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INTERNATIONAL STANDARD

Semiconductor devices –
Part 5-4: Optoelectronic devices – Semiconductor lasers

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SEMICONDUCTOR DEVICES –

Part 5-4: Optoelectronic devices – Semiconductor lasers

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.
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IEC 60747-5-4 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices. It is an International Standard.

This second edition cancels and replaces the first edition published in 2006. This edition constitutes a technical revision.

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

a) References for the terms and definitions related to the lighting area, IEC 60050-845, are revised based on IEC 60050-845:2020;
b) Emission angle is changed to radiation angle in 3.3.2;
c) Definitions of rise time and fall time in 3.4.1 are revised based on the publication IEC 60050-521:2002;
d) Spectral linewidth is added to Table 1 in Clause 4;
e) Conditions for carrier-to-noise ratio of Table 1 in Clause 4 is amended.

f) Error in the equation for carrier-to-noise ratio in 5.2.2 is corrected;

g) Precaution against the equipment used for carrier-to-noise ratio measurement is added in 5.2.2;

h) Explanation for the measurement method of the small signal cut-off frequency in 5.3.2 of the first edition is deleted because it has been defined in the latest version of ISO 11554;

i) Reference document for the lifetime in 5.4 is amended;

j) Precaution against the measuring arrangement used for the half-intensity width and $1/e^2$-intensity is added in 5.5.3;

k) Reference tables in Annex A, Annex B and Annex C are revised by following the latest version of ISO publications.

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

Draft	Report on voting
47E/783/FDIS	47E/785/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 in the IEC 60747 series, published under the general title *Semiconductor devices*, can be found on the IEC website.

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

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- withdrawn,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

INTRODUCTION

The first edition of this part of IEC 60747 was published in 2006 under close collaboration between IEC TC 47 SC 47E (IEC TC 47 SC 47C at that moment) and ISO TC 172 SC 9. The scope of IEC/TC47/SC47E includes laser diodes as one of the discrete semiconductor devices while that of ISO/TC172/SC9 includes laser diodes as one of the laser and laser-related equipment. Consequently, technical contents in this publication extend over IEC and ISO.

In order to harmonize the IEC and ISO laser-related standards in 1997, a joint working group (JWG) consisted of the experts from both IEC SC 47E and ISO TC 172 SC 9 was established. As a result of discussion, items based on the electrical and electronic technologies are dealt with by subcommittee 47E of IEC technical committee 47, while optical characteristics of the output beam are under the responsibility of subcommittee 9 of ISO technical committee 172. This was agreed, after long discussion, in 2002 between subcommittee 47E of IEC technical committee 47 and subcommittee 9 of ISO technical committee 172. Based on this agreement, terms and definitions, and test and measurement methods for the optical beam parameters in this part of IEC 60747-5-4 are referenced to the ISO standards that specify the topics.

The joint working group was disbanded in 2017. However, close co-operation and contact between two groups is indispensable in order to avoid any conflicts and to keep harmonization of IEC and ISO laser standards.

This second edition of IEC 60747-5-4 has been updated by following the revision and amendments in the latest versions of laser standards of both IEC and ISO.

SEMICONDUCTOR DEVICES –

Part 5-4: Optoelectronic devices – Semiconductor lasers

1 Scope

This part of IEC 60747 specifies the terminology, the essential ratings and characteristics as well as the measuring methods of semiconductor lasers.

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 62572-2, *Fibre optic active components and devices – Reliability standards – Part 2: Laser module degradation*

ISO 11146-1, *Lasers and laser-related equipment – Test methods for laser beam widths, divergence angles and beam propagation ratios – Part 1: Stigmatic and simple astigmatic beams*

ISO 11554, *Optics and photonics – Lasers and laser-related equipment – Test methods for laser beam power, energy and temporal characteristics*

ISO 12005, *Lasers and laser-related equipment – Test methods for laser beam parameters – Polarization*

ISO 17526, *Optics and optical instruments – Lasers and laser-related equipment – Lifetime of lasers*

3 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 Physical concepts

3.1.1
electromagnetic radiation, <phenomenon>
phenomenon by which energy in the form of electromagnetic waves or photons emanates from a source and is transferred through space

Note 1 to entry: The term “electromagnetic radiation” is also used for the electromagnetic waves or photons produced (see IEV 705-02-01).

Note 2 to entry: The physical concepts of photons and electromagnetic waves are used to describe the same phenomenon of transmission of radiant energy in different ways, depending on the nature of the interaction of the energy with the physical world (wave-particle dualism).

[SOURCE: IEC 60050-702:1992/AMD5:2019, 702-02-07]

3.1.2
electromagnetic radiation, <waves or photons>
energy that emanates from a source in the form of electromagnetic waves or photons and is transferred through space

Note 1 to entry: The term “electromagnetic radiation” is also used for the phenomenon producing the electromagnetic waves or photons (see IEV 702-02-07).

Note 2 to entry: The physical concepts of photons and electromagnetic waves are used to describe the same phenomenon of transmission of radiant energy in different ways, depending on the nature of the interaction of the energy with the physical world (wave-particle dualism).

[SOURCE: IEC 60050-705:1995/AMD4:2019, 705-02-01]

3.1.3
optical radiation
electromagnetic radiation at wavelengths between the region of transition to X-rays ($\lambda \approx 1$ nm) and the region of transition to radio waves ($\lambda \approx 1$ mm)

Note 1 to entry: This entry was numbered 845-01-02 in IEC 60050-845:1987.

[SOURCE: IEC 60050-845:2020, 845-21-002]

3.1.4
light, <psychophysical> noun
radiation that is considered from the point of view of its ability to excite the visual system

Note 1 to entry: The term "light" is sometimes used for optical radiation extending outside the visible range, but this usage is not recommended.

Note 2 to entry: This entry was numbered 845-01-06 in IEC 60050-845:1987.

[SOURCE: IEC 60050-845:2020, 845-21-012]

3.1.5
light, <photometric> noun
radiation within the spectral range of visible radiation

Note 1 to entry: Sometimes, the term "light" is also used in physics as a synonym of optical radiation, covering the spectral range from 100 nm to 1 mm and sometimes even covering the X-ray spectral range. This misuse of the term ''light'' should be avoided.

