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Fine ceramics (advanced ceramics, advanced technical ceramics) — LED light source for testing semiconducting photocatalytic materials used under indoor lighting environment

Céramiques techniques — Source de lumière LED pour les essais des matériaux photocatalytiques semi-conducteurs utilisés dans un environnement d'éclairage intérieur

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Foreword

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This document was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Photocatalytic performance depends on testing light sources. To fairly evaluate photocatalytic performance, an ISO Standard on testing light sources for photocatalytic materials used under indoor lighting environments was developed based on the lighting environment prevalent at the time of its drafting (ISO 14605[1]). Fluorescent lamps are specified as a testing light source in the document. However, in order to achieve a low-carbon society and reduce the environmental load of mercury, production of this type of lamp will stop in the near future. Light sources for indoor lighting will change from this type of lamp to white LED lamps. According to a global lighting market report, the LED share in general lighting was 45 % in 2016 and almost 70 % in 2020.[11] Another report estimates the 2018 share of solid-state light products, including LEDs, as 64 %, and predicts that by 2030 this will rise to 96 %.[12] This document has been developed based on this background.

Fine ceramics (advanced ceramics, advanced technical ceramics) — LED light source for testing semiconducting photocatalytic materials used under indoor lighting environment

1 Scope

This document specifies light emitting diodes (LED) for light source and radiometers used in the performance evaluation of semiconducting photocatalytic materials under indoor LED lighting environments in a laboratory. Light sources for indoor lighting environments do not include sunlight passing through window glass.

This document does not replace ISO 14605.[1] Either document can apply depending on the lighting environment in which the photocatalytic material is used.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
indoor lighting environment
lighting environment with artificial light source for general lighting service that does not include sunlight

[SOURCE: ISO 14605:2013, 3.3[1]]

3.2
light emitting diode
LED
solid-state device embodying a p-n junction, emitting incoherent optical radiation when excited by an electric current

[SOURCE: IEC 60050-845:1987, 845-04-40[3]]

3.3
correlated colour temperature
temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions

Note 1 to entry: The correlated colour temperature is expressed in kelvins (K).

Note 2 to entry: The recommended method of calculating the correlated colour temperature of a stimulus is to determine on a chromaticity diagram the temperature corresponding to the point on the Planckian locus that is intersected by the agreed isotemperature line containing the point representing the stimulus.

Note 3 to entry: Reciprocal correlated colour temperature is used rather than reciprocal colour temperature whenever correlated colour temperature is appropriate.

[SOURCE: IEC 60050-845:1987, definition 845-03-50[3]]

3.4
colour rendering index
measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation

Note 1 to entry: In German, the term “Farbwiedergabe-Index” is also applied to colour reproduction.

[SOURCE: IEC 60050-845:1987, definition 845-02-61[3]]

3.5
CIE 1974 general colour rendering index
Ra
mean of the CIE 1974 special colour rendering indices for a specified set of eight test colour samples

[SOURCE: IEC 60050-845:1987, definition 845-02-63[3]]

3.6
spectral luminous efficiency
$V(\lambda)$ for photopic vision
<monochromatic radiation of wavelength λ> ratio of the radiant flux at wavelength λ_m to that at wavelength λ such that both radiations produce equally intense luminous sensations under specified photometric conditions and λ_m is chosen so that the maximum value of this ratio is equal to 1

Note 1 to entry: Unless otherwise indicated, the values used for the spectral luminous efficiency in photopic vision are the values agreed internationally in 1924 by the CIE, completed by interpolation and extrapolation, and recommended by the International Committee of Weights and Measures (CIPM) in 1972.

[SOURCE: IEC 60050-845:1987, definition 845-01-22, modified[3]]

3.7
general $V(\lambda)$ mismatch index
f'_1
index describing the deviation of the relative spectral responsivity of the photometer from the $V(\lambda)$ function

[SOURCE: ISO/CIE 19476:2014, 3.2.2[2]]

3.8
directional response index (cosine response index) for illuminance
f_2
index describing the responsivity of the photometer to light incident at an angle other than normal (the cosine law for general purpose illuminance meters)

[SOURCE: ISO/CIE 19476:2014, 3.2.5[2]]

4 Light sources

The following requirements apply to white LED lamps used as a testing light source of photocatalytic materials under indoor LED lighting environments.

a) A phosphor-type LED lamp with a peak wavelength of optical radiation emitting from solid of 450 nm ± 10 nm shall be used (see A.1 for additional information).

b) A phosphor-type LED lamp with a CIE 1974 general colour rendering index *Ra* of $80 \le Ra < 90$ shall be used.

c) Correlated colour temperature of a white phosphor-type LED lamp shall be defined by a national testing light source standard for photocatalytic materials, a regional (e.g. EU) light source standard for photocatalytic materials or a light source standard of each national photocatalytic association.

