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COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

PROCEEDINGS of the CIE Expert Symposium on

Advances in Photometry and Colorimetry

7-8 July 2008

Hotel Concorde
Turin, Italy

CIE x033:2008 **CD-ROM INCLUDED**

THE INTERNATIONAL COMMISSION ON ILLUMINATION

The International Commission on Illumination (CIE) is an organisation 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 organisations concerned with matters related to the science, technology, standardisation and art in the fields of light and lighting.

The work of the CIE is carried on by seven Divisions each with about 20 Technical Committees. 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 reviewed, reported and plans are made for the future. The CIE is recognised as the authority on all aspects of light and lighting. As such it occupies an important position among international organisations.

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 7 Divisions, ayant chacune environ 20 Comités Techniques. 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 internationaler Mittelpunkt 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 in 7 Divisionen, jede mit etwa 20 Technischen Komitees, geleistet. 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 von der ganzen Welt anerkannt.

Tagungen werden alle vier Jahre abgehalten, in der die Arbeiten der Divisionen überprüft und berichtet und 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.

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co-hosted by the Instituto Nazionale di Ricerca Metrologica
and
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Expert Symposium 2008 Advances in Photometry and Colorimetry

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KEYNOTE PAPER

GONIOPHOTOMETRY: NEW CHALLENGES AND NOVEL SOLUTIONS

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1. INTRODUCTION

Goniophotometric measurements are carried out using three different geometries between the light source and the photometer: (i) large distance, to collect values of angular distributions of luminous intensity $I(\theta,\phi)$ by a photometer held in a fixed position, (ii) medium distance, to measure the pattern of illuminances $E(\vartheta,\varphi)$ on a fictitious envelope by moving a photometer and evaluation of luminous flux values with low uncertainty, (iii) short distance, to determine the angular distribution of luminance $L(x,y,\theta,\phi)$ for each element of the light emitting surface of the source by a moving imaging photometer.

The constructions of goniophotometers, calibration, data acquisition and principle models for an evaluation of the quantities are subject of this report. Gonioreflectometers for a determination of the indicatrix of reflectance are not included.

2. LUMINOUS INTENSITY

Today, the design for a lighting of sceneries is evaluated from angular distributions of the luminous intensity $I(\theta,\phi)$ assigned to luminaires and sources. The angles $0 \le \theta \le \pi$, $0 \le \phi \le 2\pi$ are spherical coordinates $\{d,\theta,\phi\}$ of a Cartesian coordinate system allocated to the source. Other plane-systems are also internationally agreed with denoted values of the angles to state the luminous intensity distribution in a defined format.

Luminous intensity is a property of a "point-like" source, which can be calculated from the illuminance even for sources with extended emitting areas or collimated beams, provided the distance is sufficiently large.

Only two types [1] of traditional goniophotometers perform large distance measurements. In any case, the photometer head is mounted in a fixed position with an arbitrary large distance to the source, while the latter is rotated about a vertical axis.

The simplest goniophotometer rotates sources additionally about a horizontal axis, which alters significantly the operational conditions and can change the luminous flux value and the relative intensity distribution e.g. of LED-clusters or high-power LEDs. An additional photometer mechanically connected to the moving source acts as monitor to compensate for changes of the luminous flux values.

The hugest goniophotometer moves a large flat mirror around the horizontal axis and the photometer head measures only the reflected image of the source. The source is placed in the effective centre of the goniophotometer and rotates about a vertical axis. Different constructions have either the mirror or the source located on the horizontal axis and the holder of the one or the other is moved on a circle about this axis.

Measurements with these types of goniophotometers are time-consuming and yet only a minor part of the full solid angle is covered by a complete measurement (e.g. a photometer with aperture 15 mm radius in 15 m distance may measure at 10 000 positions and covers just 0.25 % of the full solid angle). Stray-light, polarization and spectral mismatch from the reflectance of the mirror increase the uncertainty associated to evaluated luminous flux values.

Usually, the luminous intensity distributions $I_x^*(\theta,\phi)$ of luminaires are listed in a "normalized" presentation: the values are stated for an internal source producing just 1000 lm.

$$I_x^*(\theta,\phi) = 1000 \cdot I_x(\theta,\phi) / \Phi_x \qquad (1)$$

The luminous flux Φ_x emitted by the internal source during measurement of the luminous intensity distribution is determined by separate measurements or evaluated from the luminous intensity distribution $I_x(\theta,\phi)$ and the efficiency η of the luminaire.

$$\Phi_x = \frac{1}{\eta} \int_0^{2\pi} \int_0^{\pi} I_x(\theta,\phi) \sin\theta \,\partial\theta\, \partial\phi \qquad (2)$$