



BSI Standards Publication

Electronic displays

Part 2-2: Measurements of optical characteristics — Ambient performance

National foreword

This British Standard is the UK implementation of IEC 62977-2-2:2020.

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INTERNATIONAL STANDARD



Electronic displays – Part 2-2: Measurements of optical characteristics – Ambient performance

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRONIC DISPLAYS –

**Part 2-2: Measurements of optical characteristics –
Ambient performance**

FOREWORD

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International Standard IEC 62977-2-2 has been prepared by IEC technical committee 110: Electronic displays.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
110/1213/FDIS	110/1232/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62977 series, published under the general title *Electronic displays*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

This document describes the common optical measurement methods applicable in the field of electronic display devices, which overlap with some of the parts of existing documents developed inside TC 110 (IEC 61747-6-2 [17]¹, IEC 62341-6-2 [18], IEC 61988-2-2 [19], IEC 62715-5-1 [20], IEC 62679-3-1 [21]), that describe the optical measurement methods of the individual technologies, such as LCD, OLED, PDP and others. This document on common optical measurement methods is intended to be used as the reference document in future documents and in revisions of existing documents (e.g. IEC 61747-6-2 [17], IEC 62341-6-2 [18], IEC 61988-2-2 [19], IEC 62715-5-1 [20], IEC 62679-3-1 [21]). The existing standards documents will be revised in their maintenance time and they will refer to this document to the largest extent.

All documents in IEC TC 110 that are concerned with the measurement of optical properties of electronic display devices under ambient illumination refer to a set of methods and procedures that are similar to each other, or sometimes even identical. This document is intended to identify these methods and to describe them, together with suitable precautions and diagnostics, as a reference for forthcoming documents to make the work of the involved experts more efficient and to avoid duplication of efforts.

Introduction of the common optical measurement methods (COMMs) is also related to a structure where each kind of optical measurement finds its unambiguous position for identification of similarities to other methods or for clarification of distinctions. This structural classification together with a general taxonomy is supposed to make the process of documents production easier, faster and thus more effective.

The above characteristics are summarized in Table 1. The display characteristics that are addressed in this part of IEC 62977 are indicated by a check mark ✓ in the table.

¹ Numbers in square brackets refer to the Bibliography.

Table 1 – Measurement structure from optical quantities to evaluation and to results (top down)

Variables	Time		Location (x, y)	Direction (θ, ϕ)	Test pattern, electrical driving, input signal	Illumination conditions	Temperature, humidity
Data sampling condition	Fast	Slow	Slow	Slow	Slow √		
Evaluation							
Results	Transitions from one optical state to another state (for example from test-pattern-1 to test-pattern-2)	Temporal stability (uniformity)	Lateral uniformity	Directional uniformity	Static pattern, √ Characteristic function (electro-optic transfer function, EOTF) Characteristic values (e.g. threshold, saturation)	Darkroom, √ Indoor, Outdoor	Standard environment √
Evaluation 1st order	Turn-on, turn-off, delay (latency) time periods, temporal modulations				Luminance, √ Contrast, √ chromaticity, √ Threshold, saturation values, steepness of transitions, etc.		
Evaluation 2nd order	Flicker prediction, moving picture response time, etc.				EOTF from which the exponent γ is evaluated Chromaticity/ colour gamut area, Colour gamut volume, √		

ELECTRONIC DISPLAYS –

Part 2-2: Measurements of optical characteristics – Ambient performance

1 Scope

This part of IEC 62977 specifies standard measurement conditions and measuring methods for determining the optical characteristics of electronic displays under indoor and outdoor illumination conditions. Standard illumination geometries are specified and the reflection properties of flat screens are determined under those conditions. Reference illumination levels and spectra are used to estimate the photometric and colorimetric characteristics of electronic displays under the same conditions. These methods apply to emissive, transmissive, and reflective displays, or combinations thereof, that render real 2D images on a flat screen.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-845, *International Electrotechnical Vocabulary (IEV) – Part 845: Lighting*

IEC 61966-2-1, *Multimedia systems and equipment – Colour measurement and management – Part 2-1: Colour management – Default RGB colour space – sRGB*

ISO/CIE 11664-1, *Colorimetry – Part 1: CIE standard colorimetric observers*

ISO/CIE 11664-4, *Colorimetry – Part 4: CIE 1976 L*a*b* colour space*

ISO 15076-1:2010, *Image technology colour management – Architecture, profile format and data structure – Part 1: Based on ICC.1:2010*

CIE 15, *Colorimetry*

CIE 168, *Criteria for the evaluation of extended-gamut colour encoding*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-845 and the following apply.

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1.1

signal pixel

smallest encoded picture element in the input image

Note 1 to entry: Signal pixel is defined as the unit of signal resolution.

3.1.2

pre-gamma average picture level

average input level of all signal pixels relative to an equivalent white pixel driven by a digital RGB input

Note 1 to entry: Unless otherwise stated, the pre-gamma average picture level (APL) will simply be referred to as average picture level in this document.