   Where these standards are not published, correlated colour temperature of the white phosphor-type LED lamp shall be between 3 800 K and 4 500 K (F4000, cool white). Lighting environments in different countries are described in A.2 for additional information.

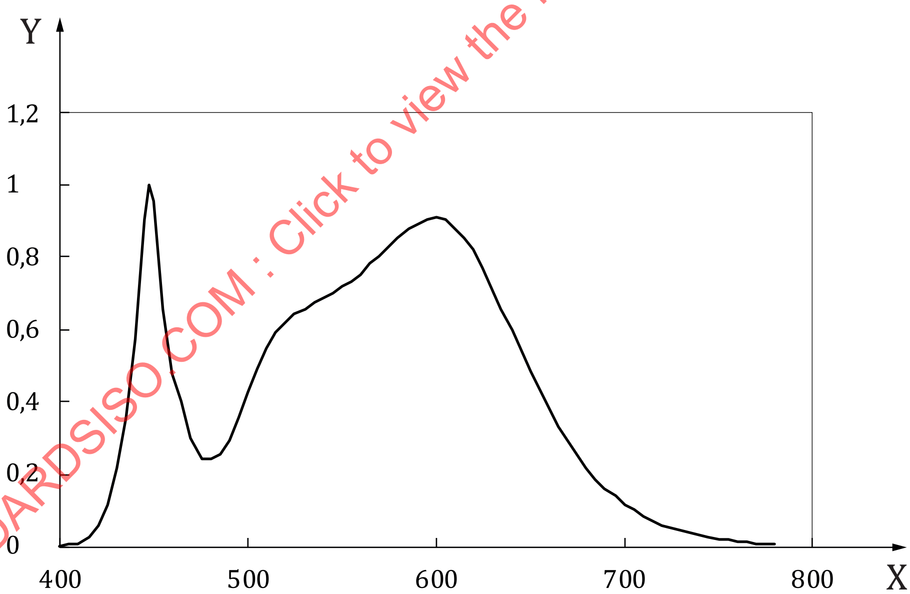
d) A phosphor-type LED lamp shall be driven by direct current (DC). An alternating current (AC)-driven phosphor-type LED lamp is not permitted.

e) If a phosphor-type LED lamp with a reflection plate is selected for the testing light source, the colour of the reflection plate shall be white.

f) If multiple white LED lamps are used to achieve a large uniform irradiation surface, at least the same white LED lamp (the same manufacturer and the same catalogue number) shall be used. A selection of white LED lamps with a peak wavelength of optical radiation emitting from solid is strongly recommended.

If the spectral distribution data of LED lamps is not obtained from the manufacturer, the peak wavelength of the optical radiation emitting from a solid shall be evaluated with a spectral irradiance meter or a spectral illuminance meter. The spectral response of a spectral irradiance meter or a spectral illuminance meter shall be calibrated with a spectral irradiance standard lamp which is traceable to the national standard.

A typical spectral distribution of white LED lamps specified by this document is shown in Figure 1.



Key

X wavelength, nm

Y relative radiant power

Figure 1 — An example of spectral power distribution of a white LED in which the correlated colour temperature is 4 000 K and CIE 1974 general colour rendering index *Ra* is 80

NOTE 1 White LEDs sold in the market are divided into two types by method of white light generation. The first is RGB type. This type of white LEDs has three LED chips which emit red, green and blue light in one LED package. The second is phosphor-type. This type of white LEDs generates white light by fluorescence of phosphor which is excited by violet light (405 nm) or blue light (450 nm) emitting from solid. The phosphor-type white LEDs using phosphors excited by blue light are commonly used in lighting environments.