[SOURCE: IEC 60050-845:2020, 845-21-013]

3.1.6
visible radiation
optical radiation (IEV 845-21-002) capable of causing a visual sensation directly

Note 1 to entry: There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant flux reaching the retina and the responsivity of the observer. The lower limit is generally taken between 360 nm and 400 nm and the upper limit between 760 nm and 830 nm.

Note 2 to entry: This entry was numbered 845-01-03 in IEC 60050-845:1987.

Note 3 to entry: ISO 20473:2007 Optics and photonics – Spectral bands defines from 380 nm to 780 nm for the range of visible radiation.

[SOURCE: IEC 60050-845:2020, 845-021-003, modified – Note 3 has been added.]

3.2 Types of devices

3.2.1
semiconductor laser
laser diode
semiconductor diode that emits coherent optical radiation through stimulated emission resulting from the recombination of conduction electrons and holes when excited by an electric current that exceeds the threshold current of the diode

Note 1 to entry: The laser diode is mounted on a submount or in a package with or without coupling means (e.g. lens, fibre pigtail).

[SOURCE: IEC 60050-521:2002, 521-04-37, modified – The term "laser diode" has been replaced by "semiconductor laser".]

3.3 General terms

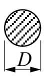
3.3.1
beam axis
straight line connecting the centroids defined by the first spatial moments of the cross-sectional power (energy) density distribution function at successive locations in the direction of propagation (z) of the beam in a homogeneous medium

[SOURCE: ISO 11145:2018, 3.2.1]

3.3.2
optical port
geometrical configuration, referenced to an external plane or surface of the device, that is used to specify the optical radiation emitted from an emitting device

EXAMPLE

Signification of annotations in the Figure 1:

α	=	acceptance angle or radiation angle
	=	optical port with diameter D
Ref.	=	reference locus for the definition of the optical port

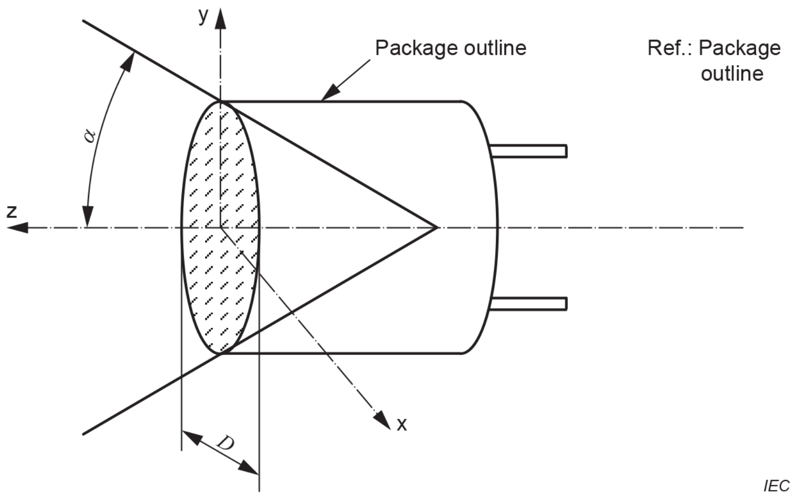


Figure 1 – Example of the device with window but without lens

Note 1 to entry: The geometrical configuration should be specified by the manufacturer by means of geometrical information, e.g:

– location, shape and size of the area of emission;

– angle of emission or acceptance;

– other parameters, e.g. numerical aperture of optical fibre;

– orientation of beam axis.

3.4 Terms related to ratings and characteristics

3.4.1 Switching times

Relation between the electrical input signal and the optical output signal is shown in Figure 2 with the indication of switching times.

3.4.1.1
rise time
t_r
time interval between the instants at which the magnitude of the pulse at the output terminals reaches specified lower and upper limits respectively when the semiconductor device is being switched from its non-conducting to its conducting state

Note 1 to entry: The lower and upper limits are usually 10 % and 90 % respectively of the final amplitude of the output pulse.

[SOURCE: IEC 60050-521:2002, 521-05-22]

3.4.1.2
fall time
t_f
time interval between the instants at which the magnitude of the pulse at the output terminals reaches specified upper and lower limits respectively when a semiconductor device is being switched from its conducting to its non-conducting state

Note 1 to entry: The upper and lower limits are usually 90 % and 10 % respectively of the initial amplitude of the output pulse.

[SOURCE: IEC 60050-521:2002, 521-05-24]

3.4.1.3
turn-on delay time
$t_{d(on)}$
time interval between the instant the electrical input signal reaches a specified level (10 % unless otherwise stated) and the instant the optical output signal reaches a specifies level (10 % of the steady-state maximum unless otherwise stated)

3.4.1.4
turn-on time
t_{on}
time interval between the instant the electrical input signal reaches a specified level (10 % unless otherwise stated) and the instant the optical output signal reaches a specified level (90 % of the steady-state maximum unless otherwise stated)

$$t_{on} = t_{d(on)} + t_r$$

3.4.1.5
turn-off delay time
$t_{d(off)}$
time interval between the instant the electrical input signal downs a specified level (90 % unless otherwise stated) and the instant the optical output signal downs a specifies level (90 % of the steady-state maximum unless otherwise stated)

3.4.1.6
turn-off time
t_{off}
time interval between the instant the electrical input signal downs a specified level (90 % unless otherwise stated) and the instant the optical output signal downs a specified level (10 % of the steady-state maximum unless otherwise stated).

