IEC 62629-22-1

Edition 2.0 2016-10

# INTERNATIONAL STANDARD

## 3D display devices –
## Part 22-1: Measuring methods for autostereoscopic displays – Optical



IEC 62629-22-1:2016-10(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
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 IEC 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 a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

**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 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

**IEC Glossary - std.iec.ch/glossary**
65 000 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.

IEC 62629-22-1

Edition 2.0 2016-10

# INTERNATIONAL STANDARD



## 3D display devices –
## Part 22-1: Measuring methods for autostereoscopic displays – Optical

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.120; 31.260

ISBN 978-2-8322-3688-8

**Warning! Make sure that you obtained this publication from an authorized distributor.**

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

# 3D DISPLAY DEVICES –

## Part 22-1: Measuring methods for autostereoscopic displays – Optical

## 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, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
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 IEC 62629-22-1 has been prepared by IEC technical committee 110: Electronic display devices.

This second edition cancels and replaces the first edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) addition of offset crosstalk and 3D pixel crosstalk as 3D crosstalk related property.

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

| FDIS | Report on voting |
|---|---|
| 110/784/FDIS | 110/797/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 the parts in the IEC 62629 series, under the general title *3D display devices*, 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 website 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.

A bilingual version of this publication may be issued at a later date.

# 3D DISPLAY DEVICES –

# Part 22-1: Measuring methods for autostereoscopic displays – Optical

## 1 Scope

This part of IEC 62629-22 specifies optical measuring methods for autostereoscopic display devices. It defines general measuring procedures for optical characteristics of two-view and multi-view displays and integral imaging displays.

## 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 62629-1-2, *3D display devices – Part 1-2: Generic – Terminology and letter symbols*

ISO/CIE 19476, *Characterization of the performance of illuminance meters and luminance meters*

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 62629-1-2 and the following 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

**3.1.1**
**3D pixel crosstalk**
pixel crosstalk by horizontal pixels for one lens pitch

### 3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

| | |
|---|---|
| CCD | charge-coupled device |
| DVD | designed viewing distance |
| FPD | flat panel display |
| FWHM | full width half maximum |
| FWTQM | full width at three-quarter maximum |
| IPD | inter pupil distance |

LMD light measuring device

# 4 Standard measuring conditions

## 4.1 Standard environmental conditions

### 4.1.1 Temperature, humidity and pressure conditions

Standard environmental conditions shall be applied for the measurements of autostereoscopic display devices.

The standard environmental conditions for the measurements of autostereoscopic display devices are (25 ± 5) °C temperature, 45 % to 75 % relative humidity, and 86 kPa to 106 kPa pressure.

### 4.1.2 Illumination conditions

Standard dark room conditions shall be applied.

In standard dark room conditions, the illuminance at any position on the screen (the display device screen) is below 0,3 lx in all directions.

NOTE Illuminance is measured without the measured display or in conditions where the display is turned off.

## 4.2 Light measuring device

### 4.2.1 General

The LMD used for measurements of the displays shall be checked for the following criteria and specified accordingly:

- aperture size (window function of LMD) (see 4.2.2);
- sensitivity of the measured quantity;
- errors caused by veiling glare and lens flare (i.e. stray light in optical system);
- timing of data acquisition, low-pass filtering and aliasing effects;
- linearity of detection and data-conversion;
- resolution and moiré when using a two-dimensional LMD.

A point-measurement LMD, such as a spot luminance meter, or a two-dimensional LMD such as a CCD area detector, shall be used for these measurements. A conoscopic type LMD can be used for some measurements. When a two-dimensional LMD and/or a conoscopic type LMD is/are used, they shall be calibrated so that the measurement results correspond to those of the point-measurement LMD. The specification of the LMD used shall be noted in the report as in the example shown in Table 1.

NOTE 1 The point-measurement LMD measures the luminance and/or colour coordinate at each measurement point on the screen. A two-dimensional LMD measures the map of luminance and/or colour coordinate over the measurement area of the screen. A conoscopic type LMD measures the directional characteristics of luminance and/or colour coordinate at each measurement point on the screen.

NOTE 2 A point-measurement LMD usually has higher sensitivity than a two-dimensional LMD. A two-dimensional LMD measures the uniformity of the measuring area more easily than a point-measurement LMD.

**Table 1 – Example of reported specification of two-dimensional LMD**

| | | |
|---|---|---|
| CCD resolution | 4 096 × 2 048 | |
| CCD A/D dynamic range | More than 12 bits = 4 096 gray scale levels | |
| Wavelength range | 380 nm to 780 nm | |
| System accuracy | Luminance variation | ± 3 % |
| | CIE 1931 chromaticity coordinates $(x, y)$ | ± 0,003 |
| Colorimetric filters | CIE 1931 colour matching functions for a 2° observer | |

### 4.2.2 Aperture size

The aperture size (entrance pupil, see ISO/CIE 19476) of an LMD, including point-measurement and two-dimensional type LMDs (smaller than the size of the object lens of the LMD), shall be equal to or smaller than 8 mm. When a larger aperture LMD is used, the measurement results shall be checked so that the results are equivalent to those of the smaller aperture LMD. The aperture size shall be reported by the supplier (the manufacturer of the 3D display device) in the relevant specification.

NOTE In the measurement of autostereoscopic displays, the aperture size of the LMD greatly affects the measurement results. So the LMD aperture size is defined in this document. The aperture size similar to the size of the pupil of an eye is ideal for the measurements (e.g. crosstalk), but a smaller aperture decreases the sensitivity. The size of 8 mm is small enough for the measurement and large enough for the sensitivity. The exact value of the aperture size of the LMD used will be informed by the LMD supplier. The relation among the aperture size, measuring area size and measuring distance is shown in Figure 1 and explained in 4.3. When a larger aperture LMD is used, the measuring distance is increased as long as the measuring distance does not affect the measurement results by changing the measuring distance.



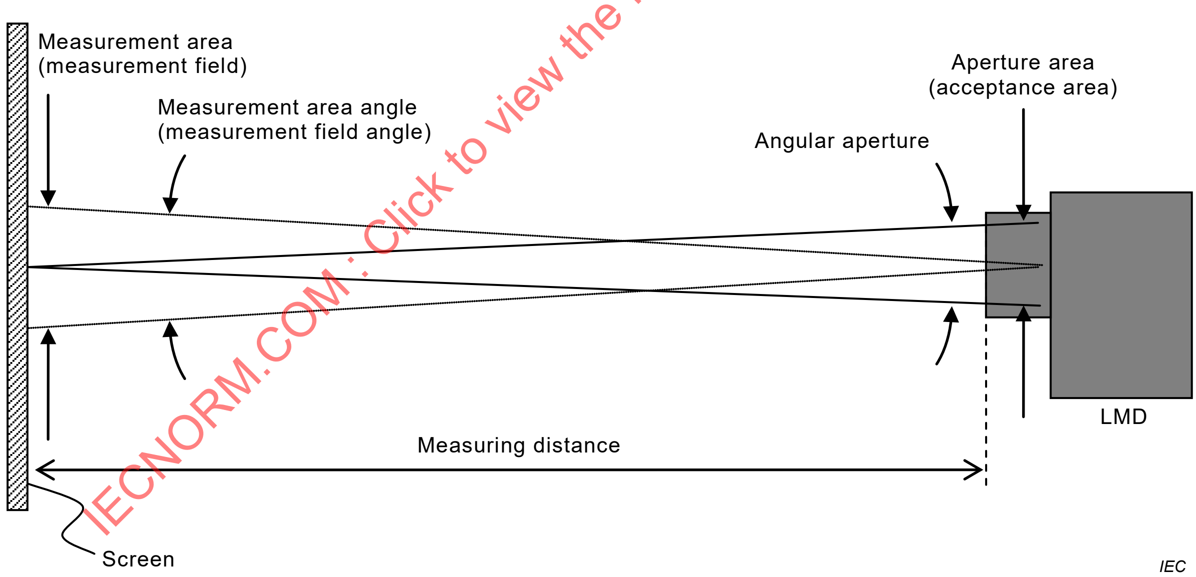



**Figure 1 – Measuring system**

## 4.3 Measuring setup

### 4.3.1 Designed viewing distance

A DVD shall be defined by the supplier in the relevant specification. The DVD is the distance from which proper stereoscopic views are intended to be observed and/or the characteristics of an autostereoscopic display are measured accurately.

For the measurements, the designed viewing distance shall be applied as the measuring distance. The measuring distance shall be fixed when items planned to be evaluated are measured. Only one designed viewing distance shall be defined and applied to an autostereoscopic display device.

### 4.3.2 Measurement area

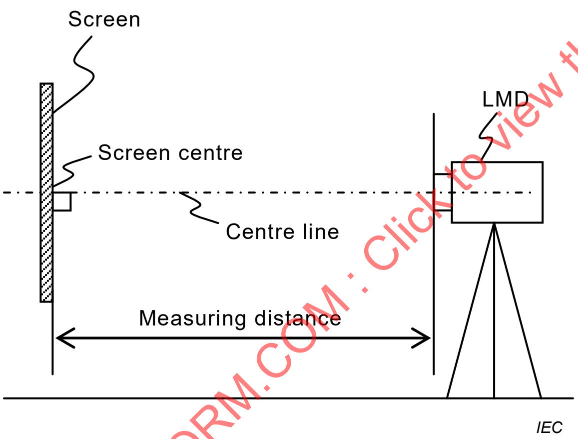
The LMD shall be set at a proper measurement area angle (measurement field angle, see Figure 1) less than or equal to 2°, and shall have a measurement area of at least 500 pixels whose diameter is less than 10 % of the screen height. This area corresponds to having a circular measurement area of at least 26 lines in diameter when the screen has a square pixel consisting of 3 subpixels. If the above conditions cannot be applied, the applied measurement area shall include as many pixels as possible. The applied measuring conditions shall be noted in the report.

NOTE Based on the information given by the supplier, such as number of views and lobe angle, the measurement field angle, aperture angle and measuring distance are determined. The aperture angle is small so that the angular luminance profile can be measured precisely. In general, the more the number of views increases, the smaller the required aperture angle is. In theory, when a smaller aperture is applied, a smaller field angle is desirable. In addition, some autostereoscopic displays are designed so that the screen produces different distribution of light rays to improve 3D observation. When considering these points, the field angle is introduced. The range of measuring distance is decided by the size of the aperture and measurement field. The measuring distance and the field angle are adjusted to achieve a viewing area greater than 500 pixels, whose diameter is less than 10 % of the screen height, if it is difficult to set the field angle above.

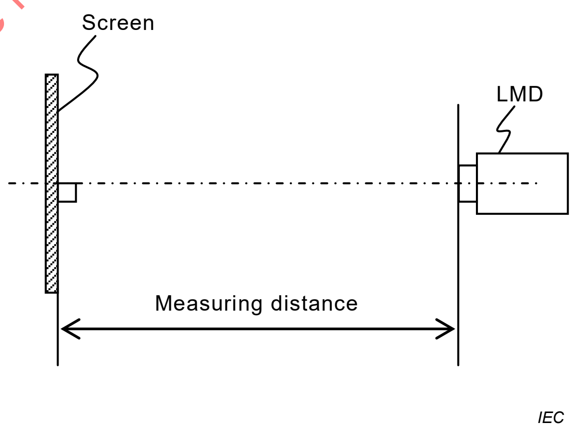
### 4.3.3 Measuring layout

#### 4.3.3.1 Centre point measurement

The measuring layout for a centre point measurement is shown in Figure 2. The aperture of the LMD shall be set at the designed viewing distance.




