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THE MEASUREMENT OF ABSOLUTE LUMINOUS INTENSITY DISTRIBUTIONS

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SUMMARY

This technical report contains the terminology required for measurements of luminous intensity distributions. It also summarizes the principles of luminous intensity measurements and the requirements for the photometer heads employed for such measurements. The coordinate systems used for the measurement and representation of luminous intensity distributions are described. The types of goniophotometers, possibilities for angle encoding, characteristics of the photo-electronic system and the acquisition and processing of the data in measurements of luminous intensity distributions are discussed in detail. Other subjects covered are the power supply, the measuring conditions and the execution, correction and representation of luminous intensity distribution measurements. The various sections contain sufficient data on the required characterization of goniophotometers.

The report is based mainly on the Technical Report of CIE Technical Committee TC-2.2 on "Methods of characterizing the performance of radiometers and photometers [1] as well as on CIE publications 24 [2], 27 [3] and 43 [4]. The terminology is largely based on the International Lighting Vocabulary [5].

RESUME

LA MESURE DES DISTRIBUTIONS D'INTENSITE LUMINEUSE ABSOLUE

Ce rapport technique contient la terminologie nécessaire pour la mesure des distributions d'intensité lumineuse. Il résume aussi les principes de mesure de l'intensité lumineuse et les qualités requises pour la tête photométrique utilisée pour de telles mesures. Les systèmes de coordonnées utilisés pour la mesure et la représentation des distributions d'intensité lumineuse sont décrits. Les types de goniophotomètre, les possibilités de repérage angulaire, les caractéristiques du système électronique et celles de l'acquisition et du traitement des données dans les mesures de distribution de l'intensité lumineuse sont décrites en détail. Les autres sujets traités sont l'alimentation électrique, les conditions de mesures et leur exécution, la correction et la représentation des mesures de distribution d'intensité lumineuse. Les différentes sections contiennent des données suffisantes sur les caractéristiques requises pour les goniophotomètres.

Ce rapport s'appuie principalement sur le rapport technique du comité technique 2.2 de la CIE "Methods of characterizing the performance of radiometers and photometers" [1] ainsi que sur les publications CIE no 24 [2], 27 [3], et 43 [4]. La terminologie est largement empruntée au Vocabulaire International de l'Eclairage [5].

ZUSAMMENFASSUNG

DIE MESSUNG DER ABSOLUTEN LICHTSTÄRKEVERTEILUNG

Dieser Technische Bericht enthält zunächst die für Lichtstärkemessungen wichtigen Begriffsbestimmungen. Danach werden die Prinzipien der Lichtstärkemessung und Angaben über die dementsprechend zu verwendenden Photometerköpfe zusammengestellt. Die für die Messung und Darstellung der Lichtstärkeverteilung verwendeten Ebenensysteme werden angegeben. Besonders werden die Arten von Goniophotometern, die Möglichkeiten der Winkelerfassung, Aussagen über die Photoelektronik und die Registrierung und Datenverarbeitung bei der Messung der Lichtstärkeverteilung behandelt. Auch Aussagen zur Spannungsversorgung, zu den Meßbedingungen und zur Durchführung, Korrektur und Darstellung der Lichtstärkemessungen werden gemacht. Bei den einzelnen Kapiteln werden ausreichende Angaben über die notwendige Kennzeichnung von Goniophotometern aufgeführt.

Dieser Bericht stützt sich vor allem auf den Technischen Bericht des CIE Technischen Komitees TC-2.2 "Methods of characterizing the performance of radiometers and photometers" [1] sowie auf die CIE-Publicationen No. 24 [2], No. 27 [3], und No. 43 [4]. Bei den Begriffsbestimmungen sind die Angaben des Internationalen Wörterbuchs der Lichttechnik [5] weitgehend zugrunde gelegt.