Note 2 to entry: The APL will normally be expressed as a percentage, where a full white screen at maximum drive level would be 100 % APL.

Note 3 to entry: The pre-gamma APL is also called gamma-corrected APL in IEC 62087-2 [14]. In addition, it is noted that the tone rendering curve may not have a power law function with a well-defined exponent (gamma).

3.1.3

APL loading

influence of average picture level on display performance, for example luminance

3.2 Abbreviated terms

APL	pre-gamma average picture level
CCT	correlated colour temperature
CIE	Commission Internationale de L'Eclairage (International Commission on Illumination)
CIELAB	CIE 1976 (L*a*b*) colour space
DUT	device under test
EOTF	electro-optic transfer function
FWHM	full-width-at-half-maximum
ILU	integrated lighting unit (e.g. an edge-lit front guide plate)
LCD	liquid crystal display
LED	light emitting diode
LMD	light measuring device
OLED	organic light emitting diode
RGB	red, green, and blue
SDR	standard dynamic range
sRGB	standard RGB colour space defined in IEC 61966-2-1

3.3 Symbols

A list of symbols used in this document is given in Table 2.

Table 2 – Summary of symbols

Symbol	Units	Definition
E	lx	illuminance
$E(\lambda)$	$\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	spectral irradiance
$E_{\text{dir}}(\lambda)$	$\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	spectral irradiance from a directed light source at normal incidence
$E_{\text{CIE,dir}}(\lambda)$	$\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	spectral irradiance of a CIE standard illuminant from a directed light source at normal incidence
$E_{\text{hemi}}(\lambda)$	$\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	spectral irradiance from a hemispherical diffuse light source
$E_{\text{CIE,hemi}}(\lambda)$	$\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	spectral irradiance of a CIE standard illuminant from a hemispherical diffuse light source
R_Q		luminous reflectance factor for a rendered display colour Q
$R_Q(\lambda)$		spectral reflectance factor for a rendered display colour Q
ρ_Q		luminous reflectance or diffuse reflectance for a rendered display colour Q
$\rho_Q(\lambda)$		spectral reflectance for a rendered display colour Q
L_Q	$\text{cd} \cdot \text{m}^{-2}$	darkroom luminance for a rendered display colour Q
$L_Q(\lambda)$	$\text{W} \cdot \text{sr}^{-1} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	darkroom spectral radiance for a rendered display colour Q
$L_{Q\text{-amb}}(\lambda)$	$\text{W} \cdot \text{sr}^{-1} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	ambient spectral radiance, including reflected and darkroom emitted light, for a rendered display colour Q
$L_{\text{Ref}}(\lambda)$	$\text{W} \cdot \text{sr}^{-1} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	reflected spectral radiance when the reflection coefficients are independent of the rendered display colour Q
$X_Q, Y_Q, \text{ and } Z_Q$	$\text{cd} \cdot \text{m}^{-2}$ for Y_Q	CIE tristimulus values of the rendered display colour Q in a darkroom
$X_{Q\text{-amb}}, Y_{Q\text{-amb}}, \text{ and } Z_{Q\text{-amb}}$	$\text{cd} \cdot \text{m}^{-2}$ for $Y_{Q\text{-amb}}$	equivalent CIE tristimulus values, including reflected and darkroom emitted light, for a rendered display colour Q
x_Q, y_Q		CIE 1931 chromaticity coordinates of the rendered display colour Q in a darkroom
$x_{Q\text{-amb}}, y_{Q\text{-amb}}$		equivalent CIE 1931 chromaticity coordinates, including reflected and darkroom emitted light, for a rendered display colour Q

4 Standard measuring conditions

4.1 Standard measuring environmental conditions

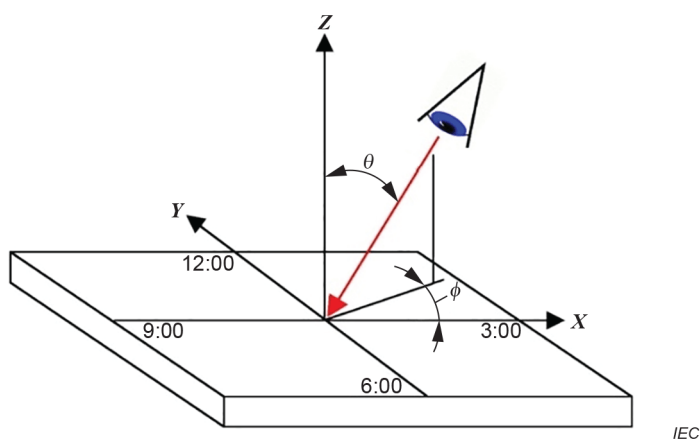
Measurements shall be carried out under the following standard environmental conditions:

- temperature: $25\text{ °C} \pm 3\text{ °C}$,
- relative humidity: 25 % to 85 %,
- atmospheric pressure: 86 kPa to 106 kPa.

