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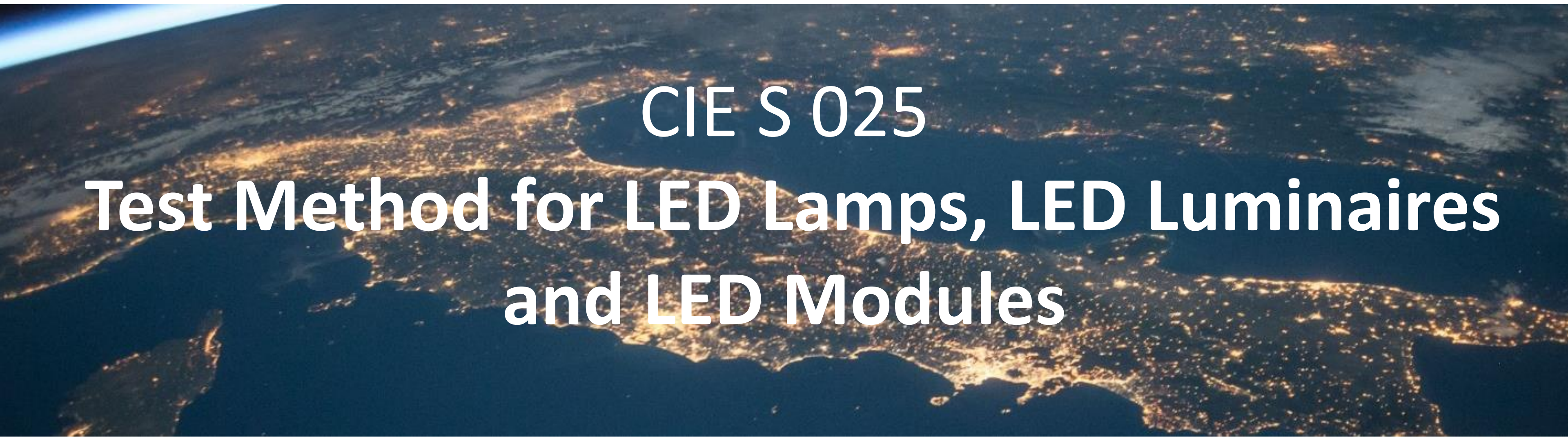

CIE S 025

Test Method for LED Lamps, LED Luminaires and LED Modules

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Global Efficient Lighting Centre
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Brief Introduction

- **requirements** to perform reproducible photometric and colorimetric measurements on LED lamps, LED modules, and LED luminaires (LED devices).

- **advice for the reporting** of the data. The availability of reliable and accurate photometric data for LED devices is a basic requirement for designing good lighting systems and evaluating performance of products.

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Brief Introduction

- The standard **specifies the requirements** for measurement of electrical, photometric, and colorimetric quantities of LED lamps, LED modules and LED luminaires, for operation with AC or DC supply voltages, possibly with associated LED control gear. LED light engines are assimilated to LED modules and handled accordingly.

Brief Introduction

- Photometric and colorimetric quantities covered in this standard include **total luminous flux, luminous efficacy, partial luminous flux, luminous intensity distribution, centre-beam intensity, luminance and luminance distribution, chromaticity coordinates, correlated colour temperature (CCT), colour rendering index (CRI), and angular colour uniformity**.

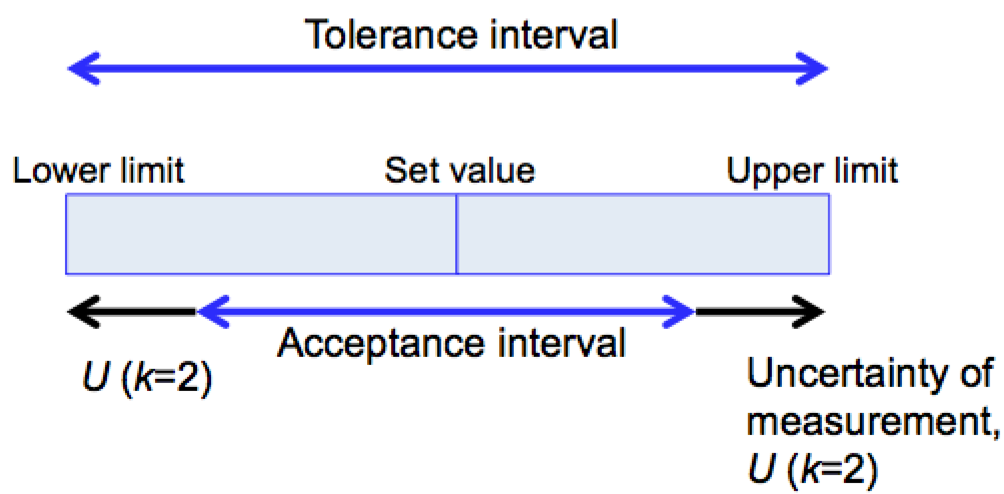
- This standard **does not cover** LED packages and products based on **OLEDs** (organic LEDs).

Special Requirement

- New conception

$t_{p, n}$； $t_{q, n}$

tolerance interval； acceptance interval



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- 4.2.4 Air Movement
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Main Text

- 4.3 Electrical Test Conditions and Electrical Equipment
- 4.3.1 Test Voltage and Test Current
- 4.3.2 Electrical Measurements

Specific requirement:
AC V I, DC V I,
POWER , BANDWITH;
INTERNAL IMPEDANCE

- 4.3.3 Electrical Power Supply

4.3.3.1 current handling capacity, very low impedance

4.3.3.2 regulated at the supply terminals of the DUT

Specific requirement: drift or fluctuation during measurement within the acceptance interval of the test voltage. If exceeds…correction.
power supply network, THD v 1.5% if PF<0.9, 3.0% IF PF>0.9; THD, Frequency

Main Text

4.3.3.3 regulated at the supply terminals of the DUT; drift or fluctuation during measurement

ripple free, AC component <=0.5%.

