Visual Appearance, Hong Kong, April 20 – 25, 2020 – in preparation, abstract submission opens July 2019.
- CIE 2021, Midterm Meeting, Georgetown, Malaysia, 17 – 25 April, 2021 (conference from April 20 – 22) – in preparation.
- CIE 2023, 30th Quadrennial Session, bids received from NC Slovenia and NC Russia.

Events under consideration for approval

D4 Workshop on Obtrusive Light and D4 Annual Meeting, 2020, Ostrava, Czech Republic.

- CIE Symposium on Optical Radiation Hazards, Vienna, 2020

QUADRENNIAL REPORTS OF THE DIVISIONS

Division 1: Vision and Colour
Quadrennial Report 2015-2019

Youngshin Kwak, KR (DD)

2019-09-01

1 Terms of Reference

To study visual responses to light and to establish standards of response functions, models and procedures of specification relevant to photometry, colorimetry, colour rendering, visual performance and visual assessment of light and lighting.

2 Division Officers

2015–2019:

Director:	Youngshin Kwak (KR)
Associate Director (Colour):	Ellen Carter (US)
Associate Director (Vision):	Nana Itoh (JP)
Editor:	Peter Hanselaer (BE)
Secretary:	Li-Chen Ou (TW)

2019–2023:

Director:	Youngshin Kwak (KR)
Associate Director (Colour):	Ellen Carter (US)
Associate Director (Vision):	Nana Itoh (JP)
Editor:	Peter Hanselaer (BE)
Secretary:	Li-Chen Ou (TW)

3 Division Meetings

2016: Prague (CZ), 2019-09-09
(meeting held in conjunction with the 4th CIE Expert Symposium on Colour and Visual Appearance)
42 attendances including 19 national representatives

2017: Jeju (KR), 2020-10-27
(meeting held in conjunction with the CIE Midterm Meeting)
42 attendances including 22 national representatives

2018: Taipei (TW), 2018-04-28
(meeting held in conjunction with the CIE Topical Conference)
26 attendances including 15 national representatives

2019: Washington DC (US), 2019-06-21
(meeting held in conjunction with the 29th CIE Session)
45 attendances including 20 national representatives

4 Symposia and Workshops

2016: 4th CIE Expert Symposium on Visual Appearance
ISC Chair: Gael Obein, FR
Prague (CZ) 2016-09-05 – 2016-09-07

5 Strategy 2015-2019

In 2015, Division1 selected five research topics before as the division level research strategy.

- Colour Quality of Light Sources Related to Perception and Preference
- Application of New CIE 2006 Colorimetry
- Visual Appearance: Perception, Measurement and Metrics
- A comprehensive colour appearance model based on CIECAM02
- Visual Impairment

Three topics from CIE research strategy i.e. Colour Quality of Light Sources Related to Perception and Preference, Application of New CIE 2006 Colorimetry, and Visual Appearance: Perception, Measurement and Metrics, are D1-lead topics.

Division1 continued to implement the Code of Procedure by reviewing TC activities following CoP.

6 Administrative Matters and Communication

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7 Publications

7.1 Published

7.1.1 CIE Technical Reports

CIE 170-2:2015	Fundamental Chromaticity Diagram with Physiological Axes – Part 2: Spectral Luminous Efficiency Functions and Chromaticity Diagrams
CIE 217:2016	Recommended Method for Evaluating the Performance of Colour-Difference Formulae
CIE 224:2017	CIE 2017 Colour Fidelity Index for accurate scientific use
CIE 228:2018	Grey-Scale Calculation for Self-Luminous Devices
CIE 015:2018	Colorimetry, 4th Edition
CIE 230:2019	Validity of Formulae for Predicting Small Colour Differences
CIE 232:2019	Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Luminance

7.1.2 CIE Standards

7.1.3 Joint ISO/IEC/CIE Standards

ISO/CIE 11664-5:2016(E) Colorimetry — Part 5: CIE 1976 L*u*v* Colour Space and u', v' Uniform Chromaticity Scale Diagram

7.1.4 CIE Draft Standards

7.1.5 CIE Technical Notes

CIE TN 006:2016	Visual Aspects of Time-Modulated Lighting Systems – Definitions and Measurement Models

CIE TN 007:2017 Interim Recommendation for Practical Application of the CIE System for Mesopic Photometry in Outdoor Lighting
CIE TN 008:2017 Final Report CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems

7.1.6 Reports by Reporterships

7.2 Expected

TC 1-76 Unique Hue Data: Technical Report

TC 1-83 Visual Aspects of Time-modulated Lighting Systems: Technical Report

TC 1-84 Definition of Visual Field for Conspicuity: Technical Report

TC 1-89 Enhancement of Images for Colour Defective Observers: Technical Report

TC 1-91 Methods for Evaluating the Colour Quality of White-Light Sources: Technical Report

TC 1-92 Skin colour database: Technical Report

TC 1-95 The Validity of the CIE Whiteness and Tint Equations: Technical Report

TC 1-96 A Comprehensive Model of Colour Vision: Technical Report

TC 1-97 Age- and Field-Size-Parameterised Calculation of Cone-Fundamental-Based Spectral Tristimulus Values: Technical Report

JTC 16 (D1/D8) Validity of Chromatic Adaptation: Technical Report

JTC 17 (D1/D2/D8) Gloss Measurement and Gloss Perception: A Framework for The Definition and Standardization of Visual Cues to Gloss: Technical Report

7.3 Review

7.3.1 Reviewed Publications

7.3.2 Status of Publications

Current:

- CIE 075-1988 Spectral Luminous Efficiency Functions based upon Brightness Matching for Monochromatic Point Sources, 2° and 10° Fields
- CIE 095-1992 Contrast and Visibility
- CIE 101-1993 Parametric Effects in Colour-Difference Evaluation
- CIE 13.3-1995 Method of Measuring and Specifying Colour Rendering Properties of Light Sources
- CIE 118-1995 CIE Collection in Colour and Vision:
- CIE 123-1997 Low Vision – Lighting Needs for the Partially Sighted
- CIE 124-1997 CIE Collection in Colour and Vision, 1997
- CIE 135-1999 CIE Collection 1999: Vision and Colour, Physical Measurement of Light and Radiation
- CIE 51.2-1999 A Method for Assessing the Quality of Daylight Simulators for Colorimetry
- CIE 141-2001 Testing of Supplementary Systems of Photometry
- CIE 142-2001 Improvement to Industrial Colour-Difference Evaluation
- CIE 145:2002 Correlation of Models for Vision and Visual Performance
- CIE 146/147:2002 CIE Collection on Glare 2002

- CIE 160:2004 A Review of Chromatic Adaptation Transforms
- CIE 165:2005 CIE 10 Degree Photopic Photometric Observer
- CIE 166:2005 Cognitive Colour
- CIE 167:2005 Recommended Practice for Tabulating Spectral Data for Use in Colour Computations
- CIE 170-1:2006 Fundamental Chromaticity Diagram with Physiological Axes – Part 1
- CIE 175:2006 A Framework for the Measurement of Visual Appearance
- CIE 177:2007 Colour Rendering of White LED Light Sources
- CIE 184:2009 Indoor Daylight Illuminants
- CIE 185:2009 Reappraisal of Colour Matching and Grassmann's Laws
- CIE 191:2010 Recommended System for Mesopic Photometry based on Visual Performance
- CIE 192:2010 Practical Daylight Sources for Colorimetry
- CIE 195:2011 Specification of Colour Appearance for Reflective Media and Self-Luminous Display Comparisons
- CIE 200:2011 CIE Supplementary System of Photometry
- CIE 204:2013 Methods for Re-defining CIE D Illuminants
- CIE 208:2014 Effect of Stimulus Size on Colour Appearance
- CIE 211:2014 Colour Appearance in Peripheral Vision
- CIE 212:2014 Guidance towards Best Practice in Psychophysical Procedures used when Measuring Relative Spatial Brightness
- CIE 170-2:2015 Fundamental Chromaticity Diagram with Physiological Axes – Part 2: Spectral Luminous Efficiency Functions and Chromaticity Diagrams
- CIE 217:2016 Recommended Method for Evaluating the Performance of Colour-Difference Formulae
- CIE 224:2017 CIE 2017 Colour Fidelity Index for accurate scientific use
- CIE 228:2018 Grey-Scale Calculation for Self-Luminous Devices
- CIE 015:2018 Colorimetry, 4th Edition
- CIE 230:2019 Validity of Formulae for Predicting Small Colour Differences
- CIE 232:2019 Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Luminance

Under Review:

Superseded:

Archive:

- CIE 78-1988 Brightness-Luminance Relations: Classified Bibliography Colorimetry
- CIE 80-1989 Special Metamerism Index: Change in Observer
- CIE 81-1989 Mesopic Photometry: History, Special Problems and Practical Solutions
- CIE 86-1990 CIE 1988 2° Spectral Luminous Efficiency Function for Photopic Vision
- CIE 87-1990 Colorimetry of Self-luminous Displays – A Bibliography
- CIE 109-1994 A Method of Predicting Corresponding Colours under Different Chromatic and Illuminance Adaptations
- CIE 116-1995 Industrial Colour-Difference Evaluation

Withdrawn:

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8 Technical Committees (TCs)

8.1 Closed TCs

TC 1-63 Validity of the Range of CIEDE2000 (chair: Klaus Richter, DE) closed in 2018

Due to inactivity

TC 1-81 Validity of Formulae for Predicting Small Colour Differences (chair: Klaus Richter, DE), closed in 2018

With publication of CIE Technical Report 230:2019

TC 1-85 Update CIE Publication 15:2004 Colorimetry (chair: Schanda, HU/Carter, US) closed in 2018

With publication of CIE Technical Report 15:2018

TC 1-86 Models of colour emotion and harmony (chair: Li-Chen Ou, TW), closed in 2019

Due to inactivity

TC 1-88 Scene Brightness Estimation (chair: Yoshiki Nakamura, JP), closed in 2018

Due to inactivity

TC 1-90 Colour Fidelity Index (chair: Hirohisa Yaguchi, JP) closed in 2017

With publication of CIE Technical Report 224:2017

TC 1-93 Calculation of Self-luminous Neutral Scale (chair: Robert Carter, US), closed in 2018

With publication of CIE Technical Report 228:2018

8.2 New and Closed TCs

8.3 TCs in Progress

TC 1-76 Unique Hue Data (chair: Sophie Wuerger, GB), started in 2009

Final report will be submitted to the BA by September 2019.

TC 1-83 Visual Aspects of Time-modulated Lighting Systems (chair: Malgorzata (Gosia) Perz, NL) started in 2011

TCC has been changed from Dragan Sekulovski (NL) to Malgorzata (Gosia) Perz in 2019 expecting to publish TR in one year.

TC 1-84 Definition of Visual Field for Conspicuity (chair: Nana Itoh, JP), started in 2011

WD of TR is now being reviewed by DE, and it has to be submitted to CB by the end of 2019.

TC 1-89 Enhancement of Images for Colour Defective Observers (chair: Po-Chieh Hung, US), started in 2012

CD is under review expecting to publish TR in 2019.

TC 1-91 Methods for Evaluating the Colour Quality of White-Light Sources (chair: Yandan Lin, CN), started in 2012

Expected to publish TR in 2019

TC 1-92 Skin colour database (chair: Kaida Xiao, GB), started in 2013

Expected to publish TR in 2020

TC 1-95 The Validity of the CIE Whiteness and Tint Equations (chair: Minchen Wei, HK), started in 2015

TCC has been changed from Robert Hirschler (DE) to Minchen Wei (HK) in 2019.

TC 1-96 A Comprehensive Model of Colour Vision (chair: Ming Ronnier Luo, GB/CN), started in 2015

Expected to publish TR in 2020

TC 1-97 Age- and Field-Size-Parameterised Calculation of Cone-Fundamental-Based Spectral Tristimulus Values (chair: Jan Henrik Wold, NO), started in 2015

Expected to publish TR in 2019

8.4 New TCs

JTC 16 (D1/D8) Validity of Chromatic Adaptation (chair: Minchen Wei, HK) started in 2018

ToR: Recent experimental work revealed the incomplete chromatic adaptation under white light, especially those with low CCT and off-Planckian chromaticities, which are important to the performance of chromatic adaptation transforms. This was not considered in existing chromatic adaptation transforms (CATs). The TC will review the existing CATs and propose modifications by including a two-step transform to take the effect of white light chromaticity on degree of chromatic adaptation into consideration.

JTC 17 (D1/D2/D8) Gloss Measurement and Gloss Perception: A Framework for The Definition and Standardization of Visual Cues to Gloss (chair: F Leloup, BE) started in 2018

ToR: To describe recommendations for standardized visual assessment conditions of individual, established cues to gloss, to make recommendations for the definition of a standard gloss observer for individual diagnostic cues and, based on the findings from the above, to suggest optical methods and metrics for describing gloss in correlation with the established gloss cues.

8.5 Proposed TCs

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9 Reporterships (DRs)

9.1 Closed DRs

DR 1-42 Extension of CIECAM02 (Changjun Li, CN), closed in 2017

transferred into new JTC 10

DR 1-53 Gloss Perception and Measurement (Frédéric Leloup, BE), closed in 2018

transferred into new JTC 17

DR 1-58 Liaison with ISO/TC 130 Graphic Technology (Phil Green, GB), closed in 2018

due to inactivity

DR 1-61 Source Whiteness Metric (Aurelian David, US), closed in 2018

due to inactivity

DR 1-65 Categorical colour identification (Taiichiro Ishida JP) closed in 2017

report published

9.2 New and Closed DRs

DR 1-68 A gamut area measure and colour-shift graphic, based on CIE 13.3-1995 (Kees Teunissen, NL / Yoshi Ohno, US / K Mukai JP), started in 2017, closed in 2019

The report is transferred into the part of TC 1-91

9.3 DRs in Progress

DR 1-60 Future colour-difference evaluation (Guihua Cui, CN), started in 2013

DR 1-62 Typical LED spectra (Sophie Jost, FR), started in 2015

DR 1-63 Tristimulus integration (Changjun Li, CN), started in 2015

DR 1-64 Real colour gamut (Changjun Li, CN), started in 2015

DR 1-66 The effect of dynamic and stereo visual images on human health (Hiroyasu Ujike, JP), started in 2015

DR 1-67 Revisiting correlated colour temperature (Youngshin Kwak, KR), started in 2017

DR 1-69 Applicability of metrics for evaluating reflected glare on displays (Shao-Tang Hung, TW), started in 2018

9.4 New DRs

9.5 New DRs – Converted Informal Liaisons

9.6 Proposed DRs

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10 Liaisons

10.1 Official Liaisons

CIE D1 do not have the liaisons sent from D1 to other organizations.

10.2 Informal Contacts

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11 Future Activities

In 2020 the Division 1 Meeting will be held as part of the 5th CIE Symposium on Colour and Visual Appearance, in Hong Kong, 20-25 April 2020.

In 2021 the Division 1 Meeting will be held as part of the CIE Mid-term Meeting, in Penang, Malaysia, 19-28 April 2021.

In 2023 the Division 1 Meeting will be held as part of the 30th CIE Session, in Ljubljana, Slovenia, 15-23 September 2023.

12 Other Achievements, Issues, etc.

Division 2: Physical Measurement of Light and Radiation
Quadrennial Report 2015-2019

Peter Blattner, CH (DD), Tony Bergen, AU (DS)

2019-07-31

1 Terms of Reference

To study standard procedures for the evaluation of ultraviolet, visible and infrared radiation, global radiation, and optical properties of materials and luminaires. To study optical properties and performance of physical detectors and other devices required for their evaluation.

2 Division Officers

2015–2019:

Director:	Peter Blattner (CH)
Associate Director 1:	Armin Sperling (DE)
Associate Director 2:	Hiroshi Shitomi (JP)
Associate Director 3:	Joanne Zwinkels (CA)
Secretary:	Tony Bergen (AU)
Editor:	Jim Gardner (AU)

2019–2023:

Director:	Tony Bergen (AU)
Associate Director 1:	Armin Sperling (DE)
Associate Director 2:	Hiroshi Shitomi (JP)
Associate Director 3:	Joanne Zwinkels (CA)
Secretary:	Dong-Hoon Lee (KR)
Editor:	Thiago Menegotto (BR)

3 Division Meetings

2016: Melbourne (AU), 2016-03-07
(meeting held in conjunction with CIE Lighting Quality & Energy Efficiency Conference)
41 attendances (plus 3 persons by WebEx) including 22 national representatives

2017: Jeju (KR), 2017-10-26
(meeting held in conjunction with the CIE 2017 mid-term meeting)
63 attendances (plus 4 persons by WebEx) including 23 national representatives

2018: Eindhoven (NL), 2018-06-13
(meeting held in conjunction with a workshop organized by NC Netherlands)
37 attendances (plus 3 persons by WebEx) including 25 national representatives

2019: Washington DC (USA), 2019-06-20
(meeting held in conjunction with the 2019 Quadrennial Session of the CIE)
63 attendances WebEx including 23 national representatives

4 Symposia and Workshops

2015: CIE Tutorial and Expert Symposium on the CIE S025 LED Lamps, LED Luminaires and LED Modules Test Standard
Co-chairs: Peter Blattner (CH) / Armin Sperling (DE)
Braunschweig (DE), 2015-11-23 to 2015-11-27

2016: 4th Expert Symposium on Appearance (in collaboration with D1)
Co-chairs: Gaël Obein (FR)/ Marek Smid (CZ)
Prague (CZ), 2016-09-06 to 2016-09-07

2017: CIE Tutorial and Practical Workshop on LED Lamp and Luminaire Testing to CIE S 025
Chair: Peter Blattner (CH)
Bern-Wabern (CH), 2017-05-08 to 2017-05-11

2018: CIE Tutorial and Practical Workshop on LED Lamp and Luminaire Testing to CIE S 025
Co-chairs: Peter Blattner (CH)/ Alexey Bartsev (RU)
Moscow (RU), 2017-05-08 to 2017-05-11

5 Strategy 2015-2019

The strategy 2015 to 2019 is an extension of the strategy 2011 to 2015. Due to the technological change of lighting products CIE D2 decided to put additional effort into the characterization and of products and several related TCs were established (TC 2-50, TC 2-63, TC 2-64, TC 2-75, TC 2-76, TC 2-83, TC 2-84, TC 2-89, TC 2-90, TC 2-91, TC 2-92).

The publication of CIE S 025/E:2015 Test Method for LED Lamps, LED Luminaires and LED Modules has triggered different activities including several tutorials and workshop. Also, the visibility of CIE has been increased.

The CIE research strategy has triggered several research projects, in particular in the framework of EMPIR (European Metrology Programme for Innovation and Research). These projects have positive effects on D2 work as the results of the projects can be used as the basis for TC work. Also new experts could be identified and many scientific papers were submitted to CIE conferences.

6 Administrative Matters and Communication

All communications to the Division, the publication of D2 meeting documents and Division ballots are done using Collaboration Tool. In the period 2015-2019 about 40 D2 ballots were conducted and 50 communiqués were sent out to the division. Ballots on critical items (e.g. creation of new TCs) are carried out in two steps: a commenting/discussion phase (typically 1 month) and a Yes/No/Abstain ballot (1 month).

Furthermore, the D2 Division Associate room includes about 240 people interested in D2 activities. About 25 communiqués were sent out to D2 Division Associate room. All TCs in Division 2 are using the Collaboration Tool. At least the draft of the publications, the status reports, the primary data, the meeting documents and minutes of the meetings have to be collected in the Collaboration Tool.

Division 2 has a quite large number of TCs (around 35 TCs). It is therefore important that the Code of Procedure is implemented and quite strictly applied to the TC work. To further prioritize the work D2 management team has decided to identify a small number of TCs (typically between 3 and 5) that are of special relevance to the stakeholders. These "urgent" TCs get support by a dedicated Associate Division Director but are also closely monitored. The first 2 years that urgent TCs have been recognised have shown that this decision has had a positive impact on the progress of these urgent TCs.

7 Publications

7.1 Published

7.1.1 CIE Technical Reports

CIE 220:2016 Characterization and Calibration Methods of UV Radiometers

CIE 225:2017 Optical Measurement of High-Power LEDs

CIE 226:2017 High-Speed Testing Methods for LEDs

CIE 229:2018 Groundwork for Measurement of Effective Intensity of Flashing Lights

CIE 198-SP2:2018 Determination of Measurement Uncertainties in Photometry Supplement 2: Spectral measurements and derivative quantities

CIE 018:2019 The Basis of Physical Photometry, 3rd Edition

CIE 231:2019 CIE Classification System of Illuminance and Luminance Meters

CIE 233:2019 Calibration, Characterization and Use of Array Spectroradiometers

7.1.2 CIE Standards

CIE S 017-SP1:2015 ILV: International Lighting Vocabulary –Supplement 1: Light Emitting Diodes (LEDs) and LED Assemblies – Terms and Definitions

CIE S 025/E:2015 Test Method for LED Lamps, LED Luminaires and LED Modules

7.1.3 Joint ISO/IEC/CIE Standards

7.1.4 CIE Draft Standards

DIS 025-SP1/E:2019 Test Method for OLED Luminaires and OLED Light Sources

7.1.5 CIE Technical Notes

CIE TN 005:2016 Specifying Product Performance for Mesopic Applications

CIE TN 004:2016 The Use of Terms and Units in Photometry – Implementation of the CIE System for Mesopic Photometry

7.1.6 Reports by Reporterships

All reports and presentations from reporterships are CIE D2 internal documents and are published in the D2 CollTool room only (see also section 9 on reporterships for more details)

7.2 Expected

TC 2-29 Measurement of Detector Linearity

TC 2-50 Measurement of the Optical Properties of LED Assemblies

TC 2-59 Characterisation of Imaging Luminance Measurement Devices

TC 2-67 Photometry of Lighting and Light-Signalling Devices for Road Vehicles

TC 2-74 Goniospectroradiometry of optical radiation sources

TC 2-75 Photometry of curved and flexible OLED and LED sources

TC 2-76 Characterization of AC-driven LED products for SSL applications

TC 2-82 Revision of CIE S 014-2

TC 2-83 CIE Standard on test methods for OLED light sources

TC 2-88 Standard Reference Solar Spectra for Industrial Applications

DR 2-75 TN on the use of “Accuracy” and related terms in the specifications of testing and measurement equipment

7.3 Review

7.3.1 Reviewed Publications

The status of all publications were reviewed in 2012. Since then the review of status is done according to the Code of Procedure (i.e. every 5 years for technical reports and 3 years for standards)

7.3.2 Status of Publications

Current:

- CIE 235:2019 Optical Measurement of LED Modules and Light Engines
- CIE TN 009:2019 The Use of “Accuracy” and Related Terms in the Specifications of Testing and Measurement Equipment
- CIE 233:2019 Calibration, Characterization and Use of Array Spectroradiometers
- CIE 231:2019 CIE Classification System of Illuminance and Luminance Meters
- CIE 018:2019 The Basis of Physical Photometry, 3rd Edition
- DIS 025-SP1/E:2019 Test Method for OLED Luminaires and OLED Light Sources
- CIE 198-SP2:2018 Determination of Measurement Uncertainties in Photometry Supplement 2: Spectral measurements and derivative quantities
- CIE 229:2018 Groundwork for Measurement of Effective Intensity of Flashing Lights
- CIE 226:2017 High-Speed Testing Methods for LEDs
- CIE 225:2017 Optical Measurement of High-Power LEDs
- CIE TN 008:2017 Final Report CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems
- CIE 220:2016 Characterization and Calibration Methods of UV Radiometers
- CIE TN 005:2016 Specifying Product Performance for Mesopic Applications
- CIE TN 004:2016 The Use of Terms and Units in Photometry – Implementation of the CIE System for Mesopic Photometry
- CIE x041:2016 Proceedings of CIE Expert Symposium on the CIE S 025 LED Lamps, LED Luminaires and LED Modules Test Standard, November 2015, Braunschweig, Germany
- CIE S 025/E:2015 Test Method for LED Lamps, LED Luminaires and LED Modules
- CIE S 017-SP1:2015 ILV: International Lighting Vocabulary –Supplement 1: Light Emitting Diodes (LEDs) and LED Assemblies – Terms and Definitions
- CIE 214:2014 Effect of Instrumental Bandpass Function and Measurement Interval on Spectral Quantities
- CIE TN 002:2014 Relating Photochemical and Photobiological Quantities to Photometric Quantities
- CIE x040:2014 Proceedings of CIE Expert Symposium on Measurement Uncertainties in Photometry and Radiometry for Industry, September 2014, Vienna, Austria
- CIE TN 001:2014 Chromaticity Difference Specification for Light Sources
- CIE 210:2014 Photometry Using V(λ)-Corrected Detectors as Reference and Transfer Standards

- ISO/CIE 19476:2014(E) Characterization of the Performance of Illuminance Meters and Luminance Meters
- CIE 202:2011 Spectral Responsivity Measurement of Detectors, Radiometers and Photometers
- CIE 198-SP1.(1-4):2011 Determination of Measurement Uncertainties in Photometry - Supplement 1: Modules and Examples for the Determination of Measurement Uncertainties (4 Parts)
- CIE 198:2011 Determination of Measurement Uncertainties in Photometry
- CIE x036:2010 Proceedings of the CIE Expert Symposium on Spectral and Imaging Methods for Photometry and Radiometry, 30-31 August 2010, Bern, Switzerland
- CIE x033:2008 Proceedings of the 2nd CIE Expert Symposium on "Advances in Photometry abd Colorimetry", 7-8 July 2008, Turin, Italy
- CIE 182:2007 Calibration methods and photoluminescent standards for total radiance factor measurements
- CIE 179:2007 Methods for characterising tristimulus colorimeters for measuring the colour of light
- CIE 127:2007 Measurement of LEDs
- ISO 11664-2:2007(E)/CIE S 014-2/E:2006 Colorimetry — Part 2: CIE Standard Illuminants for Colorimetry
- CIE 176:2006 Geometric tolerances for colour measurements
- CIE x029:2006 Proceedings of the 2nd CIE Expert Symposium on Uncertainty, 12-13 June 2006, Braunschweig, Germany
- CIE x028:2005 Proceedings of the CIE Symposium 2005 "Vision and Lighting in Mesopic Conditions", 21 May 2005, Leon, Spain
- ISO 23539:2005(E)/CIE S 010/E:2004 Photometry - The CIE system of physical photometry
- CIE 153:2003 Report on intercomparison of measurement of the luminous flux of highg-pressure sodium lamps
- CIE x025:2003 Proceedings of the CIE Symposium 2002 on "Temporal & Spatial Aspects of Light and Colour Perception and Measurement", 22-23 August 2002, Veszprém, Hungary
- CIE 149:2002 The use of tungsten filament lamps as secondary standard sources
- CIE x022:2001 Proceedings of the 2nd CIE Expert Symposium on LED Measurement "Standard methods for specifying and measuring LED and LED cluster characteristics"
- CIE 054.2-2001 Retroreflection: Definition & Measurement
- CIE x018-1999 Proceedings of the CIE Symposium '99 "75 years of CIE photometry", 30 September - 2 October 1999, Budapest, Hungary
- CIE 130-1998 Practical Methods for the Measurement of Reflectance and Transmittance
- CIE 122-1996 The Relationship between digital and colorimetric data for computer-controlled CRT displays
- CIE 121-1996 The Photometry & Goniophotometry of Luminaires
- CIE x009-1995 Proceedings of the CIE Expert Symposium '95 on "Advances in Photometry", 1-3 December 1994, Vienna, Austria
- CIE 114-1994 CIE Collection in photometry and radiometry
- CIE 105-1993 Spectroradiometry of pulsed optical radiation sources

- CIE 089-1991 CIE Technical Collection 1990
- CIE 076-1988 Intercomparison on measurement of (total) spectral radiance factor of luminescent specimens
- CIE 059-1984 Polarization: Definitions and nomenclature, instrument polarization
- CIE 046-1979 A review of publications on properties and reflection values of material reflection standards
- CIE 044-1979 Absolute methods for reflection measurements
- CIE 043-1979 Photometry of floodlights
- CIE 038-1977 Radiometric and photometric characteristics of materials and their measurement..... .....

