

# INTERNATIONAL STANDARD



---

## Display lighting unit – Part 2-4: Electro-optical measuring methods of laser module



**THIS PUBLICATION IS COPYRIGHT PROTECTED**  
**Copyright © 2020 IEC, Geneva, Switzerland**

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

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

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://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 corrigendum or an amendment might have been published.

**IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)**

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 It also gives information on projects, replaced and withdrawn publications.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](http://webstore.iec.ch/justpublished)**

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

**IEC Customer Service Centre - [webstore.iec.ch/csc](http://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: [sales@iec.ch](mailto:sales@iec.ch).

**Electropedia - [www.electropedia.org](http://www.electropedia.org)**

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

**IEC Glossary - [std.iec.ch/glossary](http://std.iec.ch/glossary)**

67 000 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 62595-2-4

Edition 1.0 2020-09

# INTERNATIONAL STANDARD



---

## Display lighting unit – Part 2-4: Electro-optical measuring methods of laser module

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

---

ICS 31.120, 31.260

ISBN 978-2-8322-8912-9

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

## CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references .....	9
3 Terms, definitions, abbreviated terms, and letter symbols.....	9
3.1 Terms and definitions.....	9
3.2 Abbreviated terms and letter symbols .....	11
3.2.1 Abbreviated terms .....	11
3.2.2 Letter symbols.....	12
4 Standard measuring conditions.....	14
4.1 Standard measuring environmental conditions .....	14
4.2 Standard measuring dark-room conditions .....	14
4.3 Safety requirements.....	14
4.4 Standard DUT conditions .....	15
4.5 Standard LMD requirements .....	15
4.6 Standard measurement setup and coordinate system .....	17
5 Measuring methods .....	20
5.1 General.....	20
5.2 Current-light output characteristics .....	21
5.2.1 General .....	21
5.2.2 $I-P_o$ and $I-P_o / P_i$ characteristics.....	21
5.2.3 CW and PWM operations.....	22
5.2.4 Threshold currents ( $I_{th}$ ).....	23
5.2.5 Measurement procedures .....	24
5.3 Spectra (wavelength) and chromaticity measurements.....	25
5.3.1 General .....	25
5.3.2 Measurement procedures .....	25
5.4 FFP .....	26
5.4.1 General .....	26
5.4.2 Monochromatic FFP.....	26
5.4.3 Colorimetric FFP.....	27
5.5 Monochromatic speckle and colour speckle .....	30
5.5.1 General .....	30
5.5.2 Monochromatic speckle measurement affected by FFP.....	30
5.5.3 Colour speckle measurement affected by FFP .....	32
5.6 Temperature dependence .....	35
5.6.1 General .....	35
5.6.2 High-power LD module .....	35
5.6.3 Low-power RGB LD module.....	36
5.7 High-speed pulse modulation properties .....	37
5.7.1 General .....	37
5.7.2 Optical output pulse waveform measurement.....	37
Annex A (informative) Laser devices.....	40
A.1 Edge-emitting laser diode .....	40
A.2 Single- and multi-transverse modes .....	41
A.3 Single- and multi-longitudinal modes.....	42

A.4	Vertical cavity surface-emitting laser diode (VCSEL).....	43
A.5	Photon up-conversion laser device.....	45
Annex B (informative)	Structure of laser module .....	46
B.1	Monochromatic laser module .....	46
B.2	RGB laser module.....	47
B.3	Other output optics .....	48
Annex C (informative)	Narrow-linewidth emission spectra of laser modules .....	49
C.1	Spectra of monochromatic high-power LD modules .....	49
C.2	Spectra of multi-colour, single-longitudinal mode LD modules.....	51
C.3	Spectra of multi-colour, multi-longitudinal mode LD modules.....	51
C.4	Chromaticity measurements using a colorimeter .....	52
Annex D (informative)	Chromaticity accuracy when measuring narrow spectral linewidth .....	53
D.1	General.....	53
D.2	Wavelength accuracy to keep chromaticity accuracy < 0,001 or < 0,005 .....	53
D.3	Spectral bandwidth to keep chromaticity accuracy < 0,001.....	55
Annex E (informative)	Numerical aperture (NA) of fibre.....	58
E.1	Fibre NA and maximum divergence angle .....	58
E.2	Colour-dependence of fibre NA .....	58
Annex F (informative)	Conversion of the spherical and Cartesian coordinate systems.....	59
Annex G (informative)	Centroid wavelength .....	60
Annex H (informative)	Examples of colour speckle pattern on colorimetric FFPs of fibre output .....	62
H.1	General.....	62
H.2	Measured FFP .....	62
Annex I (informative)	Temperature dependence of LDs.....	65
I.1	Formulation of the thermal performance of LD chips .....	65
I.2	Calculated examples of $I-P_0$ characteristics .....	66
I.3	Temperature dependence of emitting wavelengths.....	69
I.4	Temperature dependence of colour speckle and FFP.....	69
Annex J (informative)	Eye diagram .....	71
J.1	Eye diagram .....	71
J.2	Examples of measured eye diagrams.....	72
Bibliography.....		73
Figure 1 – Measurement setup and coordinate system (spherical) .....		18
Figure 2 – Measurement setup and coordinate system (Cartesian) .....		19
Figure 3 – Measurement setup and coordinates for speckle-related optical performance .....		20
Figure 4 – Example of $I-P_0$ and $I-P_0 / P_i$ characteristics .....		22
Figure 5 – Pulse repetition waveforms of PWM drive with respect to duty cycle .....		23
Figure 6 – $I_{th}$ and $I-P_0$ characteristics.....		24
Figure 7 – Example of measured colorimetric FFP .....		29
Figure 8 – Example of conversion of the measured speckle data on the FFP into data on a uniform pattern.....		31
Figure 9 – Example of conversion of measured normalised illuminance data of colour speckle on the FFP into data on a uniform pattern .....		33