4.3.3.4 EMC

- **4.4 Stabilization before Measurement**

  DUT & EQUIPMENT

  1 minute interval

- **4.4.1 LED Lamps and LED Luminaires**

  30min, 15min 0.5%;

  45min, 150min ,report, but wait if gradient decrease

  related to thermal equilibrium ; "experience"

- **4.4.2 LED Modules**

  without heat sink, Tp, temperature-controlled heat sink or additional heating ,15min Tp

  with heat sink, 25 ° C ,Tp

Main Text

- **4.5 Photometric and Colorimetric Measurement Instruments**

  sphere-photometer
  sphere- spectroradiometer
  NOTE: hemisphere, tristimulus colorimeter head,
  goniophotometer
  gonio-spectroradiometer
  gonio-colorimeter
  NOTE on: near-field, Gonio-colorimeters ,
  Luminance mters
  NOTE on: ILMD

  …acceptable if they are demonstrated to produce equivalent results as a conventional integrating sphere system or conventional goniophotometer system.

  selected depending on the types of product and measurement quantities to be measured.

calibrated to ensure traceability to the SI.

photometric measurements based on the spectral luminous efficiency function for photopic vision *V(λ)*

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Main Text

- **4.5.1 Spectral Responsivity Requirements for Photometers**

  -V(λ)-corrected detectors (sphere-photometer, goniophotometer, luminance meter)

$$f_1^{'} \leq 3\%$$

white light LED, ...

colored light ,...

or:

correction and report

or: uncertainty

correction , remaining uncertainty

Main Text

- **4.5.2 Integrating Sphere (all Types)**

  auxiliary lamp NOTE: self-absorption

  size of the integrating sphere should be large enough relative to the size of the DUT

  DUT *2 % of the total area of the sphere inner surface (1/10, 1/3)*

  linear shaped DUT …

  coating of the integrating …diffuse, high-reflectance, non-spectrally selective and should not show fluorescence. Coating reflectances> 90 % are recommended

  NOTE : non-uniformity of reflectance

  holder and auxiliary equipment -> smallest size, highest reflectance NOTE: baffle coating

  detector port's entrance optics…,

  sufficient mechanical repeatability , ≤0.5%, uncertainty

  sufficient stability , *appropriate intervals* ,<0.5%,

  similar intensity distribution ,…

Main Text

- 4.5.2.1 **Sphere-Spectroradiometer**

  …calibrated with or verified against a total spectral radiant flux standard traceable to the SI.

  …or spectral irradiance standard lamp(s) and total luminous flux standard lamp(s), both traceable to the SI . …the derivation methods and related data (e.g. angular uniformity of spectrum or that of correlated colour temperature of the standard lamp) should be reported.

  The integrating sphere and the spectroradiometer together shall be calibrated as one system for total spectral radiant flux.

  wavelength range shall cover at least 380 nm to 780 nm

  wavelength uncertainty within 0,5 nm (k=2).

  bandwidth (full width half maximum) and scanning interval , 5 nm.

linear response, nonlinearity ->uncertainty budget.

internal stray light of the spectroradiometer ->uncertainty budget.

auxiliary lamp wavelength range

Main Text

- **4.5.2.2 Sphere-Photometer**

…calibrated with a total luminous flux standard traceable to the SI. It is desirable , similar spectral distribution ,if available.

…total relative spectral responsivity (sphere plus photometer head) *V(λ)*

correction if necessary, see Annex C.

…changes with time, especially when the sphere is new, or when the sphere is heavily used and subject to contamination. re-measured periodically , particularly important for reflectance >95%.

NOTE: Guidance on measuring the relative spectral throughput of a sphere system is available in Annex B of IES LM-78 (2007).

It is desirable that the auxiliary lamp for self-absorption measurement has a spectral distribution similar to that of the DUT measured, especially for single colour LED modules.

Main Text

- **4.5.3 Goniophotometer (all Types)**

  angular scan range

  The angular aiming of the DUT shall be adjusted and maintained within ±0,5° of the intended direction. Display resolution of 0,1° or better.

  *(FAR-FIELD):*DUT->effectively a point source

  test distance:

  – near cosine (Lambertian) distribution (beam angle ≥ 90°) in all C-planes: ≥ 5 × D

  – broad angular distribution different from a cosine distribution (beam angle ≥ 60°) in some of the C-planes: ≥ 10 × D

  – narrower angular distributions , steep gradients in the luminous intensity distribution or critical glare control: ≥ 15 × D

  – there are large non-luminous spaces between the luminous areas: ≥ 15 × (D+S)

  where D is the maximal luminous dimension of the DUT and S is the largest distance between two adjacent luminous areas.

Main Text

- NOTE 1 **For these test distances** it may be expected that the photometric inverse square law is verified at better than 1 % in the optical axis, up to 3 % within twice of the beam angle. Other test distances verifying this rule may be applied without applying corrections. (See also Annex C.3.6.)

- NOTE 2 **For some LED products where individual LEDs are effectively acting as small floodlights pointing in different directions** (e.g. divergent LEDs on a linear luminaire or separate LED modules mounted within the one luminaire), the recommended test distances may be insufficient. In case of doubt it should be verified if the inverse square law applies correctly.

- **For near-field photometry**, the test distance is theoretically considered infinite, but it should be validated.

Main Text

- **For measurement of total luminous flux** (and not for luminous intensity distribution), the far-field condition is not required, as total luminous flux can be derived by integration of illuminance distribution.

- Goniophotometers in general have some angular region (called **dead angle**) where emission from a light source is blocked by its mechanism, e.g. an arm to hold the light source. Goniophotometers having a large dead angle exceeding a solid angle of 0,1 sr (corresponding to a cone angle of approximately 10° radius) should not be used to measure total luminous flux of omnidirectional lamps or such luminaires unless appropriate correction procedures are implemented.