Under Review:

- CIE 085-1989 Solar spectral irradiance
- CIE 070-1987 The measurement of absolute luminous intensity distributions
- CIE 063-1984 The spectroradiometric measurement of light sources
- CIE 084-1989 Measurement of luminous flux
- ISO 11664-2:2007(E)/CIE S 014-2/E:2006 Colorimetry — Part 2: CIE Standard Illuminants for Colorimetry
- CIE 065-1985 Electrically Calibrated Thermal Detectors of Optical Radiation (Absolute Radiometers)
- CIE 121-SP1:2009 The photometry and goniophotometry of luminaires - Supplement 1: Luminaires for emergency lighting

Archive:

- CIE 053-1982 Methods of characterizing the performance of radiometers and photometers
- CIE 065-1985 Electrically Calibrated Thermal Detectors of Optical Radiation (Absolute Radiometers)

8 Technical Committees (TCs)

8.1 Closed TCs

TC 2-47 Characterization and Calibration Methods of UV Radiometers (chair: Armin Sperling, DE)

reason for closure: report published as CIE 220:2016

TC 2-49 Photometry of Flashing Light (chair: Yoshi Ohno, US)

reason for closure: report published as CIE 229:2018

TC 2-51 Calibration of Multi-Channel Spectrometers (chair: Richard Young, UK)

reason for closure: report published as CIE 233:2019

TC 2-60 Effect of Instrumental Bandpass Function and Measurement Interval on Spectral Quantities (chair: Jim Gardner, AU)

reason for closure: report published as CIE 214:2014

TC 2-63 Optical Measurement of High Power LEDs (chair: Yuqin Zong, US)

reason for closure: report published as CIE 225:2017

TC 2-64 High speed Testing Methods for (chair: Günther Heidel, US)

reason for closure: report published as CIE 226:2017

TC 2-65 Photometric Measurements in the Mesopic (chair: Teresa Goodman, UK)

reason for closure: publication of CIE TN 004:2016 and CIE TN 005

TC 2-66 Terminology of LEDs and LED (chair: Janos Schanda, HU)

reason for closure: publication of CIE S 017-SP1:2015

TC 2-71 CIE Standard on Test Methods for LED Lamps, Luminaires and (chair: Yoshi Ohno, US)

reason for closure: publication of CIE S 025/E:2015

TC 2-72 The Evaluation of Uncertainties in Measurement of the Optical Properties of Solid State Lighting Devices, including Coloured LEDs (chair: Jim Gardner, AU)

reason for closure: publication of CIE 198-SP2:2018

TC 2-73 Measurement of Quantities Relating to Photobiological Safety of Lighting Products (chair: Tongsheng Mou, CN)

reason for closure: There was a lot of duplication between TC 2-73 and other TCs such as TC 2-72 which worked on uncertainty relating to blue-light hazard including geometric aspects. TC 2-73 was therefore no longer required until the IEC 62471 revision is completed. The TC was converted at the D2 meeting 2016 into a reportership to monitor the status of IEC 62471 revision (DR 2-77).

JTC 02 (CIE-CCPR) Principles Governing Photometry (chair: Yoshi Ohno, US)

Reason for closure: publication of CIE 018:2019

8.2 New and Closed TCs

8.3 TCs in Progress

TC 2-29 Measurement of Detector Linearity (chair: George Eppeldauer, US), started in 1988

TC 2-50 Measurement of the Optical Properties of LED Assemblies (chair: Richard Distl, DE), started in 1999

TC 2-59 Characterisation of Imaging Luminance Measurement Devices (chair: Udo Krueger, DE), started in 2004

TC 2-62 Imaging-Photometer-Based Near-Field Goniophotometry (chair: Udo Krueger, DE), started in 2007

TC 2-67 Photometry of Lighting and Light-signalling Devices for Road Vehicles (chair: Thomas Reiners, DE), started in 2010

TC 2-68 Optical Measurement Methods for OLEDs used for Lighting (chair: Yasuki Yamauchi, JP), started in 2010

TC 2-74 Goniospectroradiometry of Optical Radiation Sources (chair: Jiangen Pan, CN), started in 2011

TC 2-75 Photometry of Curved and Flexible OLED and LED Sources (chair: Hsueh-Ling Yu, TW), started in 2011

TC 2-76 Characterization of AC-Driven LED Products for SSL Applications (chair: Pei-Ting Chou, TW), started in 2011

TC 2-77 Fundamental Concepts (chair: Tony Bergen, AU), started in 2013

TC 2-78 The Goniophotometry of Lamps and Luminaires (chair: Tony Bergen, AU), started in 2013

TC 2-79 Integrating sphere photometry and spectroradiometry (chair: Dong-Hoon Lee, KR), started in 2013

TC 2-80 Spectroradiometric measurement of light sources (chair: Tobias Schneider, DE), started in 2013

8.4 New TCs

TC 2-81 Update of CIE 065-1985 Absolute Radiometers (chair: Marek Smid, CZ), started in 2015

ToR: To update the existing CIE 065-1985 on the operating principle of absolute detectors of optical radiation.

TC 2-82 Revision of CIE S014-2 (chair: Peter Csuti, HU), started in 2015

ToR: To revise CIE Standard S014-2 (CIE Standard Illuminants) to include Illuminant D50

TC 2-83 CIE Standard on test methods for OLED light sources (chair: Guy Vandermeersch, BE), started in 2016

ToR: To amend CIE S 025:2015 with the requirements for measurement of electrical, photometric, and colorimetric quantities of OLED light sources

TC 2-84 Recommendations on LED package test data reporting (chair: Andras Poppe, HU), started in 2016

ToR: To recommend the minimal set of consistent test data regarding light output characteristics (such as total luminous flux, total radiant flux, spectral power distribution, etc), electrical characteristics (such as diode I-V characteristics) and thermal properties (like thermal resistance, dissipated power, junction temperature, junction temperature dependence of light output properties and electrical properties) to be included in LED package test data sheets. As the amount of a minimal set of test data representative even to a single LED package is large, an electronic format seems to be feasible. Recommendations on a vendor independent format of such an electronic data sheet is also within the scope of the TC.

TC 2-85 Recommendation on the geometrical parameters for the measurement of the Bidirectional Reflectance Distribution Function (BRDF) (chair: Gael Obein, FR), started in 2016

ToR: To provide geometrical recommendations for the BRDF measurement according to the type of sample under investigation, in order to allow better comparison between the different instruments, to improve the traceability of the measurements, and to help the user to choose the right angular configuration.

TC 2-86 Glare Measurement by Imaging Luminance Measurement Device (ILMD) (chair: Cheng-Hsien Chen, TW), started in 2016

ToR: Glare measurement principles by imaging luminance measurement devices (ILMD) will be studied. Glare metrics are calculated from luminance distribution of the visual environment applying the particular model of vision and calculation methods described in relevant publications. To summarize the characteristics of ILMD and best practice for measuring luminance distributions that allow users to calculate glare metrics.

TC 2-87 Broadband UV LED radiometric measurements between 320 nm and 420nm (chair: George Eppeldauer, US), started in 2016

ToR: Standard LED sources with different peak wavelengths (colours) and a standard broadband LED measurement procedure will be worked out to perform uniform, fast, and low-uncertainty radiometric LED measurements. In contrast to existing spectral detector-response based standards (where LEDs are measured with large errors), the procedure is based on a standardized LED and the spectral product (signal) of the standardized LED distribution and the spectral responsivity of the standardized LED measuring reference radiometer. The standardized LED integrated radiance or the integrated irradiance from it and also the integrated responsivity of the reference radiometer can be determined. The reference scale will be propagated with the reference radiometer to field radiometers to perform one-step LED (broadband radiance or irradiance)

measurements. The measurements can be applied for all kinds of LEDs and/or groups of different LEDs.

TC 2-88 Standard Reference Solar Spectra for Industrial Applications (chair: Shigeo Suga, JP), started in 2017

ToR: To update the CIE 085-1989 "Solar Spectral Irradiance" that includes increased sampling intervals based on explicit meteorological input parameters for the SMARTS 2.9.5 model that produces the tabulated data for electronic data processing.

TC 2-89 Measurement of Temporal Light Modulation of Light Sources and Lighting Systems (chair: Menno Schakel, NL), started in 2017

ToR: To provide guidance on the measurement of temporal light modulation of light sources and lighting systems. The TC shall first develop a technical note on a measurement protocol that will include recommended measurement conditions and methods to measure waveforms of light (time intervals, duration, bandwidth, photometer requirements, etc.) and frequency-domain power spectra (FFT and other methods) that enabling all researchers to report the results with sufficient information of the light investigated in a consistent way. In addition a standard test method shall be developed for flicker and stroboscopic effect using any existing or new metrics to be developed (i.e. proposed by TC 1-83). Conventional metrics such as modulation depth can also be determined from the measurement data. The TC should analyse the reproducibility and uncertainties related to all metrics.

TC 2-90 LED Reference Spectrum for Photometer Calibration (chair: Tuomas Poikonen, FI), started in 2018

ToR: To define an LED Reference spectrum for photometer calibration and detail its implementation. The purpose of this TC is to investigate and publish an LED Reference spectrum to complement the Standard Illuminant A. The TC will investigate and decide the spectral shape, wavelength range and the format to be used for publishing the reference spectrum. In addition a metric for the quality of the match of spectral distribution of real sources to the reference spectrum will be defined for the purpose of photometric calibrations.

TC 2-91 Optical Measurement Methods of LED Packages and LED Arrays (chair: Markus Schneider, DE), started in 2018

ToR: The purpose of this TC is to define an international standard for the optical measurements of semiconductor light sources (in particular LED packages and LED arrays as defined in CIE S 017-S01) to the extent to which they emit incoherent optical radiation. Semiconductor light sources in terms of this standard are individual inorganic light emitting diodes or combinations of multiple objects of the same type in different two- or three-dimensional structures, which are distinguished and identified herein as LED packages and LED arrays. This document will not deal with e.g. LED lamps and luminaires as they are already covered by CIE S 025 or other applications of higher integration levels. The standard shall describe in particular the geometrical arrangements, the electrical, thermal and temporal operating conditions and the measurement of the values of photometric, colorimetric and spectroradiometric quantities. Moreover, measurement quantities and associated measurement procedures are defined for describing the specific properties of LEDs and to take into account the restricted measurement options available during their manufacture or binning procedure. The document does not cover semiconductor emitters for coherent optical radiation (lasers), nor limit values for evaluating radiation safety. The document does not cover measurements of bare LED dice (chip or wafer probing).

TC 2-92 International Standard Format for the Electronic Transfer of Luminaire Optical Data (chair: Ian Ashdown, CA), started in 2018

ToR: To provide an internationally agreed-upon data exchange format supporting most lighting applications, including colour-changing and horticultural luminaires. The new data exchange format will be defined in terms of the W3C Extensible Markup Language XML Schema 1.0 Fifth Edition (https://www.w3.org/TR/REC-xml/), and be compatible with the ANSI/IES TM33 and UNI 1603054.

JTC 12 (D2/D1/D8): The measurement of sparkle and graininess (Chair: Alejandro Ferrero ES)

ToR: To provide a methodology to measure sparkle and graininess, and to develop a measurement scale. Measurands will be defined and the requirements for their measurements will be well normalized, in such a way that different instruments can provide the same spectrophotometric data from the same specimen. A psychophysical method will be recommended to obtain visual data, and its correlation with the spectrophotometric data will be worked out to develop the measurement scale for sparkle and graininess.

JTC 17 (D1/D2/D8): Gloss measurement and gloss perception: A framework for the definition and standardization of visual cues to gloss (Chair: Frederic Leloup, BE)

ToR: To describe recommendations for standardized visual assessment conditions of individual, established cues to gloss, to make reommendations for the definition of a standard gloss observer for individual diagnostic cues and, based on the findings from the above, to suggest optical met hods and metrics for describing gloss in correlation with the established gloss cues.

8.5 Proposed TCs

As proposed at the D2 meeting 2019 in Washington:

TC 2-xx Measurement of haze, ToR in drafting stage

TC 2-xx Adaptive and modulated lighting, ToR in drafting stage…..

TC 2-xx Revision of S010 (ISO 23539:2005) Photometry – the CIE system of physical photometry

JTC xx Terms and definition for horticulture lighting

TC 2-xx Unified metrology system for light pollution

9 Reporterships (DRs)

9.1 Closed DRs

DR 2-52 Flicker measurement and flicker index study on solid state lighting (reporter: Kuei-Neng (Gilbert) Wu, TW), closed in 2016

Reason for closure: Internal report was presented at D2 meeting and published at D2 CollTool. A new TC was created (TC 2-89)

DR 2-55 Simple Practical Guide for Measurement Uncertainty Estimations (supplement to CIE 198), (reporter: David Chan, MY), closed in 2018

Reason for closure: There has been no progress observed and no progress report received for several years. There is also general disagreement in the meeting as to what was required for guidance: should it be a simple qualitative discussion regarding how to go about putting together an uncertainty budget or should it be providing quantitative spreadsheet examples

DR 2-56: Monitoring Progress in Regional Metrology Organizations (RMOs), (reporter Maria Lisa Rastello IT), closed in 2016

Reason for closure: D2 decided to close this reportership and open a liaison with EURAMET to report on matters of significance to CIE D2 (liaison L2-12)

DR 2-57: Monitoring Progress of IEC TR 62778, reporter: Hiroshi Shitomi (JP), closed in 2017

Reason for closure: D2 decided to close this reportership and open a liaison with IEC TC 34/WG6 (liaison L2-14)

DR 2-58: Standard lamps: availability of and alternatives to commercially available incandescent Sources (reporter: Steffen Goerlich, DE), closed in 2018

Reason for closure: Internal report was presented at D2 meeting and published at D2 CollTool. No further action.

DR 2-61: Review of Published D2 Publications (reporter: Peter Blattner CH), closed in 2018

This is automatically an ongoing task for DD and so the reportership is not required

DR 2-68: Measurement of light output degradation of LED light source (reporter: Pei-ting Chou, TW) closed in 2016

Reason for closure: Internal report was presented at D2 meeting and published at D2 CollTool. No further action.

DR 2-71: Towards a CIE standard illuminant/source L (reporter: Tuomas Poikonen, FI)

Reason for closure: Internal report was presented at D2 meeting and published at D2 CollTool. A new TC was created (TC 2-90)

DR 2-72: Towards a new CIE file format for luminous intensity distributions of luminaires (reporter: Peter Blattner, CH)

Reason for closure: A TC proposal is being prepared and a new TC was created (TC 2-92)

DR 2-73 Colour Luminance File Format Specification

Given that there is no longer the strong demand for the colour luminance file format this reportership can be closed.

DR 2-74: Physical characterisation of new visual effects in the field of appearance of materials (reporter: Alejandro Ferrero), closed in 2017

Reason for closure: Internal report was presented at D2 meeting and published at D2 CollTool. A new TC was created (JTC 12)

9.2 New and Closed DRs

DR 2-78 Investigation of the need for documentary guidance relating to 0°:d (d:0°) reflectance instrument (reporter: Annette Koo, NZ), started in 2016, closed in 2017
ToR: To consult with D2 and other interested parties to determine the motivation for the original TC 2-70 (with regard to 0:d/d:0 reflectance) and to identify whether a standard or technical note can meet this need. If so, to propose a TC with a well-defined scope to address the issues identified.

Reason for closure: the reporter has conducted a survey and received a significant number of responses. The conclusion is that guidance is definitely needed, and a new TC proposal will follow soon.

9.3 DRs in Progress

DR 2-60 Report on the discussions on the definition of luminance/radiance (reporter: Teresa Goodman, UK)

DR 2-64 Review of Draft TC 2-28 in preparation of archiving it as a D2 internal report (reporter: Edwin Mofokeng, SA)

DR 2-69 TN on the validation of a near-field goniophotometer in support of CIE S 025 (reporter: Johannes Ledig, DE)

DR 2-70 Guide for the Field Photometric Measurements for the Verification of Lighting Systems (reporter: Roman Dubnicka, SK)

9.4 New DRs

DR 2-76 TN on measurement uncertainties for testing of LED Lamps, Luminaires and Modules (reporter: Udo Krüger, DE), started in 2015

ToR: To prepare a technical note on guidance for evaluation of the uncertainty of SSL product in support of CIE S 025

DR 2-77 Measurement of Quantities Relating to Photobiological Safety of Lighting Products (reporter: Tongsheng Mou, CN), started in 2015;

ToR: To monitor the progress of the revision of IEC TR 62471-4

DR 2-79 Measurement of total transmittance, diffuse transmittance, and transmittance haze (reporter: Hsueh-Ling Yu, TW), started in 2016

ToR: To lay the groundwork for a possible future TC to make a CIE recommendation on measurement methods for total transmittance, diffuse transmittance, and transmittance haze.

DR 2-80 Metrology of laser-based lighting (reporter: Anders Thorseth, DK), started in 2017

ToR: To report on developments of the technology and applications of laser-based lighting relating to measurement of photometric and spectroradiometric quantities. To identify areas where guidance could be needed relating to measurement of characteristics such as spectral power distribution, luminous area, divergence angle of collimated beams and photobiological safety

DR 2-81 Flash effective intensity calculation (reporter: Dennis Couzin, DE), started in 2018

ToR: Following the work of TC 2-49 and publication of CIE 229:2018:

1) Sketch how the original goals of TC 2-49 (to provide a CIE recommendation on the measurement of effective intensity of flashing lights used for signaling applications) can be completed.

2) Seek independent advice from D1 experts (outside of the TC 2-49 membership) regarding the validity of the available experimental results, which were all referenced in the TC 2-49 document.

3) Evaluate whether the available experimental results are sufficient to complete the goals outlined in point 1)

4) Recommend creation of a new TC if points 2) and 3) are answered positively.

DR 2-82 TN on clarification of the difference between adjustment, calibration and verification (reporter: Tony Bergen, AU), started in 2017

ToR: To write a technical note outlining the difference between adjustment, calibration, and verification of testing and measurement equipment, with a target audience of users who send the equipment to a calibration laboratory for calibration, adjustment, or verification.

DR 2-83 Characterization and measurement of horticulture lighting products (reporter: Qian (Cherry) Li, CN), started in 2019

DR 2-84 CIE D2 strategy on spectrophotometry (reporter: Joanne Zwinkels, CA), started in 2019

DR 2-85 Quality indices for light dosimeters including visual and non-visual effects (reporter: Florian Stuker, CH), started in 2019

DR 2-86 Definitions for bidirectional scattering surface reflectance distribution function (BSSRDF), (reporter: Alejandro Ferrero, ES), started in 2019

9.5 New DRs – Converted Informal Liaisons

9.6 Proposed DRs

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10 Liaisons

10.1 Official Liaisons

CIE Division 2 has liaisons to the following organizations

No	Organization	Liaison Officers to CIE	Liason Officers from CIE
L2-1	CCPR - Consultative Committee of Photometry and Radiometry	Yoshi Ohno to CIE	DD2 to CCPR
L2-3	ISO/TC 6 Paper, board & pulps	Joanne Zwinkels	Joanne Zwinkels
L2-4	IEC TC 34: Lamps and related equipment	Guy Vandermeersch	
L2-5	ISO on reflectance and transmittance issues	Danny Rich	Danny Rich
L2-6	OIML (Organization of International Legal Metrology), TC 11 and TC 14	Armin Sperling	
L2-7	IALA (International Association of Lighthouse Authorities)	Alwyn Williams	Alwyn Williams
L2-11	ISO/TC 12/WG 19	Armin Sperling	Armin Sperling
L2-12	Monitoring progress in EMPIR	Marek Smid	
L2-13	Technical Committee of Standardization (TCS) of the International SSL Alliance	He Yang	
L2-14	IEC TC 34 WG 6	Hiroshi Shitomi	

10.2 Informal Contacts

11 Future Activities

D2 will continue to explore possibilities for focused workshops and tutorials. As an example, a joint D6/D2 event will be organized in late 2020 in Eindhoven, dedicated to the measurement of photobiological effects. Furthermore additional tutorials on CIE S 025 are under consideration reaching out to new regions (i.e. South America, Asia, Africa). On the technical level, the field of appearance is getting more important. D2 has therefore established a reportership DR 2-84 which reviews the status of the CIE documents related to spectrophotometry and propose a strategy and that topic.

12 Other Achievements, Issues, etc.

One important achievement was the D2 contribution on the revision of the International System of Units. The revised SI is based on a set of seven defining constant, including the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, Kcd, which relates the photometric quantities to the radiometric quantities. Experts have contributed drafting the 9th edition of the SI-Brochure. In annex 2 guidance is given on the use of quantities and units for photobiological and photochemical quantities.

Division 3: Interior Environment and Lighting Design
Quadrennial Report 2015-2019

Jennifer A. Veitch, CA (DD)

2019-07-31

1 Terms of Reference

Division 3 of the CIE is concerned with factors which influence the satisfaction of the occupants of a building with their environment, including the effects of both daylighting and electric lighting.