**a) Side view**

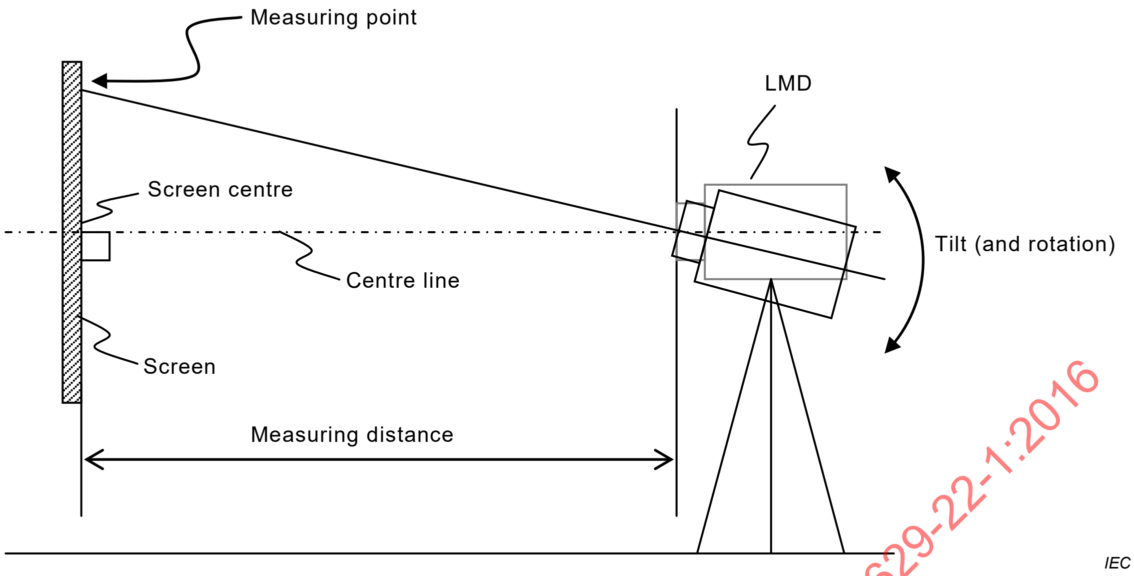



**b) Top view**

**Figure 2 – Measuring layout for centre point measurement**

#### 4.3.3.2 Multi-point measurement

The measuring layout for a multi-point measurement is shown in Figure 3. When a multi-point measurement is carried out using the two-dimensional LMD, the measuring layout shown in Figure 2 shall be applied. In this case the measurement result shall be confirmed to be the same as that measured by the multi-point measurement shown in Figure 3.




NOTE A similar layout is applied to the measurement with rotation.

**Figure 3 – Measuring layout for multi-point measurement (side view)**

The measuring layout shown in Figure 4 can also be applied to certain measuring items. This layout is suitable for certain measuring items where the display does not strongly depend on LMD positions (i.e. integral imaging display). The layout used for the measurement shall be noted in the report. When a different measuring layout is used, this shall be noted in the report.

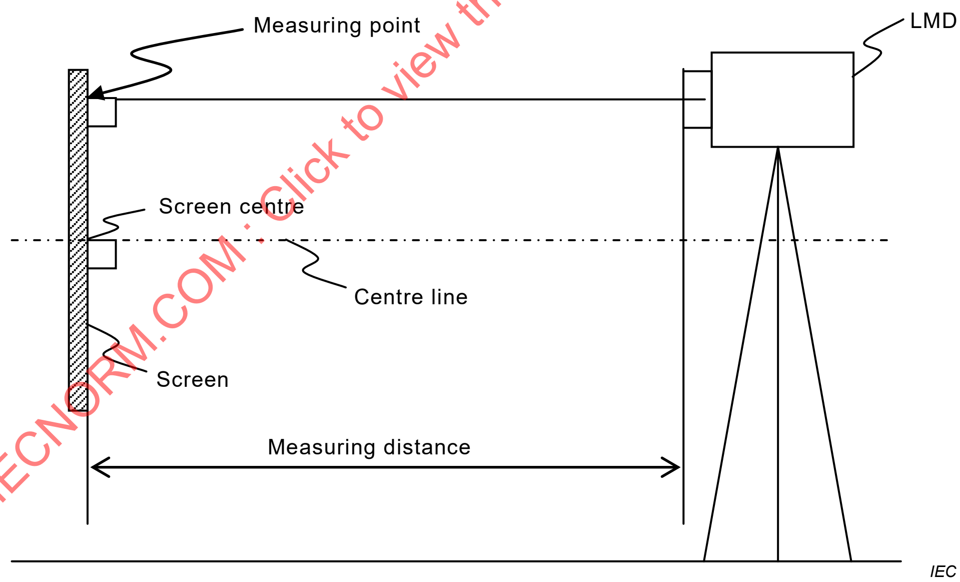
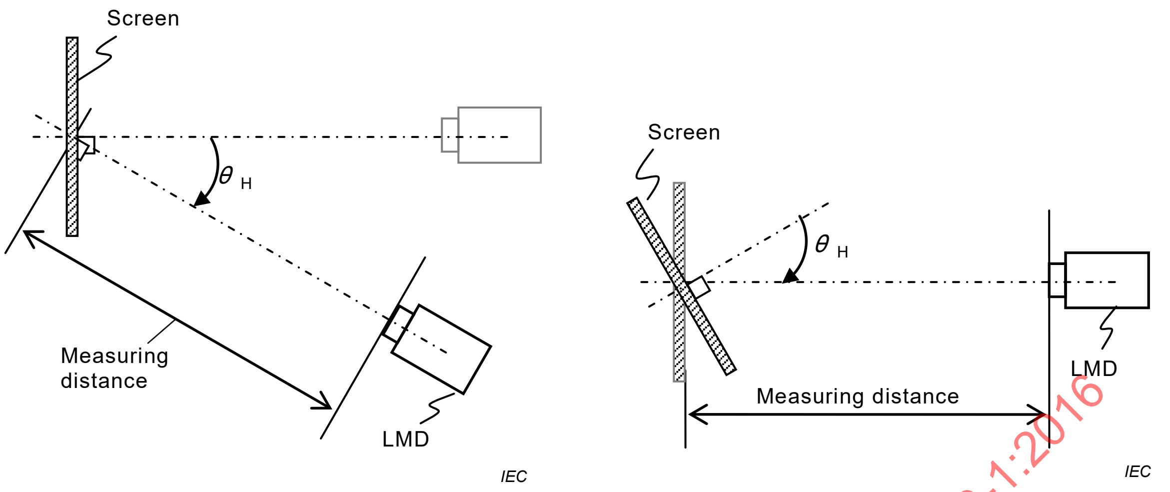



**Figure 4 – Other measuring layout for multi-point measurement (side view)**

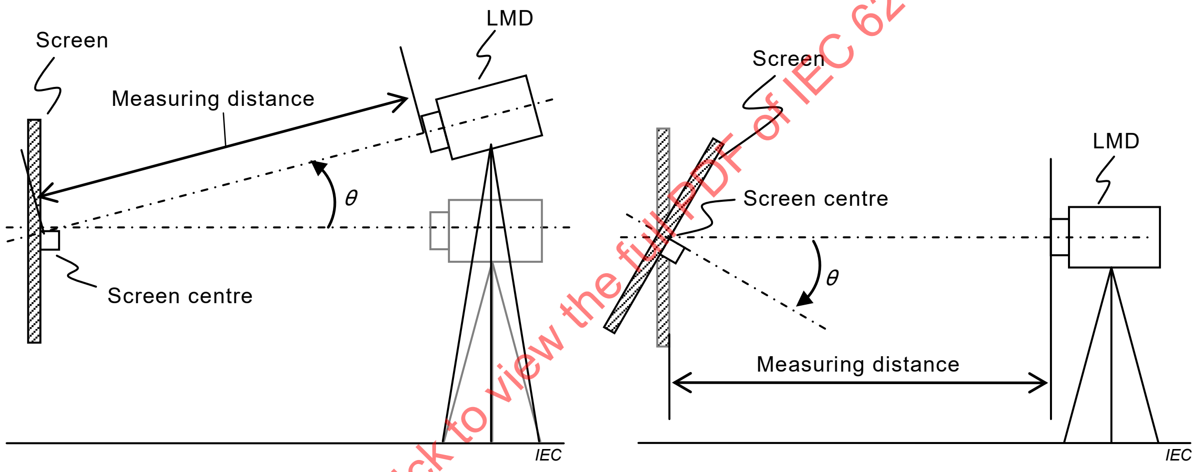
#### 4.3.3.3 Measurement of viewing direction dependency

To measure viewing direction dependency, the characteristics at the centre of the screen are measured from the vertical or horizontal viewing directions defined in each measurement method or relevant specification, as shown in Figure 5 and Figure 6. Instead of moving the LMD, the autostereoscopic display can be tilted vertically or turned horizontally to be measured as shown in Figure 5 b) and Figure 6 b). The horizontal and vertical measuring angular ranges and angular scanning steps shall be defined by the supplier in the relevant specification, and shall be noted in the report.




**a) Movement of LMD (top view)** **b) Rotation of display (top view)**

**Figure 5 – Measuring layout for horizontal viewing direction dependency**




**a) Movement of LMD (side view)** **b) Tilt of display (side view)**

**Figure 6 – Measuring layout for vertical viewing direction dependency**

## 4.4 Test signal

The all-pixel white signal, all-pixel black signal, and $i^{th}$-pixel white signal are defined below:

a) $Im_{\text{all white}}$: all-pixel white signal (at 100 % level) or all-pixel white

NOTE 1 The all-pixel white signal denotes that all pixels on the screen are activated by the input of level 100 %.

b) $Im_{\text{all black}}$: all-pixel black signal (at 0 % level) or all-pixel black

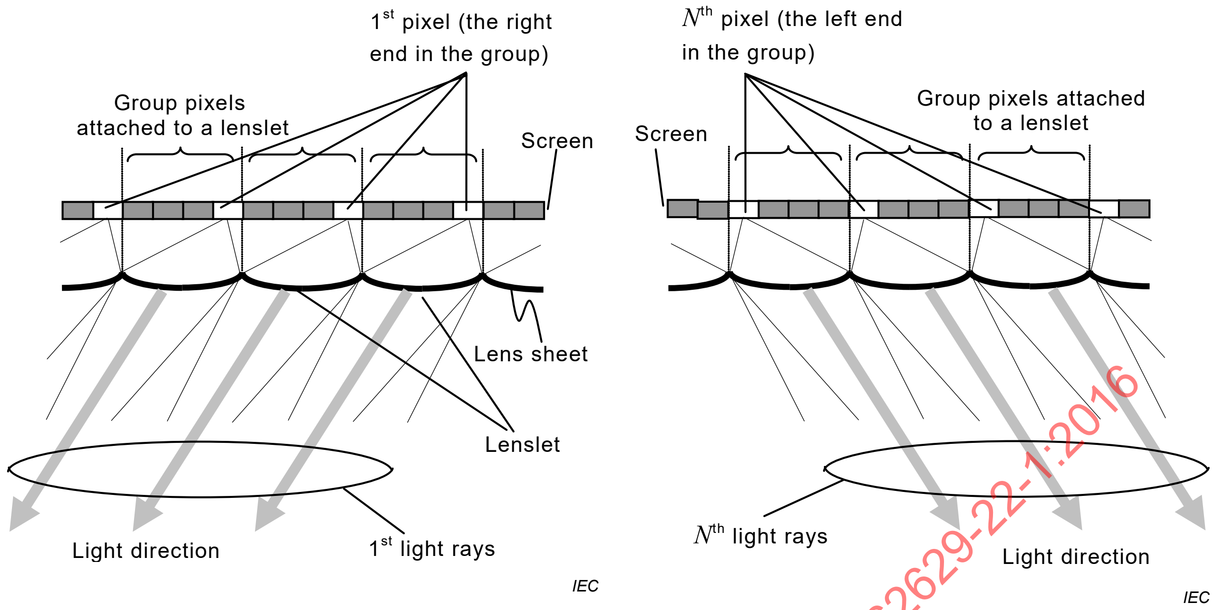
NOTE 2 The all-pixel black signal denotes that all pixels on the screen are suppressed by the input of level 0 %.

c) $Im_i$: $i^{th}$ -pixel white signal (at 100 % level) with the other pixel blackened or $i^{th}$ -pixel white,where $i$ is 1 to $N$ (see Figure 7) and $N$ is the number of views (multi views). For temporal use, the $i^{th}$ light ray white signal (at 100 % level) with the other light rays blackened or the $i^{th}$ light ray white can be used.