NOTE 2 An example of the different characteristics of white LED lamps in the same product sold in the market is shown in Annex B. An example of an irradiation box with a large uniform irradiation surface is shown in Annex C.

5 Illuminance meters

Illuminance (E) shall be measured by an illuminance meter. The following specifications apply.

a) A conventional filter-type illuminance meter shall be used. A spectral radiometer or a spectral illuminance meter shall not be used as an illuminance meter.

b) A conventional filter-type illuminance meter with a general $V(\lambda)$ mismatch index f'_1 of ≤ 6 % shall be used.

c) A conventional filter-type illuminance meter with a directional response index (cosine response index) for illuminance f_2 of ≤ 4 % shall be used.

d) A conventional filter-type illuminance meter which has been calibrated by a national calibration laboratory or with a standard lamp which is traceable to the national measurement standard shall be used.

The importance of defining the characteristics of illuminance meters is described in Annex D.

6 Measurement and use conditions

a) The illuminance for testing shall be set at the standard value specified in each testing standard.

b) Ambient temperature and relative humidity for testing shall be set in standard conditions specified in each testing standard.

c) The illuminance shall be measured in stable conditions. The drift of illuminance shall be ≤ 1,25 %/h.

d) The illuminance shall be measured at the start and the end of the irradiation to a photocatalytic material.

e) The light source shall be replaced when the illuminance has decreased to 70 % of the initial value.

NOTE The variation of illuminance, condition c), is decided by maximum irradiation time (8 h) and illuminance level control level (±5,0 %) in irradiation.

7 Test report

The test report in each application standard on photocatalytic materials shall include at least the following information as a testing light source:

a) a reference to this document, i.e. ISO 24448:2023;

b) the kind of light source used (catalogue number, manufacturer, *Ra*, wavelength of the peak emission from solid, spectral emission data of the lamp. If possible, correlated colour temperature);

c) the kind of illuminance meter used in the measurement (catalogue number, manufacturer);

d) illuminance at the sample surface;

e) the date of the test.

Annex A
(informative)

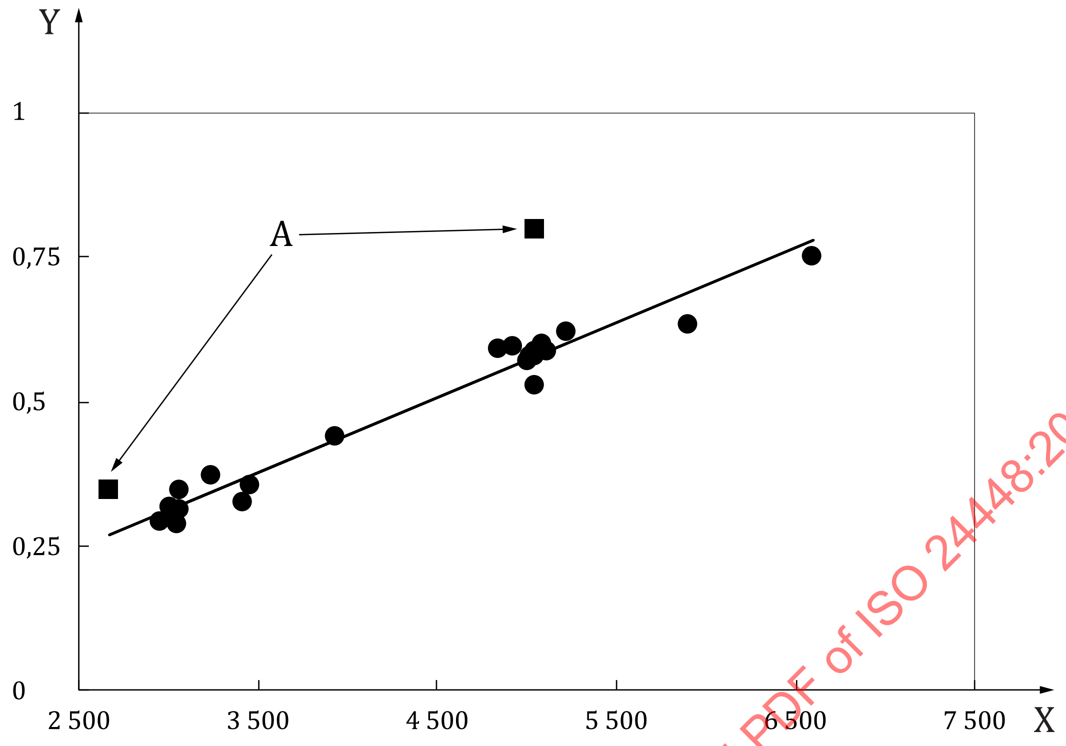
Relationship between photocatalytic performance and correlated colour temperature of light source and indoor lighting environments

