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

Optique et photonique — Lasers et équipements associés aux lasers — Vocabulaire et symboles

Please see the administrative notes on page iii

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ISO/CEN PARALLEL PROCESSING

This final draft has been developed within the International Organization for Standardization (ISO), and processed under the **ISO-lead** mode of collaboration as defined in the Vienna Agreement. The final draft was established on the basis of comments received during a parallel enquiry on the draft.

This final draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel two-month approval vote in ISO and formal vote in CEN.

Positive votes shall not be accompanied by comments.

Negative votes shall be accompanied by the relevant technical reasons.

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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/e2, 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 (= $2w_u$) may 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

Table 1 *(continued)*

Symbol	Unit	Term
P	W	Cw-power
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 lg $R(f)$ 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_S.

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_S.

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_S.

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.