Whole content

- **4.5.3.1 Goniophotometer Using a Photometer Head**
- The relative spectral responsivity of the photometer head (combined with the spectral reflectance of a mirror if it is used) shall match the spectral luminous efficiency function for photopic vision *V*(λ). The general *V*(λ) mismatch index of the photometer head (including the mirror if used) shall meet the requirements in 4.5.1.

- Where necessary, a spectral mismatch correction shall be applied. For this correction, the relative spectral distribution of the DUT and the relative spectral responsivity of the photometer head (including mirror if used) are necessary. See Annex C for spectral mismatch correction.

Main Text

- Goniophotometers shall be calibrated against a luminous intensity standard or illuminance standard traceable to the SI, and if total luminous flux is also measured, the measured total luminous flux value (expressed in lm) shall also be verified by measuring a total luminous flux standard traceable to the SI. Alternatively, the goniophotometer system for measurement of total luminous flux may be calibrated against a total luminous flux standard traceable to the SI, if the dead angle of the goniophotometer does not affect the measurement of the total luminous flux standard lamp.

- NOTE For mirror type goniophotometers, a luminous intensity standard lamp is normally used to calibrate the photometer head, in which case, the photometric distance and the reflectance of the mirror are automatically included in the calibration.

Main Text

- **4.5.3.2 Gonio-spectroradiometer**
- Gonio-spectroradiometers shall be calibrated against spectral irradiance or spectral radiant intensity standard traceable to the SI. For a mirror-type gonio-spectroradiometer, the spectral reflectance of the mirror shall be taken into account if a spectral irradiance standard is used. If total spectral radiant flux is also measured, the values (expressed in W/nm) shall also be verified by measuring a total spectral radiant flux standard lamp traceable to the SI.

- Alternatively, the gonio-spectroradiometer system for total luminous flux or total spectral radiant flux measurements may be calibrated against a total spectral radiant flux standard traceable to the SI, if the dead angle of the gonio-spectroradiometer does not affect the measurement of the total spectral radiant flux standard lamp.

Main Text

- The spectroradiometer used for the gonio-spectroradiometer system shall cover the visible wavelength range and have appropriate bandwidth and scanning interval for measurement of the LEDs being tested. The wavelength range shall cover at least 380 nm to 780 nm.

- *Specific requirement: The bandwidth (full width half maximum) and scanning interval shall not be greater than 5 nm. The spectroradiometer shall have a wavelength uncertainty within 0,5 nm (k=2).*

- The spectroradiometer shall have a linear response to the input radiation at each wavelength over the visible range. The influence of non-linearity shall be considered in the uncertainty budget.

- The internal stray light of the spectroradiometer shall be considered in the uncertainty budget.

Main Text

- **4.5.3.3 Gonio-colorimeter**
- Gonio-colorimeters employ tristimulus colorimeter heads (filter-detector combinations having spectral responsivity matched to the CIE colour matching functions) to measure tristimulus values *X*, *Y*, *Z*. The *Y*-channel of a gonio-colorimeter shall meet all requirements in 4.5.3.1.

- Unless otherwise demonstrated, a gonio-colorimeter alone shall not be used for absolute measurement of colour quantities, and may be used only for colour difference measurement (or relative colour measurement combined with calibration by a spectroradiometer for a particular DUT).

Main Text

- **4.5.4 Luminance Meters**
- A luminance meter shall be calibrated with a luminance standard traceable to the SI. The following applies to both classical luminance meters (single point luminance measurement devices) and imaging luminance measurement devices (ILMD).
- The relative spectral responsivity of the luminance meter shall match the spectral luminous efficiency function $V(\lambda)$ for photopic vision. The general $V(\lambda)$ mismatch index of the luminance meter shall meet the requirements in 4.5.1.
- Where necessary, a spectral mismatch correction shall be applied. For this correction, the relative spectral distribution of the DUT and the relative spectral responsivity of the photometer are necessary, see Annex C for spectral mismatch correction.
- If an ILMD is used, its measurement uncertainty shall be verified by comparing the results for luminance distribution of a typical LED device measured with a discrete luminance meter.

Main Text

- **5 Preparation, Mounting and Operating Conditions**

- **5.1 Ageing**

  Ageing shall be according to the appropriate LED product performance standard (Clause 2).

- 5.2 Test Device

  The applicant shall provide all necessary instructions for proper use. The optical parts of devices shall be clean, except if otherwise required by the applicant (e.g. determination of maintenance factors).

Main Text

- **5.3 Mounting**
- **5.3.1 Operating Orientation**
- LED lamps shall be operated in free air in a vertical base-up position, unless other operating orientation is specified by the applicant (or regulation). If an applicant has declared that the lamp is suitable for use in a specific orientation only, the lamp shall be mounted in the declared orientation during all tests. If a different operating position is used during the test the specifications of 4.2.5 apply.

- LED luminaires shall be mounted in the operating position recommended by the manufacturer for intended use so that their thermal condition due to air flow inside and outside the device will be the same as its normal use condition (in terms of operating position) and that their alignment is mechanically true and all components rigidly located in their designed positions. Adjustable parts shall be correctly set according to the manufacturer's instructions. If a different operating position is used during the test the specifications of 4.2.5 apply.

Main Text

- LED modules can be operated at any operating position if their temperature is set and maintained to performance temperature *t*p.
- The test device shall be mounted so that any thermal conduction through supporting elements holding the device causes negligible unintended cooling effects.

- NOTE 1 For example, a luminaire may be suspended in air by wire or held by support materials that have a low heat conductivity, e.g. Teflon.

  In all cases, the operating position of the device shall be reported.

