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BSI Standards Publication

Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols (ISO 11145:2016)

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National foreword

This British Standard is the UK implementation of EN ISO 11145:2016. It supersedes BS EN ISO 11145:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee CPW/172, Optics and Photonics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Optik und Photonik - Laser und Laseranlagen - Begriffe und Formelzeichen (ISO 11145:2016)

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN ISO 11145:2016) has been prepared by Technical Committee ISO/TC 172 "Optics and photonics" in collaboration with Technical Committee CEN/TC 123 “Lasers and photonics” the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2016, and conflicting national standards shall be withdrawn at the latest by September 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN ISO 11145:2008.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive, see informative Annex ZA, which is an integral part of this document.

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Endorsement notice

The text of ISO 11145:2016 has been approved by CEN as EN ISO 11145:2016 without any modification.

Annex ZA
(informative)
Relationship between this European Standard and the Essential Requirements of EU Directive 2006/42/EC on machinery

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 2006/42/EC on machinery.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and EU Directive 2006/42/EC on machinery

Clauses and subclauses of this European standard	Essential Requirements (ERs) of EU Directive 2006/42/EC	Qualifying remarks/Notes
3	1.5.10	
3	1.5.12	

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Electro-optical systems*.

This fourth edition cancels and replaces the third edition (ISO 11145:2006) which has been technically revised with the following changes:

a) in 3.5.3, a formula for beam ellipticity has been added;

b) in 3.53, the definition of relative intensity noise has been revised and a formula was added.

Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols

1 Scope

This International Standard defines basic terms, symbols, and units of measurement for the field of laser technology in order to unify the terminology and to arrive at clear definitions and reproducible tests of beam parameters and laser-oriented product properties.

NOTE The laser hierarchical vocabulary laid down in this International Standard differs from that given in IEC 60825–1. ISO and IEC have discussed this difference and agree that it reflects the different purposes for which the two standards serve. For more details, see informative Annex A.

2 Symbols and units of measurement

2.1 The spatial distribution of power (energy) density of a laser beam does not always have circular symmetry. Therefore, all terms related to these distributions are split into those for beams with circular and those with non-circular cross-sections. A circular beam is characterized by its radius, w, or diameter, d. For a non-circular beam, the beam widths, d_x and d_y, for two orthogonal directions have to be given.

2.2 The spatial distributions of laser beams do not have sharp edges. Therefore, it is necessary to define the power (energy) values to which the spatial terms refer. Depending on the application, different cut-off values can be chosen (for example 1/e, 1/e^2, 1/10 of peak value).

To clarify this situation, this International Standard uses the subscript u for all related terms to denote the percentage of the total beam power (energy) taken into account for a given parameter.

NOTE For the same power (energy) content, beam width $d_{x,u}$ and beam diameter d_u (= $2w_u$) can differ for the same value of u (for example, for a circularly symmetric Gaussian beam $d_{86,5}$ is equal to $d_{x,95,4}$).

Table 1 lists symbols and units which are defined in detail in Clause 3.

Table 1 — Symbols and units of measurement

Symbol	Unit	Term
A_u or A_σ	m^2	Beam cross-sectional area
d_u or d_σ	m	Beam diameter
$d_{x,u}$ or $d_{\sigma x}$	m	Beam width in x-direction
$d_{y,u}$ or $d_{\sigma y}$	m	Beam width in y-direction
$d_{0,u}$ or $d_{\sigma 0}$	m	Beam waist diameter
$d_{\sigma 0} \cdot \Theta_\sigma / 4$	rad m	Beam parameter product
E_u or E_σ	W/m^2	Average power density
f_p	Hz	Pulse repetition rate
H_u or H_σ	J/m^2	Average energy density
K	1	Beam propagation factor
l_c	m	Coherence length
M^2	1	Beam propagation ratio
p	1	Degree of linear polarization
P	W	Cw-power

