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INTERNATIONAL STANDARD

colour inside

Eyewear display –
Part 22-10: Specific measurement methods for AR type – Optical properties

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FOREWORD

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International Standard IEC 63145-22-10 has been prepared by IEC technical committee 110: Electronic displays.

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

FDIS	Report on voting
110/1160/FDIS	110/1173/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 63145 series, published under the general title *Eyewear display*, 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- withdrawn,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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EYEWEAR DISPLAY –

Part 22-10: Specific measurement methods for AR type – Optical properties

1 Scope

This part of IEC 63145 specifies the standard measurement conditions and measuring methods for determining the see-through optical properties and imaging quality of augmented reality (AR) eyewear displays. This includes the transmission characteristics and ambient optical performance of the eyewear displays.

Contact lens type displays are out of the scope of this document.

NOTE The relationship between the scope and other documents (IEC 63145-20-10, IEC 63145-22-10) is shown in Annex A.

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.

ISO/CIE 11664-5, *Colorimetry – Part 5: CIE 1976 L*u*v* colour space and u', v' uniform chromaticity scale diagram*

3 Terms, definitions, abbreviated terms and letter symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions 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

NOTE 1 Terms related to eyewear displays will be defined in specific projects.

NOTE 2 Some terms relating to eyewear displays are given in IEC TR 63145-1-1 [1][1]

3.1.1
front side stray light
for light going to the eyes through the eyewear, light other than light effective for forming an image or a scenery

1 Numbers in square brackets refer to the Bibliography.

3.2 Abbreviated terms

AR augmented reality

CCD charge-coupled device

CCFL cold cathode fluorescent lamp

CPD cycles per degree

DUT device under test

FOV field of view

LMD light measuring device

NOTE The abbreviated terms refer to IEC TR 63145-1-1 [1], IEC 63145-20-10 [2], and IEC 63145-20-20 [3].

3.3 Letter symbols (symbols for quantities, and units)

The letter symbols are shown in Table 1.

Table 1 – Letter symbols (quantity symbols and units)

Quantities	Symbols and units	
Measuring point (i = 0: centre)	P_i	
Luminance	L_v	(cd/m^2)
Maximum luminance	L_vM	(cd/m^2)
Minimum luminance	L_vm	(cd/m^2)
Luminance of the illuminating source without DUT	$L_\mathrm{v,ill}$	(cd/m^2)
Luminance of the reference white standard	$L_\mathrm{v,std}$	(cd/m^2)
CIE 1931 chromaticity coordinates at P_i	$(x_\mathrm{i},y_\mathrm{i})$	
CIE 1931 chromaticity coordinates of the illuminating source without DUT	$(x_\mathrm{ill},y_\mathrm{ill})$	
Transmittance	$T_{0/0}$	(%)
Chromaticity difference	$\Delta u'v'_{0/0}$	
Front side stray light	$H_\mathrm{de/0}$	(%)
Contrast modulation	C_CM	

4 Standard measurement conditions

4.1 Standard environmental conditions

Unless otherwise specified, all tests and measurements for eyewear displays shall be carried out after sufficient warm-up time for the illumination sources and the DUT (see 4.3), under the following standard environmental conditions:

– temperature 22 °C to 28 °C,
– relative humidity 25 % to 85 %, and
– atmospheric pressure 86 kPa to 106 kPa.

When different environmental conditions are used, they shall be reported in detail in the specification.

4.2 Power supply

In order to stabilize the performances of the DUT, the power supply for driving the DUT shall be adjusted according to the specification of the DUT.

NOTE When the DUT is driven by a battery, it is less susceptible to power supply fluctuations.

4.3 Warm-up time

The optical performances of the DUT are affected by the transient temperature behaviour of the device. It takes a certain time for the luminance output of the DUT to reach the steady state. If the luminance output is not within a ±3 % variation, it shall be reported. All measuring conditions shall be kept constant during the measurements.

NOTE If the measuring result does not become a steady state, it might be influenced by the output fluctuation of the DUT and/or the fluctuation of the LMD such as noise.

4.4 Dark room condition

The luminance contribution from the background of the test room reflected off the measurement space shall be less than 1/20 of the minimum luminance output from the DUT. If this condition is not satisfied, then background luminance can be subtracted and it shall be reported.

5 Measurement systems

5.1 Standard coordinate system

To indicate the size and position of a virtual image, a spherical coordinate system of elevation (latitude) and azimuth (longitude) shall be used in the measurements; the polar axis is vertically oriented as shown in Figure 1. The angles measured in the vertical half planes of the data are elevation angles, denoted as α, and the horizontal angles to the half plane are azimuth angles, denoted as Ψ. The origin direction (α = 0, Ψ = 0) of the spherical coordinate system shall be coincident with the optical axis of the DUT.

To indicate the positional relationship among the eye-box, the reference point on the DUT, eye point and eye relief of the DUT, the entrance pupil of the LMD and so on, a three-dimensional Cartesian coordinate system (x, y, z) shall be used, as shown in Figure 2. Unless specified otherwise, the eye point of the DUT is placed in the centre of the entrance pupil of the eye, which is in the centre of the iris. The eye point defines the origin of the coordinate system. The manufacturer or supplier of the DUT shall specify the distance between a reference point on the DUT and the eye point. The eye relief is defined as the distance from the cornea of the eye to the closest optical element of the DUT.

The origins of both the spherical coordinate system and the Cartesian coordinate system shall be located at the eye point.

NOTE In the case of a binocular eyewear display, the left eye can be used as the origin of the Cartesian coordinate system.