When different environmental conditions are used, they shall be noted in the report.

4.2 Viewing direction and light source coordinate system

The viewing direction is the direction under which the observer looks at the point of interest on the display under test (DUT). During the measurement, the light measuring device (LMD) simulates the observer, by aiming the LMD at the point of interest on the DUT from the viewing direction. The viewing direction is defined by two angles: the angle of inclination θ (relative to the surface normal of the DUT) and the angle of rotation ϕ (also called azimuth angle) as illustrated in Figure 1. Although the azimuth angle is measured in the counter-clockwise direction, it is related to the directions on a clock face as follows: $\phi = 0^\circ$ is the 3-o'clock direction ("right"), $\phi = 90^\circ$ the 12-o'clock direction ("top"), $\phi = 180^\circ$ the 9-o'clock direction ("left") and $\phi = 270^\circ$ the 6-o'clock direction ("bottom"). The same coordinate system can be used to specify the positioning of the light sources used to represent the ambient lighting environment.



NOTE This coordination is defined by the angle of inclination and the angle of rotation (azimuth angle) in a polar coordinate system.

Figure 1 – Representation of the viewing direction (direction of measurement) and coordinate system used for light source configuration

4.3 Standard lighting conditions

4.3.1 General

A light source is chosen to provide as broad, stable, and smooth a spectrum as possible in order to reliably measure the spectral reflectance and reflection coefficients of the display surface specific to the geometry of the light source. This document then applies the reflection coefficients to simulate the display performance under the same geometric conditions using an illuminant, that is, a model or measured light source with an illumination level and/or spectrum that could be different from the light source used in the measurement.

An illuminant can be used to represent the use of a display that is viewed indoors (e.g. office), or in direct daylight (outdoors). These environments generally contain a combination of directed and uniform hemispherical diffuse light sources. The visual performance of the display can depend on the type of illumination and measurement geometry. Subclause 4.3 specifies the detailed conditions of the light sources for reflectance measurements under otherwise darkroom conditions.

A warm-up time can be necessary. The light source signal shall remain stable to within $\pm 0,5$ % standard deviation within a single measurement, and ± 2 % for longer (>30 min) measurements.

4.3.2 Standard measuring darkroom conditions

The influence of unwanted background illumination shall be minimized, typically by illuminating the display in a darkroom. Unwanted background illumination is mainly a consideration for directed light sources, which is often solved by using light sources with spectral irradiance values that are substantially larger than the background. The darkroom spectral radiance contribution from the background illumination, that is, the measured spectral radiance reflected off the DUT, shall be not more than $1/10^{\text{th}}$ of the spectral radiance from the device black state with the illumination source on. If this condition is not satisfied, then background subtraction is required and it shall be noted in the report. In addition, if the sensitivity of the LMD is more than $1/100^{\text{th}}$ of the spectral radiance from the device black state, then the spectral radiance sensitivity limit of the LMD shall be noted in the report.

4.3.3 Standard ambient illumination

The following illumination conditions are specified for the optical measurements of displays under ambient illumination. The ambient illumination shall simulate indoor or outdoor illumination conditions. A combination of a hemispherical diffuse and directed source geometry is generally used to simulate either ambient indoor illumination or outdoor daylight illumination under a clear sky [1], [2]. Uniform hemispherical diffuse illumination will be used to simulate the background lighting in a room with the directed light source such as an occluded luminaire in a room, or the hemispherical skylight incident on the display, with the sun occluded. A directed light source in a darkroom will simulate the effect of directional illumination on a display by a luminaire in a room, or from direct sunlight.

The following reference illumination conditions shall be used to simulate indoor and outdoor display viewing environments. Additional conditions can also be used, depending on the use case.

a) Indoor room illumination conditions:

- Uniform hemispherical diffuse illumination – Use a light source closely approximating CIE Standard Illuminant A, CIE Standard Illuminant D65, or CIE Standard Illuminant D50 as defined in CIE 15. For spectral measurements, a spectrally smooth broadband light source (such as an approximation to CIE Standard Illuminant A) shall be used. A measurement of the spectral reflectance factor using a broad light source (such as Illuminant A) enables the indoor photopic and colour metrics to be calculated later for the desired reference spectra (for example CIE D65 Illuminant). The performance metrics shall be calculated using 300 lx for an indoor reading environment [3]. The actual hemispherical diffuse reflectance factor measurement can require higher illumination levels for better measurement accuracy. The results are then scaled down to the required illumination levels.
- Directional illumination – The same source spectra shall be used as with hemispherical diffuse illumination. The indoor room photopic and colour metrics shall be calculated using directional illumination of 200 lx incident on the display surface for an indoor reading environment with the display in the vertical orientation. The actual reflectance factor measurement can require higher illumination levels for better measurement accuracy. The results are then scaled down to the required illumination levels. The directed source shall be 45° above the surface normal ($\theta_s = 45^\circ$) and have an angular subtense of no more than 5° . The angular subtense is defined as the full angle span of the light source from the centre of the display's measurement area.
- Other illumination levels may be used in addition to those defined above for calculating the ambient contrast ratio under indoor illumination conditions. However, approximately 60 % of the total illuminance should be hemispherical diffuse, and 40 % directional illumination. Additional ratios of diffuse to directional illumination may also be measured.

