IEC 62341-6-4

Edition 1.0 2017-05

INTERNATIONAL STANDARD

colour inside

Organic light emitting diode (OLED) displays –
Part 6-4: Measuring methods of transparent properties

IEC 62341-6-4:2017-05(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.260 ISBN 978-2-8322-4297-1

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ORGANIC LIGHT EMITTING DIODE (OLED) DISPLAYS –

Part 6-4: Measuring methods of transparent properties

FOREWORD

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International Standard IEC 62341-6-4 has been prepared by IEC technical committee 110: Electronic display devices.

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

FDIS	Report on voting
110/843/FDIS	110/866/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 62341 series, published under the general title *Organic light emitting diode (OLED) displays*, can be found on the IEC website.

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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

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ORGANIC LIGHT EMITTING DIODE (OLED) DISPLAYS –

Part 6-4: Measuring methods of transparent properties

1 Scope

This part of IEC 62341 specifies the standard measurement conditions and measuring methods for determining the optical performance of transparent properties of organic light emitting diode (OLED) display panels and modules. This document includes the display performance under darkroom conditions, and front and back illumination.

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 62341-1-2, *Organic light emitting diode (OLED) displays – Part 1-2: Terminology and letter symbols*

IEC 62341-6-1, *Organic light emitting diode (OLED) displays – Part 6-1: Measuring methods of optical and electro-optical parameters*

IEC 62341-6-2, *Organic light emitting diode (OLED) displays – Part 6-2: Measuring methods of visual quality and ambient performance*

ISO 9241-307, *Ergonomics of human-system interaction – Part 307: Analysis and compliance test methods for electronic visual displays*

ISO 11664-2, *Colorimetry – Part 2: CIE standard illuminants*

CIE 15-2004, *Colorimetry*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62341-1-2 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
transmittance factor
ratio of the radiant or luminous flux transmitted in the direction delimited by the given solid angle cone to that transmitted in the same direction and solid angle cone by a perfect transmitting diffuser identically irradiated or illuminated

Note 1 to entry: When the term transmittance factor is used in this document, it refers to the photopically-weighted luminous flux.

3.2
spectral transmittance factor
ratio of the spectral radiant flux transmitted in the direction delimited by the given solid angle cone to that transmitted in the same direction by a perfect transmitting diffuser identically irradiated

3.3
transmitted haze
percentage of transmitted luminance, passing through a specimen, which deviates from the incident light by no more than 0,044 rad (2,5°) by forward scattering

3.4
purity
ratio of the luminance measured in the 0,2° region to the luminance of the total transmitted light

Note 1 to entry: The purity is defined as how clearly the see-through image could be seen. The purity is derived from the measurement of distorted light due to diffraction or refraction.

3.5
on-screen performance
optical performance that can be measured on the transparent screen when viewing an image on the screen

4 Measuring conditions

4.1 Standard measuring environmental conditions

Measurements shall be carried out under the standard environmental conditions:

Temperature:	25 °C ± 3 °C
Relative humidity:	25 % RH to 85 % RH
Atmospheric pressure:	86 kPa to 106 kPa

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

4.2 Standard lighting conditions

4.2.1 Darkroom conditions

The luminance contribution from the background illumination reflected off and/or transmitted through the test display shall be less than 0,01 cd/m^2 or 1/20 of the display's black state luminance, whichever is lower. If these conditions are not satisfied, then background subtraction is required and it shall be noted in the report. In addition, if the sensitivity of the light measuring device (LMD) is inadequate to measure at these low levels, then the lower limit of the LMD shall be noted in the measurement report.

4.2.2 Ambient illumination conditions

Ambient lighting conditions can make a large impact on the performance of a transparent display. For observers who will watch a transparent display, various ambient conditions shall be suggested based on previous research. Table 1 shows the standard indoor and daylight ambient illumination conditions.

Uniform hemispherical diffuse illumination will be used to simulate the background lighting in a room or the hemispherical skylight incident on the display, with sun occluded. The detail information to simulate those ambient conditions is described in IEC 62341-6-2 and IDMS [1][1].

Table 1 – Standard ambient conditions

Design screen illuminance	Indoor and daylight illumination environment	Recommended illumination geometry
Up to 200 lx	(mostly) General building areas (ISO 9241-307)	60 % hemispherical, 40 % directional at 45°
Up to 300 lx	(mostly) General machine work, rough assembly work, (general) museum (ISO 9241-307), office environment [8]	60 % hemispherical, 40 % directional at 45°
Up to 500 lx	Medium assembly and decorative work, simple inspection, counters, libraries, (mostly) educational areas, control rooms (ISO 9241-307)	60 % hemispherical, 40 % directional at 45°
Up to 750 lx	Fine work, technical drawing (ISO 9241-307)	60 % hemispherical, 40 % directional at 45°
Up to 1 000 lx	Precision work, quality control, inspection, medical examination and treatment (ISO 9241-307)	60 % hemispherical, 40 % directional at 45°
Up to 1 500 lx	High precision work (ISO 9241-307)	60 % hemispherical, 40 % directional at 45°
> 1 500 lx	Special workplaces in the medical area (ISO 9241-307)	60 % hemispherical, 40 % directional at 45°
80 000 lx	The daylight contrast ratio and colour shall be calculated using a combination of hemispherical diffuse illumination (with specular included) and directional illumination incident on a display surface in a vertical orientation [8][9]	15 000 lx hemispherical, 65 000 lx directional at 45°

4.2.3 Ambient illumination spectra

The ambient performance of the display can be significantly impacted by the spectral distribution of the illumination source. Unless it is specified otherwise, the source illumination shall closely approximate CIE Illuminant D65 (see CIE 15). The source illumination used for measuring the display reflection and transmission properties shall have a spectrally smooth and broadband emission. Spectral reflection and transmission measurements can then be used to predict the ambient display performance for any desired illumination spectra.

When evaluating the display's ambient indoor performance, it is recommended to use the same spectral distribution for the hemispherical and directional source illumination. Light source spectra approximating CIE Illuminant A, Illuminant D50, and Illuminant D65 are recommended for indoor applications. For simulating outdoor applications, Illuminant D50 is recommended for the directional illumination, and Illuminant D75 is recommended for hemispherical illumination.

4.3 Standard setup conditions

4.3.1 Starting conditions of measurements

Standard setup conditions are given below. Measurements shall be started after the transparent OLED display and measuring instruments achieve stability. Sufficient warm-up time has to be allowed for the transparent OLED display panels and modules to reach a

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1 Numbers in square brackets refer to the Bibliography.

luminance stability level of less than ±5 % over the entire measurement for a given display image.

4.3.2 Conditions of measuring equipment

The general conditions of this measurement shall be as follows.

1) The standard measurement setup is shown in Figure 1. The LMD shall be a luminance meter, colourimeter, or a spectroradiometer capable of measuring spectral radiance over at least the 380 nm to 780 nm wavelength range, with a maximum bandwidth of 10 nm for smooth broadband spectra. For light sources that have sharp spectral features, like LEDs and fluorescent lamps, the spectroradiometer's maximum bandwidth shall be < 5 nm. The spectral bandwidth of the spectroradiometer shall be an integer multiple of the sampling interval. For example, a 5 nm sampling interval can be used for a 5 nm or 10 nm bandwidth. Care shall be taken to ensure that the device has enough sensitivity and dynamic range to perform the required task.
2) The light measuring device shall be focused on the image plane of the transparent display for on-screen performance and on the image plane of the background for transmission performance. The LMD will be aligned perpendicularly to its surface, unless stated otherwise.
3) The relative uncertainty and repeatability of all the measuring devices shall be maintained by following the instrument supplier's recommended calibration schedule.

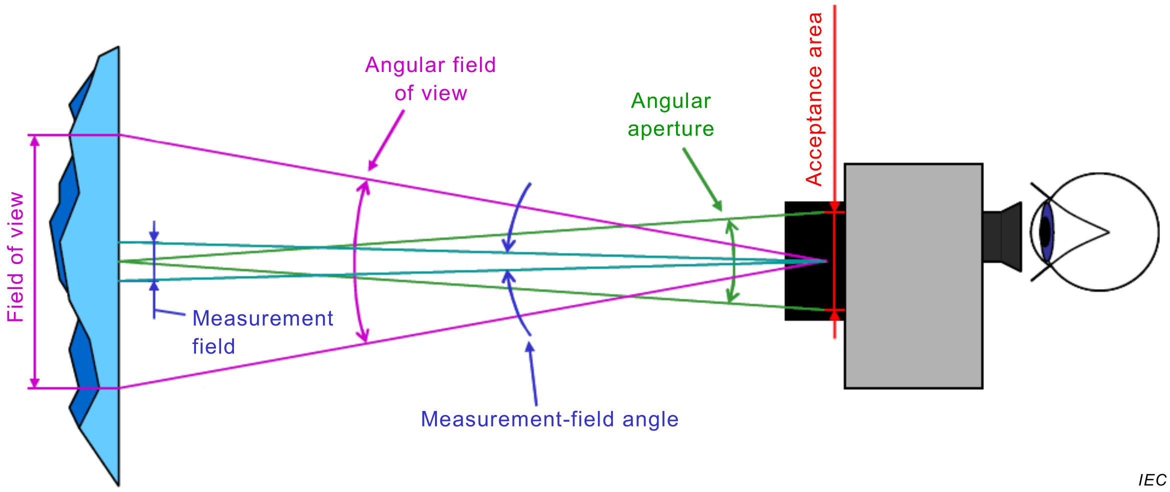


Figure 1 – Layout diagram of measurement setup

4) The LMD integration time shall be an integer number of frame periods, synchronized to the frame rate, or the integration time shall be greater than two hundred frame periods.
5) When measuring matrix displays, the light measuring devices shall be set to a measurement field that includes more than 500 pixels. If smaller measurement areas are necessary, equivalence to 500 pixels shall be confirmed.
6) The angular aperture shall be less than or equal to 5°, and measurement field angle shall be less than or equal to 2° (see Figure 1). The measuring distance and the measurement-field angle may be adjusted to achieve a measurement field greater than 500 pixels if setting the above measurement-field angle is difficult.
7) Display modules shall be operated at their design field frequency. When using separate driving signal equipment to operate a panel, the drive conditions shall be noted in the performance report.