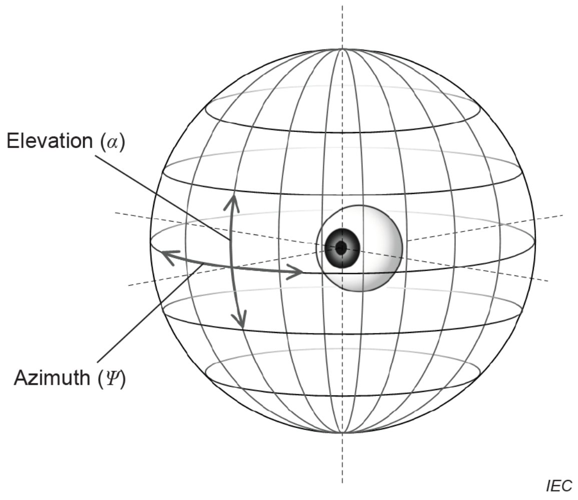
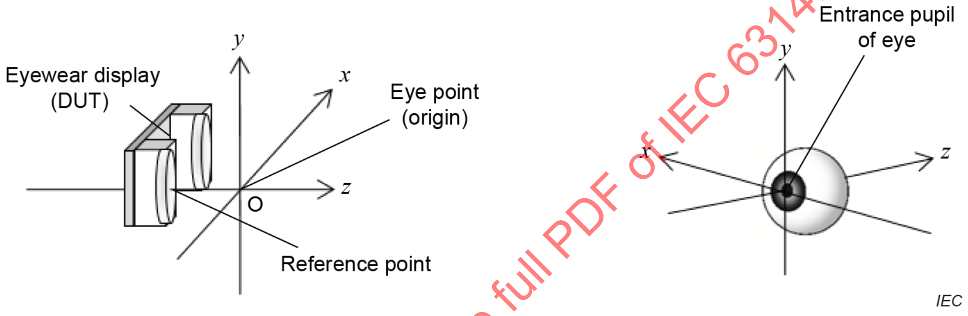


Figure 1 – Spherical coordinate system



NOTE This figure is an example of the eye pupil adjusting to the eye point which is the origin position.

Figure 2 – Three-dimensional Cartesian coordinate system

5.2 Measurement equipment

5.2.1 Light measuring device (LMD)

5.2.1.1 General

The configurations and operating conditions of the equipment should comply with the structures specified in each item. To ensure accurate measurements, the following requirements shall be applied. Otherwise, the differences shall be noted in the report. ISO/CIE 19476 [9] describes the LMD evaluation procedures.

The optics of the LMD (a spot LMD or a 2D imaging LMD) shall be equivalent to the human eye, as shown in Figure 3. The LMD shall be equipped with a finder. The position of the entrance pupil (aperture) of the LMD shall be provided by the manufacturer or the supplier. The entrance pupil size of the LMD should be set between 2 mm and 5 mm, and shall be smaller than the light field projected by the DUT. The LMD to measure the optical characteristics such as luminance and colour shall be calibrated with the appropriate photometric or spectrometric standards. The LMD should be carefully checked before measurements, considering the following points:

– sensitivity of the measured quantity to the measuring light;
– errors caused by the veiling glare and lens flare (i.e., stray light in the optical system);
– timing of data-acquisition, low-pass filtering and aliasing-effects;
– linearity of detection and data-conversion;
– measurement field size.

NOTE See IEC TR 63145-1-1:2018 [1], 6.2.

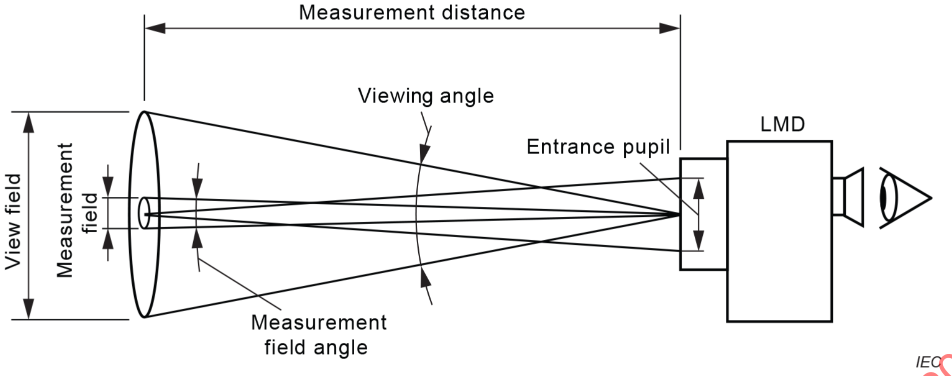


Figure 3 – Example of LMD structure

5.2.1.2 Spectrometer-type LMD

When a spectrometer-type LMD such as a spectroradiometer is used, the wavelength range shall be at least 380 nm to 780 nm, the spectral bandwidth shall be 5 nm or smaller, and the wavelength accuracy shall be 0,3 nm or smaller.

5.2.1.3 Filter-type LMD for measuring luminance

When a filter-type LMD such as a luminance meter is used, to ensure the luminance accuracy for the intended DUT light sources, its spectral responsivity should comply with the spectral luminous efficiency for CIE photopic vision or it should be compared with a calibrated spectrometer. The spectral mismatch correction factor can be applied, if necessary.

NOTE CIE-f_1' indicates the spectral mismatch function between the spectral responsivity of the filter-type LMD and the CIE photopic luminous efficiency function. Details of the spectral mismatch correction factor are given in ISO/CIE19476 [9].