$$t_{off} = t_{d(off)} + t_f$$

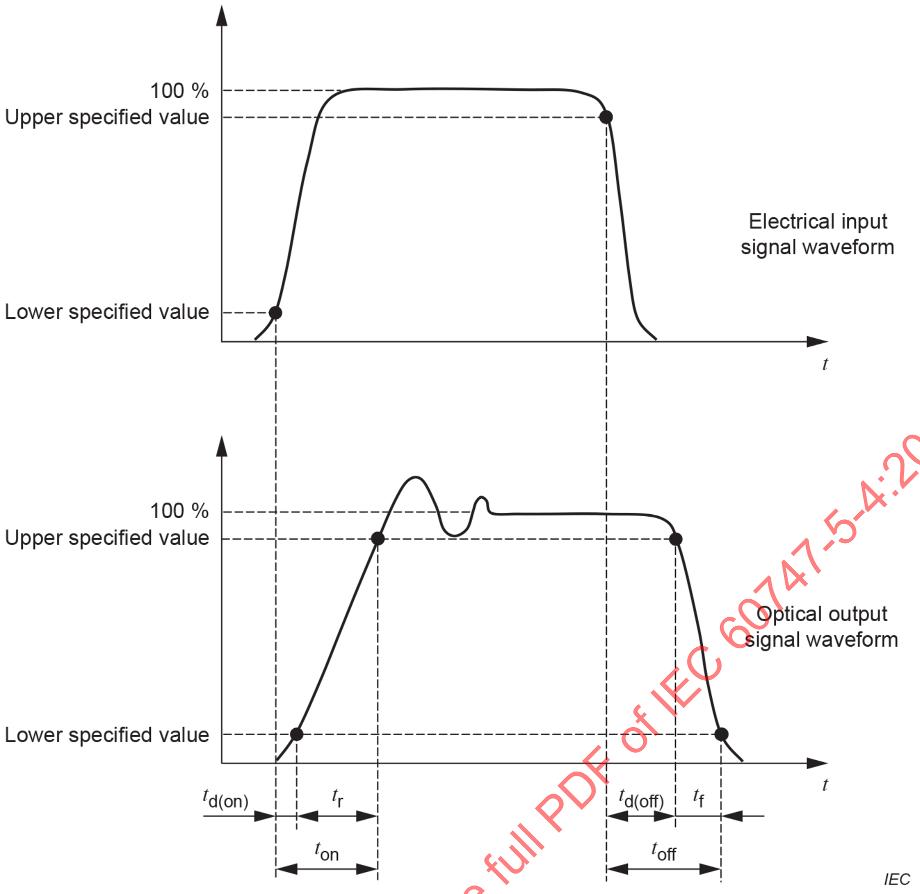


Figure 2 – Switching times

NOTE Lower and upper specified values indicate 10 % and 90 %, respectively, unless otherwise stated.

3.4.2 Output and current characteristics

3.4.2.1
output power, <of a semiconductor laser>
P
radiant power transferred from the semiconductor laser through the optical port

[SOURCE: ISO 11145:2018, 3.18, modified – The symbol “$R(f)$“has been replaced by “RIN”.]

3.4.2.2
radiant flux
radiant power
Φ_e
change in radiant energy with time

$$\Phi_e = \frac{dQ_e}{dt}$$

where Q_e is the radiant energy emitted, transferred or received, and t is time

Note 1 to entry: The corresponding photometric quantity is "luminous flux". The corresponding quantity for photons is "photon flux".

Note 2 to entry: The term "radiant flux" is the preferred term for most radiometric applications, with the notable exception of laser radiometry where the term "radiant power" is more commonly used.

Note 3 to entry: The radiant flux is expressed in watt (W).

Note 4 to entry: This entry was numbered 845-01-24 in IEC 60050-845:1987.

[SOURCE: IEC 60050-845:2020, 845-21-038]

3.4.2.3
differential output power efficiency
η_d
output power efficiency for small-signal modulation:

$\eta_d = dP/dI_F$

Note 1 to entry: Dimension of η_d is W/A.

Note 2 to entry: The term "small-signal modulation efficacy" is used as a synonym.

Note 3 to entry: Differential output power quantum efficiency = $q/(h\nu)$. η_d is also applicable,

where

q is the electron charge,

ν is the optical frequency,

h is equal to 6,626 070 15 × 10-34 Js (Planck's constant).

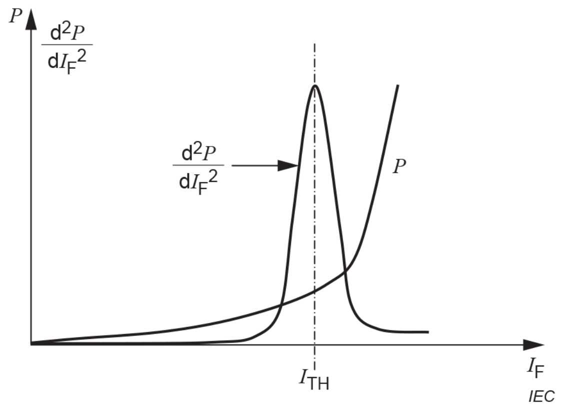
3.4.2.4
threshold current, <of a semiconductor laser>
I_{TH}
forward current derived from one of the following two methods:

a) derivative threshold current $I_{TH(D)}$

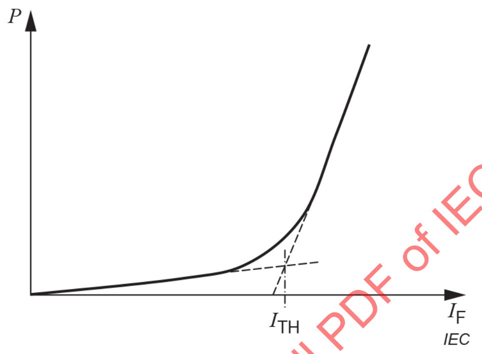
forward current at which the second derivative of the curve showing output power P versus forward current I_F has its first maximum [see Figure 3 a)];

b) extrapolated threshold current

forward current at which the extrapolated two straight lines of the stimulated emission and the spontaneous emission cross each other [see Figure 3 b)].



a) Derivative threshold current of a laser diode



b) Extrapolated threshold current of a laser diode

Figure 3 – Threshold current of a laser diode

3.4.3 Noise characteristics (of a semiconductor laser)

3.4.3.1
relative intensity noise
RIN
R(*f*)
ratio of the mean square radiant power fluctuations to the mean square radiant power, normalized to a frequency band of unit width, for radiant power $P(f)$ as a function of frequency f

$$R(f) = \frac{\left\langle \Delta P(f)^2 \right\rangle}{\left\langle P(f)^2 \right\rangle} \frac{1}{\Delta f}$$

Note 1 to entry: The relative intensity noise as defined above is strictly "relative intensity noise spectral density", but usually simplify referred to as RIN.