Any deviations from these conditions shall be noted in the performance report.

5 Measuring methods of transparent properties

5.1 Measuring methods of transmission performance

5.1.1 Hemispherical transmittance factor with specular included

5.1.1.1 Purpose

The purpose of this method is to measure the transmitted light, including the specular component, through a transparent OLED display.

5.1.1.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) light measuring device that can measure luminance or spectral radiance;
   2) driving power source;
   3) driving signal equipment;
   4) integrating sphere with ports and a stabilized light source (see Figure 2), which shall be as follows:
      i) The light source in the integrating sphere should have a smooth broadband spectrum approximating CIE standard Illuminant D65, as specified in ISO 11664-2. The integrating sphere should have a photopic optical detector which monitors the relative luminance level m inside the sphere. The monitor shall be fitted with baffles to prevent light from the light source or the sample port from falling on it directly. The spectral characteristics of the light source shall be kept constant during measurements on a transparent OLED display. The measurement conditions shall be such that the transparent OLED display temperature does not increase while measurements are made.
      ii) The integrating sphere may be of any diameter as long as the total port area does not exceed 4,0 % of the internal area of the sphere. It is recommended that the diameter of the integrating sphere is not less than 150 mm so that specimens of a reasonable size can be used. When diameter of the integrating sphere is 150 mm and the diameters of the sample, compensation and light trap ports are 30 mm, the ratio of the total port area to the internal area of the sphere is 3,0 %. For specular included measurements, a port plug or diffuse white standard with similar reflectance to the inner wall can be used to fill the port. A sphere geometry may also be used instead for the configuration illustrated in Figure 2 (see Annex A). If the integrating sphere does not have a compensation port, and placing the OLED display at the sample port significantly changes the spectral distribution of the light in the sphere, the alternate sphere method in Annex A shall be used. In addition, if it is necessary to measure the hemispherical transmittance factor with the OLED display on, then the alternate sphere method shall be used.
      iii) It is recommended to use a sample port between 30 mm to 75 mm. If a compensation port is used, the sample and compensation ports of the integrating sphere shall be circular and of the same size. The compensation port shall be positioned at an angle of less than 1,57 rad (90°) from the sample port. The sample port, compensation port and light trap port shall not lie on the great circle of the sphere. The ports shall be designed in such a way that samples placed at the port will lie at nearly the same surface as the inner sphere wall.
      iv) The surfaces of the interior of the integrating sphere and the baffles shall be of substantially equal luminous reflectance which shall be 90 % or more and shall not vary by more than ±3 %. The sphere wall reflectance can be determined relative to a known reflection standard using the method described in Annex A.

v) Using this instrument, the repeatability standard deviation shall be 0,2 % or less. The within-laboratory reproducibility over long time intervals shall not exceed the repeatability by a factor of more than 3.

vi) The flat sample shall be held against the sample port so that the normal of the sample is within 2° of the normal of the sample port. The sphere interior should provide uniform illumination on the screen, with the screen receiving a constant luminance over its hemispherical inclination angles. This criterion is often satisfied when the sphere's internal light source dominates the illuminance inside the sphere compared to any sample contribution.

vii) The LMD is aligned normal to the centre of the sample port at an approximate distance of 0,5 m. The measurement field shall be focused on the sample port plane.

b) Standard measuring environmental conditions:
   1) darkroom conditions;
   2) standard setup conditions.

5.1.1.3 Measuring method

The method is similar to ASTM D1003 [2], and analogous to ISO 13468-1 [3]. This method assumes that the transmission properties of the transparent OLED display are not affected by the illumination level on the display.

1) If the integrating sphere has a light trap port, place a port plug or diffuse white standard at the port. Turn on the integrating sphere light source and allow the light source and LMD to stabilize. The measurement configuration in Figure 2 shall be set up in a dark room, and ingress of external light into the integrating sphere shall be prevented.
2) If the integrating sphere has a compensation port, place the backside of the transparent OLED display against that port. The display is turned off.
3) Measure the luminance L_{ref} or spectral radiance at the sample port, and record the monitor detector value m_{ref}.
4) Place the backside of the transparent OLED display against the sample port. If the integrating sphere has a compensation port, place a light trap at that port. Measure the transmitted luminance (or spectral radiance) at the sample port $L_{\mathrm{di/0}}$, and record the monitor detector value $m_{\mathrm{di/0}}$.
5) Calculate the luminous hemispherical transmittance factor with specular included $T_{\mathrm{di/0}}$ using Formula (1):

$$T_{\mathrm{di/0}} = \frac{L_{\mathrm{di/0}}}{L_{\mathrm{ref}}} \cdot \frac{m_{\mathrm{di/0}}}{m_{\mathrm{ref}}} \tag{1}$$

6) Repeat the readings for L_{ref}, m_{ref}, $L_{\mathrm{di/0}}$, and $m_{\mathrm{di/0}}$, making additional readings with the specimen in positions selected to determine uniformity.
7) Carry out the procedure three times, and use the average of the three calculated results as the luminous hemispherical transmittance factor value.
8) All details are required to be recorded for identification of the test specimens and the source of the specimens (type of light source used, information of transparent OLED display).

If the transmission properties of the transparent OLED display are different in the off from the on state, then the alternate sphere method in Annex A shall be used.

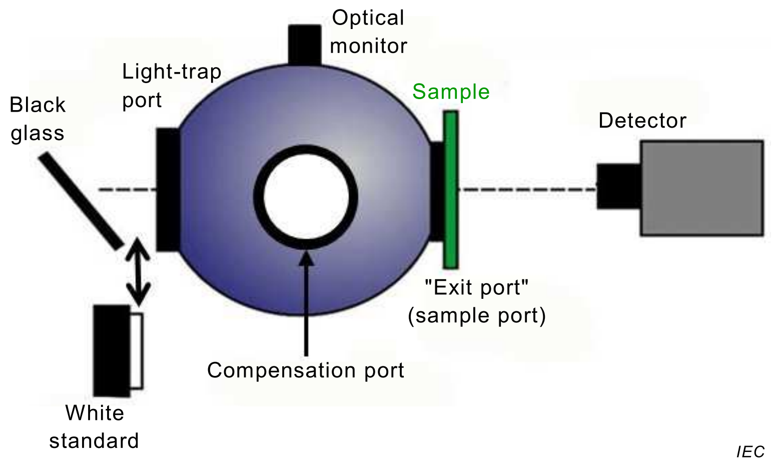


Figure 2 – Side view of measuring concept for the hemispherical transmittance factor measurement with specular included or excluded

5.1.2 Transmitted haze under hemispherical illumination

5.1.2.1 Purpose

The purpose of this method is to measure the amount of haze transmitted to the viewer from a transparent OLED display back-illuminated with hemispherical illumination.

5.1.2.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) light measuring device that can measure luminance or spectral radiance;
   2) driving power source;
   3) driving signal equipment;
   4) integrating sphere with ports and a stabilized light source (see Figure 2), which shall be as follows:
      i) The light source in the integrating sphere should have a smooth broadband spectrum approximating CIE standard Illuminant D65, as specified in ISO 11664-2. The integrating sphere should have a photopic optical detector which monitors the relative luminance level m inside the sphere. The monitor shall be fitted with baffles to prevent light from the light source or the sample port from falling on it directly. The spectral characteristics of the light source shall be kept constant during measurements on a transparent OLED display. The measurement conditions shall be such that the transparent OLED display temperature does not increase while measurements are made.
      ii) The total port area of the integrating sphere should not exceed 4,0 % of the internal area of the sphere. It is recommended that the diameter of the integrating sphere is not less than 150 mm so that specimens of a reasonable size can be used. When the diameter of the integrating sphere is 150 mm and the diameters of the sample, compensation and light trap ports are 30 mm, the ratio of the total port area to the internal area of the sphere is 3,0 %. If the integrating sphere does not have a compensation port, and placing the OLED display at the sample port does not significantly change the spectral distribution of the light in the sphere, the monitor detector shall be used to compensate for change in the sphere illuminance due to the presence of the display at the sample port.
      iii) A detailed illustration of the specular excluded and transmitted haze geometry is given in Figure 3.

iv) The sample port and light trap port shall be centred on the same optical axis as the LMD. The diameter of the sphere z_s, and the light trap port diameter d_{LT} shall be sized such that the opening of the light trap port shall subtend θ_{LT} = 8° from the centre of the sample port. The LMD shall be positioned a distance z_{LMD} away from the sphere, producing a measurement field of diameter d_{mf} focused at the sample port, where $d_{mf} = z_d d_{pmf}/(z_{LMD}+z_s)$ and d_{pmf} is the projected measurement field diameter at the light trap port. The LMD and sphere shall be set up such that the angular gap (annulus) $\xi = \theta_{LT}/2 - \arctan[d_{pmf}/(2\,z_s)]$ between the projected measurement field diameter d_{pmf} and the light trap port diameter shall give ξ = 1,3°. When the above requirements are satisfied, the maximum angle ϕ that any measured light ray can have relative to the normal is less than 3°. Ensure that the LMD measurement field is contained within the image of the light trap port area.

b) Standard measuring environmental conditions:

1) darkroom conditions;

2) standard set-up conditions.

