



Edition 1.0 2014-04

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE



Electronic paper displays TANDARD PREVIEW Part 3-1: Optical measuring methods (standards.iteh.ai)

Afficheurs de papier électroniques – Partie 3-1: Méthodes de mesures optiques ac2372a2f0d7/iec-62679-3-1-2014





## THIS PUBLICATION IS COPYRIGHT PROTECTED Copyright © 2014 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office	Tel.: +41 22 919 02 11
3, rue de Varembé	Fax: +41 22 919 03 00
CH-1211 Geneva 20	info@iec.ch
Switzerland	www.iec.ch

#### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

#### IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on TEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

## IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a79variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications. ac2372a210d7/iec-

#### IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

#### Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 14 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

## IEC Glossary - std.iec.ch/glossary

More than 55 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

#### IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

### A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

## Catalogue IEC - webstore.iec.ch/catalogue

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

#### Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

#### IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

### Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 14 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

## Glossaire IEC - std.iec.ch/glossary

Plus de 55 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

#### Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.





Edition 1.0 2014-04

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE



Electronic paper displays TANDARD PREVIEW Part 3-1: Optical measuring methods rds.iteh.ai)

Afficheurs de papier électroniqu<u>es</u> <u>62679-3-1:2014</u> Partie 3-1: Méthodes de mesures optiques ist/24478f1c-0621-496a-94e6ac2372a2f0d7/iec-62679-3-1-2014

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE



ICS 31.120; 31.260

ISBN 978-2-8322-1515-9

Warning! Make sure that you obtained this publication from an authorized distributor. Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

 Registered trademark of the International Electrotechnical Commission Marque déposée de la Commission Electrotechnique Internationale

## CONTENTS

FOF	REWORD	)		5
1	Scope			7
2	Normati	ve referenc	es	7
3	Terms, o	definitions a	and abbreviations	7
	3.1	Terms and	definitions	7
	3.2	Abbreviati	ons	8
4	Standar	d measurin	a conditions	8
	4 1	Standard r	measuring environmental conditions	8
	4.2	Viewing di	rection coordinate system	8
	4.3	Standard I	ighting conditions	9
		4.3.1	General comments and remarks on the measurement of	
			electronic paper displays	9
		4.3.2	Dark-room conditions	9
		4.3.3	Standard ambient illumination spectra	10
		4.3.4	Standard illumination geometries	11
	4.4	Standard of	conditions of measuring equipment	16
		4.4.1	General	16
		4.4.2	Adjustment of EPD	16
		4.4.3	Conditions of measuring equipment.	16
		4.4.4	Contact measurements with integrated illumination/detection instruments	17
	4.5	Working st	tandards and references	18
		4.5.1 https://	, Diffuse reflectance standard	18
		4.5.2 <sup>maps//</sup>	Specular reflectance standard 1-2014	18
	4.6	Standard I	ocations of measurement field	19
		4.6.1	Matrix displays	19
		4.6.2	Segment displays	19
5	Optical i	measuring	methods	20
	5.1	Reflection	measurements	20
		5.1.1	Purpose	20
		5.1.2	Measuring conditions	20
		5.1.3	Measuring the hemispherical diffuse spectral reflectance factor	20
		5.1.4	Measuring the reflectance factor for a directed light source	22
	5.2	Display ph	otometric in-plane uniformity	23
		5.2.1	Purpose	23
		5.2.2	Measuring equipment	23
		5.2.3	Measurement method	23
		5.2.4	Definitions and evaluations	24
	5.3	Contrast ra	atio	24
		5.3.1	Purpose	24
		5.3.2	Measuring equipment	24
		5.3.3	Measurement method	24
		5.3.4	Definitions and evaluations	25
	5.4	Ambient co	ontrast ratio	25
		5.4.1	Purpose	25
		5.4.2	Measuring conditions	25

