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# Optics and photonics - Lasers and laser-related equipment - Vocabulary and symbols (ISO 11145:2018)

**I.S. EN ISO 11145:2018**

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The National Standards Authority of Ireland (NSAI) produces the following categories of formal documents:

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## National Foreword

I.S. EN ISO 11145:2018 is the adopted Irish version of the European Document EN ISO 11145:2018, Optics and photonics - Lasers and laser-related equipment - Vocabulary and symbols (ISO 11145:2018)

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EUROPEAN STANDARD  
NORME EUROPÉENNE  
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EN ISO 11145

December 2018

ICS 01.040.31; 01.080.40; 31.260

Supersedes EN ISO 11145:2016

English Version

Optics and photonics - Lasers and laser-related equipment  
- Vocabulary and symbols (ISO 11145:2018)

Optique et photonique - Lasers et équipements  
associés aux lasers - Vocabulaire et symboles (ISO  
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Optik und Photonik - Laser und Laseranlagen - Begriffe  
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## European foreword

This document (EN ISO 11145:2018) 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of an identical text or by endorsement, at the latest by June 2019, and conflicting national standards shall be withdrawn at the latest by June 2019.

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This document supersedes EN ISO 11145:2016.

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

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## Endorsement notice

The text of ISO 11145:2018 has been approved by CEN as EN ISO 11145:2018 without any modification.

## Annex ZA (informative)

### Relationship between this European Standard and the essential requirements of Directive 2006/42/EC aimed to be covered

This European Standard has been prepared under a Commission's standardization request M/396 (Machinery) "Mandate to CEN and Cenelec for standardisation in the field of machinery" to provide one voluntary means of conforming to essential requirements of Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast).

Once this standard is cited in the Official Journal of the European Union under that Directive, compliance with the normative 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 Directive 2006/42/EC**

Essential Requirements of Directive 2006/42/EC	Clause(s)/sub-clause(s) of this EN	Remarks/Notes
1.5.10	3	
1.5.12	3	

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# INTERNATIONAL STANDARD

**ISO  
11145**

Fifth edition  
2018-11

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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*



Reference number  
**ISO 11145:2018(E)**

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## ISO 11145:2018(E)

## 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](http://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](http://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 “ $\sigma$ ”.

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

## ISO 11145:2018(E)

## 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  $z$

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

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

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  $z'$

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

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

where  $\bar{x}(z')$  and  $\bar{y}(z')$  are the beam centroids in the  $z'$  plane,  $\bar{x}(z')$  and  $\bar{y}(z')$  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** $\Delta\theta$ 

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  $d_\sigma$ .

**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 is given by

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

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

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  $d_\sigma$ .

**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  $w_\sigma$ .

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.

## ISO 11145:2018(E)

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  $w_\sigma$ .

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:

$$\sigma_x^2(z) = \frac{\iint (x - \bar{x}(z))^2 \cdot E(x, y, z) \cdot dx dy}{\iint E(x, y, z) \cdot dx dy}$$

$$\sigma_y^2(z) = \frac{\iint (y - \bar{y}(z))^2 \cdot E(x, y, z) \cdot dx dy}{\iint E(x, y, z) \cdot dx dy}$$

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



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  $A_\sigma$ .

**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  $A_{\sigma}$ .

**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.

## ISO 11145:2018(E)



## 3.7.3

**astigmatic beam waist separation** $\Delta z_a$ 

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  $d_{\sigma}$  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  $w_{\sigma}$  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

$\theta_u, \theta_{x,u}, \theta_{y,u}$

<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  $\theta_u$  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:  $\theta_\sigma, \theta_{\sigma x}, \theta_{\sigma y}$  or  $\theta_u, \theta_{x,u}, \theta_{y,u}$ .

#### 3.8.2

##### divergence angle

$\theta_\sigma, \theta_{\sigma x}, \theta_{\sigma y}$

<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  $\theta_\sigma$  is determined from the beam diameter  $d_\sigma$ . 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:  $\theta_\sigma, \theta_{\sigma x}, \theta_{\sigma y}$  or  $\theta_u, \theta_{x,u}, \theta_{y,u}$ .

#### 3.8.3

##### effective f-number

ratio of focal length of an optical component to the beam diameter  $d_\sigma$  of the centred beam passing through that component

### 3.9 Rayleigh length

#### 3.9.1

##### Rayleigh length

$z_R, z_{Rx}, z_{Ry}$

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:

$$z_R = \left( \frac{\pi}{4} \right) \frac{d_{\sigma 0}^2}{\lambda}$$

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

## ISO 11145:2018(E)

### 3.9.2

#### far field

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

### 3.9.3

#### relative astigmatic beam waist separation

$\Delta z_r$

astigmatic beam waist separation divided by the arithmetic mean of the Rayleigh lengths  $z_{Rx}$  and  $z_{Ry}$

$$\Delta z_r = \frac{2\Delta z_a}{z_{Rx} + z_{Ry}}$$

## 3.10 Beam parameter product

### 3.10.1

#### 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 simple astigmatic beams can be given separately for the principal axes of the power (energy) density distribution.