5.2.1.4 Filter-type LMD for measuring colour

When a filter-type LMD such as a colorimeter is used, to ensure the colour accuracy for the intended DUT light sources, its spectral responsivity should comply with the CIE colour-matching functions for the CIE 1931 standard colorimetric observer (see ISO 11664-1 [7]) or it should be compared with a calibrated spectrometer. The colour correction factors can be applied, if necessary. The filter-type LMD shall not be used for absolute colour quantities but for relative colour quantities such as colour uniformity.

5.2.1.5 2D imaging LMD

The 2D imaging LMD (using a two-dimensional sensor such as a CCD) is a kind of a filter type LMD. The performances of the 2D imaging LMD shall comply with 5.2.1.3 and 5.2.1.4. The valid measurement field angle of the 2D imaging LMD shall be confirmed and the peripheral image of the 2D imaging LMD shall confirm the absence of vignetting. The number of pixels of the 2D imaging LMD should not be less than four times the sub-pixels number within the measurement field.

NOTE 1 The field of view of some 2D imaging LMDs is affected by the smaller entrance aperture.

NOTE 2 The 2D imaging LMD using a colour filter array might cause moiré.

NOTE 3 The 2D imaging LMD might not accurately represent the influence of eye rotation at larger viewing angles.

5.2.2 Stage condition

5.2.2.1 General

The stage shall be used to realize the coordinate system specified in 5.1. The stage should be constructed with the equivalent of a biaxial goniometer and an orthogonal three-axis translation stage. This may include complex positioning systems, such as a multi-axis robotic arm.

5.2.2.2 Goniometer

A biaxial goniometer shall be assembled to be capable of measuring the azimuth (horizontal) and elevation (vertical) angles in the spherical coordinate system as shown in Figure 1. Examples of a five-axis stage are shown in Figure 4. The angular accuracy should be no less than 0,1°. The goniometer can be pivoted at the centre of the entrance pupil of the LMD or 10 mm behind the entrance pupil to include the effect of eye rotation.

5.2.2.3 Translation stage

An orthogonal three-axis translation stage is assembled with an adequate range to cover the measuring distance such as the eye-box volume, and if necessary to cover the interpupillary distance for binocular DUTs, as in the examples shown in Figure 4. The translation accuracy should be no less than 0,05 mm.

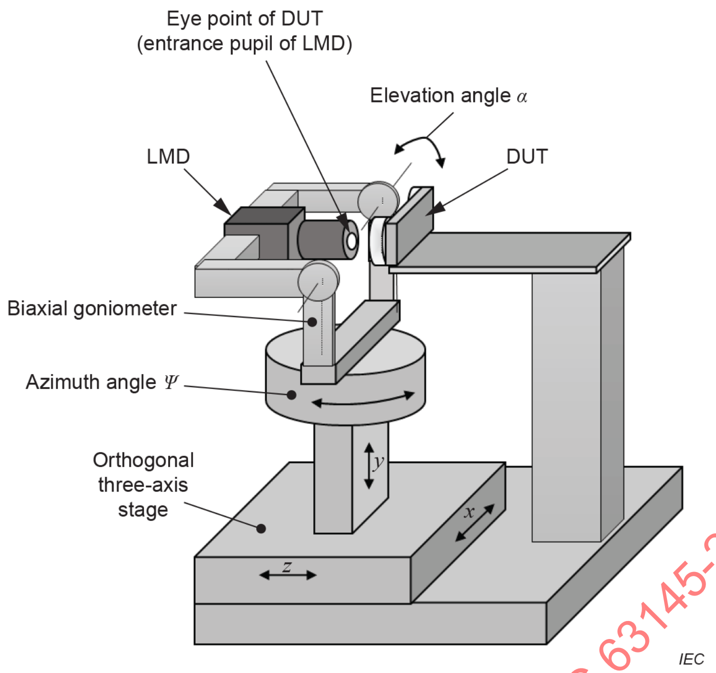
5.2.3 Setup conditions

The DUT shall be mounted on a stable platform to ensure image stability. The LMD position relative to the DUT shall be moved and it can use a five-axis system (a biaxial goniometer and orthogonal three-axis translation stage). Examples of a measuring setup are shown in Figure 4. The eye point of the DUT shall match the origin of the biaxial goniometer. The optical axis of the DUT which is decided by the manufacturer or supplier shall be adjusted to the optical axis of the LMD and shall be aligned with the z-axis of the orthogonal three-axis translation stage. For DUTs with a rectangular virtual image, the edges of the virtual image shall be adjusted parallel to the x- and y-axes of the orthogonal three-axis translation stage.

