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INTERNATIONAL STANDARD

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colour inside

Electronic paper displays –
Part 3-1: Optical measuring methods

Afficheurs de papier électroniques –
Partie 3-1: Méthodes de mesures optiques

IEC 62679-3-1:2014-04(en-fr)

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The text of this standard is based on the following documents:

FDIS	Report on voting
110/548/FDIS	110/561/RVD

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

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

A list of all parts in the IEC 62679 series, published under the general title *Electronic paper displays*, can be found on the IEC website.

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ELECTRONIC PAPER DISPLAYS –

Part 3-1: Optical measuring methods

1 Scope

This part of IEC 62679 specifies the standard measurement conditions and measurement methods for determining the optical performance of Electronic Paper Display (EPDs). The scope of this document is restricted to EPDs using either segment, passive, or active matrix with either monochromatic or colour type displays. The measuring methods are intended for EPDs operated in a reflective mode. The EPDs may include an integrated lighting unit (ILU), but the ILU will be turned off for these measuring methods. Colour systems beyond three primaries are not covered in this document.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at www.electropedia.org)

IEC 62679-1-1[1], *Electronic paper displays – Part 1-1: Terminology*

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

CIE 15, *Colorimetry*

CIE 38, *Radiometric and Photometric Characteristics of Materials and their Measurement*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62679-1-1, IEC 60050, as well as the following apply.

3.1.1
ambient contrast ratio
contrast ratio of a display with both hemispherical diffuse and directional illumination incident onto its surface used to simulate real lighting environments

3.1.2
daylight display colour
colour of a display with both hemispherical diffuse and directional illumination incident onto its surface at a defined geometry, spectra, and illumination levels that simulate a realistic daylight lighting environment

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1 To be published.

3.1.3
colour gamut volume
single number corresponding to the largest possible range of display colours (including all possible mixtures of the primaries, white W and black K), described as a volume in a three-dimensional colour space such as CIELAB

3.1.4
daylight colour gamut volume
colour gamut volume of a display with both hemispherical diffuse and directional illumination incident onto its surface at a defined geometry, spectra, and illumination levels that simulate a realistic daylight lighting environment

3.2 Abbreviations

CCT	correlated colour temperature
CIE	International Commission on Illumination
CIELAB	CIE 1976 (L*a*b*) colour space
DUT	device under test
EPD	electronic paper display
ILU	integrated lighting unit (e.g. an edge-lit front guide plate)
ISO	International Organization for Standardization
LED	light emitting diode
LMD	light measuring device
RGB	red, green, blue
SDCM	standard deviation of colour matching
sRGB	a standard RGB colour space as defined in IEC 61966-2-1

4 Standard measuring conditions

4.1 Standard measuring environmental conditions

Optical and electro-optical measurements shall be carried out under the standard environmental conditions, at a temperature of 25 °C ± 3 °C, a relative humidity of 25 % to 85 %, and a pressure of 86 kPa to 106 kPa. When different environmental conditions are used, they shall be noted in the report.

4.2 Viewing direction coordinate system

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

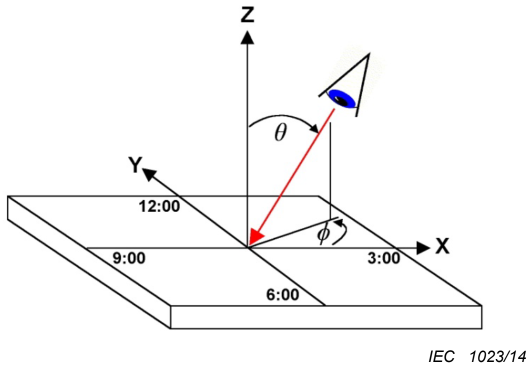

Figure 1 – Representation of the viewing direction, or direction of measurement, defined by the angle of inclination, and the angle of rotation (azimuth angle) in a polar coordinate system

