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INTERNATIONAL STANDARD

colour inside

Flexible display devices –
Part 5-1: Measuring methods of optical performance

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FLEXIBLE DISPLAY DEVICES –

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FOREWORD

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

FDIS	Report on voting
110/859/FDIS	110/870/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 of the IEC 62715 series, published under the general title *Flexible display devices,* 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- withdrawn,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
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INTRODUCTION

This part of IEC 62715 was designed for the standardization of measuring methods and detailed setup conditions that are used to characterize the optical performance of flexible display devices.

The surface conditions and shape of flexible displays can change depending on the application. For example, a smart watch may have a fixed convex display, a cell phone or TV a fixed concave display, and a bendable display may have either a concave or convex shape with a variable radius of curvature. Up to now, all of these displays would usually be characterized in their flat state. However, since it is possible that mechanical stress induced by bending the display can change its optical characteristics, the display should be measured in its designed bent state. This ensures that the display's optical performance is representative of its intended application. This document specifies the necessary conditions and methods to measure the optical performance of a display in a bent state.

FLEXIBLE DISPLAY DEVICES –

Part 5-1: Measuring methods of optical performance

1 Scope

This part of IEC 62715 specifies the standard measuring conditions and measuring methods for determining the optical performance of flexible displays in the dark or under ambient illumination. This document mainly applies to display modules that are bendable about one axis. The display is measured in a static mechanical state. The measuring methods apply to monochrome or colour displays with a single radius of curvature of 35 mm or greater.

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 60050-845, *International Electrotechnical Vocabulary – Part 845: Lighting* (available at <http://www.electropedia.org>)

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

IEC 62715-1-1, *Flexible display devices – Part 1-1: Terminology and letter symbols*

IEC 62341-6-2:2015, *Organic light emitting diode (OLED) displays – Part 6-2: Measuring methods of visual quality and ambient performance*

IEC 62679-3-1:2014, *Electronic paper displays – Part 3-1: Optical measuring methods*

IEC TR 62728, *Display technologies – LCD, PDP and OLED – Overview and explanation of differences in terminology*

CIE 15:2004, *Colorimetry*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62715-1-1 and IEC TR 62728 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

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

3.2 Abbreviated terms

CCT correlated colour temperature

CIE Commission Internationale de l'Eclairage (International Commission on Illumination)

CIELAB CIE 1976 (L*a*b*) colour space

DUT device under test

ILU integrated lighting unit (e.g. a front light in a reflective display)

LMD light measuring device

PL photoluminescence

RGB red, green, blue

sRGB standard RGB colour space as defined in IEC 61966-2-1

4 Structure of measuring equipment

4.1 Measuring configuration – Display mounting

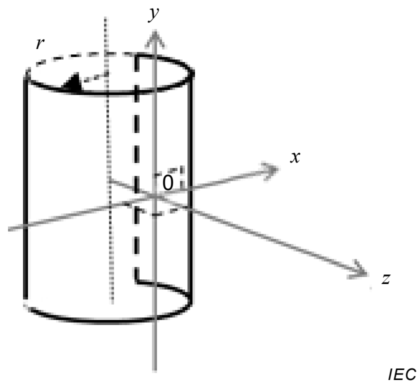
4.1.1 General

The fixture used to mount a curved display plays a critical role in obtaining accurate and reproducible results.[1,2][1] The display mount should be designed to accommodate the specific bendable, foldable and/or curved characteristics of the flexible display in its intended use configuration. The mount should be capable of maintaining the intended shape of the display and locate it in the required measurement position and viewing direction. For curved displays, these measuring methods only apply for displays that have a constant radius of curvature about a single axis (e.g. cylindrical shape). Figure 1 illustrates the coordinate system for a convex display that is curved about the y-axis. The origin of the coordinate system is positioned at the imaging surface of the display and centred on the screen. The same coordinate system applies for a concave display with the image rendering surface facing the positive z-axis.

For flat displays, the image rendering plane is aligned in the x-y plane. A foldable display that contains flat areas connected by a narrow region with a short radius of curvature shall be measured in the flat areas, and treated as a flat display.