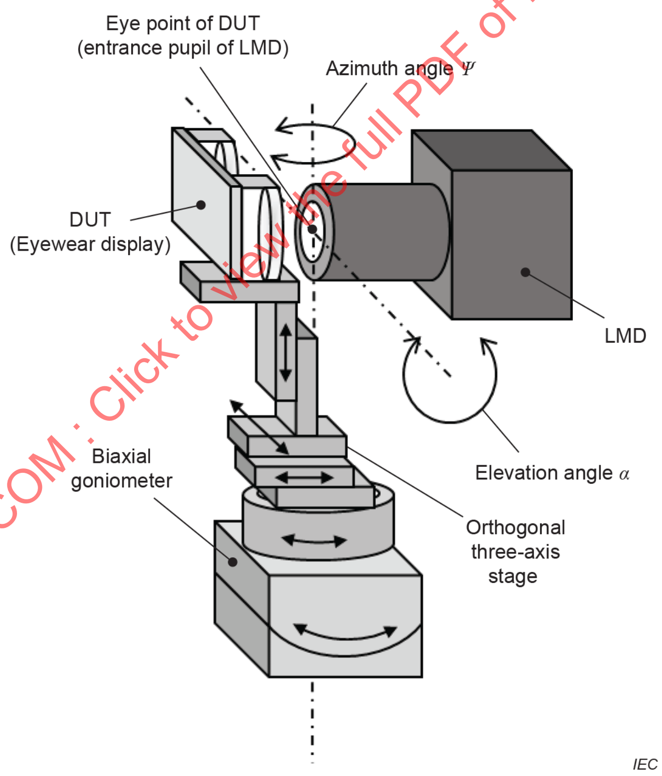
To measure the condition from an anterior view, when the DUT does not suppose a change of gaze angle (eye rotation), the origin of a biaxial goniometer shall be assumed to be the entrance pupil of the eye (eye point) but not the rotation centre of the eyeball (eye movement). When the origin of the biaxial goniometer does not match the eye point of the DUT, the coordinate correction shall be required and shall be reported. When the DUT supposes a change of the gaze angle, the detailed information such as the position of the rotation centre shall be specified by the manufacturer or the supplier and shall be reported.

NOTE 1 The cornea position is about 3 mm in front of the iris position. Some optical designs are used based on the cornea position.

NOTE 2 The rotation centre of the eyeball is located about 10 mm behind the iris.



a) LMD mounted on a biaxial goniometer and orthogonal three-axis translation stage



b) DUT mounted on a biaxial goniometer and an orthogonal three-axis translation stage

NOTE 1 When the LMD is installed on the biaxial goniometer, the elevation stage is set on the azimuth stage.

NOTE 2 Some eyewear displays change their virtual image depending on their orientation.

Figure 4 – Example of measuring setup for eyewear displays

5.3 Test patterns

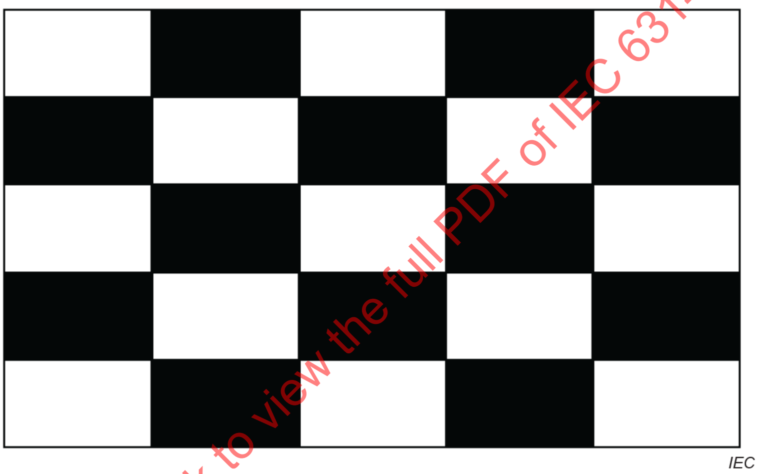
5.3.1 General

The following test patterns shall be specified by the manufacturer or the supplier, and the applied test pattern shall be noted in the report. When other test patterns are applied, they shall be noted in the report.

NOTE Unlike a conventional display, the boundary of the display area is not clear, and the choice of a test pattern might affect the measurement results.

5.3.2 Checkerboard pattern

The checkerboard pattern as shown in Figure 5 should be used to measure the applicable properties, and can be used for alignment of the DUT and LMD optics. The checkerboard pattern with crosses whose example is specified in ISO 9241-305 [6], should also be used for alignment of the DUT and LMD optics. Both patterns of white and black at the centre can be used. Usually, a white and black checkerboard pattern is used, but a checkerboard pattern of the other colour (red, green, blue and so on) and black can be used if necessary.



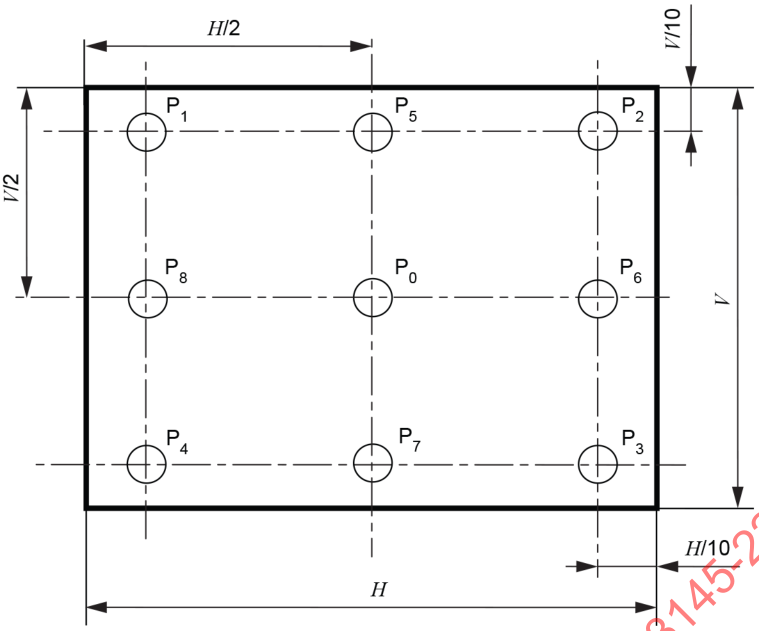
NOTE The 5 x 5 checkerboard pattern is helpful in navigating across the virtual image and focusing the LMD.