A.1 Relationship between photocatalytic performance and correlated colour temperature of light source

The rate of photocatalytic reaction, which generally depends on the wavelength of the light source used for irradiation, can be estimated by the action spectrum of the reaction and spectral distribution of the light source used (these factors of the light sources for photocatalysis are summarized in CEN/TS 16599 [5]). In the case of photocatalytic reaction, a category of photochemical reactions, a reflection spectrum is used instead of the action spectrum which is not easily available. Spectral data of LED is obtained from the manufacturer. Figure A.1 shows the performance of a nitrogen-doped titanium dioxide photocatalyst thus generated, for the phosphor-type (450-nm excitation, Type PC-B as visible LED defined in CEN/TS 16599 [5]) white LED lamps with different correlated colour temperatures under the same illuminance.

The photocatalytic performance is well correlated with the correlated colour temperature of light source as shown by the ascending line in Figure A.1. Similar relationship has been observed in the case of fluorescent lamps when the ultraviolet radiation is eliminated (Type A condition defined in ISO 14605). This means that the test results obtained with different white LEDs whose emission spectra are different can be intercompared by just specifying the correlated colour temperature.

However, the two points at around 2 500 K and 5 000 K in Figure A.1 (shown as A) are clearly off the regression line. These points are generated by the phosphor-type white LED with violet light excitation (405 nm). Although the radiation at around 405 nm in wavelength does not affect illuminance measurement significantly, it activates photocatalyst much more efficiently than that of 450-nm excitation. For this reason, this document specifies the use of commonly available white LEDs whose peak wavelength from solid is 450 nm.



Key

X correlated colour temperature, K

Y photocatalytic performance, AU

A photocatalytic performance by 405 nm light emitting from solid-type white LEDs

Figure A.1 — Relationship between correlated colour temperature and photocatalytic performance generated by white LED lamps.

A.2 Indoor lighting environment in different countries

Photocatalytic performance depends on the spectrum of the light source. High correlated colour light source provides a high photocatalytic performance as shown in Figure A.1. Regulating a correlated colour temperature of testing light source in this document is the best for realization of mutual authentication system. However, it is impossible to regulate one correlated colour temperature now and in the future because of the difference of indoor lighting environment.

Indoor lighting environments differ between countries and room usage. In general, indoor lighting environments in North America and Europe use light sources of low correlated colour temperature. In Asia, high correlated colour temperature of light source is commonly used. The correlated colour temperature in offices is higher than that in private houses. This difference is based on culture differences, working performance and safety requirements. Therefore, this document does not make requirements relating to correlated colour temperature.

Annex B
(informative)

Difference in characteristics of white LED lamps in the same product sold in the market

Optical properties of white LED lamps are not clearly shown in the product catalogue or characteristic table provided by manufactures because the production process of LED chips is very sensitive. Spectral irradiance of white LED lamps in the same product is measured at the same distance, and illuminance and photocatalytic performance are calculated. The results are shown in Table B.1.

The maximum difference (maximum/minimum) of illuminance and photocatalytic performance is about 8 % and 5,6 %, respectively. On the photocatalytic performance test, the illuminance level shall be controlled within ±5,0 % in irradiation. This means selection of white LED lamps is recommended for precise evaluation on the photocatalytic performance if multiple white LED lamps are used in an irradiation box.