NOTE 3 The $i^{th}$ pixel white signal indicates that only $i^{th}$ pixels in the group are activated by the input of 100 % level.

NOTE 4 Light ray is explained in Annex A.

The signal details of signals for the $i$ $^{th}$-pixel white signal, or the details of the pixels and lenslet as shown in Figure 7 shall be described by the supplier in the relevant specification.




**Key** ☐: pixel at level 100 %, ■: pixel at level 0 %, $Im_1$ and $Im_N$ are 1st and $N$th pixel white signals

**a) Test image ($Im_1$)** **b) Test image ($Im_N$)**

NOTE As shown in a), every pixel at the right end in the group (every 1st pixel) is at level 100 %, and as shown in b), so is every pixel on the left end in the group (every $N$th pixel).

**Figure 7 – Two examples of the relation between pixel and lenslet in multi-view display**

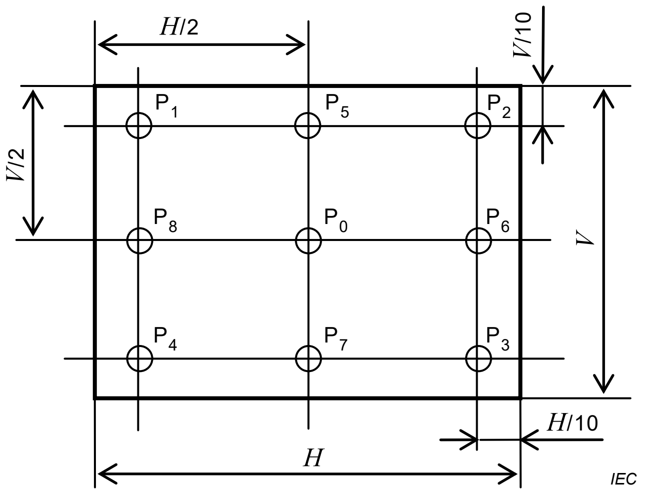
### 4.5 Standard measuring points

The centre point (one-point) and multi-point (three-point, five-point or nine-point) measurements are applied. The measuring points are shown in Figure 8. The measuring point of one-point measurement is named $P_0$. In multi-point measurements the three points are $P_0$, $P_6$ and $P_8$, the five points and nine points are from $P_0$ to $P_4$ and from $P_0$ to $P_8$, respectively.

The $n$ by $m$ points for 3D crosstalk variation on screen are shown in Figure 9. The applied number of measuring points ($n$ by $m$) shall be defined by the supplier in the relevant specification.

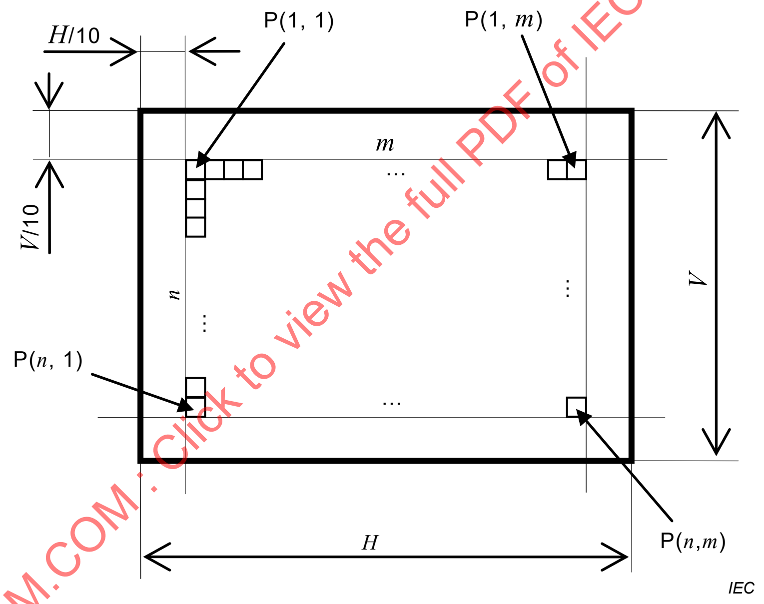
The applied measuring points are defined in each measurement item. If other measuring points are applied, this shall be defined by the supplier in the relevant specification.

NOTE One-point measurement is carried out to obtain the typical characteristics at the centre of the screen. Others are carried out to obtain deviations, averages and uniformities.




NOTE $V$ is the short side width of the screen (usually screen height). $H$ is the long side width of the screen (usually screen width). $P_0$, $P_1$, $P_2$, $P_3$, $P_4$, $P_5$, $P_6$, $P_7$ and $P_8$ show the measuring points.

**Figure 8 – Measuring points for the centre and multi-point measurement**




NOTE $V$ is the short side width of the screen (usually screen height). $H$ is the long side width of the screen (usually screen width). P($a$,$b$), where $a$ = 1 to $n$ and $b$ = 1 to $m$, show the measuring points.

**Figure 9 – Example of *n* by *m* measuring points**



# 5 Measuring method for two-view and multi-view displays

## 5.1 Maximum luminance direction

### 5.1.1 General

The purpose of this measurement is to measure the angular luminance profile and to obtain a maximum luminance direction. The maximum luminance direction is calculated as an angular position where the luminance is the highest on the angular luminance profile.

### 5.1.2 Measuring equipment

The following equipment shall be used:

a) driving power source;

b) driving signal equipment; and

c) LMD.

### 5.1.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: $i^{\text{th}}$-pixel white (see 4.4);

b) measuring point: centre point (see Figure 2);

c) measuring angular range: the supplier specifies the measuring angular range and the measuring angular scanning step (see Figure 5);

d) measuring distance: designed viewing distance (see 4.3.1).

### 5.1.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the test signal $Im_1$;

b) measure the angular luminance profile at each selected angle and record the luminance values;

c) change the test signal, and repeat b) until all tests (test signals $Im_1$ to $Im_N$) are carried out.

### 5.1.5 Measurement report

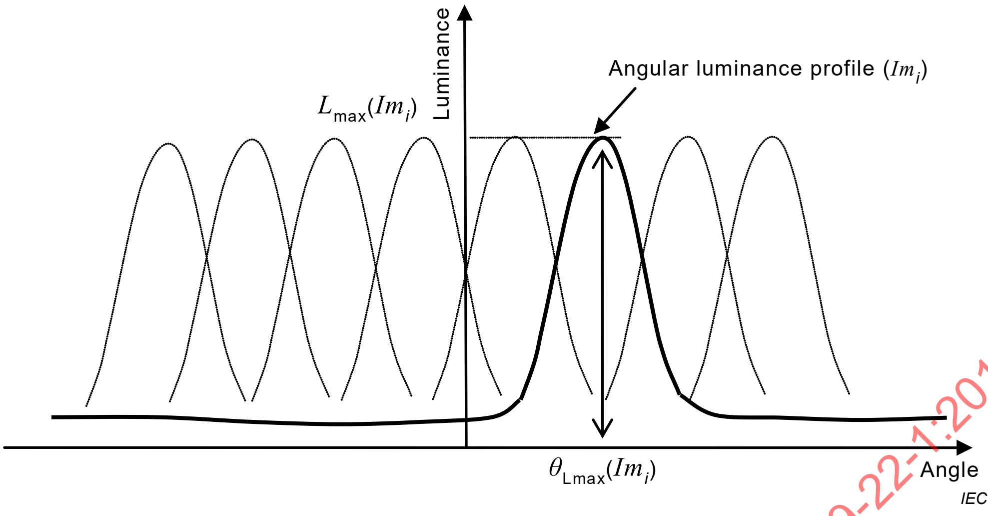
The measurement report shall include the following:

a) plot the angular luminance profiles as shown in Figure 10;

b) report the angular position of each maximum luminance $\theta_{\text{Lmax}}(Im_i)$ in a table. Table 2 shows an example.

The angular position of each maximum luminance $\theta_{\text{Lmax}}(Im_i)$ is the angle of each maximum luminance value of the closest peak from the perpendicular of the display.

When the angular luminance profile does not show a clear peak, the center of FWHM can be applied (see Annex B).




**Key**

$L_{max}(Im_i)$: maximum luminance of the angular luminance profile ($Im_i$)

$\theta_{Lmax}(Im_i)$: angular position of $L_{max}(Im_i)$

**Figure 10 – Example of measurement results for angular luminance profile**

**Table 2 – Example of measurement results for maximum luminance direction**

| Test signal | $\theta_{Lmax}(Im_i)$ degree |
|---|---|
| $Im_1$ | –12,2 |
| $Im_2$ | –8,6 |
| $Im_3$ | –4,5 |

## 5.2 Lobe angle and lobe angle variation on screen

### 5.2.1 General

The purpose of this measurement is to measure the lobe angle and lobe angle variation on screen.

NOTE 1 In general, autostereoscopic displays form the group of pixels corresponding to each lens/slit. The light rays from each pixel group form a lobe. When the light rays go through the corresponding lens/slit, they form the main lobe, or side lobes in other cases. On the boundary of the lobes, pseudostereoscopy or image breaking is perceived. A wider lobe angle can reduce these phenomena.

NOTE 2 In this document, the term "lobe" means the bundle of light rays emitted from each pixel group going through the corresponding lens/slit. However, note that the term "lobe" is sometimes used with a different meaning.

### 5.2.2 Measuring equipment

The following equipment shall be used:

a) driving power source;

b) driving signal equipment; and

c) LMD.

### 5.2.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: 1st pixel white and $N^{\text{th}}$ pixel white are applied (see 4.4);

b) measuring points: the multi-point measurements are applied (see Figure 8). The applied number of measuring points (nine points) shall be noted in the report. Three-point measurement may be used, when it is enough for characterization;

c) measuring directions: the supplier specifies measuring directions;

d) measuring distance: designed viewing distance (see 4.3.1).

### 5.2.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the test signals for $Im_1$;

b) measure the angular luminance profile at each selected angle at each selected point and record the luminance values;

c) change the test signal to $Im_N$, and repeat b).

### 5.2.5 Measurement report

The following measurement report shall be written:

a) at each measuring point, plot the angular luminance profiles;

b) find the maximum luminance angles $\theta_{\text{aLmax}}(Im_1)$ and $\theta_{\text{aLmax}}(Im_N)$ of the $Im_1$ and $Im_N$ profiles of each measuring point $P_a$ (see Figure 10), and then calculate the lobe angle $\theta_{\text{aLA}}$ (see Figure 11)

$$\theta_{\text{aLA}} = |\theta_{\text{aLmax}}(Im_1) - \theta_{\text{aLmax}}(Im_N)|$$

where

$\theta_{\text{aLmax}}(Im_i)$ is the maximum luminance angle of $Im_i$ of $i^{\text{th}}$ ray at the measuring point $P_a$;

c) report the angles in a table. Table 3 shows an example.

NOTE This measurement can be applied not only to the main lobe, but also to side lobes.