Figure 5 – Example of 5 x 5 checkerboard pattern

5.4 Measuring points

The centre point (one point) or the multi-point (five points or nine points) measurements shall be applied, which are provided by the manufacturer or the supplier. The measuring point(s) of one-point, five-point and nine-point measurements are: P_0, P_0 to P_4, and P_0 to P_8, respectively, as shown in Figure 6. When using other measuring points, the manufacturer or the supplier should point out these positions. The applied measuring points are defined in each measuring item. If other measuring points are applied, this shall be defined in the relevant specification.

NOTE The centre-point measurement is carried out to measure the typical characteristics of the DUT. The five-point and nine-point measurements are carried out to measure the deviations, averages and uniformities.



H: Horizontal size of virtual image
V: Vertical size of virtual image

Figure 6 – Measuring points for the centre- and multi-point measurements

6 Measurement methods

6.1 Spectral directional transmittance

6.1.1 General

The purpose of this method is to measure the spectral directional transmittance of the DUT when the DUT is off. This method is based on CIE 015:2004 [10], 5.3.1, except for the illuminating source and LMD directions (not always normal to the DUT, and aligned with the optical axis of the DUT). Both the illuminating source and LMD are directional, not diffuse, and the direction of both optical axes are the same. The directional LMD imitates a human eye. If the measured result is low, it means that the DUT is diffusing (scattering) or absorbing. In case the transmittance can be switched by the electronic dimming device [11], it shall be measured in each mode. In addition, it is important to measure the switch speed itself (see Annex B).

6.1.2 Conditions

6.1.2.1 Apparatus

The following apparatus shall be used:

1) measurement system: standard measurement system;
2) illuminating source for testing: for a spectrometer, a spectrally smooth bandwidth light source in a visual range such as a halogen lamp equipped with an integrating sphere or a reference display device.

The purpose of the reference display device is to be used as the illuminating source in front of the DUT. If the reference display device is applied, the polarization dependency shall be checked. If the reference display uses a backlight, it should not have sharp spectral features (as in some CCFLs).

NOTE In order to check the polarization of the reference display, a polarizer film can be applied. For example, a linear polarizer film and a circular polarizer film can be rotated in front of the reference display, and luminance change will be checked.

6.1.2.2 Setup

In addition to the standard measurement system, the following setup shall be applied (see also Figure 7):

1) illuminating source position: in front of the DUT;
2) illuminating source direction, distance and size: the illuminating source is set so that the direction is aligned with the optical axis of the DUT which is decided by the manufacturer or supplier. The distance is set so that the illuminating source aperture subtends a half angle of not more than 3° around the DUT optical axis. If the size is larger, a black cover with an aperture can be applied. The distance is also longer than 20 times the focal length of the imaging lens of the LMD;

NOTE If there are optical components which generate diffraction of transmitted light within the measurement field angle of the illuminating source, it can cause a measurement error.

3) LMD focus: the LMD should be focused at the same focal distance as the DUT virtual image;
4) measuring point P_0: place the illuminating source at the LMD focal distance, and ensure that the LMD measurement field is smaller than the size of the illuminating source.

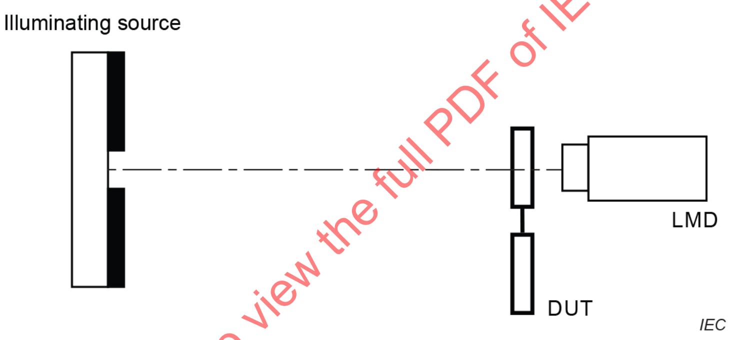


Figure 7 – Setup of transmittance measurement

6.1.3 Procedure

The following measurement procedure shall be applied for single- or multi-point measurements:

1) the DUT is turned on for alignment, then the LMD focus is set on the displayed image, and the DUT is turned off for the transmittance measurement. While the DUT is in the off mode, measure the spectral radiance $L_{v,0}(\lambda)$;
2) remove the DUT, and, maintaining the position of the illuminating source and LMD, measure the spectral radiance of the illuminating source, $L_{v,ill}(\lambda)$;
3) repeat for the other ocular, if applicable.

6.1.4 Calculation

Calculate the transmittance, $T_{0/0}$, as follows:

$$T_{0/0} = k \cdot \int_{\lambda_1}^{\lambda_2} \frac{L_{v,0}(\lambda)}{L_{v,ill}(\lambda)} \cdot V(\lambda) \cdot D_{65}(\lambda) \cdot d\lambda \quad (1)$$

$$k = \frac{100}{\int_{\lambda_1}^{\lambda_2} V(\lambda) \cdot D_{65}(\lambda) \cdot d\lambda} \qquad (2)$$

where

$V(\lambda)$ is the CIE standard photometric observer for photopic vision;

$D_{65}(\lambda)$ is the CIE Standard Illuminant D65;

λ_1 is the lower wavelength of the visible spectrum range;

λ_2 is the upper wavelength of the visible spectrum range.