5.1.2.3 Measuring method

The method is similar to ASTM D1003 [2] and analogous to ISO 14782 [4].

NOTE 1 This method assumes that the transmission properties of the transparent OLED display are not affected by the illumination level on the display.

NOTE 2 This method also assumes that the transmission properties are invariant to the rendered colour on the display, and allows the transmission properties to be measured with the display turned off.

1) Place a port plug or diffuse white standard at the light trap port. Turn on the integrating sphere light source and allow the light source and LMD to stabilize. The measurement configuration in Figure 2 shall be set up in a dark room, and ingress of external light into the integrating sphere shall be prevented.
2) If the integrating sphere has a compensation port, place the backside of the transparent OLED display against that port. The display is turned off.
3) Align the LMD normal to the sample port and focus the measurement field at the centre of the port. Measure the luminance L_1 at the centre of the sample port, and record the monitor detector value m_1.
4) Place the backside of the transparent OLED against the sample port. If the integrating sphere has a compensation port, place a light trap at that port.
5) Measure the transmitted luminance L_2 through the display at the centre of the sample port, and record the monitor detector value m_2.
6) Replace the port plug or diffuse white standard at the light trap port with a light trap. If the integrating sphere has a compensation port, place the port plug or the diffuse white standard at that port. Measure the transmitted luminance L_4 through the display at the centre of the sample port, and record the monitor detector value m_4.
7) Remove the transparent OLED display from the sample port. Measure the luminance L_3 at the centre of the sample port, and record the monitor detector value m_3.
8) The luminous hemispherical transmittance factor with specular excluded $T_{de/0}$ is given as:

$$T_{\mathrm{Q,de/0}} = \frac{m_1}{L_1}\left[\frac{L_4}{m_4} - \frac{L_3 L_2 m_1}{L_1 L_3 m_2}\right] \tag{2}$$

where each variable is associated with the measurement configuration list in Table 2.

9) The percent luminous hemispherical transmitted haze $H_{de/0}$ is determined by:

$$H_{\text{de/0}} = 100\% \times \left[\frac{m_2}{m_4} \times \frac{L_4}{L_1} - \frac{m_1}{m_3} \times \frac{L_3}{L_1} \right] \quad (3)$$

Table 2 –Measuring conditions of the ports

Measured luminance	Sample port	Light trap port	Compensation port
L_1		White reference	Display sample
L_2	Display sample	White reference	Light trap
L_3		Light trap	White reference
L_4	Display sample	Light trap	White reference

10) All details are required to be recorded for identification of the test specimens and the source of the specimens, such as type of light source used, information on transparent OLED display.

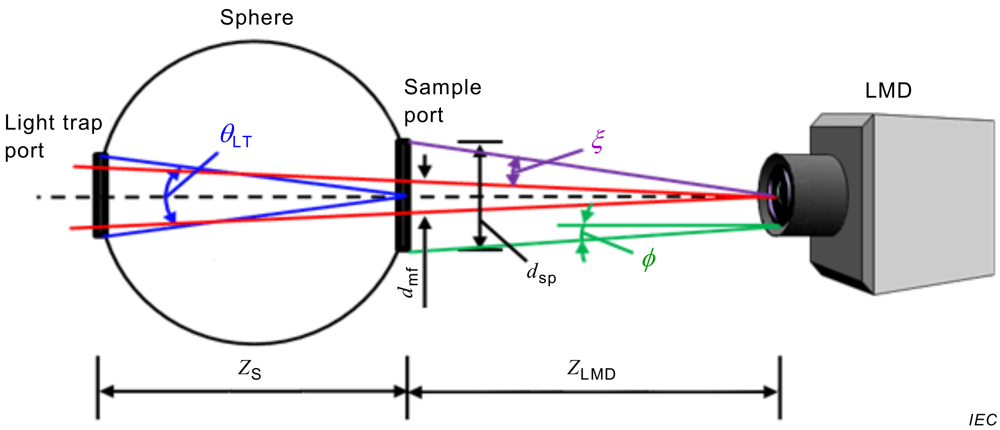


Figure 3 – Schematic arrangement of haze measurement

5.1.3 Directional transmittance factor

5.1.3.1 Purpose

The purpose of this method is to measure the transmittance factor of a transparent OLED display that is back-illuminated with a directional light source.

5.1.3.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:

   1) light measuring device that can measure luminance or spectral radiance;
   2) driving power source;
   3) driving signal equipment;
   4) white reflectance standard;
   5) ring light with a stabilized light source, which shall be as follows:
      i) Directional illumination shall be simulated by a ring light (Figure 4) centred about the display normal. A fibre optic ring light designed for a working distance that approximates 45° light inclination at the centre of the measurement position is

recommended. The illumination within the measuring field area on the display shall be uniform < 5 %.

ii) For the ring light, the source should have an emitter angular subtense of approximately 0,5°. The ring light emitting plane shall be co-planar with the display surface and centred about the measurement area. The central clear aperture of the ring light shall be at least 30 % larger than the effective aperture of the LMD lens.

iii) The ring light source should have a smooth broadband spectrum approximating CIE standard Illuminant D65, as specified in ISO 11664-2. The spectral characteristics of the light source shall be kept constant during measurements on a transparent OLED display. The measurement conditions shall be such that the transparent OLED display temperature does not increase while measurements are made.

b) Standard measuring environmental conditions:

1) darkroom conditions;

2) standard setup conditions.

5.1.3.3 Measuring method

For this measurement, the following method shall be applied.

NOTE 1 This method assumes that the scatter properties of the transparent OLED display are independent of the illumination level on the display.

NOTE 2 It is noted that it is not uncommon for the OLED transmission properties to be largely invariant with the rendered colour.

NOTE 3 If that can be demonstrated, then the transmission properties can be measured with the display turned off.

1) Place a white reflectance standard at the sample plane used for the display measurements. Unless the viewing distance is specified, position the LMD approximately 0,5 m from the sample plane and align the optical axis of the LMD centred and normal to the reflectance standard surface. Place the ring light facing the reflectance standard, centred on the optical axis, and positioned at a distance such that its light is incident at a 45° inclination angle to the centre of the measurement field.

2) Allow the ring light source to stabilize. Ensure that the LMD measurement field is centred within the uniform illumination of the ring light illumination on the reflectance standard. Measure the luminance L_{std} or spectral radiance $L_{\text{std}}(\lambda)$ of the light reflected from the reflectance standard.

3) Calculate the illuminance E_{dir} (or spectral irradiance $E_{\text{dir}}(\lambda)$) of the ring light at the sample plane using the known luminous reflectance factor R_{std} (or spectral reflectance factor $R_{\text{std}}(\lambda)$) of the white standard for the same illumination/detector configuration:

$$E_{\text{dir}} = \frac{\pi L_{\text{std}}}{R_{\text{std}}} \quad (4)$$

The calculation of the spectral irradiance has the same form.

4) Replace the reflectance standard with the transparent OLED display positioned at the same sample plane, with the back surface normal of the display parallel with the LMD optical axis. The desired measurement location on the display shall be centred about the measurement field of the LMD.

5) Move the LMD to the front of the transparent OLED display, maintaining the same measurement distance, and align the LMD to the same optical axis and measurement field position as in the last measurement. A test pattern may be used to position the measurement field to the same location.

6) With the display rendering the desired colour Q, measure the luminance $L_{\text{T},45/0}$ or spectral radiance $L_{\text{T},45/0}(\lambda)$ of the transmitted light through the display.

7) Turn off the ring light source and measure the darkroom emission from the display L_{em}.
8) The luminous directional transmittance factor $T_{45/0}$ for the 45° back illumination/normal detection configuration is given as:

$$T_{45/0} = \pi \frac{\left(L_{T,45/0} - L_{em}\right)}{E_{dir}} \quad (5)$$

The expression for the spectral directional transmittance factor $T_{45/0}(\lambda)$ has the same form.

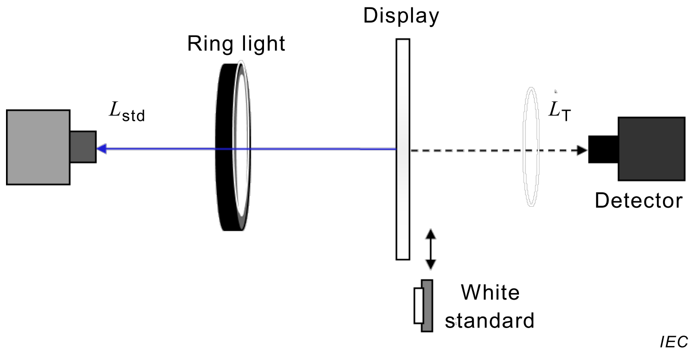


Figure 4 – Side view of measuring concept for the hemispherical transmittance factor measurement with specular included or excluded

5.1.4 Measurement method of purity

5.1.4.1 Purpose

The purpose of this method is to measure the purity of a transparent OLED display.

5.1.4.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) light measuring device (LMD) that can measure luminance;
   2) reference display device to display the test pattern behind the transparent display;
   3) driving power source;
   4) driving signal equipment.
b) Standard measuring environmental conditions:
   1) darkroom conditions;
   2) standard setup conditions.

5.1.4.3 Measuring method

For this measurement, the following method shall be applied.

1) Set a reference display device to display the test pattern as shown in Figure 5 (a), and allow the apparatus sufficient time to reach thermal equilibrium before making any measurements.
2) Display the test pattern on the reference display device and measure the luminance of all the test patterns in Figure 6 in sequence at the centre of the screen using an LMD having a measurement field of 0,2°. The LMD measurement field should be contained completely within the 0,2° target area, and should sample at least 500 display pixels. If the

measurement field contains fewer than 500 display pixels, it should be confirmed that the same luminance can be obtained with more than 500 pixels.