Table B.1 — Difference in illuminance and photocatalytic performance of white LED lamps in the same product (down light)

ID	Lot. No.	Illuminance lx	Photocatalytic performance
100–85–5K-1	A	803	0,504 4
100–85–5K-2	A	803	0,506 6
100–85–5K-3	A	805	0,503 2
100–85–5K-4	A	799	0,504 1
100–85–5K-5	A	809	0,505 0
100–85–5K-6	A	792	0,496 5
100–85–5K-7	A	837	0,524 3
100–85–5K-8	A	801	0,503 6
100–85–5K-9	A	782	0,496 7
100–85–5K-10	A	788	0,499 6
100–85–5K-11	A	823	0,523 1
100–85–5K-12	A	796	0,502 1
100–85–5K-1W	B	835	0,519 7
100–85–5K-2W	B	811	0,504 5
100–85–5K-3W	B	838	0,520 9
100–85–5K-4W	B	842	0,520 1
Average		810	0,508 4
Max./min.		1,08	1,056 0

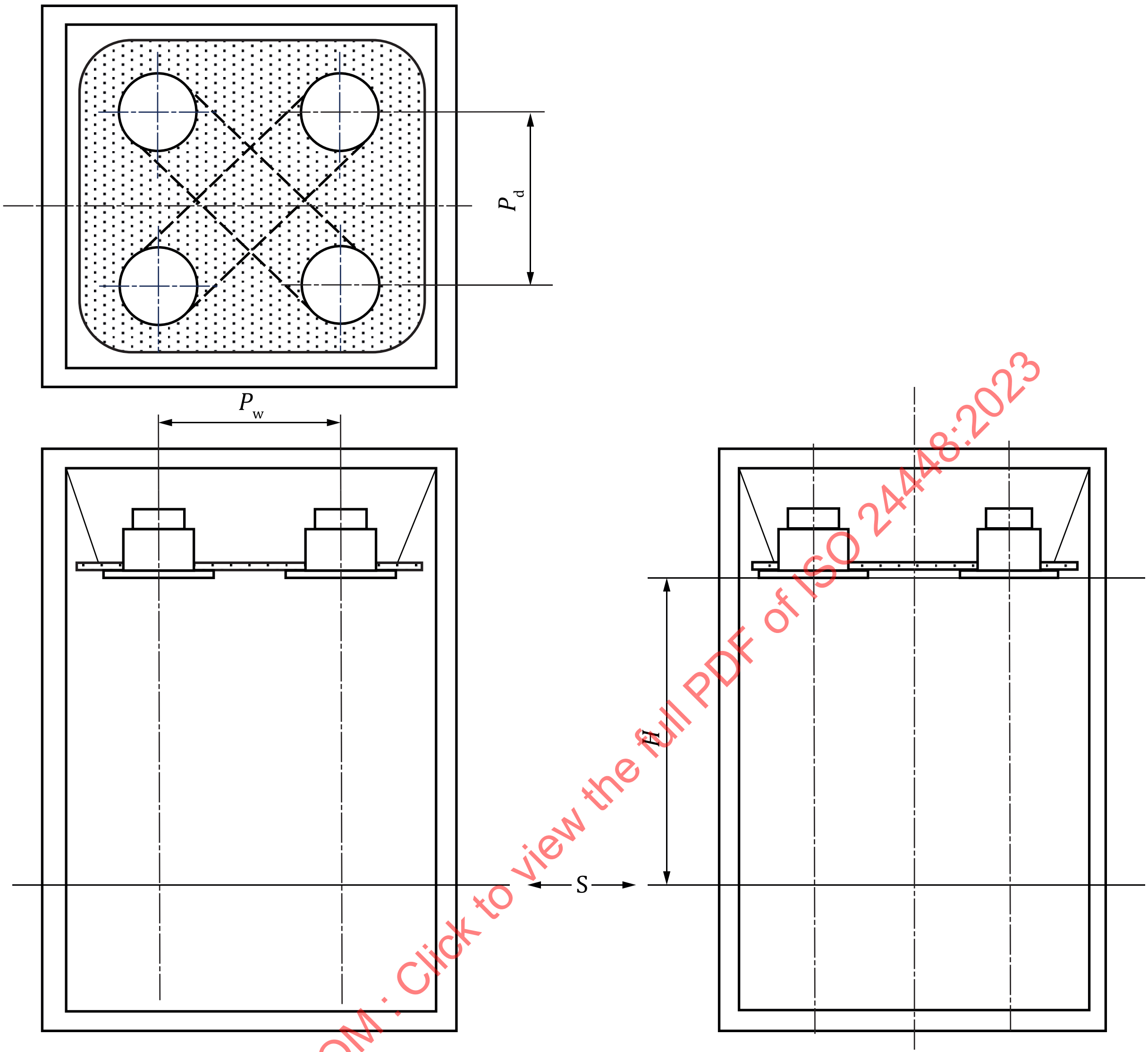
Annex C
(informative)