b) Daylight illumination conditions:

- Uniform hemispherical diffuse illumination – Use a light source closely approximating skylight with the spectral distribution of CIE Illuminant D75 [4]. Additional CIE daylight illuminants (such as D65) may also be used, depending on the intended application. For spectral measurements, the spectral reflectance factor measurements can be made using a spectrally smooth broadband source (such as an approximation to CIE Standard Illuminant A). Skylight photopic and colour metrics can be calculated later for the CIE D75 Illuminant spectra. The skylight photopic and colour metrics shall be calculated using 15 000 lx of hemispherical diffuse illumination (with specular included) incident on a display surface in a vertical orientation [4],[5]. The actual hemispherical diffuse reflectance factor measurement may be taken at lower illumination levels. The results are then scaled up to the required illumination levels.
- Directional illumination – The directional light source shall approximate CIE daylight Illuminant D50 [4]. Additional CIE daylight illuminants (such as D65) may also be used, depending on the intended application. A spectrally smooth broadband source (such as an approximation to CIE Standard Illuminant A) may be used for the reflectance factor measurement. The sunlight photopic and colour metrics can be calculated later with the D50 Illuminant spectra. The daylight contrast ratio or colour shall be calculated using 65 000 lx for a directed source at an inclination angle of $\theta_s = 45^\circ$ to the display surface, and the LMD shall be aligned normal to the display surface ($\theta_d = 0$) [4],[5]. The actual reflectance factor measurement may be taken at lower illumination levels. The results are then scaled up to the required illumination levels. The contrast ratio and colour are calculated for the scaled-up illuminance levels. The directed source shall have an angular subtense of approximately $0,5^\circ$.

For daylight photopic and colour metric calculations from spectral reflectance factor measurements, the relative spectral distributions of CIE Illuminants A, D50, D65 and D75 tabulated in CIE 15 shall be used. Additional CIE daylight illuminants shall be determined using the appropriate eigenfunctions, as defined in CIE 15.

The UV region (< 380 nm) of the light source shall be cut off by a UV blocking filter. When high light source illumination levels are used, an infrared-blocking filter is recommended to minimize device heating.

If there is fluorescent light with a radiance larger than 1/100 that of the DUT black state (including background reflected light) the spectral reflectance analysis should not be used. In this case, the spectrum of the light sources should match the spectrum of the CIE illuminants, and the photometric reflection coefficients shall be measured directly. These coefficients will then include the contribution from the fluorescence. The presence of fluorescence can be checked by turning the display off and shining a directional source (with a blue filter) on the display at a 45° inclination angle and determining if a glow from the illumination area can be observed.

4.3.4 Standard illumination geometries

4.3.4.1 General

The measurement geometry can have a significant effect on the measured reflection properties of a display [6]. Three types of illumination geometries shall be used for determining the performance of the display. Standard configurations for implementing these illumination geometries are defined in 4.3.4. Additional illumination geometries may also be used. The details of the illumination geometry used for a given measurement shall be reported. Further guidance on the proper implementation of these illumination geometries is given in the SID Information Display Measurements Standard [1].

4.3.4.2 Directional illumination

Directional illumination is obtained when a light source produces approximately parallel rays incident on the DUT. The maximum deviation of the rays from the optical axis depends on the diameter of both the source and measuring spot. The maximum angle of deviation from the optical axis is given by

$$\arctan\left(\left[r_{\text{ms}} + r_{\text{s}}\right] / |d|\right) < 5^\circ \quad (1)$$

where r_{s} is the source radius, d is the distance to the measuring spot, and r_{ms} is the measuring spot radius. The illumination across the cross-section of the beam shall be uniform to within 5 % ($[L_{\text{max}} - L_{\text{min}}] / L_{\text{max}}$). A source of light sufficiently distant from the DUT can provide directional illumination (e.g. sun and moon). When simulating outdoor directional ambient illumination like the sun and moon, the subtense of the source (as observed by the DUT) should be $\leq 0,5^\circ$.

Directional illumination can be realized with at least three different types of sources when the source dimensions are small enough compared to the distance between the source and the measuring spot on the sample. These geometries are depicted in Figure 2:

- flat Lambertian source, for example the exit port of an integrating sphere (top, with light source in grey),
- spherical isotropic source (e.g. incandescent bulb inside a diffusing glass-sphere) (middle, with light source in grey),
- projection system with lenses or mirrors (bottom, with lens on the right).