6.1.5 Report

The following items shall be reported:

– transmittance, $T_{0/0}$, and spectral radiance, $L_{\mathrm{v,0}}(\lambda)$, $L_{\mathrm{v,ill}}(\lambda)$;
– detailed information of the illuminating source;
– setup details, including LMD and aperture size, eye point and DUT optical axis.

6.2 Colour difference

6.2.1 General

The purpose of this method is to measure the colour difference caused by the DUT when the DUT is off. This method is based on 6.1.

6.2.2 Conditions

6.2.2.1 Apparatus

The following apparatus shall be used.

1) measurement system: standard measurement system;
2) illuminating source: for a spectrometer, a spectrally smooth bandwidth light source in a visual range such as a halogen lamp equipped with an integrating sphere; for a filter-type LMD, a uniform flat light source similar to CIE Standard Illuminant D65, or a reference display device.

The purpose of the reference display device is to be used as the illuminating source in front of the DUT.

6.2.2.2 Setup

In addition to the standard measurement system, the following setup shall be applied:

1) illuminating source position: in front of the DUT;
2) illuminating source direction, distance and size: the illuminating source is set so that the direction is aligned with the optical axis of the DUT which is decided by the manufacturer or supplier. The distance is decided so that the size is less than 3° of the optical axis of the DUT. If the size is larger, a black cover with an aperture can be applied;
3) LMD type: spectrometer or colourimeter (filter type);
4) LMD focus: displayed image on the DUT;
5) measuring point P_0: ensure that the position of the LMD measurement field corresponds to the illuminating source position, and that the size of the LMD measurement field is smaller than that of the illuminating source.

6.2.3 Procedure

The following measurement procedure shall be applied:

1) turn off the DUT, and measure the spectral radiance, $L_{v,0}(\lambda)$, or the CIE 1931 chromaticity coordinates, (x_0, y_0);
2) remove the DUT, and, maintaining the position of the illuminating source and LMD, measure the spectral radiance, $L_{v,ill}(\lambda)$, or the CIE 1931 chromaticity coordinates, (x_{ill}, y_{ill});
3) repeat for the other ocular, if applicable.

6.2.4 Calculation

The following calculation shall be applied:

1) in case a spectrometer is used, calculate the CIE 1931 chromaticity coordinates, (x_0, y_0) and (x_{ill}, y_{ill}), from the spectral radiance using the following formulae:

$$X_0 = k \cdot \int_{\lambda_1}^{\lambda_2} \frac{L_{v,0}(\lambda)}{L_{v,ill}(\lambda)} \cdot \bar{x}(\lambda) \cdot D_{65}(\lambda) \cdot d\lambda$$
$$Y_0 = k \cdot \int_{\lambda_1}^{\lambda_2} \frac{L_{v,0}(\lambda)}{L_{v,ill}(\lambda)} \cdot \bar{y}(\lambda) \cdot D_{65}(\lambda) \cdot d\lambda \qquad (3)$$
$$Z_0 = k \cdot \int_{\lambda_1}^{\lambda_2} \frac{L_{v,0}(\lambda)}{L_{v,ill}(\lambda)} \cdot \bar{z}(\lambda) \cdot D_{65}(\lambda) \cdot d\lambda$$

$$X_{ill} = k \cdot \int_{\lambda_1}^{\lambda_2} \bar{x}(\lambda) \cdot D_{65}(\lambda) \cdot d\lambda$$
$$Y_{ill} = k \cdot \int_{\lambda_1}^{\lambda_2} \bar{y}(\lambda) \cdot D_{65}(\lambda) \cdot d\lambda \qquad (4)$$
$$Z_{ill} = k \cdot \int_{\lambda_1}^{\lambda_2} \bar{z}(\lambda) \cdot D_{65}(\lambda) \cdot d\lambda$$

$$x = \frac{X}{X+Y+Z}, \quad y = \frac{Y}{X+Y+Z} \qquad (5)$$

2) calculate u', and v' of the CIE 1976 chromaticity coordinates from the CIE 1931 chromaticity coordinates using the following formula (see ISO/CIE 11664-5):

$$u' = \frac{4x}{3 - 2x + 12y}$$
$$v' = \frac{9y}{3 - 2x + 12y} \qquad (6)$$

3) calculate the colour difference, $\Delta u'v'_{0/0}$ using the following formula:

$$\Delta u'v'_{0/0} = \sqrt{(u'_0 - u'_{ill})^2 + (v'_0 - v'_{ill})^2} \qquad (7)$$

6.2.5 Report

The following items shall be reported:

– colour difference, $\Delta u'v'_{0/0}$, and chromaticity coordinates, (x_0, y_0), (x_{ill}, y_{ill});

– detailed information of the illuminating source;
– setup details, including LMD and aperture size, eye point and DUT optical axis.

6.3 Front side stray light

6.3.1 General

The purpose of this method is to measure the front side stray light (also called haze) of the DUT, under hemispherical illumination, with the DUT turned off. This method is based on CIE 015:2004 [10], 5.3.3, except for the LMD directions (not always normal to the DUT and aligned with the optical axis of the DUT). The illuminating source is diffuse, and the LMD is directional. If this measured result is high, it means that the DUT tends to be hazy, and that the user would observe more stray light from the front side of the DUT.

NOTE 1 This method is similar to IEC TR 62977-2-5:2018 [4], 5.2.

NOTE 2 See Annex C for the back side stray light.