### 3.10.2

#### beam propagation ratio



Measure of how far the beam parameter product is from that of a perfect Gaussian beam

$$M^2 = \left( \frac{\pi}{\lambda} \right) \cdot \frac{d_{\sigma 0} \Theta_{\sigma}}{4}$$

Note 1 to entry: This quantity is equal to the ratio of the beam parameter product of the actual laser beam to the beam parameter product of the fundamental Gaussian beam (TEM<sub>00</sub>), both beams with the same wavelength.

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.



### 3.10.3

#### beam propagation factor

$K$

reciprocal of the beam propagation ratio

$$K = 1/M^2$$

## 3.11 Coherence

### 3.11.1

#### coherence

characteristic of a beam of electromagnetic radiation where there is a deterministic (not random) phase relationship between each pair of points in the beam

### 3.11.2

#### temporal coherence

characteristic of a beam of electromagnetic radiation to have a degree of phase correlation between different moments in time at the same spatial point in the beam

**3.11.3****spatial coherence**

characteristic of a beam of electromagnetic radiation to have a degree of phase correlation between different spatial points in the beam at the same moment in time

**3.11.4****coherence length**
 $l_c$ 

distance along the beam propagation direction within which the radiation emitted by the laser retains a significant phase correlation

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.

**3.11.5****coherence time**
 $\tau_c$ 

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.

**3.12 Polarization****3.12.1****polarization**

restriction of electromagnetic field oscillation 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, i.e. the oscillations are orthogonal to the direction of propagation. It is customary to consider these oscillations as being those of the electric field vector.

**3.12.2****circular polarization**

property of electromagnetic radiation in which the electric field 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

**3.12.3****elliptical polarization**

property of electromagnetic radiation in which the electric field vector rotates about the direction of propagation at the radiation frequency and periodically oscillates in amplitude, in a homogeneous optical medium

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

**3.12.4****linear polarization**

property of electromagnetic radiation in which the electric field vector oscillates along a fixed direction

Note 1 to entry: The oscillation 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.

## ISO 11145:2018(E)

## 3.12.5

**degree of linear polarization** $p$ 

ratio of the difference to the sum of beam powers  $P$  (energies  $Q$ ) in two orthogonal directions of polarization

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

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

## 3.12.6

**partial polarization**

state in which a beam of electromagnetic radiation 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 smaller than 0,9 and the polarization direction is constant over time.

## 3.12.7

**random polarization**

state in which a beam of electromagnetic radiation is composed of two linearly polarized beams of electromagnetic radiation having orthogonal fixed polarization directions and having amplitudes that vary randomly over time with respect to each other

## 3.13 Power and Energy

## 3.13.1

**average energy density** $H_u, H_\sigma$ 

total energy of a beam divided by its cross-sectional area  $A_u$  or  $A_\sigma$

## 3.13.2

**average power density** $E_u, E_\sigma$ 

total power of a beam divided by its cross-sectional area  $A_u$  or  $A_\sigma$

## 3.13.3

**pulse energy** $Q$ 

energy in one pulse

## 3.13.4

**energy density** $H(x_p, y_p, z)$ 

portion of the beam energy (time integrated power) at location  $z$  which impinges on the area  $\delta A$  at the location  $P(x_p, y_p)$  divided by the area  $\delta A$  in the limit  $\delta A \rightarrow 0$

Note 1 to entry: Energy density is physically equivalent to radiance exposure. Both have SI units of joules per square meter ( $\text{J}/\text{m}^2$ ). 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 13694:2018, 3.1.2.1.



**3.13.5****continuous wave power**

cw power

 $P$ 

power output of a continuous wave laser

**3.13.6****power density** $E(x_P, y_P, z)$ 

portion of the beam power at location  $z$  which impinges on the area  $\delta A$  at the location  $P(x_P, y_P)$  divided by the area  $\delta A$  in the limit  $\delta A \rightarrow 0$

Note 1 to entry: Power density is physically equivalent to irradiance. Both have SI units of watts per square meter ( $\text{W}/\text{m}^2$ ). 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 13694:2018, 3.1.1.1.

**3.13.7****pulse power** $P_H$ ratio of the pulse energy  $Q$  to the pulse duration  $\tau_H$ **3.13.8****average power** $P_{av}$ product of the average pulse energy  $Q$  and the pulse repetition rate  $f_p$ **3.13.9****peak power** $P_{pk}$ 

maximum of the power as a function of time for a pulse

**3.14 Pulse duration and repetition rate****3.14.1****pulse duration** $\tau_u$ 

time interval between the moment of  $u$  % peak power on the leading edge of a pulse and the moment of  $u$  % peak power on the trailing edge of the pulse

Note 1 to entry:  $\tau_{10}$  is the time interval between the moments of 10 % peak power on the leading and trailing edges of the pulse.

**3.14.2****FWHM pulse duration**

full width half maximum pulse duration

 $\tau_H$ 

time interval between the moments of half peak power on the leading and trailing edges of a pulse

**3.14.3****pulse repetition rate** $f_p$ 

number of laser pulses per second of a repetitively pulsed laser

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