3) Calculate the purity reference value using Formula (6), and check the validity of the measurement using Formula (7). Unless Formula (7) is satisfied, adjust the alignment of setup and repeat the measurement. The 2 % in Formula (7) is the maximum luminance accuracy fluctuation of the LMD.

$$P_{\text{ref}} = \frac{L_{\text{CW,ref}} - L_{\text{FK,ref}}}{L_{\text{FW,ref}} - L_{\text{FK,ref}}} \tag{6}$$

$$\frac{\left\| L_{\text{FW,ref}} - L_{\text{CW,ref}} \right| - \left| L_{\text{FK,ref}} - L_{\text{CK,ref}} \right\|}{\left| L_{\text{FW,ref}} - L_{\text{CW,ref}} \right|} \times 100 \leq 2\% \tag{7}$$

where

P_{ref} is the ratio of the luminance range with full screen patterns to the pattern of 0,2° measurement field restriction;

$L_{\text{CW,ref}}$ is the reference luminance of the white 0,2° circle,

$L_{\text{FK,ref}}$ is the reference luminance for the full black screen,

$L_{\text{FW,ref}}$ is the reference luminance for the full white screen,

$L_{\text{CK,ref}}$ is the reference luminance of the black 0,2° circle.

4) The transparent OLED display shall be mounted between the measuring instrument and the reference display device, and OLED display except the circle specified in Figure 5 (b) should be covered so that light from reference display pass through the circle only (see Figure 5(b)).

5) With the test pattern on the OLED display fixed, measure the luminance of all the reference display test patterns in Figure 6 through the transparent OLED display using an LMD having a measurement field of 0,2°. The LMD should still be focused on the reference display.

6) Calculate the sample value using Formula (8), and check the validity of the measurement using Formula (9). Unless Formula (9) is satisfied, adjust the alignment of setup and repeat the measurement.

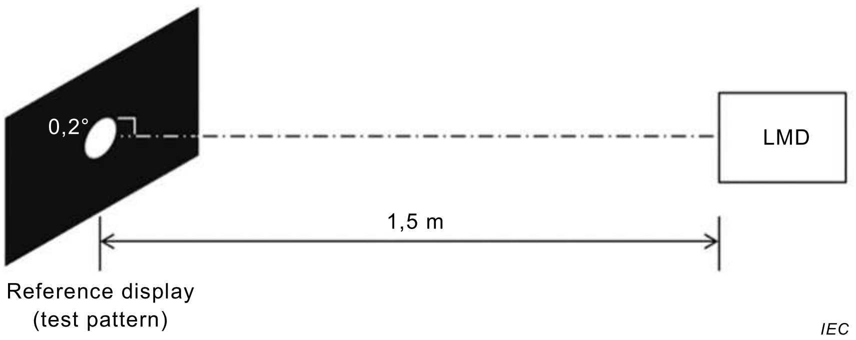
$$P_{\text{sample}} = \frac{L_{\text{CW,sample}} - L_{\text{FK,sample}}}{L_{\text{FW,sample}} - L_{\text{FK,sample}}} \tag{8}$$

$$\frac{\left\| L_{\text{FW,sample}} - L_{\text{CW,sample}} \right| - \left| L_{\text{FK,sample}} - L_{\text{CK,sample}} \right\|}{\left| L_{\text{FW,sample}} - L_{\text{CW,sample}} \right|} \times 100 \leq 2\% \tag{9}$$

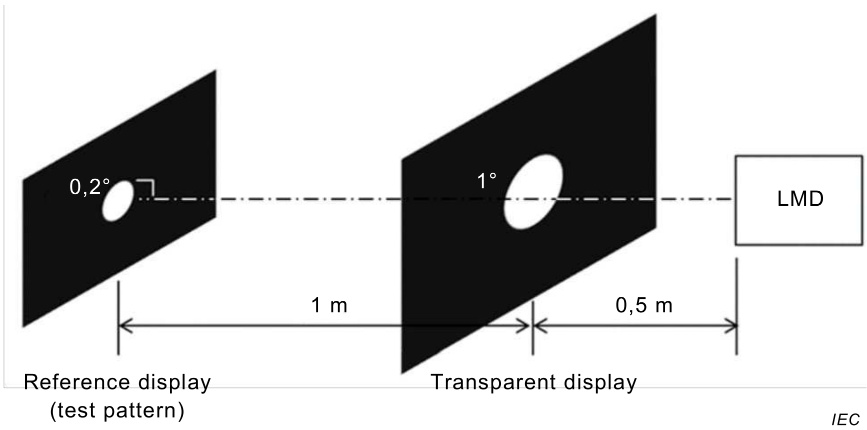
7) Calculate the purity of the transparent OLED display using Formula (10).

8) Report the results of measurements as shown in the examples in Table 3.

$$P_{\text{ur}} = \frac{P_{\text{sample}}}{P_{\text{ref}}} \times 100 \tag{10}$$

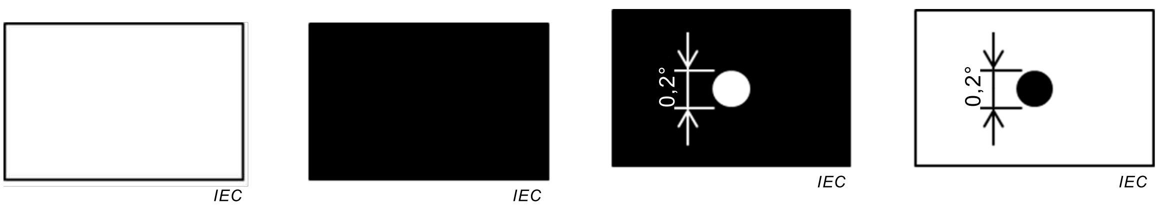


a)



b)

Figure 5 – Measuring configuration for purity measurement



a) full white test pattern **b) full black test pattern** **c) circle of white (CW) test pattern** **d) circle of black (CK) test pattern**

Figure 6 – Test patterns for purity measurement

Table 3 – Measured example for purity

	L_{FW}	L_{FK}	L_{CW}	L_{CK}	*Validity*	P_{ur}
	cd/m²					
Reference	49,50	0,14	48,99	-	-	99%
Sample	20,03	0,06	16,46	3,65	0,64 %	82%
Purity						**83 %**

5.1.5 Colour variation caused by a transparent display

5.1.5.1 Purpose

The purpose of this method is to measure the colour variation caused by a transparent OLED display.

5.1.5.2 Measuring conditions

For this measurement, apply the following conditions.

a) Apparatus:

   1) spectroradiometer or equivalent light measuring device that can measure chromaticity of transparent display device;

   2) CIE Standard Illuminant A, or a reference display device to display the test pattern behind the transparent display.

      NOTE This reference display can be used for evaluation of colour variation; driving power source; and driving signal equipment.

b) Standard measuring environmental conditions:

   1) darkroom condition;

   2) standard setup conditions.

5.1.5.3 Measuring method

For this measurement, the following method shall be applied.

1) Set a CIE Standard Illuminant A or reference display device. If CIE Standard Illuminant A is chosen as light source, measure the CIE 1931 chromaticity coordinates (x, y) of the illuminant and proceed from 10).
2) Turn on the full screen white and 4 % window sized signal at a 100 % grey level.
3) Measure the CIE 1931 chromaticity coordinates W(x, y) at the centre of the screen of the reference display.
4) Turn on the full screen red and 4 % window sized red signal.
5) Measure the CIE 1931 chromaticity coordinates R(x, y) at the centre of the screen of the reference display.
6) Turn on the full screen green and 4 % window sized green signal.
7) Measure the CIE 1931 chromaticity coordinates G(x, y) at the centre of the screen of the reference display.
8) Turn on the full screen blue and 4 % window sized blue signal.
9) Measure the CIE 1931 chromaticity coordinates B(x, y) at the centre of the screen of the reference display.
10) Calculate u’, and v’ from the measured x, y values using Formula (11).

$$u' = \frac{4x}{3-2x+12y} \quad , \quad v' = \frac{9y}{3-2x+12y} \tag{11}$$

11) Set the transparent display in the designated place between the reference display and the measuring instrument.
12) Measure the chromaticity values for white, red, green, and blue colour pattern on the same location with the transparent display.
13) Calculate the colour variation with and without the transparent display for white and primary colours. Formula (12) is used for this calculation.

$$\Delta u'v' = \sqrt{\left(u'_{\mathrm{i}} - u'_{\mathrm{j}}\right)^2 + \left(v'_{\mathrm{i}} - v'_{\mathrm{j}}\right)^2} \tag{12}$$

14) Report the values for the colour difference for each test pattern (white, red, green, and blue). Table 4 shows the example of the results.
15) Various colours can be selected and measured for this measurement method such as the Munsell2 colour reference.

Table 4 – Working example for colour variation index

Colour variation index		Test pattern			
		white	red	green	blue
Without transparent display	u'	0,187 2	0,458 5	0,122 6	0,179 7
	v'	0,437 9	0,524 6	0,567 1	0,148 9
With transparent display	u'	0,190 2	0,460 0	0,124 3	0,177 2
	v'	0,454 1	0,524 3	0,562 3	0,154 8
Colour variation	$\Delta u'v'$	0,016 5	0,001 5	0,005 1	0,006 4

5.2 Measuring methods of on-screen performance in a darkroom

5.2.1 Luminance and its uniformity

5.2.1.1 Purpose

The purpose of this method is to measure the full-screen and peak luminance, luminance loading and uniformity of luminance for a transparent OLED display.

5.2.1.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) light measuring devices that can measure luminance;
   2) driving power source;
   3) driving signal equipment.
b) Standard measuring environmental conditions:
   1) darkroom conditions;
   2) standard setup conditions.

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2 The Munsell Color system is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this products.