Example of an irradiation box with a large uniform illuminance on an irradiation surface

When a large uniform illuminance on the irradiation surface is required, such as in antibacterial or antiviral tests, multiple white LED lamps should be installed in the irradiation box. Uniformity of illuminance on the irradiation surface can be estimated by calculation software for lighting design provided by lamp manufacturers.

An example of the structure of an irradiation box with a large uniform illuminance on an irradiation surface is shown in Figure C.1. The box is a cuboid made of steel angle (96 cm wide, 90 cm deep and 120 cm high) covered with a blackout curtain. The height includes the spaces above the lighting units and below the sample stage. The upper panel and sample stage also have black or dark surface so as to minimize light reflection.

Four-white LED downlight units are installed on the upper panel of the irradiation box. The downlight unit used is 90 mm o.d. and 42 mm high in size, and provides 1 020 lm (5 000 K, *Ra* 85, 9,9 W) with an 85° beam angle. The illuminance can be adjusted by changing the height of the panel and moving each lighting unit radially on the panel. Figure C.2 shows an example of illuminance distribution obtained on the sample stage. With the distance between optical axis of downlights (P_w, P_d) 50 cm and the height of downlight panel (H) 89,5 cm, the area within 50 cm circle can be used for testing, where the relative illuminance (E_{max} = 1,0) is higher than 0,9.



Key

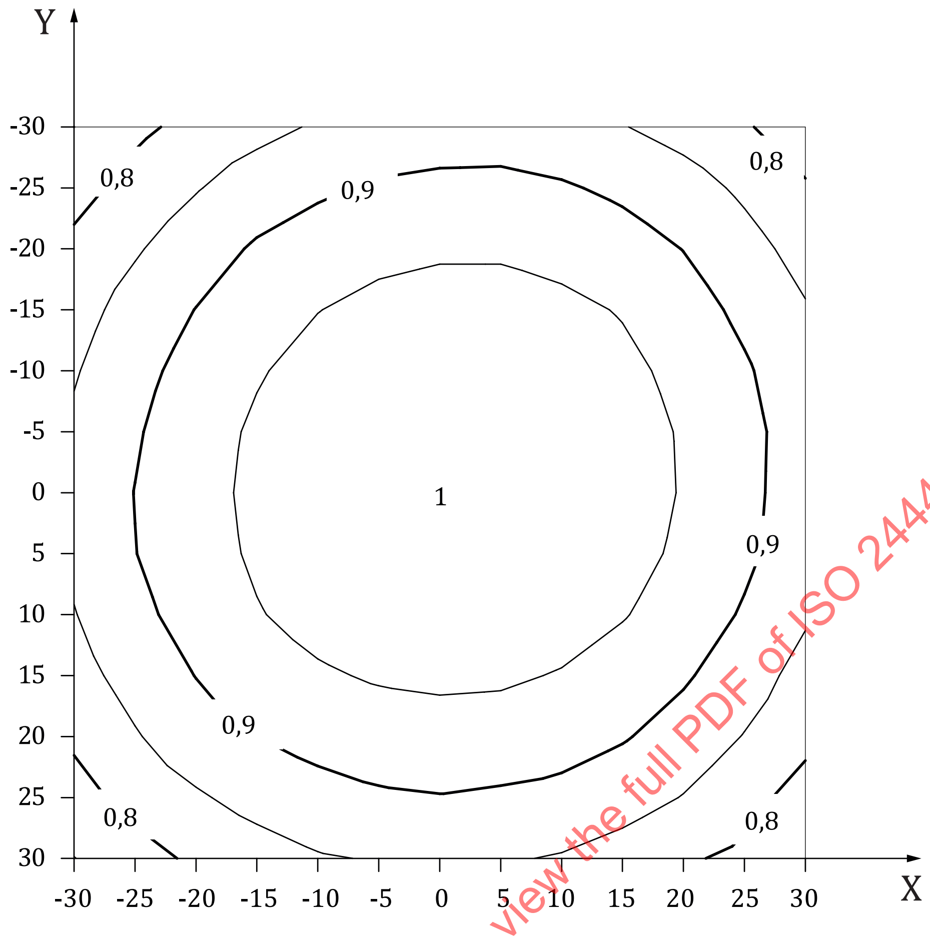
S irradiation surface (sample stage)