- NOTE 2 The light emission process of a LED is not affected by orientation (with respect to gravity). However, the orientation of a LED lamp and LED luminaire can cause changes in thermal conditions for the LEDs used in the device, and thus the light output can be affected by the orientation of the device.

Main Text

- **5.3.2 Coordinate System**

  Photometric and colorimetric distributions of lighting devices are dependent on locations and directions. Therefore a coordinate system shall be linked to the DUT and the photometric/colorimetric distributions are referenced to this coordinate system. The mechanical position of the device referenced to the coordinate system shall be unique and declared. The coordinate system centre is coincident with the photometric centre of the DUT.

- General guidance on coordinate systems is given in CIE 121-1996.

Main Text

- **5.3.3 Photometric Centre**
- The position of the photometric centre of a device shall be at the centre of the solid figure bounded in outline by the luminous surfaces.
- For LED luminaires with substantially opaque sides, where the lamp (or module) compartment is substantially white or luminous, the position shall be at the centre of the main luminaire opening, but for LED luminaires with substantially opaque sides, where the lamp (or module) compartment is substantially black or non-luminous, the position shall be at the lamp photometric centre (centre of the solid figure bounded in outline by the luminous surfaces of the lamp or centre of the module).
- When using a far-field goniophotometer and measuring devices with multiple light-emitting areas that have significant separation and which do not comply with the specific requirement for test distances in 4.5.3, the devices shall be measured in several steps with each light emitting area centred accordingly. Data for each lighting emitting area shall be reported.

Main Text

- NOTE Light emitting areas are considered to be significantly separated when the deviation from the inverse square law when measured together, are non-negligible.
- Complementary guidance for photometric centre is given in CIE 121-1996, Clause 5.3.2.

- **5.4 Operating Conditions of the LED Lighting Devices**
- **5.4.1 General**
- LED devices with dimming control shall be adjusted to maximum light output for all tests or to pre-defined levels if instructed by the applicant.
- LED devices with internal feedback-control circuits not externally adjustable shall be tested as provided.

Main Text

- LED devices with adjustable colour points shall be adjusted or set to the defined settings as indicated by the manufacturer or applicant.
- LED devices with a tuneable white spectrum shall be adjusted to the settings specified by the applicant or according to a relevant standard.
- For multicolour LED devices e.g. RGB LED devices, each colour shall be measured individually with the full-power setting and all colours together with the full-power setting.

Main Text

- **5.4.2 LED Lamps**
- LED lamps are measured in standard test conditions and data shall be reported for *t*amb = 25 °C. If other operating temperatures are declared by the manufacturer, the measured results at the given temperature shall be reported or a service conversion factor shall be provided by a table or graph for those temperatures.
- **5.4.3 LED Modules**
- For LED modules provided without control gear, the applicant shall provide the necessary specifications for the auxiliary equipment to be used.
- LED modules are measured in standard test conditions at the rated performance temperature. The temperature at the *t*p-point shall be set at this value for the measurements. If not accessible, the manufacturer or the applicant shall indicate a temperature monitoring point. If heat sinks are needed for the correct operating of the LED module and the LED module does not have an own heat sink, a suitable temperature controlled heat sink may be used. Interpolation techniques may also be applied (see Annex C).

Main Text

- A LED module may show more than one rated maximum performance temperature values $t_{p,n}$.
- Light engines that do not incorporate heat sink(s) are measured at the rated performance temperature as described above.
- Light engines incorporating heat sink(s) shall be measured first in standard test conditions for t_{amb} = 25 °C, with the value t_p measured and reported. Then further measurements are made at specified performance temperatures at the t_p-point. If the t_p-point is not accessible, the applicant shall indicate a temperature monitoring point.

Main Text

- 5.4.4 LED Luminaires
- LED luminaires are measured in standard test conditions at t_{amb} = 25 ° C.
-
- NOTE t_p is not relevant for the LED luminaire end-user and is often not accessible.

- Data shall be reported for t_{amb} = 25 ° C. If a rated maximum performance ambient temperature $t_{q,n}$ other than 25 ° C is declared, a service conversion factor shall be delivered for this temperature (see also 4.2.2 and Annex C.1.2). There can be more than one rated maximum performance ambient temperature declared.

Main Text

6 **Measurement of Photometric Quantities**

6.1 General

The measurement of the following photometric quantities is covered by this standard:

- total luminous flux,
- luminous efficacy,
- luminous intensity distribution and
- luminance.

Absolute photometry methods are required for all LED devices.

Main Text

- **6.2 Measurement of Total Luminous Flux**

  General guidance for luminous flux measurements is given in CIE 84-1989.

  The luminous flux of a light source can be determined by different methods. The method may be chosen depending on what other measurement quantities (colour, intensity distribution) are needed to be measured or depending on the geometrical dimensions of the DUT. The following methods are available:

  - **Method A:** Measurement with an integrating sphere (with a photometer head or a spectroradiometer). For the sphere theory, see CIE 84-1989, Clause 6.2.
  - **Method B: Calculation from the luminous intensity distribution. For calculation principles see CIE 84-1989, Clause 4.**

  Luminous intensity can be determined from integrated luminance. See CIE 70-1987 Clause 2.2.

  - **Method C:** Calculation from the illuminance distribution and photometric distance. For calculation principles see CIE 84-1989, Clause 5.

Main Text

- **6.3 Partial Luminous Flux**

  For the specified cone angle α, the partial luminous flux is obtained from summation of intensity distribution data $I(\theta_i, \varphi_j)$, with scanning intervals of Δθ and Δφ.

  - If the goniophotometer is not calibrated in absolute scale, the ratio of total luminous flux and partial flux can be obtained from the goniophotometer, the total luminous flux can be measured with an integrating sphere, and the partial flux can be calculated as the multiplication of total flux and the ratio.
  - For measurement of partial luminous flux in a cone of 90° or larger, the measurement should be made with scanning intervals of 5° or less for θ angles (γ angles in *C*,γ coordinate system) and 45° or less for *φ* angles (*C* angles in *C*,γ coordinate system). Smaller angle intervals may be needed for DUTs for specific applications (e.g. street lighting luminaires).