5.2.1.3 Measurement method of full screen luminance

For this measurement, the following method shall be applied.

1) Follow the full screen darkroom white luminance measurement procedure described in IEC 62341-6-1.
2) Report the full screen darkroom white luminance.

5.2.1.4 Measurement method of 4 % window luminance

This method is used to measure the maximum time-averaged luminance of a small emitting region in the centre of the active area. The centre luminance of a 4 % window will be used as the maximum window luminance.

1) Follow the 4 % window darkroom white luminance measurement procedure described in IEC 62341-6-1. The 4 % window test pattern is illustrated in Figure 7.
2) Report the 4 % window darkroom white luminance.

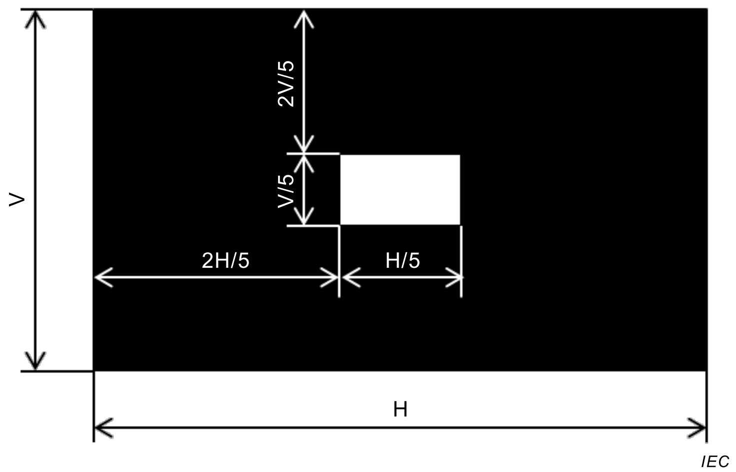


Figure 7 – Test pattern for 4 % window luminance

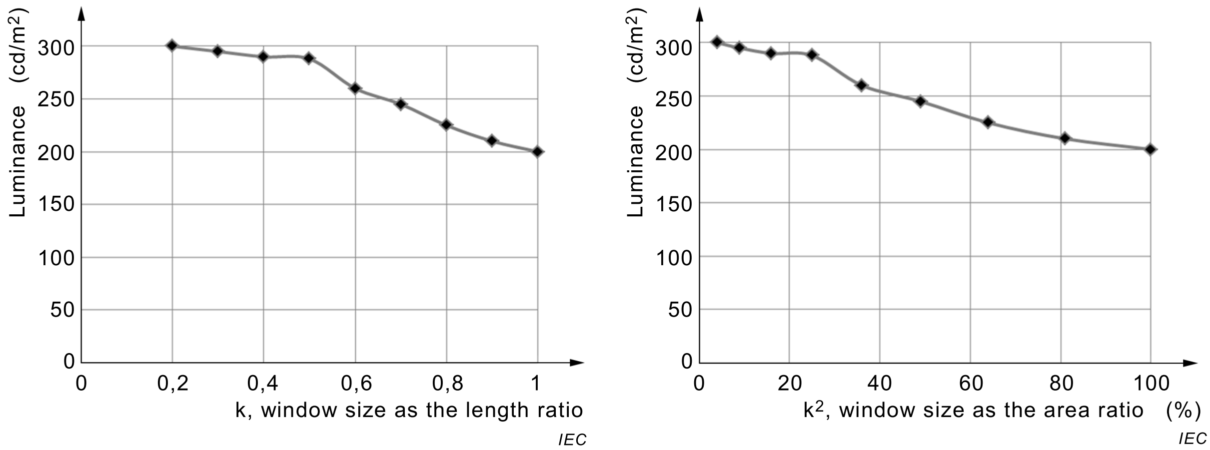
5.2.1.5 Measurement method of luminance loading

This method is used to measure the luminance of a white box with a black background as the size of the box is adjusted from a small fraction of the screen to full screen.

1) Set the transparent OLED display under the standard measuring conditions.
   a) Set up the measurement following the layout diagram shown in Figure 1.
   b) Use a sequence pattern of centred white windows on a black background with the size of the window being kH x $kV,$ where k = 0,2, 0,3, ⋯, 1,0. For example, the k = 0,2 situation is show in Figure 8.
2) For a monochromatic display, apply a signal at the highest grey level. For a colour display, apply a white signal level of 100 %.
3) Measure the time-averaged luminance at the centre of the active area in both front-plane view and back-plane view part and plot the luminance of the window versus the k factor or the area (k^2) of the window.

Table 5 – Worked example for luminance loading

k	k^2 %	Window luminance cd/m^2
0,2	4	300
0,3	9	295
0,4	16	290
0,5	25	288
0,6	36	260
0,7	49	245
0,8	64	225
0,9	81	210
1,0	100	200



a) Luminance according to length ratio **b) Luminance according to area ratio**

Figure 8 – Example of luminance loading measurement

5.2.1.6 Measurement method of sampled luminance non-uniformity

For this measurement, the following method shall be applied.

1) Follow the full screen white sampled luminance non-uniformity measurement procedure described in IEC 62341-6-1. The measurement locations are described in Figure 9.
2) Report all of the luminance measurements at each of the sampled display positions as shown in Table 5. Also, report the average luminance L_{av}, the maximum luminance L_{max}, the minimum luminance L_{min}, and the percent luminance deviation from the average at each display position. The luminance non-uniformity of the display is characterized as the maximum value of the percent luminance deviation ($\Delta L_i/L_{av} \times 100$ %). The non-uniformity is reported in percent to no more than three significant figures. The driving signal, such as AC or pulse, shall be specified, along with the number of measurement positions.

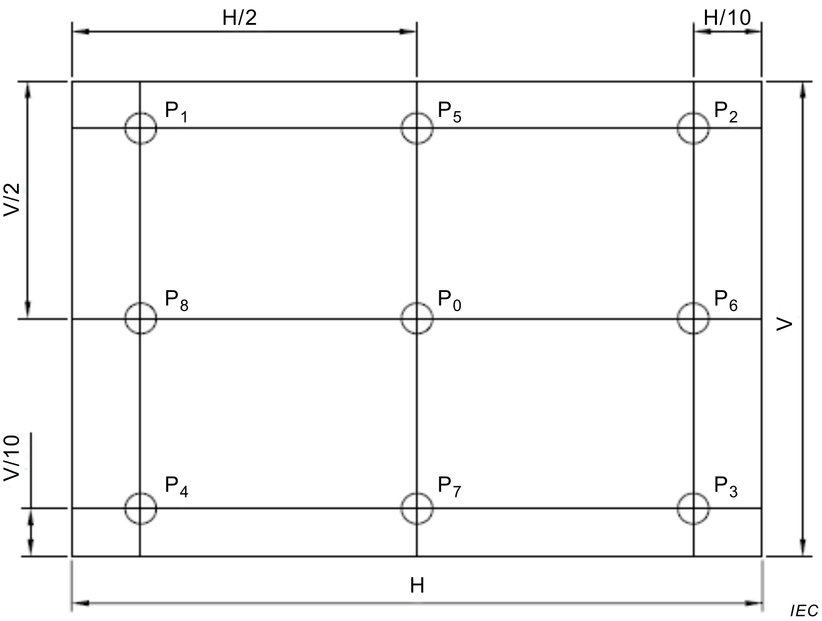


Figure 9 – Measurement locations

Table 6 – Example of luminance non-uniformity

Measuring point	Luminance L_i cd/m^2	$(\Delta L_i/L_{av}) \times 100$ % %
P_0	210	+1,9
P_1	205	-0,5
P_2	208	+1,0
P_3	199	-3,4
P_4	195	-5,3
P_5	211	+2,4
P_6	215	+4,4
P_7	204	-1,0
P_8	207	+0,5
L_{max}: 215 cd/m^2; L_{min}: 195 cd/m^2; Average luminance: 206 cd/m^2		

5.2.2 Chromaticity and colour non-uniformity

5.2.2.1 Purpose

The purpose of this method is to measure the CIE 1931 chromaticity coordinates (x, y) or CIE 1976 uniform colour space (UCS) chromaticity coordinates (u', v'), and the colour non-uniformity of a transparent OLED display in a dark room.

5.2.2.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:

1) spectroradiometer or equivalent light measuring devices that can measure the chromaticity of the emitted light;
2) driving power source;

3) driving signal equipment.

b) Standard measuring environmental conditions:

1) darkroom conditions;

2) standard setup conditions.

5.2.2.3 Measurement method of chromaticity

For this measurement, the following method shall be applied.

1) Follow the procedure described in IEC 62341-6-1 to measure the CIE 1931 and CIE 1976 chromaticity coordinates for a maximum luminance white and the red, green, and blue primaries. The chromaticity coordinates shall be measured at the screen centre using a full screen and 4 % luminance test pattern.

2) Report the chromaticity coordinates for all the colours.

5.2.2.4 Measurement method of sampled colour non-uniformity

For this measurement, the following method shall be applied.

1) Follow the sampled colour non-uniformity measurement procedure described in IEC 62341-6-1 for at least a full screen white test pattern at the maximum luminance level.

2) Report the chromaticity coordinates for of the rendered colour at each screen position as shown in the examples in Table 6. Use the CIE 1976 chromaticity coordinates (u', v') at each location P_i (see Figure 9) to determine the colour difference between pairs of sampled colours using the colour difference formula (Formula (12)) for i, j = 0 to 4 or i, j = 0 to 8, and $i \neq j$. Colour non-uniformity is defined as the largest sampled colour difference $(\Delta u'v')_{max}$ between any two points.