Its objectives are to study and evaluate those factors to provide guidance on relevant design criteria, to study design techniques (including relevant calculations) for the interior lighting of buildings, to incorporate the findings and those of other CIE divisions into lighting guides for interiors in general or of particular types.

2 Division Officers

2015–2019:

Director:	Jennifer A. Veitch (CA)
Associate Director 1 (Daylighting):	John Mardaljevic (UK)
Associate Director 2 (Electric Lighting):	Nozomu Yoshizawa (JP)
Secretary:	Martine Knoop (DE)
Editor:	Peter Thorns (UK)

2019–2023:

Director:	Peter Thorns (UK
Associate Director 1 (Daylighting):	Martine Knoop (DE)
Associate Director 2 (Electric Lighting):	Nozomu Yoshizawa (JP)
Secretary:	Adrie de Vries (NL)
Editor:	TBD

3 Division Meetings

2016: WebEx, 26-Sep-2016
The meeting was held by WebEx with national representatives, liaison officers and TCCs only, following online discussion including the whole D3 roster.
There were 26 attendees from 19 countries including 16 national representatives.

2017: Jeju,Korea, 26-Oct-2017
The meeting was held in conjunction with the CIE Mid-term Conference.
There were 28 attendees from 15 countries including 6 national representatives.

2018: WebEx, 19-Jun-2018
The official D3 annual meeting was held by WebEx with national representatives, liaison officers and TCCs only. There were 18 attendances from 15 countries, including 13 national representatives.
There was a preparatory meeting by WebEx meeting, open to all Division Associates, to discuss the Division's work plan and research strategy on May 3, 2019. This meeting had 21 participants from 16 countries, 7 of whom also attended the official D3 meeting six weeks later.

2019: Washington, DC, 21-Jun-2019
The meeting was held in conjunction with the 29th Session of the CIE.
There were 35 attendees from 19 countries, including 13 national representatives.

4 Symposia and Workshops

The CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems was led by Division 3 and co-sponsored by Divisions 1, 2, and 6. 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. Twenty-seven invited participants representing industry, academia, standards development organizations, regulators, and national metrology laboratories attended this two-day event in Ottawa, Canada, February 8-9, 2017. Financial support was provided by Natural Resources Canada – Office of Energy Efficiency; National Electrical Manufacturers' Association; Philips Lighting; BC Hydro, the Independent Electricity System Operator Conservation Fund (Province of Ontario) and the National Research Council of Canada. The workshop was documented in CIE TN 008:2017.

The CIE Expert Tutorial and Workshop on Research Methods for Human Factors in Lighting was held in Copenhagen August 13-14, 2018. Nearly 100 people participated, representing over 30 countries, from graduate students at the start of their courses to senior researchers who attended for their own training. The organizing committee was chaired by Dr. Ásta Logadóttir. Aalborg University hosted, and VELUX sponsored the opening reception. The independent LumeNet PhD workshop followed, at which several of the attendees presented their research plans and received feedback from experts and from their peers.

The Expert Tutorial and Workshop on Research Methods for Human Factors in Lighting was linked to a special issue of *LEUKOS – The Journal of the IES* on Lighting Research Methods. Many of the articles in the special issue derived from presentations given in Copenhagen, and the editorial summarized the meeting. CIE in partnership with the Illuminating Engineering Society and publisher Taylor and Francis made all the articles in this special issue open access, as a contribution towards furthering the strength of the evidence base for recommendations and standards in light and lighting and towards the development of the next generation of lighting researchers.

5 Strategy 2015-2019

Division 3 began the quadrennium with a brainstorming discussion at the Manchester meeting, followed by an online survey sent to all Division Associates. Topics were rated both in terms of importance and difficulty. This resulted in the following list of priority topics for Division 3 work, either through new technical committees or reporterships:

Important but difficult

1. Recommendations for healthful lighting, taking into account all human needs from lighting installations.

2. Integrated glare metric, appropriate to predicting discomfort from both electric lighting and daylighting.

Important, neither easy nor difficult

3. Conditional lighting recommendations, meaning recommendations in which one metric depends on the value of another (e.g. illuminance recommendations that vary depending on light source colour rendering).

4. Retrofitting for improved daylighting

5. Post-occupancy evaluation and verification

6. Lighting and the Internet of Things

Somewhat important, neither easy nor difficult

7. Spectral sky models

8. Design guide for lighting controls in tertiary spaces, providing direction on installation, commissioning, and user interfaces

9. Lighting for display screens

This work informed both the ongoing discussions within Division 3, and the development of the CIE Research Strategy 2016. Division 3's work plan will benefit from further research addressing needs articulated in four of the 10 elements in the research strategy:

- Recommendations for Healthful Lighting and Non-Visual Effects of Light
- Integrated Glare Metric for Various Lighting Applications
- Adaptive, Intelligent and Dynamic Lighting
- Support for Tailored Lighting Recommendations

6 Administrative Matters and Communication

Since 2011, the Division Director has aimed to achieve faster delivery of useful documents with less administrative effort and new work to focus on a limited number of tasks with demonstrated value to the lighting community. Among the tactics used were electronic tools, efforts to engage TC Chairs, Reporters, and Liaison Representatives more regularly, a focus on decisions and discussions rather than routine reports in meetings, and active efforts to engage opinion leaders to guide the selection of new activities.

A tactic that was attempted in the 2011-2015 Quadrennium was to create a discussion group on LinkedIn. Over 90 people joined the group, but there were minimal discussions; furthermore, changes to the software platform made group participation more difficult for members. E-mails to the Division Associates requesting responses to specific topics were more successful.

The Division is open in its communications, posting all of its meeting materials on the Division Associates space on CollTool for all those connected to the Division to have access to read. The casting of ballots, of course, remains the responsibility of the official Division Members for each country.

The use of a template for TCs to report on their progress was mandated by D3 in 2013, with the intent of requiring a report every 6 months (as required in the Code of Procedure). Soliciting these reports remains a challenge.

7 Publications

7.1 Published

7.1.1 CIE Technical Reports

CIE 232:2019 Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Luminance [JTC 7]

CIE 227:2017 Lighting for Older People and People with Visual Impairment in Buildings [TC 3-44]

CIE 222:2017 Decision Scheme for Lighting Controls in Non-Residential Buildings [TC 3-49]

CIE 218:2016 Research Roadmap for Healthful Interior Lighting Applications [TC 3-46]

7.1.2 CIE Standards

CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light [JTC 9]

7.1.3 Joint ISO/IEC/CIE Standards

ISO/CIE TS 22012:2019(E) Light and Lighting — Maintenance Factor Determination — Way of Working

ISO/CIE 20086:2019(E) Light and Lighting — Energy Performance of Lighting in Buildings .

7.1.4 CIE Draft Standards

None.

7.1.5 CIE Technical Notes

CIE TN 008:2017 Final Report CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems

7.1.6 Reports by Reporterships

7.2 Expected

JTC 4 (D3/D6): Visual, Health, and Environmental Benefits of Windows in Buildings during Daylight Hours

3 Technical Notes, 1 Technical Report

JTC 6 (ISO/CIE): Revision of ISO10916 Calculation of the impact of daylight utilization on the net and final energy demand for lighting

JTC 14 (ISO/CIE): ISO/CIE 21783 Light and lighting — Integrative lighting — Non-visual effects

JTC 15 (ISO/CIE): Revision of ISO 8995-1 / CIE S 008 Joint ISO*CIE Standard: Lighting of Work Places - Part 1: Indoor

Joint ISO/CIE Standard

TC 3-54: Revision of CIE 16-1970: Daylight

Technical Report

TC 3-55: Metrics for sunlighting and daylight passing through sunshading devices Technical Report

TC 3-56: Assessment of Discomfort Glare from Daylight in Buildings Technical Report

7.3 Review

7.3.1 Reviewed Publications

Documents published since 2015 were not reviewed.

CIE 019.21-1981 An analytic model for describing the influence of lighting upon visual performance 2nd ed. Vol. 1

CIE 019.22-1981 An analytic model for describing the influence of lighting upon visual performance 2nd ed. Vol. 2

CIE 040-1978 Calculations for interior lighting : Basic method

CIE 052-1982 Calculations for interior lighting : Applied method

CIE 055-1983 Discomfort glare in the interior working environment

CIE 097/2:2005 Maintenance of indoor electric lighting systems

CIE 099-1992 Lighting education (1983-1989)

CIE 103/2-1993 Industrial lighting and safety at work

CIE 103/5-1993 The economics of interior lighting maintenance

CIE 108-1994 Guide to recommended practice of daylight measurement

CIE 110-1994 Spatial distribution of daylight – Luminance distributions of various reference skies

CIE 117-1995 Discomfort glare in interior lighting

CIE 147:2002 Glare from small, large and complex sources

CIE 157:2004 Control of damage to museum objects by optical radiation

CIE 161:2004 Lighting design methods for obstructed interiors

CIE 164:2005 Hollow light guide technology and applications

CIE 171:2006 Test cases to assess the accuracy of lighting computer programs

CIE 173:2012 Tubular daylight guidance systems

CIE 190:2010 Calculation and Presentation of Unified Glare Rating Tables for Indoor Lighting

CIE 196:2011 CIE Guide to Increasing Accessibility in Light and Lighting

CIE 205:2013 Review of lighting quality measures for interior lighting with LED lighting systems

CIE 209:2014 Rationalising nomenclature for UV doses and effects on humans

CIE 213:2014 Guide to protocols for describing lighting

CIE 215:2014 CIE standard general sky guide

ISO 8995-1:2002 / CIE S 008:2001 Lighting of indoor workplaces

7.3.2 Status of Publications

Current:

- CIE 016-1970: Daylight
- CIE 19.21-1981 An analytic model for describing the influence of lighting upon visual performance 2nd ed. Vol. 1
- CIE 19.22-1981 An analytic model for describing the influence of lighting upon visual performance 2nd ed. Vol. 2
- CIE 40-1978 Calculations for interior lighting : Basic method
- CIE 52-1982 Calculations for interior lighting : Applied method
- CIE 55-1983 Discomfort glare in the interior working environment
- CIE 110-1994 Spatial distribution of daylight – Luminance distributions of various reference skies
- CIE 117-1995 Discomfort glare in interior lighting
- CIE 147:2002 Glare from small, large and complex sources
- CIE 157:2004 Control of damage to museum objects by optical radiation
- CIE 161:2004 Lighting design methods for obstructed interiors

- CIE 164:2005 Hollow light guide technology and applications
- CIE 173:2012 Tubular daylight guidance systems
- CIE 190:2010 Calculation and Presentation of Unified Glare Rating Tables for Indoor Lighting
- CIE 196:2011 CIE Guide to Increasing Accessibility in Light and Lighting
- CIE 205:2013 Review of lighting quality measures for interior lighting with LED lighting systems
- CIE 209:2014 Rationalising nomenclature for UV doses and effects on humans
- CIE 213:2014 Guide to protocols for describing lighting
- CIE 215:2014 CIE standard general sky guide
- CIE 218:2016 Research Roadmap for Healthful Interior Lighting Applications
- CIE 227:2017 Lighting for Older People and People with Visual Impairment in Buildings
- CIE 222:2017 Decision Scheme for Lighting Controls in Non-Residential Buildings]
- CIE 232:2019 Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Luminance
- CIE S 011:2003 Spatial distribution of daylight – CIE standard general sky
- CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light
- ISO/CIE TS 22012:2019(E) Light and Lighting — Maintenance Factor Determination — Way of Working
- ISO/CIE 20086:2019(E) Light and Lighting — Energy Performance of Lighting in Buildings

Current, under revision:

- CIE 016-1970 Daylight (TC 3-54)
- CIE 099-1992 Lighting education (1983-1989) (proposed JTC 18)
- ISO 8995-1:2002 / CIE S 008:2001 Lighting of indoor workplaces (JTC 15)

Current requiring review and possible revision when resources permit:

- CIE 103/2-1993 Industrial lighting and safety at work
- CIE 103/5-1993 The economics of interior lighting maintenance
- CIE 171:2006 Test cases to assess the accuracy of lighting computer programs

Under Review:

- CIE 97/2:2005 Maintenance of indoor electric lighting systems
- CIE 108-1994 Guide to recommended practice of daylight measurement

Superseded:

Archive:

Withdrawn:

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8 Technical Committees (TCs)

8.1 Closed TCs

TC 3-44: Lighting for Older People and People with Visual Impairment in Buildings (Chair: Yukio Akashi, JP), started in 2007. Published CIE 227:2017, closed 2017.

TC 3-46: Research Roadmap for Healthful Interior Lighting Applications (Chair: Jennifer Veitch, CA), started in 2007. Published CIE 218:2016, closed 2016.

TC 3-48: CIE Standard Method of UF Table Calculation for Indoor Luminaires (Chair: Peter Thorns, GB), started 2008, closed 2017. No publication.

To produce a CIE standard methodology for the calculation of utilization factor (UF) tables for indoor luminaires.

TC 3-49: Decision Scheme for Lighting Controls for Tertiary Lighting in Buildings (Chair: Peter Dehoff , AT), started 2009. Published CIE 222:2017, closed 2017.

TC 3-45: Luminance Based Design Approach (Chair: Yoshiki Nakamura, JP), started in 2007. Closed 2015, no publication.
Terms of reference: To determine suitable design factors and criteria for luminance based design, and to produce suitable tools to allow luminance based design to be performed and validated. This will involve a detailed literature search in the area of luminance based design and an examination of the tools for a luminance based design that have been developed or are currently available. The validity of the tools will be undertaken and compared to standard data

TC 3-53: Revision of CIE S 008 Joint ISO*CIE Standard: Lighting of Work Places - Part 1: Indoor (Chair: Yasuko Koga. JP), started in 2012. Closed 2018 to form JTC 15 (ISO/CIE).

JTC 7 (D3/D1): Discomfort caused by glare from luminaires with a non-uniform source luminance (Chair: Naoya Hara, JP), started 2015. Published CIE 232:2019, Closed 2019.

8.2 New and Closed TCs

JTC 9 (D6/D2/D3) Quantifying ocular radiation input for nonvisual photoreceptor stimulation (co-chairs L. Schlangen, NL; A. Wojtysiak, DE; H. Noguchi (JP)). Closed following publication of CIE S026:2018.

JTC 11 (ISO-CIE) Maintenance Factor Determination — Way of Working (Chair: A. de Vries, NL). Published TS 22012:2019(E) Light and Lighting — Maintenance Factor Determination — Way of Working and closed 2019.

8.3 TCs in Progress

TC 3-54: Revision of CIE 16-1970: Daylight (Chair: Yannik Sutter, FR [as of May 2019]), started in 2012, but had changes of Chair in 2015 and 2019.

To revise and update publication CIE 16-1970: Daylight in the light of the advances in technology and design since 1970.

TC 3-55: Metrics for Sunlighting and Daylight Passing through Sunshading Devices (Chair: Marc Fontoynont, FR), started 2012.

To propose a metric to assess contribution of sunlight to the daylighting a building, and to rate lighting contribution of daylight and sunlight passing through sunshading systems. The proposal should avoid performing long term climate based calculations, and be of interest both for building designers and manufacturers of window components.

TC 3-56: Assessment of Discomfort Glare from Daylight in Buildings (Chair: Toshie Iwata, JP), started 2015.

To complete the work of the former TC 3-39, fulfilling its Terms of Reference: To review existing discomfort glare assessment methods with respect to their suitability to daylight glare. To identify strengths/weaknesses and threats/opportunities in these existing methods. To make a recommendation on a provisional method for daylight glare assessment. To identify additional parameters that might influence the perception and assessment of discomfort and glare from daylight. To develop proposals for possible research directions and projects suitable to advance the understanding of these parameters.

JTC 4 (D3/D6) Visual, Health, and Environmental Benefits of Windows in Buildings during Daylight Hours (Chairs: D3: J.Wienold, CH to 2019; D6: D. Sliney, US (2018-2019), started in 2012.

To review the scientific literature in all relevant fields and to produce a concise document that identifies the values of windows in buildings. Examples of such values could the provision of light for visibility, ventilation, means of egress; aesthetic benefits, access to a view, and light for physiological functioning, including circadian rhythm regulation. If possible, based on this literature, the committee will propose preliminary criteria for daylighting metrics (the metrics being already under development by TC 3-47) to support these functions.

JTC 6 (CIE-ISO): Energy Performance of Lighting in Buildings (ISO Convenor: Soheil Moghtader, DE), started 2015. JTC 6 Chair, TBD.

This is now a continuing TC to mirror ISO/TC 274/JWG 1. Its work plan will consist of the work items of ISO/TC 274/JWG 1. At time of writing,this is the revision of Revision of ISO10916 Calculation of the impact of daylight utilization on the net and final energy demand for lighting.

JTC 13 (D4/D3) Depreciation and Maintenance of Lighting Systems (Chair D. Gasparovsky, SK. D3- co-char: TBD)

To revise CIE 97:2005 and CIE 154:2003 in order to bring them up to date by incorporating recently used approaches for determination of lumen maintenance of LED lamps, dealing with lamp and ballast/driver survival factor and upgrading the luminaire maintenance factor according to current technologies and environmental factors. To deal additionally with distortion of luminous intensity distribution due to environmental influences. To extend the document by maintenance of LED luminaires regarding their cooling specific requirements.

8.4 New TCs

None.

8.5 Proposed TCs

The following JTC was in the process of being balloted during the CIE Session in Washington, DC:

JTC 18 (D3/D4): Lighting Education (Chair: Piotr Pracki (PL)

To revise and update CIE 99-1992 and to provide recommendations on curricula for higher education and continuing education. To propose recommendations for education of lighting professionals and recommend options to improve and support continuing lighting education throughout the professional working life.

9 Reporterships (DRs)

9.1 Closed DRs

DR 3-29 Variable Transmission Glazing (VTG): Current Trends and Future Prospects for Uptake by the Building Sector (J. Mardaljevic, UK), opened in 2011.

DR 3-31 Available Daylighting Metrics (J. Mardaljevic, UK), opened in 2014.

9.2 New and Closed DRs

DR 3-32 Final Report CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems (J. Veitch, CA), Opened in 2017 and closed in 2017 with publication of CIE TN 008:2017.

9.3 DRs in Progress

DR 3-33 Reportership on Guidelines for Post-Occupancy Evaluation of Lighting Installations (V. Garcia-Hansen, AU, with J. Wienold, CH)

DR 3-34 Documentation template for studies on nonimage-forming effects (J. Veitch, CA, with M. Knoop, DE)

9.4 New DRs

None.

9.5 New DRs – Converted Informal Liaisons

None.

9.6 Proposed DRs

None.

10 Liaisons

10.1 Official Liaisons

Dr. Hillevi Hemphälä, SE	ISO TC 159 / SC4 Ergonomics of Human-System Interactions
Dr. Hillevi Hemphälä, SE	ISO TC 159 / SC5 Ergonomics of the Physical Environment
Mr. Soheil Moghtader, DE	ISO TC 163 Thermal performance and energy use in the built environment
TBD	ISO/TC 205/WG7 Building environment design - Indoor visual environment
Mr. Tapio Kallasjoki, FI	CEN TC 169 / WG 2 Lighting of Work Places
Mr. Peter Thorns, GB	CEN TC 169 / WG 3 Emergency Lighting in Buildings
Dr. Raphael Kirsch, DE	CEN TC 169 / WG 9 Energy Performance of Buildings
Dr. Jan Wienold, CH	CEN TC 169 / WG 11 Daylight

10.2 Informal Contacts

Mr. Terry K. McGowan, US	International Dark-Sky Association IDA (informal)
Prof. Yoshiki Nakamura, JP	Illuminating Engineering Institute of Japan (informal)
Dr. Jennifer A. Veitch, CA	Indoor Environmental Quality Global Alliance (informal)

11 Future Activities

At the 2019 meeting, the incoming DD3 presented a list of possible priority areas and invited an open discussion. Among the high-priority topics under consideration are:

- revision of CIE 60-1984 “‘Vision and the visual display unit work”
- resilient lighting
- emergency lighting
- spectral sky measurement

12 Other Achievements, Issues, etc.

Division 4: Lighting and signalling for transport
Quadrennial Report 2015-2019

Ron Gibbons, US (DD till 2017), Dionyz Gasparovsky, SK (DD from 2017)

2020-05-25

1 Terms of Reference

Division 4: Lighting and Signalling for Transport, 2015 – 2017: To study lighting and visual signalling and information requirements of transport and traffic, such as road and vehicle lighting, delineation, signing and signalling for all types of public roads and all kinds of users and vehicles, and visual aids for modes other than road transport.

Division 5: Exterior and Other Lighting Applications, 2015 – 2017: To study procedures and prepare guides for the design of lighting for exterior work areas, security lighting, floodlighting, pedestrian and other urban areas without motorized traffic, areas for sports and recreation, and for mine lighting.

Division 4: Transportation and Exterior Applications, 2017 – 2019: To study and prepare guides for the design of exterior lighting and light signalling.

2 Division Officers

2015-2019:

Half-term 2015 – 2017, Division 4:

Director:	Ron Gibbons (US)
Associate Director 1 (TC 4-15...40):	Yandan Lin (CN)
Associate Director 2 (TC 4-45...51):	Dionyz Gasparovsky (SK)
Secretary:	Maurice Donners (NL)
Editor:	Nigel Parry (GB)

Half-term 2015 – 2017, Division 5:

Director:	Peter Schwarcz (HU)
Secretary:	Dionyz Gasparovsky (SK)
Editor:	Warren Julian (AU)

Half-term 2017 – 2019, Division 4:

Director:	Dionyz Gasparovsky (SK)
Associate Director 1 (Fundamentals):	Steve Fotios (GB)
Associate Director 2 (Road Lighting):	Raoul Lorphevre (BE)
Associate Director 3 (Exterior Light.):	Sermin Onaygil (TR)

2019–2023:

Director:	Dionyz Gasparovsky (SK)
Associate Director 1	Steve Fotios (GB)
Associate Director 2	Raoul Lorphèvre (BE)
Associate Director 3	Sermin Onaygil (TR)
Secretary:	Maurice Donners (NL)
Editor:	Nigel Parry (GB)

3 Division Meetings

2015: Manchester (GB), 2015-06-30 – 2015-07-04
(meeting held in conjunction with the CIE 2019 28th Quadrennial Session)

2016: Melbourne (AU), 2016-03-07 – 2016-03-08
(meeting held in conjunction with the CIE 2016 Lighting Quality and Energy Efficiency)

2017: Jeju (KR), 2017-10-26 – 2017-10-27
(meeting held in conjunction with the CIE 2017 Midterm Meeting)
36 attendances including 20 national representatives

2018: Berlin (DE), 2018-05-22 – 2018-05-23
(meeting held in conjunction with the CIE Workshop on a New Vision of Visibility for Roadway Lighting)
31 attendances including 11 national representatives

2019: Washington D.C. (US), 2019-06-20 – 2019-06-21
(meeting held in conjunction with the CIE 2019 29th Quadrennial Session)
43 attendances including 12 national representatives

4 Symposia and Workshops

2015: Adaptive Lighting and Visibility
Convener: Ronald B Gibbons (US)
Manchester (GB), 2015-06-30

2017: Road Surface Photometric Characteristics: Measurement Systems and Results
Convener: Giuseppe Rossi (IT)
Jeju (KR), 2017-10-25

2017: Temporal Light Artefacts in Automotive and General Lighting
Convener: Chan-Su Lee (KR), Tran Quoc Khanh (DE)
Jeju (KR), 2017-10-25

2018: CIE Workshop on a New Vision of Visibility for Roadway Lighting
Convener: Stephan Voelker (DE)
Berlin (DE), 2018-05-24 – 2018-05-25

2019: In Search of a New Approach to the Maintenance Factor
Convener: Dionyz Gasparovsky (SK)
Washigton, D.C. (US), 2019-06-18

5 Strategy 2015 – 2019

Commencing the new CIE Division 4 in 2017, Dionyz Gasparovsky as Division Director presented the Division's Strategy for the rest of quadrennial period 2017 – 2019 and beyond:

Consolidating the merger: After merger of Divisions 4 and 5 it is necessary to consolidate technical issues of the merger so that the new Division 4 can be put to life and start to work. This comprise also appointment of the new Division Management Team (DMT).

Focus on team work: Together for the common benefit. DMT will hold regular WebEx meetings (approximately once a month) to manage the work of the Division and to draw corporate decisions. Face-to-face division meetings are to be held at least once a year during events organized by CIE. Informal team building (TC 4-11) will be the part of annual meetings. „Sleeping" Division members will be encouraged to share their expertise and to get involved in the life of the Division.