[SOURCE: ISO 11145:2018, 3.18]

3.4.3.2
carrier-to-noise ratio
C/*N*
quotient of:

– the mean square radiant power at the specified frequency, to
– the mean square radiant power fluctuations normalized to a frequency band of unit width centered on the carrier frequency

3.4.4
small signal cut-off frequency
f_c
frequency at which the laser power output modulation drops to half the value obtained at low frequencies when applying small, constant input power modulation and increasing the frequency

[SOURCE: ISO 11554:2017, 3.2]

3.4.5
half-intensity angle
$\theta_{1/2}$
in a radiation diagram, angle within which the radiant intensity is greater than or equal to half of the maximum intensity

3.4.6
1/*e*²-intensity angle
θ_{1/e^2}
in a radiation diagram, angle within which the radiant intensity is greater than or equal to $1/e^2$ of the maximum intensity

3.4.7
half-intensity width
$D_{1/2}$
full width of a beam, within which the power density is greater than or equal to half of the maximum power density at a specified position z along the beam propagation direction

3.4.8
1/e²-intensity width
D_{1/e^2}
full width of a beam, within which the power density is greater than or equal to $1/e^2$ of the maximum

3.5 Spatial profiles and spectral characteristics

Reference list of technical terms and definitions related to spatial profiles and spectral characteristics are defined in several ISO documents as shown in Annex A (informative).

4 Essential rating and characteristics

4.1 Type

Ambient-rated or case-rated semiconductor lasers shall be stated.

4.2 Semiconductor

4.2.1 Material

Material such as GaAlAs, InGaAsP, InGaAlP, InGaAlN, GaN, InGaN, etc. shall be provided.

4.2.2 Structure

Structure such as (single or multi) quantum well, quantum dots, surface emitting, etc. shall be provided.

4.3 Details of outline drawing and encapsulation

a) IEC and/or national reference number of the outline drawing;

b) method of encapsulation: glass/metal/plastic/other;

c) terminal identification and indication of any electrical connection between a terminal and the case;

d) characteristics of the optical port: orientation relative to mechanical axes, position relative to mechanical axes, area, numerical aperture.

NOTE Numerical aperture is essential depending on the application.

4.4 Limiting values (absolute maximum ratings over the operating temperature range, unless otherwise stated)

a) minimum and maximum storage temperatures (T_{stg})

b) minimum and maximum operating temperatures

- ambient or case temperature (T_{amb} or T_{case});
- submount temperature, where appropriate (T_{sub}).

c) maximum soldering temperature (soldering time and minimum distance to case) (T_{sld})

d) maximum reverse voltage (V_{RM})

e) additional informations

f) one or more of the following at an ambient or case temperature of 25 °C together with a derating curve or derating factor with temperature

- maximum continuous forward current (I_{FM});
- maximum continuous output power (P_{M});
- maximum pulsed forward current at stated frequency and pulse duration (I_{FM});
- maximum pulsed output power at stated frequency and pulse duration (P_{M}).

4.5 Electrical and optical characteristics

Output power shall be specified as continuous or pulsed as appropriate to the device. ΔI_{F} indicates a forward current above the measured threshold current I_{TH} of the device being measured. Electrical and optical characteristics are referenced in following Table 1.

Table 1 – Electrical and optical characteristics

Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Symbol	Specifications		
			Required	Options [a]	Requirement
Forward voltage	I_F or P specified	V_F	×		max.
Threshold current		I_{TH}	×		min. and max.
Output power at threshold	I_{TH}	P_{TH}	×		max.
Forward current above threshold	P specified	ΔI_F	×		max.
Forward current above threshold at T_{case} max or T_{amb} max	P specified, $T = T_{case}$ max or T_{amb} max	ΔI_F	×		max.
Differential output power efficiency	P or ΔI_F specified	η_d	×		min. and max.
Peak emission wavelength	ΔI_F or P specified	λ_p	×		min. and max.
Central wavelength	ΔI_F or P specified	λ_c	×		min. and max.
Spectral bandwidth or: RMS spectral bandwidth or: Number of longitudinal modes within a specified bandwidth and mode spacing in the wavelength domain	ΔI_F or P specified ΔI_F or P specified ΔI_F or P specified Bandwidth specified	$\Delta\lambda$ $\Delta\lambda_{rms}$ n_m s_m	× × × ×		min. and max. min. and max. min. and max. min. and max.
Spectral linewidth	ΔI_F or P specified	$\Delta\lambda_L$		×	max.
Side-mode suppression ratio	ΔI_F or P specified	SMSR		×	min.
Divergence angles [b, c]	ΔI_F or P specified	θ σ		×	min.
or: Half-intensity angle in two specified planes [c]	ΔI_F or P specified reference planes specified	$\theta_{1/2}$ (1) [d] $\theta_{1/2}$ (2) [e]		× ×	max.
or: $1/e^2$-intensity angle in two specified planes [c]	ΔI_F or P specified reference planes specified	θ_{1/e^2} (1) [d] θ_{1/e^2} (2) [e]		× ×	max.
Misalignment angle	ΔI_F or P specified	$\Delta\theta$		×	max.
Half-intensity width at the facet of laser diode	ΔI_F or P specified, reference axes specified	$D_{1/2}$ (x) [d] $D_{1/2}$ (y) [e]		× ×	min. and max.
or: $1/e^2$-intensity width at the facet of laser diode	ΔI_F or P specified, reference axes specified	D_{1/e^2} (x) [d] D_{1/e^2} (y) [e]		× ×	min. and max.
Astigmatic difference [f]	ΔI_F or P specified, reference axes specified	d_A		×	max.
Rise time and fall time	Bias conditions (ΔI_F or ΔP) specified	t_r, t_f		×	max.
or: Turn-on time and turn-off time	Input pulse current, width and duty specified	t_{on}, t_{off}		×	max.

Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Symbol	Specifications		
			Required	Options [a]	Requirement
Small-signal cut-off frequency	ΔI_F or P specified	f_c		×	min.
Relative intensity noise	P, f_o, Δf_N specified	$R(f)$		×	max.
Carrier-to-noise ratio	P, f_o, Δf, f_m specified, modulation format specified	C/N		×	max.
Total capacitance	ΔI_F or P, or V_R specified frequency specified	C_{tot}		×	max.
Total inductance	ΔI_F or P, or V_R specified frequency specified	L_{tot}		×	max.
S_{11} parameter	ΔI_F or P specified frequency specified	S_{11}		×	max.

[a] Options should be specified appropriate to applications.

[b] Only divergence angle according to ISO 11145 should be used. However, for the time being, data sheets may use both divergence angle and half-intensity angle. Manufacturers and users shall determine the parameter depending on applications.

[c] Care should be taken in confusing the divergence angle with the half-intensity angle, because they are defined based on the completely different concept.

[d] Parallel to the reference plane.

[e] Perpendicular to the reference plane.

[f] The astigmatic difference shall be derived based on ISO 11146-1.

4.6 Supplementary information

Temperature dependence of emission wavelength should be provided as a supplementary information.

5 Measurement methods

5.1 Power measurement

Power measurement shall be performed by using the method defined in ISO 11554.

5.2 Output stability

5.2.1 Relative intensity noise

Relative intensity noise measurement shall be performed by using the method defined in ISO 11554.

5.2.2 Carrier-to-noise ratio

a) Purpose

To measure the carrier-to-noise ratio (C/N) of semiconductor lasers at a specified output power level in continuous wave (cw) under specified modulation conditions.

b) Circuit diagram

The measurement circuit diagram for the carrier-to-noise ratio is shown in Figure 4.

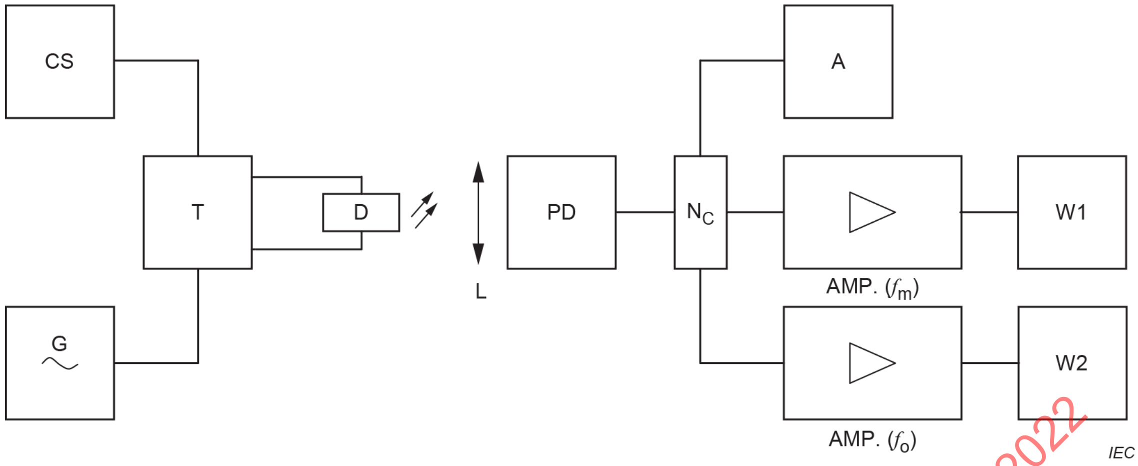


Figure 4 – Basic circuit diagram

c) Circuit description

CS = DC current source

D = device being measured

G = AC generator

T = bias T or passive biasing circuit

L = focusing lens systems

PD = photodetector

A = current measuring instrument

AMP(f_m) = amplifier suitable for use at frequency f_m

W1 = power meter

AMP(f_o) = amplifier and filter suitable for use at frequency f_o

W2 = power meter

N_C = impedance matching and signal dividing network

d) Precautions to be observed

Specifications of each equipment that is used for the measurement should be carefully examined in order to ensure the accuracy of the test required.

The associated "photodetector + ammeter" shall be calibrated corresponding to the output power of D over the required wavelength range.

The focusing systems shall be designed:

– to avoid radiation being reflected back into the laser diode or the laser module;

– to bring to focus the optical port of the device being measured onto the optical port of the photodetector.

e) Measurement procedure

The specified supply and drive conditions are applied to the device being measured, D.

The photocurrent (I_{ph}) resulting from the illumination (P specified) of the photodetector is measured first and noted. RF modulation is applied to the device being measured through the biasing circuit: specified modulation format with carrier frequency f_m. The electrical power P_1 at frequency f_m is measured on the power meter W1. This electrical power P_1 is related to the modulated output power squared as follows:

$$(\Delta\Phi_m)^2 = \frac{P_1}{S^2 - R_c}$$

where

S is the responsivity of the photodetector PD;

R_c is the load resistance of PD [input of AMP(f_m)].

The noise electrical power N_{tot} at frequency f_o in the frequency band Δf is measured on the power meter W2 (f_o should be as close as technically possible to f_m). This is the sum of the pure shot noise associated with the photocurrent I_{ph} and the excess noise due to the radiation source intensity fluctuations. The pure shot noise shall be measured under the same illumination conditions (same I_{ph}) using a "radiation source with broad optical spectrum". The electrical noise power corresponding to the pure shot noise equivalent output power fluctuations (N_s) can be measured with W2:

$$\left(\frac{C}{N}\right)_{lin} = \frac{(\Delta\Phi_m)^2}{\left\langle \Delta\Phi_e^2 \right\rangle} = \frac{P_1}{(N_{tot} - N_s)} \text{ or}$$

$$\left(\frac{C}{N}\right) = 10\log_{10}\left(\frac{C}{N}\right)_{lin}$$

f) Specified conditions

– ambient, case or submount temperature;

– measurement bias conditions (P, I_F or ΔI_F);

– frequency and bandwidth (f_o, Δf);

– carrier frequency (f_m);

– modulation format.

5.2.3 Output power stability

Output power stability measurement shall be performed by using the method defined in ISO 11554.

5.2.4 Output energy stability

Output energy stability measurement shall be performed by using the method defined in ISO 11554.