Table 7 – Example of colour uniformity measurement

Measuring point	x_i	y_i	u'_i	v'_i	$\Delta u'v'$								
					P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
P_0	0,311	0,325	0,198	0,466	0,000								
P_1	0,330	0,320	0,214	0,466	0,016	0,000							
P_2	0,307	0,323	0,196	0,464	0,003	0,018	0,000						
P_3	0,309	0,328	0,196	0,467	0,002	0,018	0,003	0,000					
P_4	0,310	0,326	0,197	0,466	0,001	0,017	0,002	0,001	0,000				
P_5	0,303	0,319	0,195	0,461	0,006	**0,020**	0,003	0,006	0,005	0,000			
P_6	0,311	0,324	0,199	0,465	0,001	0,015	0,003	0,004	0,002	0,006	0,000		
P_7	0,315	0,320	0,203	0,464	0,005	0,011	0,007	0,008	0,006	0,009	0,004	0,000	
P_8	0,314	0,327	0,199	0,467	0,001	0,015	0,004	0,003	0,002	0,007	0,002	0,005	0,000
Max$\Delta u'v'$ = 0,020													

5.2.3 Darkroom contrast ratio

5.2.3.1 Purpose

The purpose of this method is to measure the darkroom contrast ratio ($DRCR$) of the transparent OLED display.

5.2.3.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:

   1) light measuring devices that can measure luminance;
   2) driving power source;
   3) driving signal equipment.

b) Standard measuring environmental conditions:
   1) darkroom conditions;
   2) standard setup conditions.

5.2.3.3 Measuring methods

5.2.3.3.1 Measurement method of full screen darkroom contrast ratio

For this measurement, the following method shall be applied.

1) Follow the full screen darkroom contrast ratio measurement procedure described in IEC 62341-6-1.
2) Report the full screen white and black luminance, and the full screen $DRCR$.

5.2.3.3.2 Measuring method of 4 % window darkroom contrast ratio

For this measurement, the following method shall be applied.

1) Follow the 4 % window darkroom contrast ratio measurement procedure described in IEC 62341-6-1.
2) Report the 4 % window luminance, the full screen black luminance, and the 4 % window darkroom contrast ratio.

5.2.4 Grey scale and gamma characteristics

5.2.4.1 Purpose

The purpose of this method is to measure the luminance of grey scale and gamma of the transparent OLED display.

5.2.4.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) light measuring devices that can measure luminance;
   2) driving power source;
   3) driving signal equipment.

b) Standard measuring conditions;
   1) darkroom conditions;
   2) standard set-up conditions.

5.2.4.3 Log-log gamma measurement

For this measurement, the following measurement methods shall be applied.

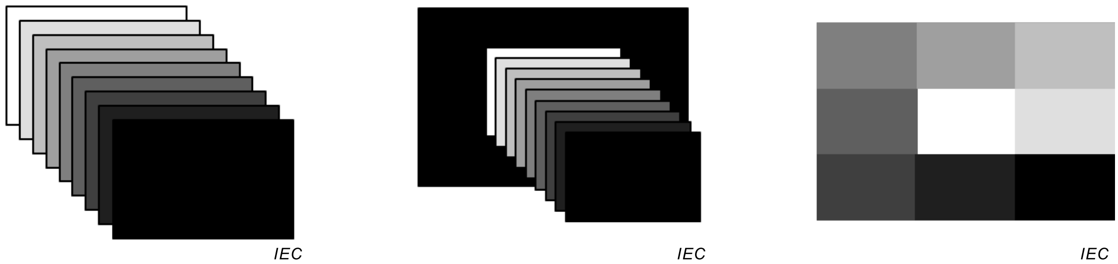
1) Set up the transparent OLED display under standard measuring conditions.
2) Display the test patterns and measure the luminance. The test patterns should have center areas that represent evenly spaced grey levels from black to white as described in Figure 10. The number of measuring levels is chosen: 9, 17, 33, etc. For example, the measuring grey levels are 0, 31, 63, 95, 127, 159, 191, 223 and 255 when the number of levels is 9 and the sample is an 8-bit display. If the sample has the property of luminance loading, the snaking constant pixel level (SCPL) pattern in Figure 10 (c) is recommended.

3) Plot the black-subtracted luminance and the grey level with log scale and identify the gamma value, γ, using Formula (13).

$$\log\left[L\left(v_{\mathrm{j}}\right)-L_{\mathrm{k}}\right]=\gamma\log\left(V_{\mathrm{j}}-V_{\mathrm{k}}\right)+\log(a) \tag{13}$$

where V is the grey level, L is the luminance and subscript k means black. Subscript j is from 1 to the number of measuring levels.

4) Report the results of measurements as shown in the examples in Table 8.



a) **Full-screen pattern** b) **Box pattern** c) **Snaking constant pixel level (SCPL) pattern**

Figure 10 – Measuring patterns for gamma measurement

Table 8 – Example of gamma measurement

j	V	$L(V_{\mathrm{j}})$	$L(V_{\mathrm{j}})$- L_{k}	**log** $(V_{\mathrm{i}} - V_{\mathrm{k}})$	**log**$[L(V_{\mathrm{i}}) - L_{\mathrm{k}}]$
1	255	389,1	388,95	2,407	2,590
2	223	308,8	308,65	2,348	2,489
3	191	219,4	219,25	2,281	2,341
4	159	147,6	147,45	2,201	2,169
5	127	89,67	89,52	2,104	1,952
6	95	47,1	46,95	1,978	1,672
7	63	17,47	17,32	1,799	1,239
8	31	3,189	3,039	1,491	0,483
9	0	015	-	-	-
gamma, γ	**2,31**	**log(a)**	**-2,931**	**correlation coefficient**	**0,9987**

5.2.4.4 Average gamma measurement

For this measurement, the following method shall be applied.

1) Set up the transparent OLED display under standard measuring conditions.
2) Display the test patterns and measure the luminance. The test patterns should have center areas that represent evenly spaced grey levels from black to white as described in Figure 10.
3) Calculate the gamma for each input and average the gamma values, using Formula (14).

$$\gamma_{\mathrm{AV}}=\frac{1}{n-2}\sum_{j=2}^{n-1}\frac{\log(L_{\mathrm{norm,j}})}{\log(V_{\mathrm{norm,j}})} \tag{14}$$

where

γ_{AV} is the average gamma;

n is the number of inputs (1st to nth), $L_n = L(255)$, $L_1 = L_k$;

$L_{norm,j}$ is the normalized value of the luminance measured at each level except black, $(L_j - L_k) / (L_n - L_k)$;

$V_{norm,j}$ is the normalized value of input digital value.

5.2.4.5 Colour gamma measurement

For this measurement, the following method shall be applied.

1) Set up the transparent OLED display under standard measuring conditions.
2) Display the primary-colour test patterns which have even space from black to the maximum primary colour level, and measure the luminance of each pattern.
3) Plot the black-subtracted luminance and the colour level with log scale and identify the gamma value γ, using Formula (13).

5.2.5 Colour gamut

5.2.5.1 Purpose

The purpose of this method is to measure the colour gamut of the transparent OLED display.

5.2.5.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) spectroradiometer or equivalent light measuring devices that can measure the chromaticity of the emitted light;
   2) driving power source;
   3) driving signal equipment.
b) Standard measuring conditions:
   1) darkroom conditions;
   2) standard setup conditions.

5.2.5.3 Colour gamut area and colour reproduction range measurement

For this measurement, the following method shall be applied.

1) Follow the darkroom centre chromaticity and colour gamut, and colour gamut area measurement procedure described in IEC 62341-6-1.
2) Report the full-screen CIE 1931 and CIE 1976 chromaticity coordinates of the primary colours (R, G, and B).
3) Report the calculated colour gamut area A of the transparent OLED in a darkroom.
4) Calculate the colour reproduction range, S, using Formula (15). The colour reproduction range is defined as the percentage of the colour gamut area to the reference area. Reference areas, A_{ref}, are presented in Table 9. The colour reproduction range is reported with the reference area.

$$S = \frac{A}{A_{ref}} \times 100 \qquad (15)$$

Table 9 – Reference areas for the colour reproduction range

		x	*y*	*u'*	*v'*	$A_{ref}(u'v')$
NTSC	R	0,67	0,33	0,476 9	0,528 5	38 %
	G	0,21	0,71	0,075 7	0,575 7	
	B	0,14	0,08	0,152 2	0,195 7	
BT. 709 [5] (sRGB)	R	0,64	0,33	0,450 7	0,522 9	33 %
	G	0,30	0,60	0,125 0	0,562 5	
	B	0,15	0,06	0,175 4	0,157 9	
Adobe RGB[3]	R	0,64	0,34	0,441 4	0,527 6	38 %
	G	0,21	0,71	0,075 7	0,575 7	
	B	0,15	0,06	0,175 4	0,157 9	

5.2.5.4 Colour gamut variation ratio measurement

For this measurement, the following method shall be applied.

1) The measuring method is the same as in 5.2.5.3, but with each primary at a defined colour level *j* (where *j* can be 255, 191, etc.).
2) The full-screen patterns of primary colour level are measured and the colour gamut area and colour reproduction range are calculated repeatedly for each colour level *j*.
3) The colour gamut variation ratio *GR* is calculated using Formula (16).

$$GR_j = \frac{S_j}{S_{max}} \times 100 \tag{16}$$

where

S_j is the colour reproduction range of the colour level *j;*

S_{max} is the colour reproduction range of the maximum colour level.

4) Report the results of measurements as shown in the examples in Table 10.

Table 10 – Example of measurement for the colour gamut variation ratio

Colour level	*R*		*G*		*B*		*S*	*GR*
	u'	*v'*	*u'*	*v'*	*u'*	*v'*		
255	0,454 7	0,524 5	0,127 1	0,559 5	0,179 3	0,145 8	103,0 %	100 %
191	0,452 5	0,523 1	0,126 9	0,558 9	0,179 5	0,145 8	102,2 %	99 %
127	0,447 6	0,520 0	0,127 1	0,557 9	0,179 7	0,148 1	99,7 %	97 %
63	0,417 0	0,500 2	0,129 4	0,549 9	0,180 2	0,166 4	83,0 %	81 %
S is calculated with the reference area of BT.709 (sRGB), A_{ref} = 33 %.								