Table 1 *(continued)*

Symbol	Unit	Term
P_{av}	W	Average power
P_H	W	Pulse power
P_{pk}	W	Peak power
Q	J	Pulse energy
$R(f)$	Hz^{-1} or dB/Hz	Relative intensity noise, RIN
w_u or w_σ	m	Beam radius
$w_{0,u}$ or $w_{\sigma 0}$	m	Beam waist radius
z_R	m	Rayleigh length
$\Delta\vartheta$	m	Misalignment angle
$\Delta\lambda$	m	Spectral bandwidth in terms of wavelength
$\Delta\nu$	Hz	Spectral bandwidth in terms of optical frequency
$\Delta_x(z')$	m	Beam positional stability in *x*-direction
$\Delta_y(z')$	m	Beam positional stability in *y*-direction
Δz_a	m	Astigmatic waist separation
Δz_r	1	Relative astigmatic waist separation
ε	1	Ellipticity of a power density distribution
η_L	1	Laser efficiency
η_Q	1	Quantum efficiency
η_T	1	Device efficiency
Θ_u or Θ_σ	rad	Divergence angle
$\Theta_{x,u}$ or $\Theta_{\sigma x}$	rad	Divergence angle for *x*-direction
$\Theta_{y,u}$ or $\Theta_{\sigma y}$	rad	Divergence angle for *y*-direction
λ	m	Wavelength
τ_H	s	Pulse duration
τ_{10}	s	10 %-pulse duration
τ_c	s	Coherence time

NOTE $R(f)$ expressed in dB/Hz equals 10 $\log_{10} R(f)$ with $R(f)$ given in Hz^{-1}.

When stating quantities marked by an index "*u*", "*u*" shall always be replaced by the concrete number, e.g. A_{90} for u = 90 %.

In contrast to these quantities defined by setting a cut-off value ["encircled power (energy)"], the beam widths and derived beam properties can also be defined based on the second moment of the power (energy) density distribution function (see 3.5.2). Only beam propagation ratios based on beam widths and divergence angles derived from the second moments of the power (energy) density distribution function allow calculation of the beam propagation. Quantities based on the second moment are marked by a subscript "σ".

3 Terms and definitions

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

3.1 Beam axis

3.1.1
beam axis
straight line connecting the centroids defined by the first spatial moment of the cross-sectional profile of power (energy) at successive positions in the direction of propagation of the beam in a homogeneous medium

3.1.2
misalignment angle
$\Delta\vartheta$
deviation of the beam axis from the mechanical axis defined by the manufacturer

3.2 Beam cross-sectional area

3.2.1
beam cross-sectional area
A_u
⟨encircled power (energy)⟩ smallest completely filled area containing u % of the total beam power (energy)

Note 1 to entry: For clarity, the term "beam cross-sectional area" is always used in combination with the symbol and its appropriate subscript: A_u or $A_{\boldsymbol{\sigma}}$.

3.2.2
beam cross-sectional area
A_σ
⟨second moment of power (energy) density distribution function⟩ area of a beam with circular cross-section

$$\pi \cdot d_\sigma^{\ 2} / 4$$

or elliptical cross-section

$$\left(\pi \cdot d_{\sigma x} \cdot d_{\sigma y}\right) / 4$$

Note 1 to entry: For clarity, the term "beam cross-sectional area" is always used in combination with the symbol and its appropriate subscript: A_u or $A_{\boldsymbol{\sigma}}$.

3.3 Beam diameter

3.3.1
beam diameter
d_u
⟨encircled power (energy)⟩ smallest diameter of a circular aperture in a plane perpendicular to the beam axis that contains u % of the total beam power (energy)

Note 1 to entry: For clarity, the term "beam diameter" is always used in combination with the symbol and its appropriate subscript: d_u or $d_{\boldsymbol{\sigma}}$.

3.3.2
beam diameter
d_σ
⟨second moment of power (energy) density distribution function⟩ smallest diameter of a circular aperture in a plane perpendicular to the beam axis, defined as

$$d_\sigma\left(z\right) = 2\sqrt{2}\sigma\left(z\right)$$

where the second moment of the power density distribution function $E(x,y,z)$ of the beam at the location z is given by

$$\sigma^2(z) = \frac{\iint r^2 \cdot E(r,\varphi,z) \cdot r\mathrm{d}r\mathrm{d}\varphi}{\iint E(r,\varphi,z) \cdot r\mathrm{d}r\mathrm{d}\varphi}$$

where

r is the distance to the centroid $(\bar{x}, \bar{y})$

φ is the azimuth angle

and where the first moments give the coordinates of the centroid, i.e.

$$\bar{x} = \frac{\iint x \cdot E(x,y,z)\mathrm{d}x\mathrm{d}y}{\iint E(x,y,z)\mathrm{d}x\mathrm{d}y}$$

$$\bar{y} = \frac{\iint y \cdot E(x,y,z)\mathrm{d}x\mathrm{d}y}{\iint E(x,y,z)\mathrm{d}x\mathrm{d}y}$$

Note 1 to entry: In principle, integration has to be carried out over the whole *xy* plane. In practice, the integration has to be performed over an area such that at least 99 % of the beam power (energy) is captured.

