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INTERNATIONAL STANDARD

colour inside

Organic light emitting diode (OLED) displays –
Part 6-7: Measuring methods of optical characteristics for display with under-screen feature

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ORGANIC LIGHT EMITTING DIODE (OLED) DISPLAYS –

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FOREWORD

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IEC 62341-6-7 has been prepared by IEC technical committee 110: Electronic displays. It is an International Standard.

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

Draft	Report on voting
110/1667/FDIS	110/1691/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

A display has originally been conceived to show content or images on the screen and been designed to be blocked on its back-plate, except for a transparent display. Along with advances in display technologies, various screen forms with the display are available, such as a notch type for the camera and sensors area, a pin-hole area, a teardrop shape, and a dual punch-hole for the front camera.

The display has changed and consistently improved its pixel structures to make it easier for a user to use multimedia without physical interference, for example, putting cameras and sensors under the display screen to achieve the functions of finger touch, taking photos, 3D sensing and so on; these technologies can be called under-screen features.

This document introduces mainly measuring conditions and measuring methods for the impact of these developing under-screen features.

ORGANIC LIGHT EMITTING DIODE (OLED) DISPLAYS –

Part 6-7: Measuring methods of optical characteristics for display with under-screen feature

1 Scope

This part of IEC 62341 specifies the standard measuring conditions and measuring methods for determining the optical characteristics of an OLED display with under-screen camera; other under-screen features, such as under-screen fingerprint or under-screen time of flight (TOF) can also be applied. This document applies to OLED displays such as mobile phone, monitor and TV with under-screen features.

NOTE Under-screen feature will want the display to be partially transparent and partially non-transparent, and this can be achieved only by certain types of display technology, for example OLED. This document mainly focuses on OLED display with under-screen feature.

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 62341-5-3, *Organic light emitting diode (OLED) displays – Part 5-3: Measuring methods of image sticking and lifetime*

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

IEC TR 62977-2-5, *Electronic displays devices – Part 2-5: Transparent displays – Measurements of optical characteristics*

IEC 62977-3-7, *Electronic displays – Part 3-7: Evaluation of optical performance – Tone characteristics*

ISO 12233, *Photography – Electronic still picture imaging – Resolution and spatial frequency responses*

3 Terms, definitions and abbreviated terms

3.1 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 terminology databases for use in standardization at the following addresses:

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

3.1.1
under-screen feature
feature placed under the display screen to achieve the functions of finger touch, taking photos, 3D sensing and so on

3.1.2
under-screen area
display area with special pixel structure and circuit design so that the under-screen feature can be achieved

3.1.3
normal display area
display area with normal pixel structure and circuit design except for the under-screen area

3.2 Abbreviated terms

CCD charge coupled device
CCT correlated colour temperature
CTF contrast transfer function
DUT device under test
LMD light measuring device
MTF modulation transfer function
SFR spatial frequency response
TOF time of flight

4 Measuring conditions

4.1 Standard measuring environmental conditions

Measurements shall be carried out under the standard environmental conditions as follows:

– temperature: 25 °C ± 3 °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 Standard darkroom conditions

The luminance contribution from the background illumination reflected off the test display shall be ≤ 0,01 cd/m^2 or less than 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 test report. In addition, if the sensitivity of the LMD is inadequate to measure at these low levels, then the lower limit of the LMD shall be noted in the test report.