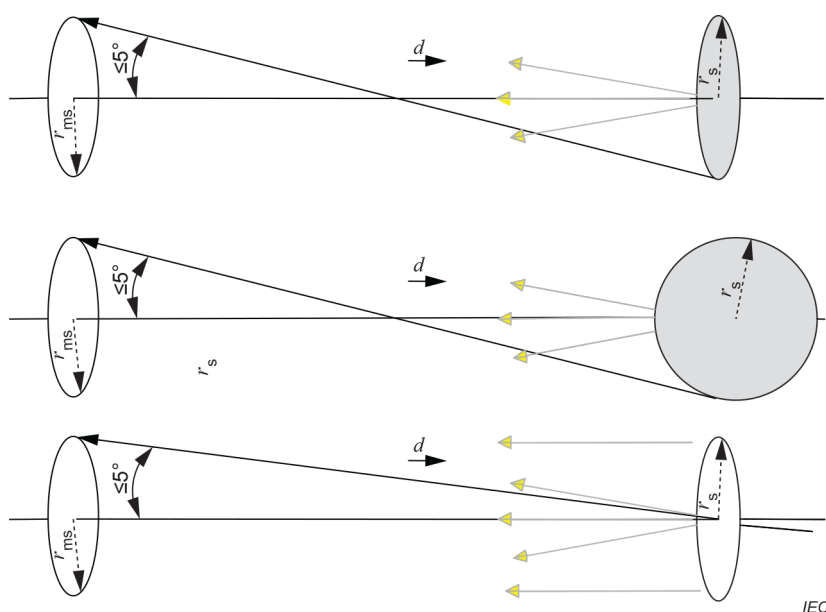


Figure 2 – Illustrated examples for directional illumination

Directional illumination is implemented by using a light source with a small diameter (compared to the distance to the measurement spot) aligned to form an inclination angle θ_{S} with respect to the surface normal of the DUT. This directed light source produces an illumination spot on the DUT. The LMD is placed at an inclination angle θ_{R} in the plane of the incident light, and its measurement field centred within the illumination spot. The light source and LMD can be adjusted over a range of inclination angles, but the LMD shall remain in the plane of incidence (i.e. $\phi_{\text{S}} = \phi_{\text{R}} + 180^\circ$). This configuration is shown in Figure 3 (left) with its representation in a polar coordinate system (right). The measurement field on the DUT is defined by the DUT area element that is imaged on the detector in the LMD.

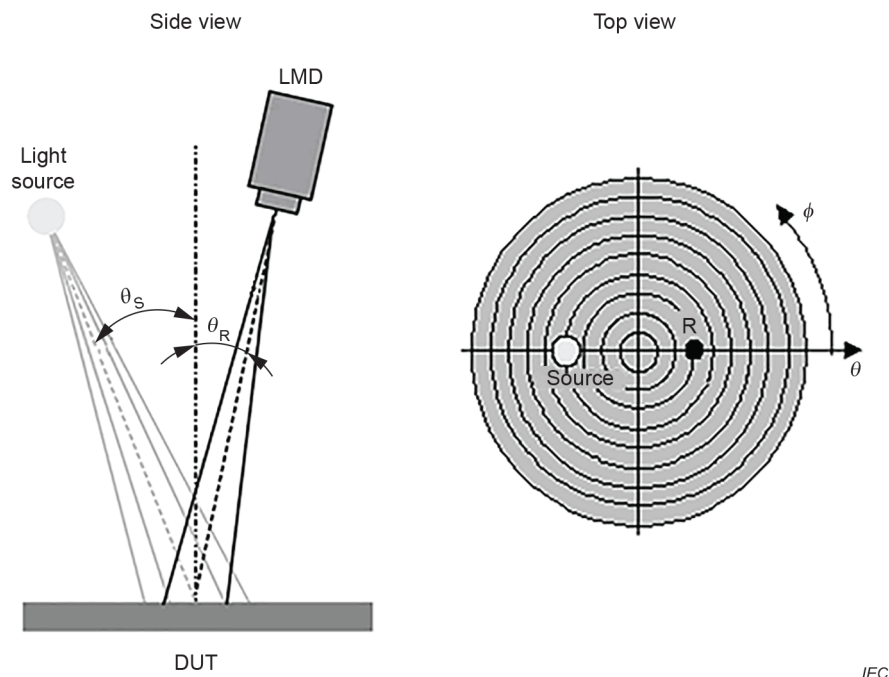


Figure 3 – Example of the measuring setup using directional illumination where $\theta_S = 40^\circ$ and $\theta_R = 30^\circ$

The standard conditions are $\theta_S = 45^\circ$ and $\theta_R = 0^\circ$. Alignment accuracy to within $\pm 0,4^\circ$ is recommended to keep alignment-related measurement error within $\pm 5\%$.

