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INTERNATIONAL STANDARD

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Laser displays –
Part 5-5: Optical measuring methods of raster-scanning retina direct projection laser displays

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INTERNATIONAL
ELECTROTECHNICAL
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CONTENTS

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LASER DISPLAYS –

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

Draft	Report on voting
110/1374/FDIS	110/1392/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts of the IEC 62906 series, under the general title *Laser display devices*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
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LASER DISPLAYS –

Part 5-5: Optical measuring methods of raster-scanning retina direct projection laser displays

1 Scope

This part of IEC 62906 specifies the standard measurement conditions and optical measuring methods for raster-scanning retina direct projection laser displays with light sources such as direct-emitting lasers, optionally equipped with higher-order harmonic generation devices. The hybrid light sources using both lasers and spontaneous-emission-based light sources are not considered.

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 TR 60825-14, *Safety of laser products – Part 14*: *A user's guide*

IEC 62595-2-4:2020, *Display lighting unit – Part 2-4: Electro-optical measuring methods of laser module*

IEC 63145-20-10:2019, *Eyewear displays – Part 20-10: Fundamental measurement methods – Optical properties*

IEC 63145-20-20:2019, *Eyewear displays – Part 20-20: Fundamental measurement methods – Image quality*

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

CIE 233, *Calibration, Characterization and Use of Array Spectroradiometers*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

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

3.1.1
raster-scanning retina direct projection laser display
RS-RDP laser display
laser projector projecting images by raster scanning directly on the retina which does not need an external screen or virtual image optics for observation

Note 1 to entry: For an example, see Annex A and [1] [1].

3.1.2
Maxwellian view image
<RS-RDP laser display> image projected on the retina using a method of observation in which a converging lens forms an image of the light source in the plane of the eye's pupil of the observer, instead of looking at the source directly

Note 1 to entry: For an example, see Annex B.

3.1.3
effective angular image resolution
<RS-RDP laser display> ability of raster-scanning retina direct projection displays to distinguish details of an image, which are measured using grille patterns and expressed as line pairs per degree

3.1.4
focal point
<RS-RDP laser display> position of the smallest beam spot in the vicinity of the exit of the optical system of the RS-RDP laser display

3.1.5
retinal free focus range
<RS-RDP laser display> length along the eye-axis in which an acceptable value of effective angular image resolution can be obtained

3.1.6
laser multi-meter
light measuring device based on non-spectrometric methods using absorption filters with linear wavelength ramps capable of measuring centroid wavelength and optical power of laser light sources operating in single or multiple longitudinal mode, from which the tristimulus values XYZ are calculated to derive colorimetric and photometric quantities using the CIE colour-matching functions

Note 1 to entry: Also defined in IEC 62595-2-4. See [2].

3.2 Abbreviated terms

CCD	charge-coupled device
CMOS	complementary metal oxide semiconductor
DUT	device under test
FOV	field of view
FWHM	full width at half maximum
IPD	inter-pupillary distance
IR	infrared
LD	laser diode
LMD	light measuring device
MEMS	microelectromechanical system

[1] Numbers in square brackets refer to the Bibliography.

RGB red, green, and blue

ROI regions of interest

RS-RDP raster-scanning retina direct projection

SHG second harmonic generation

2D two-dimension, two-dimensional

3D three-dimension, three-dimensional

4 Standard measuring conditions

4.1 Standard measuring environmental conditions

Optical measurements related to RS-RDP laser displays shall be carried out under the following standard environmental conditions:

– temperature: 25 ºC ± 3 ºC,

– relative humidity: 25 % to 85 % RH,

– atmospheric pressure: 86 kPa to 106 kPa.

