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

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Foreword

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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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This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Laser and electro-optical systems*.

This fifth edition cancels and replaces the fourth edition ISO 11145:2016, which has been technically revised. The main changes compared to the previous edition are as follows:

a) the term beam position has been renamed “beam centroid” and defined formally as a first-order moment;

b) the term beam ellipticity has been clarified;

c) the term beam waist location has been included;

d) the term optical resonator has been included;

e) the term 10 % pulse duration has been generalized to a selected percentage pulse duration;

f) the formula in the term beam diameter has been adjusted;

g) the order of the terms has been adjusted.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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

1 Scope

This document 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 document 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 Normative references

There are no normative references in this document.

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:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

NOTE 1 The spatial distribution of the power (energy) density in a cross section of a laser beam does not always have circular symmetry. In this document, all terms related to these spatial distributions are split into those for beam cross sections with circular distributions and those for beam cross sections with non-circular distributions. 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 are given.

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

NOTE 3 This document uses the subscript u to denote a percentage. For example, the percentage of the total beam power (energy) included in the value of a given parameter. When stating quantities marked by an index “u”, “u” is replaced by the specific number, e.g. A_{90} for $u = 90$ %.

NOTE 4 The beam width $d_{x,u}$ (see 3.5.1) and the beam diameter d_u (see 3.3.1) can differ for the same value of u ($d_{x,u} \neq d_u$).

NOTE 5 In contrast to 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 moments of the power (energy) density distribution function (see 3.5.2). Only beam propagation ratios (see 3.10.2) that are calculated from beam widths and divergence angles derived from the second moments of the power (energy) density distribution function allow calculation of beam propagation. In this document, quantities based on the second moment are marked by a subscript “σ”.

NOTE 6 A list of symbols is given in Annex B.

3.1 Beam position

3.1.1
beam centroid

$\bar{x}(z), \bar{y}(z)$

coordinates of the first-order moments of a power (energy) distribution of a beam at location z

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

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

where the integration shall be performed over an area such that at least 99 % of the beam power (energy) is captured

Note 1 to entry: The power density E is replaced by the energy density H for pulsed lasers.

Note 2 to entry: The terms beam centroid, centre of gravity and beam position are equivalent, formerly the term beam position was used.

Note 3 to entry: These quantities are defined in the beam axis system x,y,z, in which z is the direction of propagation of the beam.

3.1.2
beam positional stability

$\Delta_x(z'), \Delta_y(z')$

four times the standard deviation of the measured beam positional movement at plane z'

$$\Delta_x(z') = 4\sqrt{\frac{\sum_{i=1}^{N}\left[\bar{x}(z')_i - \overline{\bar{x}(z')}\right]^2}{N-1}}$$

$$\Delta_y(z') = 4\sqrt{\frac{\sum_{i=1}^{N}\left[\bar{y}(z')_i - \overline{\bar{y}(z')}\right]^2}{N-1}}$$

where $\bar{x}(z')$ and $\bar{y}(z')$ are the beam centroids in the z' plane, $\overline{\bar{x}(z')}$ and $\overline{\bar{y}(z')}$ are the mean beam centroids in the z' plane, and N is the number of measurements

Note 1 to entry: The term "beam angular stability", sometimes referred to as "beam pointing stability", is defined in ISO 11670:2003.

[SOURCE: ISO 11670:2003, 3.6, modified — The NOTE has been deleted, the text after "at plane z'" has been added and Note 1 to entry has been added.]

3.2 Beam axis

3.2.1
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

3.2.2
misalignment angle
$\Delta\vartheta$
deviation angle of the beam axis from the mechanical axis defined by the manufacturer

3.3 Beam diameter

3.3.1
beam diameter
$d_u(z)$
<encircled power (energy)> 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_σ.

3.3.2
beam diameter
$d_\sigma(z)$
<second moment of power (energy) density distribution function> diameter defined by using the second moment of the power (energy) density distribution function

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

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

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

where the first moments give the coordinates of the beam centroid $\left[\bar{x}(z), \bar{y}(z)\right]$

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_σ.

3.4 Beam radius

3.4.1
beam radius
$w_u(z)$
<encircled power (energy)> radius of a circular 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.

Note 2 to entry: The beam radius is half the beam diameter $d_u(z)$.

3.4.2
beam radius
$w_\sigma(z)$
<second moment of power (energy) density distribution function> radius defined by using the second moment of the power (energy) density distribution function

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

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.

Note 3 to entry: The beam radius is half the beam diameter $d_\sigma(z)$.

3.5 Beam width

3.5.1
beam width

$d_{x,u}(z)$, $d_{y,u}(z)$

<slit transmitted power (energy)> width of the smallest slit aligned with the x or y transverse axes of the power (energy) density distribution function, transmitting u % of the total beam power (energy) along x or y

Note 1 to entry: For circular Gaussian beams, $d_{x,95,4}$ and $d_{y,95,4}$ both equal $d_{86,5}$.

Note 2 to entry: For clarity, the term “beam width” 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 width

$d_{\sigma x}(z)$, $d_{\sigma y}(z)$

<second moment of power (energy) density distribution function> width defined by using the second moment of the power (energy) density distribution function along x or y

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

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

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

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

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

where $\left(x - \bar{x}(z)\right)$ and $\left(y - \bar{y}(z)\right)$ are the distances from the current point’s coordinates to the beam centroid $\left(\bar{x}(z), \bar{y}(z)\right)$

Note 1 to entry: For clarity, the term “beam width” is always used in combination with the symbol and its appropriate subscripts: $d_{\sigma x}$, $d_{\sigma y}$ or $d_{x,u}$, $d_{y,u}$.