5.2.5 Temporal pulse shape

Temporal pulse shape measurement shall be performed by using the method defined in ISO 11554. Evaluation for the temporal pulse shape measurement should coincide with the description in ISO 11554:2017, 8.6.

5.3 Time domain profile

5.3.1 Switching times

5.3.1.1 Rise time and fall time

Rise time and fall time measurements shall be performed by using the method defined in ISO 11554. Evaluation for the rise time and fall time measurements should coincide with the description in ISO 11554:2017, 8.6.

5.3.1.2 Turn-on delay time and turn-off delay time

a) Purpose

To measure the turn-on time t_{on} (turn-on delay time $t_{d(on)}$ + rise time t_r) and turn-off time t_{off} (turn-off delay time $t_{d(off)}$ + fall time t_f) of semiconductor lasers under specified conditions.

b) Circuit diagram

The measurement circuit diagram for turn-on and turn-off delay times is shown in Figure 5.

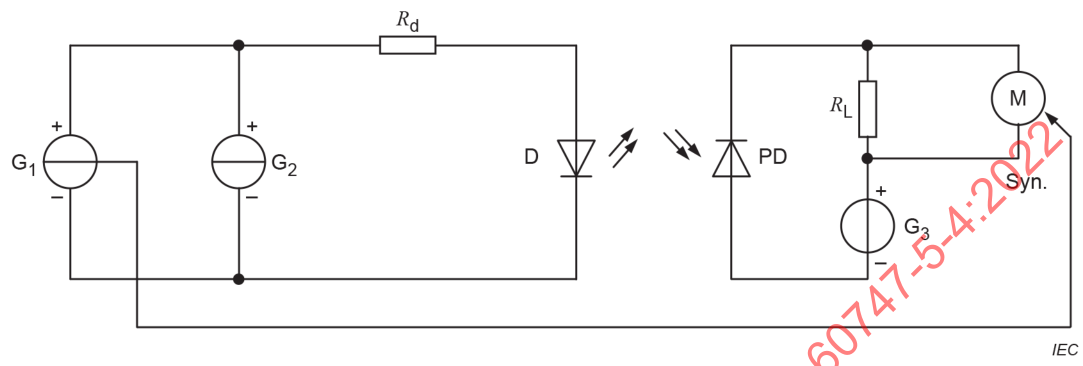


Figure 5 – Basic circuits diagram

c) Circuit description

G_1 = current pulse generator, with high impedance

G_2 = d. c. current bias source

G_3 = d. c. voltage bias source

R_d = resistance for matching the impedance with generator

D = device being measured

PD = photodiode

R_L = load resistance

M = measuring instrument

Syn. = synchronization signal

d) Precautions to be observed

The switching time of the photodiode, the delay time of the circuit and measuring instrument, the rise and fall times of the input current pulse should be short enough not to affect the accuracy of the measurement. For example, the upper cut-off frequency f_D (6 dB decay of the sensitivity) of the photodiode including the circuit should at least be three times the reciprocal value of the rise time t_r and the fall time t_f of the laser pulse.

$f_D \geq 3\frac{1}{t_r}$ and also $f_D \geq 3\frac{1}{t_f}$

The lower cut-off frequency should be zero.

The mean output power obtained at the top of the optical pulse (see Figure 6) may not necessarily be equivalent to the cw output power at a current equal to the sum of the DC bias and input pulse current.

Only the optical port of the device being measured shall be considered.

e) Measurement procedure

Apply the specified DC and pulse current to the device being measured.

Measure the switching times with the measuring instrument M.

The 100 % output power level is the mean output power obtained at the top of the radiant pulse. The 0 % level is the output power obtained at the DC bias current.

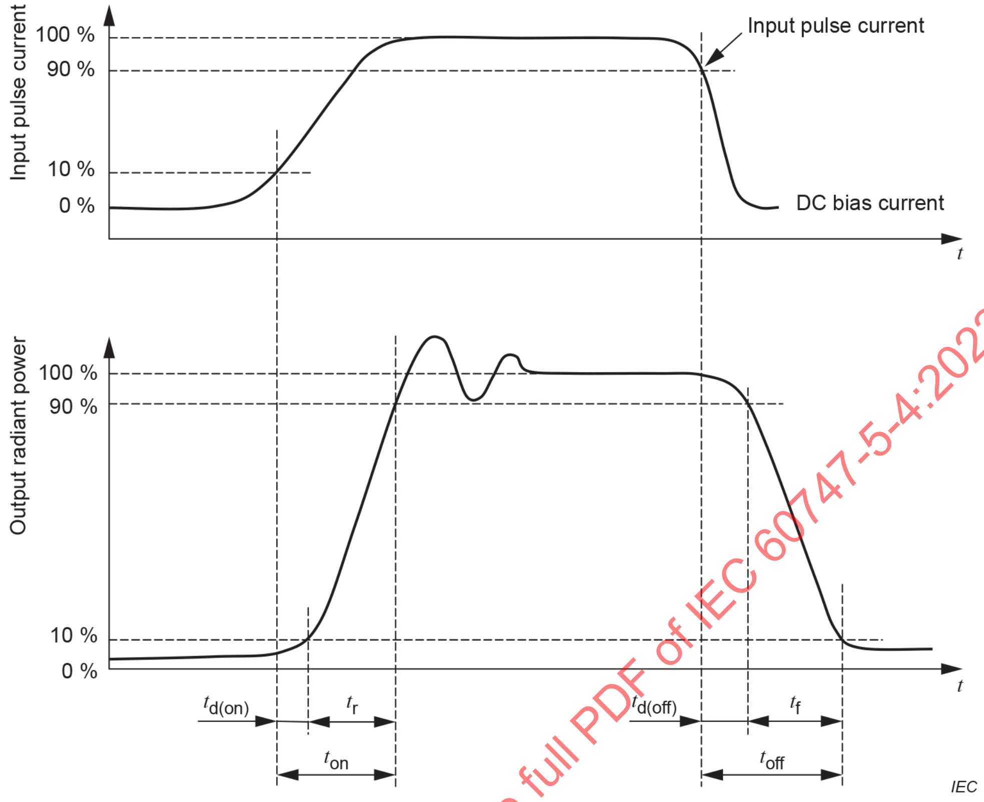


Figure 6 – Typical pulse response diagram

f) Specified conditions
   – ambient or case temperature;
   – DC bias current;
   – input pulse current, width and duty cycle;
   – optical port;
   – optical configuration.