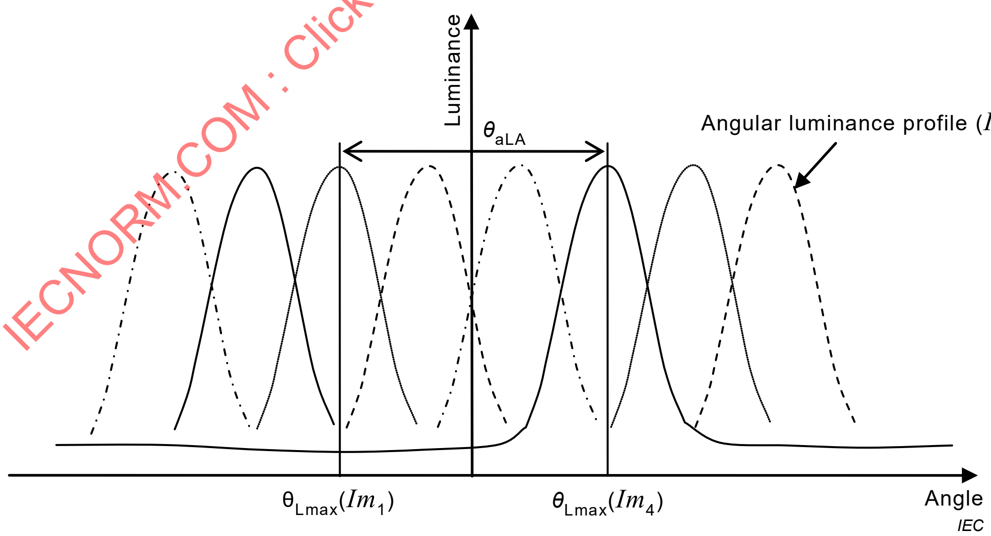



**Figure 11 – Example of lobe angle measurement**

**Table 3 – Example of measurement results for lobe angle variation on screen**

| Measuring point | $\theta_{aLmax}(Im_1)$ degree | $\theta_{aLmax}(Im_N)$ degree | $\theta_{aLA}$ degree |
|---|---|---|---|
| $P_0$ | -15,2 | 15,4 | 30,6 |
| $P_1$ | -15,3 | 15,2 | 30,5 |
| $P_2$ | -15,0 | 15,4 | 30,4 |
| $P_3$ | -15,5 | 15,0 | 30,5 |
| $P_4$ | -15,7 | 14,8 | 30,5 |
| $P_5$ | -14,8 | 15,8 | 30,6 |
| $P_6$ | -15,2 | 15,6 | 30,8 |
| $P_7$ | -15,7 | 14,6 | 30,3 |
| $P_8$ | -14,7 | 15,5 | 30,2 |

## 5.3 Luminance, screen luminance uniformity, and angular luminance variation

### 5.3.1 Luminance and screen luminance uniformity

#### 5.3.1.1 General

The purpose of this measurement is to measure the luminance and luminance uniformity of the screen. The measurement of screen luminance uniformity is related to luminance moiré due to the structure of autostereoscopic displays. Low-frequency moiré can be observed as screen non-uniformity. When luminance moiré occurs, luminance uniformity will be degraded.

#### 5.3.1.2 Measuring equipment

The following equipment shall be used:

a) driving power source;
b) driving signal equipment; and
c) LMD.

#### 5.3.1.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: all-pixel whites are applied (see 4.4);
b) measuring points: the multi-point measurements are applied (see Figure 8). The applied number of measuring points (five points or nine points) shall be noted in the report;
c) measuring direction: perpendicular to the display (see Figure 4);
d) measuring distance: designed viewing distance is applied (see 4.3.1).

#### 5.3.1.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the all-pixel white test signal ($Im_{\text{all white}}$);
b) measure the luminance at each selected point and record the luminance values;
c) calculate average luminance $L_{sav}$, and luminance deviation $\Delta L_{si}$ as follows:
   1) for five-point measurement:

$$L_{sav} = (L_{s0} + L_{s1} + L_{s2} + L_{s3} + L_{s4}) / 5 \quad \text{or}$$

2) for nine-point measurement:

$$L_{sav} = (L_{s0} + L_{s1} + L_{s2} + L_{s3} + L_{s4} + L_{s5} + L_{s6} + L_{s7} + L_{s8}) / 9$$

$$\Delta L_{si} = L_{si} - L_{sav}$$

where

$L_{si}$ is the luminance measured at the measuring point $P_i$,

$i$ = 0 to 4 for the five-point measurement, and

$i$ = 0 to 8 for the nine-point measurement.

#### 5.3.1.5 Measurement report

The measurement result shall be reported in a table. Table 4 shows an example. Luminance uniformity shall be reported as a list of luminance non-uniformity.

**Table 4 – Example of measurement results for luminance and screen luminance non-uniformity**

| Measuring point | Luminance<br>$L_{si}$<br>cd/m² | Luminance non-uniformity<br>$\Delta L_{si} / L_{sav} \times 100$<br>% |
|---|---|---|
| $P_0$ | 115 | 3,9 |
| $P_1$ | 107 | -3,3 |
| $P_2$ | 111 | 0,3 |
| $P_3$ | 108 | -2,4 |
| $P_4$ | 106 | -4,2 |
| $P_5$ | 113 | 2,1 |
| $P_6$ | 115 | 3,9 |
| $P_7$ | 110 | -0,6 |
| $P_8$ | 111 | 0,3 |
| Average luminance $L_{sav}$: 111 cd/m² | | |

### 5.3.2 Angular luminance variation

#### 5.3.2.1 General

The purpose of this measurement is to measure angular luminance variation. Angular luminance variation is related to luminance moiré due to the unique optical structure of autostereoscopic displays. When the angular luminance variation is large, luminance moiré may occur.

#### 5.3.2.2 Measuring equipment

The following equipment shall be used:

a) driving power source;

b) driving signal equipment; and

c) LMD.

#### 5.3.2.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: all-pixel whites are applied (see 4.4);

b) measuring point: the centre point is applied (see Figure 2);

c) measuring directions: maximum luminance directions (see 5.1) and middles of neighbouring maximum luminance directions are applied. The measuring angular range shall contain the main lobe. When more detail of angular luminance variation is needed, extra measuring directions can be added. The applied measuring directions shall be described in the relevant specification;

d) measuring distance: designed viewing distance shall be applied (see 4.3.1).

#### 5.3.2.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the test signal $Im_{\text{all white}}$;

b) measure luminance at each selected direction and record the luminance values;

c) calculate angular luminance variation $\Delta L_{\mathrm{H}i0,5}$, $\Delta L_{\mathrm{H}i}$ as follows:

$$\Delta L_{\mathrm{H}i0,5} = L_{\mathrm{H}i} - L_{\mathrm{H}i\text{-}0,5}$$

$$\Delta L_{\mathrm{H}i} = L_{\mathrm{H}i} - L_{\mathrm{H}i\text{-}1}$$

where

$L_{\mathrm{H}i}$ is the luminance measured in the $i^{\text{th}}$ measuring direction, and

$L_{\mathrm{H}i\text{-}0,5}$ is the luminance measured in the middle of the $i^{\text{th}}$ measuring direction and $(i\text{-}1)^{\text{th}}$ measuring direction.

#### 5.3.2.5 Measurement report

The measured result shall be reported in a table. Table 5 shows an example.

**Table 5 – Example of measurement results for angular luminance variation**

| $i^{\text{th}}$ measuring direction | Angle of measurement $\theta_{\mathrm{H}}$ degree | Luminance $L_{\mathrm{H}i}$ cd/m$^2$ | Angular luminance variation between maximum luminance direction and middle direction $\Delta L_{\mathrm{H}i0,5}$ | Angular luminance variation between maximum luminance directions $\Delta L_{\mathrm{H}i}$ |
|---|---|---|---|---|
| 1 | –12,2 | 115 | – | – |
| 1,5 | –10,4 | 107 | –8 | – |
| 2 | –8,6 | 111 | 4 | –4 |
| 2,5 | –6,6 | 109 | –2 | – |
| 3 | –4,5 | 113 | 4 | 2 |
| 3,5 | –2,5 | 108 | –5 | – |

## 5.4 White chromaticity, white chromaticity uniformity on screen, and white chromaticity variation in angle

### 5.4.1 White chromaticity and white chromaticity uniformity on screen

#### 5.4.1.1 General

The purpose of this measurement is to measure white chromaticity and white chromaticity uniformity of the display. The measurement of chromatic screen uniformity is related to chromatic moiré due to the structure of autostereoscopic displays. When chromatic moiré occurs, chromatic screen uniformity will be degraded.

#### 5.4.1.2 Measuring equipment

The following equipment shall be used:

a) driving power source;
b) driving signal equipment; and
c) LMD.

#### 5.4.1.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: all-pixel whites are applied (see 4.4);
b) measuring points: the multi-point measurements are applied (see Figure 8). The applied number of measuring points (5 points or 9 points) shall be noted in the report;
c) measuring direction: perpendicular to the display (see Figure 4);
d) measuring distance: designed viewing distance is applied (see 4.3.1).

#### 5.4.1.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the all-pixel white signal;
b) measure the white chromaticity $C_i(u' \; v')$ at each selected point and record the chromaticity values, where $u'$ and $v'$ are the chromaticity coordinates of the UCS chromaticity diagram as shown in CIE 15:2004;

NOTE 1 It is possible to use the chromaticity coordinates $x$, $y$ of CIE 1931 chromaticity coordinates defined in CIE 15:2004 for the measurement. The chromaticity coordinates $u'$, $v'$ are transformed from the chromaticity coordinates $x$, $y$ as:

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

c) calculate the chromaticity deviation $\Delta u'_{si}\,\Delta v'_{si}$ as follows:

$$\Delta u'_{si} = u'_{si} - u'_{s0}$$

$$\Delta v'_{si} = v'_{si} - v'_{s0}$$

NOTE 2 CIE 1976 geometric colour difference formula is as follows:

$$\Delta u'v' = ((u'_{si} - u'_{s0})^2 + (v'_{si} - v'_{s0})^2)^{0,5}$$

where

$(u'_{si}\; v'_{si})$ is the white chromaticity measured at the measuring point $P_i$ in Figure 8,

$i$ = 0 to 4 for five-point measurement, and

$i$ = 0 to 8 for the nine-point measurement;

d) calculate the maximum deviation $\Delta u'_{md}$ and $\Delta v'_{md}$ among all measuring points.

#### 5.4.1.5 Measurement report

The measurement result shall be reported in a table. Table 6 shows an example.

**Table 6 – Example of measurement results for white chromaticity and white chromaticity uniformity on screen**

| Measuring point | $u'_{si}$ | $\Delta u'_{si}$ | $v'_{si}$ | $\Delta v'_{si}$ |
|---|---|---|---|---|
| $P_0$ | 0,195 | 0,000 | 0,436 | 0,000 |
| $P_1$ | 0,192 | –0,003 | 0,436 | 0,000 |
| $P_2$ | 0,195 | 0,000 | 0,428 | –0,008 |
| $P_3$ | 0,188 | –0,007 | 0,437 | 0,001 |
| $P_4$ | 0,193 | –0,002 | 0,437 | 0,000 |
| $P_5$ | 0,191 | –0,004 | 0,433 | –0,003 |
| $P_6$ | 0,190 | –0,005 | 0,431 | –0,005 |
| $P_7$ | 0,195 | –0,001 | 0,436 | 0,000 |
| $P_8$ | 0,190 | –0,006 | 0,440 | 0,004 |
| Maximum deviation | $\Delta u'_{\text{md}}$= 0,007 | | $\Delta v'_{\text{md}}$= 0,008 | |

### 5.4.2 White chromaticity angular variation

#### 5.4.2.1 General

The purpose of this measurement is to measure white chromaticity angular variation. The measurement of chromatic angular uniformity is related to chromatic moiré due to the unique optical structure of autostereoscopic displays. When the white chromaticity angular variation is large, chromatic moiré may occur.

#### 5.4.2.2 Measuring equipment

The following equipment shall be used:

a) driving power source;

b) driving signal equipment; and

c) LMD.