3.6 Beam cross-sectional area

3.6.1
beam cross-sectional area

$A_u(z)$

<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_σ.

3.6.2
beam cross-sectional area
$A_\sigma(z)$
<second moment of power (energy) density distribution function> area of a beam with circular cross-section

$$A_\sigma = \left(\frac{\pi}{4}\right) \cdot d_\sigma(z)^2$$

or elliptical cross-section

$$A_\sigma = \left(\frac{\pi}{4}\right) \cdot d_{\sigma x}(z) \cdot d_{\sigma y}(z)$$

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_σ.

3.6.3
beam ellipticity
$\varepsilon(z)$
parameter for quantifying the circularity or squareness of a power (energy) density distribution at z

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

where the direction of x is chosen to be along the major axis of the distribution, such that $d_{\sigma x} \geq d_{\sigma y}$

Note 1 to entry: If $\varepsilon \geq 0{,}87$, elliptical distributions can be regarded as circular.

Note 2 to entry: In case of a rectangular distribution, ellipticity is often referred to as "aspect ratio".

Note 3 to entry: In contrast to the definition given here, in literature the term "ellipticity" is sometimes related to $1 - \frac{d_{\sigma y}(z)}{d_{\sigma x}(z)}$. The definition given here has been chosen to be in concordance with the same definition of ellipticity in ISO 11146-1 and ISO 13694.

3.6.4
circular power density distribution
power density distribution having an ellipticity greater than or equal to 0,87

3.7 Beam waist

3.7.1
beam waist
portion of a beam where the beam diameter or beam width has a local minimum

3.7.2
beam waist location
z_{0x}, z_{0y}, z_0
location where the beam widths or the beam diameters reach their minimum values along the beam axis

Note 1 to entry: A particular beam can have multiple beam waist locations.

3.7.3
astigmatic beam waist separation

Δz_a

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

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

[SOURCE: ISO 15367-1:2003, 3.3.4, modified — In the term, "beam" has been added.]

3.7.4
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 $d_{\sigma 0}$.

3.7.5
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 $d_{\sigma 0}$.

3.7.6
beam waist radius

$w_{0,u}$

<encircled power (energy)> radius w_u of the beam at the location of the beam waist, which is half the beam waist diameter $d_{0,u}$

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 $w_{\sigma 0}$.

3.7.7
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, which is half the beam waist diameter $d_{\sigma 0}$

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 $w_{\sigma 0}$.

3.7.8
beam waist width

$d_{x0,u}$, $d_{y0,u}$

<slit transmitted power (energy)> beam width $d_{x,u}$ or $d_{y,u}$ at the location of the beam waist in the x or y direction, respectively

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

3.7.9
beam waist width

$d_{\sigma x0}$, $d_{\sigma y0}$

<second moment of power (energy) density distribution function> beam width $d_{\sigma x}$ or $d_{\sigma y}$ at the location of the beam waist in the x or y direction, respectively

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

3.8 Divergence

3.8.1
divergence angle

Θ_u, $\Theta_{x,u}$, $\Theta_{y,u}$

<encircled, slit transmitted power (energy)> full angle formed by the asymptotic envelope of a diverging beam that propagates with increasing beam diameter (width)

Note 1 to entry: For circular cross-sections, the divergence angle Θ_u is determined from the beam diameter d_u. For non-circular cross-sections, the divergence angles $\Theta_{x,u}$ and $\Theta_{y,u}$ are separately determined from the respective beam widths in the *x*- and *y*-directions, $d_{x,u}$ and $d_{y,u}$.

Note 2 to entry: When specifying divergence angles, subscripts are used to indicate the relevant beam diameter (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 width 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, $\Theta_{x,u}$, $\Theta_{y,u}$.

3.8.2
divergence angle

Θ_σ, $\Theta_{\sigma x}$, $\Theta_{\sigma y}$

<second moment of power (energy) density distribution function> full angle formed by the asymptotic envelope of a diverging beam that propagates with increasing beam diameter (width)

Note 1 to entry: For circular cross-sections, the divergence angle Θ_σ is determined from the beam diameter d_σ. For non-circular cross-sections, the divergence angles $\Theta_{\sigma x}$ and $\Theta_{\sigma y}$ are separately determined from the respective beam widths in the *x*- and *y*-directions, $d_{\sigma x}$ and $d_{\sigma y}$.

Note 2 to entry: The definition of the coordinate systems as described here as well as the beam width definitions do not include 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, $\Theta_{x,u}$, $\Theta_{y,u}$.

3.8.3
effective f-number

ratio of focal length of an optical component to the beam diameter d_σ of the centred beam passing through that component

3.9 Rayleigh length

3.9.1
Rayleigh length

z_R, $z_{\mathrm{R}x}$, $z_{\mathrm{R}y}$

distance from the beam waist in the direction of propagation for which the beam diameter and beam width are equal to $\sqrt{2}$ times their respective values at the beam waist

Note 1 to entry: For the Gaussian fundamental mode:

$$z_\mathrm{R} = \left(\frac{\pi}{4}\right)\frac{d_{\sigma 0}^{\;2}}{\lambda}$$

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