4.3.4.3 Ring light illumination

Ring light illumination can be considered a special case of directional illumination. It provides directional illumination with rotational symmetry about the display's surface normal and is centred on the measurement spot. Ring light illumination can be realized in the following ways:

- fiber-optic ring light,
- integrating sphere with a ring-shaped aperture (annulus),
- optical systems with lenses and mirrors, for example a concave ring mirror.

A ring-shaped light-source centred about the surface normal of the DUT illuminates the DUT from an angle of inclination $\theta_S \pm \Delta$ for all azimuthal angles $\phi_S = 0$ to 360° . The LMD is aligned to form an angle $\theta_R < \theta_S - \Delta$ with respect to the surface normal of the DUT. Figure 4 shows a side view of the measuring setup (left) and its representation in a polar coordinate system (right). A more detailed illustration of the ring light characteristics is given in Figure 5. The subtense of the ring light (2Δ in this case) shall be specified. The source and detector shall be aligned to the defined geometry to within $\pm 3^\circ$. The illumination of the measuring spot on the DUT shall be uniform within 5% . This setup is used with the light source fixed, and the LMD can be adjusted within the limits of the ring light opening. The standard conditions are $\theta_R = 0^\circ$ and a source inclination angle of $\theta_S \pm \Delta = 45^\circ \pm 3^\circ$.

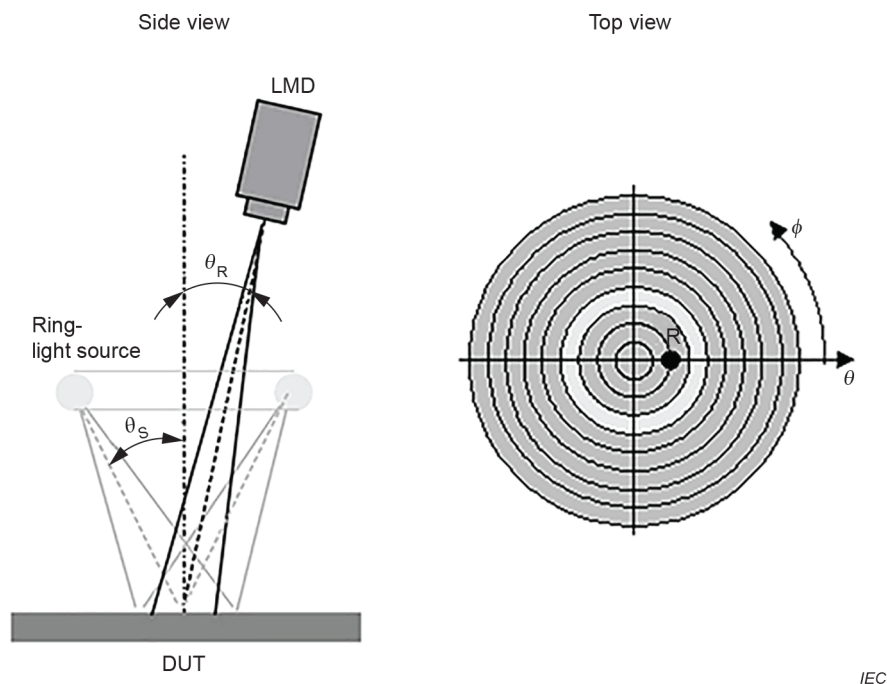
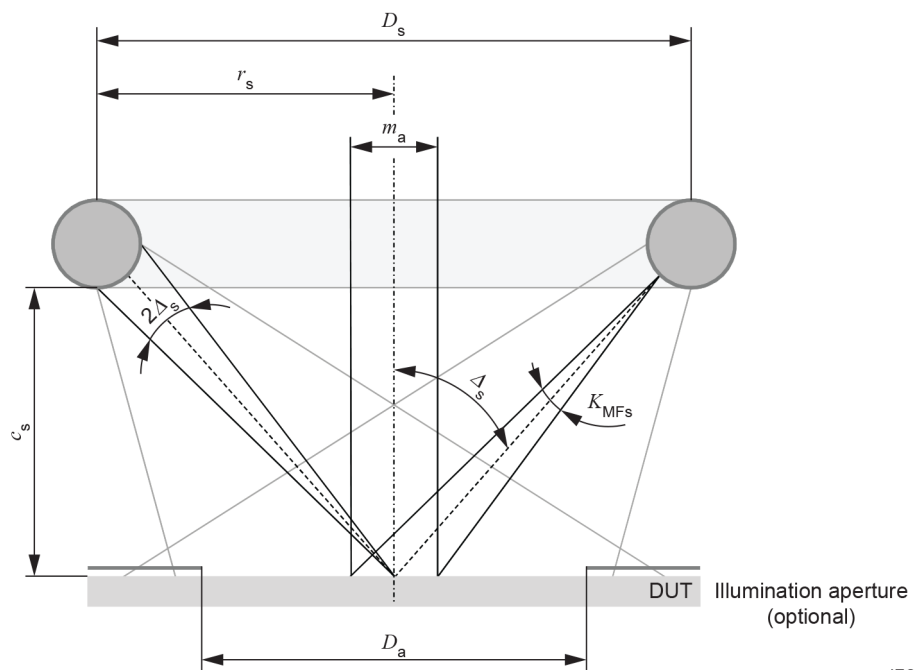