#### 5.4.2.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: all-pixel whites are applied (see 4.4);

b) measuring point: the centre point is applied (see Figure 2);

c) measuring directions: maximum luminance directions (see 5.1) and middles of neighbouring maximum luminance directions are applied. The measuring angular range shall contain the main lobe. When more detail of angular luminance variation is needed, extra measuring directions can be added. The applied measuring directions shall be described in the relevant specification;

d) measuring distance: designed viewing distance is applied (see 4.3.1).

#### 5.4.2.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the test signal $Im_{\text{all white}}$;

b) measure the white chromaticity in each selected direction and record the chromaticity values;

c) calculate the white chromaticity variation in angle $\Delta u'_{\text{H}i0,5}$ $\Delta v'_{\text{H}i0,5}$, $\Delta u'_{\text{H}i}$ $\Delta v'_{\text{H}i}$ as follows:

$$\Delta u'_{\mathrm{H}i0,5} = u'_{\mathrm{H}i} - u'_{\mathrm{H}i\text{-}0,5}$$

$$\Delta v'_{\mathrm{H}i0,5} = v'_{\mathrm{H}i} - v'_{\mathrm{H}i\text{-}0,5}$$

$$\Delta u'_{\mathrm{H}i} = u'_{\mathrm{H}i} - u'_{\mathrm{H}i\text{-}1}$$

$$\Delta v'_{\mathrm{H}i} = v'_{\mathrm{H}i} - v'_{\mathrm{H}i\text{-}1}$$

NOTE The CIE 1976 geometric colour difference formula is as follows:

$$\Delta\, u'\, v' = ((u'_{\mathrm{H}i} - u'_{\mathrm{H}i\text{-}0,5})^2 + (v'_{\mathrm{H}i} - v'_{\mathrm{H}i\text{-}0,5})^2)^{0,5}$$

$$\Delta\, u'\, v' = ((u'_{\mathrm{H}i} - u'_{\mathrm{H}i\text{-}1})^2 + (v'_{\mathrm{H}i} - v'_{\mathrm{H}i\text{-}1})^2)^{0,5}$$

where

$(u'_{\mathrm{H}i}\ v'_{\mathrm{H}i})$ is the white chromaticity measured in the $i^{\mathrm{th}}$ measuring direction; and

$(u'_{\mathrm{H}i\text{-}0,5}\ v'_{\mathrm{H}i\text{-}0,5})$ is the white chromaticity measured in the middle of the $i^{\mathrm{th}}$ measuring direction and $(i\text{-}1)^{\mathrm{th}}$ measuring direction.

#### 5.4.2.5 Measurement report

The measured result shall be reported in a table. Table 7 shows an example.

**Table 7 – Example of measurement results for white chromaticity variation in angle**

| $i^{\mathrm{th}}$ measuring direction | Angle of measurement $\theta_{\mathrm{H}}$ degree | $u'_{\mathrm{H}i}$ | $\Delta u'_{\mathrm{H}i0,5}$ | $\Delta u'_{\mathrm{H}i}$ | $v'_{\mathrm{H}i}$ | $\Delta v'_{\mathrm{H}i0,5}$ | $\Delta v'_{\mathrm{H}i}$ |
|---|---|---|---|---|---|---|---|
| 1 | –12,2 | 0,195 | – | – | 0,436 | – | – |
| 1,5 | –10,4 | 0,192 | –0,003 | – | 0,436 | 0,000 | – |
| 2 | –8,6 | 0,195 | 0,003 | 0,000 | 0,428 | –0,008 | –0,008 |
| 2,5 | –6,6 | 0,188 | –0,007 | – | 0,437 | 0,009 | – |
| 3 | –4,5 | 0,193 | 0,005 | -0,002 | 0,437 | 0,000 | 0,009 |
| 3,5 | –2,5 | 0,188 | –0,005 | – | 0,437 | 0,000 | |

# 6 Standard measuring method for integral imaging displays (1D/2D)

## 6.1 General

An integral imaging display is based on the spatial image reproduction method, which optically reproduces an object surface in space so that it features homogeneous image quality with no specific viewing position. It is important to know how homogeneous the image quality is and, therefore, in the measurements of integral imaging displays, the uniformity in space (i.e. angular uniformity and screen uniformity) shall be evaluated.

The most popular structure for the integral imaging display is a combination of a fly-eye lens sheet and a high-resolution display. This document calls it a two-dimensional (2D) integral imaging display, because the display can produce horizontal and vertical parallaxes. Lately, one-dimensional (1D) integral imaging displays have been developed. In order to provide only horizontal parallax, a one-dimensional optical sheet such as a lenticular sheet or a parallax barrier is adopted in place of the fly-eye lens. The measurement methods in Clause 6 can be applied to 1D and 2D integral imaging displays.

NOTE 1 Multi-view displays are generally designed so that they create the viewing positions where each stereoscopic image can be observed all over the screen. The position is often called “viewpoint”. Clause 5 describes methods in which the viewpoint is treated as the specific position for measurements (i.e. DVD). For example, in the measurements for screen uniformity, optical characteristics at each point on the screen are measured from the position determined by the DVD and maximum luminance direction.

NOTE 2 The design approach of integral imaging displays is similar to that of conventional 2D displays because no specific viewing position is supposed and in some measurements for uniformity, the policy of conventional methods for 2D displays can be applied. However, the binocular characteristics for stereopsis are unknown in integral imaging displays. Current standards only focus on the fundamental characteristics.

### 6.2 Lobe angle and lobe angle variation on screen

See 5.2.

When the relevant specification requires measurements in the vertical angular direction, the measurement method described in 5.2 shall be applied.

### 6.3 Luminance, screen luminance uniformity, and angular luminance variation

#### 6.3.1 Luminance and screen luminance uniformity

The measurement method is the same as the one described in 5.3.1.3. The measuring direction has to be perpendicular to the screen.

NOTE The integral imaging display is designed so that the display has uniformity. Therefore, the measuring direction can be perpendicular at each point on the screen.

#### 6.3.2 Angular luminance variation

See 5.3.2.

When the relevant specification requires measurements in the vertical angular direction, the measurement method described in 5.3.2 shall be applied.

### 6.4 White chromaticity, white chromaticity uniformity on screen, and white chromaticity variation in angle

#### 6.4.1 White chromaticity and white chromaticity uniformity on screen

The measurement method is the same as the one described in 5.4.1.3. The measuring direction has to be perpendicular to the screen.

#### 6.4.2 White chromaticity variation in angle

See 5.4.2.

When the relevant specification requires measurements in the vertical angular direction, the measurement method described in 5.4.2 shall be applied.

## 7 Measuring method for 3D crosstalk related property

### 7.1 3D crosstalk (luminance components ratio), 3D crosstalk variation on screen, and 3D crosstalk variation in angle for two-view and multi-view displays

#### 7.1.1 3D crosstalk (luminance components ratio) and 3D crosstalk variation on screen

##### 7.1.1.1 General

The purpose of this measurement is to measure 3D crosstalk and its variation on screen. 3D crosstalk as well as the luminance components ratio and 3D crosstalk variation on screen shall be reported. 3D crosstalk variation on screen is expressed as the maximum, minimum and average of 3D crosstalk. If 3D crosstalk variation on screen is small, when the $i^{th}$ pixel white signal is applied, the full-screen white signal will be observed in the maximum luminance direction of the closest peak from the perpendicular of the display. If 3D crosstalk variation is greater, as shown in Figure 12, in some cases luminance variation can be observed on screen as in Figure 13.

NOTE The relation between 3D crosstalk and depth visibility would ask for further discussion. In some cases, an autostereoscopic display with high 3D crosstalk cannot provide a clear image with great depth (see Figure 12). However, in the definition provided in this document, 3D crosstalk depends on the number of views. When the number of views increases, 3D crosstalk is greater. This means that it is difficult for a multi-view display with a larger number of views to achieve lower 3D crosstalk. In addition, when depth is limited by visual ergonomic factors, clear images can be perceived even if 3D crosstalk is high. Therefore, the luminance components ratio is checked one by one.

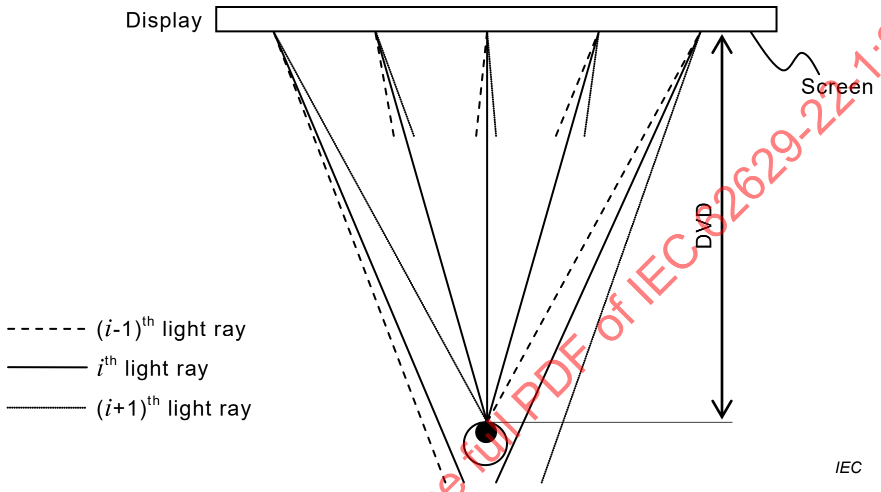



**Figure 12 – Example of 3D crosstalk variation on screen**


**Figure 13 – Example of acquired images in multi-view display**

#### 7.1.1.2 Measuring equipment

The following equipment shall be used:

a) driving power source;
b) driving signal equipment; and
c) LMD.

#### 7.1.1.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: $i^{th}$-pixel white is applied (see 4.4).
b) measuring points: the multi-point measurements are applied (see Figure 9). The applied number of measuring points ($n$ by $m$) shall be noted in the report;
c) measuring direction: at the centre point on the screen, the maximum luminance direction of the closest peak from the perpendicular of the display is obtained (see 5.1). From the centre point, the measuring direction is this maximum luminance direction. The luminance

of light ray where the closest peak exists is assigned to $L_{main}$. $L_{main}$ $(a, b)$ is the luminance of the selected light ray at the measuring point, P$(a, b)$. For each measuring point, the measuring direction is the direction from the LMD position to each measuring point. The selected light ray as main and the selected direction shall be noted in the report;

NOTE For a two-view display, at least two measuring points exist.

d) measuring distance: designed viewing distance is applied (see 4.3.1).

#### 7.1.1.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the test signals for $Im_1$;

b) measure the luminance and record the luminance values;

c) change the test signal, and repeat b) until all test signals $Im_1$ to $Im_N$ are measured;

d) calculate 3D crosstalk at each position P$(a, b)$ (see Figure 13 and Figure 14):

$$X_{3D}\ (a,b) = \frac{\sum_{i=1}^{N}[L_i(a,b)] - L_{main}(a,b)}{L_{main}(a,b)} \times 100\,\%$$

where

$X_{3D}$ $(a, b)$ is 3D crosstalk at each position P$(a, b)$;

$L_{main}$ $(a, b)$ is the luminance of the selected light ray at the measuring point P$(a, b)$;

$L_i$ $(a, b)$ is the luminance of the $i^{th}$ light ray at the measuring point P$(a, b)$; and

$N$ is the number of views.

#### 7.1.1.5 Measurement report

3D crosstalk as well as the luminance components ratio and 3D crosstalk variation on screen shall be reported in a table. Table 8 shows an example.

Report the 3D crosstalk at the centre position. For the 3D crosstalk variation on screen, report the maximum and minimum of 3D crosstalk with their positions on screen, and average 3D crosstalk on screen. The 3D crosstalk at each position shall be reported, if required in the relevant specification.