Main Text

- **6.4 Luminous Efficacy**

  The luminous efficacy η_v, expressed in lm/W, is determined by the ratio of the luminous flux Φ of the LED device to the electrical power P_{tot} including all components required for the LED device operation.

  $$\eta_v = \Phi / P_{tot} \quad (8)$$

  The luminous flux of the LED product is measured according to 6.2. The electrical power is measured according to 4.3.2, or, for non-integrated and semi-integrated LED devices, as specified by the applicant or regulation

  NOTE The term “luminous efficacy” is used in this document in the meaning of *luminous efficacy of a source* as defined in the ILV.

Main Text

- **6.5 Luminous Intensity Distribution and Data Presentation**

  Unless otherwise specified, the CIE *C*,*γ* coordinate system (see CIE 121-1996) shall apply (see 5.3).

  The angular interval between readings of intensity within the vertical planes and the angular spacing between adjacent vertical planes should be such that luminous intensity distribution can be accurately presented and as to permit interpolation of intensity values during post-processing (lighting calculations) with an acceptable accuracy. The number of planes should also be determined by the nature of the distribution having regard to symmetry or irregularity and to the end results desired from the test. Guidance for goniophotometry of luminaires in specific applications may be available in the appropriate CIE Technical Reports for lighting applications.

  Measurements of luminous intensity distributions are usually made with goniophotometers. The provisions for goniophotometers apply: see 4.5.3. For types of goniophotometers, see also CIE 121-1996.

Main Text

- **6.5.2 LED Luminaires**

  The intensity distribution of these devices shall be expressed in cd.

  NOTE 1 For lighting calculation programs requiring luminous intensity distribution data in cd/klm, …

  NOTE 2 LOR may be determined for LED luminaires using interchangeable sources (e.g. LED lamps) in some cases.

Main Text

- 6.6 Centre Beam Intensity and Beam Angles

  The luminous intensity distributions shall be measured according to 6.5. For guidance for determining the centre beam intensity and beam angles on the basis of the luminous intensity distributions, see IEC/TR 61341:2010.

  NOTE For intensity distribution measurements in a goniophotometer, the direction (0,0) is usually the direction of the design optical axis (mechanical reference axis) of the light source, the axis through the photometric centre and perpendicular to the light exit plane, unless otherwise specified by the manufacturer. In IEC/TR 61341, the centre beam intensity is determined in the direction of the observed optical beam axis (the axis about which the luminous intensity distribution is substantially symmetrical) and the beam angle is evaluated around the observed optical beam axis. The mechanical reference axis may be used for measurement but evaluation must be made around the observed optical beam axis. The method to determine this optical beam axis is described in Clause 6 of IEC/TR 61341. Mechanical reference axis and observed optical beam axis are not necessarily coincident and this should be accounted for in the evaluation of the beam angle.

Main Text

- **6.7 Luminance Measurements**

  For reasonably uniform light surfaces, the following measurements may be considered:

  a) Measurement of the average luminance of the whole luminaire in a stated direction, or in a series of directions: This method is often used, e.g. for the evaluation of glare. In this method the luminous intensity (distribution) is measured, usually with a goniophotometer, and the average luminance is calculated by dividing the luminous intensity by the projected luminous area.

  b) Measurement of "patch luminance": This method is often used for the evaluation of spatial non-uniformity of the luminance of large indoor luminaires – for details see CIE 121, Clause 6.5.3. The average luminance(s) of specified small areas within the luminous area of the luminaire, areas called "luminous patch" (only size and shape are specified, realized by a mask with an opening), are measured in stated direction(s). These patches are distributed over the luminous surface of the luminaire and the average luminance is determined for each patch. The maximum and minimum of these average luminances are usually reported. The measurements may be made either with a goniophotometer set to the stated direction, using such a physical mask moved around over the luminous area of the luminaire (using the principle described in method a), or with a luminance meter measuring the average luminances of the luminous patches at different locations.

Main Text

If the LED sources and LED luminaires have no diffusing covers and are observed as a sum of point sources (thus appearing as a mixture of luminous and non-luminous portions within the outer contour), method a) above for the determination of the average luminance from the luminous intensity in the viewing direction and the projected luminous area (the outer contour of the light output area) is not valid. For such LED devices, only measurements of the luminances of the luminous portions of the light output area are appropriate. Such measurements can be made using a luminance meter or an imaging luminance measurement device (ILMD).

NOTE The luminous area can be calculated while summing up the object area of all marked pixels if the ILMD is calibrated with respect to the object space. The algorithm to divide between luminous area and background should be defined depending on the application (e.g. fixed threshold, adaptive threshold).

Main Text

- 7 Measurement of Colour Quantities
- 7.1 Colorimetric Measurements
- 7.1.1 General Aspects

The following colorimetric quantities are covered in this standard:

- Chromaticity coordinates,
- Correlated colour temperature,
- Distance from Planckian locus,
- Colour rendering indices and
- Angular colour uniformity.

Calculations of colorimetric quantities shall take into account the standards ISO 11664-1:2007(E)/CIE S 014-1/E:2007, ISO 11664-2:2007(E)/CIE S 014-2/E:2006 and ISO 11664-3:2012(E)/CIE S 014-3/E:2011. Spectroradiometers are used to measure these colour quantities. Tristimulus colorimeters normally do not have sufficient accuracy for absolute colour measurement but they may be used for evaluating changes of chromaticity in different directions.

Main Text

Colour rendering indices require spectral data.

The value of the colorimetric quantities of LED lamps, LED modules and LED luminaires may be angularly non-uniform.