4.3 Standard lighting conditions

4.3.1 General comments and remarks on the measurement of electronic paper displays

This document treats electronic paper displays (EPDs) as reflective displays. A reflective information display is a display that modulates the reflected light so that the information is carried by the reflected light. Reflective displays do not emit any light so that ambient light is required to view that information. Therefore it is critical that measurement specifications on reflective displays include the illumination conditions during measurement. The measurement illumination consists of one or more light sources, each of whose spectral distribution and illumination geometry have to be specified. Thus, display performance measurements shall be carried out under specific and well defined conditions of illumination and detection in order to be reproducible.

ILUs are integrated into an EPD to provide supplemental illumination to compensate for the lack of adequate ambient illumination. The measuring methods in this document are performed with the ILU turned off.

Subclause 4.3 describes a selection of standard lighting conditions for measuring the performance metrics of the EPD. The EPD may also be measured under other illumination and detection geometries in addition to the standard geometries.

A warm-up time may be necessary. The light source signal shall remain stable to within ±5 % over the course of the complete measurement.

4.3.2 Dark-room conditions

The EPD is intended to be measured under controlled lighting conditions. Unwanted background illumination shall be minimized, typically by illuminating the display in a darkroom. The darkroom spectral radiance contribution from the background illumination, that is the measured spectral radiance reflected off the DUT, shall be not more than $1/100^{th}$ of the spectral radiance from the device black state with the illumination source on. If this condition is not satisfied, then background subtraction is required and it shall be noted in the report. In addition, if the sensitivity of the LMD is inadequate to measure at these low levels, then the lower limit of the LMD shall be noted in the report.

Unless stated otherwise, the standard background lighting conditions shall be the dark-room conditions.

4.3.3 Standard ambient illumination spectra

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

The following illumination conditions shall be used to simulate indoor and outdoor display viewing environments:

- Indoor room illumination conditions:

  Uniform hemispherical diffuse illumination – Use a light source closely approximating CIE Standard Illuminant A, CIE Standard Illuminant D65, or CIE Standard Illuminant D50 as defined in CIE 15. For spectral measurements, a spectrally smooth broadband light source (such as an approximation to CIE Standard Illuminant A) shall be used. A measurement of the spectral reflectance factor using a broad light source (such as Illuminant A) enables the indoor photopic and colour metrics to be calculated later for the desired reference spectra (for example CIE D65 Illuminant). The performance metrics shall be calculated using 300 lx for an indoor reading environment.[3] The actual hemispherical diffuse reflectance factor measurement may require higher illumination levels for better measurement accuracy. The results are then scaled down to the required illumination levels.

  Directional illumination – The same source spectra shall be used as with hemispherical diffuse illumination. The indoor room photopic and colour metrics shall be calculated using directional illumination of 200 lx incident on the display surface for an indoor reading environment with the display in the vertical orientation. The actual reflectance factor measurement may require higher illumination levels for better measurement accuracy. The results are then scaled down to the required illumination levels. The directed source shall be 45° above the surface normal (θ_s = 45°) and have an angular subtense of no more than 5°. The angular subtense is defined as the full angle span of the light source from the centre of the display's measurement area.

  Other illumination levels may be used in addition to those defined above for calculating the ambient contrast ratio under indoor illumination conditions. However, approximately 60 % of the total illuminance should be hemispherical diffuse, and 40 % directional illumination.

- Daylight illumination conditions:

  Uniform hemispherical diffuse illumination – Use a light source closely approximating skylight with the spectral distribution of CIE Illuminant D75.[4] Additional CIE daylight illuminants (such as D65) may also be used, depending on the intended application. For spectral measurements, the spectral reflectance factor measurements can be made using a spectrally smooth broadband source (such as an approximation to CIE Standard Illuminant A). Skylight photopic and colour metrics can be calculated later for the CIE D75 Illuminant spectra. The skylight photopic and colour metrics shall be calculated using 15 000 lx of hemispherical diffuse illumination (with specular included) incident on a display surface in a vertical orientation.[4,5] The actual hemispherical diffuse reflectance factor measurement may be taken at lower illumination levels. The results are then scaled up to the required illumination levels.