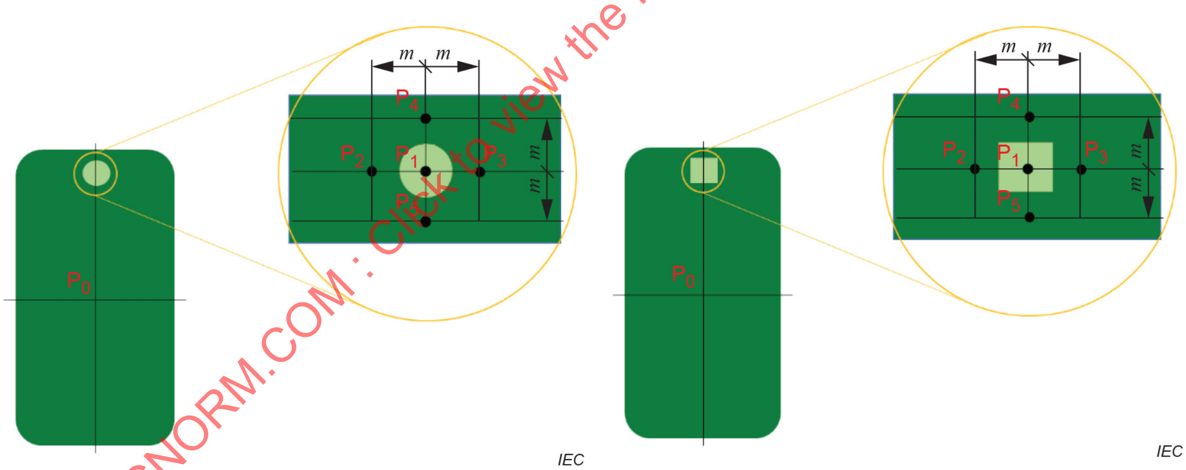
4.3 Standard measurement locations

Measurement shall be undertaken at several specified locations on the surface of the DUT. P_0 is the centre of the whole display area, P_1 is the centre of the under-screen area, P_2, P_3, P_4, P_5 are the centre of the adjacent display area, and m is the distance between test points which is determined by the display design. If the shape of the under-screen area is round, m is the diameter of the circle (see Figure 1 a)); if the shape of the under-screen area is square, m is the length of the side of the square (see Figure 1 b)); if the under-screen area has a different shape, m is the short side length of the shape. The measuring spots on the display shall not overlap.

A microscope should be used before making optical measurements to check the shape of the under-screen area and to determine the distance m for test points.

NOTE The under-screen area is generally located in the edge part of the display panel, so if the adjacent points such as P_2, P_3 or P_4 are out of the display area, the corresponding measurement data will not be taken into account.

Any deviation from the above-described standard locations shall be added to the detail specification.



a) under-screen circle shape b) under-screen square shape

Figure 1 – Example of measurement locations

5 Measuring methods of display performance

5.1 Reflectance difference

5.1.1 General

The purpose of this method is to measure the reflectance difference between the under-screen area and normal display area, including the display spectral reflectance and the luminous reflectance for hemispherical diffuse illumination. It is recommended that the spectral reflectance be measured. If a luminance meter is used to obtain the luminous reflectance, then the measured luminous reflectance is only valid for the illumination spectra used during the measurement. This reflection should not be used for calculating the reflection properties from other spectral distributions.

5.1.2 Measuring equipment

The apparatus shall be as follows:

– driving power source;
– driving signal source;
– sampling sphere with stabilized light source.

For reflectance measurement, an LMD that can measure luminance and spectral radiance is necessary, as well as a white diffuse reflectance standard with a known hemispherical diffuse spectral reflectance factor calibrated for the intended measurement geometry.

The aperture of the LMD shall be smaller than the size of the under-screen area of the DUT to ensure the measurement completely focuses on the transparent under-screen area.

5.1.3 Measuring procedure

The measurement shall be taken at standard darkroom conditions and proceed as follows:

a) Place the DUT against the sample port of a sampling sphere, as indicated in Figure 2. Keep the centre of the sample port pointed to the under-screen area of the display. Turn on the sampling sphere's hemispherical diffuse illumination to the desired correlated colour temperature (CCT).

   NOTE Since the DUT is partially transparent, an opaque base plate will be attached to the bottom of the DUT to prevent the light from passing through.

b) Measure the luminous hemispherical reflectance or spectral hemispherical reflectance R of the centre of the entire display area P_0 and the centre of the under-screen area P_1 shown in Figure 1, as specified in IEC 62341-6-2.

c) Calculate and report the relative reflectance difference between P_0 and P_1 in accordance with Formula (1).

$$\Delta R = \left| \frac{R_0 - R_1}{R_0} \right| \times 100(\%) \quad (1)$$

The DUT shall be measured at the OFF-state. The spectral characteristics and CCT of the illuminant source should be recorded and reported.

The display reflectance should not change with the state of the display. If it does, then it shall be measured at both OFF-state and white pattern.