Improving the efficiency: Efficiency is the essential aspect of good work. Management of the tasks will incorporate establishment and maintenance of a „To do List" and „Check List".

Reports of TC chairs will undergo review by the Division in order to verify fulfilment of the workplan and to provide necessary adjustments. Review of CIE publications in the scope of Division 4 will have a regular basis. There will be a „Welcome Pack“ provided for new Division members with all the essential information at a glance. Meeting minutes and reports of Division officers will be well structured to easily find the necessary information.

Strenghten the role of education: Education is a tool to assist in growing up the future generations. Intention is to introduce the education as one of the regular agenda item for each of the division meetings. Division members will be encouraged to report the status and news on education in their respective countries they represent, to share experience and to go home with new inspirations. As part of this strategic point, update of the publication CIE 99-1992 will be suggested.

Be more transparent: Work of the Division including all the Technical Committees will be provided at disposal for Division Members and TC members according to their access rights in the framework of the well-structured CollTool, comprising summary reports, progress reports, working drafts etc. Division website for the open public will be kept regularly updated.

Support the collaboration: The Division will play an active role in liaisonship with third parties like professional organizations and standardization bodies. Development of new technical reports or standards will be co-ordinated with the subjects of interest, following the research priorities of CIE. Interdivisional collaboration within JTCs will be especially supported.

6 Administrative Matters and Communication

Application problems of outdoor lighting have been formerly covered by two CIE Divisions 4 and 5. Dealing with similar problems, having overlap in many particular issues and having many double nominated representatives opened the question of merger to enhance the working effectiveness. The merger took place at the CIE Midterm Meeting in 2017 and the new CIE Division 4 has been established “to study and prepare guides for the design of exterior lighting and light signalling”, as defined in the terms of reference. The Division 4 now covers all outdoor lighting applications as like as road lighting, lighting for transportation, sports lighting, lighting of outdoor workplaces, architectural and urban lighting and masterplanning, environmental aspects of outdoor lighting etc., including fundamental problems as such as mesopic vision and maintenance factor. New Division Management Team has been commenced in 2017 with Dionyz Gasparovsky as Division Director, Steve Fotios, Raoul Lorphèvre and Sermin Onaygil as Associate Division Directors, Maurice Donners as Division Secretary and Nigel Parry as Division Editor.

7 Publications

7.1 Published

7.1.1 CIE Technical Reports

CIE 150:2017 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations, 2nd Edition

CIE 140:2019 Road Lighting Calculations, 2nd Edition

CIE 083:2019 Guide for the Lighting of Sports Events for Colour Television and Film Systems, 3rd Edition

7.1.2 CIE Standards

CIE S 017-SP1:2015 ILV: International Lighting Vocabulary –Supplement 1: Light Emitting Diodes (LEDs) and LED Assemblies – Terms and Definitions

7.1.3 Joint ISO/IEC/CIE Standards

ISO/CIE 8995-3:2018(E) Lighting of Work Places – Part 3: Lighting Requirements for Safety and Security of Outdoor Work Places

ISO/CIE TS 22012:2019(E) Light and Lighting — Maintenance Factor Determination — Way of Working

7.1.4 CIE Draft Standards

DIS 017/E:2016 ILV: International Lighting Vocabulary, 2nd Edition

7.1.5 CIE Technical Notes

CIE TN 004:2016 The Use of Terms and Units in Photometry – Implementation of the CIE System for Mesopic Photometry

CIE TN 005:2016 Specifying Product Performance for Mesopic Applications

CIE TN 007:2017 Interim Recommendation for Practical Application of the CIE System for Mesopic Photometry in Outdoor Lighting

7.2 Expected

TC 4-52 Lighting for Pedestrians: New Empirical Data
Technical Report

TC 4-56 A Guide to Urban Lighting Masterplanning
Technical Report

7.3 Review

7.3.1 Reviewed Publications

Publication reviewed in 2018:

- ISO 16508:1999(E)/CIE S 006.1/E-1998 Road traffic lights - Photometric Properties of 200 mm Roundel Signals

Publications reviewed in 2017:

- CIE 194:2011 On Site Measurement of the Photometric Properties of Road and Tunnel Lighting
- CIE 193:2010 Emergency Lighting in Road Tunnels
- CIE 189:2010 Calculation of tunnel lighting quality criteria
- CIE 188:2010 Performance assessment method for vehicle headlighting systems
- CIE 180:2007 Road transport lighting for developing countries
- CIE 136-2000 Guide to the lighting of urban areas
- CIE 115:2010 Lighting of roads for motor and pedestrian traffic, 2nd edition
- CIE 094-1993 Guide for floodlighting
- CIE 067-1986 Guide for the photometric specification and measurement of sports lighting installations

Publications reviewed in 2016:

- CIE 154:2003 The maintenance of outdoor lighting systems
- CIE 132-1999 Design methods for lighting of roads + Disk
- CIE 129-1998 Guide for lighting exterior work areas
- CIE 128-1998 Guide to the lighting for open-cast mines
- CIE 112-1994 Glare evaluation system for use within outdoor sport and area lighting
- CIE 034-1977 Road lighting lantern and installation data: photometrics, classification and performance

- CIE 033-1977 Depreciation of installations and their maintenance
- CIE 032-1977 Lighting in situations requiring special treatment
- CIE 031-1976 Glare and uniformity in road lighting installations

7.3.2 Status of Publications

Current:

- CIE 083:2019 Guide for the Lighting of Sports Events for Colour Television and Film Systems, 3rd Edition
- ISO/CIE 8995-3:2018(E) Lighting of Work Places – Part 3: Lighting Requirements for Safety and Security of Outdoor Work Places
- ISO/CIE TS 22012:2019(E) Light and Lighting — Maintenance Factor Determination — Way of Working
- CIE 140:2019 Road Lighting Calculations, 2nd Edition
- CIE 150:2017 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations, 2nd Edition
- CIE 206:2014 The Effect of Spectral Power Distribution on Lighting for Urban and Pedestrian Areas
- CIE 194:2011 On Site Measurement of the Photometric Properties of Road and Tunnel Lighting
- CIE S 021/E:2011 Vehicle Headlighting Systems Photometric Performance - Method of Assessment
- CIE 193:2010 Emergency Lighting in Road Tunnels
- CIE 115:2010 Lighting of roads for motor and pedestrian traffic, 2nd edition
- CIE 189:2010 Calculation of tunnel lighting quality criteria
- CIE 188:2010 Performance assessment method for vehicle headlighting systems
- CIE 183:2008 Definition of the cut-off of vehicle headlines
- CIE 180:2007 Road transport lighting for developing countries
- ISO 30061:2007(E)/CIE S 020/E:2007 Emergency Lighting
- CIE 169:2005 Practical design guidelines for the lighting of sport events for colour
- CIE S 015/E:2005 Lighting of outdoor work places
- CIE 088:2004 Guide for the lighting of road tunnels and underpasses, 2nd edition
- CIE 154:2003 The maintenance of outdoor lighting systems
- CIE x023:2002 Proceedings of two CIE Workshops on Photometric Measurements Systems for Road Lighting Installations, Liège, Belgium, 1994; Poitiers, France, 1996
- CIE 144:2001 Road surface and road marking reflection characteristics
- CIE 143-2001 International recommendations for colour vision requirements for transport
- CIE x020-2001 Proceedings of the CIE Symposium "Uncertainty evaluation - Methods for analysis of uncertainties in optical radiation measurement", 23-24 January 2001, Vienna, Austria
- CIE x019-2001 Proceedings of three CIE Workshop on Criteria for Road Lighting, Durban, South Africa, 1997; Bath, United Kingdom, 1998; Warsaw, Poland 1999
- CIE S 004/D:2001 Farben von Signallichtern
- CIE S 004/F:2001 Couleurs des signaux lumineux
- CIE S 004/E:2001 Colours of light signals
- CIE 136-2000 Guide to the lighting of urban areas

- CIE 132-1999 Design methods for lighting of roads + Disk
- ISO 16508:1999(E)/CIE S 006.1/E-1998 Road traffic lights - Photometric properties of 200 mm roundel signals
- ISO 16508:1999(F)/CIE S 006/F-1998 Feux de circulation - Caractéristiques photométriques des feux de signalisation avec un diamètre de 200 mm
- CIE 129-1998 Guide for lighting exterior work areas
- CIE 128-1998 Guide to the lighting for open-cast mines
- CIE 126-1997 Guidelines for minimizing sky glow
- CIE 112-1994 Glare evaluation system for use within outdoor sport and area lighting
- CIE x008-1994 Proceedings of a Symposium of CIE TC 4-21 "Urban sky glow, a worry for astronomy", 3 April 1993, Edinburgh, Scotland
- CIE 094-1993 Guide for floodlighting
- CIE 093-1992 Road lighting as an accident countermeasure
- CIE 072-1987 Guide to the properties and uses of retroreflectors at night
- CIE 067-1986 Guide for the photometric specification and measurement of sports lighting installations
- CIE 066-1984 Road surfaces and lighting (joint technical report CIE/PIARC)
- CIE 062-1984 Lighting for swimming pools
- CIE 061-1984 Tunnel entrance lighting: A survey of fundamentals for determining the luminance in the threshold zone
- CIE 058-1983 Lighting for sports halls
- CIE 057-1983 Lighting for football
- CIE 039.2-1983 Recommendations for surface colours for visual signalling, 2nd ed.
- CIE 001-1980 Guidelines for minimizing urban sky glow near astronomical observatories (Joint publication IAU/CIE)
- CIE 047-1979 Road lighting for wet conditions
- CIE 045-1979 Lighting for ice sports
- CIE 042-1978 Lighting for tennis
- CIE 034-1977 Road lighting lantern and installation data: photometrics, classification and performance
- CIE 033-1977 Depreciation of installations and their maintenance
- CIE 032-1977 Lighting in situations requiring special treatment
- CIE 031-1976 Glare and uniformity in road lighting installations

Superseded:

- CIE 150:2003 Guide on the limitation of the effects of obtrusive light from outdoor lighting installations
- CIE S 006-1998 Road traffic light - 200 mm roundel signals photometric properties
- CIE 115-1995 Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic
- CIE 107-1994 Review of the Official Recommendations of the CIE for the Colours of Signal Lights
- CIE 079-1988 A Guide for the Design of Road Traffic Lights
- CIE 068-1986 Guide to the Lighting of Exterior Working Areas
- CIE 030.2-1982 Calculation and Measurement of Luminance and Illuminance in Road Lighting

- CIE 048-1980 Light Signals for Road Traffic Control
- CIE 035-1978 Lighting of Traffic Signs
- CIE 012.2-1977 Recommendations for the Lighting of Roads for Motorized Traffic
- CIE 037-1976 Exterior Lighting in the Environment
- CIE 002.2-1975 Colours of Light Signals, 2nd Edition
- CIE 028-1975 The Lighting of Sports Events for Colour TV Broadcasting
- CIE 027-1973 Photometry of Luminaires for Street Lighting
- CIE 026-1973 International Recommendations for Tunnel Lighting
- CIE 023-1973 International Recommendations for Motorway Lighting
- CIE 092-1972 Guide to the Lighting of Urban Areas
- CIE 008-1960 Street Lighting and Accidents

Archive:
- CIE 137-2000 The Conspicuity of Traffic Signs in Complex Backgrounds
- CIE 113-1995 Maintained Night-Time Visibility of Retroreflective Road Signs
- CIE 111-1994 Variable Message Signs
- CIE 104-1993 Daytime Running Lights (DRL)
- CIE 100-1992 Fundamentals of the Visual Task of Night Driving
- CIE 073-1988 Visual Aspects of Road Markings (Joint Technical Report CIE/PIARC; French Translation: Aspects visuels des marquages routiers is available from PIARC)
- CIE 074-1988 Roadsigns

8 Technical Committees (TCs)

8.1 Closed TCs

TC 4-15 Road Lighting Calculations (chair: Sermin Onaygil, TR), closed in 2019 with publication of CIE Technical Report CIE 140:2019, 2nd Edition

TC 4-19 Road Visibility in Fog (chair: Michele Colomb, FR), closed in 2015 due to inactivity and the work transferred into TC 4-51

TC 4-21 Interference by Light with Astronomical Observations (chair: Marc Gillet, BE), closed in 2015 due to merger with TC 5-28

TC 4-32 Surface Colours for Traffic Signs (chairs: Pieter Walraven, NL, until 2007; David Burns, US, 2007–2008; Jürgen Ewald, NL, 2008–2015), closed in 2015 due to non-compliance with the Code of Procedure

TC 4-36 Visibility Design for Roadway Lighting (chair: vacant), closed in 2015 due to non-compliance with the Code of Procedure

TC 4-40 Requirements for Retroreflective Traffic Signs (chair: Paul Carlson, US), closed in 2015 due to non-compliance with the Code of Procedure

TC 4-45 Performance Assessment Method for Vehicle Headlamps (chair: Gert Langhammer, DE), closed in 2019 due to inactivity

TC 4-46 300 mm Roundel Signals (chair: Ron Gibbons, US), closed in 2015 due to non-compliance with the Code of Procedure

TC 4-49 Guide to the Properties and Uses of Retroreflectors at Night (chair: Gernot Sauter, DE), closed in 2015 due to non-compliance with the Code of Procedure

TC 5-18 Practical Design Guidelines for the Lighting Of Exterior Work Areas (chair: Kevin Austin, GB), closed in 2015 due to lacking capacity to conclude the report, and non-compliance with the Code of Procedure

TC 5-20 Guide for Sports Lighting (chair: Alan Smith, GB), closed in 2017 after being renumbered as TC 4-57 with the merger of Divisions 4 and 5

TC 5-21 A Guide to Urban Lighting Masterplanning (chair: Müjgan Serefhanoglu-Sözen, TR), closed in 2017 closed in 2017 after being renumbered as TC 4-56 with the merger of Divisions 4 and 5

TC 5-23 Guidelines for the Use of Different Illuminance Patterns in Outdoor Applications (chair: Patrick Rombauts, BE), closed in 2015 due to inactivity and non-compliance with the Code of Procedure

TC 5-24 Guide for Architectural and Decorative Lighting (chair: Andre Tammes), closed in 2015 due to inactivity and non-compliance with the Code of Procedure

TC 5-26 Guide for the Lighting of Sport Events for Colour Television and Film Systems (chair: Alan Smith, GB), closed in 2017 closed in 2017 after being renumbered as TC 4-55 with the merger of Divisions 4 and 5

TC 5-27 Artificial Light and its Impact on the Natural Environment (chair: Bob Parks, GS), closed in 2015 due to non-compliance with the Code of Procedure

TC 5-28 Guide on the Limitation of the Effects of Obtrusive Light (chair: Nigel E Pollard, GB), closed in 2017 with publication of CIE Technical Report CIE 150:2017, 2nd Edition

8.2 New and Closed TCs

TC 4-55 Guide for the Lighting of Sport Events for Colour Television and Film Systems (chair: Alan Smith, GB), closed in 2019 with publication of CIE Technical Report CIE 083:2019, 3nd Edition

JTC 11 Light and Lighting – Maintenance factor – Way of working (chair: Nigel Parry, GB) (CIE-ISO), closed in 2019 with publication of the standard ISO/CIE TS 22012:2019(E)

8.3 TCs in Progress

TC 4-11 High Level Matters (chair: Nigel Parry, GB), permanent TC

TC 4-33 Discomfort Glare in Road Lighting (chairs: Ron Gibbons, US, before 2015; Stephan Völker, DE, 2015-2019), started in 1994

TC 4-47 Application of LEDs in Transport Lighting and Signalling (chair: Steve E Jenkins, AU), started in 2007

TC 4-50 Road Surface Characterization for Lighting Applications (chairs: Haldun Demirdes, TR, until 2019; Stephan Völker, DE, since 2019), started in 2011

TC 4-51 Optimization of Road Lighting (chairs: Per Ole Wanvik, NO, 2011-2016; Pal J Larsen, NO, since 2016), started in 2011

TC 4-52 Lighting for Pedestrians: New Empirical Data (chair: Steve Fotios, GB), started in 2014

JTC 01 Implementation of CIE 191:2010 Mesopic Photometry in Outdoor Lighting (chair: Stuart Mucklejohn, GB), started in 2011 (D4/D1/D2)

JTC 08 Terminology in light and lighting (chair: Peter Zwick, DE), started in 2015 (D1/D2/D3/D4/D5/D6/D8)

8.4 New TCs

TC 4-53 Tunnel Lighting Evolution (chair: Raoul Lorphevre, BE), started in 2016

TC 4-54 Road Lighting for Ageing Drivers (chair: Maurice Donners, NL), started in 2016

TC 4-56 A Guide to Urban Lighting Masterplanning (chair: Müjgan Serefhanoglu-Sözen, TR), started in 2017 as continuation of TC 5-21 which started in 2001

TC 4-57 Guide for Sports Lighting (chair: Alan Smith, GB), started in 2017 as continuation of TC 5-20 which started in 2000

TC 4-58 Obtrusive Light from Colourful and Dynamic Lighting and its Limitation (chair: Steve Lau, CN), started in 2018

TC 4-59 Guide for Lighting Urban Elements (chair: Diana del Negro, PT), started in 2018

TC 4-60 Road Traffic Lights – Photometric Properties of Roundel Signals (chair: Ron Gibbons, US), started in 2019

JTC 13 Depreciation and Maintenance of Lighting Systems (chair: Dionyz Gasparovsky, SK), started in 2018 (D4/D3)

JTC 18 Lighting Education (chair: Piotr Pracki, PL), started in 2019 (D3/D4)

8.5 Proposed TCs

TC 4-61 Artificial Lighting and its Impact on the Natural Environment (chair: Annika K Jägerbrand, SE)

ToR: To provide guidance on ways to minimize the effects of artificial lighting on the natural environment, including impacts on flora and fauna. This would be accomplished by making recommendations on light levels, spectral distributions, and other specific considerations of a broad range of organisms as well as specific habitats.

TC 4-62 Adaptive Road Lighting (chair: Thomas Baenziger, CH)

ToR: To analyze needs, specify recommendations, develop methodology and promote application of adaptive road lighting based on various conditions and input data from field sensors and interconnected systems with respect and tailored to specific requirements of different user groups and user patterns.

9 Reporterships (DRs)

9.1 Closed DRs

DR 4-34 Retro reflective and other passive devices as Energy Savers (Bob Parks, US), closed in 2018 due to inactivity

DR 4-35 Crime and Road Lighting (Otto Letamendi, US), closed in 2015 due to inactivity

DR 4-36 CEN/TC 169, Lighting Applications (Axel Stockmar, DE), closed in 2017 due to duplicity with LO 4-1, L 4-1 later suspended and maintained at the CB level

DR 4-37 CEN/TC 226, Road Equipment (Pentti Hautala, FI), closed in 2017 and transferred into L 4-2, L 4-2 later suspended and maintained at the CB level

DR 4-38 IAU (International Astronomical Union) (Elizabeth Alvarez del Castillo, US), closed in 2017 and converted into L 4-3

DR 4-39 GTB (The International Automotive Lighting and Light Signalling Expert Group - Groupe de Travail "Bruxelles 1952") (Ad de Visser, NL), closed in 2017 and converted into L 4-5

DR 4-41 Lighting for Elderly (Axel Stockmar, DE and Cyril Chain, FR), closed in 2017 and transferred into TC 4-54

DR 4-42 LUCI (Lighting Urban Community International) (Cyril Chain, FR), closed in 2017 and converted into L 4-6

DR 4-43 PIARC (Jean-Claude Martin and Eric Dumont, FR), closed in 2017 and converted into L 4-4

DR 4-44 IALA (International Association of Marine) (Malcolm Nicholson, GB), closed in 2017 and converted into L 4-7

DR 4-45 Enabling technologies for energy savings (Pal J Larsen, NO), closed in 2015 due to inactivity

DR 4-46 GLA (Global Lighting Association) (Raoul Lorphèvre, BE), closed in 2015 due to losing contact with GLA and further maintaining at the CB level

DR 4-47 LED Billboards (Steve E Jenkins, AU), closed in 2018 when no volunteer was found to continue after retirement of the reporter

DR 4-48 Intrusive Light (vacant), closed in 2017 when no reporter was found for this topic

DR 5-12 Lighting and ECO Systems (Scott Davis, US), closed in 2018 due to inactivity

DR 5-16 Photometric Specification and Measurement of Sports Lighting Installations (Alan Smith, GB), closed in 2017 upon actual reporter's request due to discontinuity of the reportership after retirement of the previous reporter

DR 5-17 Environmental Impact Assessments (Martin Morgan Taylor, GB), closed in 2018 due to inactivity

DR 5-18 Comparison of Glare Assessment Methods (Stephan Voelker, DE), closed in 2017 upon reporter's request

DR 5-19 IAU (International Astronomical Union) (Elizabeth Alvarez del Castillo, US), closed in 2017 when merged with DR 4-38 with the merger of Divisions 4 and 5, later converted into L 4-3

DR 5-20 IDA (International Dark-sky Association) (Martin Morgan Taylor, GB), closed in 2017 due to inactivity and loss of contact with the reporter

DR 5-21 CEN/ISO (Axel Stockmar, DE), closed in 2017 when merged with DR 4-36 with the merger of Divisions 4 and 5

DR 5-22 IALD (International Association of Lighting Designers) (Andre Tammes, AU), closed in 2017 due to inactivity and loss of contact with the reporter

DR 5-23 LUCI (Lighting Urban Community International) (Cyril Chain, FR), closed in 2017 when merged with DR 4-42 with the merger of Divisions 4 and 5, later converted into L 4-6

9.2 New and Closed DRs

No items

9.3 DRs in Progress

DR 4-49 Flicker from Lighting on High Speed Road (Chao-Hua Wen, TW), started in 2015

DR 4-50 Document Status and Review (Dionyz Gasparovsky, SK), started in 2015

9.4 New DRs

DR 4-51 Visibility and Glare Study of LED Traffic Signs (Tsung-Xian Lee, TW), started in 2017

ToR: To investigate the visibility and visual comfort of LED traffic signs. To extend to a variety of research of LED traffic signal and sign devices, and be a reference for the future smart traffic systems. To provide an effective, safe and comfortable transport lighting environment.

DR 4-52 Visibility under Adverse Weather Conditions (Chan-Su Lee, KR), started in 2019

ToR: Terminology review on the visibility and weather conditions. Summary of research activities related to the visibility under adverse weather conditions in automotive lighting and on the road. Required research activities and standardization activities related to the visibility under adverse weather conditions for automotive lighting. Visual Performance. Effect of Lighting Parameters.

DR 4-53 Environmental Aspects of Obtrusive Light from Outdoor Lighting Installations (Constantinos Bouroussis, GR), started in 2019

ToR: To analyse CIE 001-1980, CIE 126-1997 and CIE 150:2017, to search for potential overlaps and to suggest harmonization of the three Technical Reports. To suggest re-structuring (combination and/or splitting) of the three Technical Reports each focusing on different aspects of obtrusive light: general considerations, astronomical observations, night-time environment (fauna and flora) and humans. To incorporate outcomes of the TC 4-58 into the structure of documentation. To consider extraction of the CIE Position Statement from CIE 001 as an updated and self-standing document. To gather practical experience with the implementation of CIE 150 and to analyze potential gaps in guidelines from practical point-of-view. To suggest new work items on metrology of obtrusive light. To initiate and prepare new Technical Committees to deal with problems of obtrusive light including finalization of the proposal for revival of the TC 5-27. To identify potential parts of the three Technical Reports suitable for standardization and to prepare new work item proposal for standardization.

9.5 New DRs – Converted Informal Liaisons

No items

9.6 Proposed DRs

DR 4-54 Lighting for Cycling – Establishing the State of Knowledge (Jim Uttley, GB)

ToR: Collate and categorise literature relating to: establishing the visual needs of cyclists (to see and to be seen), optimising road lighting for cyclists, optimising cycle-mounted lighting, considering the conflict between road lighting and cycle lighting

10 Liaisons

10.1 Official Liaisons

L 4-3 Richard Wainscoat, US – IAU (Internatioal Astronomical Union)

L 4-4 Jean-Claude Martin, FR – PIARC (World Road Association – Permanent International Association of Road Congresses)

L 4-5 Ad de Visser, NL – GTB (The International Automotive Lighting and Light Signalling Expert Group – Groupe de Travail "Bruxelles 1952")

L 4-6 Cyril Chain, FR – LUCI (Lighting Urban Community International)

L 4-7 Alwyn Williams, GB – IALA (International Association of Marine)

L 4-8 Sermin Onaygi, TRI – CEN/TC 169/WG12 Road Lighting

10.2 Informal Contacts

Ad de Visser (NL) – ISO/TC 022 “Road Vehicles”, sub-committees:

- SC 08 "Lighting and light-signalling"
- SC 22 "Motorcycles"
- SC 23 "Mopeds"
- SC 35 "Lighting and visibility"
- SC 38 "Motorcycles and mopeds"

11 Future Activities

2020 Calculation and Measurement of Obtrusive Light (workshop), Ostrava (CZ)

2021 Adaptive Road Lighting (workshop), Penang (MY)

2022 New Directions in Research and Development of Road Lighting (symposium)

2023 Lighting Up the Cities (workshop), Ljubljana (SI)

12 Other Achievements, Issues, etc.

Division Director D. Gasparovsky represented Division 4 in Street Lighting and Smart Controls Conference in Sydney 2019 with a presentation on Adaptive Road Lighting.