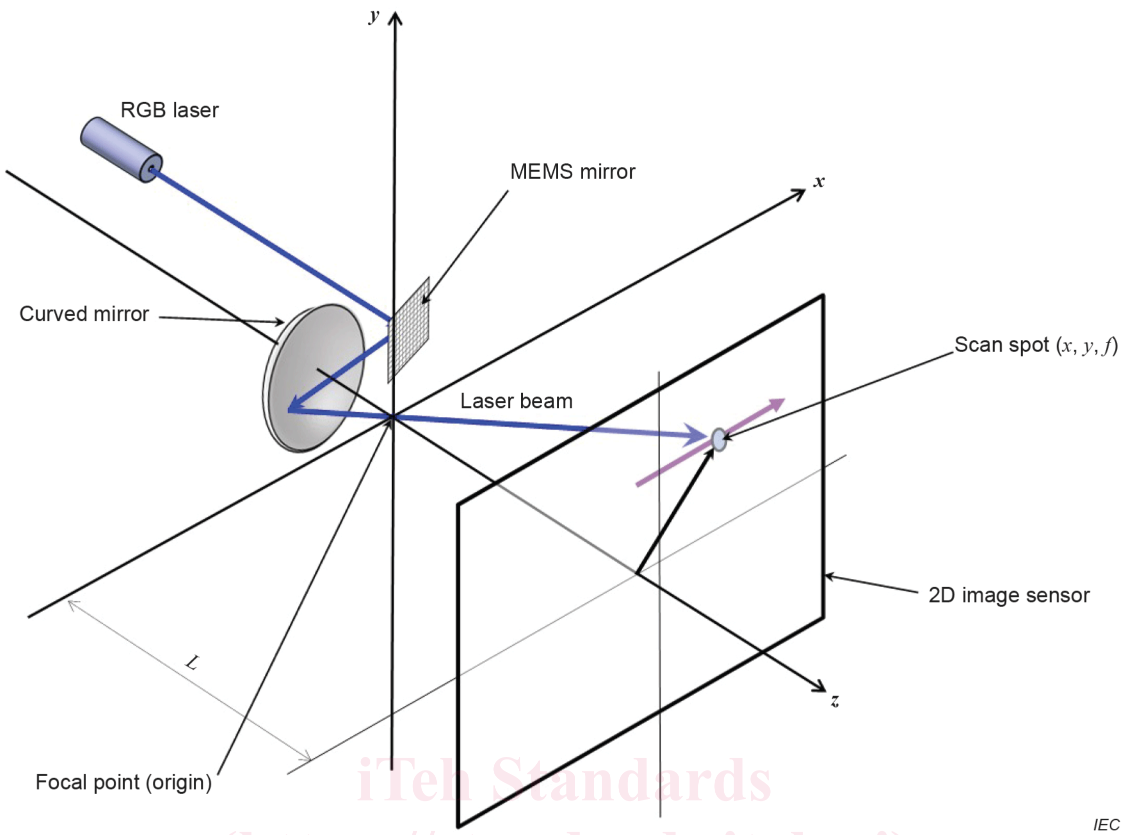
When different environmental conditions are used, they shall be noted in the report. The dark room illuminance at the focal point shall be less than 0,01 lx, or the luminance contribution from the background in the test room reflected off the measurement space shall be less than 1/20 of the minimum luminance output from the DUT. If the condition is not satisfied, then background subtraction is required, and it shall be noted in the report.

4.2 Coordinate system

The measurement coordinate system is shown in Figure 1 for illuminance or irradiance measurements. The origin of the coordinate system is placed at the focal point of the RS-RDP laser display. In the Cartesian system, the horizontal x axis and the vertical y axis lie on a plane (x-y plane) parallel to the line between the two eyes. The z axis is normal to the x-y plane. The optical measurements shall be carried out on a planar sensor parallel to the x-y plane if noted. The coordinate conversion between the retinal screen and the planar screen is shown in Annex C.

The length from the focal point (origin) to the 2D image sensor L shall be 16,7 mm when the f = 16,7 mm lens is applied in the measurement, reflecting the lens power of the human eye (60 m^{-1}) in air. See Annex C for details. It should be noted that the focal point usually does not coincide exactly with the centre of the pupil and can also be inside the vitreous body.

For spectral radiance and luminance measurements, the lens is not required and the measurement coordinate system with eye rotation described in IEC 63145-20-10 shall be used. In that case, the entrance pupil of the LMD is centred at the focal point and the LMD is pivoted about a point 10 mm behind the entrance pupil when scanning the field of view over the virtual image.



NOTE This is an example. Two single-axis MEMS mirrors can be also used.