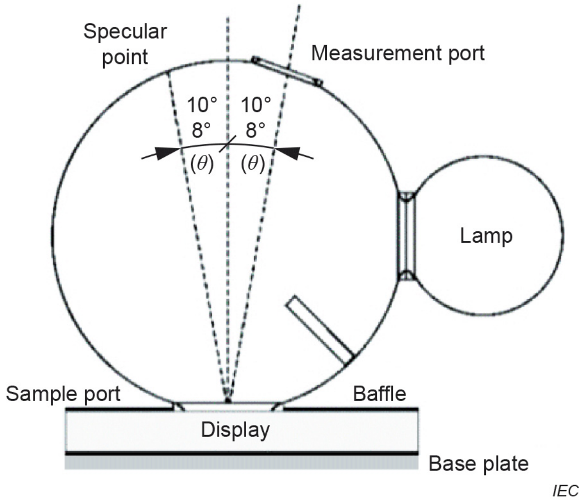


Figure 2 – Measurement geometries for reflectance

5.2 Uniformity

5.2.1 General

The purpose of this method is to measure the luminance uniformity and chromaticity uniformity of the normal display area and the under-screen area.

5.2.2 Measuring apparatus

The apparatus shall be as follows:

– 2D measuring equipment that can measure luminance and CIE 1931 chromaticity coordinates (x, y);
– driving power source;
– driving signal equipment.

The pixel number of the LMD should be at least ten times that of the DUT to avoid moiré pattern.

5.2.3 Measuring procedure

The measurement shall be taken at standard darkroom conditions and proceed as follows:

a) Allow the apparatus sufficient time to reach thermal equilibrium before the measurements.
b) Allow the DUT to display a full screen white pattern and measure the luminance and CIE 1931 chromaticity coordinates (x, y) of the display from positions P_1 to P_5.
c) Calculate the luminance uniformity in accordance with Formula (2):

$$N = \left(1 - \frac{L_{\text{min}}}{L_{\text{max}}}\right) \times 100(\%) \qquad (2)$$

d) Calculate the chromaticity difference between P_1 and the other four measurement points, i.e., P_1 versus P_2, P_1 versus P_3, P_1 versus P_4, and P_1 versus P_5. Other differences among P_2 to P_5 can also be calculated in accordance with Formula (3) and Formula (4):

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

$$\Delta u'v' = \sqrt{\left(u'_i - u'_j\right)^2 + \left(v'_i - v'_j\right)^2} \tag{4}$$

e) Report the maximum chromaticity difference as chromaticity uniformity.

5.3 Gamma

5.3.1 General

The purpose of this method is to measure the gamma characteristics of the normal display area and the under-screen display area.

5.3.2 Measuring apparatus

The apparatus shall be as follows:

– light measuring device that can measure luminance;
– driving power source;
– driving signal equipment.

5.3.3 Measuring procedure

The measurement shall be taken at standard darkroom conditions and proceed as follows:

a) Allow the apparatus sufficient time to reach thermal equilibrium before the measurements.
b) Allow the DUT to display a full screen W, R, G, B pattern and measure the luminance of the display from location P_1 to P_5 under gray scale from 0 to 255 or 0 to 1 023.
c) Calculate the gamma value in accordance with IEC 62977-3-7.
d) Draw the tone curve of P_1 to P_5. The curve should be between the maximum and minimum value specified by the display supplier. Figure 3 shows an example of gamma 2,0 for the minimum and gamma 2,4 for the maximum.

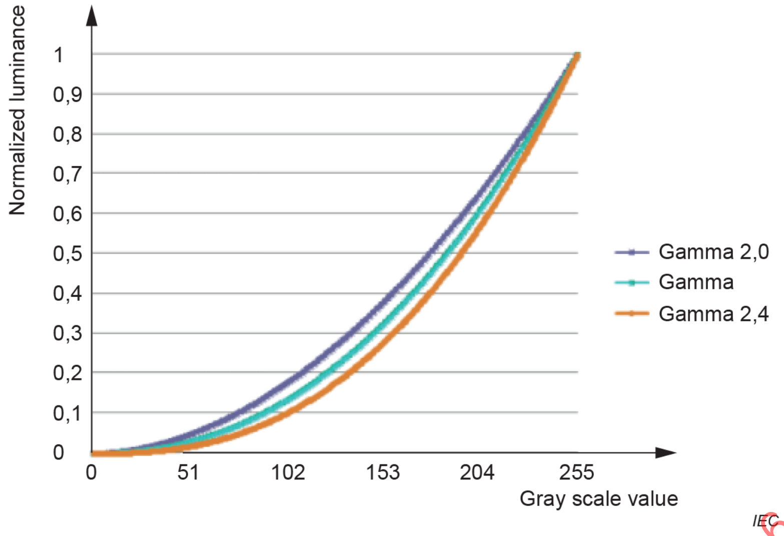


Figure 3 – Example tone curve of the display

5.4 Angular chromaticity shift

5.4.1 General

The purpose of this method is to evaluate the chromaticity shift of the normal display area and the under-screen display area at different viewing angles.