1. TERMINOLOGY

1.1 QUANTITIES [5]

1.1.1 LUMINOUS INTENSITY

The luminous intensity I (of a source in a given direction) is the quotient of the luminous flux $d\phi$ leaving the source, propagated in an element of solid angle containing the given direction, by the element of solid angle $d\Omega$.

$$I = d\phi/d\Omega \quad (1)$$

Symbol: I, I_v

Unit : Candela (symbol: cd)

1.1.2 ILLUMINANCE

The illuminance E at a point of a surface is the quotient of the luminous flux $d\phi$ incident on an element of the surface dA containing the point, by the area of that element.

$$E = d\phi/dA \quad (2)$$

Symbol: E, E_v

Unit : Lux (symbol: lx)

1.1.3 LUMINANCE

The luminance L (in a given direction, at a point on the surface of a source or a receptor, or at a point in the path of a beam) is the quotient of the luminous flux, $d^2\phi$, leaving, arriving at, or passing through an element of surface dA at this point and propagated in directions defined by an elementary cone $d\Omega$ containing the given direction, by the product of the solid angle of the cone and the area of the orthogonal projection of the element of surface on a plane perpendicular to the given direction.

$$L = \frac{d^2\phi}{d\Omega \cdot dA \cdot \cos\epsilon} \quad (3)$$

ϵ Angle between the normal to the area and the direction considered

Symbol: L, L_v

Unit : Candela per square meter (symbol: $\text{cd} \cdot \text{m}^{-2}$)

1.2 SURFACE OF LUMINOUS INTENSITY DISTRIBUTION

The surface of luminous intensity distribution is the surface formed by the extremities of all the radius vectors drawn from a common origin, the length of each radius vector being proportional to the luminous intensity of the source in the corresponding direction.

1.3 LUMINOUS INTENSITY DISTRIBUTION CURVE

The luminous intensity distribution curve (for a lamp or light fitting) is the curve, generally polar, which represents the luminous intensity in a plane passing through the source, as a function of the angle measured from some given direction.

Note:

- a) When the source has a symmetrical luminous intensity distribution, the plane is generally a meridian plane.
- b) When the reference direction is vertical, angles are measured from the downward vertical.

1.4 ISOCANDELA DIAGRAM

The isocandela diagram is the array of isocandela curves. These are curves traced on an imaginary sphere with the source at its centre and joining all the points corresponding to those directions in which the luminous intensity is the same, or a plane projection of this curve.

1.5 MEASURING FIELD AND MEASURING-FIELD ANGLE IN LUMINANCE MEASUREMENTS [6]

The measuring field of a luminance meter is the totality of all points in the external space that radiate into the acceptance area and are sensed by the detector and evaluated by it with a direction-dependent responsivity of at least 10% of the maximum responsivity.

Note:

The measuring field is usually circular. Other fixed or variable shapes are also possible, however (e.g., trapezoidal, rectangular, quadratic).

The measuring-field angle α is the angle under which the measuring field appears when viewed from the measuring plane.

1.6 TERMS FOR MEASURING INSTRUMENTS

1.6.1 PHOTOMETER

A photometer is an instrument for the measurement of photometric quantities.

Note:

Photometric quantities are quantities that can be derived from radiometric quantities by means of certain conventions (law of additivity, $V(\lambda)$ function, definition of the unit of luminous intensity) [7].

1.6.2 GONIOPHOTOMETER

A goniophotometer is a photometer for the measurement of the angular dependence of a photometric quantity.

Note:

A goniophotometer for the measurement of the spatial luminous intensity distribution is also called a luminous intensity distribution photometer.

A goniophotometer for the measurement of the spatial luminous intensity distribution usually consists of a mechanical device for the support and positioning of the light source and the photometer head and one (or more) - often moveable - photometer heads together with the necessary transducers and readouts as well as devices for acquiring and processing data.

1.6.3 PHOTOMETER HEAD

A photometer head consists of a light-sensitive detector and facilities for the spectral evaluation (e.g., colour filters) or for the spectral dispersion (e.g., gratings) of the light. It may also contain facilities for the directional evaluation of the light, e.g., diffusing windows, lenses, apertures. The light-sensitive detector converts the incident light into an electrical quantity.