5.3.2 Small signal cut-off frequency (f_c)

Small signal cut-off frequency measurement shall be performed by using the method defined in ISO 11554. Preparation for the small signal cut-off frequency measurement should coincide with the description in ISO 11554:2017, 6.1.4.

5.4 Lifetime

Lifetime measurement shall be performed by using the method defined in ISO 17526.

However, for the laser modules with fibre pigtail used for telecommunication systems, IEC 62572-2 and IEC 62757-3 shall be referred.

Reference table of the lifetime measurement method in ISO documents is listed in Annex C (informative)

5.5 Optical characteristics of the laser beam

5.5.1 Polarization

Polarization measurement shall be performed by using the method defined in ISO 12005.

5.5.2 Half-intensity angle $\theta_{1/2}$ and $1/e^2$-intensity angle θ_{1/e^2}

a) Purpose

To measure the half-intensity angle and $1/e^2$-intensity angle of semiconductor lasers under specified conditions.

NOTE The half intensity angle $\theta_{1/2}$ or $1/e^2$-intensity angle θ_{1/e^2} of semiconductor lasers is the angle within which the radiant intensity is greater than or equal to half or $1/e^2$ of the maximum intensity as indicated in Figure 8. This angle $\theta_{1/2}$ is defined for a specified plane which in turn is defined by φ. The angle φ defines the orientation of the device D in the mechanical reference plane as indicated in Figure 9.

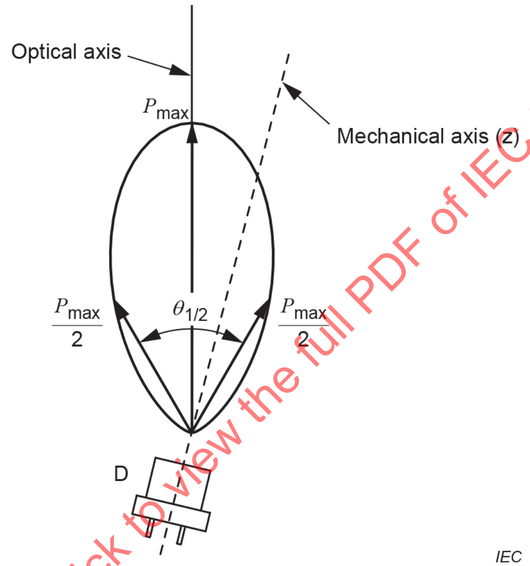
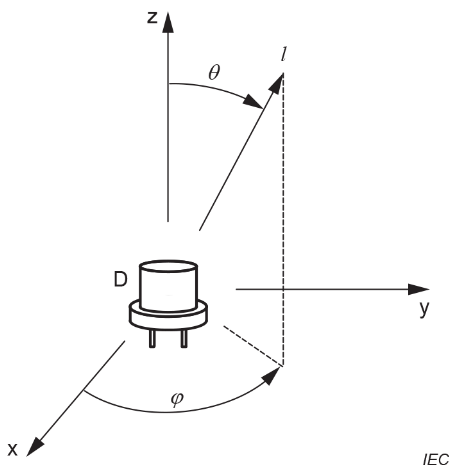


Figure 7 – Half-intensity angle



Axes x and y define a mechanical reference plane of the device being measured D, e.g. the mounting angle.

The angle φ defines the orientation of the device D in that plane.

Figure 8 – Relationship between the specified plane and the mechanical reference plane

b) Diagram

The basic arrangement and definition of axes are shown in Figure 7.

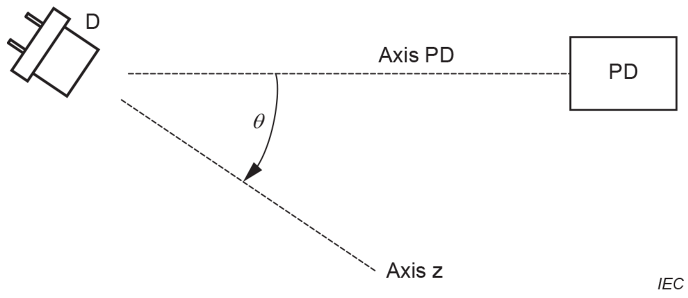


Figure 9 – Basic measurement setup diagram

c) Measurement description and requirements

D = device being measured

PD = photodetector

Axis z = defined mechanical axis of the device being measured

Axis PD = axis of photodetector

θ = inclination angle of axis z to axis PD.

The solid angle, defined by the device being measured and the aperture of the photodiode, should be small. The solid angle is considered small if the measurement result does not change significantly when the solid angle is halved.

The device being measured D shall be mounted in a fixture which allows:

– precise, reproducible positioning of the device D;
– changes to the angle θ, keeping the centre of the optical port of the device D fixed;
– measurement of the angle of inclination θ;
– rotation of the device D around its z axis as indicated in Figure 8;
– measurement of the angle of rotation φ about the x axis.

d) Measurement procedure

The specified current is applied to the device being measured D.

The mechanical axis of the device D is aligned along the axis of the photodetector, i.e. $\theta = 0$, and the signal on the photodetector is measured.

This value is set at P_0.

The device D is inclined as illustrated in Figure 10, and the relative intensity P/P_0 versus θ is plotted.

The preferred plot should be in polar diagram form. Other formats e.g. cartesian may be used when defined in the specification.

The half intensity angle $\theta_{1/2}$ is the angle between the two points at which $P = P_{max}/2$.

The $1/e^2$ intensity angle θ_{1/e^2} is the angle between the two points at which $P = P_{max}/e^2$.

e) Specified conditions

– ambient, case or submount temperature;
– measurement bias conditions (P, or I_F or ΔI_F);
– mechanical reference plane;
– angle φ.

5.5.3 Half-intensity width $D_{1/2}$ and $1/e^2$-intensity width D_{1/e^2}

a) Purpose

To measure the half-intensity width and $1/e^2$-intensity width on the facet (z = 0) of the laser diode with respect to a defined axis.

b) Measuring arrangement

Measuring arrangement for the half-intensity width and $1/e^2$-intensity is shown in Figure 10.