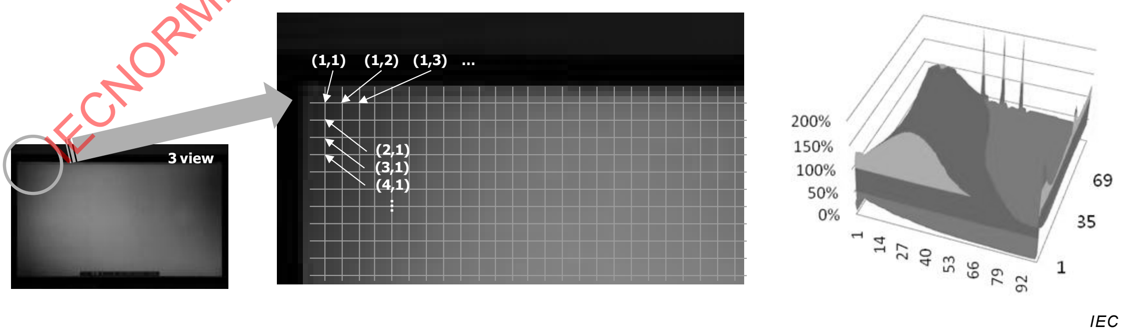



**Figure 14 – Spatial luminance data acquisition (left) and example of calculated spatial crosstalk graph (right)**

**Table 8 – Example of measurement results for 3D crosstalk variation on screen**

| | Result | Measurement position P($a$, $b$) |
|---|---|---|
| Main | 3rd view | – |
| Average | 95 % | – |
| Maximum | 152 % | P(3, 4) |
| Minimum | 53 % | P(35, 22) |
| Measuring positions are P(1, 1) to P(80, 45). | | |



### 7.1.2 3D crosstalk angular variation

#### 7.1.2.1 General

The purpose of this measurement is to measure 3D crosstalk angular variation.

#### 7.1.2.2 Measuring equipment

The following equipment shall be used:

a) driving power source;
b) driving signal equipment; and
c) LMD.

#### 7.1.2.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: $i^{\text{th}}$-pixel white is applied (see 4.4);
b) measuring point: the centre point is applied (see Figure 2);
c) measuring direction: the supplier specifies the measuring angular range and resolution (see Figure 5). The applied measuring angular resolution shall be described in the relevant specification. The applied angular range and resolution shall be noted in the report;

   NOTE For a two-view display, at least two measuring points exist.

d) measuring distance: the designed viewing distance is applied (see 4.3.1).

#### 7.1.2.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the test signals for $Im_1$;
b) change the measuring direction, measure the luminance and record the luminance values;
c) change the test signal to $Im_N$, and repeat the measurement;
d) calculate 3D crosstalk and luminance components ratio:

$$X_{3D} = \frac{\sum_{i=1}^{N} L_i - \max(L_i)_{i=1}^{N}}{\max(L_i)_{i=1}^{N}} \times 100\%$$

$$LCR(i) = \frac{L_i}{\sum_{i=1}^{N} L_\mathrm{i}} \times 100\%$$

where

| | |
|---|---|
| $X_{3D}$ | is 3D crosstalk; |
| $L_i$ | is the white luminance of each test signal $Im_1$ to $Im_N$; and |
| $LCR(i)$ | is the luminance components ratio. |

#### 7.1.2.5 Measurement report

3D crosstalk and luminance components ratio at each angle shall be reported. Table 9 shows an example.

**Table 9 – Example of measurement results for 3D crosstalk angular variation**

| Measuring direction $\theta_H$ | 3D crosstalk % |
|---|---|
| 0 | 5,0 |
| 1 | 5,2 |
| 2 | 5,8 |
| 3 | 5,6 |
| 4 | 5,2 |

## 7.2 3D crosstalk related property for multi-view display

### 7.2.1 General

Two measures are introduced to represent 3D crosstalk related property for multi-view displays in 7.2.

NOTE Auto-stereoscopic 3D multi-view displays continue to be developed. One of the development trends is to increase the number of views up to dozens of views. The 3D crosstalk characteristics are determined by various factors such as lens specification, display panel structure, target depth, etc. As a result, the 3D crosstalk can influence display performances such as blur appearance, reproducible depth range, etc. However, there is a limit to represent these aspects using a single 3D crosstalk measuring method. Thus, two measures are introduced and the term 'related' is added between '3D crosstalk' and 'property' in the title of 7.2.

### 7.2.2 Offset crosstalk

#### 7.2.2.1 General

The purpose of this measurement is to measure the offset crosstalk, that is, the offset luminance component of the angular profile of luminance. As shown in Figure B.1 and Figure 15, generally the angular profile of luminance has the minimum luminance, which is caused by the imperfection of optics for 3D displays, diffraction or scattering of attaching the optics (i.e., the optics material, glue, and so on). The offset crosstalk shows the luminance leakage into an observed monocular view from the other monocular image assigned to show the largest parallax against the observed image. When the offset crosstalk is large, this means that the separation of parallax images will be worse, and many ghosts will be observed.

This is the worst situation for multi-view displays, and therefore this level needs to be evaluated. The offset crosstalk is applied not only to multi-view displays, but also to two-view displays. In two-view displays, this explanation is the same as that in described in 7.1.1.

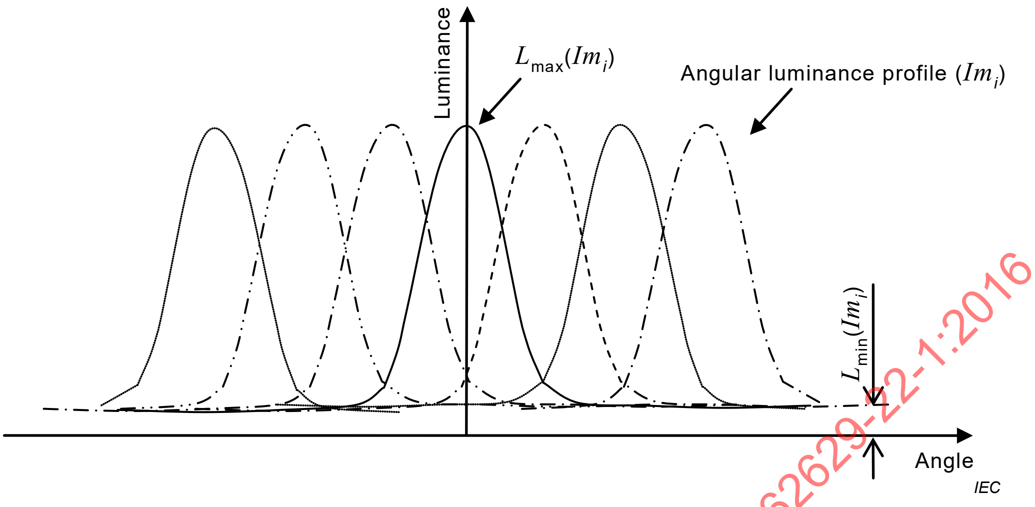



**Figure 15 – Example of minimum luminance and maximum luminance for offset crosstalk**



#### 7.2.2.2 Measuring equipment

The following equipment shall be used:

a) driving power source;
b) driving signal equipment; and
c) LMD.

#### 7.2.2.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: $i^{th}$-pixel white is applied (see 4.4).
b) measuring points: centre point (see Figure 2);
c) measuring direction: at the centre point on screen, the angular position of each maximum luminance $\theta_{Lmax}(Im_i)$ is obtained (see 5.1). From the centre point, the measuring direction is set to be the closest peak direction $\theta_{Lmax}(Im_N)$ from the perpendicular of the display. The luminance of light ray where the closest peak exists is assigned to $L_{max}(Im_N)$. The selected light ray as main and the selected direction shall be noted in the report;
d) measuring distance: the designed viewing distance is applied (see 4.3.1).

#### 7.2.2.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the test signals for $Im_i$, where $Im_i$ is assigned to show the largest parallax against $Im_N$;
b) measure luminance and record the luminance values as the minimum luminance $L_{min}(Im_i)$;
c) apply the all-pixel black signal (at 0 % level) or all-pixel black, and measure luminance $Im_{all\ black}$;
d) calculate the offset crosstalk:

$$X_{offset} = \frac{L_{min}(Im_i) - L_{all\ black}}{L_{max}(Im_N) - L_{all\ black}} \times 100\,\%$$

where

$X_{\text{offset}}$ is the offset crosstalk.

Instead of the minimum luminance $L_{\text{min}}(Im_i)$, the minimum luminance of the luminance profile $Im_i$ can be applied, if the value level is almost same.

#### 7.2.2.5 Measurement report

Report the offset crosstalk, the maximum luminance, the number of light rays for the maximum luminance, the minimum luminance, the number of light rays for the minimum luminance, and the luminance of the all-pixel black signal. Table 10 shows an example.

**Table 10 – Example of measurement results for offset crosstalk**

| **Offset crosstalk** % | **Maximum luminance** cd/m$^2$ | **Number of light rays for maximum luminance** | **Minimum luminance** cd/m$^2$ | **Number of light rays for minimum luminance** | **Luminance of all-pixel black signal** |
|---|---|---|---|---|---|
| 2,2 | 120,2 | 5 | 4,2 | 1 | 1,6 |

NOTE The adjacent overlap, as shown in Figure 16, is one of the performance parameters for multi-view displays. However, it is not the same as crosstalk, because some benefits exist even in case of a higher overlap value, such as making the motion parallax smoother. This value is only valid for showing the status of the luminance profile. The adjacent overlap is calculated as the ratio of the luminance of the adjusted profile at the maximum luminance direction to the maximum luminance.

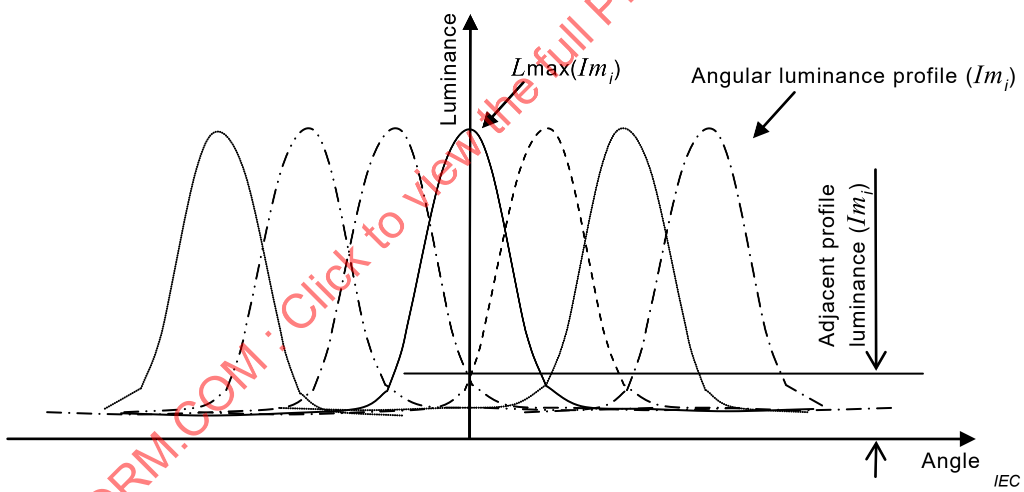



**Figure 16 – Example of adjacent overlap**



### 7.2.3 3D pixel crosstalk

#### 7.2.3.1 General

A set of light rays can be produced from the sub-pixels in a row for one lens pitch. These light rays reproduce a set of perspective images. Figure 17 illustrates an example of slanted lens configuration where 4,688 sub-pixels in a row are covered in one lens pitch. The same set of perspective images can be presented repeatedly from every lens. Otherwise, different sets of perspective images can be reproduced respectively according to the lens. The arrangement of output perspective images is determined by suppliers. Subclause 7.2.3 introduces 3D pixel crosstalk characteristics that can be obtained from a set of output images reproduced by the sub-pixels in a row for one lens pitch. The reasons causing 3D pixel crosstalk are various:

1) design property for lens and sub-pixels (width/height of sub-pixels, slanted angle of lens, black matrix size, etc.) in the display architecture, and

2) lens position error, inhomogeneous gap between lens and front panel, lens properties such as spherical aberration, astigmatism, etc., and imperfection of optics due to errors of fabrication in the manufacturing process.