Figure 10 – Example of conversion of measured colour speckle chromaticity data on the FFP into data on a uniform pattern.....	33
Figure 11 – Temperature dependence measurement setup for high-power laser modules.....	36
Figure 12 – Temperature dependence measurement setup for low-power laser modules .....	37
Figure 13 – Measurement setup for output pulse waveform.....	38
Figure 14 – Example of input/output pulse waveforms.....	38
Figure A.1 – Schematic structure of narrow-stripe edge-emitting laser diode.....	40
Figure A.2 – Schematic structure of wide-stripe edge-emitting laser diode .....	41
Figure A.3 – Single- and multi-transverse mode patterns .....	42
Figure A.4 – Single- and multi-longitudinal mode patterns.....	42
Figure A.5 – Schematic structure of VCSEL .....	44
Figure A.6 – VCSEL array.....	44
Figure A.7 – Conceptual image of photon up-conversion.....	45
Figure A.8 – Example of SHG laser device emitting at 532 nm.....	45
Figure B.1 – High-power monochromatic laser module.....	46
Figure B.2 – High-power RGB laser module.....	47
Figure B.3 – Low-power RGB laser module.....	48
Figure B.4 – Other types of optical output .....	48
Figure C.1 – Superposition of multi-mode structures of three LDs .....	49
Figure C.2 – Spectral power density $S(\lambda)$ with a resolution of 0,1 nm .....	50
Figure C.3 – Spectral power density $S(\lambda)$ with a resolution of 1 nm .....	50
Figure C.4 – Example of RGB single-longitudinal mode spectra.....	51
Figure D.1 – Calculated wavelength accuracy to keep $ \Delta x ,  \Delta y  < 0,001$ .....	54
Figure D.2 – Calculated wavelength accuracy to keep $ \Delta x ,  \Delta y  < 0,005$ .....	54
Figure D.3 – Calculated wavelength accuracy to keep $ \Delta u' ,  \Delta v'  < 0,001$ .....	55
Figure D.4 – Calculated wavelength accuracy to keep $ \Delta u' ,  \Delta v'  < 0,005$ .....	55
Figure D.5 – Assumption for calculating the spectral bandwidth accuracy .....	56
Figure D.6 – Calculated spectral bandwidth accuracy to keep $ \Delta x ,  \Delta y  < 0,001$ .....	56
Figure D.7 – Calculated spectral bandwidth accuracy to keep $ \Delta u' ,  \Delta v'  < 0,001$ .....	57
Figure E.1 – Fibre cross-section of MMF (step-index) .....	58
Figure G.1 – Example of laser spectrum (peak and centroid wavelengths).....	60
Figure G.2 – Comparison of chromaticity error distributions between the data obtained by the peak wavelength and the centroid wavelength.....	61
Figure H.1 – Measured colour speckle patterns on colorimetric FFP for the low-power RGB laser module with an SMF output.....	62
Figure H.2 – Measured speckle-free colorimetric FFPs for the low-power RGB laser module with an SMF output.....	63
Figure H.3 – Example of speckled FFPs projected on the standard diffusive screen ( $x$ - $y$ plane) out of the MMF of a high-power RGB laser module .....	63
Figure H.4 – Example of un-speckled FFPs projected on the standard diffusive screen ( $x$ - $y$ plane) out of the MMF of a high-power RGB laser module .....	64
Figure I.1 – Example of temperature dependence of $I$ - $P_0$ characteristics of an LD package.....	66