Note 2 to entry: The power density E has to be replaced by the energy density H for pulsed lasers.

Note 3 to entry: For clarity, the term “beam diameter” is always used in combination with the symbol and its appropriate subscript: d_u or d_σ.

3.4 Beam radius

3.4.1
beam radius

w_u

⟨encircled power (energy)⟩ smallest radius of an aperture in a plane perpendicular to the beam axis which contains u % of the total beam power (energy)

Note 1 to entry: For clarity, the term “beam radius” is always used in combination with the symbol and its appropriate subscript: w_u or w_σ.

3.4.2
beam radius

w_σ

⟨second moment of power (energy) density distribution function⟩ smallest radius of an aperture in a plane perpendicular to the beam axis, defined as

$$w_\sigma(z) = \sqrt{2}\sigma(z)$$

Note 1 to entry: For a definition of the second moment $\sigma^2(z)$, see 3.3.2.

Note 2 to entry: For clarity, the term “beam radius” is always used in combination with the symbol and its appropriate subscript: w_u or w_σ.

3.5 Beam widths

3.5.1
beam widths

$d_{x,u}$, $d_{y,u}$

⟨encircled power (energy)⟩ width of the smallest slit transmitting *u* % of the total beam power (energy) in two preferential orthogonal directions *x* and *y* which are perpendicular to the beam axis

Note 1 to entry: The preferential directions are given by the smallest beam width and the orthogonal direction.

Note 2 to entry: For circular Gaussian beams, $d_{x,95,4}$ equals $d_{86,5}$.

Note 3 to entry: For clarity, the term “beam widths” is always used in combination with the symbol and its appropriate subscripts: $d_{\sigma x}$, $d_{\sigma y}$ or $d_{x,u}$, $d_{y,u}$.

3.5.2
beam widths

$\boldsymbol{d_{\sigma x}}$, $\boldsymbol{d_{\sigma y}}$

⟨second moment of power (energy) density distribution function⟩ width of the smallest slit in two preferential orthogonal directions x and y which are perpendicular to the beam axis, defined as

$$d_{\sigma x}\left(z\right) = 4\sigma_x\left(z\right)$$

$$d_{\sigma y}\left(z\right) = 4\sigma_y\left(z\right)$$

where the second moments of the power density distribution function $E(x, y, z)$ of the beam at the location z are given by

$$\sigma_x^{\,2}\left(z\right) = \frac{\iint (x-\overline{x})^2 \cdot E(x,y,z)\mathrm{d}x\mathrm{d}y}{\iint E(x,y,z)\mathrm{d}x\mathrm{d}y}$$

$$\sigma_y^{\,2}\left(z\right) = \frac{\iint (y-\overline{y})^2 \cdot E(x,y,z)\mathrm{d}x\mathrm{d}y}{\iint E(x,y,z)\mathrm{d}x\mathrm{d}y}$$

where $\left(x-\overline{x}\right)$ and $\left(y-\overline{y}\right)$ are the distances to the centroid $\left(\overline{x},\overline{y}\right)$ and where the first moments give the coordinates of the centroid, i.e

$$\overline{x} = \frac{\iint x \cdot E(x,y,z)\mathrm{d}x\mathrm{d}y}{\iint E(x,y,z)\mathrm{d}x\mathrm{d}y}$$

$$\overline{y} = \frac{\iint y \cdot E(x,y,z)\mathrm{d}x\mathrm{d}y}{\iint E(x,y,z)\mathrm{d}x\mathrm{d}y}$$

Note 1 to entry: In principle, integration has to be carried out over the whole *xy* plane. In practice, the integration has to be performed over an area such that at least 99 % of the beam power (energy) are captured.

Note 2 to entry: The power density *E* has to be replaced by the energy density *H* for pulsed lasers.

Note 3 to entry: For clarity, the term “beam widths” is always used in combination with the symbol and its appropriate subscripts: $d_{\sigma \mathrm{x}}$, $d_{\sigma \mathrm{y}}$ or $d_{\mathrm{x,u}}$, $d_{\mathrm{y,u}}$.

3.5.3
beam ellipticity
$\varepsilon(z)$
parameter for quantifying the circularity or squareness of a power [energy] density distribution at *z*

$$\varepsilon(z) = \frac{d_{\sigma y}(z)}{d_{\sigma x}(z)}$$

Note 1 to entry: The direction of *x* is chosen to be along the major axis of the distribution so $d_{\sigma x} \geq d_{\sigma y}$.