[3] Adobe® RGB (1998) is the trade name of a product supplied by Adobe Systems Incorporated. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

5.2.6 Directional optical characteristics

5.2.6.1 Purpose

The purpose of this method is to measure the directional optical characteristics of the transparent OLED display. All the measurement methods in 5.2.6 are taken from IEC 62341-6-3 [6].

5.2.6.2 Measuring conditions

For this measurement, the following conditions shall be applied:

a) Apparatus:
   1) spectroradiometer or equivalent light measuring devices that can measure the luminance and chromaticity of the emitted light;
   2) driving power source;
   3) driving signal equipment.

b) Standard measuring conditions:
   1) darkroom conditions;
   2) standard setup conditions.

5.2.6.3 Measuring methods

For this measurement, the following methods shall be applied.

1) The measuring methods are same as in 5.2.1 to 5.2.5. Each item is measured at specific viewing angles rendering a red, green, and blue full screen in sequence.
2) Report the measurement results with the perpendicular measurement. The directional distortion ratio, Dθ, of the electro-optical value (for luminance and gamma) is calculated using Formula (17):

$$D_{\theta}(M_{\theta}) = \frac{\left|M_{\theta} - M_{0^{\circ}}\right|}{M_{0^{\circ}}} \times 100 \qquad (17)$$

   where θ is the viewing angle and M_{θ} is the electro-optical value. When evaluating the colour directional distortion, the CIE 1976 chromaticity coordinates are used with Formula (18).

$$D_{\theta}(\Delta u'v') = \sqrt{(u'_{\theta} - u'_{0^{\circ}})^2 + (v'_{\theta} - v'_{0^{\circ}})^2} \qquad (18)$$

3) Report the results of measurements as shown in the examples in Table 11.

Table 11 – Example of measurement for the directional electro-optical characteristic

Viewing angle		0°		30°		45°		60°		80°	
Luminance (L_W)		402		377		348		301		183	
D_θ *(L)*		-		6 %		13 %		25 %		54 %	
Gamma		2,21		2,20		2,21		2,21		2,23	
D_θ *(Gamma)*		-		0,1 %		0,1 %		0,0 %		1,1 %	
		u'	*v'*	*u'*	*v'*	*u'*	*v'*	*u'*	*v'*	*u'*	*v'*
Chromaticity	R	0,455	0,525	0,457	0,525	0,459	0,525	0,460	0,525	0,460	0,524
	G	0,127	0,560	0,124	0,561	0,123	0,562	0,121	0,564	0,119	0,564
	B	0,179	0,146	0,178	0,149	0,177	0,150	0,177	0,150	0,179	0,147
D_θ $(\triangle u'v')$	R	-		0,002		0,004		0,006		0,005	
	G	-		0,003		0,005		0,007		0,009	
	B	-		0,004		0,005		0,005		0,001	

6 Measuring methods of reflection properties

6.1 Hemispherical reflectance factor with specular included

6.1.1 Purpose

The purpose of this method is to measure the fraction of reflected light, including the specular component, from the front of a transparent OLED display when illuminated with hemispherical illumination.

6.1.2 Measuring conditions

For this measurement, the following conditions shall be applied:

a) Apparatus:
   1) light measuring device that can measure luminance or spectral radiance;
   2) driving power source;
   3) driving signal equipment;
   4) integrating sphere or sampling sphere with a stabilized light source.
b) Specific guidance for the sphere design and measurement best practice is given in IEC 62341-6-2.
c) Standard measuring environmental conditions:
   1) darkroom conditions;
   2) standard set-up conditions.

6.1.3 Measuring method

For this measurement, the following methods shall be applied.

NOTE 1 This method assumes that the scatter properties of the transparent OLED display are independent of the illumination level on the display.

NOTE 2 It is noted that it is not uncommon for the OLED reflection properties to be largely invariant with the rendered colour.

NOTE 3 If that can be demonstrated, then the reflection properties can be measured with the display turned off.

1) The measuring method in IEC 62341-6-2 shall be used to measure the luminous hemispherical reflectance ρ or spectral hemispherical reflectance $\rho(\lambda)$, with specular included, for the front of the transparent OLED display with the display rendering the desired colour Q.
2) All other necessary colours will be measured in the same fashion in turn.

6.2 Directional reflectance factor

6.2.1 Purpose

The purpose of this method is to measure the fraction of reflected light, relative to an ideal Lambertian diffuser, from the front of a transparent OLED display when illuminated by a directional source at a 45° inclination angle.

6.2.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) light measuring device that can measure luminance or spectral radiance;
   2) driving power source;
   3) driving signal equipment;
   4) ring light with a stabilized light source.
b) Specific guidance for the sphere design and measurement best practice is given in IEC 62341-6-2.
c) Standard measuring environmental conditions:
   1) darkroom conditions;
   2) standard set-up conditions.

6.2.3 Measuring method

For this measurement, the following method shall be applied.

NOTE 1 This method assumes that the scatter properties of the transparent OLED display are independent of the illumination level on the display.

NOTE 2 It is noted that it is not uncommon for the OLED reflection properties to be largely invariant with the rendered colour.

NOTE 3 If that can be demonstrated, then the reflection properties can be measured with the display turned off.

1) The ring light measuring method in IEC 62341-6-2 shall be used to measure the luminous directional reflectance factor R or spectral directional reflectance factor $R(\lambda)$ for the front of the transparent OLED display with the display rendering the desired colour Q.
2) All other necessary colours will be measured in the same fashion in turn.

7 Optical on-screen performance under ambient illumination

7.1 Ambient contrast ratio

7.1.1 Purpose

The purpose of this method is to determine the ambient contrast ratio of a transparent OLED display module under defined indoor or daylight illumination conditions.

NOTE If the OLED exhibits significant PL, then the on-screen ambient contrast ratio calculation is only valid for the same illumination spectra and geometry used to measure the transmission and reflection coefficients.

7.1.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) light measuring device that can measure luminance or spectral radiance;
   2) driving power source;
   3) driving signal equipment;
   4) directional light source;
   5) integrating sphere or sampling sphere with a stabilized light source.

b) Illuminance condition:
   1) the standard ambient illumination conditions for an indoor room or clear sky daylight shall be used, as specified in Clause 4;
   2) additional illumination conditions may also be used, depending on the application.

c) Standard measuring environmental conditions:
   1) darkroom conditions;
   2) standard setup conditions.

7.1.3 Measuring method

For this measurement, the following method shall be applied.

NOTE 1 The ambient contrast ratio is determined from the transmission and reflection measurements of the display under hemispherical diffuse and directed source illumination conditions.

NOTE 2 These measuring methods are described in 5.2.3.3.

NOTE 3 The resulting transmission and reflection coefficients will be used to calculate the combined (emitted, transmitted, and reflected) luminance of a display with a black screen and white screen at the required illuminance levels.

NOTE 4 The ambient contrast ratio is the ratio of the combined white screen luminance to the combined black screen luminance.

1) Measure the black luminance L_{min} at the centre and perpendicular to the display at a 0 % grey level for a full black screen.
2) Set the test input signal to the display to generate a 100 % grey level over the full screen or 4 % window (see 5.2.3.3.2) located in the centre of the display, depending on the intended application.
3) Measure the white luminance L_{max} at the centre and perpendicular to the white display pattern under dark room conditions.
4) Calculate the ambient contrast ratio as specified for the intended application using the following formula:

$$ACR_{\text{j}} = \frac{L_{\text{max}} + L_{\text{max,amb}}}{L_{\text{min}} + L_{\text{min,amb}}} \quad (19)$$

and

$$L_{\text{Q,amb}} = \frac{\rho_{\text{Q,di/0}} \times E_{\text{F,hemi}}}{\pi} + \frac{\rho_{\text{Q,45/0}} \times E_{\text{F,hemi}} \times \cos\theta_{\text{F,s}}}{\pi} + \frac{T_{\text{Q,di/0}} \times E_{\text{B,hemi}}}{\pi} + \frac{T_{\text{Q,45/0}} \times E_{\text{B,hemi}} \times \cos\theta_{\text{B,s}}}{\pi} \quad (20)$$

where

Q represents the measured values with the display in the white state (maximum) or black state (minimum);

$\rho_{Q,di/0}$ is the front reflectance for uniform hemispherical illumination with specular included;

$E_{F,hemi}$ is the front illuminance for uniform hemispherical illumination of the spectral source to be evaluated;

$R_{Q,45/0}$ is the front spectral reflectance factor for a directional light source at an inclination angle $\theta_{F,s}$ = 45°;

$E_{F,dir}\cos\theta_{F,s}$ is the front illuminance at an inclination angle $\theta_{F,s}$ for the directional source to be evaluated;

$T_{Q,di/0}$ is the transmittance factor for uniform hemispherical illumination on the back of screen;

$E_{B,hemi}$ is the back illuminance for uniform hemispherical illumination of the spectral source to be evaluated;

$T_{Q,45/0}$ is the transmittance factor for a directional light source at an inclination angle $\theta_{B,s}$ = 45° on the back of the screen;

$E_{B,dir}\cos\theta_{B,s}$ is the back illuminance at an inclination angle $\theta_{B,s}$ for the directional source to be evaluated.

5) If the reflection and transmission coefficients of the transparent OLED display are not dependent on the rendered colour, then $L_{max,amb} = L_{min,amb}$. The spectral radiance version of Formula (19) has the same form.
6) The actual values to be used to calculate the ambient contrast ratio shall be specified based on the intended application. Recommend values are given in Table 1 and 4.2.3.
7) All values used to calculate the ambient contrast ratio shall be recorded in the test report.