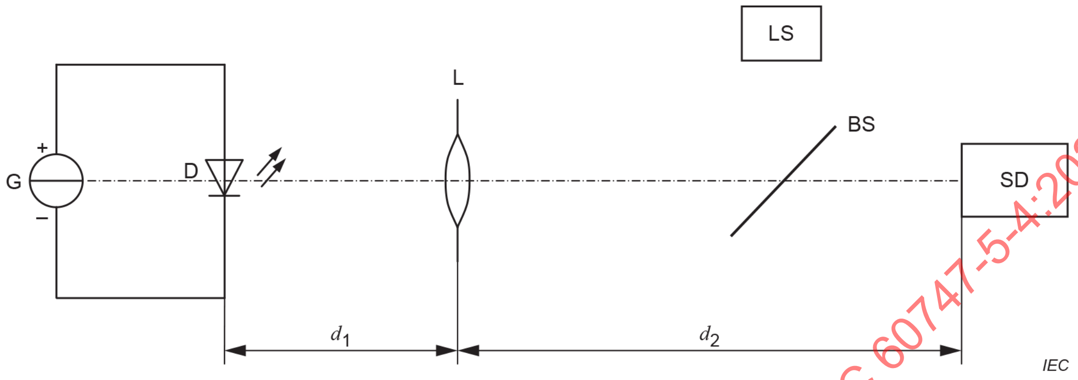


Figure 10 – Measuring arrangement for $D_{1/2}$ and D_{1/e^2}

c) Equipment description and requirements

G = current source

D = device being measured

L = lens system

SD = scanning photodetector with a narrow slit

LS = light source with filter or LED the emission wavelength of which is close to that of the device being measured

BS = beam splitter

$d_2 >> d_1$

d) Precautions to be observed

The lens system L shall be substantially achromatic over the range of wavelengths encompassed by the light source LS and the device D.

The lens system L, the device D and the scanning photodetector SD should be on the same horizontal line.

e) Measurement procedure

The light source LS is turned on and the lens system L adjusted to obtain a focused image of the front face of the device D on the photodetector SD. Distances d_1 and d_2 are then read.

The specified DC current or the DC current corresponding to the specified radiant power ϕ_e is applied to the device being measured D.

The scanning direction of the photodetector SD is aligned with the major and minor axes of the focused image.

The photodetector SD is scanned along the major and the minor axes. The half-intensity width and $1/e^2$-intensity width of the emission source are given by the distance between the 3 dB and $1/e^2$ power points respectively along the major and minor axes multiplied by d_1/d_2.

f) Specified conditions
   - ambient, case or submount temperature;
   - direct forward current or radiant power;
   - reference axes (major and minor axes);
   - position z along the beam propagation direction, if required.

NOTE Unless otherwise stated, the specified position z is the position at the facet of the laser diode.

5.5.4 Spectral characteristics and other spatial profile

Reference table of ISO documents for the measurement related to spectral characteristics and spatial parameters other than defined in this document is listed in Annex B (informative).

Annex A
(informative)

Reference list of technical terms and definitions related to spatial profile and spectral characteristics

	ISO 11145: 2018	ISO 11146-1: 2005	ISO 11146-2: 2005	ISO 11670: 2003	ISO 12005: 2003	ISO 13694: 2018	ISO 13695: 2004	ISO 15367-1: 2003	IEC 60747-5-4
Optical port									3.3.2
Beam centroid	3.1.1								
Beam positional stability	3.1.2			3.6					
Beam axis	3.2.1			4.1,4.2					
Misalignment angle	3.2.2								
Beam diameter	3.3.1 3.3.2	3.8	3.1						
Beam radius	3.4.1 3.4.2								
Beam width	3.5.1 3.5.2	3.5	3.14						
Beam cross-sectional area	3.6.1 3.6.2								
Beam ellipticity	3.6.3								
Circular power density distribution	3.6.4								
Beam waist	3.7.1								
Beam waist location	3.7.2	3.12	3.2						
Astigmatic beam waist separation	3.7.3								
Beam waist diameter	3.7.4 3.7.5	3.14							
Beam waist radius	3.7.6 3.7.7								
Beam waist width	3.7.8 3.7.9	3.13							
Divergence angle	3.8.1 3.8.2	3.15							
Rayleigh length	3.9.1		3.3						
Far field	3.9.2								
Beam parameter product	3.10.1								
Beam propagation ratio	3.10.2	3.16	3.9						
Beam propagation factor	3.10.3								
Beam positional stability				3.6					

	ISO 11145: 2018	ISO 11146-1: 2005	ISO 11146-2: 2005	ISO 11670: 2003	ISO 12005: 2003	ISO 13694: 2018	ISO 13695: 2004	ISO 15367-1: 2003	IEC 60747-5-4
Angular movement				3.1					
Beam angular stability				3.2					
Pivot				3.3					
Transverse displacement				3.4					
Beam positional movement				3.5					
Relative beam angular stability				3.7					
Relative beam positional stability				3.8					
Beam stability parameter product				3.9					
Beam positional change from cold start				3.10					
Short-term stability				3.11					
Medium-term stability				3.12					
Long-term stability				3.13					
Coherence	3.11.1								
Temporal coherence	3.11.2								
Spatial coherence	3.11.3								
Coherence length	3.11.4								
Coherence time	3.11.5								
Polarization	3.12.1				3.1				
Circular polarization	3.12.2								
Elliptical polarization	3.12.3								
Linear polarization	3.12.4				3.8				
Degree of linear polarization	3.12.5								
Partial polarization	3.12.6								
Random polarization	3.12.7								
Average energy density	3.13.1								
Average power density	3.13.2								
Pulse energy	3.13.3					3.1.4			
Energy density	3.13.4					3.1.2.1			
Continuous wave power	3.13.5								
Power density	3.13.6					3.1.1.1			
Pulse power	3.13.7								
Average power	3.13.8								
Peak power	3.13.9								
Pulse duration	3.14.1								
FWHM pulse duration	3.14.2								
Pulse repetition rate	3.14.3								