Unless otherwise specified, the optical axis of the LMD shall be aligned to within 1° of the display surface normal at the centre of the measurement field in order to minimize the alignment error introduced by the display curvature. For spot type LMDs, the retro-reflection of the LMD can be used to obtain this alignment. Otherwise, an alignment laser can be used to ensure that the LMD optical axis passes through a curved display's centre of curvature. The methods also assume that the rotation stages and mechanical mounting have sufficient accuracy and stability to maintain a $<$ 1° tolerance for any rotational or tilt motions.

1 Numbers in square brackets refer to the Bibliography.

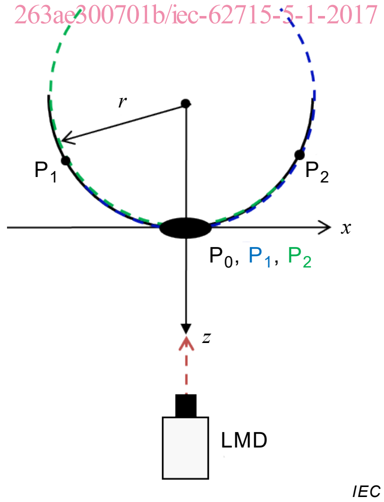


NOTE The origin is centred on the screen which is curved with a constant radius r at the surface of the imaging plane.

Figure 1 – Example of the coordinate system used for a convex display of a constant radius of curvature about the y-axis

4.1.2 Display mounting for uniformity measurements

For flat displays, the display uniformity is generally measured by translating the LMD parallel to the screen and measuring the display characteristics at different screen locations. However, for convex or concave displays, the display mounting shall allow the display to be rotated about its centre of curvature while ensuring that the imaging plane always passes through the y-axis at the origin. This is illustrated in Figure 2 for the case of a convex display. The same motion shall be used for concave displays. Figure 2 illustrates how lateral locations P_0, P_1, and P_2 can be rotated into the LMD measurement field. This display rotation allows the display uniformity to be measured at a constant viewing direction. Alternatively, the LMD can be mounted on a goniometer that rotates about the display's centre of curvature.

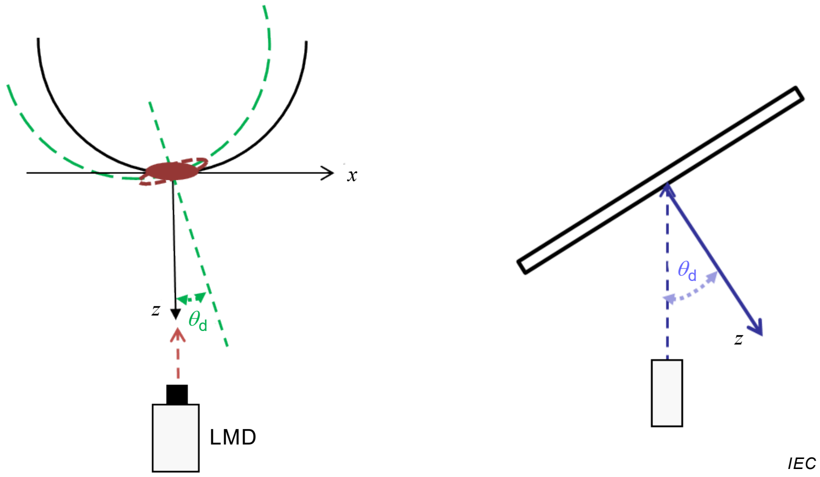


NOTE Figure 2 shows how a convex display which is curved with a constant radius r can be rotated about its centre of curvature to align different display locations in the x-z plane within the measurement field.

Figure 2 – Top view example of how a convex display can be rotated within the measurement field

4.1.3 Display mounting for viewing direction measurements

Viewing direction measurements on curved displays require the exact alignment of the LMD and the display.[1] The centre of the LMD measurement field is usually aligned perpendicular to the display surface. Alignment accuracy to within ±1° is recommended in order to minimize the alignment error introduced by the display curvature. It should be the same with the flat conditions. For the coordinate system defined in Figure 1, the LMD optical axis would pass through a curved display's centre of curvature. When measuring the viewing dependence of a curved display, the display mount would need to rotate about a point on the display surface at the centre of the measurement field in the x-z plane (as shown in Figure 3), or rotate in the y-z plane. The same motion would be required for a flat display. Alternatively, the LMD can be mounted on a goniometer that rotates about the same point on the display surface at the centre of the measurement field (the origin in the coordinate system defined in Figure 1).