  Directional illumination – The directional light source shall approximate CIE daylight Illuminant D50.[4] Additional CIE daylight illuminants (such as D65) may also be used, depending on the intended application. A spectrally smooth broadband source (such as an approximation to CIE Standard Illuminant A) may be used for the reflectance factor measurement. The sunlight photopic and colour metrics can be calculated later with the

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2 Numbers in square brackets refer to the Bibliography.

D50 Illuminant spectra. The daylight contrast ratio or colour shall be calculated using 65 000 lx for a directed source at an inclination angle of θ_s = 45° to the display surface, and the LMD shall be aligned normal to the display surface (θ_d = 0°).[4,5] The actual reflectance factor measurement may be taken at lower illumination levels. The results are then scaled up to the required illumination levels. The contrast ratio and colour are calculated for the scaled-up illuminance levels. The directed source shall have an angular subtense of approximately 0,5°.

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

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

4.3.4 Standard illumination geometries

4.3.4.1 General

Three types of illumination geometries shall be used for determining the performance of the EPD. Standard configurations for implementing these illumination geometries are defined in 4.3.4. Additional illumination geometries may also be used. The details of the illumination geometry used for a given measurement shall be reported. Further guidance on the proper implementation of these illumination geometries is given in the SID display measurement standard. [1]

4.3.4.2 Directional illumination

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

$$\arctan\left([r_{ms} + r_s] / |d|\right) < 5° \quad (1)$$

where r_s is the source radius, d is the distance to the measuring spot, and r_{ms} is the measuring spot radius. The illumination across the cross-section of the beam shall be uniform to within 5 %. A source of light sufficiently distant from the DUT can provide directional illumination (e.g. sun and moon). When simulating outdoor directional ambient illumination like the sun and moon, the subtense of the source (as observed by the DUT) should be ≤ 0,5°.