Figure 4 – Example of ring light illumination measuring setup where $\theta_S \pm \Delta = 35 \pm 5$ and $\theta_R = 20^\circ$

It is recommended that the ring light and LMD have an alignment accuracy of $\pm 0,7^\circ$ in order to keep the alignment-related measurement error within $\pm 5\%$. When simulating outdoor directional ambient illumination using the ring light, the subtense 2Δ of the source (as observed by the DUT) should be $\leq 0,5^\circ$. A fiber-optic ring light is recommended in this case.



Key:

Ring light subtense	$(2\Delta_s, K_s)$
Ring light inclination	(Δ_s, Δ_r)
Ring light distance	(C_s)
Light radius	(r_s)
Ring light width	(D_s)
Measurement field	(m_a)
Illumination field (aperture)	(D_a)
Measurement field illumination subtense	(K_{MFs})

Figure 5 – Detailed schematic of ring light characteristics

The maximum angle of deviation from the optical axis is given by:

$$\arctan\left(\frac{c_s}{r_s}\right) - \arctan\left(\frac{c_s}{r_s - \frac{m_a}{2}}\right) < 5^\circ \quad (2)$$

Thus, the ring light diameter (D_s) should be at least six times larger than the measurement field diameter (m_a).

The illuminated area diameter (D_a) should be at least 1,5 times larger than the measurement field diameter (m_a).

If the display consists of thick layers (>1 mm) above the reflective surface of the DUT's imaging plane, care should be taken to measure the ring light distance (c_s) from the farthest visible layer in the display, not the front surface of the display.

NOTE If the reflected light from the display exhibits an asymmetric scatter pattern (e.g. matrix scatter), then the ring light source is used for directional illumination measurements [7]. If a directional source is used with asymmetric scatter, it is possible that the results are not reproducible.

4.3.4.4 Hemispherical illumination

Hemispherical illumination is omni-directional light that is uniformly incident on a display surface. It can be used to simulate the diffuse background illumination of indoor environments or the diffuse illumination of outdoor skylight (with direct sunlight blocked). In the true hemispherical case, incident light rays of constant luminance are uniformly distributed over all angles of inclination at the measuring spot. Two possible examples of the measurement geometry are shown in Figure 6. A good approximation of ideal hemispherical illumination (i.e. constant luminance from all directions up to 90° inclination) can only be provided by integrating spheres where the diameter of the measurement port (Figure 6, configuration A) or the sample port (configuration B) is small compared to the diameter of the sphere. If an integrating sphere that is at least seven times the physical outer diagonal of the display is available, the display can be mounted in the centre of the sphere (Figure 6, configuration A). For large displays, a sampling sphere (Figure 6, configuration B) or a hemisphere would be more suitable, following the guidance in CIE 38. In all cases, the configuration shall follow the standard $d_i:8^\circ$ to $d_i:10^\circ$ illumination/detection geometry, where d_i is the standard notation for diffuse illumination with the specular component included. The following procedure shall be used when performing hemispherical illumination measurements:

- The display is placed in the centre of an integrating sphere/hemisphere, or against the sample port of a sampling sphere.
- Establish the required illumination at the measurement spot. The colour temperature and illumination spectra can be measured from the reflected light of a white diffuse reflectance standard near the display measurement area (Figure 6, configuration A) or the sampling sphere wall adjacent to the sample port (Figure 6, configuration B). The type of light source used, its spectrum, and CCT shall be noted in the test report.