	2	
_	.5	-

	5.4.3	Measuring method	25
5.5	Cross-ta	lk	26
	5.5.1	Purpose	26
	5.5.2	Measuring equipment	26
	5.5.3	Greyscale matrix displays	26
	5.5.4	Black and white (two-level) matrix displays	
5.6	Display of	colour, colour gamut, and colour gamut area	
	5.6.1	Purpose	
	5.6.2	Measuring equipment	28
	5.6.3	Measurement method	29
	5.6.4	Definitions and evaluations	29
	5.6.5	Display colour gamut	
	5.6.6	Display colour gamut area	
5.7	Display of	colorimetric in-plane uniformity	
	5.7.1	Purpose	
	5.7.2	Measuring equipment	
	5.7.3	Measurement method	
	5.7.4	Definitions and evaluations	
5.8	Daylight	display colour	
	5.8.1	Purpose	
	5.8.2	Measuring conditions, R.D., P.R.F.V.F.W.	
	5.8.3	Measuring method	
5.9	Daylight	colour gamut volume	
	5.9.1	Purpose	35
	5.9.2	<u>IFC 62679-3-1:2014</u> Measuring conditions	
	5.9.3	Measuring/method/7/ees/62679-3-1-2014	35
	5.9.4	Reporting	
5.10	Viewing	direction dependence	
	5.10.1	Purpose	
	5.10.2	Measuring conditions	
	5.10.3	Measuring method	
	5.10.4	Definitions and evaluations	
5.11	Ghosting	]	41
	5.11.1	Purpose	41
	5.11.2	Measuring equipment	41
	5.11.3	Measuring method	41
	5.11.4	Definitions and evaluations	42
Annex A (in	formative)	Calculation method of daylight colour gamut volume	43
A.1	Purpose		
A.2	2 Procedure for calculating the colour gamut volume		
A.3	Surface	subdivision method for CIELAB gamut volume calculation	
	A.3.1	Purpose	
	A.3.2	Assumptions	
	A.3.3	Algorithm	
	A 3 4	Software example	45
Bibliograph	V		
<b>U</b> 1	-		

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	9
Figure 2 – Illustrated examples for directional illumination	12
Figure 3 – Example of the measuring setup using directional illumination where $\theta_{\rm S}$ = 40° and $\theta_{\rm R}$ = 30°	12
Figure 4 – Example of the ring light illumination measuring setup where $\theta_S \pm \Delta = 35^{\circ} \pm 5^{\circ}$ and $\theta_R = 20^{\circ}$	13
Figure 5 – Detailed schematic of ring light characteristics	14
Figure 6 – Example of measurement geometries for hemispherical illumination using an integrating sphere (left) and sampling sphere (right)	15
Figure 7 – Layout diagram of measurement setup	17
Figure 8 – Standard measurement positions	19
Figure 9 – Window pattern for cross-talk measurement	27
Figure 10 – Example of display colour gamut	30
Figure 11 – Example of evaluation results for the colour gamut area on the $a*b*$ plane of the CIELAB colour space	32
Figure 12 – An example of range in colours produced by a given display as represented by the CIELAB colour space	36
Figure 13 – Illumination/detection geometry for measuring, the viewing direction properties of the display.	38
Figure 14 – Example of contrast ratio dependence on viewing direction	40
Figure 15 – Display pattern used to characterize ghosting.	42
Figure A.1 – Analysis flow chart for calculating the colour gamut volume	43
Figure A.2 – Graphical representation of the colour gamut volume for sRGB in the CIELAB colour space	44
Table 1 – Eigenvalues $M_1$ and $M_2$ for CIE daylight Illuminants D50 and D75	21
Table 2 – Input signals for CIELAB and CIE UCS <i>u</i> 'v' colour gamut area	
measurements	31
Table 3 – Example data of in-plane colour non-uniformity	33
primary 8-bit display	35
Table 5 – Measured tristimulus values for the minimum set of colours (see Table 4) required for gamut volume calculation under the specified daylight illumination	27
Table 6 Colour genut volume in the CIELAR colour appea	، د حد
Table 7 Example format used for reporting viewing direction performance	/د ۱۸
Table $\Lambda = \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{j=1$	۱ +۰۰۰. ۸ ۸
Table A.1 – The initial values of the SKGD primary colours	44
Table A.2 – Example of sRGB colour set represented in the CIELAB colour space	44
Table A.S – Example of SKGB colour gamut volume in the CIELAB colour space	45

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## ELECTRONIC PAPER DISPLAYS -

## Part 3-1: Optical measuring methods

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, <u>access to HEC marks</u> of conformity. IEC is not responsible for any services carried out by independent certification bodies ds/sist/24478f1c-0621-496a-94e6-
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard 62679-3-1 has been prepared by IEC technical committee 110: Electronic display devices.