Colorimetric or spectral measurements may basically be performed using one of the following geometries:

a) along a specific direction;
b) as a directional distribution using gonio-colorimetric or gonio-spectroradiometric measurements equipment;
c) as spatially averaged values (i.e. from the total spectral radiant flux), using an integrating sphere or numerically averaging the gonio-spectroradiometric data or the gonio-colorimetric data.

Main Text

Spatially averaged colour quantities are used for all LED lamps, light engines, and LED luminaires except otherwise specified by the manufacturer or applicant.

Spatially averaged colour quantities may be obtained using one of the following methods:

① Sphere-spectroradiometer measurements provide spatially averaged colour quantities calculated from the total spectral radiant flux;

② If gonio-spectroradiometric data are available, total spectral radiant flux is calculated as a basis for the calculation of spatially-averaged colour quantities;

③ If gonio-colorimetric data $X(\theta,\phi)$ $Y(\theta,\phi)$, and $Z(\theta,\phi)$ are available, …

Colour rendering indices can only be derived using either method 1) or 2).

The chromaticity coordinates (x,y) and/or (u'，v') are calculated according to CIE 15. ,*u*'*v*'

Main Text

- 7.1.2 Correlated Colour Temperature (White LED Light Sources)

  The chromaticity can also be expressed by the correlated colour temperature (*Tcp*) and the parameter *D*uv. Correlated colour temperature is calculated according to CIE 15. *D*uv is the signed distance from the Planckian locus on the CIE () diagram, which is positive for above and negative for below the Planckian locus. 23,*u*′*v*′

- 7.1.3 Colour Rendering Indices (White LED Light Sources)

  Calculation of colour rendering indices shall be made in accordance with CIE 13.3.

- 7.1.4 Angular Colour Uniformity

  Angular colour uniformity is measured as the largest deviation of chromaticity (u′,v′) of a LED device emitted in different directions, from its spatially averaged chromaticity () calculated as, （*ua*′, *va*′）。。。

Main Text

The chromaticity coordinates (*u',v'*) are measured with a gonio-colorimeter or gonio-spectroradiometer at a vertical angle interval of 10° or less (2,5° is recommended) and a horizontal angle interval of 90° or less (22,5° is recommended). For reflector lamps, the angle increments shall be 1/10 or less of the beam angle (diameter of the angular cone emitting more than 1/2 of the peak intensity) but no larger than 10°. The data at angle points where the luminous intensity is less than 10 % (unless otherwise specified by a relevant product standard) of the peak intensity shall be ignored in the calculation.

Main Text

- The average chromaticity () for this calculation is obtained from the gonio-colorimetric measurement points described above using the calculation procedures in 7.1.1. (3), not from a different measurement system (e.g. sphere-spectroradiometer). If data from a different measurement system is used, there may be some errors, as low intensity points may be included in other results. Also, the absolute accuracy of chromaticity measurement for this angular colour uniformity is not as critical as that for chromaticity measurement for DUT described in 7.1.1. aa,*uv*''

- NOTE General guidance on colour difference specification for light sources is available in CIE TN 001:2014.

Main Text

- **8 Measurement Uncertainties**

  The uncertainties shall be evaluated according to ISO/IEC Guide 98-3 and its supplements. Guidance is also available from CIE 198.

  For all measured quantities the expanded uncertainty shall be given and expressed for a confidence level of 95 %. The expanded uncertainty is stated to at most two significant digits.

  For the purposes of testing, each test report may report uncertainty values for a typical product of the similar type having similar spectral distributions and intensity distributions to the DUT (see NOTE 1). In this case the type of the product used in the uncertainty budget shall be stated in the test report (see NOTE 2). Laboratories shall have a detailed uncertainty budget for the similar type of product and keep them available on demand. If such uncertainty budget is made for a range of products (e.g. CCT from 2 700 K to 4 000 K), the largest uncertainty value within the range shall be stated.

Main Text

- NOTE 1 In this context, products could be considered similar type if the following properties are the same as the DUT: phosphor type or RGB(A) type; similar geometrical shape (e.g. compact or tubular type for lamps); similar intensity distributions; omnidirectional or directional (beam angle between +50 % and -25 % of the value of the DUT); CCT within ±15 % of the CCT value of the DUT.

- NOTE 2 An example statement in the test report: "The uncertainty values stated in this test report are those for a similar type of product: phosphor type LED lamp (compact), directional (beam angle 60°), CCT 3 500 K." If the type of DUT does not match the type categories listed in NOTE 1, the product type should be described specifically.

- NOTE 3 When corrections are applied to the measurement results, the correction must always use the characteristics of the DUT (or product of the same model), and not of the similar type product.

Main Text

- For practical reasons, it is not always possible to estimate or measure the influence of the DUT repeatability between different cold-start operations; however this information shall be known from type investigations and shall be included in the uncertainty evaluation. It shall be mentioned in the uncertainty budget whether this parameter is estimated from type specific data or from individual measurements of the DUT.

- For luminous intensity distributions, the measurement uncertainty shall be reported at least in one given representative direction where the luminous intensity is fairly flat. The uncertainty on angular setting (including alignment of the DUT in the goniometer) or measurements shall be reported separately.

- For luminance distributions, measurement uncertainty shall be reported at least in one representative point where the luminance distribution is fairly flat.

Main Text

- **8.1 Guidance for Measurement Uncertainty Budgets**
- **8.1.1 Common Parameters to all Measurements**

At least the following contributions shall be considered:

- ☐ Temperature setting and uncertainty on temperature measurement
- ☐ Electrical settings and uncertainty on electrical measurements (power supply, electrical measuring instruments)
- ☐ Fluctuation of light output of the DUT (if significant)
- ☐ Calibration standard (calibration certificate)
- ☐ Operating of the calibration standard (ageing, electrical measurements, calibration process)
- ☐ Linearity of measuring instruments
- ☐ Reproducibility and repeatability (if applicable, default value for the equipment and generic device type may be used if this is not evaluated for the specific DUT)

For all measurements not only the contributions from the measurement system and procedures but also the contributions from the specific characteristics of the DUT (or similar type) must be taken into account.