5.4.2 Measuring apparatus

Test apparatus shall be as follows:

– colorimeter or spectroradiometer that can measure the CIE 1931 chromaticity coordinates (x, y);
– driving power source;
– driving signal equipment.

5.4.3 Measuring procedure

The measurement shall be taken at standard darkroom conditions and proceed as follows:

a) Allow the apparatus sufficient time to reach thermal equilibrium before the measurements are made.

b) Align the LMD to the normal line of the display surface and measure the CIE 1931 chromaticity coordinates (x, y) of the DUT at location P_1 to P_5.

c) Change the measuring direction to a settled viewing angle, as shown in Figure 4. The angle relative to the display normal in the horizontal plane is expressed as θ_L and θ_R, the angle relative to the display normal in the vertical plane is expressed as φ_T and φ_B. The LMD can be moved within these planes.

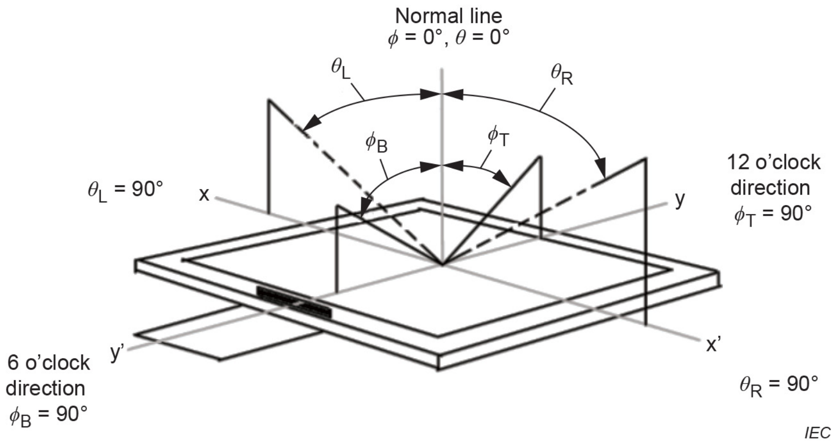


Figure 4 – Viewing angle set up

d) Measure the CIE 1931 chromaticity coordinates (x, y) of the DUT at location P_1 to P_5.

e) Calculate the chromaticity shift of different points in the same measuring direction and the chromaticity shift of the same point in different measuring directions in accordance with Formula (3) and Formula (4).

f) Record the measurement results, as shown in Table 1.

NOTE The accuracy of the chromaticity shift can be affected by the quality of the colorimeter or spectroradiometer.

Table 1 – Measurement results

Angle		**Position**					$\Delta u'v'_{max}$
θ	φ	**P$_1$**	**P$_2$**	**P$_3$**	**P$_4$**	**P$_5$**	
0	15						
0	30						
0	-15						
0	-30						
15	0						
30	0						
-15	0						
-30	0						
$\Delta u'v'_{max}$							—

5.5 Luminance degradation

5.5.1 General

The purpose of this method is to evaluate the luminance degradation of an OLED display with under-screen feature; the luminance degradation is evaluated by the elapsed time required when the luminance of the normal area and transparent area decrease to a satisfied threshold value.

5.5.2 Measuring apparatus

The test apparatus shall be as follows:

- light measuring device that can measure luminance;
- driving power source;
- driving signal equipment.

5.5.3 Measuring procedure

The measurement shall be taken at standard darkroom conditions and proceed as follows:

a) Allow the apparatus sufficient time to reach thermal equilibrium before the measurements are made.

b) Apply a full white screen driving signal to the DUT at 100 % gray level.

c) Measure the initial luminance of the centre position of the entire display area P_0 and the centre position of the under-screen area P_1, shown in Figure 1.

d) Keep the above operating conditions and measure the luminance of P_0 and P_1 at the specified time. The specified time can be 1 h, 10 h, 100 h, 1 000 h, 2 000 h, 3 000 h, 4 000 h and 5 000 h. An example of the luminance behaviour in operation is shown in Figure 5, as specified in IEC 62341-5-3.