Division 4 contributed to the CIE Research section of the LED Professional Review journal by these articles:

- CIE supports tailored lighting recommendations (2017)
- Adaptive, dynamic and intelligent lighting (2018)
- Environmental Aspects of Obtrusive Light from Outdoor Lighting Installations (2019)

In framework of the Washington meeting in 2019, long-term significant contributors of the CIE Division 4 (or the past CIE Division 5) have been honoured by acknowledgement of their technical services:

- Nigel Pollard, GB, for his valuable contributions and chairing of TC 5-28
- Mujgan Serefhanoglu Sozen, TR, for her valuable contributions and chairing of TC 4-56

Division 6: Photobiology and Photochemistry
Quadrennial Report 2015-2019

John O'Hagan, GB (DD)

2019-09-04

1 Terms of Reference

To study and evaluate the effects of optical radiation on biological and photochemical systems (exclusive of vision).

2 Division Officers

2015–2019:

Director:	John O'Hagan (GB)
Associate Director 1:	Karl Schulmeister (AT)
Associate Director 2:	David Sliney (US)
Associate Director 3:	Shu Takeshita (JP)
Secretary:	Luke Price (GB)
Editor:	Eric Liggins (GB)

2019–2023:

Director:	Luc Schlangen (NL)
Associate Director 1:	David Sliney (US)
Associate Director 2:	Shu Takeshita (JP)
Secretary:	Luke Price (GB)
Editor:	Eric Liggins (GB)

3 Division Meetings

2016: WebEx, 2016-09-15
There were 10 participants including 4 national representatives and one NC proxy. This was the first D6 meeting held exclusively by WebEx and worked well. It was agreed to run meetings on alternate years by WebEx unless opportunities for in-person meetings arose at D6-relevant events.

2017: Jeju (KR), 2017-10-26
Held in conjunction with the Conference on "Smarter Lighting for Better Life" at the CIE Midterm Meeting 2017 in Jeju, Korea.
There were 19 participants including 3 national representatives and one NC proxy.

2018: WebEx, 2018-06-27
Held in conjunction with the Lighting Quality and Energy Efficiency Conference.
There were 16 participants including 7 national representatives

2019: Washington (US), 2019-06-20
Held in conjunction with the 29th CIE Session
There were 35 participants including 11 national representatives

4 Workshops and Tutorials

2017: Workshop: Temporal Light Artefacts in Automotive and General Lighting Conveners: Chan-Su Lee, KR; Tran Quoc Khanh, DE

Jeju (KR), 2017-10-25

2018: CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems (joint with D3 and others). By invitation only.

Ottawa (CA), 2018-02-08/09

Tutorial 2: Healthful Lighting-Harmful Effects of Optical Radiation

Presenter: John O'Hagan

Taipei (TW), 2018-04-24, preceding the CIE 2018 "Topical Conference on Smart Lighting"

Tutorial 3: Lighting for Health and Well-Being

Presenter: George Brainard

Taipei (TW). 2018-04-24, preceding the CIE 2018 "Topical Conference on Smart Lighting"

2019: Tutorial: CIE Tutorial on S 026 - use and application of the new metrology for ipRGC-influenced responses to light

Convener: Luc Schlangen

Eindhoven (NL), 2019-03-14/15

Workshop: Use and Application of the New CIE S 026:2018 Metrology for ipRGC-Influenced Responses to Light "Specifying Light for its Eye Mediated Non-Visual Effects in Humans"

Convenors: Luc Schlangen and Luke Price

Washington (US), 2019-06-18

Workshop: Horticultural Lighting

Convenor: John O'Hagan

Washington (US), 2019-06-18

5 Strategy 2015-2019 and beyond

The period 2015 to 2019 was used to try to complete outstanding work. However, following the publication of a high-profile paper on "Measuring and using light in the melanopsin age" (Trends in Neurosciences, January 2014, Vol. 37, No. 1, pp 1-9), with input from Division 6, a JTC was formed to produce a standard (S 026) to specify the metrics for experimental studies considering the non-vision aspects of eye exposure to light.

In terms of new work, there is growing interest in appropriate artificial light for horticulture and agriculture, especially with the options now available with LED lighting.

Looking to the future, the following topics have been identified:

1. What light and dark daily pattern (intensity, spectrum, timing, duration) best supports well-being (young/old)?

Ongoing activities: JTC 14 “Integrative Lighting” – ISO/TC 274/ JWG4; DR 6-46 “2nd circadian Manchester workshop”; ICNIRP: PG Short Wavelength Light and Circadian Rhythm.

   a. Knowledge of dose-response relationships
   b. Metrics and devices to quantify dose accurately
   c. Recommendations (particular contexts, light at night indoors,…)?

2. JTC 5 Review of IEC 62471/CIE S009 “Photobiological Safety of Lamps and Lamp Systems”

3. Next to circadian regulation, what physiological and psychological processes are influenced by ocular light exposure?

   a. Role of inadequate light exposure during childhood in development of myopia

4. Horticulture lighting: terms and definitions and action spectrum

5. Daylight definition, visual/colour focus: update with respect to non-visual, spectral radiance, etc

6. Medical uses of light to treat certain skin disorders and hyperbilirubinemia.

6 Administrative Matters and Communication

Most Technical Committees are now using Collaboration Tools. In addition, the Division Secretary maintains an email list of about 290 people who are interested in the work of the Division. At the 2015 Division Meeting, it was agreed to set up an area on Collaboration Tools for anyone who wishes to be kept informed of work relevant to the Division – Division 6 Associates. This is based on a scheme already operated by Division 3. Access is given on request. One of the main reasons for this area is that it can be used to maintain information that would otherwise be hidden to former Technical Committee members once the work of the Technical Committee is completed.

7 Publications

7.1 Published

7.1.1 CIE Technical Reports

CIE 221:2016 Infrared Cataract

CIE 219:2016 Maintaining Summer Levels of 25(OH)D during Winter by Minimal Exposure to Sunbeds: Requirements and Weighing the Advantages and Disadvantages

7.1.2 CIE Standards

CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light

7.1.3 Joint ISO/IEC/CIE Standards

ISO/CIE 17166:2019(E) Erythema reference action spectrum and standard erythema dose

ISO/CIE 28077:2016(E) Photocarcinogenesis action spectrum (non-melanoma skin cancers)

7.1.4 CIE Draft Standards

DIS 017/E:2016 ILV: International Lighting Vocabulary 2nd Edition

7.1.5 CIE Technical Notes

CIE TN 008:2017 Final Report CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems

7.1.6 Reports by Reporterships

None during the period

7.2 Expected

TC 6-52 CIE Guide for the Measurement of Upper Air Ultraviolet Germicidal Irradiation Luminaries using Low Pressure Germicidal [short wavelength] UV-C Lamps

Technical Report has been drafted, but a call for additional expertise from Division 2 has delayed the work.

TC 6-64 Optical Safety of Infrared Eye Trackers applied for Extended-Durations

Technical Report has been reviewed by the Division Editor

7.3 Review

7.3.1 Reviewed Publications

ISO/CIE 17166:2019(E) Erythema reference action spectrum and standard erythema dose

Reviewed by Division Director, Division experts and the CIE Technical Manager. Editorial comments were submitted to ISO. It was felt that there was no additional scientific data to justify amending the action spectrum.

7.3.2 Status of Publications

Current:

- ISO/CIE 17166:2019(E) Erythema reference action spectrum and standard erythema dose
- CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light
- CIE TN 008:2017 Final Report CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems
- CIE 221:2016 Infrared Cataract
- CIE 219:2016 Maintaining Summer Levels of 25(OH)D during Winter by Minimal Exposure to Sunbeds: Requirements and Weighing the Advantages and Disadvantages
- ISO/CIE 28077:2016(E) Photocarcinogenesis action spectrum (non-melanoma skin cancers)
- CIE TN 003:2015 Report on the First International Workshop on Circadian and Neurophysiological Photometry, 2013
- CIE 209:2014 Rationalizing Nomenclature for UV Doses and Effects on Humans
- CIE 207:2014 Sensitivity of Human Skin to Ultraviolet Radiation, Expressed as Minimal Erythema Dose (MED)
- CIE 203:2012 (incl. Erratum) A Computerized Approach to Transmission and Absorption Characteristics of the Human Eye
- CIE 201:2011 Recommendations on Minimum Levels of Solar UV Exposure

- CIE 187:2010 UV-C photocarcinogenesis risks from germicidal lamps
- CIE 186:2010 UV-A protection and sunscreens
- CIE 158:2009 (including Erratum 1) Ocular Lighting Effects on Human Physiology and Behaviour
- CIE 181:2007 Hand protection by disposable gloves against occupational UV exposure
- CIE x031:2006 Proceedings of the 2nd CIE Expert Symposium on Lighting and Health, 7-8 September 2006, Ottawa, Canada
- CIE 174:2006 Action spectrum for the production of previtamin D3 in human skin
- CIE 172:2006 UV protection and clothing
- IEC 62471:2006/CIE S 009:2002 Photobiological safety of lamps and lamp systems / Sécurité photobiologique des lampes et des appareils utilisant des lampes (bilingual edition)
- CIE x026:2005 CIE Symposium 2004 "LEDs Light Sources: Physical Measurement and Visual and Photobiological Assessment", 7-8 June 2004, Tokyo, Japan
- CIE x027:2004 CIE Symposium 2004 "Light and Health: non-visual effects", 30 September - 2 October 2004, Vienna, Austria
- CIE 155:2003 Ultraviolet Air Disinfection
- CIE 151:2003 Spectral weighting of solar ultraviolet radiation
- CIE S 013/E:2003 International Standard Global Solar UV Index
- CIE 148:2002 Action spectroscopy of skin with tunable lasers
- CIE S 009/D:2002 Photobiologische Sicherheit von Lampen und Lampensystemen
- CIE 139-2001 The Influence of Daylight and artificial light variations in humans. A bibliography
- CIE 138-2000 CIE Collection in photobiology and photochemistry 2000
- CIE 134-1999 CIE Collection in Photobiology & Photochemistry 1999
- ISO 17166:1999(F)/CIE S 007/F-1998 Spectre d'action érythémale de référence et dose érythémale normalisée
- CIE x016-1998 Measurements of Optical Radiation Hazards, Gaithersburg, Maryland, USA
- CIE S 007/D:1998 Erythemale Referenzwirkungsfunktion und standardisierte Erythemdosis
- CIE 125-1997 Standard Erythema Dose, a Review
- CIE 106-1993 CIE Collection in photobiology and photochemistry
- CIE 098-1992 Personal dosimetry of UV radiation
- CIE 090-1991 Sunscreen testing (UV.B)

Under Review:

- CIE 174:2006 Action Spectrum for the Production of Previtamin D3 in Human Skin
- IEC 62471:2006/CIE S 009/E&F:2002 Photobiological Safety of Lamps and Lamp Systems
- CIE S 009/D:2002 Photobiologische Sicherheit von Lampen und Lampensystemen

Superseded:

- None

Archive:

- None

Withdrawn:

– None

8 Technical Committees (TCs)

8.1 Closed TCs

TC 6-49 Infrared Cataract (chair: Tsutomu Okuno, JP), started in 1998.

Report published: CIE 221:2016 Infrared Cataract.

TC 6-66 Maintaining summer levels of 25OH vitamin D during winter by minimal exposure to artificial UV sources; requirements and weighing the (dis)advantages (chair: Ann Webb, GB), started in 2013.

Report Published: CIE 219:2016 Maintaining Summer Levels of 25(OH)D during Winter by Minimal Exposure to Sunbeds: Requirements and Weighing the Advantages and Disadvantages

JTC-9 CIE System for Metrology of Optical Radiation for Light Responses Influenced by Intrinsically-Photosensitive Retinal Ganglion Cells (Chair Luc Schlangen, Secretary Luke Price).

Standard published: CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light.

8.2 TCs in Progress

TC 6-52 Proper Measurement of Passive UV Air Disinfection Sources (chair: Richard Vincent, US), started in 2000.

TC 6-64 Optical Safety of Infrared Eye Trackers Applied for Extended-Durations (chair: David Sliney, US), started in 2008.

JTC 4 (D3/D6): Visual, Health, and Environmental Benefits of Windows in Buildings during Daylight (chair: Martine Knoop, NL), started in 2012.

It was agreed in 2019 to consider closure of this JTC and start a new TC within D3, with support from D6.

JTC 5 (CIE-IEC): Review of IEC 62471/CIE S009 (chair: John O'Hagan, GB), started in 2012.

JTC 8 (D1/D2/D3/D4/D5/D6/D8): Terminology in light and lighting (chair: Peter Zwick, DE), started in 2015.

JTC 14 (CIE-ISO) Integrative Lighting (JWG 4 in ISO/TC 274)

8.3 New TCs

None

8.4 Proposed TCs

JTC (D2/D6) Characterization of the performance of non-visual weighted irradiance and actigraphy logging devices (chair: Luke Price, GB).

Proposed ToR: to provide performance measurement requirements for wearable instruments designed to be used in the study of non-visual light exposures, activity, sleep and health. The report would follow similar principles to ISO/CIE 19476:2014 (CIE S 023/E:2013) "Characterization of the performance of illuminance meters and luminance meters" but include the five non-visual sensitivity curves from TN003:2015 Report on the First International Workshop on Circadian, and to include a method for characterization of the measurement of motion and timing used in the actigraphy from a collaboration with a suitable specialist non-commercial organization. The scope on light sensors will be restricted to acquisition of spectrally weighting irradiance.

TC Action spectrum for UV-induced DNA damage in humans

9 Reporterships (DRs)

9.1 Closed DRs

DR 6-37 Definition of UV Wavebands (Masako Sasaki, JP), closed in 2014.

Report available on Collaboration Tools (Division 6 Associates area): DR 6-37 Short-hand Notations of UV Selected Bands in Photobiology

DR 6-40 A Survey of Action Spectra in the Scientific Literature: 19XX – 200X (Alois Schmalwieser), Closed in 2014.

Reporter published in the open literature.

DR 6-41 The Issues of Vitamin D Kinetics (Irina Terenetskaya, UA), closed in 2014.

Report available on Collaboration Tools (Division 6 Associates area): DR 6-41 Mismatch between the in vivo and in vitro Vitamin D Synthesis Action Spectra: Cause-and-effect Relationship

DR 6-42 Report on the 1st International Workshop for Action Spectra of Non-Image Forming Photobiological Effects of Light, IWAS 2013 (Luke Price,GB), closed in 2015.

Report published: TN 003:2015 Report on the First International Workshop on Circadian and Neurophysiological Photometry, 2013.

9.2 DRs in Progress

DR 6-43 Illuminators for Treatment of Infant Hyperbilirubinemia (Michael Lynn & Graham Hart, GB)

DR 6-44 Optical Radiation Hazard Measurements in the Workspace (David Sliney & Robert Angelo, US), started in 2015

9.3 New DRs

DR 6-45 Publication and maintenance of the CIE S026 Toolbox (Luke Price)

This reportership had been set up for the production and maintenance of a Toolbox to facilitate calculations according to CIE S 026.

DR 6-46 2nd International Workshop on Circadian and Neurophysiological Photoreception (Luke Price)

Luke Price had been appointed to report on the second workshop from Manchester on circadian neurophysiological photoreception. The first workshop in 2013 had ultimately resulted in S 026, and it was hoped this time there would be a focus on putting together some agreed practical advice for healthy light exposure.

9.4 New DRs – Converted Informal Liaisons

None

9.5 Proposed DRs

None

10 Liaisons

10.1 Official Liaisons

L6-1 IEC/TC 76/WG 9 International Electrotechnical Commission: Optical radiation safety and laser equipment/Non coherent sources (Werner Horak)

L6-2 World Health Organization (John O'Hagan)

L6-3 ISO/TC 217/WG 7 International Organization for Standardization: Cosmetics/Sun protection test methods (Uli Osterwalder)

L6-4 ICNIRP International Commission on Non-Ionizing Radiation Protection (Karl Schulmeister)

L6-5 IEC/TC 76/WG 1 International Electrotechnical Commission: Optical radiation safety and laser equipment/Optical radiation safety (David Sliney)

L6-6 American Society for Photobiology (David Sliney)

L6-7 World Meteorological Organization (Ann R. Webb)

L6-8 CEN/TC 169/WG 8 Photobiology (John O'Hagan)

L6-9 CEN/TC 169/WG 13 Non-visual effects of light on human beings (Luke Price)

L6-10 IEC/TC 34 Lamps and related equipment (John O'Hagan)

10.2 Informal Contacts

John O'Hagan – ISO/TC 274

Contribute to the TC and/or the CIE/ISO liaison group on matters relating to Division 6.

11 Future Activities

The next meeting of Division 6 is planned to be by WebEx towards the middle of 2020.

The 2021 meeting of Division 6 will take place in conjunction with the CIE Mid-Term meeting in Malaysia, April 2021.

A workshop is planned to follow the publication of the revised S009/IEC 62471-1.

12 Other Achievements, Issues, etc.

None

Division 8: Image Technology
Quadrennial Report 2015-2019

Po-Chieh Hung, JP (DD)

2019-08-13

1 Terms of Reference

To study procedures and prepare guides and standards for the optical, visual and metrological aspects of the communication, processing and reproduction of images, using all types of analogue and digital imaging devices, storage media and imaging media.

2 Division Officers

2015–2019:

Director:	Po-Chieh Hung (JP/US)
Secretary:	Christine Fernandez-Maloigne (FR)
Editor:	Danny Rich (US)

2019–2023:

Director:	Po-Chieh Hung (US)
Secretary:	Christine Fernandez-Maloigne (FR)
Editor:	Danny Rich (US)

3 Division Meetings

2015: Darmstadt (DE), 2015-10-21
(Informal meeting held in conjunction with the 24th Color and Imaging Conference)
26 attendees

2016: San Diego (US), 2016-11-08
(Formal meeting held in conjunction with the 25th Color and Imaging Conference)
32 attendees including 8 national representatives

2017: Lillehammer (NO), 2017-09-13
(Formal meeting held in conjunction with the 26th Color and Imaging Conference)
34 attendees including 8 national representatives

2018: Vancouver (CA), 2018-11-12
(Formal meeting held in conjunction with the 27th Color and Imaging Conference)
27 attendees including 12 national representatives

2019: Washington D.C. (US) 2019-06-21
(Formal meeting held in conjunction with the CIE Quadrennial Session)
42 attendees including 14 national representatives

4 Symposia and Workshops

2019: Color imaging, perception, and reproduction: New directions in colour science and technology
Po-Chieh Hung (CIE), Youngshin Kwak (CIE), Manuel Spitschan (OSA), Francisco Imai (IS&T)
Washington D.C. (US), 2019-06-19

5 Strategy 2015-2019

Use of social media to increase opportunities for discussion

Easy entrance to the CIE activity using Reportership, rigid review for publication

6 Administrative Matters and Communication

None

7 Publications

7.1 Published

7.1.1 CIE Technical Reports

223:2017 Multispectral Image Formats

7.1.2 CIE Standards

None

7.1.3 Joint ISO/IEC/CIE Standards

None

7.1.4 CIE Draft Standards

None

7.1.5 CIE Technical Notes

None

7.1.6 Reports by Reporterships

DR 8-11 Colour image reproduction for 3D printing

DR 8-12 3D Multi-view Image/Video Colour Data Format Conversion and Quality Control

DR 8-13 Common colour appearance

7.2 Expected

None

7.3 Review

7.3.1 Reviewed Publications

None

7.3.2 Status of Publications

Current:
- None

Under Review:
- None

Superseded:
- None

Archive:
- None

Withdrawn:
- None

8 Technical Committees (TCs)

8.1 Closed TCs

TC 8-07 Multispectral Imaging (Masahiro Yamaguchi, JP), closed in 2017

With publication of CIE Technical Report 223

8.2 New and Closed TCs

TC 8-15 Archival Colour Imaging (chair: Melitte Buchman, US), started in 2015, closed in 2019

Due to inactivity. Closed without report

8.3 TCs in Progress

TC 8-12 Image and Video Compression Assessment (chair: Pascal Bourdon, FR), started in 2007

TC 8-13 Colour Gamuts for Output Media (chair: Kiran Deshpande, GB), started in 2013

TC 8-14 Specification of Spatio-Chromatic Complexity (chair: Noël Richard, FR), started in 2015

8.4 New TCs

JTC 10 A new colour appearance model for colour management systems: CIECAM16 (chair: Changjun Li, CN), started in 2017

ToR: To recommend a new colour appearance model, CIECAM16, to replace the CIECAM02 model for colour management systems.

TC 8-16 Consistency of colour appearance within a single reproduction medium (chair: Craig Revie, UK), started in 2017

ToR: To study and report on sets of reproductions of the same source image that have a consistent colour appearance and are most similar to a reference reproduction, including recommending assessment methods that measure the similarity of reproductions of an image with different colour gamuts, for printed images on substrates with approximately similar characteristics in a fixed viewing environment. Only the effect of colour reproduction on appearance will be considered by this TC and so the assessment will be performed using hard copy or soft copy proofing. To propose a metric which can measure consistency of colour appearance.

TC 8-17 Methods for Evaluating Colour Difference between 3D Colour Objects (chair: Kaida Xiao, GB), started in 2017

ToR: To study the subjective assessment methods and recommend a dataset for colour difference evaluation of pairs of 3D colour objects. To prepare a report on the investigations of the effects on the perception of colour difference that may be caused by differences of 3D shape, gloss and material.

8.5 Proposed TCs

None

9 Reporterships (DRs)

9.1 Closed DRs

DR 8-12 3D Multi-view Image/Video Colour Data Format Conversion and Quality Control (Hezerul, Abdul Karim, MY), 2015

Report published.

DR 8-11 Colour image reproduction for 3D printing (Kaida Xiao, UK), closed in 2016

Transferred into new TC 8-17.

DR 8-13 Common colour appearance (Craig Revie, UK), closed in 2017

Transferred into new TC 8-16.

9.2 New and Closed DRs

None

9.3 DRs in Progress

DR 8-14 Office Lighting for Imaging (Yasuki Yamauchi, JP), started in 2015

DR 8-15 A survey on Quality Metrics on Stereoscopic Imaging (Christine Fernandez-Maloigne, FR, Jesus Jaime Moreno, MX, Alessandro Rizzi, IT), started in 2015

9.4 New DRs

DR 8-16 Material Adjustment Transforms (Max Derhak, US), started in 2016

ToR: Terms of Refer To study the topic of adjusting tristimulus values of material (object) colours to predict how they change due to differences in both lighting spectral power distribution and observer functions with the purpose of recommending one or more approaches that can be used in advance colour management systems.

DR 8-17 Literature Survey on Uniform Colour Space for Imaging Applications including Wide Colour Gamut and High Dynamic Range Images (Youngshin Kwak, KR), started in 2017

ToR: To survey the literature on modern uniform colour spaces for Wide Colour Gamut and High Dynamic Range imaging applications, including picture quality evaluation and image compression. The report will identify trends in the technology and make recommendations for one or more technical committees or joint technical committees with Division 1.

9.5 New DRs – Converted Informal Liaisons

None

9.6 Proposed DRs

None

10 Liaisons

10.1 Official Liaisons

CIE Central Bureau – ISO/TC 036: Cinematography

Danny Rich – ISO/TC 130: Graphic Technology

Hideyasu Kuniba – ISO/TC 042: Photography

Po-Chieh Hung – ISO/TC 159/SC 04/WG2: Ergonomics, SC 4: Signals and Controls, WG 2: Visual display requirements

Olfa Ben Ahmed – ISO/IEC/JTC 1/SC 29: Joint Committee on information technology, SC29: Coding of audio, picture, multimedia and hypermedia information

Naoya Katoh – IEC TC 100/TA2 Multimedia Systems and Equipment

Ellen Carter – ASTM

Klaus Richter – ISO/IEC/JTC 1/SC 28: Joint Committee on information technology, SC28: Office Equipment

Maxim Derhak – International Color Consortium

Changed from Marc Mahy

10.2 Informal Contacts

Po-Chieh Hung Society for Imaging Science and Technology

11 Future Activities

To be planned.