Main Text

- **8.1.2 Luminous Flux**

  In addition to 8.1.1 at least the following contributions shall be considered (where appropriate):

  Measurement (depending on the method)

  a) Goniophotometer

  - ✓ Flatness of mirrors and polarization effects
  - ✓ Spectral reflectance of mirrors
  - ✓ Stray light (spatial)
  - ✓ Positioning accuracy
  - ✓ Spectral matching (detector + mirror, different spectral power distributions of the calibration standard and DUT)
  - ✓ Detector acceptance area
  - ✓ Cosine response (illuminance integration)
  - ✓ Uncertainty of photometric distance if the photometer head is calibrated for illuminance responsivity
  - ✓ Uncertainty of the reflectance of the mirror if it is used, if the photometer head is calibrated for illuminance responsivity

Main Text

b) Sphere Photometer

- ✓ Self-absorption
- ✓ Thermal behaviour
- ✓ Spatial non-uniformity of sphere responsivity
- ✓ Sphere reflectance (influence to the spectral matching)
- ✓ Spectral matching (detector + sphere, different spectral power distributions of calibration standard and DUT)
- ✓ Mechanical repeatability when the sphere is opened and closed
- ✓ Stability of sphere responsivity during the period between recalibrations
- ✓ Cosine response of photometer head
- ✓ Fluorescence effects from sphere coating

Main Text

c) Sphere-spectroradiometer

- ✓ Self-absorption
- ✓ Thermal behaviour
- ✓ Spatial non-uniformity of sphere responsivity
- ✓ Sphere reflectance
- ✓ Wavelength accuracy
- ✓ Stray light of the spectroradiometer
- ✓ Bandpass of the spectroradiometer
- ✓ Cosine response of the spectroradiometer entrance port
- ✓ Mechanical repeatability when the sphere is opened and closed
- ✓ Stability of the sphere responsivity during the period between recalibrations
- ✓ Fluorescence effects from sphere coating

Main Text

d) Gonio-spectroradiometer

- ✓ Flatness of mirrors and polarization effects
- ✓ Spectral reflectance of mirrors
- ✓ Stray light (spatial)
- ✓ Positioning accuracy
- ✓ Detector acceptance area
- ✓ Cosine response (illuminance integration)
- ✓ Wavelength accuracy
- ✓ Stray light of the spectroradiometer
- ✓ Bandpass of the spectroradiometer
- ✓ Uncertainty of photometric distance if the spectroradiometer is calibrated with a spectral irradiance standard
- ✓ Uncertainty of the spectral reflectance of the mirror if it is used, if the spectroradiometer is calibrated with a spectral irradiance standard

Main Text

8.1.3 Luminous Intensity and Luminance

Similar parameters as in 8.1.2 shall be considered.

8.1.4 Colour Quantities

This includes chromaticity coordinates, correlated colour temperature, and colour rendering indices. In addition to 8.1.1 at least following contributions shall be considered:

- Correlations due to the colour temperature uncertainty of the calibration source
- Stray light of the spectroradiometer
- Bandwidth (influence, correction)
- Wavelength accuracy
- Dynamic range over the spectral range

Main Text

8.1.5 Electrical Power

In addition to 8.1.1 at least the following contribution shall be considered:

- Bandwidth of the AC power meter (influence, correction)
- Input impedance of the AC power meter

8.1.6 Luminous Efficacy

The correlations between the luminous flux value and the electrical power measurement should be taken into account to reduce the associated measurement uncertainty. For example, if supply current affects both luminous flux output and electrical power of a DUT in the same direction with same sensitivity, the uncertainty in luminous efficacy for this component will be cancelled out.

Main Text

- 9 Presentation of Test Results
- 9.1 Test Report
- 9.1.1 General Information
- 9.1.2 Information on the Device(s) under Test
- 9.1.3 Information on the Test Procedure
- 9.1.4 Photometric and/or Colorimetric Data

Main Text

- Annex A (informative) Guidance on the Application of this Standard
- Annex B (informative) Stray Light — Screening against Stray Light in a Goniophotometer
  Annex C (informative) Practical Laboratory Conditions
- C.1 Correction Factors
- C.1.1 Measurement Correction Factors
- C.1.2 Service Conversion Factors
- C.2 Sensitivity Coefficients
- C.3 Typical Sensitivity Coefficients and Tolerance Intervals
- C.3.1 Ambient Temperature
- C.3.3 Air Movement
- C.3.4 Test Voltage
- C.3.5 Spectral Mismatch of Photometer
- C.3.6 Model for Luminous Intensity

Main Text

- Annex D (informative) Guidance on Calculating Measurement Uncertainties
- D.1 General
- D.2 Uncertainty Budget
- D.3 Example of Measurement Uncertainties
- Annex E (informative) Guidance for Determining Rated Values of Photometric Quantities of LED Luminaires
- E.1 Introduction
- E.2 Rating and Tolerance of LED-Luminaire Data

Highlight Points

Common components of uncertainty for measurement of LED devices are listed

Common Parameters to all Measurements

- Temperature setting and uncertainty on temperature measurement
- Electrical settings and uncertainty on electrical measurements (power supply, electrical measuring instruments)
- Fluctuation of light output of the DUT (if significant)
- Calibration standard (calibration certificate)
- Operating of the calibration standard (ageing, electrical measurements, calibration process)
- Linearity of measuring instruments
- Reproducibility and repeatability (if applicable, default value for the equipment and generic device type may be used if this is not evaluated for the specific DUT)