The 3D pixel crosstalk reflects how much these factors affect the spreading of light rays (FWHM and tail in the luminance profile). From the 3D pixel crosstalk value, the mixing amount can be estimated between a target output image from a sub-pixel and the neighboring images from its adjacent sub-pixels whose sub-pixels are located under the same lens.

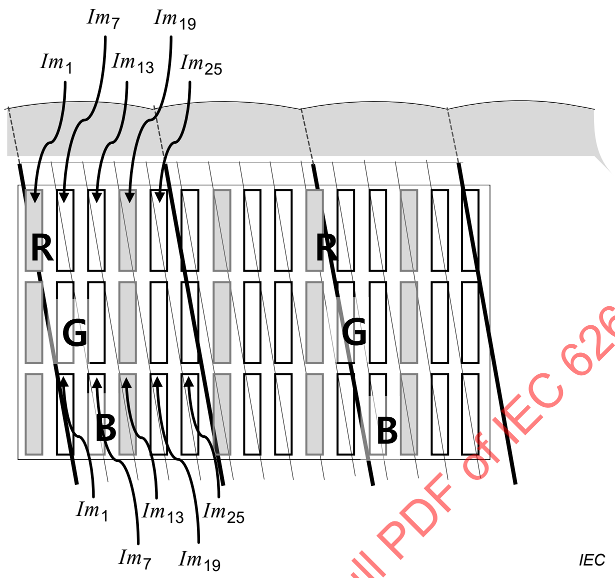



**Figure 17 – Example of slanted lens configuration where 4,688 sub-pixels in a row are covered in one lens pitch**

### 7.2.3.2 Measuring equipment

The following equipment shall be used:

a) driving power source;

b) driving signal equipment, and

c) LMD.

The inter-view angle between two adjacent images becomes smaller if the number of perspective output images is increased to dozens. This requires the LMD having high angular resolution in order to measure densely spaced luminance profiles. The measuring layout example using a 2D LMD such as a CCD is shown in Figure 18. The CCD shall be moved with a very narrow gap in the $x$ and $z$ axes to measure lights traversing in the $x$ and $z$ axes. The measuring system illustration in Figure 18 can be applied not only to multi-view displays having dozens of perspective images but also to integral imaging displays for which a CCD is required to be located close to the display for measuring the luminance in every pixel.

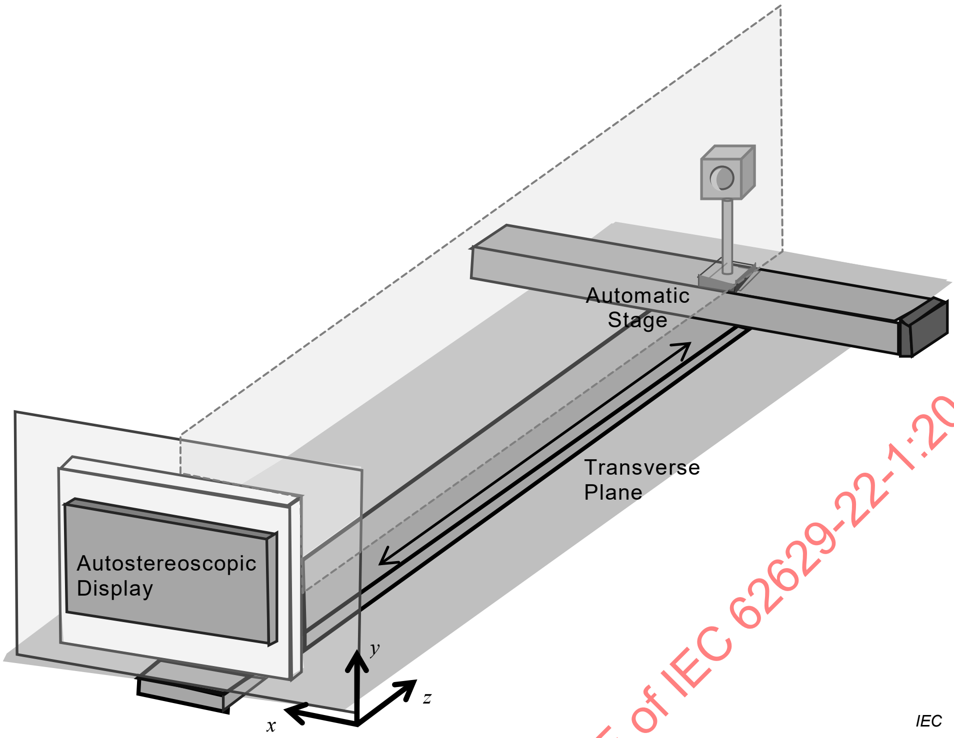



**Figure 18 – Measuring layout example for 3D pixel crosstalk for multi-view displays having dozens of perspective output images**



#### 7.2.3.3 Measuring conditions

The following detailed conditions shall be applied:

a) test signal: one of test images, $Im_1$ to $Im_N$, is applied (see 4.4);

b) measuring points: the multi-point measurements are applied (see Figure 8). The applied number of measuring points (5 points or 3 points) shall be noted in the report;

NOTE A test pattern is applied for the multi-point measurements when the measuring layout using a CCD system in Figure 18 is applied.

c) measuring angular range: the supplier shall specify the measuring angular range (e.g. $xy$ ranges in Figure 18);

d) measuring distance: The supplier shall suggest the measuring distance range (e.g. $xyz$ ranges in Figure 18).

#### 7.2.3.4 Measuring procedure

The following measuring procedure shall be carried out:

a) after warming up the display, apply the test signals for $Im_1$ where the full white signal is given to $Im_1$;

b) measure the luminance angular profile at each selected angle and record the luminance values;

c) change the test signal and repeat b) until all tests (test signals $Im_1$ to $Im_N$) are carried out.

#### 7.2.3.5 Measuring report

The measured results shall be reported according to the following calculation procedure:

a) plot the luminance angular profiles as shown in Figure 19;

b) report $\theta_{\text{Lmax}}(Im_i)$, the angular position of maximum luminance for each of the test signals $Im_1$ to $Im_N$;

c) report a group of test signals produced from the same lens. The relevant information shall be offered by suppliers;

d) calculate the 3D crosstalk value for each of the test signals that are produced from the same lens. Table 11 shows an example of 3D crosstalk calculation results.

The angular position of $\theta_{\mathrm{Lmax}}(Im_i)$ is calculated from the measuring positions in the $x$ and $z$ plane in Figure 18. The angular position of each maximum luminance $\theta_{\mathrm{Lmax}}(Im_i)$ is the angle of each maximum luminance value of the closest peak from the normal of the display. When the luminance angular profile does not show a clear peak, the centre of FWHM can be applied (see Annex B).

$$X_{\mathrm{3DP}}(i) = \frac{\sum_j L_j(\theta_{\mathrm{Lmax}}(Im_i))}{L_i(\theta_{\mathrm{Lmax}}(Im_i))} \times 100\%$$

where

$X_{\mathrm{3DP}}\ (i)$ is 3D pixel crosstalk;

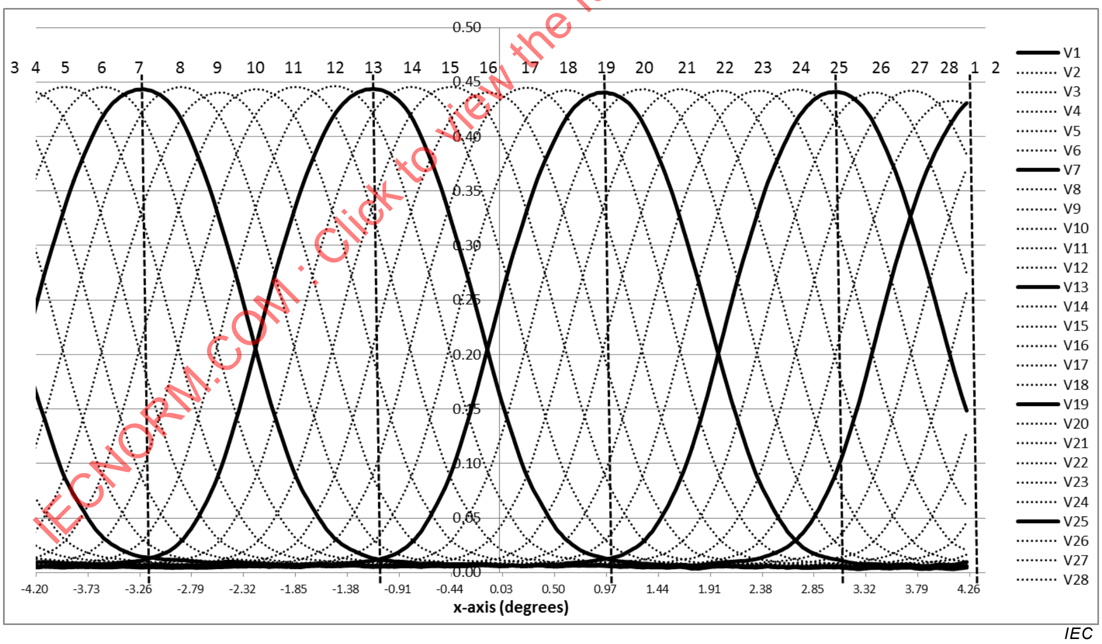
$\theta_{\mathrm{Lmax}}(Im_i)$ is the angular position of maximum luminance for each of the test signals $Im_1$ to $Im_N$;

$L_i$ is the luminance of $Im_\mathrm{i}$ white signal at $\theta_{\mathrm{Lmax}}(Im_i)$;

$L_j$ is the luminance for each of the test signals produced from the same lens as for $Im_i$; and

$j$ indicates each of the test signals coming out from the sub-pixels located under the same lens as for the target test signal $i$. This information shall be provided by suppliers.






NOTE $Im_1$, $Im_7$, $Im_{13}$, $Im_{19}$ and $Im_{25}$ are produced from the same lens.

**Figure 19 – Example of luminance angular profile for a multi-view display having 28 views (perspective images)**

**Table 11 – Example of 3D pixel crosstalk calculation results**

| Test signal $Im_i$ | $\theta_{Lmax}(Im_i)$ degree | Test signals produced from the same lens as for $Im_i$ | 3D pixel crosstalk % |
|---|---|---|---|
| $Im_7$ | -3,23 | 1, 13, 19, 25 | 8,3 |
| $Im_{13}$ | -1,15 | 1, 7, 19, 25 | 7,9 |
| $Im_{19}$ | 0,95 | 1, 7, 13, 25 | 8,6 |

NOTE The $Im_1$, $Im_7$, $Im_{13}$, $Im_{19}$, and $Im_{25}$ test signals in Figure 19 are produced from the same lens. These five test signals are reproduced from the sub-pixels located under the same lens whose example is illustrated in Figure 17. These constitute a set of output perspective images in one lens pitch. For example, the 3D crosstalk values for $Im_7$, $Im_{13}$ and $Im_{19}$ are calculated by considering $Im_1$, $Im_7$, $Im_{13}$, $Im_{19}$, and $Im_{25}$ test signals.

