CIE liaison report to the 24th session of CCU

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Since the last meeting of CCU the International Commission on Illumination (CIE) was involved in the preparation of the revised SI at different levels. In a joint activity, experts from CIE and CCPR have drafted the revised version of the BIPM monograph "Principle Governing Photometrie". The revised document was published on the World Metrology Day 2019 by CIE as Technical Report 018:2019 "Basis of Physical Photometry, 3rd Edition" and by BIPM as “Principles Governing Photometry, 2nd Edition. (https://www.bipm.org/utils/common/pdf/rapportBIPM/RapportBIPM-2019-05.pdf). The document refers to the revised SI by including the defining constant K_{cd}. It introduces additional standard observers, including the mesopic observer for light adaption level between scotopic (night vision) and photopic (day vision) and an observer for 10° photopic vision, applicable for very specific applications. Also, a new chapter on the relation between photochemical and photobiological quantities and photometric quantities is introduced, referring to Appendix 3 of the SI brochure.

CIE has contributed to Appendix 3 of the 9th edition of the SI Brochure. It is an important document for the stakeholders of CIE as it provides clear guidance on the use of quantities and SI units in the field of photobiology and photochemistry. As an example, the new CIE Standard S 026:2018 "CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light" defines a set of quantities that shall be used for quantifying the lighting levels for stimulating non-visual effects (i.e. circadian rhythm stimulated by light, pupil reflex, daytime alertness, etc."). All quantities are expressed in SI-units referring to Appendix 3 of the SI-Brochure, avoiding the introduction of new units (i.e. Mesopic-lux, rhodopic-lumen, etc.).

Appendix 3 of the SI Brochure (https://www.bipm.org/utils/common/pdf/si-brochure/SI-Brochure-9-App3-EN.pdf) proposes two systems for expressing photobiological and photochemical effects:

- A spectral radiometric system that relates to the optical power, irradiance, etc. using the units W, $W{\cdot}m^{-2}$, etc.
- A spectral photon system that relates to photon flux, photon irradiance, etc. using the units s^{-1}, $s^{-1}{\cdot}m^{-2}$, etc.

In "classical" radiometry, the first system is most commonly used. Experts that are interested in light interaction at a molecular level will typically use the latter system. In this context, a new field of application is emerging that deals with quantifying light for horticultural applications. Indeed, the introduction of LEDs offers unique opportunities for varying spectral distributions to match the needs of specific plants and to stimulate their growth, blooming and harvesting process. Most scientific publications and guidelines express the photon flux by defining values through the Avogadro constant N_A. Thus, in the field of horticultural lighting it is common to read photon quantities expressed in $\mu mol{\cdot}s^{-1}$.

The revised SI has had little impact on the partucular work of CIE. The uncertainties in the realization of radiometric quantities is in the order of 1e-4, whereas the changes in the practical realization of the unit Watt is in the order of 2e-7. However, CIE has changed the recommendation for the realization of the CIE standard illuminant A. In fact, CIE had introduced standard illuminant A in 1924 by defining a spectral distribution based on a blackbody radiator of T = 2848 K. In the past, whenever any of the constants h, c and k changed, CIE had to change the recommendation for the temperature of the blackbody to maintain the same spectral distribution (i.e. through Planck's law). The last recommendation based on ITS-90 was T = 2856 K (rounded from the value 2855.542 K). With the revised SI this value changes by -46 mK to become 2855.496 K. CIE has therefore changed the recommendation on the realization of CIE standard illuminant A to the "final" value of 2855.5 K.

One of the highlights for CIE since the last CCU meeting has been the participation at the 26th CGPM. A delegation consisting of the CIE President, CIE General Secretary, Division 2 Director and D2 Director-elect had the opportunity to attend to this historical event.

In respect to the question of the definition of "unit", CIE made a consultation among their experts. Most experts expressed their opinion that a unit is simply a specific reference quantity. The expression "the distance between a lamp and a detector is 4.2 m" means that this length is 4.2 times the length of a "reference" meter. Expressions such as "the *value* of the length between a lamp and a detector is 4.2 m" are very uncommon.

In the field of optics, many quantities are defined as the quotient of two quantities of the same kind. For example, luminous transmittance is defined as the quotient of the luminous flux transmitted by a surface and the incident luminous flux. As a consequence, the luminous transmittance is simply a (mathematical) number with a unit one.

Finally, photometric quantities make extensive use of solid angles. In particular, the luminous intensity (cd) is the quotient of the luminous flux propagating through a solid angle and the element of solid angle (1 cd = 1 lm sr^{-1}). A fundamental relation is the so-called photometric distance law, relating the illuminance E (light incident on a surface) to the intensity I (light emitted by a source in a given direction within a solid angle). Most textbooks and lectures describe the relation as $E = I \cdot d^{-2}$, where d is the distance between the source and the surface. In terms of quantity calculus this writes as " lx = cd m^{-2} ". Mathematically, this is correct as the solid angle is defined as the ratio of a surface area by the square of the radius and thus simply dimensionless. However, the expression " lx = cd m^{-2} " confuses the photometric community and thus the concept of quantity calculus is not commonly used in this field.