1.6.4 ACCEPTANCE AREA

The acceptance area is the area of the photometer head which is receiving and directionally evaluating the incident light.

1.7 PHOTOMETRIC CENTRE (OF A LAMP OR LUMINAIRE)

The photometric centre of a lamp or luminaire is the reference point from which the photometric distance law is applicable (see section 2.1). For lamps the photometric centre corresponds to the centre of gravity of the light-emitting area. For lamps with reflectors the photometric centre is situated at the centre of the exit aperture. For luminaires data about the photometric centre are contained in the Technical Report "Photometry of Luminaires" [8].

Note:

For the measurement of the luminous intensity distribution the photometric centre of the light source should lie on the crosspoint of the axes of the goniophotometer.

1.8 STRAY LIGHT

Stray light is the part of the luminous flux incident on and evaluated by the photometer head that does not reach the measuring area of the photometer head in a direct line from the light source.

1.9 LIMITING PHOTOMETRIC DISTANCE

The limiting photometric distance is the allowed minimum distance between light source and photometer head, for which the measuring error is smaller than the permitted error.

2. PRINCIPLES OF LUMINOUS INTENSITY MEASUREMENTS

Luminous intensities can be measured via a measurement of the illuminance and calculation via the photometric distance law, or by integration of the luminance. Both possibilities follow from the basic law of photometry.

2.1 PHOTOMETRIC DISTANCE LAW

The photometric distance law allows one to determine the luminous intensity according to

$$I = E \cdot r^2 / (\cos \varepsilon_2 \cdot \Omega_0) \quad (4)$$

I	Luminous intensity in the direction to the acceptance area
E	Illuminance on the acceptance area
r	Distance between light source and acceptance area
ε_2	Angle of incidence, measured relative to the normal to the acceptance area
Ω_0	$1sr$ (unit solid angle)

The quantity Ω_0 is used in accordance with the fourth edition of the CIE vocabulary (in preparation), which permits its optional use. There is no complete agreement on the need to use Ω_0 , which may equally well be omitted or replaced by the number 1.

The Equation (4) only applies for distances r that exceed the limiting photometric distance.

measuring error depends on:

- the largest dimension of the light source
- the spatial and directional luminance distribution of the light source
- the spatial and directional responsivity of the acceptance area of the photometer head.

Note 1:

For a circular emitting area with constant luminance (Lambertian radiator) and a circular receiving area the limiting photometric distance r is taken as 10 times (5 times) the diameter of the larger of the two areas. In this case the error of I in the direction of the axis of the disk in the calculation according to the photometric distance law is less than 0,5 % (1 %).

Note 2:

For narrow luminous intensity distributions the limiting photometric distance is greater than for a Lambertian radiator [9,10].

Note 3:

When calculating the luminous intensity according to equation (4) it should be ascertained, if necessary by means of measurements at different distances, whether the limiting photometric distance is exceeded. For goniophotometers with stationary photometer heads for which the measuring distance is smaller than the limiting photometric distance, the measuring distance can be extended by the use of a sufficiently large deflecting mirror. The polarization of the light by the deflecting mirror as well as the spectral reflectance of the deflecting mirror must be taken into account.

Note 4:

When the luminous intensity is derived according to equation (4) it is important to limit the incidence of stray light on the photometer head by means of baffles between the light source and the photometer head.

All parts of the background of the light source that are visible from the measuring area of the photometer head should be as black as possible [11]. As large a distance as possible should be kept between the light source and the background (Fig. 1).