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.

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

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

## iTeh STANDARD PREVIEW (standards.iteh.ai)

<u>IEC 62679-3-1:2014</u> https://standards.iteh.ai/catalog/standards/sist/24478flc-0621-496a-94e6ac2372a2f0d7/iec-62679-3-1-2014

## 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.

#### Normative references 2

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 iTeh STANDARD PREVIEW

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

ac2372a2f0d7/iec-62679-3-1-2014

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

<sup>&</sup>lt;sup>1</sup> 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 threedimensional 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 TANDARD PREVIEW
- RGB red, green, blue (standards.iteh.ai)
- SDCM standard deviation of colour matching

sRGB a standard RGB colour space as defined in the constraint of the standards.iteh.ai/catalog/standards/sist/24478flc-0621-496a-94e6-

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  $\pm$  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  $\theta$ (relative to the surface normal of the DUT) and the angle of rotation  $\phi$  (also called azimuth angle) as illustrated in Figure 1. Although the azimuth angle is measured in the counterclockwise direction, it is related to the directions on a clock face as follows:  $\phi = 0^{\circ}$  is the 3o'clock direction ("right"),  $\phi = 90^{\circ}$  the 12-o'clock direction ("top"),  $\phi = 180^{\circ}$  the 9-o'clock direction ("left") and  $\phi = 270^{\circ}$  the 6-o'clock direction ("bottom").



# 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  $\pm 5$  % 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<sup>th</sup> 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]<sup>2</sup> 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 ( $\theta_s = 45^\circ$ ) and have an angular subtense of no more than 5°. The angular subtense is defined as the full angle span of the light source from the centre of the display's measurement area.

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

• 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

<sup>&</sup>lt;sup>2</sup> 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  $\theta_s = 45^\circ$  to the display surface, and the LMD shall be aligned normal to the display surface ( $\theta_d = 0^\circ$ ).[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] (standards.iteh.ai)

## 4.3.4.2 Directional illumination IEC 62679-3-1:2014

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 
$$([r_{ms} + r_{s}] / |d|) < 5^{\circ}$$
 (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  $\leq 0.5^{\circ}$ .

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).



- 12 -

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  $\theta_S$  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  $\theta_R$  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 (ile:  $\theta_S = \theta_R + 180^\circ$ ). This configuration is shown in Figure 3 (left) with its representation in a polar coordinate system (right). The measurement field on the DUT is defined by the DUT area element that is imaged on the detector in the LMD.



Figure 3 – Example of the measuring setup using directional illumination where  $\theta_{\rm S}$  = 40° and  $\theta_{\rm R}$  = 30°

The standard conditions are  $\theta_S = 45^\circ$  and  $\theta_R = 0^\circ$ . Alignment accuracy to within  $\pm 0.4^\circ$  is recommended to keep measurement error within  $\pm 5\%$ .

## 4.3.4.3 Ring light illumination

Ring light illumination can be considered a special case of directional illumination. It provides directional illumination with rotational symmetry about the display's surface normal and 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  $\phi_S = 0^\circ$  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 ( $2\Delta$  in this case) shall be specified. The source and detector shall be aligned to the defined geometry to within  $\pm 3^\circ$ . The illumination of the measuring spot on the DUT shall be uniform within 5%. This setup is used with the light source fixed, and the LMD can be adjusted within the limits of the ring light opening. The standard conditions are  $\theta_R = 0^\circ$  and a source inclination angle of  $\theta_S \pm \Delta = 45^\circ \pm 3^\circ$ .



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

The ring light and LMD are recommended to have an alignment accuracy of  $\pm 0.7^{\circ}$  in order to keep the measurement error within  $\pm 5$  %. When simulating outdoor directional ambient illumination using the ring light, the subtense 2 $\varDelta$  of the source (as observed by the DUT) should be  $\leq 0.5^{\circ}$ . A fiber-optic ring light is recommended in this case.