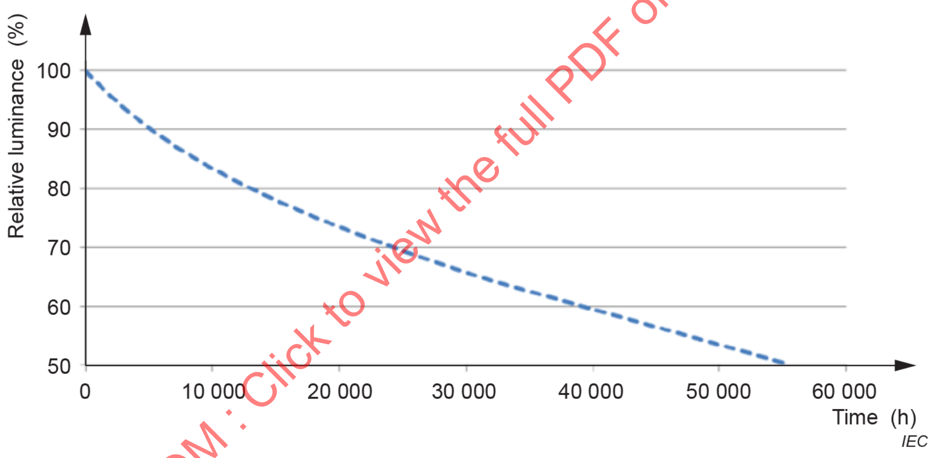


Figure 5 – Example of luminance decreases versus operating time

e) Calculate the luminance difference of P_0 and P_1 in accordance with Formula (5):

$$\Delta L = L_0 - L_1 \tag{5}$$

f) Record the elapsed time when the luminance difference between the normal display area (at P_0) and under-screen display area (at P_1) decreases to a satisfied threshold value.

NOTE The threshold value of the luminance difference can be defined by the display manufacturer according to its own quality control target.

Generally, the luminance of the under-screen display area will decrease faster than the normal display area because of the special pixel structure and circuit design. Table 2 and Figure 6 show an example of measured data for a display with an under-screen camera.

Table 2 – Example of measured data

Luminance (cd/m²)	Time (*h*)							
	0	**100**	**200**	**300**	**400**	**500**	**600**	**700**
L_0	361	344	335	328	320,5	312,5	305	296,5
L_1	367	340	329,5	324	321	318,5	317	316
ΔL	-6	4	5.5	4	-0.5	-6	-12	-19,5

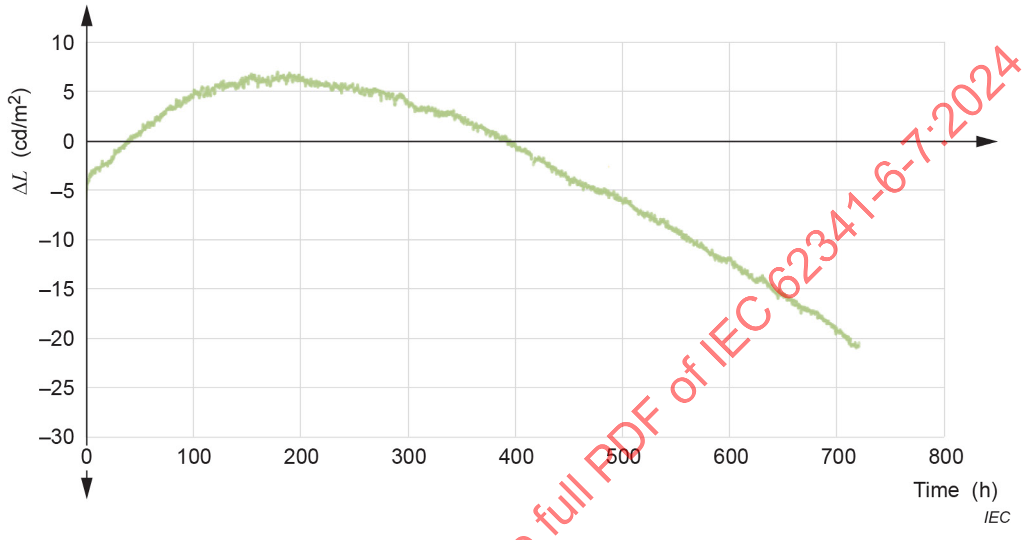


Figure 6 – Example of the decrease of a luminance difference curve

6 Measuring methods of transmittance performance

6.1 Transmittance

6.1.1 General

Transmittance refers to the proportion of light passing through the display screen. It is an important parameter for under-screen camera. In general, higher display transmittance in the region of the under-screen feature will result in better image quality. However, having higher display transmittance in the under-screen region compared to that of the rest of the display can impact display uniformity. A special pixel structure and circuit design are necessary in order to optimize this tradeoff.