Note 2 to entry: If $\varepsilon \geq 0{,}87$, elliptical distributions can be regarded as circular. In case of a rectangular beam profile, ellipticity is often referred to as aspect ratio.

3.5.4
circular power density distribution
power density distribution having an ellipticity greater than 0,87

[SOURCE: ISO 11146-1:2005, 3.7]

3.6
beam parameter product
product of the beam waist diameter and the divergence angle divided by 4

$$d_{\sigma 0} \cdot \Theta_{\sigma} \;/\; 4$$

Note 1 to entry: Beam parameter products for elliptical beams can be given separately for the principal axes of the power (energy) distribution.

3.7
beam propagation ratio
M^2
DEPRECATED: beam propagation factor
K
measure of how close the beam parameter product is to the diffraction limit of a perfect Gaussian beam

$$M^2 = \frac{1}{K} = \frac{\pi}{\lambda} \times \frac{d_{\sigma 0}\Theta_{\sigma}}{4}$$

Note 1 to entry: This is equal to the ratio of the beam parameter products for the actual modes of the laser and the fundamental Gaussian mode (TEM_{00}).

Note 2 to entry: The beam propagation ratio is unity for a theoretically perfect Gaussian beam, and has a value greater than one for any real beam.

Note 3 to entry: It is preferable to use M^2 because *K* is the symbol for the deprecated term and future editions will no longer use the term “beam propagation factor”.

3.8
beam position
displacement of the beam axis relative to the fixed mechanical axis of an optical system at a specified plane perpendicular to the mechanical axis of the optical system

Note 1 to entry: The mechanical axis is given by the straight line joining the centroids of the limiting apertures.

3.9
beam positional stability
$\Delta_x(z')$, $\Delta_y(z')$
four times the standard deviation of the measured beam positional movement at plane z'

[SOURCE: ISO 11670:2003, 3.6]

Note 1 to entry: These quantities are defined in the beam axis system *x,y,z*.

3.10
beam waist
portion of a beam where the beam diameter or beam width takes local minimum

3.11 Beam waist diameters

3.11.1
beam waist diameter
$d_{0,u}$
⟨encircled power (energy)⟩ diameter d_u of the beam at the location of the beam waist

Note 1 to entry: For clarity, the term "beam waist diameter" is always used in combination with the symbol and its appropriate subscripts: $d_{0,u}$ or $d_{\sigma 0}$.

3.11.2
beam waist diameter
$d_{\sigma 0}$
⟨second moment of power (energy) density distribution function⟩ diameter d_σ of the beam at the location of the beam waist

Note 1 to entry: For clarity, the term "beam waist diameter" is always used in combination with the symbol and its appropriate subscripts: $d_{0,u}$ or $d_{\sigma 0}$.

3.12 Beam waist radius

3.12.1
beam waist radius
$w_{0,u}$
⟨encircled power (energy)⟩ radius w_u of the beam at the location of the beam waist

Note 1 to entry: For clarity, the term "beam waist radius" is always used in combination with the symbol and its appropriate subscripts: $w_{0,u}$ or $w_{\sigma 0}$.

3.12.2
beam waist radius
$w_{\sigma 0}$
⟨second moment of power (energy) density distribution function⟩ radius w_σ of the beam at the location of the beam waist

Note 1 to entry: For clarity, the term "beam waist radius" is always used in combination with the symbol and its appropriate subscripts: $w_{0,u}$ or $w_{\sigma 0}$.

3.13 Beam waist widths

3.13.1
beam waist widths
$d_{x0,u}$, $d_{y0,u}$
⟨encircled power (energy)⟩ beam widths $d_{x,u}$ and $d_{y,u}$ at the locations of the beam waists in both the *x* and *y* directions

Note 1 to entry: For clarity, the term "beam waist widths" is always used in combination with the symbol and its appropriate subscripts: $d_{x0,u}$, $d_{y0,u}$ or $d_{\sigma x0}$, $d_{\sigma y0}$.

3.13.2
beam waist widths
$d_{\sigma x0}$, $d_{\sigma y0}$
⟨second moment of power (energy) density distribution function⟩ beam widths $d_{\sigma x}$ and $d_{\sigma y}$ at the locations of the beam waists in both the *x* and *y* directions

Note 1 to entry: For clarity, the term "beam waist widths" is always used in combination with the symbol and its appropriate subscripts: $d_{x0,u}$, $d_{y0,u}$ or $d_{\sigma x0}$, $d_{\sigma y0}$.