Figure 1 – Coordinate system and setup for planar measurements

4.3 Standard conditions of RS-RDP laser displays and light measuring devices

4.3.1 General

Measurements shall be started after the DUT (device under test: RS-RDP laser display) and LMD (light measuring device) have gained sufficient stability. All the LMDs shall be suitably calibrated, and the calibration data shall be recorded. Residual infrared (IR) radiation shall be filtered out if a photon up-conversion laser device including SHG (second harmonics generation) is used as a light source (see IEC 62595-2-4:2020, Clause A.5).

4.3.2 Adjustment of RS-RDP laser display

The RD-RDP laser display shall be measured in the default mode unless otherwise specified. All measurements shall be carried out in the same display mode.

4.3.3 Requirements for light measuring device

The requirements for narrow linewidth laser spectra are described in IEC 62906-5-6 [5]. The wavelength accuracy required for a certain chromaticity accuracy is described in IEC 62595-2-4. The LMD performance particularly used for the RS-RDP laser displays shall be as follows.

a) Laser power meter
   1) power range: 10 nW to 1 mW
   2) accuracy: ±5 %
   3) spectral wavelength range: covering at least the R, G, B-LD wavelengths
   4) spectral responsivity: calibrated for a given wavelength
   5) integration time: integral multiples of frame period

b) 2D image sensor
   1) type of sensor: CMOS or CCD
   2) pixel size: < 10 μm
   3) pixel number: > 8 mega (3 264 x 2 488) pixels
   4) minimum illuminance: 0,01 lx
   5) linearity error: < 2 %

      over 5 % to 95 % of the LMD measurement range, particularly for the resolution measurement.
   6) AD converter: ≥ 10 bits
   7) exposure time: an integer multiple of frame period
   8) polarization error: < ±2 %

   The 2D image sensor is used for eye-box measurement, FOV measurement, and angular resolution measurement. For the measurement of chromaticity non-uniformity, the 2D sensor should be used only for measuring the relative intensity distribution of monochromatic lasers.
c) Illuminance meter (ISO/CIE 19476)
   1) minimum illuminance: 0,01 lx
d) Spectral irradiance meter
   1) wavelength range: covering the R, G, B-LD wavelengths
   2) spectral bandwidth: ≤ 5 nm (FWHM)
   3) wavelength accuracy: ± 0,3 nm
   4) polarization error: < ±2 % at R, G, B-LD wavelengths
   5) diameter of the measurement area, typically ≤ 4 mm
   6) spectral stray light correction recommended
e) Laser multi-meter (see 3.1.6)
   1) wavelength range: covering the R, G, B-LD wavelengths
   2) power range: zero to the absolute maximum rating
   3) wavelength accuracy: ±0,3 nm
f) Spectroradiometer (according to IEC 63145-20-10 and CIE 233)
   1) wavelength range: covering the R, G, B-LD wavelengths
   2) spectral bandwidth: ≤ 5 nm (FWHM)
   3) polarization error: < ±2 % R, G, B-LD wavelengths
   4) measurement field angle: ≤ 2°
   5) entrance pupil diameter: 2 mm to 5 mm
   6) wavelength accuracy: ±0,3 nm
   7) spatial variation in entrance pupil response [3]: < 5 %
   8) spectral stray light corrected
g) Spectral radiant flux meter (according to CIE 233)
   1) integrating sphere with ≥ 4 mm diameter measurement port
   2) wavelength range: covering the R, G, B-LD wavelengths
   3) spectral bandwidth: ≤ 5 nm (FWHM)
   4) wavelength accuracy: ±0,3 nm
   5) polarization error: < ±2 % R, G, B-LD wavelengths
   6) spectral stray light correction recommended

h) 2D imaging LMD (according to IEC 63145-20-20)
   1) entrance pupil diameter: 2 mm to 5 mm
   2) at least four sensor pixels per virtual image sub-pixel
   3) AD converter: ≥ 10 bits
   4) exposure time: an integer multiple of frame period
   5) polarization error: < ±2 %
   6) includes background subtraction, flat field correction, and geometric correction

NOTE LMDs for scanning laser displays are subject to detector saturations errors (see [4]).

4.4 Laser-safety requirements for measurement

The measurement shall be carried out strictly in accordance with the requirements of IEC TR 60825-14.