12 Other Achievements, Issues, etc.

None.

REPORTS ON WORKSHOPS ON THE OCCASION OF THE GENERAL ASSEMBLY

Report on the
NATIONAL COMMITTEE WORKSHOP

Convener: Peter Blattner, CH (CIE President-elect)

In the afternoon of the 2019 General Assembly, an NC workshop was held. The aim of the workshop was to inform the National Committees about their rights, benefits and obligations, but also to stimulate an informal exchange between the NCs. The workshop was divided into two parts: First, the CIE President-elect, Dr. Peter Blattner, gave his views on the organization. In the second part, discussions took place between the representatives of the NCs in small groups.

In his introduction, the CIE President-elect stressed the role of the CIE as the umbrella organization of the National Lighting Associations. It is therefore important for the CIE Board of Administration to understand the needs of the National Committees. He then highlighted some sections of the CIE Statutes to discuss the rights and duties of the NCs. For example, section 4.5.7 states that a National Committee can participate in the technical work of the Commission and has the right to vote in technical, administrative and organizational matters. The statutes give the NCs the rights in which they participate, but there are no direct obligations. However, the President-elect emphasized the fact that active participation in the voting is important for the CIE to be able to act as a global organization. It is also one of the main objectives of the organization, which is intended to be an international forum for the discussion of all issues relating to the science, technology and art of light and lighting. Paragraph 4.5.1 states that the country wishing to join the Commission will form a National Committee with the participation of organizations in that country which have a particular interest in light and lighting. It is therefore important that the NCs link to all the national organizations and experts covering the CIE's field of activity.

The discussion between the NCs took place in small groups organized at random. Each group was moderated by a BA member:

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Australia	Austria	China	Denmark	Saudi Arabia	Germany
Hungary	Czech Republic	Great Britain	France	Finland	Korea
Norway	Canada	New Zealand	Hong Kong	Japan	Chinese Taipei
Russia	Malaysia	Sweden	USA	Slovak Republic	Slovenia
Switzerland	South Africa	Turkey	Belgium	The Netherlands	
President	*President-elect*	*VPS*	*DD3*	*DD8*	*GS*

The discussions were divided into three parts: Each NC briefly presented its structure and field of activity. In a second round, the challenges and cooperation between the NCs and CIE were discussed. Finally, the expectations, wishes and suggestions for the future relationship were formulated.

The discussion among the NCs has shown that there are great differences between the various countries in terms of structure, activities and financial model. A few NCs have a similar structure to the CIE with explicit mirror working groups to the CIE divisions, while most

other NCs have structures that are detached from the CIE structures. The NC's financial model is also very diverse. In many countries the NCs are financed by cooperative memberships. Additional funds are raised by organizing national conferences or educational activities. Only a few NCs receive mainly government funding or only through individual membership. The size of the NC secretariats varies greatly from country to country. Some NCs have no employees, but the work is done entirely by volunteers. In other countries there are larger secretariats, some of which also work for other national organizations. In some countries the NCs concentrate on national activities and do not have the resources at international level, as the work seems to involve a lot of travel. There are also some language barriers to participating in CIE technical committees and it is often a challenge to make employers aware of the benefits of working for the CIE. The creation of ISO/TC 274 further exacerbates this challenge. There was general agreement that better recognition by CIE would be helpful for future contributions. As an example, an e-mail directly from the CIE President would be motivating. A few participants expressed that the CIE documents were too scientific and that the link to practical applications was missing. The lack of national experts on some topics also affects the participation level at votings on technical documents. There is also room for improvement with regard to the collaboration platform, which is considered by most participants as not user-friendly and as an obstacle to active participation in balloting. Only a few NCs criticized the slow progress of some Technical Committees and questioned the possibility of publishing interim reports (e.g. as a technical note), but most NCs recognized a significant improvement in the efficiency of TC work since the introduction of the new Rules of Procedure in 2011.

Most NCs expressed that additional interactions with the CIE would be beneficial. One example is the translation of the CIE position statement on the blue light hazard. Position statements could be further investigated to increase visibility at national and international level.

All participants agreed that this NC workshop was very useful in stimulating new ideas. Following the workshop, the Board decided to examine the suggestions and wishes in detail. A further NC workshop shall be organized at the mid-term meeting in 2021.

Report on the Workshop with the
INTERNATIONAL LIGHTING NETWORK AND CIE NATIONAL COMMITTEES

Convener: Kathryn Nield, AT (CIE General Secretary)

The CIE has interactions with many other organizations, of which some interactions are supported by formal agreements (Table 1) and others are to ensure that there is an awareness of the activities of the CIE. The number of these external organizations serves to emphasize the breadth of the scope of the CIE along with the intrinsic importance of light to all.

The International Lighting Network (ILN) was an initiative established during the 2011 to 2015 quadrennium, and was comprised of the CIE and those organizations that have formal agreements with the CIE.

Organization	Type	Geographic Extent	Membership
ISO	SDO	International	National Standards bodies
IEC	SDO	International	National Standards bodies
CEN	SDO	Regional	National Standards bodies
CIPM	PRO	Inter-Governmental	Individuals from member states. CIPM is the technical body of CGPM (country members)
Euramet	PRO	Regional	National Metrology Institutes
IALD	PRO	International	Individuals
GLA	IND	International	Regional (national) industry associations
LUCI	GOV	International	Cities; Associated members: international companies, lighting designers and architects, universities, independent lighting professionals, …
SDO: Standards Development Organization PRO: Professional Organization IND: Industry Organization GOV: Governmental Organization			

After some time of inactivity it was decided to hold a workshop of the ILN and the CIE NCs, holding this during the afternoon of the CIE General Assembly (GA). In addition to the members of the ILN other organizations were also invited, due to either potential new CIE technical work, or because these were organizations that the CIE has had active cooperation with, recently or in the past. The workshop provided the opportunity to exchange the views of these organizations along with the needs of the NCs. The holding of this workshop at the time of the GA was particularly important as at the GA meeting we welcomed both established and new NC delegates and it was expected that this workshop would deepen the enthusiasm of the NCs for the role that the CIE has played, and will continue to play, in benefiting its external stakeholders.

Ten organizations accepted the invitation to attend and contribute to the workshop, four of which were invited to give brief presentations, each of these four organizations having a different role in the area of light and lighting: GLA, IES, SPIE and LUCI.

Organizations Represented at the Workshop	
Design Lights Consortium	DLC
Global Lighting Association	GLA
International Association of Lighting Designers	IALD
International Commission on Non Ionizing Radiation Protection	ICNIRP
International Commission on Optics	ICO
Illuminating Engineering Society	IES
Lighting Urban Community International	LUCI
Optical Society of America	OSA
SPIE (formerly The International Society for Optical Engineering)	SPIE
Underwriters Laboratory	UL

The workshop opened with an introductory presentation given by the CIE President, Dr Yoshi Ohno on the CIE as a global standardization organization. This introductory talk gave an overview of the history of the CIE and the importance of collaboration, and highlighted the agreement made with the CIPM in 2007, which formalized the role of the CIE as the international body responsible for metrics and action spectra relating to light, along with the formal agreement with the ISO and the ongoing collaboration between the CIE and the ISO/TC 274 *Light and lighting*.

Following this each of the presenting organizations gave their inputs to the workshop:

1) Global Lighting Association, represented by Annette Steinbusch
   The GLA represents over 5 000 lighting manufacturers, and has official partnerships with organizations including the CIE, IALD and Zhaga, with the scientific outputs of the CIE being of value. Focal points of the GLA include: energy efficiency, LED lighting, internet of things, circular economy, user well-being. On this last point the importance of the CIE work on iGPRC was noted along with the scientific needs of the GLA to support the ongoing work on “Human Centric Lighting” (HCL), for which the GLA is able to offer support to the CIE in applying for grants for scientific work on HCL.

2) International Association of Lighting Designers, represented by Emily Bowers
   The IALD is a global professional organization, which has represented the interests of mainly architects for over 50 years. The IALD is an advocate for lighting quality and excellence in lighting design. The IALD supports and markets the work of their members, who operate within 59 countries world-wide.

3) Illumination Engineering Society, represented by Brian Liebel
   The IES is a regional organization covering the USA, Canada and Mexico. The IES is recognized by ANSI as a standardization body in the USA; in addition the IES has individual members in 62 countries world-wide. The IES has a foundation of “four pillars”: standards, research, advocacy and education. This last pillar of education was highlighted as an area of need; the question was asked “What can be done to get illumination into university programmes and to the next generation?”

4) OSA, resented by Manuel Spitschan
   The OSA was founded in1916 and now has around 21k members world-wide. The OSA is a scientific body with its interest being divided into six Technical Groups, those of key interest to the CIE being concerned with vision and colour, and bio-medical optics. The OSA promotes its work through activities such as early career awards for researchers, conferences, webinars and its well-known series of journals including JOSA A: Optics, Image Science and Vision.

A moderated discussion session followed the presentations, with the floor being opened up to the NCs and other organizations present. Topics raised included:

- The SPIE adding to the IES comment about getting optical engineering into universities.
- UL, which has a focus in safety of lighting products, raised the topic of safety and circadian health.
- ICNIRP re-iterated education and promotion of health aspects of lighting to the general public. ICNIRP was currently working on public statements on LED lighting and circadian effects of lighting (noting we don't have sufficient validated research in this area).
- The DLC raised the topic of how do we work together to support our complimentary activities? For example, how do quality of light and non-visual effects of light impact upon lighting for horticulture.
- In terms of matters such as light pollution and non-visual effects of light SPIE noted that politicians and regulators needed to be educated on the importance of light in our lives and photonics in general.

At the conclusion of the workshop and looking ahead it was agreed by all, that this discussion and sharing by all involved internationally in the many aspects of light and lighting should be followed up on, with a future workshop. Plus as an initial action it was agreed by all that the matter of education on all aspects of light and lighting was paramount and that this was a space that all involved could mutually contribute to.

REPORTS ON WORKSHOPS IN THE SCIENTIFIC PROGRAMME OF THE SESSION

Report on the Workshop
RESEARCH METHOD FOR INVESTIGATING LIGHT SOURCE COLOUR RENDITION

Convener: Minchen(Tommy) Wei, HK

Background:

There have been dozens of experiments related to light source colour rendition in the past several decades, including a renewed push in the past decade, following the proliferation of LEDs. These studies have employed a variety of methods. For example, some experiments have used side-by-side viewing booths, whereas others have used full-scale rooms. Some have used Color Checker Charts, whereas others have used many varieties of real objects. With each choice on methods comes tradeoffs and limitations. How these are addressed can substantially influence the generalizability and scientific merit of the results. This workshop was designed based on the general discussions from the workshop on Research Methods for Human Factors in Lighting, which was held during the CIE 2017 Midterm Meeting at Jeju, Korea, and to specifically focus on experimental methods specific to light source colour rendition.

Summary about the workshop:

Dr Tommy Wei delivered an opening in the workshop, welcoming all the participants and outlining the objectives of this workshop. In addition, Dr Wei briefly explained the how recent studies differed from past studies, in terms of experimental methods, due to the spectrally tunable LED sources.

Dr Kevin Houser first discussed about how research hypotheses should be developed in a study. This is particularly important in selecting appropriate independent variables and control variables. In particular, an independent variable in one study can be a control variable in another study. In addition, explanations were given to the five categories of lighting variables, including spatial, spectral, intensity, temporal, and others.

Dr Alp Durmus then discussed about dependent variables that were investigated in colour rendition studies. These variables were divided into four categories: preference-related, vividness-related, naturalness-related, and colour difference. Also these dependent variables were derived using different methods, including rating, discrimination, adjustment, and matching. Based on different types of data derived using these methods, how statistical methods should be used to test the effect of independent variables were discussed.

Dr Michael Royer discussed about objects and viewing conditions used in past studies. Particularly, how different types of objects (e.g. single hue vs various hues, with context vs without context, natural objects vs man-made objects), types of experimental spaces (i.e. booth vs room, single presentation vs double/sequential presentation), variation of SPD colour rendition, and experimental protocol/procedures (e.g. chromatic adaptation) may affect the experiment results. A list of potential research questions for investigating whether objects and viewing conditions was presented at the end.

Dr Tony Esposito discussed about various biases that may be introduced in experiments and how these biases can be reduced. The biases were identified to be introduced from four sources: apparatus/procedure, investigator, observer, and order. Examples about how to test whether biases existed were given.

Dr Tommy Wei summarized the key points made by the other four presenters. A checklist, which can be used by researchers to consider in designing experiments, was compiled based on the summaries and reviews performed by the speakers, with an QR code being presented to the participants.

Around 30 minutes were left for discussions at the end. The participants generally expressed that the workshop was helpful and useful.

Summary:

This workshop was initially organized by Dr Tommy Wei and Dr Michael Royer. They performed a comprehensive review on various colour rendition studies in the past several decades, from which they found different methods were used in these studies. Later, they designed the workshop to five topics and invited the other three speakers. As the main deliverable of the workshop, the checklist was posted online for free download. Some participants expressed the interest to organize similar workshops on experiment methods for other lighting research topics.

Report on the Workshop
MEASURING TEMPORAL LIGHT MODULATION AND ASSESSING ITS EFFECTS ON VIEWERS: MOVING TOWARDS SETTING LIMITS

Convener: Jennifer Veitch, CA

Abstract

Cyclic variations in luminous output of a lighting system are known as temporal light modulation [TLM]. TLM can affect visual perception, cognition, and neurophysiology, with effects ranging from visual illusions, to disrupted reading, uncomfortable eyestrain, and, rarely, epileptic seizures in photosensitive individuals, depending on the frequency, modulation depth, waveform, and duty cycle of the TLM, the characteristics of the viewer, and the duration of exposure. Industry and society need measurement protocols to permit consistent assessments of the TLM properties of lamps and lighting systems. This workshop was a project of CIE Research Forum RF-02, “Matters relating to temporal light modulation”. The panel speakers included leaders from two CIE technical committees – TC 2-89 on TLM metrology and TC 1-83 on the visual effects -- and two presenters who gave an overview of their related original research. The subsequent discussion will provide guidance for the further development of research and recommendations.

Keywords: e.g. Temporal Light Modulation; Temporal Light Artefacts; Flicker; Stroboscopic Effect; Individual Differences; Metrology

1 Introduction

Cyclic variations in luminous output of a lighting system, whether they arise because of the light source (e.g. a fluorescent lamp on a magnetic ballast) or the addition of controls to the lighting system (e.g. pulse-width modulation to dim a light-emitting diode lamp) are known as *temporal light modulation* [TLM]. Legacy light sources tended to exhibit the same general TLM properties within a product category regardless of manufacturer. For example, all magnetically-ballasted T12 fluorescent lamps exhibited TLM at twice the mains frequency, although the specific waveform varied in relation to the phosphor composition. Electronic ballasts for fluorescent lighting generally operated at 20,000 – 40,000 Hz, creating an almost undetectable TLM pattern. Solid-state lighting systems (SSL), however, do not have this same generalizable character. SSL drivers can be designed in many different ways, which means that there are no longer generalizations to be made about the TLM properties of light sources in common use today (Arias et al., 2012, Poplawski and Miller, 2011, October).

This is important because TLM can cause unwanted effects on viewers (Wilkins et al., 2010, IEEE Power Electronics Society, 2015, Wilkins, 2016). These effects encompass visual perception effects, often referred to as temporal light artefacts; cognitive and behavioural effects, and neurophysiological effects (CIE, 2016, CIE, 2017). Standards and regulations will be needed to prevent the introduction and use of products that might cause these effects. Recognizing this need, the CIE convened in 2017 a stakeholder workshop to bring together scientists, manufacturers, standards development organizations, lighting designers, and regulators to scope out what would be needed to develop an appropriate societal response. The workshop identified several actions that would be needed (CIE, 2017), some of which were:

- Establish protocols for power spectrum measurement and reporting
- Develop models for the visibility of temporal light artefacts
- Foster international research effort to better understand and to predict cognitive and neurophysiological effects based on new TLM quantities

These activities were to be supported by the CIE with technical committees to focus on specific tasks, and with the creation of a research forum to provide a platform for information-sharing and discussion between scientists interested in this topic. This workshop at the CIE 29th Quadrennial Session was an activity of the research forum RF-02. Its goals were to raise awareness of both the issues and the progress being made towards solutions, to encourage discussions among researchers, and to inspire the audience to making new contributions in this area.

The workshop consisted of four invited presentations from panellists who are members of RF-02. Two are leaders in existing CIE technical committees, and two are active investigators of issues related to TLM and its effects. Following their short presentations, there was an open discussion with audience members.

2 Panel Presentations

2.1 Measuring temporal light modulation

Menno Schakel is the Chair of CIE TC 2-89, “Measurement of Temporal Light Modulation of Light Sources and Lighting Systems”. The first task of this technical committee is to write ” a technical note on a measurement protocol that will include recommended measurement conditions and methods to measure waveforms of light (time intervals, duration, bandwidth, photometer requirements, etc.) and frequency-domain power spectra (fast Fourier transforms, [FFT] and other methods)”. This task was the result of discussions at the CIE stakeholder workshop in 2017. Schakel observed in his remarks during the workshop that it is relatively easy to produce measurements of a single light source in an integrating sphere or an otherwise dark room. (Their technical note on this topic is expected to be completed shortly.) Metrology is meticulous, but with attention to detail it can be straightforward.

What is more difficult is to develop a measurement protocol for application measurements, doing so in a manner more typical of the way in which TLM is experienced in the field. For example, if there are multiple luminaires in one room, where does one measure in relation to those luminaires? With what geometry? The metrology community remains uncertain, Schakel said, about what the application community needs to be able to measure. For example, our recommendations remain focused on horizontal illuminance on a working plane, but the growing literature on ipRGC-influenced responses to light demonstrates the need to measure the vertical light that reaches the eye (Commission Internationale de l'Eclairage (CIE), 2004/2009); depending on what we want to predict, the measurement protocol might differ. In a similar way, metrologists need the guidance of the applications community to know what measurement protocols are needed to provide good numbers for TLM experienced in real conditions.

2.2 Quantifying temporal light artefacts

Małgorzata Perz spoke on behalf of CIE TC 1-83, “Visual Aspects of Time-Modulated Lighting Systems – Definitions and Measurement Models”. The CIE published a technical note written by this TC in 2016 (CIE, 2016) and the TC is working towards completion of its full technical report, expected shortly. Her focus in this panel presentation was on the development and validation of the stroboscopic visibility measure (SVM), which can be used to predict the visibility of the stroboscopic effect in general lighting applications. The SVM is computed based on a measurement of the temporal luminous output of a light source or a lighting system. The SVM outputs a value that predicts whether the effect should be visible or not, when viewing moving objects under the target illumination.

SVM is described in detail in CIE TN 006:2016 and in journal publications (Perz et al., 2015, Perz et al., 2018). Briefly, it is calculated as a Minkowski summation of the energy in the Fourier frequency components of the light waveform, normalized for human sensitivity. The sensitivity normalization function was derived from five perception experiments, performed in two different labs (in Eindhoven, NL, and Nanjing, CN) measuring the visibility thresholds,

expressed in terms of modulation depth, for sinusoidal light waveforms at several frequencies. The value of the Minkowski summation exponent was determined experimentally to be n = 3,7. If the value of the SVM equals to 1, the stroboscopic effect is at the visibility threshold, i.e. an average observer should detect the effect with a probability of 0,5.

Perz observed that SVM is not intended as a measure for use in industrial settings where there could be safety implications of failing to detect that an object is moving. It is intended to quantify visibility of the stroboscopic effect in general illumination conditions, such as offices and homes, where human movements define the upper speed limit (i.e. 4 m/s). She further noted that detection of the stroboscopic effect (or not) does not equate to a health effect associated with TLM. That is a different question, requiring other research.

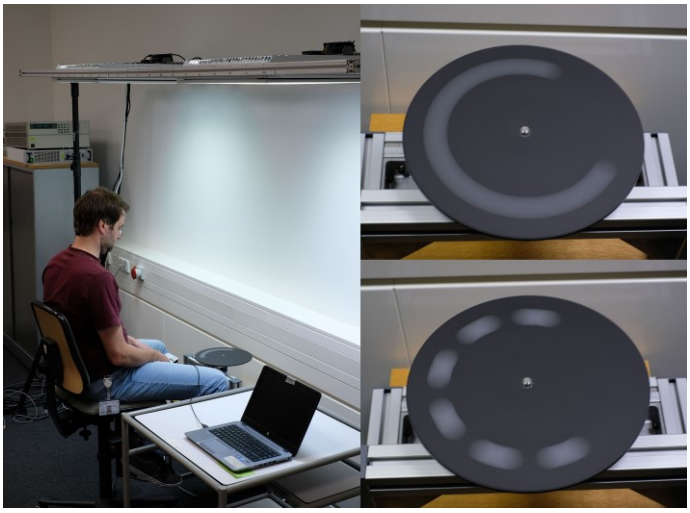


Figure 1 – This image shows the experimental setup for the work leading to the development of the SVM (Perz et al., 2015). The disk has a black surface and one white dot; it is illuminated by varied light stimuli and it rotates during the experiments. If the white dot on the rotating disk gives rise to a blurred image, as shown in the top right, there is no stroboscopic effect. Such blurred image is also perceived under daylight. The stroboscopic effect occurs if the illuminated white dot gives rise to unsmooth/jerky/broken image, one example is shown in the bottom right panel.

2.3 Field measurements

Naomi Miller discussed an informal exploration of TLM/TLA, looking at a wide range of light sources and their waveforms, with different levels of TLA visibility. She has examined light sources in a laboratory and lighting installations in the field, both visually and with measurements to characterize the light output.

Her observations suggest that no one metric is adequate to describe TLM conditions that might lead to unwanted TLA. Modulation depth combined with fundamental frequency is inadequate to identify visible flicker because it does not take duty cycle into account (Figure 2). Flicker index does take duty cycle into account and seems to be a much better predictor of visibility when combined with frequency, because the visibility seems to be related to the area of a cycle that is “missing” from the waveform relative to DC output.

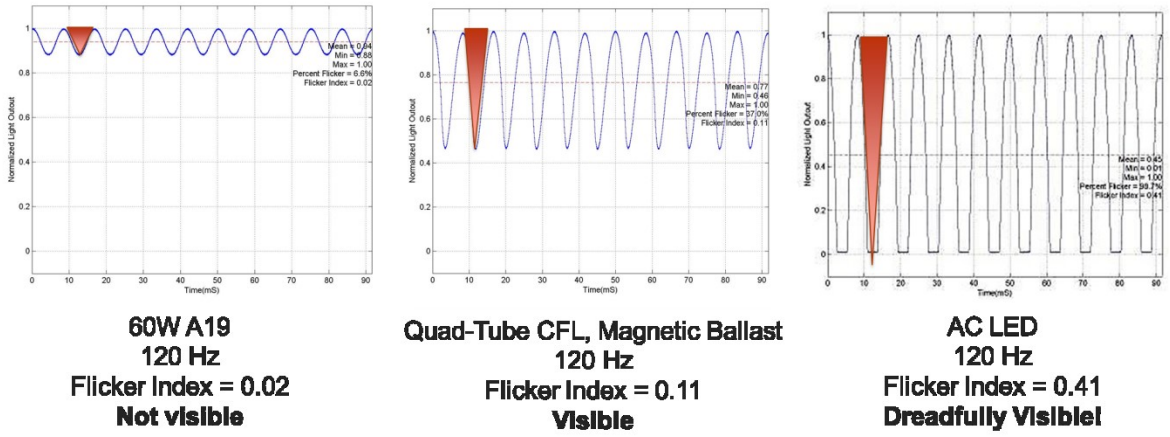


Figure 2 – Duty cycle refers to the proportion of the cycle when there is no light output.

However, a project at Pacific Northwest National Laboratory (PNNL) showed that handheld meters are very inconsistent in estimating frequency (PNNL, 2018). For example, one complex waveform of an LED lamp operated on 60 Hz AC power measured with eight different handheld meters returned values for the dominant frequency ranging from 44 Hz to 566 Hz. Until that waveform measurement issue is resolved, flicker metrics are somewhat moot, as it will be nearly impossible to obtain accurate measurements in field conditions.