3.14 Beam waist separation

3.14.1
astigmatic waist separation
Δz_a
axial distance between the beam waist locations in the orthogonal principal planes of a beam possessing simple astigmatism

[SOURCE: ISO 15367-1:2003, 3.3.4]

Note 1 to entry: Astigmatic waist separation is also known as astigmatic difference.

3.14.2
relative astigmatic waist separation
Δz_r
astigmatic waist separation divided by the arithmetic mean of the Rayleigh lengths z_{Rx} and z_{Ry}

$$\Delta z_\text{r} = \frac{2\Delta z_\text{a}}{z_{\text{R}x} + z_{\text{R}y}}$$

3.15
coherence
characteristic of an electromagnetic wave where there is a constant phase relationship between each point

3.15.1
temporal coherence
characteristic of the correlation of the phases of an electromagnetic wave for different times at the same location

3.15.2
spatial coherence
characteristic of the correlation of the phases of an electromagnetic wave at different locations at the same time

3.16
coherence length
l_c
distance in beam direction within which the radiation emitted by the laser retains a significant phase relationship

Note 1 to entry: It is given by $c/\Delta\nu_H$ where c is the velocity of light and $\Delta\nu_H$ is the frequency bandwidth of the emitted laser light.

3.17
coherence time
τ_c
time interval within which the radiation emitted by the laser retains significant phase relationship

Note 1 to entry: It is given by $1/\Delta\nu_H$, where $\Delta\nu_H$ is the frequency bandwidth of the emitted laser light.

3.18
device efficiency
η_T
ratio of the total power (energy) in the laser beam to the total input power (energy) including all subordinate systems

3.19 Divergence angles

3.19.1
divergence angle
Θ_u, $\Theta_{x,u}$, $\Theta_{y,u}$
⟨encircled power (energy)⟩ full angle formed by the asymptotic cone of the envelope formed by the increasing beam width

Note 1 to entry: For a circular cross-section, the beam width is given by the beam diameter d_u. For non-circular cross-sections, the divergence angles are separately determined by the corresponding beam width in *x*- and *y*-directions, $d_{x,u}$, $d_{y,u}$, respectively.

Note 2 to entry: When specifying divergence angles, subscripts shall be used to indicate the relevant beam width.

EXAMPLE $\Theta_{x,50}$ indicates that beam width $d_{x,50}$ has been used.

Note 3 to entry: The definition of the coordinate systems as described here as well as the beam widths definitions does not include the case of general astigmatism.

Note 4 to entry: For clarity, the term "divergence angle" is always used in combination with the symbol and its appropriate subscripts: Θ_σ, $\Theta_{\sigma x}$, $\Theta_{\sigma y}$ or Θ_u, $\Theta_{x,u}$, $\Theta_{y,u}$.

3.19.2
divergence angle
Θ_σ, $\Theta_{\sigma x}$, $\Theta_{\sigma y}$
⟨second moment of power (energy) density distribution function⟩ full angle formed by the asymptotic cone of the envelope formed by the increasing beam width

Note 1 to entry: For a circular cross-section, the beam width is given by the beam diameter d_σ. For non-circular cross-sections, the divergence angles are separately determined by the corresponding beam width in *x*- and *y*-directions, $d_{\sigma x}$, $d_{\sigma y}$, respectively.

Note 2 to entry: The definition of the coordinate systems as described here as well as the beam widths definitions does not contain the case of general astigmatism.

Note 3 to entry: For clarity, the term "divergence angle" is always used in combination with the symbol and its appropriate subscripts: Θ_σ, $\Theta_{\sigma x}$, $\Theta_{\sigma y}$ or Θ_u, $\Theta_{x,u}$, $\Theta_{y,u}$.

3.20
effective f-number
ratio of focal length of an optical component to the beam diameter d_σ at that component

3.21
average energy density
H_u, H_σ
total energy of a beam divided by its cross-sectional area A_u or A_σ

3.22
pulse energy
Q
energy in one pulse

3.23
energy density
H(x,y)
beam energy which impinges on the area δA at the location (x,y) divided by the area δA

Note 1 to entry: Energy density is physically equivalent to radiance exposure. Both are measured in joules per unit area. Energy density is generally used to describe the distribution of radiation within a beam, whereas radiance exposure is generally used to describe the distribution of radiation incident upon a surface.

Note 2 to entry: See ISO 13694:2015, 3.1.2.1.

3.24
far field
radiation field of a laser at a distance z from the beam waist which is much greater than the Rayleigh length z_R

3.25
laser
amplifying medium capable of generating coherent radiation with wavelengths up to 1 mm by means of stimulated emission

Note 1 to entry: See Figure 1 and Annex A.