5 Optical measuring methods

5.1 General

An RS-RDP laser display is a specific type of raster-scanning projector. This document particularly specifies the following optical measurement items:

– optical power at the primary colour wavelength
– eye-box
– field of view
– aspect ratio
– effective angular image resolution
– retinal free focus range
– retinal white illuminance
– luminance and chromaticity of virtual image
– white chromaticity non-uniformity

5.2 Optical power at the primary colour wavelength

5.2.1 General

The measurement of the optical output power of the DUT and of the optical power coupled into an eye through the pupil is very important. It can be classified by the optical power levels of eyewear displays. The optical power of the narrow linewidth spectrum at each R, G, B primary colour wavelength is separately measured for the analysis of the performance of each laser device.

The two points in Figure 2 are appropriate for measuring the optical power. One is the output exit window (measurement point 1) which is closest to the beam spot at the MEMS mirror inside the DUT. The other is the focal point of the power incident to the eye (measurement point 2).

The DUT shall be measured under the dark room conditions specified in 4.1.

5.2.2 Measurement at exit window (measurement point 1)

The exit window is not always accessible because the optical path can be routed inside the DUT housing. Therefore, this measurement may be skipped if it is inaccessible. Otherwise, the measurement shall be carried out.

A full-frame scan area at the measurement point 1 is calculated by the scan angle and the distance from the MEMS position. Depending on the DUT design, the full-frame scan area can be larger than the aperture of the optical power meter. In such a case, a centre pattern much smaller than the full-frame scan area should be used to measure the optical power within the aperture of the laser power meter. Any shapes of the centre pattern may be used if the size at the measurement point 1 is smaller than the aperture size of the power meter.

The individual R, G, B laser powers shall be measured as follows:

a) Measure the wavelength λ_R with a spectrometer at the measurement point 1.

b) Check whether spectral output powers other than red are present or not. If present, one of the methods specified in 5.2.4 is applied.

c) Confirm that the laser power meter collects all the optical power.

d) Display a full-screen monochromatic red colour image or a smaller centre monochromatic red colour pattern with the maximum signal coding.

e) Measure the time-averaged optical power P_R for red at the measurement point 1 using a laser power meter, or spectral radiance flux LMD, with ≥ 4 mm aperture without laser beam clipping (4.3.3, a) or g)).

f) Repeat a) to e) for green and blue to obtain (P_G, λ_G) and (P_B, λ_B), respectively.

g) Convert the measured power into the full-screen power by multiplying the scaling factor of the centre pattern and the full-screen area when the smaller centre pattern is used, assuming that the laser power changes linearly with the scan area.

h) Report the power and the centroid wavelength for the red, green, and blue images.

5.2.3 Measurement at focal point (measurement point 2)

The individual R, G, B laser powers shall be measured as follows:

a) Measure the wavelength λ_R with a spectrometer at the measurement point 2.

b) Check whether spectral output powers other than red are present or not. If present, one of the methods specified in 5.2.4 shall be applied.

c) Confirm that the laser power meter collects all the optical power.

d) Display a full-screen monochromatic red colour image with the maximum signal coding.

e) Measure the time-averaged optical power P_R at the measurement point 2 using a laser power meter, or spectral radiance flux LMD, with ≥ 4 mm aperture without laser beam clipping (4.3.3, a) or g)).

f) Repeat a) to e) for green and blue to obtain (P_G, λ_G) and (P_B, λ_B), respectively.

g) Report the power and the centroid wavelength for the red, green, and blue images.

5.2.4 Elimination of the effect of other spectral powers

The optical output power at each primary colour shall be measured and reported. When there is significant spectral output power that can affect the measured power at the intended specific colour wavelength, it shall be eliminated using appropriate optical filters.

The extinction ratio is the optical power ratio of the measured output power P_1 at the specific colour wavelength to the biased level P_0 with zero-input signal at the same wavelength. If the unexpected spectral output power with zero-input signal significantly affects the measured data, it shall be reported. For example, laser diodes are usually biased around the threshold current for high-speed modulation. The bias just above the threshold current sometimes reduces the extinction ratio because of the small output power at the bias level.

The residual IR power shall be also filtered out if a photon up-conversion laser device including SHG is used (see 4.3.1). The IR power shall be measured and reported.