P_w distance of optical axis (width)

H distance between LED units and irradiation surface

P_d distance of optical axis (depth)

Figure C.1 — Example of irradiation box with a uniform illuminance on the large irradiation surface, design by lighting design software



Key

X position, cm

Y position, cm

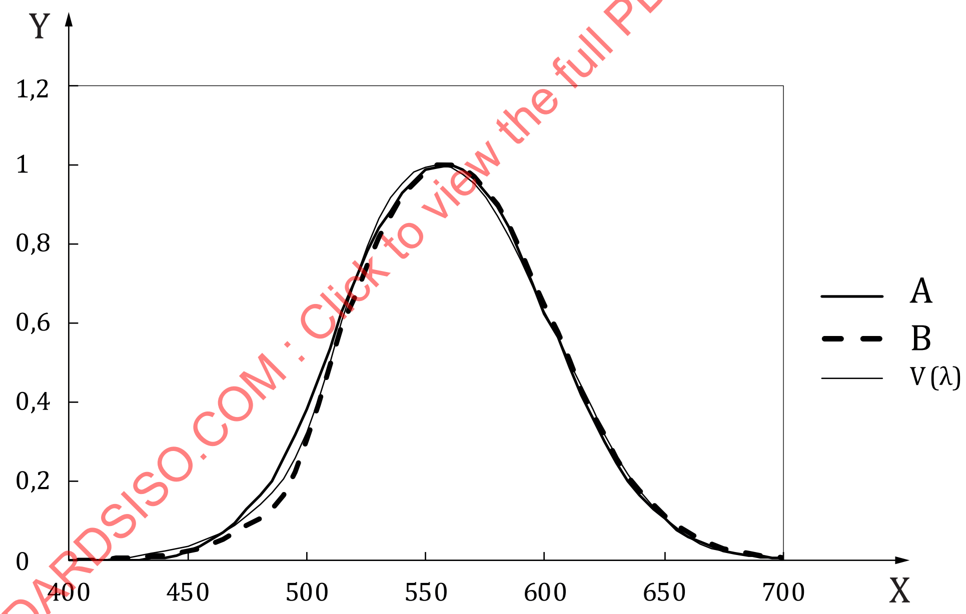
Figure C.2 — Relative illuminance (E_{max} = 1,0) measured on the irradiation surface of the irradiation box shown in Figure C.1

Annex D
(informative)

Characteristics of illuminance meters

D.1 General $V(\lambda)$ mismatch index f_1

General $V(\lambda)$ mismatch index f'_1 is the most important fundamental index of the characteristics of illuminance meters. This index describes the deviation of the relative spectral responsivity of the illuminance meter from the spectral luminous efficiency $V(\lambda)$ function. In general, all illuminance meters are manufactured so that its spectral response should be adjusted to the $V(\lambda)$ function. However, it is quite difficult to realize a perfect spectral response, especially in wavelengths of between 400 nm and 500 nm, because of the limitation of the optical filters. There is a peak spectral irradiance which emits from the solid of white LED lamps in this wavelength range. This means the general $V(\lambda)$ mismatch index f'_1 affects the results of illuminance measurement generated by white LED lamps. To make a low uncertainty of illuminance measurement, this index is regulated. An example of the spectral response of different illuminance meters is shown in Figure D.1.



Key
X wavelength, nm
Y relative spectral response

Figure D.1 — Example of the spectral responses of illuminance meters

D.2 Directional response index (cosine response index) for illuminance f_2

Directional response index (cosine response index) for illuminance f_2 is also a fundamental characteristic of illuminance meters. The index describes the responsivity of illuminance meters to light incident at an angle other than normal. This response must theoretically be adjusted to the cosine curve, therefore it is also called cosine response.

This characteristic affects the result when non-parallel beam photometry is carried out near the light source. In general, the size of the light source is larger than that of the receiving surface of illuminance