Miller also observed that TLA is divided into three categories: flicker, the stroboscopic effect, and the phantom array effect. Stroboscopic effect in particular is defined as occurring with no head or eye movement on the part of the viewer. Seldom in any indoor or outdoor activity does this occur, because the eyes saccade, gaze moves, heads move, and objects move with motions larger than those used in some TLM research. It is important to develop metrics keeping in mind that relative movement will make the stroboscopic effect more visible. It may be that the phantom array effect is increasing the visibility in combination with the stroboscopic effect, and this should not be neglected from the TLA metrics.

2.4 Individual differences in sensitivity

Hillevi Hemphälä observed that her research has found that between 20 % and 40 % of people are sufficiently sensitive to temporal light modulation that they experience unpleasant problems such as eyestrain, headache, and migraine that can affect performance and wellbeing. Some studies have also shown that TLM between 50 % and 100 % modulation depth in lower frequencies, such as 100 Hz to 120 Hz can affect brain activity (Küller and Laike, 1998). One way to assess sensitivity is to measure the frequency at which modulated light merges into an apparently continuous signal, which is called the CFF, or Critical Fusion Frequency. People whose CFF is higher than others' report more headache and eye fatigue when exposed to TLM in a study at Lund University.

There is a new visual risk assessment method for visual ergonomists, named the Visual Ergonomics Risk Assessment Method (VERAM), which has been iteratively developed with input from the ergonomics community. This computer-based assessment includes both self-report by the worker and an expert assessment. The method has shown good reliability and validity, although it does require detailed training for the expert assessors (Heiden et al., 2019, Zetterberg et al., 2019). Nonetheless, the expert assessors have greater sensitivity to possible visual risks than do individuals (Hemphälä and Olivik, 2019).

In the field tests of the VERAM method, approximately 30 % of workplaces were judged by experts to have a possible TLM problem. Preliminary data analysis presented in the workshop

showed that there were statistically significant correlations between the presence of TLM at the workstation and both visual ability and with overall self-reported stress levels, but no correlation to work demands.

The expert assessment of TLM in the workplace using VERAM relies on a smartphone image as a rough screening tool. Although smartphone cameras are not perfect tools for assessing the degree of TLM, Hemphälä argued that they can provide a practical tool for screening individuals in the field to identify those requiring more detailed examination.

3 Discussion and Next Steps

Following the individual presentations, audience members addressed questions to the panellists. There was spirited discussion of the problems of field measurement, particularly of the merits (or not) of using smartphone cameras to assess any light phenomenon, including TLM. No one suggested that there could be a calibration suitable for quality measurements using such a device, but there remained interest in having an inexpensive way for practitioners to screen for potential TLM problems. The current generation of field instruments does not provide consistent results, nor are all of them easily affordable for practitioners. Both protocols for field measurements and instruments to make them remain gaps.

There also is not yet consensus concerning the possible effects of TLM. The SVM has attracted attention as a way to characterize light sources because it predicts the visibility of the stroboscopic effect, has defined measurement guidelines (International Electrotechnical Commission (IEC), 2018), and has guided the development of some commercially available devices. Nonetheless, some argue that seeing the stroboscopic effect in itself might not be the most important problem arising from lighting system TLM. Few published investigations have focused on individuals who might be more sensitive to lighting conditions: How might we identify these individuals? Are there health consequences of exposure to particular TLM conditions for these individuals? What are the health effects that they experience as a result of exposure to various TLM conditions? This information might be a guide to setting limits on TLM conditions.

There was some discussion of research challenges, particularly ethical concerns. One cannot knowingly expose individuals to conditions that might cause severe harm. This might account for the focus on TLA rather than other outcomes, because studies of visual perception effects following short exposures to TLM above ~80 Hz are low risk. Large-scale field investigations that use currently existing conditions probably are required to obtain sufficient data about infrequently occurring problems (e.g. problems that affect a small percentage of the population, or that require long exposures, or that require interactions with other variables to manifest), but these are expensive and can lack sufficient control over extraneous variables to isolate causal mechanisms. Others argue that such long-term, well-controlled investigations are the only way to obtain reliable and valid data on possible health effects caused by TLM, and that short-term experiments are inadequate.

As intended, the workshop sparked thoughtful discussion and some debate. The matter is not resolved, but the seeds of future research were planted. Further discussion continues among members of Research Forum RF-02 and in the existing technical committees.

References

ARIAS, M., VÁZQUEZ, A. & SEBASTIÁN, J. 2012. An overview of the AC-DC and DC-DC converters for LED lighting applications. *Automatika,* 53**,** 156-172.

COMMISSION INTERNATIONALE DE L'ECLAIRAGE (CIE) 2004/2009. Ocular lighting effects on human physiology and behaviour. Vienna, Austria: CIE.

COMMISSION INTERNATIONALE DE L'ECLAIRAGE (CIE) 2016. Visual aspects of time-modulated lighting systems – Definitions and measurement models. Vienna, Austria: CIE.

COMMISSION INTERNATIONALE DE L'ECLAIRAGE (CIE) 2017. Final report CIE stakeholder workshop for temporal light modulation standards for lighting systems Vienna, Austria: CIE.

HEIDEN, M., ZETTERBERG, C., LINDBERG, P., NYLÉN, P. & HEMPHÄLÄ, H. 2019. Validity of a computer-based risk assessment method for visual ergonomics. *International Journal of Industrial Ergonomics,* 72**,** 180-187.

HEMPHÄLÄ, H. & OLIVIK, H. 2019. A new method for evaluating the visual environment. *Proceedings of the 29th CIE Quadrennial Session, June 16-22, Washington, D.C., USA.* Vienna, Austria: Commission Internationale de l'Eclairage.

IEEE POWER ELECTRONICS SOCIETY 2015. IEEE recommended practices for modulating current in high-brightness LEDs for mitigating health risks to viewers. New York, NY: Institute for Electrical and Electronics Engineers, Inc. (IEEE).

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC) 2018. Equipment for general lighting purposes - Objective test method for stroboscopic effects of lighting equipment. Geneva, Switzerland: IEC.

KÜLLER, R. & LAIKE, T. 1998. The impact of flicker from fluorescent lighting on well-being, performance, and physiological arousal. *Ergonomics,* 41**,** 433-447.

PACIFIC NORTHWEST NATIONAL LABORATORY (PNNL) 2018. Characterizing photometric flicker: Handheld meters. Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

PERZ, M., SEKULOVSKI, D., VOGELS, I. M. & HEYNDERICKX, I. E. J. 2018. Stroboscopic effect: Contrast threshold function and dependence on illumination level. *Journal of the Optical Society of America A: Optics and Image Science, and Vision,* 35**,** 309-319.

POPLAWSKI, M. E. & MILLER, N. J. 2011, October. Exploring flicker in solid-state lighting: What you might find, and how to deal with it. *Illuminating Engineering Society of North America Annual Conference.* Austin, TX.

WILKINS, A. J. 2016. A physiological basis for visual discomfort: Application in lighting design. *Lighting Research and Technology,* 48**,** 44-54.

WILKINS, A. J., VEITCH, J. A. & LEHMAN, B. 2010. LED lighting flicker and potential health concerns: IEEE Standard PAR1789 update. *Proceedings of the Energy Conversion Congress and Exposition (ECCE) 2010 IEEE, 12-16 Sept., 2010.* New York, NY: Institute of Electrical and Electronics Engineers.

ZETTERBERG, C., HEIDEN, M., LINDBERG, P., NYLÉN, P. & HEMPHÄLÄ, H. 2019. Reliability of a new risk assessment method for visual ergonomics. *International Journal of Industrial Ergonomics,* 72**,** 71-79.

Report on the Workshop
IN SEARCH OF A NEW APPROACH TO THE MAINTENANCE FACTOR

Convener: Dionyz Gasparovsky, SK

Background

Accounting for depreciation of a lighting system during its lifetime is indispensable at the designing stage as well as for the measurement of the current lighting parameters in order to estimate the lowest lighting levels and thus to fulfil the target values or lighting criteria, and in constant light output systems to estimate the raise of energy consumption. Due to technological changes, better cleanliness of our working or living environment and new related technical standards and recommendations the current approach to description of the depreciation of lighting systems which can be compensated by proper maintenance is outdated and should be replaced by modern and technically improved methods and procedures.

Brief description

Aim of the workshop is to overview and summarize currently available knowledge and experience with depreciation of lighting system components, to discuss options how to gather bulk of data from laboratory and field measurements and to discuss actual proposals for re-structuring and parting the maintenance factor from different perspectives.

Programme

1. Introduction
2. Current knowledge and experience with depreciation of lighting system components
   a. Available scientific papers, publications, reports
   b. National standards and recommendations
   c. Data from laboratory and field measurements
3. Particular proposals on new approach to the maintenance factor
   a. Re-structuring and parting the maintenance factor
   b. Finding the appropriate terminology for new components of the maintenance factor
   c. Measurement method for luminaire related components
   d. Depreciation of the reflectance of room surfaces versus the current RSMF component
4. Round table discussions
5. Summary and conclusions

Presenters

Adrie de Vries (NL)
ISO/CIE TS 22012: What Have we Learned from Developing the Technical Specification

Janne Askola (FI)
Reduced Lifetime of LED Street Luminaires Due To Adaptive Control

Peter Schwarcz (HU)
Review and Proposals for Upgrade of Metrics of Useful Lifetime of Professional LED Luminaires

Costis Bouroussis (GR)
Towards a 2D Luminaire Maintenance Factor for Street and Tunnel Luminaires

Ron Gibbons (US)
Spatial distribution of the dirt depreciation on luminaires

Dionyz Gasparovsky (SK)
Depreciation of the reflectance of room surfaces

Summary and outcomes

Summary of the workshop have been reported and used for the work of the technical committee CIE JTC 13. Main conclusions from the presentations:

- Lifetime does appear to be impacted by switching/control scheme. Incidentally, luminaire failure and luminaire type also seemed to be impacted during the experiment by the switching behaviour.
- Measurement uncertainty and the 'to-be-measured' differences do not match. Solutions need to be found where repeatability of the measurements is key
- Application should come first when thinking about a maintenance factor methodology. E.g. when talking about lifetime metrics, one should look for the relevant lifetime, and then for the corresponding depreciation instead of the lifetime for a given depreciation.
- Dirt and scratches on optics have an effect on (road) lighting performance. However, consequences can be both positive or negative (e.g. uniformity can become higher and lower depending on the dirt/scratch patterns and installation)
- Dirt based depreciation has a large impact on lighting distribution and overall level of depreciation. These effects are, however, dependent on luminaire type/design, but also light source type (e.g. the fact that traditional light sources become much hotter has consequences)
- Surface maintenance factor should go from a single value for the entire space, to a value per surface. Additionally, this should not be a part of the maintenance factor, but a part of the reflection factor in the lighting design.
- TS 22012 is a very usable document, but still has many gaps that need to 'filled'. Proposed new solution however, does need to be pragmatic to ensure adoption in the field.

Discussions on terminology

- LMF terminology alternatives discussion:
  - "pollution" is not seen as the right word as it has a specific meaning and a negative connotation
  - "environment" is suggested, but not appreciated by all as it is not about the environment and in general has a different meaning
  - other alternatives: atmospheric, surrounding, application maintenance factor, operating environment, extrinsic
  - "external" not seen as the right word
  - overall no consensus on the best solution
- Other comments:
  - Alternative to Lamp Survival Factor: Luminaire Survival Factor
  - Device Maintenance Factor (DMF): no negative comments from the audience
  - Control gear should include not just the failure, but also the depreciation over time

Report on the Workshop
MODELLING COLOUR QUALITY OF LIGHT SOURCES

Convener: Ming Ronnier Luo, CN/GB

The CIE general colour rendering index, R_a, has been widely used for specifying the colour rendition properties of white-light sources. In 2017, a colour fidelity index, R_f, was proposed by the CIE for scientific usage. However, there is a consensus that colour rendition quality is more than just colour fidelity, comparing the colour appearance of objects illuminated under a test source and a reference illuminant. There is no exact definition of colour rendition quality, but at least it is related to preference, vividness, naturalness, attractiveness, colourfulness, and colour discrimination. A 2-hours workshop was organized by Prof. Tran Khanh and Prof. Ronnier Luo. The goal was to update the progress regarding to the development and evaluation of colour quality metrics (CQMs), excluding colour fidelity metrics.

Seven speakers were invited to introduce their works. The workshop included 6 13-minutes presentations and a 10 minutes discussion session. A brief account is given to summarize each presentation. It attracts a full house

Kevin Smet and Yandan Lin first updated the progress of CIE TC 1-91 Technical report on 'Overview of Methods for Evaluating Colour Rendition of White-Light Sources Beyond Colour Fidelity'. It includes 7 colour quality metrics (CQMs) together with different experimental data for the evaluation of these metrics.

Michael Royer and Kevin Houser introduced the framework proposed by IES TM30 CQMs. It includes global average values (R_f, R_g), local average values ($R_{cs,hj}$, $R_{hs,hj}$, $R_{f,hj}$), sample specific values ($R_{f,CESi}$) and a graphical representation (CVG). The testing results to evaluate these CQMs were summarized as i) in polychromatic environments, red chroma was very important to preference, vividness, and naturalness ; ii) combinations of R_f, $R_{cs,h1}$ (or $R_{cs,h16}$), and R_g were produced the best regression models of subjective evaluations ; iii) models using these three CQMs improved correlation compared with existing (average) colour preference, gamut area, and colour fidelity measures; iv) the models were independent of chromaticity. However, because regression models themselves are generally too specific for application and single-number combination metrics hide contributing factors while reducing flexibility. TM-30 is recommending a new method to provide specification criteria for three design intents (colour preference, colour vividness, colour fidelity), each including three priority levels.

Peter Bodrogi introduced their large-scale experimental work carried out at Technical University of Darmstadt. They also derived a colour quality model, which is a product of three terms (E (lux), ΔC_{ab}^* and $(S/V)^{0,2}$), where the latter is a function of CCT. Each term is a polynomial equation.

Ronnier Luo introduced their experiment at Zhejiang University. The results in terms of perceived preference, naturalness and colourfulness. A colour preference index (named CPI) was derived and it is a function including three terms (D_p, R_f, $R_{cs,h1}$), where D_p is called preferred degree of chromatic adaptation, equals to ($1-800/$CCT). It indicates that a higher CCT will lead to a higher degree of chromatic adaptation, thus higher D_p and CPI.

Yoshi Ohno introduced his recent work to evaluate the colour quality due to different illuminance levels. The results showed that the Hunt effect plays an important role in colour preference and the illuminance should be included in colour preference metrics.

Qiang Liu reported his results by testing 26 CQMs using meta-databased including 56 groups of data. The results showed that his new Colour Quality Index (CQI), a combined metric of

CCT and Memory Colour Rendering Index (MCRI) exhibited the best performance in predicting colour preference of lighting while the arithmetic mean of Gamut Area Index (GAI) and Colour Rendering Index (R_a) also performed well. This implies that certain linear combinations of absolute gamut-based metrics and relative colour fidelity metrics could accurately quantify colour preference. Based on this finding, a novel combined metric was proposed by fitting the large psychophysical dataset, which remarkably improved the metric performance. Moreover, he also found that the metric performance also varies with contextual lighting conditions (i.e. consistent CCT or multiple CCTs) and experimental situation (i.e. light booth or immersive environment).

Finally, Kees Teunissen provided an update of the CIE D1 Research Forum on colour quality (RF-03). He addressed that there could be some issues in colorimetric tools included in the CQMs, such as (the application of) colour matching functions (2-deg vs 10-deg), uniform colour space (in 3 dimensions), chromatic adaptation transform (sources with chromaticity coordinates off blackbody locus or away from the CCT range 5 500 K–6 500 K), colour appearance model (imaging systems versus lighting applications). He also pointed-out that the scientific models and terminology may not (always) be easily understood by the intended audience (e.g. specifiers, industry, consumers) and that efforts should be made to have different levels of complexity in models and the communication of the features and benefits.

In the final discussion, a consensus was formed. A single CQM cannot predict well colour quality attributes such as colour preference, colourfulness and naturalness. Regression models could do a good job, but generalization beyond the experimental condition and set-up could be difficult to justify. Therefore, it might be better to tune and combine the output parameters of the CQMs according to the desired design intents.

Report on the Workshop
USE AND APPLICATION OF THE NEW CIE S 026/E:2018, METROLOGY FOR IPRGC-INFLUENCED RESPONSES TO LIGHT "SPECIFYING LIGHT FOR ITS EYE-MEDIATED NON-VISUAL EFFECTS IN HUMANS"

Conveners: Luc Schlangen, NL, Luke Price, GB, David Sliney, US, Manuel Spitschan, GB

In December 2018, the international standard CIE S 026/E:2018 "CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light" (doi.org/10.25039/S026.2018) was published. This standard defines spectral sensitivity functions, quantities and metrics to describe the ability of optical radiation to stimulate each of the five retinal photoreceptor classes that can contribute, via the melanopsin-containing intrinsically-photosensitive retinal ganglion cells (ipRGCs), to the retinally mediated non-visual effects of light in humans. This one-hour workshop started with four 10 minute presentations about the standard, followed by a general discussion and questions. The four presentations focused on the following topics:

1) Introduction to CIE S 026 and its quantities (Luc Schlangen)
2) Demonstration of toolkit (in preparation) to calculate CIE S 026 quantities (Presented by Luc Schlangen on behalf of Luke Price)
3) Accounting for field of view (David Sliney)
4) ipRGCs and pupil response (Manuel Spitschan)

In the first presentation, Luc Schlangen discussed the relevance of the new standard CIE S 026/E:2018 for lighting practice and scientific research: it helps to specify lighting conditions that may promote (or diminish) certain non-visual-responses to light. Moreover, it allows scientists and practitioners to explore whether one can predict non-visual response amplitude from photoreceptor input(s).

CIE S 026/E:2018 defines five spectral weighting functions (e.g. action spectra), $s_{\alpha}(\lambda)$, for the five retinal photoreceptor classes: S cone, M cone, L cone, rhodopsin and melanopsin-encoded photoreception of ipRGCs. For each of these five (α-opic) photoreceptors an α-opic irradiance (or radiance etc.) can be calculated from the spectral irradiance of a light source, see Table 1. The α-opic irradiance of a light source divided by its illuminance defines the α-opic efficacy of luminous radiation (α-opic ELR) of this source, see Table 1. Moreover, one can also express how much daylight (D65) is needed to achieve a given α-opic irradiance. This quantity is denoted as the α-opic equivalent daylight (D65) illuminance (α-opic EDI), and is expressed in lx, see Table 1. The ratio of the α-opic ELR of a test source to the α-opic ELR of standard daylight (D65) defines the α-opic daylight (D65) efficacy ratio (α-opic DER), see Table 1.

Three different systems are commonly used to physically measure and specify light: the photon system, the radiometric system and the photometric system. Figure 1 shows the quantities and units for various ways to characterize light within these three systems. The corresponding α-opic quantities as defined in CIE S 026/E:2018 are included in the figure.

The informative annex of CIE S 026 discusses various ways to measure (α-opic) irradiance. Some examples are discussed in the workshop (see also David Sliney's presentation below):

- (α-opic) irradiance on a vertical plane (analogous to vertical illuminance)
- (α-opic) irradiance on a vertical half cylinder (analogous to semi cylindrical illuminance)
- (α-opic) irradiance measured with field-of-view restriction (horizontal 180° extent, vertical: +20° to –70° for indoors, and +50° to –70° for outdoors)

Table 1 – Examples of α-opic quantities as defined in CIE S 026/E:2018. The table provides definitions based on irradiance and illuminance. However, also radiance and luminance can be used to define the corresponding α-opic quantities, see Fig. 1.

α-opic quantities in CIE S 026 – some examples

α-opic can be: S-cone-opic (α=sc) M-cone-opic (α=mc); L-cone-opic (α=lc); Rhodopic (α =rh); Melanopic (α=mel)

	Quantity	Formula	Meaning	Unit
	α-opic irradiance	$E_\alpha = \int E_{e,\lambda}(\lambda)\, s_\alpha(\lambda)\, d\lambda$ (α-opic action spectrum)	weighted spectral irradiance, $E_{e,\lambda}$, integrated over wavelength	W·m^{-2}
α-opic ELR	α-opic efficacy of luminous radiation	$K_{\alpha,v} = E_\alpha / E_v$	quotient of α-opic irradiance, E_α, and illuminance, E_v	W·lm^{-1}
α-opic EDI	α-opic equivalent daylight (D65) illuminance	$E_{v,\alpha}^{D65} = E_\alpha / K_{\alpha,v}^{D65}$	Illuminance level of daylight (D65), producing an equal α-opic irradiance, E_α, as the test source	lx
α-opic DER	α-opic daylight (D65) efficacy ratio	$\gamma_{\alpha,v}^{D65} = K_{\alpha,v} / K_{\alpha,v}^{D65}$	ratio of the α-opic ELR of the test source, $K_{\alpha,v}$, to the α-opic ELR of daylight (D65), $K_{\alpha,v}^{D65}$.	-

Practical example

1 lx of standard daylight (D65) has a melanopic irradiance of 1.33 mW/m2

melanopic efficacy of luminous radiation (for D65) = melanopic irradiance/ illuminance

$K_{mel,v}^{D65}$ = 1.33 mW / lm

converting melanopic irradiance ⇒ melanopic equivalent daylight (D65) illuminance (melanopic EDI)

E_{mel} = 1.33 mW/m2 ⇒ melanopic EDI = 1 lx

E_{mel} = 133 mW/m2 ⇒ melanopic EDI = 100 lx

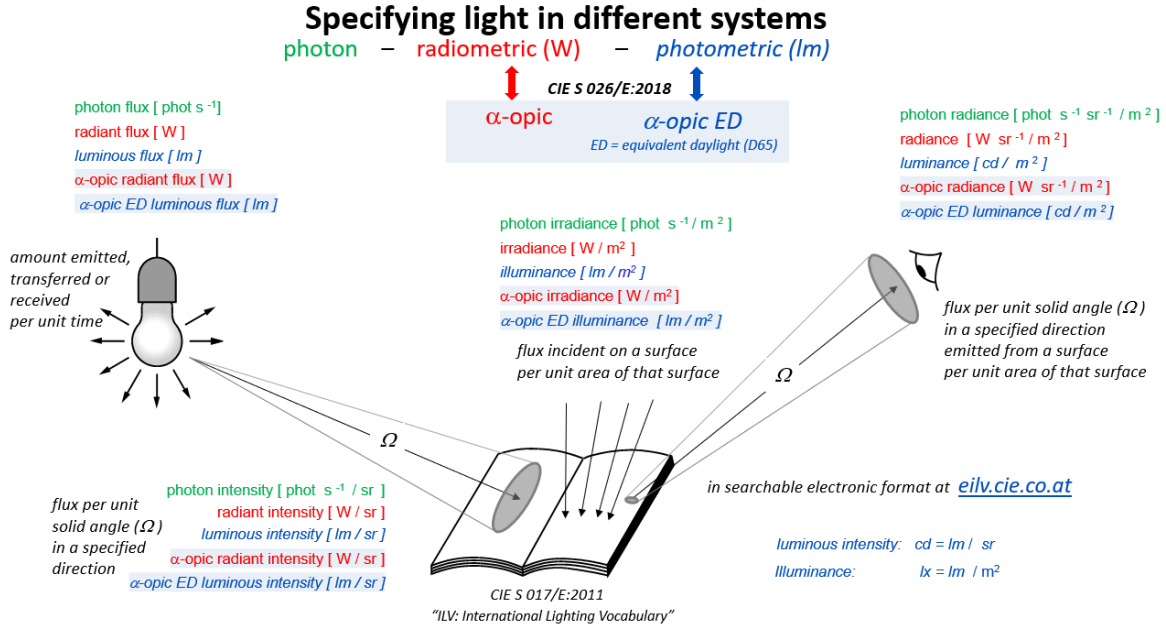


Figure 1 – CIE defined quantities and their units which can specify light in the photon system, the radiometric system and the photometric system. The corresponding α-opic parameters as defined in CIE S 026/E:2018 are also shown.