Note 2 to entry: The term "laser" is an acronym for "light amplification by stimulated emission of radiation".

3.26
continuous wave laser
cw laser
laser continuously emitting radiation over periods of time greater than or equal to 0,25 s

3.27
pulsed laser
laser which emits energy in the form of a single pulse or a train of pulses where the duration of a pulse is less than 0,25 s

3.28
laser assembly
laser device together with specific, normally optical, mechanical and/or electrical or electro-optical system components for beam handling and forming

Note 1 to entry: See Figure 1 and Annex A.

3.29
laser beam
spatially directed laser radiation

3.30
laser device
laser where the radiation is generated, together with essential additional facilities (e.g. cooling, power and gas supply) that are necessary to operate the laser

Note 1 to entry: See Figure 1 and Annex A.

3.31
laser efficiency
η_L
ratio of the total power (energy) in the laser beam to the total pump power (energy) that is directly supplied to the laser

3.32
laser radiation
coherent electromagnetic radiation with wavelengths up to 1 mm, generated by a laser

3.33
laser unit
one or more laser assemblies together with handling, measurement and control systems

Note 1 to entry: See Figure 1 and Annex A.

3.34
lifetime
interval (time or number of pulses) over which a laser device or a laser assembly maintains the performance characteristics specified by the manufacturer

Note 1 to entry: Conditions of use, service and maintenance are specified by the manufacturer.

3.35
longitudinal mode
eigenfunction of the electric field distribution within a resonator of length L along the direction of propagation of the electromagnetic wave

Note 1 to entry: The longitudinal mode number $q = 2n(\lambda)\ L/\lambda$, where n is the refractive index of the medium, describes the number of half-wavelengths in the cavity path length.

3.36
transverse mode
eigenfunction of the electric field distribution within the resonator or of the power (energy) density distribution of the laser beam perpendicular to the direction of propagation of the electromagnetic wave

Note 1 to entry: For rectangular symmetry, the numbers m and n account for the nodes in the field distribution in the x- and y-direction, perpendicular to the direction of propagation of the electromagnetic wave (Hermite-Gauss modes).

Note 2 to entry: The 01* mode is a linear combination of equal amounts of the rectangular 10 and 01 modes providing a circular symmetry with a node in the centre.

Note 3 to entry: For cylindrical symmetry, p and l account for the radial and azimuthal nodes (Laguerre-Gauss modes).

3.37
polarization
restriction of electromagnetic wave motion to certain directions

Note 1 to entry: This is a fundamental phenomenon which can be explained by the concept that electromagnetic radiation is a transverse wave motion, i.e. the vibrations are at right angles to the direction of propagation. It is customary to consider these vibrations as being those of the electric field vector.

3.38
circular polarization
description of a radiation wave in which the electric vector is of constant amplitude and rotates about the direction of propagation at a frequency equal to the radiation frequency in a homogeneous optical medium

3.39
elliptical polarization
description of a radiation wave in which the electric vector rotates at the radiation frequency but varies in amplitude in a homogeneous optical medium

Note 1 to entry: The terminal point of the electric vector describes an ellipse.

3.40
linear polarization
description of a radiation wave in which the electric field vector is at a fixed azimuth

Note 1 to entry: It is confined to a plane containing the direction of propagation of the radiation in a homogeneous optical medium.

Note 2 to entry: A laser beam is called “linearly polarized” if the degree of linear polarization is greater than 0,9 and the polarization direction is constant over time.

3.41
degree of linear polarization
p
ratio of the difference to the sum of beam powers *P* (energies *Q*) in two orthogonal directions of polarization

$$p = \frac{P_x - P_y}{P_x + P_y} \text{ or } p = \frac{Q_x - Q_y}{Q_x + Q_y}$$

Note 1 to entry: The directions *x* and *y* are chosen as those for which the beam power (energy) is attenuated minimally or maximally, respectively, after transmission through a linear polarizer. The direction *x*, for which the beam attenuation after transmission through a linear polarizer is minimal, is the polarization direction.

3.42
partial polarization
state in which a beam of radiation, whether originating from a natural or artificial source, is neither completely polarized nor completely unpolarized

Note 1 to entry: A partially polarized beam can be regarded as being composed of two components, one polarized and the other unpolarized.

Note 2 to entry: A laser beam is called “partially linearly polarized” if the degree of linear polarization is greater than 0,1 and the polarization direction is constant over time.

