# The common issues in lighting test and potential solutions (key technical measurement requirements based on CIE S 025)

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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

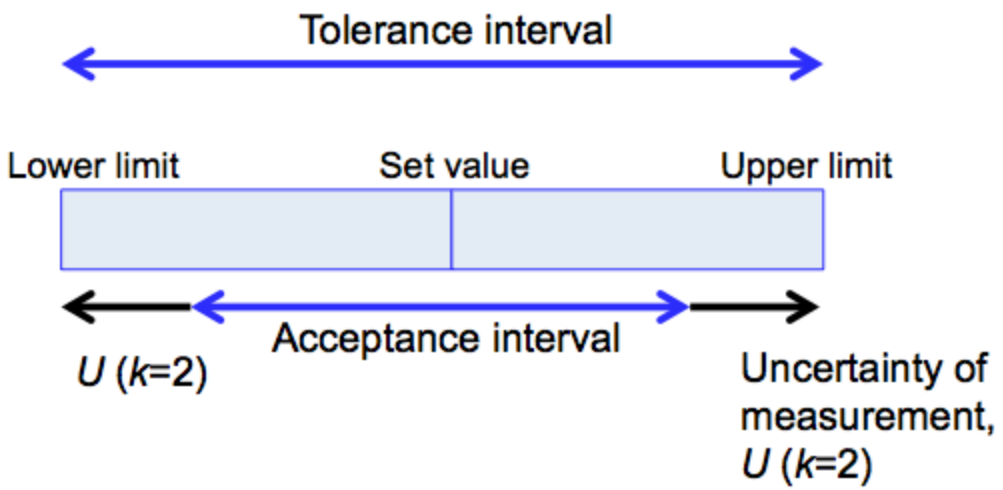
- The standard **specifies the requirements** for measurement of electrical, photometric, and colorimetric quantities of LED lamps, LED modules and LED luminaires, for operation with AC or DC supply voltages, possibly with associated LED control gear. LED light engines are assimilated to LED modules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

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# Content of this standard

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# Content of this standard

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# Content of this standard

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- 6.5.2 LED Luminaires
- 6.6 Centre Beam Intensity and Beam Angles
- 6.7 Luminance Measurements
- 7 Measurement of Colour Quantities
- 7.1 Colorimetric Measurements
- 7.1.1 General Aspects
- 7.1.2 Correlated Colour Temperature (White LED Light Sources)
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# Content of this standard

- 8 Measurement Uncertainties
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- 8.1.1 Common Parameters to all Measurements
- 8.1.2 Luminous Flux
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- 8.1.6 Luminous Efficacy
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- 9.1.1 General Information
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- 9.1.3 Information on the Test Procedure
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# Content of this standard

- 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
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# Content of this standard

- 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

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# Highlights

## Chapter 8 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)

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# 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

**B) Sphere-spectroradiometer**

- Self-absorption
- Thermal behavior
- 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. | | | | | | | | | |

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