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

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

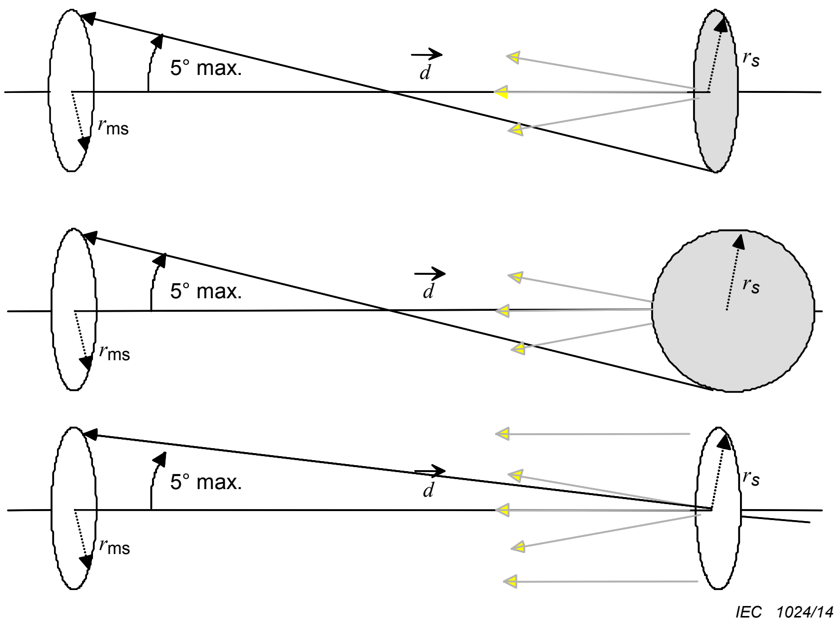

Figure 2 – Illustrated examples for directional illumination

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

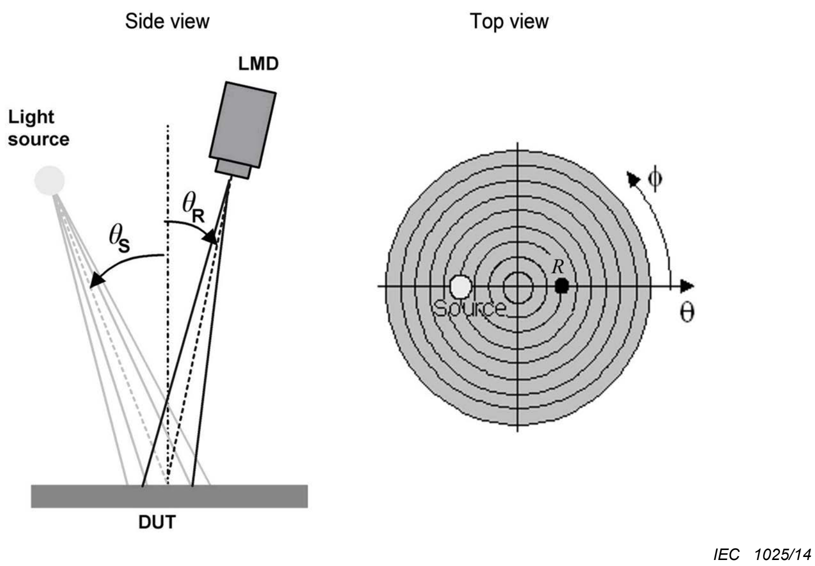

Figure 3 – Example of the measuring setup using directional illumination where θ_S = 40° and θ_R = 30°

The standard conditions are θ_S = 45° and θ_R = 0°. Alignment accuracy to within ± 0,4° is recommended to keep measurement error within ± 5 %.

4.3.4.3 Ring light illumination

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

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

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

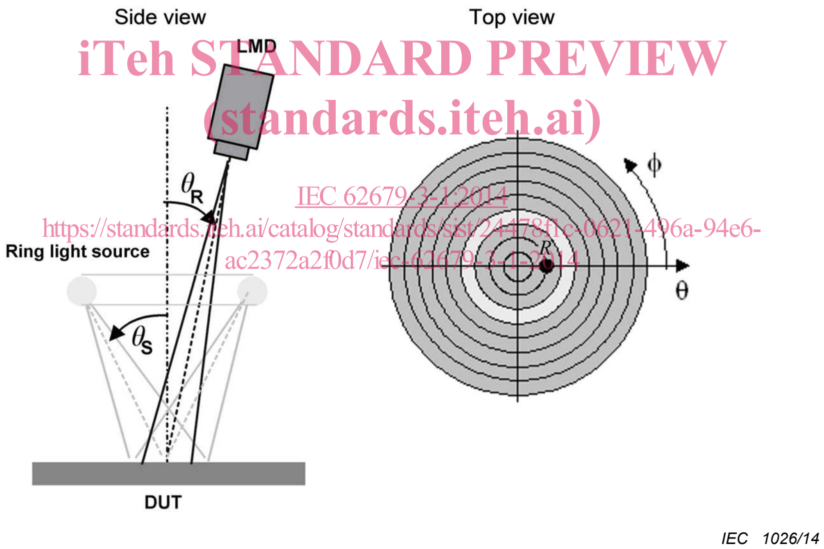

Figure 4 – Example of the ring light illumination measuring setup where $\theta_S \pm \Delta = 35° \pm 5°$ and $\theta_R = 20°$

The ring light and LMD are recommended to have an alignment accuracy of ± 0,7° in order to keep the measurement error within ± 5 %. When simulating outdoor directional ambient illumination using the ring light, the subtense 2Δ of the source (as observed by the DUT) should be ≤ 0,5°. A fiber-optic ring light is recommended in this case.