3.43
randomly polarized radiation
radiation that can be considered as the composition of two orthogonal linearly polarized waves of fixed directions whose amplitudes vary randomly over time with respect to each other

3.44
average power density
E_u, E_σ
total power of a beam divided by its cross-sectional area A_u or A_σ

3.45
cw-power
P
power output of a cw-laser

3.46
power density
$E(x,y)$
beam power which impinges on the area δA at the location (x, y) divided by the area δA

Note 1 to entry: Power density is physically equivalent to irradiance. Both are measured in watts per unit area. Power density is generally used to describe the distribution of radiation within a beam, whereas irradiance is generally used to describe the distribution of radiation incident upon a surface.

Note 2 to entry: See ISO 13694:2015, 3.1.1.1.

3.47
pulse power
P_H
ratio of the pulse energy *Q* to the pulse duration τ_H

3.48
average power
P_{av}
product of the average pulse energy Q and the pulse repetition rate f_p

3.49
peak power
P_{pk}
maximum of the power-time function

3.50
pulse duration
τ_H
time interval between the half peak power points at the leading and trailing edges of a pulse

3.51
10 %-pulse duration
τ_{10}
interval between the first and last times when the pulse reaches 1/10 of the peak power

3.52
pulse repetition rate
f_p
number of laser pulses per second of a repetitively pulsed laser

3.53
relative intensity noise
RIN
$R(f)$
quotient of the radiant power mean square fluctuations to the mean square radiant power, normalized to a frequency band of unit width

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

Note 1 to entry: The relative intensity noise $R(f)$ or RIN as defined above is explicitly spoken as the “relative intensity noise spectral density”, but usually simply referred to as RIN.

3.54
quantum efficiency
η_Q
ratio of the energy of a single laser photon to the energy of a single pumping photon which causes the inversion in an optically pumped laser

3.55
Rayleigh length
z_R, z_{Rx}, z_{Ry}
distance from the beam waist in the direction of propagation for which the beam diameter or beam widths are equal to $\sqrt{2}$ times their value at the beam waist

Note 1 to entry: For the Gaussian fundamental mode:

$$z_R = \frac{\pi d_{\sigma 0}{}^2}{4\lambda}$$

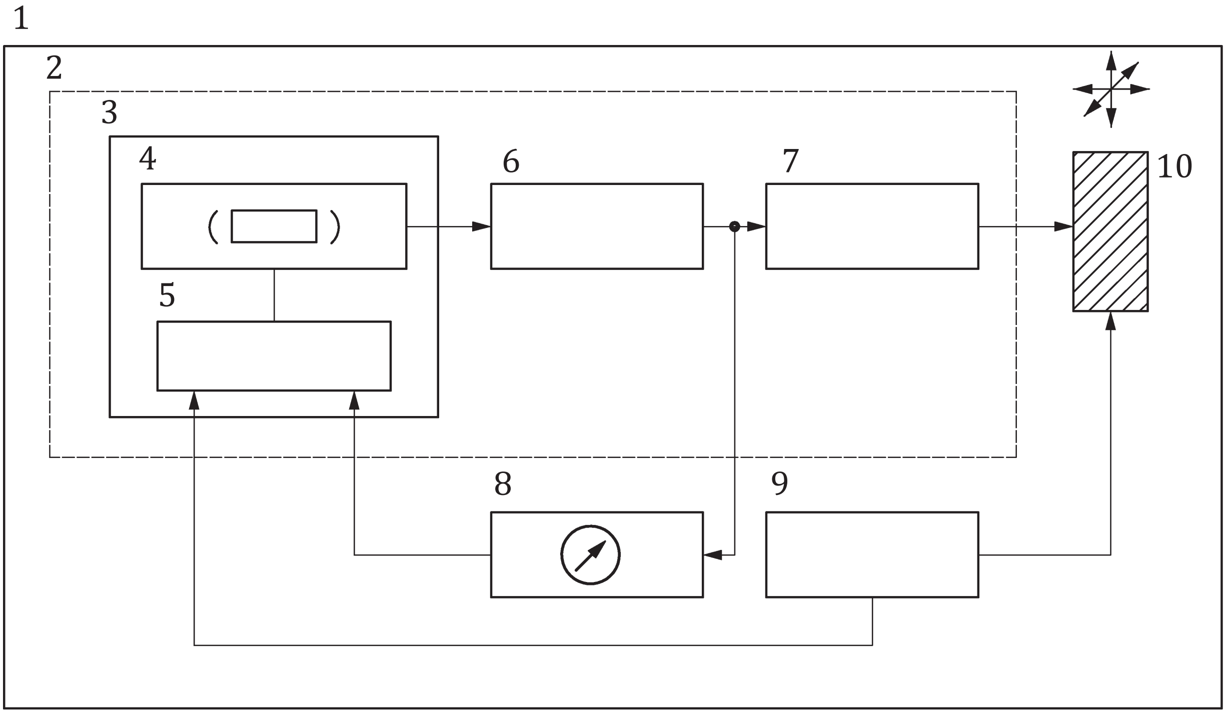
Note 2 to entry: Generally, the formula $z_R = d_{\sigma 0} / \Theta_\sigma$ is valid.