NOTE The purpose of this test item is to measure the transmittance of the under-screen area (P_1) of the OLED display under test. If necessary, the transmittance of the normal display area (P_0 and P_2-P_5) can also be considered.

6.1.2 Measuring apparatus

The apparatus shall be as follows:

- driving power source;
- driving signal equipment;
- light measuring device that can measure luminance or spectral radiance;
- integrating sphere with a stabilized light source which covers the visible light range from 380 nm to 780 nm.

6.1.3 Measuring procedure

The transmittance is obtained by comparing the luminous value of the light source before and after it passes through the transparent area of the OLED display. All conditions shall remain constant during the measurement of both luminance values (temperature, illumination, measuring distance, etc.).

The measurement shall be taken at standard darkroom conditions and proceed as follows:

a) Allow the apparatus sufficient time to reach thermal equilibrium before making any measurement.

b) Turn on the integrating sphere light source and allow the light source and LMD to stabilize.

c) If the integrating sphere has a light trap port, place a port plug, or diffuse white standard, at that port.

d) Measure the initial luminance of the light source L_1 at the sample port.

e) Turn off the DUT and place the centre position P_1 of the under-screen area against the sample port of the integrating sphere. The measurement configuration is shown in Figure 7 , and ingress of external light into the integrating sphere is prevented. The aperture of the LMD shall be smaller than the size of the under-screen area of the DUT to ensure the measurement completely focuses on the transparent under-screen area.

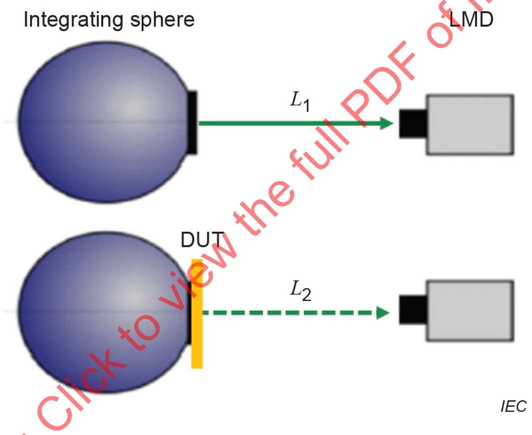


Figure 7 – Measurement geometry

In order to obtain the accurate transmittance data, the diameter of the integrating sphere should be smaller than the under-screen area, if not, the normal area of the DUT should be covered with opaque material such as lightproof foam to prevent the light passing through.

f) Measure the transmitted luminance L_2 at the sample port.

g) Calculate the luminous hemispherical transmittance factor as a percentage using Formula (6):

$$\tau = \frac{L_2}{L_1} \quad (6)$$

h) Carry out the procedure three times and use the average of the three calculated results as the luminous hemispherical transmittance factor value.

The type and wavelength of the light source used and other factors which can affect the measurement result should be reported.

Small subtense light sources should be avoided, because it is found that they are very sensitive to the measuring conditions and have poor reproducibility.

6.2 Clarity

6.2.1 General

Due to the periodicity arrangement of the display pixel, the light source will have a certain degree of diffraction after passing through the display panel, and this will have an effect on the under-screen feature. For example, the under-screen camera usually has serious starlight, image blur, edge ghosting and other problems, as shown in Figure 8.

a) normal camera **b) under-screen camera**

Figure 8 – Diffraction phenomenon of under-screen camera

The purpose of this method is to measure the diffraction which is caused by the OLED display with under-screen feature. There are two methods that can be used to measure clarity, one is the modulation transfer function (MTF), another is the spatial frequency response (SFR).

6.2.2 Measuring method of modulation transfer function (MTF)

6.2.2.1 Measuring apparatus

The apparatus shall be as follows:

– light measuring device that can measure the luminance;

– driving power source;

– driving signal equipment;

– reference display device to display the test pattern;

– CCD camera that can capture the image of the test pattern.