In the second presentation Luc Schlangen discussed the slides made by Luke Price about the toolbox with CIE S 026 calculations. This toolbox is in preparation and will be published

(doi.org/10.25039/S 026.2018) on the CIE webpage of the standard (see above). The main features of the toolbox are:

- CIE S 026 calculations and conversions: weighted and unweighted quantities (see Figure 2), α-opic equivalent daylight (D65) illuminance (α-opic EDI), etc.
- Irradiance or radiance geometry: illuminance or luminance, α-opic equivalent daylight (D65) illuminance or luminance, etc.
- Built-in illuminants: A, D65, E, F11, LED-B3
- User-defined Test spectrum: choice of resolution (1 nm, 2 nm, 4 nm, 5 nm, 8 nm, 10 nm) and SI prefixes (E, P, T, G, M, k, , m, μ, n, p, f, a) / (, c, m)^2
- Backward compatibility with the CIE TN 003 Toolbox (Lucas et al., Trends in Neuroscience 2014, Toolbox)
- User-defined reference function: enter your own spectrum, or use standard illuminants A, D65, E, F11, LED-B3
- Glossary and spectral weighting charts
- Implementation of age adjustment for α-opic quantities is in consideration, if included the toolbox will always provide standard quantities alongside age-adjusted quantities.

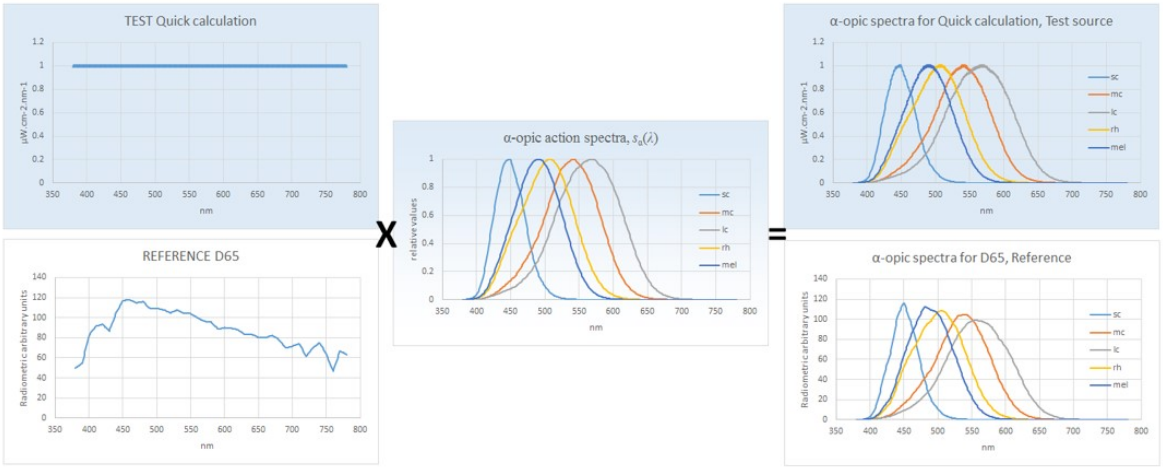


Figure 2 – Example of one of the worksheets within the CIE S 026 toolbox. In this example, the spectral irradiance of an equi-energy spectrum (top left panel) is used as the test source. The bottom left panel gives the spectrum of the D65 reference source. Weighting both these spectra with the α-opic action spectra yields the α-opic spectral irradiance for each spectrum, which, after integration over wavelength, yields the α-opic irradiance (see Table 1).

In the third presentation, David Sliney discussed retinal exposure and spatial aspects of the visual field of view (FoV). Retinal exposure rate (either irradiance or illuminance) can be directly related to the radiance (or luminance) of the object (e.g. light source) being viewed. However, the retinal exposure rate it is not directly related to measured corneal irradiance (or illuminance)! Historically, around 1983, in the early days of light therapy (at a meeting held at NIH, USA), illuminance was applied to quantify retinal exposure for a large, line-of-sight fixed light source. While this is informative for the same type of large source, it can introduce errors and lack of reproducible results when comparing the many different sources/configurations as used in light and lighting research today. Likewise, the α-opic EDI metric, which only adjusts for the spectral characteristics of the α-opic photoreceptor (see Table 1), does not really characterize what light (and spectrum) is really falling on the retina. The upper eyelid plays an important role in how much light reaches the retina, and what parts of the retina are really exposed. The position of the eyelid depends on the brightness of the scene viewed. Outdoors, the eyelids typically restrict the field of view to between +15°-25° and -70° in the vertical

direction, while indoors the field of view expands from +45° to -70° in the vertical direction. Also, the area of the pupil aperture (which is highly variable between individuals for a given luminance) determines the amount of light entering the eye. Other factors contributing to interindividual variability of retinal exposure are sun avoidance behaviour, eye-lid opening and lens transmittance. The latter is known to vary with age and latitude. In clinical perimetry, the primary FoV in the vertical direction expands from +40° to -60° only, and in the horizontal direction from 50° nasally to 60° temporally (side). Another point that David thought important related to the relative distribution of the ipRGCs, and he cited recent studies mapping their relative concentration in different retinal locations (ipRGCs were more dense in the inferior retina and Glickman, in J. Biol. Rhythms, 2003, had measured a stronger melatonin suppression when the inferior retina was exposed to light). So what measurements would be most useful? By placing an elliptical cone hood (baffle) over an irradiance/illuminance meter or a digital camera, one can measure a spatially averaged irradiance/illuminance that is integrated over an effective solid angle field-of-view (Ω) using:

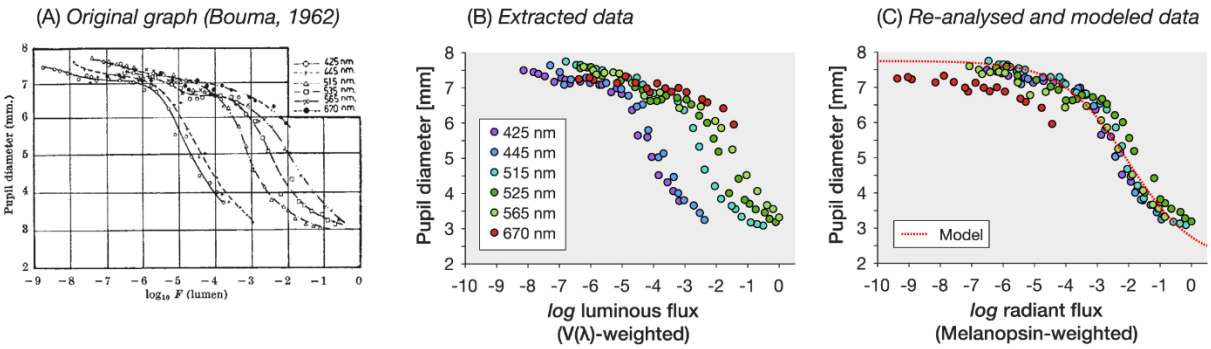
- ~ 3,2 sr (total geometry) for outdoor assessments
- ~ 4,2 sr (total geometry) for indoor assessments

Although the meter should be cosine-corrected within the field-of-view, it is the spatial limits that are the crucial characteristics. Instead of a hooded irradiance/ illuminance meter, one can also consider use of a radiance/luminance meter (set at the largest field-of-view, e.g. 6◦) and move it around the visual scene as to establish a time weighted average radiance/ luminance that effectively represents a spatially averaged radiance/luminance. For simplicity, one can also employ a 1-sr circular hood (~57°) that allows the illuminance reading of lx to have the same numerical value as the luminance in $cd \cdot m^{-2}$ (i.e. $lm \cdot m^{-2} \cdot sr^{-1}$) and move this over the visual field.

In conclusion David mentioned the following points:

- A measurement of overhead sunlight or overhead artificial lighting luminaires is not highly related to retinal illumination, since good lighting design will place luminaires above ~45° so that a bright luminaire is outside the visual FoV.
- Vertical illuminance is a metric that is really only relevant to light boxes within the direct FoV.
- The reflectance of natural or built materials in the lower field-of-view dominates retinal illumination, and for most woods and building materials, the short-wavelength reflectance is low compared to the reflectance at longer visible wavelengths.
- Individuals demonstrate significant variability in upper eye-lid position and pupil size when viewing the same scene out-of-doors, and this needs to be considered in any careful research study.
- Ignoring the viewing/exposure geometry may result in false negative experimental results

In the fourth contribution, Manuel Spitschan discussed how the different photoreceptor classes contribute to the control of the pupil. It is well known that the size of the pupil depends on light level. Steady-state pupil size can be predicted by a unified formula for light adapted pupil size as proposed by Watson and Yellott in J. Vision, 2012 (doi.org/10.1167/12.10.12), though their parametrization relied on luminance, which reflects a combination of L and M cones. However, luminance does not predict pupil size. All photoreceptors (S-cone, M-cone, L-cone, rhodopsin and melanopsin-based photoreception) can drive pupil-responses, but at different time scales. Analysing existing data from Bouma (1962), melanopsin-weighted quantities, in conjunction with the Watson & Yellott's formula, adequately model intensity-dependent pupil size. It is important to realize that also other factors like age, arousal, accommodation and eye movements can also influence pupil size, though light is the strongest driver.



From: https://jov.arvojournals.org/article.aspx?articleid=2748647

In the second part of the lecture Manuel explained the principle of univariance formulated by Rushton, which states that photoreceptors cannot distinguish between changes in intensity and changes in wavelength. This principle can be used to generate stimulus conditions to selectively stimulate the different photoreceptors using the method of silent substitution (Spitschan & Woelders 2018, https://www.ncbi.nlm.nih.gov/pubmed/30538662), thereby revealing their temporal contributions.

Report on the Workshop
HORTICULTURAL LIGHTING

Convener: John O'Hagan, GB

Summary

The availability of a wide range of lamps utilising LEDs with different spectra is driving the desire of the horticultural industry to optimize the lighting for different plants grown under artificial conditions. This workshop brought together three key individuals involved with the fundamental research and delivery of horticultural lighting.

Bruce Bugbee is Professor of Crop Physiology at Utah State University. Much of Bruce's career has been defined by his research with NASA to develop regenerative life support systems. He and his students developed a dwarf variety of wheat that has been used in several studies on the International Space Station, and he is currently working with NASA to study the use of fibre optics for growing plants in space. Tessa Pocock joined Plenty in 2019 after five years as a Senior Research Scientist at the Center for Lighting Enabled Systems and Applications (LESA) at Rensselaer Polytechnic Institute (RPI). After obtaining a PhD in plant physiology in Canada she moved her research to Sweden as a recipient of a prestigious Marie Curie Fellowship. She joined RPI in 2014 after a decade in the European horticultural lighting industry where she oversaw over 800 LED spectral high-throughput experiments on greens, herbs and medicinal plants. Damon Bosetti is a Technical Manager with the Design Lights Consortium's Horticultural Lighting and Networked Lighting Controls programmes. He has also worked at EnerNOC on demand response programmes, and at Digital Lumens on intelligent light fixtures and controls.

Presentations

Far Red: The Forgotten Photons – Bruce Bugbee

Keith McCree was one of the first to determine the relative photosynthetic efficiency as a function of wavelength for single leaves. However, he proposed using equal weighting for all photons from 400 to 700 nm. He also didn't address the effects of multiple wavelengths on plant growth and quality. A review of data from several researchers is available at: https://www.actahort.org/books/1134/1134_1.htm.

The Stark-Einstein law states that one absorbed photon excites one electron. The synergistic effect of exposure to simultaneous far-red photons has been called the "Emerson enhancement effect". This has been demonstrated in 16 diverse species where the addition of far-red light improves crop yield. Studies showed that far-red photons were nearly as efficient as LEDs that produce blue and red photons (https://www.nature.com/articles/s41586-018-0706-x). Various studies of the action spectra for the phytochrome have suggested peak responses in the red and far-red (into the infrared) parts of the optical spectrum. The phytochrome molecule in the cytoplasm is heavily shaded by chlorophyll in chloroplasts

In practice, an individual leaf is unlikely to receive light direct from a light source: the exposure will include reflection from, and transmission through, other leaves. Therefore, Phytochrome Photoequilibrium measured above the canopy is not a good predictor of plant morphology with mixed background spectra.

A Narrow View of Broad-Spectrum Lighting – Tessa Pocock

Crops grown under broad-spectrum LED lighting tend to have stronger growth. However, information about the optimum spectrum is still being developed. Studies have been carried out, which compare commercial LED products intended for horticultural lighting with other

sources. This is of special interest for crops containing pigments, such as anthocyanins. Nine spectral regions based on their high spectral variance were examined for their effect on lettuce yield, photochemistry and anthocyanin concentration. Spectral bins ranged from 15 nm to 72 nm wide. It was shown that 430-445 nm and 545-570 nm light increased the yield, but 465-510 nm light decreased the yield (Pocock, T., Hortscience Vol. 50(9) September 2015).

In conclusion, Dr Pocock asked whether consideration should be given to the use of collections of narrow-band sources for optimum plant growth.

Beyond PPF: Action spectra for horticultural lighting – Damon Bosetti

Damon used the analogy of our knowledge about the surface of the moon over time to describe the situation with the use of artificial lighting in horticulture. We can advance at the speed limit of our technical discoveries, but we are also limited by the speed at which we disseminate and convince each other of their usefulness. Maps are both the way of showing each other what we do know, and spurring on exploration in the gaps in the map. At the DLC, they make their “maps” as a downstream consumer of the knowledge and standardization of that knowledge that groups like CIE produce. We’re going to get to the equivalent of this map in the photo-horticultural world, but we can do it faster when we work together.

The importance of consensus standards was emphasized, for example IES LM-79, LM-80 + TM-21 and LM-84 + TM-28; and ASABE S642. But a published standard is not enough. Who accredits a group to evaluate against the standard? Are enough groups ready to perform the tests? Is the industry mature enough to have repeatability for things like random surveillance testing?

Discussion

One of the key points from the discussion was about the parts of the optical spectrum that may not be used currently, especially ultraviolet radiation. As more is known about the synergy between different wavelengths for plant growth, the more likely it is that most of the solar spectrum will have a role. This will also need to take account of the potentially different needs of the crop through the different stages of growth.

Report on the Workshop
COLOUR IMAGING, PERCEPTION, AND REPRODUCTION: NEW DIRECTIONS IN COLOUR SCIENCE AND TECHNOLOGY

Conveners: Po-Chieh Hung, US (CIE D8), Youngshin Kwak, KR (CIE D1),
Manuel Spitschan, GB (OSA), and Francisco Imai, US (IS&T)

This workshop was held as a joint event with the Optical Society (OSA) and the Society for Imaging Science and Technology (IS&T) to discuss and scope status and challenges of currently relevant topics in colour, vision and imaging. The purposes of this workshop were: 1) to bring together researchers, practitioners and policymakers in the fields of colour imaging, rendering and reproduction to discuss the state-of-the-art knowledge, 2) how new findings from vision science can be integrated into policies and practice, and 3) to also define which problems are unsolved and require attention.

As the advance of novel technologies such as high-dynamic range displays (HDR) and virtual and augmented reality (VR/AR), colour science for imaging, rendering and reproduction deserves a reconsideration in terms of its fundamental assumptions. In addition, recent developments in vision science point to the need to at least consider the role of so-called intrinsically photosensitive retinal ganglion cells (ipRGCs) expressing the photopigment melanopsin as a separate visual pathway, and the need to take into consideration individual differences in colour vision.

Four thought leaders in the following topical areas were invited:

1) New directions in colorimetry, colour vision, and colour appearance; Dr. Michael Murdoch, Rochester Institute of Technology, US
2) Contributions of melanopsin to visual functions in humans; Dr. Manuel Spitschan, University of Oxford, GB
3) High-dynamic range imaging; Dr. Erik Reinhardt, InterDigital, FR
4) Virtual reality and augmented reality; Dr. Gizem Rufo, Facebook Reality Labs., US

The workshop was held using two sessions (each session with a duration of 2 hours) and was structured as follows:

In the first session, the thought leaders in the four topical areas gave introductory and didactic talks into each topic area.

In the second session, the workshop participants engaged in round-table discussions led by the thought leaders for an hour, identifying and discussing areas of cross-fertilisation and developing a set of action items.

To conclude the workshop, the thought leaders summarized the discussions, picked up three topics per topical area, and reported back to the entire audience.

In their talks, Dr. Murdoch summarized the current colorimetry and CIE 170 as well as colour appearance models. Dr. Spitschan discussed the human receptors including ipRGC and temporal response. Dr. Reinhardt explained ways to express HDR images and requirement for devices. Dr. Rufo covered practical issues in VR/AR using movies.

The participants gathered into four corners of the workshop room and discussed under the guidance of the thought leaders. As a result, the following topics were identified as future challenges and were presented by the thought leaders.

1) New directions in colorimetry, colour vision, and colour appearance

- Individual variation of cone sensitivities: How to measure, evaluate, and apply. Pros and cons between universal CMF and individual CMFs
- Colour Appearance Models (CAMs): Image-based CAM, HDR, chromatic simultaneous contrast, mixed adaptation, appearance parameters
- Chromatic Adaptation: How to measure and model, incomplete and/or non-linear, effects of field size, luminance level, mixed illuminance, complexity

2) Contributions of melanopsin to visual functions in humans

- Need for metrics: Quantification of the “circadian” effect of light and light-emitting products
- Meaningful physiological differences: Relationship between real-world significance and light calculated by melanopsin function
- Complexity of biological systems: Better understanding on spatial and adaptive aspects

3) High-dynamic range imaging

- How the human visual system (HVS) adapts to luminance distributions: Algorithms for image reproduction
- What range we should able to reproduce: Compromise between device performance and real HDR image
- Combination of HDR and wide colour gamut (WCG): Need for more 3 primaries, handling of out-of-gamut pixels

4) Virtual reality and augmented reality

- Health issues of AR/VR + human factors for physical fit: Various spatio-temporal artefacts like phantom array and flicker, and impact on visual comfort and long-term effect, physical fit in terms of IPD and head shapes
- Metrics for colour and luminance artefacts and extending these to eccentricity: Measurement of colour aberrations and colour and luminance non-uniformities. Vision in the periphery.
- Adaptation effects of AR/VR: AR with HDR light, eye adaptation to various aberrations and distortions caused by optics

Report on the Workshop
TOWARDS AN INTEGRATED DISCOMFORT GLARE MEASURE BASED ON THE HUMAN VISUAL SYSTEM

Conveners: Gilles Vissenberg, NL, Maurice Donners, NL

Opening of the workshop by Gilles Vissenberg

An integrated glare measure for various lighting applications has been identified as a top priority topic in the CIE Research strategy. Preferably, such a measure would be based on a model of the human visual system. Such a glare measure has several advantages:

- It would be applicable to all applications:
    - This is a huge simplification compared to the current situation with 50+ glare models. A single glare measure would promote the use of the glare measure in lighting design, in a way similar to the successful adoption of UGR for indoor lighting applications.
    - This would enable cross-learning between application areas and speed up scientific progress.
- It would be applicable to all light sources:
    - No more revisions needed after the introduction of new technologies / application conditions.
- No more phenomenological fitting parameters, only physiological parameters
    - This would improve our understanding of and communication about lighting quality and comfort

Overview of the current glare measures

- Discomfort glare indoor (JTC7) – **Yukio Akashi**
    - In indoor lighting, the unified glare rating (UGR) has been the most widely and successfully adopted glare measure since 1995. With the introduction of LEDs in lighting, the applicability of UGR to LED luminaires has been questioned. One of the main issues was that UGR tended to underestimate the glare sensation provoked by strongly non-uniform luminaires, for instance luminaires consisting of arrays of directly visible LEDs. JTC7 recently published report CIE 232-2019 that solves this issue by proposing a luminance measurement protocol to determine the glare source area.
- Discomfort glare outdoor (TC 4-33) – **Stephan Voelker**
    - There are many measures for glare from vehicle and road lighting. These measures are very different, sometimes based on unclear data, produced by very different methods. Especially the large interpersonal differences in glare perception make data gathering and analysis difficult. Because there is no convergence to or agreement about a preferred measure, discomfort glare measures are rarely used in outdoor lighting design, although there is a clear need. Further research, providing credible data from proper experimental methodologies and a revised discomfort glare model is therefore needed.
- Discomfort glare by daylight in buildings (TC 3-56) – **Toshie Iwata/Clotilde Pierson**
    - An overview was given of the many daylight glare models that have been proposed. This overview is one of the main results of TC 3-56, which intends to finish the report by the end of 2019.

The elements of a discomfort glare model based on the human visual system – Maurice Donners

Current discomfort glare models are all equations describing a fit between discomfort as reported by test participants and specific geometrical and photometrical properties of the glare source(s). These fits have however been made for limited ranges of these properties. Applying these models in slightly different circumstances (e.g. a different level of background luminance) or to different light source (e.g. a smaller source or a peak luminance) will give invalid, or at least not validated results. Recent publications about discomfort glare modelling indicate possible directions for an integrated glare model. Discomfort glare models based on the mechanisms by which our visual system perceives luminance distributions would be more robust against changes in light sources or circumstances. The responsible neural mechanism, receptive fields, can be mathematically modelled and a glare model based on this has been proposed by Donners et al (2015, 2016) with further work by Scheir et al. (2016) and Safdar et al. (2016). Taking luminance images as input, these models have been shown to correlate well in applications as diverse as lighting for roads, offices, indoor sports and warehouses. Although there are still quite some issues to resolve, this seems to be a promising avenue, as it can provide synergy and cross-learning between the different application areas and provide a model which is robust against future changes in lighting technology.

Next steps – discussion led by Gilles Vissenberg

Aside from the visual system model itself, different workflows need to be developed for different user types:

- *Lighting product designers need to specify the glare quality level of a luminaire*. This requires a set of standard applications and product datasheets that contain a glare number relating to such a standard application (similar to the definition of UGR in Europe). Furthermore, product downloads will need to contain luminance distributions or sufficient other photometric data that can be imported in lighting design software.
- *Lighting designers/installers need to predict glare in a non-existing lighting installation.* This requires software to calculate luminance distributions and luminance input from luminaire datasheets.
- *End-users (occupants, owners, regulators, …) need to evaluate glare in an existing lighting installation.* This requires luminance cameras with a high dynamic range, a high resolution, and a large field of view.

This means a lot of work!

- At the input side:
  - Luminance images: camera hardware and simulation software
  - Task classification (reading on paper, cycling, playing tennis…)
  - Observer classification (age, sensitivity, …)
  - Translation of task and observer parameters to visual model parameters
- The visual system model:
  - There are many parameters linked to optics of the eye, photoreceptors, and neurons, though most of these parameters may be determined directly from physiology, and are known from vision research and neurology.
  - The model needs to be tested with experimental data from all application areas
- At the output side:
  - Limiting values need to be defined for all applications (but for some applications these values may be directly derived from existing limiting values)

The following proposal for ToR of a new D3/D4 JTC was discussed:

A perception-based discomfort glare measure can be applied to various applications and lighting technologies. The aim of the proposed Technical Committee is

- To create an overview of relevant elements of a visual system model for quantifying discomfort glare;
- To create an overview of elements in the glare evaluation workflow for lighting designers, installers, luminaire designers and end users;
- To identify the knowledge and technology gaps in the visual system model and glare evaluation workflow that need to be researched;
- To create a minimum viable model and workflow that could be used to evaluate discomfort glare;
- To indicate next steps that would be needed to improve the minimum viable model.

The presented model was enthusiastically received and a large (10+ people) group of workshop attendants indicated that they would be willing to actively contribute to the proposed JTC. On the other hand, the fear was expressed by some that the proposed TOR was too ambitious and several people expressed their worry that the formation of a JTC based on these TOR might lead to a TC without an ending. The scope should be sharpened to a goal that is recognized to be feasible within 4 years.

References

DONNERS, M.A.H., VISSENBERG, M.C.J.M., GEERDINCK, L.M., VAN DEN BROEK-COOLS, J.H.F., BUDDEMEIJER-LOCK, A. (2015): A psychophysical model of discomfort glare in both outdoor and indoor applications. Proceedings of 28th Session of the CIE, Manchester, UK, 1602–1611.

DONNERS, M.A.H., VISSENBERG, M.C.J.M., GEERDINCK, L.M., VAN DEN BROEK-COOLS, J.H.F., BUDDEMEIJER-LOCK, A. (2016): A psychophysical model of discomfort glare for both indoor and outdoor applications. Proceedings of CIE 2016 “Lighting Quality and Energy Efficiency”, Melbourne, Australia, 142–151.

SCHEIR, G.H., DONNERS, M., GEERDINCK, L.M., VISSENBERG, M.C.J.M., HANSELAER, P., RYCKAERT, W.R. (2016): Visual discomfort prediction based on receptive fields. Proceedings of CIE 2016 “Lighting Quality and Energy Efficiency”, Melbourne, Australia, 195–203.

SAFDAR, M., MUGHAL, M.F., YANG, Y., LUO, M.R. (2016): The human vision model to predict discomfort glare from luminance image. Proceedings of CIE 2016 “Lighting Quality and Energy Efficiency”, Melbourne, Australia, 125–131.