# Annex A
(informative)

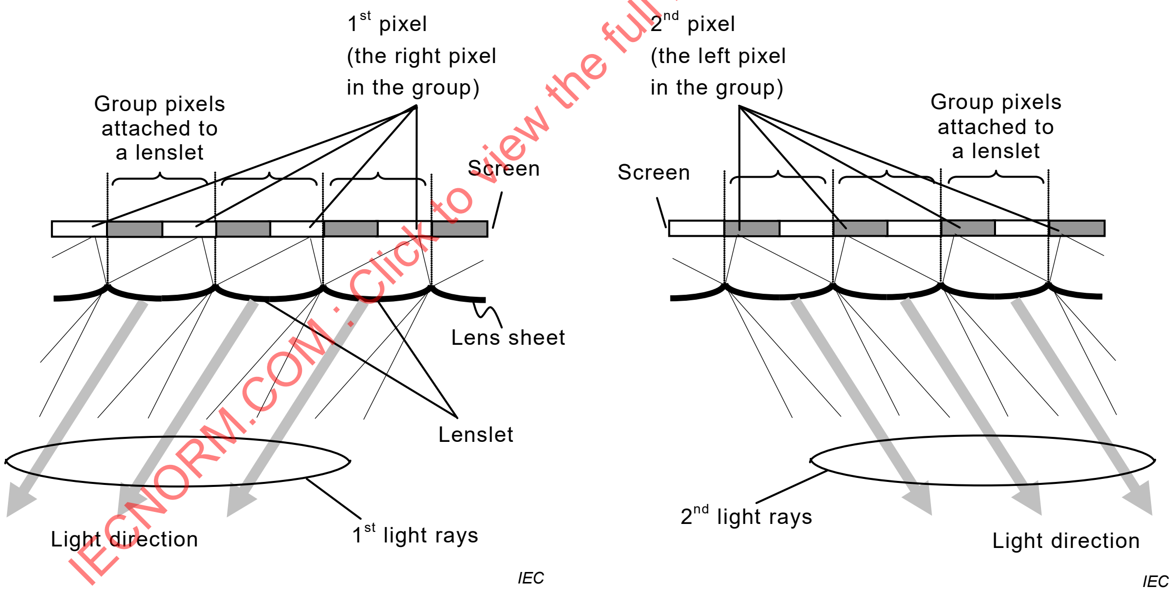
# Principle of autostereoscopic display

## A.1 General

The autostereoscopic display treated in this document is characterized by radial light emission from group pixels on the screen and classified into three types according to how the emission is controlled, i.e. two-view display, multi-view display and integral imaging display. This classification follows recent academic and industrial trends in general. Clauses A.2 to A.4 briefly introduce these three types respectively.

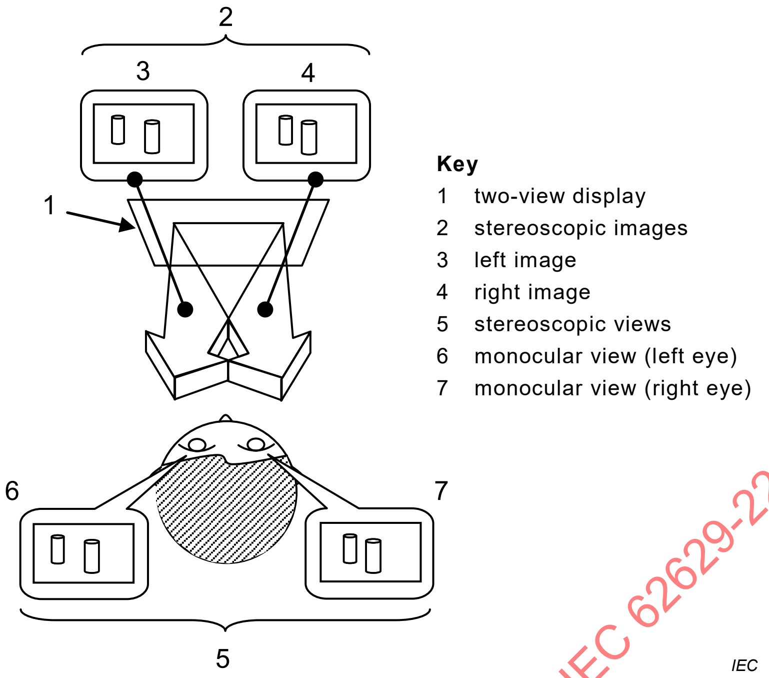
## A.2 Two-view display

A two-view display has two kinds of pixel for showing left and right images (1st pixel and 2nd pixel), as shown in Figure A.1. On the screen, an optical component for distributing the light from each pixel into each eye, such as a lens sheet, is attached. Each lenslet of the lens sheet corresponds to each pixel group of 1st and 2nd pixels. The light ray from the 1st pixel passing through the corresponding lenslet will generate 1st light rays, while the light ray from the 2nd pixel will generate 2nd light rays. When the left part of stereoscopic images is observed by the left eye, and the right part is observed by the right eye, as illustrated in Figure A.2, binocular parallax for depth perception is created.




**a) Test image $Im_1$** **b) Test image $Im_2$**

**Figure A.1 – Structure of two-view display**




**Key**

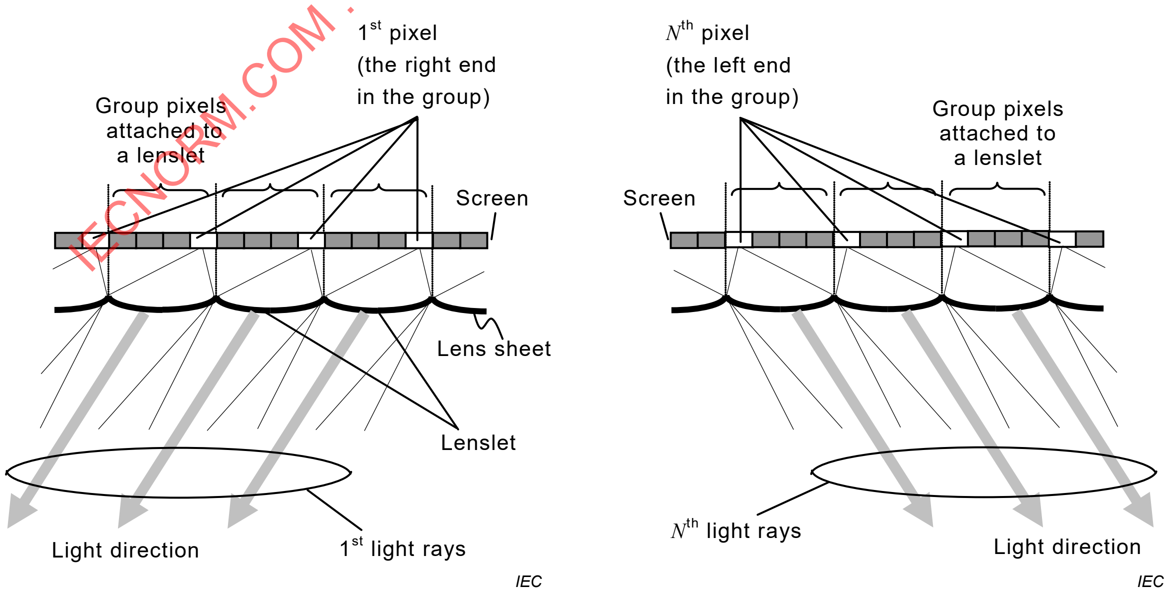
1 two-view display
2 stereoscopic images
3 left image
4 right image
5 stereoscopic views
6 monocular view (left eye)
7 monocular view (right eye)

**Figure A.2 – Basic principle of two-view display**



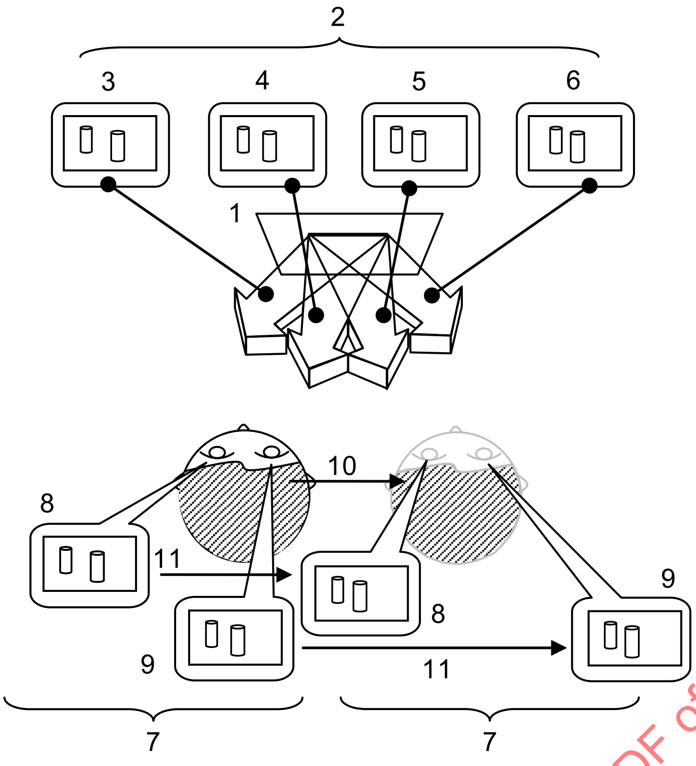
## A.3 Multi-view display

A multi-view display is an autostereoscopic display that creates more than two monocular views with which the stereoscopic images are coupled. Figure A.3 and Figure A.4 show a typical multi-view display whose number of views is four. The number of views is defined as the number of monocular views with which stereoscopic images are coupled. In this case four stereoscopic images (images 1, 2, 3 and 4) are shown. When the left eye sees image 1 and the right eye sees image 2, binocular parallax for depth perception can be created. In addition, when each eye sees the other images, binocular parallax can also be created. This means that motion parallax can be obtained, when the head moves from left to right and vice versa.




a) Test image $Im_1$ b) Test image $Im_N$

**Figure A.3 – Structure of multi-view display**




**Key**
1 multi-view display
2 stereoscopic images
3 image 1
4 image 2
5 image 3
6 image 4
7 stereoscopic views
8 monocular view (left eye)
9 monocular view (right eye)
10 head movement
11 motion parallax

**Figure A.4 – Basic principle of multi-view display**

## A.4 Integral imaging display

An integral imaging display is based on the method of spatial image reproduction, which optically reproduces an object surface in space. The integral imaging display simulates the reflected light so that plural observers can see the surface of the displayed object. Therefore, it is necessary that the surface of the real object is optically sampled and that the obtained small images, which are called elemental images, are projected in space. Observers perceive a reproduced object as if it exists in space with binocular or motion parallax. For the sampling and projection shown in Figure A.5, a fly-eye lens – a sheet of two-dimensionally arranged lenslets – is generally used. A lenticular sheet is adopted in place of the fly-eye lens to provide only horizontal parallax.

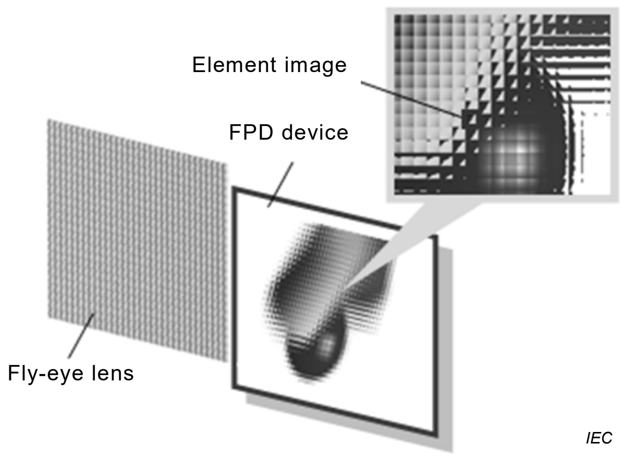



**Figure A.5 – Basic principle of integral imaging display**

The structure of the integral imaging display is similar to that of the multi-view display. However, the design of an integral display is not based on the premise that there should be a specific viewing position that many light rays concentrate on.