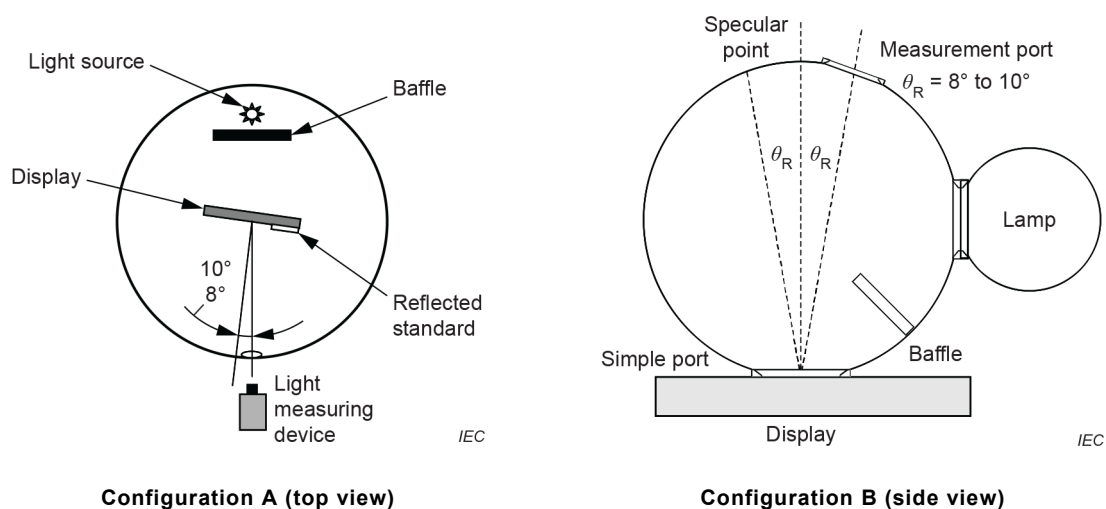


Figure 6 – Example of measurement geometries for hemispherical illumination using an integrating sphere (left) or sampling sphere (right)

- The LMD is aligned to view the centre of the display through a measurement port in the sphere wall at an inclination angle of 8° $+2^\circ$ -0° from the display normal. The required LMD angle of inclination can also be realised by tilting the display within the integrating sphere. The LMD is focused on the display's image plane.

- d) The measurement port diameter shall be 20 % to 30 % larger than the effective aperture of the LMD lens. Care needs to be taken to avoid any direct light from the sources, or any bright reflections off any surface (other than the screen itself), from hitting the lens of the LMD in order to minimize the veiling glare contamination of the reflected luminance measurement. The LMD shall be moved back from the measurement port so that the bright walls of the sphere are not visible to the LMD. In addition, the sample port diameter will typically need to be larger than 25 mm in order for the LMD's measurement field to be completely contained within the sample port.
- e) The measurement port shall be bevelled away from the lens. The small diameter of the bevel is toward the LMD, and the large diameter on the inside of the sphere.
- f) The spectral irradiance or illuminance on the display can be measured using a white diffuse reflectance standard with a known hemispherical diffuse spectral reflectance factor $\rho(\lambda)$, or the photopically-weighted (or luminous) hemispherical diffuse reflectance factor ρ . The white diffuse reflectance standard shall be calibrated under uniform hemispherical diffuse illumination in an integrating sphere. When an integrating sphere (configuration A) or hemisphere is used, the white diffuse reflectance standard shall be placed on the display surface. If t is the thickness of the white diffuse reflectance standard, then it shall be placed on the surface at a distance of $5 \times t$ to $7 \times t$ from the measurement area to avoid shadowing. The white reflectance standard can also be placed adjacent to and in the same plane as the display if the sphere illumination is uniform over that distance. For uniform illumination, the integrating sphere should be at least seven times larger than the physical outer diagonal of the display under test. In the case of the sampling sphere, the spectral irradiance can be determined by a measurement of the interior sphere wall adjacent to the sample port [8]. The hemispherical diffuse spectral reflectance factor, or the luminous hemispherical diffuse reflectance factor, of the interior sphere wall can be determined by comparing the spectral radiance (or luminance) of the wall with that of a calibrated white diffuse reflectance standard placed at the sample port (i.e. $\rho_{\text{wall}} = \rho_{\text{std}} \times (L_{\text{wall}} / L_{\text{std}})$).
- g) If a sampling sphere is used, the display measurement area shall contain more than 500 display pixels. It is recommended that the sampling sphere be at least six times larger than the sample port diameter. If there is a significant distance between the display emitting surface and the sample port entrance, then the size of the sample port may need to be increased [9].

The standard conditions are $\theta_R = 8^\circ$ and a source subtense of $2 \times \theta_{S-\text{max}} \geq 170^\circ$. The illumination of the measuring spot on the DUT shall be uniform to within 5 %.

4.4 Standard setup conditions

4.4.1 General

Standard setup conditions are given below. Any deviations from these conditions shall be reported.

4.4.2 Adjustment of display

The display shall be measured at its factory settings. If other settings are used, they shall be noted in the test report. These settings shall be held constant for all measurements. It is important, however, to make sure that not only the adjustments are kept constant, but also that the nominally steady-state physical quantities remain constant during the measurement. This is not automatically the case because of, for example, warm-up effects or auto-dimming features. Any automatic luminance or gain control shall be turned off. Otherwise it should be noted in the report. This document does not intend to include the effect of the ambient light (or brightness) control, and this display function shall be turned off. If that is not possible, then it is recommended that it should be set to turn on no lower than 300 lx. If the ambient light control cannot be set, then a constant illumination source of at least 300 lx should be mounted on the ambient light sensor and should be optically shielded from the test room. The state of the auto-light control shall be reported. In addition, if the display has an auto-dimming feature which reduces the display luminance of a static image after a prolonged time, then in some cases it is effective to render a black frame for at least 8 s prior to rendering the