6.3.2 Conditions

6.3.2.1 Apparatus

The following apparatus shall be used:

a) measurement system: standard measurement system;
b) illuminating source: integrating sphere with ports and a stabilized light source as follows:

The light source in the integrating sphere has a smooth broadband spectrum approximating the CIE Standard Illuminant D65, as specified in ISO 11664-2 [8]. The integrating sphere has a photopic optical detector which monitors the relative luminance level m inside the sphere. The monitor will 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 will be kept constant during measurements. The measurement conditions will be such that the DUT temperature does not increase while measurements are made.

NOTE The measured spectral characteristics are not same as those of the illuminating light source in the case of including the fluorescence from the illuminated material.

1) The total port area of the integrating sphere does not exceed 4,0 % of the internal area of the sphere. It is recommended that the diameter of the integrating sphere be 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 DUT at the sample port does not significantly change the spectral distribution of the light in the sphere, the monitor detector will be used to compensate for change in the sphere illuminance due to the presence of the DUT at the sample port.
2) As shown in Figure 8, the diameter of the sphere z_s, and the light trap port diameter d_{LT} will be sized such that the opening of the light trap port will subtend θ_{LT} = 8° from the centre of the sample port.

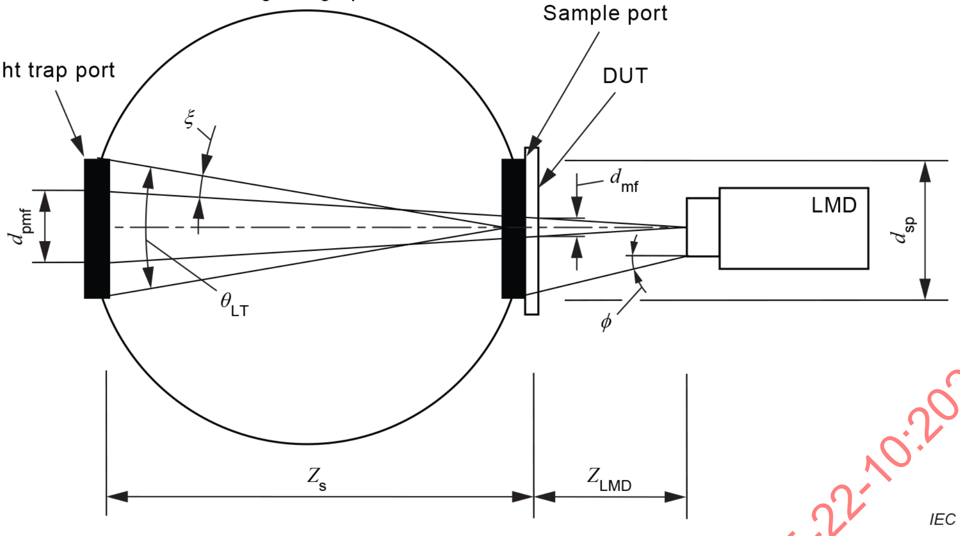


Figure 8 – Setup of haze measurement

6.3.2.2 Setup

In addition to the standard measurement system, the following setup shall be applied:

1) illuminating source position: in front of the DUT;
2) LMD and illuminating source setup:

   The LMD is positioned at a distance of z_{LMD} away from the sphere, which produces a measurement field of diameter d_{mf}, calculated using the following formula:

$$d_{mf} = z_{LMD} \cdot \frac{d_{pmf}}{z_{LMD} + z_s} \tag{8}$$

   where

   d_{pmf} is the projected measurement field diameter at the light trap port.

   The LMD and the integrating sphere are set up in such a way that the angular gap (annulus) between the measurement field of the diameter and the sample port diameter will give ξ = 1,3° as follows:

$$\zeta = \frac{\theta_{LT}}{2} - \tan^{-1}\frac{d_{pmf}}{2 \cdot (Z_s + Z_{LMD})} \tag{9}$$

   When the above requirements are satisfied, the maximum angle ϕ that any measured light ray can have relative to the optical axis of DUT is less than 3°;
3) LMD focus: displayed image on the DUT;
4) measuring point: P_0.

6.3.3 Procedure

The following measurement procedure shall be applied (see also Table 2):

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;
2) if the integrating sphere has a compensation port, place the DUT against that port so that it is aligned with the optical axis of the DUT which is decided by the manufacturer or supplier. The DUT is turned off;
3) measure the luminance, L_{v1}, and optionally record the monitor detector value m_1;

4) place the DUT 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_{v2}, through the DUT, and optionally 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_{v4}, through the DUT, and optionally record the monitor detector value m_4;
7) remove the DUT from the sample port. Measure the luminance, L_{v3}, and optionally record the monitor detector value m_3;
8) repeat for the other ocular, if applicable.

Table 2 – Measuring conditions

Measured luminance	Monitor detector value (optional)	Sample port	Light trap port	Compensation port
L_{v1}	m_1		White reference	Display sample
L_{v2}	m_2	DUT	White reference	Light trap
L_{v3}	m_3		Light trap	White reference
L_{v4}	m_4	DUT	Light trap	White reference

6.3.4 Calculation

Calculate the front side stray light, $H_{de/0}$, as follows:

$$H_{de/0} = \left(\frac{m_2}{m_4} \times \frac{L_{v4}}{L_{v2}} - \frac{m_1}{m_3} \times \frac{L_{v3}}{L_{v1}} \right) \times 100 \tag{10}$$

In case the monitor detector is not used, all m_i values are equal to 1.