Luminous Flux Uncertainty

a) Goniophotometer

- Flatness of mirrors and polarization effects
- Spectral reflectance of mirrors
- Stray light (spatial)
- Positioning accuracy
- Spectral matching (detector + mirror, different spectral power distributions of the calibration standard and DUT)
- Detector acceptance area
- Cosine response (illuminance integration)
- Uncertainty of photometric distance if the photometer head is calibrated for illuminance responsivity
- Uncertainty of the reflectance of the mirror if it is used, if the photometer head is calibrated for illuminance responsivity

Luminous Flux Uncertainty

c) Sphere-spectroradiometer

- Self-absorption
- Thermal behaviour
- Spatial non-uniformity of sphere responsivity
- Sphere reflectance
- Wavelength accuracy
- Stray light of the spectroradiometer
- Bandpass of the spectroradiometer
- Cosine response of the spectroradiometer entrance port
- Mechanical repeatability when the sphere is opened and closed
- Stability of the sphere responsivity during the period between recalibrations
- Fluorescence effects from sphere coating

Colour Quantities Uncertainty

This includes chromaticity coordinates, correlated colour temperature, and colour rendering indices. In addition to 8.1.1 at least following contributions shall be considered:

- Correlations due to the colour temperature uncertainty of the calibration source
- Stray light of the spectroradiometer
- Bandwidth (influence, correction)
- Wavelength accuracy
- Dynamic range over the spectral range

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Some Advice

- D.2 — Example of uncertainty budget summary for luminous flux measurement of an LED lamp using a sphere-spectroradiometer

Name of the quantity X_i	Relative contribution to the output standard uncertainty $u_{rel,i}(y)$	
	Broad [a]	Narrow [b]
Luminous flux uncertainty of NMI traceable total spectral radiant flux standard	1,0 %	
Ageing of luminous flux standard lamp (tungsten halogen lamp)	0,3 %	
DC current uncertainty for standard lamp	0,4 %	
Ambient temperature (and uncertainty of thermometer)	0,3 %	
Supply voltage of LED (and uncertainty of volt meter)	0,2 %	
Nonlinearity of spectroradiometer	0,8 %	
Wavelength uncertainty (0,5 nm (k=2))	0,4 %	
Stray light of spectroradiometer (2 700 K to 6 500 K source)	1,0 %	
Reproducibility of spectroradiometer	0,1 %	
Self-absorption correction (residual uncertainty) [c]	0,3 %	
Spatial non-uniformity of sphere (difference in intensity distribution from the standard lamp)	0,9 %	1,8 %
Repeatability of the sphere system	0,3 %	
Stability of the sphere system (between calibrations)	0,3 %	
Near-field absorption	0,3 %	
Reproducibility of test lamp (including stabilization condition)	0,3 %	
Stability of standard lamps	0,2 %	
Relative combined standard uncertainty	2,1 %	2,6 %
Total expanded uncertainty (k=2)	**4,2 %**	**5,2 %**

[a] Values for sources having broad angular intensity distribution are shown in the left column.

[b] Values for sources having narrow beam distribution, and if standard lamp is omnidirectional and no correction is made, are shown in the right column.

[c] Values for the case of 1,5 m sphere with 95 % reflectance measuring a typical compact LED lamp. This will change for different sphere condition and for DUTs of larger sizes.

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Some Advice

- **D. 5 — Example of uncertainty budget summary for colorimetric measurements of a LED lamp or LED luminaire using a sphere-spectroradiometer or gonio-spectroradiometer**
- (Values are shown for products with white LEDs of phosphor technology for *T*cp = 3 000 K and 6 000 K.)

		Absolute contribution to the output standard uncertainty							
Name of the quantity X_i		$u_i(x)$	$u_i(y)$	$u_i(u')$	$u_i(v')$	$u_i(T_{cp})$ 3 000 K	$u_i(T_{cp})$ 6 000 K	u_i(Duv)	$u_i(R_a)$
Calibration uncertainty of SI traceable secondary spectral radiant flux standard or spectral irradiance standard		0,001 4	0,001 9	0,000 5	0,001 2	26,6	67,8	0,000 5	0,44
Ageing of standard lamp		0,000 1	0,000 1	0,000 0	0,000 1	2,1	5,4	0,000 0	0,00
Wavelength uncertainty		0,000 4	0,000 7	0,000 1	0,000 4	6,9	17,5	0,000 2	0,08
Reproducibility of lamp and spectroradiometer		0,000 2	0,000 3	0,000 2	0,000 2	3,7	9,4	0,000 1	0,10
Nonlinearity of spectroradiometer		0,000 7	0,000 3	0,000 5	0,000 2	11,8	30,2	0,000 1	0,23
Bandpass of spectroradiometer		0,000 1	0,000 1	0,000 0	0,000 1	1,1	2,7	0,000 0	0,03
Stray light of spectroradiometer	3 000 K	0,000 6	0,001 0	0,000 0	0,000 5	5,3	—	0,000 3	0,25
	6 000 K	0,001 9	0,002 9	0,000 3	0,001 7	—	101,5	0,000 6	0,14
Combined standard uncertainty	3 000 K	0,001 7	0,002 3	0,000 7	0,001 4	30,7	—	0,000 7	0,57
	6 000 K	0,002 5	0,003 6	0,000 8	0,002 1	—	127	0,000 8	0,53
Total expanded uncertainty (k=2)	**3 000 K**	**0,003 5**	**0,004 7**	**0,001 4**	**0,002 7**	**61**	**—**	**0,001 4**	**1,1**
	6 000 K	**0,005 0**	**0,007 2**	**0,001 6**	**0,004 2**	**—**	**255**	**0,001 6**	**1,1**

Note For the uncertainty of chromaticity coordinates as distances from the true point on the (x, y) or (u',v') chromaticity diagram, a coverage factor k=2,45 should be used for expanded uncertainty at 95 % confidence interval.


Thank you!

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