Figure I.2 – Example of temperature dependence of $I$ - $P_O$ characteristics of an LD package with higher thermal resistance $R_{th}$ .....	67
Figure I.3 – Example of temperature dependence of $I$ - $P_O$ characteristics of an LD package for $I_{th} = 0,25$ (A) and $T_0 = 100$ (K) .....	68
Figure I.4 – Example of temperature dependence of output power, $P_O$ , for an RGB laser module .....	68
Figure I.5 – Example of temperature dependence of R, G, B wavelengths for an RGB laser .....	69
Figure I.6 – Example of temperature dependence of speckled FFP for an RGB laser .....	70
Figure J.1 – Example of PRBS .....	71
Figure J.2 – Example of eye diagram .....	71
Figure J.3 – Eye diagrams for digital frequencies at 100 MHz, 200 MHz, 300 MHz, and 500 MHz (R channel at $I = 38$ mA) .....	72
Table 1 – Letter symbols (quantity symbols/unit symbols) .....	12
Table 2 – Summarised results of the colour speckle measurements (example) .....	34
Table A.1 – Features of single- and multi-mode LDs .....	43
Table C.1 – CIE 1931 chromaticity calculated from the higher to the lower resolution spectra .....	51

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## DISPLAY LIGHTING UNIT –

## Part 2-4: Electro-optical measuring methods of laser module

## 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 62595-2-4 has been prepared by IEC technical committee 110: Electronic displays.

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

FDIS	Report on voting
110/1224/FDIS	110/1246/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 in the IEC 62595 series, published under the general title *Display lighting unit*, 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
- amended.

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

## INTRODUCTION

Laser modules, in general, have been used widely for various applications such as, optical communications, laser beam machining, bar-code reading, optical disc drives and so on. The laser module in this document is limited to display applications. It is a key light source for laser displays, laser backlight/front light units for liquid crystal displays (LCDs), holographic displays and so on. A typical laser module for display applications comprises multiple laser devices, electrical inputs and an optical output combining the outputs of the laser diodes (LDs). The laser device used in the laser module here is an edge-emitting laser diode (LD), a vertical cavity surface-emitting laser diode (VCSEL), or a photon up-conversion laser including second-harmonic generation (SHG).

The optical output is usually provided out of an optical component such as a pigtail fibre, a fibre with a connector, a waveguide, a light guide, or a lens unit for the convenience of users.

In advanced display applications, not only visible laser diodes but also near infrared (near IR) laser diodes are included in the module for sensor applications such as the LiDAR system (light detection and ranging, or laser image detection and ranging).

Therefore, the wavelength range for display applications covers all the visible wavelengths from 380 nm to 780 nm, including the laser diodes for pumping phosphors. That is, a violet laser diode emitting at 405 nm is included. Photometric and colorimetric measurements are the primary focus of this document. The near IR LD for a LiDAR system included in the module can be measured as a monochromatic light output using the light measuring device (LMD) covering the IR wavelength region. However, the measurements of IR lasers are out of the scope of this document.

It is important for the designing of the above display systems and devices to standardise the electro-optical measuring methods of the laser modules. Photometric and colorimetric measurements are particularly important for display applications because each LD has different electrical and optical performances, such as threshold currents, efficiency, spectrum, far field pattern (FFP) of the output laser beam, speckle-related behaviours and their temperature dependence.

Particularly for the colour speckle of the output laser beam, the measured speckle data are very useful to predict the visual quality of laser displays and to design speckle reducing devices.

## DISPLAY LIGHTING UNIT –

### Part 2-4: Electro-optical measuring methods of laser module

#### 1 Scope

This part of IEC 62595 specifies the electro-optical measuring methods of laser modules with multiple laser devices and an optical output for various displays and display lighting applications which require photometric and colorimetric measurements, covering the wavelength range of 380 nm to 780 nm. The module has multiple laser devices such as edge-emitting laser diodes (LDs), vertical cavity surface-emitting laser diodes (VCSELs), or photon up-conversion laser devices including second-harmonic generation (SHG). The module has an optical output such as an optical fibre, waveguide, light guide, lens unit, or other optics, emitting a laser beam combining the output of the multiple laser devices.

NOTE See 3.1.1 for a definition of a laser device inside the laser module.

#### 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 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 62906-5-2, *Laser display devices – Part 5-2: Optical measuring methods of speckle contrast*

IEC 62906-5-4, *Laser display devices – Part 5-4: Optical measuring methods of colour speckle*

#### 3 Terms, definitions, abbreviated terms, and letter symbols

##### 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

##### **laser device**

<of display lighting unit> semiconductor-based or compactly assembled solid-state up-conversion laser

EXAMPLE Edge-emitting laser diode, vertical cavity surface-emitting laser diode, or photon up-conversion laser including second-harmonic generation (SHG), or third-harmonic generation (THG).

Note 1 to entry: See Annex A.