3.56
spectral bandwidth
$\Delta\lambda$, $\Delta\nu$
maximum difference between the wavelengths (optical frequencies) for which the spectral power (energy) density is half of its peak value

3.57
stable resonator
resonator with two terminating mirrors, the paths of the paraxial rays of which remain within the resonator for an infinite number of round trips

3.58
unstable resonator
resonator with two terminating mirrors, the paths of the paraxial rays of which escape from the resonator after a finite number of round trips

Note 1 to entry: One axial ray stays in the resonator as long as diffraction is neglected.



Key

1	laser unit	6	beam-guiding device (mirrors, fibres, lenses)
2	laser assembly	7	beam-forming device (telescope, focusing)
3	laser device	8	measurement and control
4	laser	9	handling units (robot, workpiece, positioning)
5	supply (power, cooling)	10	workpiece

NOTE 1 This example is taken from materials processing.

NOTE 2 The safety equipment that is usually required is not included here.

NOTE 3 See Annex A.

Figure 1 — Illustration of the terms laser, laser device, laser assembly and laser unit

Annex A
(informative)

Explanation of the difference in terminology between IEC 60825-1 and ISO 11145

The laser hierarchical vocabulary illustrated in Figure 1 differs from the hierarchical vocabulary given in IEC 60825-1. ISO and IEC have discussed this difference and agree that it reflects the different purposes for which the two standards were developed.

The IEC 60825-1 vocabulary was developed on the basis of the applicability of the safety standard to manufacturers of products that are sold to end users, and not to follow-on manufacturers who incorporate lasers and laser systems into a higher level of assembly for sale to an end user. The purpose of IEC 60825-1, Clause 2 is to make the manufacturer of end-user products, “laser product(s)”, incorporating lasers responsible for complying with the safety requirements of IEC 60825-1. Additionally, the safety requirements are more extensive for “lasers” with attached power sources. Hence the term “laser system” was established to distinguish from “laser”. The IEC terms were adopted from national laser safety standards, and have been adopted into numerous national and international safety standards, indicating that the terms are appropriate for the standards incorporating them.

The ISO vocabulary was developed with the intention of producing absolute definitions of the hierarchical stages of laser equipment. Because the IEC vocabulary is explicitly dependent on what happens to the laser equipment in the future, it does not satisfy the ISO requirement of being absolute. The IEC definitions for “laser system” and “laser product” are not part of the ISO terminology. They are given below for information purposes.

“Laser product: any product or assembly of components which constitutes, incorporates or is intended to incorporate a laser or laser system, and which is not sold to another manufacturer for use as a component (or replacement for such component) of an electronic product.”

“Laser system: a laser in combination with an appropriate laser energy source with or without additional incorporated components”.

Annex B
(informative)

List of symbols

A_u	3.2.1
A_σ	3.2.2
d_σ	3.3.2
$d_{\sigma 0}$	3.11.2
$d_{\sigma x}$, $d_{\sigma y}$	3.5.2
$d_{\sigma x0}$, $d_{\sigma y0}$	3.13.2
d_u	3.3.1
$d_{x,u}$, $d_{y,u}$	3.2.1
$d_{0,u}$	3.11.1
$d_{x0,u}$, $d_{y0,u}$	3.13.1
$E(x,y)$	3.46
E_u, E_σ	3.44
f_P	3.52
$H(x,y)$	3.23
H_u, H_σ	3.21
K	3.7
l_c	3.16
M^2	3.7
p	3.41
P	3.45
P_av	3.48
P_H	3.47
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$\Delta\lambda$, $\Delta\nu$	3.56
$\Delta\vartheta$	3.1.2
ε	3.5.3
η_L	3.31
η_Q	3.54
η_T	3.18
Θ_u, $\Theta_{x,u}$, $\Theta_{y,u}$	3.19.1
Θ_σ , $\Theta_{\sigma x}$, $\Theta_{\sigma y}$	3.19.2
τ_c	3.17
τ_H	3.50
τ_{10}	3.51

Annex C
(informative)

Alphabetical index

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