NOTE These figures show how the display mount rotates about the surface of a convex or flat display for viewing direction measurements.

Figure 3 – Top view example of display mount that rotates in the x-z plane for viewing direction measurements

4.2 Light measuring device

It is generally assumed that the LMD will be a spot photometer, colorimeter, or spectroradiometer. The optical characteristics of these instruments are illustrated in Figure 4. The LMDs often have a selectable measurement-field angle (sometimes called the measurement aperture) that for a given measuring distance defines the measuring field on the display surface. The measurement-field angle shall be no greater than 2°. The measuring distance from the LMD to the display surface is nominally 0,5 m. This combination of measuring-field angle and distance usually satisfies the recommendation that the measurement field contain at least 500 pixels. However, for curved displays, if the measurement field becomes larger (or the radius of curvature becomes smaller), then the LMD samples light from the display surface over a larger range of inclination angles $\Delta\theta_d$. The range of inclination angles sampled by the LMD is given by:

$$\Delta\theta_d = \arcsin\left(\frac{c}{2r_c}\right) \qquad (1)$$

where c is the diameter of the measurement field and r_c is the display radius of curvature.

Figure 5 provides an example of how the range of inclination angles can vary for a given measurement field on displays with a 35 mm and 45 mm radius of curvature. In this example, the range of measurement fields that contain at least 500 pixels is identified by the shaded region under the curves. Figure 5 also includes an example of the measurement fields that can be obtained by a commercial spectroradiometer at a 0,5 m measurement distance as identified by its measurement-field angles (LMD aperture).

In general, it is desirable to minimize $\Delta\theta_d$ in order to avoid averaging over a large range of viewing directions during the measurement. For this reason, the range of inclination angles shall be $\Delta\theta_d$ < 5°. In the example illustrated in Figure 5, the LMD with the 1° measurement-field angle would subtend a measurement field that has $\Delta\theta_d$ < 5° for the 45 mm radius of curvature display, but $\Delta\theta_d$ > 5° for the 35 mm radius of curvature display. However, if the LMD measurement distance is reduced to 0,4 m for the 35 mm radius of curvature display, then $\Delta\theta_d$ would also fall below 5°.

Another method to reduce the range of display inclination angles is to reduce the measurement-field angle of the LMD. But as the example in Figure 5 suggests, the smaller measurement-field angles produce measurement fields that may not sample the recommended > 500 display pixels. This may be mitigated for the 0,2° measurement-field angle example in Figure 5 by increasing the measuring distance. However, the combination of smaller measurement-field angle and longer measuring distance tends to produce noisier data, and could result in reproducibility problems. But if it can be demonstrated that the smaller measurement-field angles at shorter measuring distances give the same results as for LMD configurations that do contain at least 500 pixels, then the smaller measurement-field angles are acceptable.