7.2 Display ambient colour measurement

7.2.1 Purpose

The purpose of this method is to determine the on-screen ambient colour of a transparent OLED display module under defined indoor or daylight illumination conditions.

NOTE If the OLED exhibits significant PL, then the ambient contrast ratio calculation is only valid for the same illumination spectra and geometry used to measure the transmission and reflection coefficients.

7.2.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) spectroradiometer that can measure spectral radiance;
   2) driving power source;
   3) driving signal equipment;
   4) directional light source;
   5) integrating sphere or sampling sphere with a stabilized light source.
b) Illuminance condition:
   1) the standard ambient illumination conditions for an indoor room or clear sky daylight shall be used, as specified in Clause 4.
   2) additional illumination conditions may also be used, depending on the application.
c) Except for the standard ambient illumination conditions, all other conditions are the standard conditions.

7.2.3 Measuring method

7.2.3.1 General

For this measurement, the following method shall be applied. The chromaticity of a display under hemispherical diffuse and directional illumination conditions is a combination of the display's intrinsic light emission, transmitted and reflected ambient light.

– The ambient chromaticity of a display at a given colour state Q (e.g. white, black, red, green, or blue screen) under illumination conditions is determined by its equivalent display ambient tristimulus values.
– These values can be obtained from darkroom measurements at the desired colour state, combined with transmission and reflection measurements of the display under hemispherical diffuse and directional source illumination conditions at that colour.
– The measuring methods used to characterize the transmission and reflection coefficients for the display under hemispherical and directional illumination are given in Clauses 5 and 6.

7.2.3.2 Measurement and calculations

For this measurement, the following measurement and calculations shall be applied.

1) The total ambient spectral radiance $L_{\mathrm{Q,tot}}(\lambda)$ with transmission and reflection contributions included will be:

$$L_{\mathrm{Q,tot}}(\lambda) = L_{\mathrm{Q}}(\lambda) + L_{\mathrm{Q,amb}}(\lambda) \quad (21)$$

where

$L_{\mathrm{Q}}(\lambda)$ is the darkroom spectral radiance of the transparent OLED display measured at the centre and perpendicular to the display for the desired colour state Q;

$L_{\mathrm{Q,amb}}(\lambda)$ is the spectral form of Formula (19).

2) The actual values to be used to calculate the total ambient spectral radiance for a given rendered display colour shall be specified based on the intended application. Recommend values are given in Table 1 and 4.2.3.
3) All values used to calculate the total ambient spectral radiance shall be recorded in the test report.
4) The effective display daylight tristimulus values of the display under these illumination conditions are:

$$X_{\mathrm{Q,tot}} = 683\int_{\lambda} L_{\mathrm{Q,tot}}(\lambda)\bar{x}(\lambda)d\lambda \quad (22)$$

$$Y_{\mathrm{Q,tot}} = 683\int_{\lambda} L_{\mathrm{Q,tot}}(\lambda)\bar{y}(\lambda)d\lambda \quad (23)$$

$$Z_{\mathrm{Q,tot}} = 683\int_{\lambda} L_{\mathrm{Q,tot}}(\lambda)\bar{z}(\lambda)d\lambda \quad (24)$$

where

$\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ are the colour matching functions (see CIE 15-2004).

5) The ambient 1931 CIE x and y chromaticity coordinates of the emitting display at the desired colour state Q under the specified illumination conditions are:

$$x_{\mathrm{Q}} = \frac{X_{\mathrm{Q,tot}}}{X_{\mathrm{Q,tot}} + Y_{\mathrm{Q,tot}} + Z_{\mathrm{Q,tot}}} \quad (25)$$

$$y_{\mathrm{Q}} = \frac{Y_{\mathrm{Q,tot}}}{X_{\mathrm{Q,tot}} + Y_{\mathrm{Q,tot}} + Z_{\mathrm{Q,tot}}} \quad (26)$$

Annex A
(normative)

Alternative method for measuring the hemispherical transmittance factor of a transparent OLED display

A.1 Purpose

An alternative method is described to measure the hemispherical transmittance factor of a transparent OLED display. This shall be the preferred method if the presence of the OLED display against the sphere significantly changes the spectral irradiance on the sphere walls. It is also necessary to use this method if the OLED display needs to be measured in its on state.

A.2 Measuring conditions

For this measurement, the following conditions shall be applied.

a) Apparatus:
   1) spectroradiometer as defined in 4.3.2;
   2) a smooth broadband light source shall be used to produce sufficient spectral irradiance from 380 nm to 780 nm inside a sampling sphere. The intensity at each wavelength in that range should be also stable to less than 1 %;
   3) a sampling sphere shall be used to implement uniform hemispherical diffuse illumination conditions. The configuration shall follow the standard 8° to 10° detection geometry, which is shown in Figure A.1. General guidance is given in IEC 62341-6-2 for making optical measurements using a sampling sphere.
b) Illuminance condition: the standard ambient illumination should be used, such as CIE illuminant A, or CIE Daylight Illuminants, as recommended in Table 1 or defined in the test specification.
c) The measurements will be performed in a dark room with an OLED display rendering the desired colour Q. It should be noted that it is not uncommon for the OLED transmission properties to be largely invariant with the rendered colour. If that can be demonstrated, then the trasmission properties can be measured with the display turned off.

A.3 Measuring the transmittance

For this measurement, the following method shall be applied.

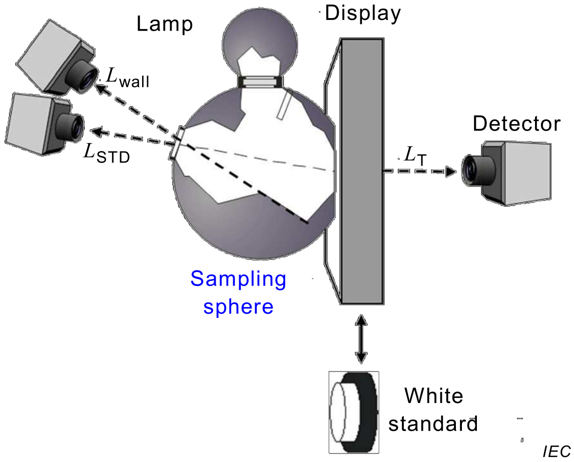


Figure A.1 – Measurement geometry using a sampling sphere

1) A spectroradiometer is aligned in such a way that its field of view is centred on the detector port (left port in Figure A.1), and its measurement field is focused and centred on the sample port (right side of sampling sphere).
2) Place a white reflectance standard, of known spectral reflectance $\rho_{std}(\lambda)$ for hemispherical illumination, against the sample port. After the light source has stabilized, measure the spectral radiance of the reflectance standard $L_{std}(\lambda)$.
3) Rotate the spectroradiometer about the detector port such that the measurement field is positioned on the inner wall of the sampling sphere adjacent to the sample port. Measure the spectral radiance of the sphere inner wall $L_{wall}(\lambda)$. The spectral reflectance of the sphere inner wall $\rho_{wall}(\lambda)$ is obtained by:

$$\rho_{wall}(\lambda) = \rho_{std}(\lambda) \cdot \frac{L_{wall}(\lambda)}{L_{std}(\lambda)} \tag{A.1}$$

4) Place the back of the transparent display against the sample port of the sampling sphere. Turn on the display to the desired colour state Q, where Q may be off, red, green, blue, etc. Allow the display to stabilize.
5) Measure the spectral radiance of the sphere inner wall $L_{Q,wall}(\lambda)$ under sphere illumination with the display rendering a colour Q.
6) The spectral irradiance $E_Q(\lambda)$ on the display from the sphere hemispherical illumination is given by:

$$E_Q(\lambda) = \frac{\pi L_{Q,wall}(\lambda)}{\rho_{wall}(\lambda)} \tag{A.2}$$

NOTE To ensure measurement integrity, the spectral irradiance $E_Q(\lambda)$ is dominated by the illumination originating from the sphere light source.

7) Move the spectroradiometer to the front of the transparent OLED display. Align the spectroradiometer normal to the display surface, and centre the measurement field in the centre of the sample port. The LMD distance to the display shall be obtained from the test specification, otherwise it shall be 0,5 m. Measure the total spectral radiance $L_{Q,T}(\lambda)$ transmitted through the transparent OLED display.
8) Maintain the position of the transparent OLED display, and remove the sphere. While the display is still rendering the same colour Q, measure the spectral radiance $L_Q(\lambda)$ of the transparent OLED display in a dark room. If the display emission is stable and reproducible, the dark room measurement can be done independently of the sphere measurements.

9) The hemispherical spectral transmittance factor $T_{\mathrm{Q,di/0}}(\lambda)$ of the transparent OLED display with the display rendering a colour Q is given by:

$$T_{\mathrm{Q,di/0}}(\lambda) = \frac{\pi\left(L_{\mathrm{Q,T}}(\lambda) - L_{\mathrm{Q}}(\lambda)\right)}{E_{\mathrm{Q}}(\lambda)} \tag{A.3}$$

The luminous transmittance factor T_{Q} for any CIE-defined illumination spectrum $E_{\mathrm{CIE}}(\lambda)$ can be calculated using the following formula:

$$T_{\mathrm{Q}} = \frac{\int_{\lambda} T_{\mathrm{Q}}(\lambda) E_{\mathrm{CIE}}(\lambda) V(\lambda) d\lambda}{\int_{\lambda} E_{\mathrm{CIE}}(\lambda) V(\lambda) d\lambda} \tag{A.4}$$

where $V(\lambda)$ is the photopic luminous efficiency function as defined in CIE 15-2004.

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