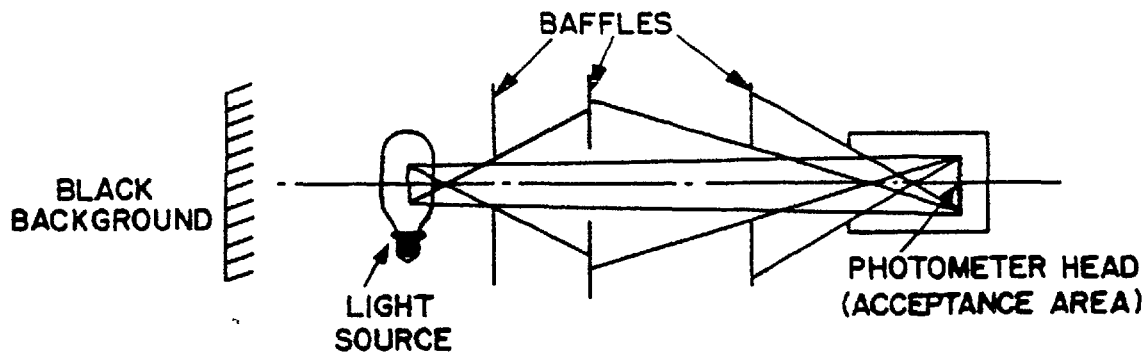


Fig. 1 Reduction of stray light in luminous intensity measurements

2.2 LUMINANCE INTEGRATION

Luminous intensity can be determined by means of luminance integration:

$$I = \int_{(A_1)} L(\epsilon_1) \cdot dA_1 \cdot \cos \epsilon_1 \quad (5)$$

A_1	emitting area
dA_1	element of the emitting area
$L(\epsilon_1)$	luminance of the area element dA_1 in the direction in which the luminous intensity is to be determined
ϵ_1	emitting angle of the area element dA_1 between its area normal and the direction for which the luminous intensity is to be determined.

3. TYPES OF PHOTOMETER HEADS

Depending on the theoretical relationship used for the determination of the luminous intensity (equation (4) or (5)), there are two types of photometer heads in use in goniophotometers.

3.1 PHOTOMETER HEAD FOR MEASURING ILLUMINANCE

For the determination of the luminous intensity according to equation (4) a photometer head for the measurement of illuminance must be employed. Such a photometer head must comply with the following requirements [1,6]:

- good fit of the relative spectral responsivity to the $V(\lambda)$ function (error f_1)
- linearity (error f_3)
- low fatigue (error f_5)
- independence from the ambient temperature (temperature coefficient α)
- as small a solid angle as possible for the acceptance area of the photometer head as seen from the photometric centre.

The terminology for the errors f_1 to f_5 and a classification of illuminance meters have been compiled by the CIE [6].

3.2 PHOTOMETER HEAD FOR LUMINANCE INTEGRATION

3.2.1 CONSTRUCTION

3.2.1.1 Photometer head with lens [12]

A photometer head for luminance integration by means of a lens consists of a lens with a diameter larger than the light source and a detector (including filter for $V(\lambda)$ correction) that is positioned behind a diaphragm at the focal point of the lens (also called the field stop) (Fig. 2). The measuring field angle α of such a photometer head is

$$\alpha = 2 \cdot \arctan(a/2f) \quad (6)$$

f focal length of lens

a diameter of measuring-field stop

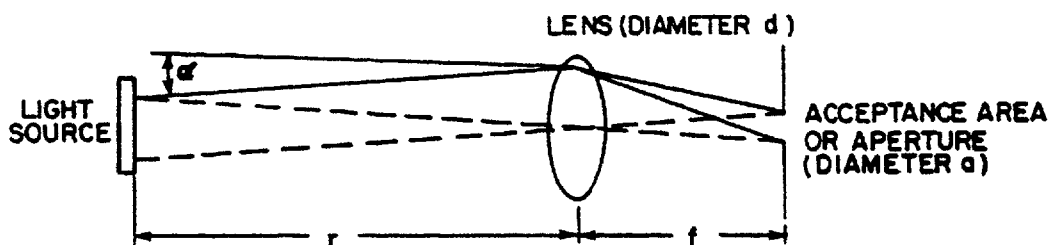


Fig. 2: Photometer head with lens for luminous intensity measurements by means of luminance integration

The largest diameter D of a light source that can be measured with a photometer head for luminance integration by means of a lens is given by

$$D \leq d - r \cdot a/f \quad (7)$$

D largest permissible extent of the light source

d diameter of the lens

r distance between lens and light source