6.3.5 Report

The following items shall be reported:

– front side stray light, $H_{de/0}$, each luminance, and monitor detector value;
– detailed information of illuminating source;
– setup details, including LMD and aperture size, eye point and DUT optical axis.

6.4 Contrast modulation

6.4.1 General

The purpose of this method is to measure the contrast modulation through the DUT when the DUT is off. If the measured value is less than 1, then the DUT reduces the viewer's visibility of objects. Contrast modulation represents the resolution of the virtual image.

NOTE This method is similar to IEC TR 62977-2-5:2018 [4], 5.4.

6.4.2 Conditions

6.4.2.1 Apparatus

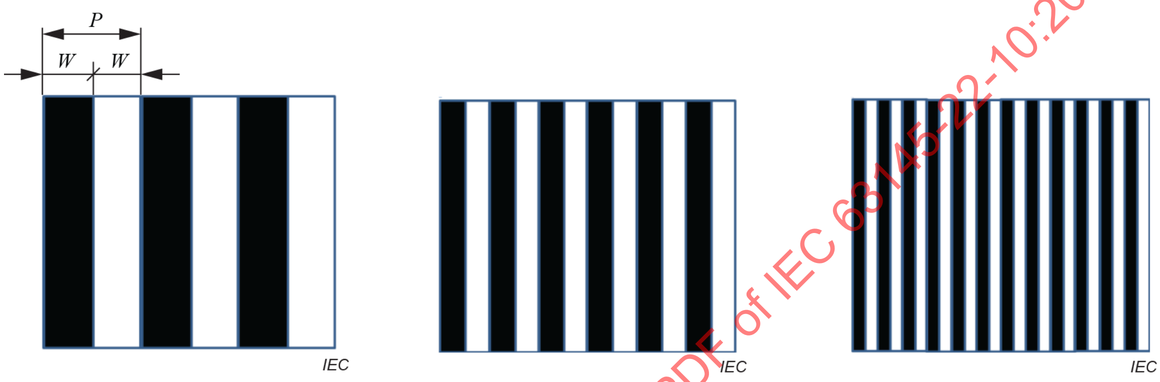
The following apparatus shall be used:

1) measurement system: standard measurement system;

2) reference object: reference object with a contrast modulation test pattern (i.e., printed pattern, or a reference display device showing a contrast modulation test pattern).

   The contrast modulation test pattern shall be black and white line-pairs with different periodicities. As shown in Figure 9, at least three different pitches of the line-pairs, which are specified by the manufacturer or the supplier, should be prepared. The stripe direction of the contrast modulation test pattern shall be vertical, horizontal, and at ±45°. The inverse of the pitch of the line-pairs is the spatial frequency (f_{CPD} = 1/P). The CPD is line-pair cycles per degree, which are viewed through the DUT. If the reference display device is applied, the polarization dependency shall be checked;

NOTE The pitches required for this test depend on the DUT and its context of use, and they are specified by the manufacturer or the supplier. However, if there is no information, some factors can be considered, for example human visual acuity (the width of one arc minute (high resolution) corresponds to the visual acuity scales of 20/20 in the foot system or 1,0 in the decimal system).



a) **Low resolution** b) **Middle resolution** c) **High resolution**

P: Pitch of the line-pair

W: Line width

Figure 9 – Example of contrast modulation test pattern

3) LMD: an imaging LMD shall be used.

   The imaging LMD shall have at least a four times higher resolution than the spatial frequency of the line-pairs.

6.4.2.2 Setup

In addition to the standard measurement system, the following setup shall be applied (see also Figure 10):

1) reference object: the reference object is set in front of the DUT, so that the direction is aligned with the optical axis of the DUT, which is decided by the manufacturer or supplier. The distance is decided so that the size is less than 3° of the optical axis of the DUT. If the size is larger, a black cover with an aperture can be applied;
2) LMD focus: reference object; the manufacturer or the supplier should specify the distance of the reference object from the LMD;

   NOTE The viewers will likely adjust their focus to the virtual image distance when the DUT is in use.

3) measuring point P_0: ensure that the position of the LMD measurement field corresponds to the illuminating source position.

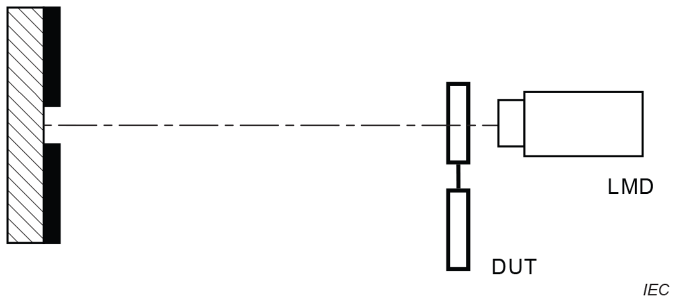


Figure 10 – Setup of contrast modulation measurement

6.4.3 Procedure

The following measurement procedures shall be applied for single- or multi-point measurements:

1) turn off the DUT;
2) obtain the maximum luminance L_{vM} and the minimum luminance L_{vm} of the reference object;
3) repeat 2) for different spatial frequency or stripe directions of the test pattern;
4) repeat for the other ocular, if applicable.

6.4.4 Calculation

Calculate the contrast modulation, C_{CM}, as follows:

$$C_{CM} = \frac{L_M - L_m}{L_M + L_m} \tag{11}$$

6.4.5 Report

The following items shall be reported:

– contrast modulation, C_{CM}, and luminance, L_{vM}, L_{vm};
– detailed information of the reference object;
– setup details, including LMD and aperture size, eye point and DUT optical axis.