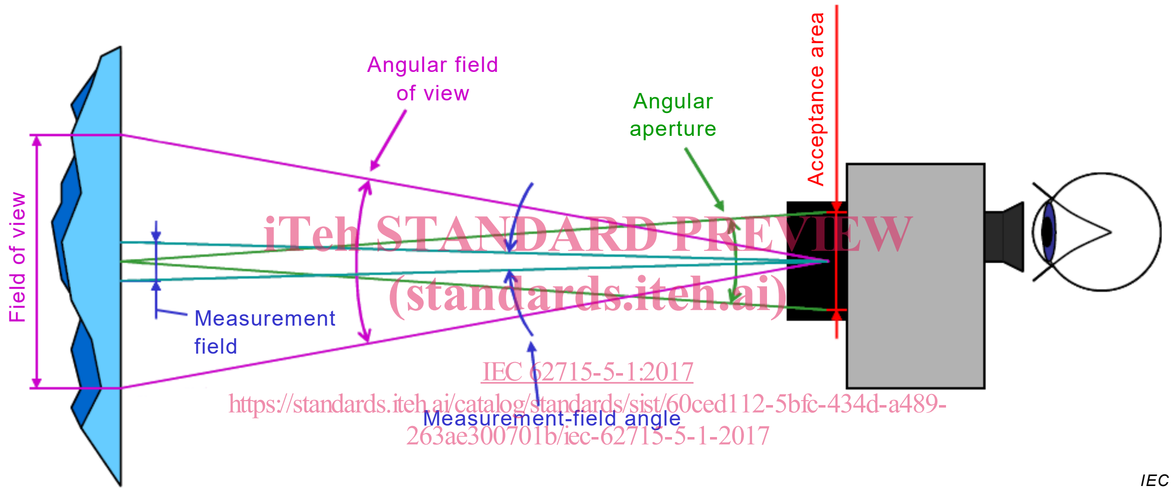
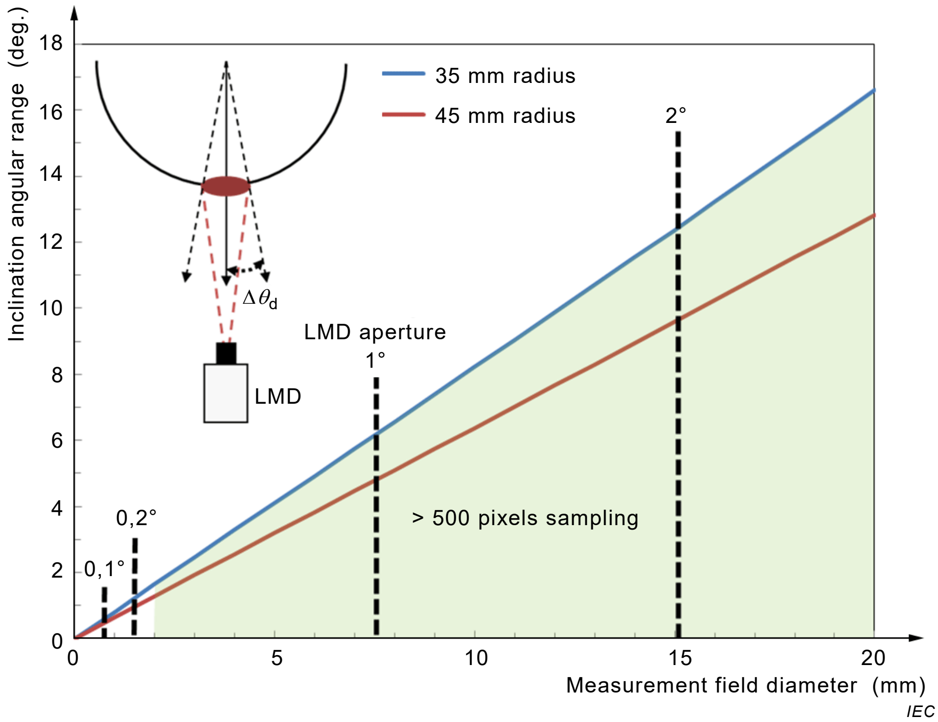


Figure 4 – Optical characteristics of a spot photometer, colorimeter, or spectroradiometer



NOTE 1 Figure 5 shows the relationship between the measurement field diameter and the range of inclinations angles captured within the measurement field for a given display radius of curvature.

NOTE 2 The shadowed area highlights the region where > 500 pixels are sampled for a given measurement field angle (dashed line).

Figure 5 – Example of the relationship between measurement field diameter and inclinations angles

4.3 Light source configurations

4.3.1 General

Light sources will be used to simulate the display performance under typical indoor or outdoor ambient lighting environments. These environments generally contain a combination of directed and uniform hemispherical diffuse light sources. Subclauses 4.3.2 and 4.3.3 define how these sources will be configured when evaluating the performance of curved displays under simulated indoor and outdoor illumination conditions. Flat displays will follow the same general configuration, without the need to consider the orientation of the display's bending axis.

4.3.2 Uniform hemispherical diffuse illumination

Uniform hemispherical diffuse illumination is generally realized by using an integrating sphere. For large displays, and displays with a large radius of curvature, the display may be placed against the sample port of a sampling sphere and the measurement area should be within the uniform illumination area of the display (see Figure 6, configuration B). However, if the display is too small to fill the sample port of a sampling sphere, or the curvature of a concave display is smaller than the curvature of the sampling sphere, then the display shall be placed in the centre of an integrating sphere (see Figure 6, configuration A). In either configuration, the long axis of the curved display (y-axis) shall be in the plane of incidence of the LMD and tilted 8° to 10° from the LMD optical axis. When using an integrating sphere, the reflection standard should be placed adjacent to the display and in the same plane as the display measurement area. Best practices for sphere design and measurements shall be followed. [3,4]