AS/NZS IEC 60825.1:2014
IEC 60825-1, Ed. 3.0 (2014)

AS/NZS IEC 60825.1:2014

Australian/New Zealand Standard™

Safety of laser products

Part 1: Equipment classification and requirements

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This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee SF-019, Personal Protection Against Laser Radiation. It was approved on behalf of the Council of Standards Australia on 2 October 2014 and on behalf of the Council of Standards New Zealand on 3 October 2014.
This Standard was published on 12 November 2014.

The following are represented on Committee SF-019:

Australasian Faculty of Occupational and Environmental Medicine
Australian Dental Association
Australian Radiation Protection and Nuclear Safety Agency
Defence Materiel Organisation
Department of Defence, Australia
Electronics Industry Association
Institute of Environmental Science and Research
NSW Business Chamber
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Safety of laser products

Part 1: Equipment classification and requirements

Originated in Australia as AS 2211—1978.
Previous edition AS/NZS IEC 60825.1:2011.
Second edition 2014.

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Jointly published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001 and by Standards New Zealand, Private Bag 2439, Wellington 6140.

ISBN 978 1 74342 875 7

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee SF-019, Personal Protection Against Laser Radiation, to supersede AS/NZS IEC 60825.1:2011.

It is important to note that the designation of this Standard has changed; prior to 2011, this Standard was designated AS/NZS 2211.1:2004, *Safety of laser products*, Part 1: *Equipment classification, requirements and user's guide* (IEC 60825-1:2001, MOD).

Standards in the IEC 60825 series may have been adopted as either AS/NZS IEC 60825 series standards (e.g. IEC/TR 60825-14 has been adopted as AS/NZS IEC 60825.14), or AS/NZS 2211 series standards (e.g. IEC 60825-4 has been adopted as AS/NZS 2211.4).

The objectives of this Standard are as follows:

(a) To protect people from laser radiation in the wavelength range 180 nm to 1 mm by introducing a system of classification of lasers and laser products according to their degree of optical radiation hazard.

(b) To specify requirements for the manufacturer to supply information so that proper precautions can be adopted.

(c) To ensure adequate warnings are provided to individuals of hazards associated with accessible radiation from laser products through the use of labels and instructions.

(d) To reduce the possibility of injury by minimizing unnecessary accessible radiation and to give improved control of the laser radiation hazards through protective features.

This Standard is identical with, and has been reproduced from, IEC 60825-1, Ed. 3.0 (2014), *Safety of laser products*, Part 1: *Equipment classification and requirements*.

This Standard adopts the 2013 maximum permissible exposure (MPE) limits published by the International Commission on Non-Ionizing Radiation Protection. The MPE limits in Annex A of this Standard are more recent than the MPE limits in other earlier standards in this series, and may be used in preference.

As this Standard is reproduced from an International Standard, the following applies:

(i) In the source text 'this part of IEC 60825' should read 'this Australian/New Zealand Standard.'

(ii) A full point substitutes for a comma when referring to a decimal marker.

References to International Standards should be replaced by references to Australian/New Zealand Standards, as follows:

Reference to International Standard		*Australian/New Zealand Standard*	
IEC 62471	Photobiological safety of lamps and lamp systems (all parts)	AS/NZS IEC 62471	Photobiological safety of lamps and lamp systems (series)

Only normative references that have been adopted as Australian or Australian/New Zealand Standard have been listed.

The term 'informative' has been used in this Standard to define the application of the annex to which it applies. An 'informative' annex is only for information and guidance.

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FOREWORD

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

- a new class, Class 1C, was introduced;
- the measurement condition 2 (“eye loupe” condition) was removed;
- classification of the emission of laser products below a certain radiance level that are intended to be used as replacement for conventional light sources can, as an option, be based on the IEC 62471 series;
- the accessible emission limits (AELs) for Class 1, 1M, 2, 2M and 3R of pulsed sources, particularly of pulsed extended sources, were updated to reflect the latest revision of the ICNIRP guidelines on exposure limits (accepted for publication in Health Physics 105 (3): 271 – 295; 2013, see also www.icnirp.org).

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AUSTRALIAN/NEW ZEALAND STANDARD

Safety of laser products

Part 1:
Equipment classification and requirements

1 Scope and object

IEC 60825-1 is applicable to safety of laser products emitting laser radiation in the wavelength range 180 nm to 1 mm.

Although lasers exist which emit at wavelengths less than 180 nm (within the vacuum ultraviolet), these are not included in the scope of the standard since the laser beam normally has to be enclosed in an evacuated enclosure, and, therefore, the potential optical radiation hazards are inherently minimal.

A laser product may consist of a single laser with or without a separate power supply or may incorporate one or more lasers in a complex optical, electrical, or mechanical system. Typically, laser products are used for demonstration of physical and optical phenomena, materials processing, data reading and storage, transmission and display of information, etc. Such systems have found use in industry, business, entertainment, research, education, medicine and consumer products.

Laser products that are sold to other manufacturers for use as components of any system for subsequent sale are not subject to IEC 60825-1, since the final product will itself be subject to this standard. Laser products that are sold by or for manufacturers of end products for use as repair parts for the end products are also not subject to IEC 60825-1. However, if the laser system within the laser product is operable when removed from the end product, the requirements of this Part 1 apply to the removable laser system.

NOTE 1 Operable equipment does not require a tool to prepare for operation.

Any laser product is exempt from all further requirements of this Part 1 if classification by the manufacturer of that product according to Clauses 4 and 5 shows that the emission level does not exceed the AEL (accessible emission limit) of Class 1 under all conditions of operation, maintenance, service and failure. Such a laser product may be referred to as an exempt laser product.

NOTE 2 The above exemption is to ensure that inherently safe laser products are exempt from Clauses 6,7,8 and 9.

In addition to the adverse effects potentially resulting from exposure to laser radiation, some laser equipment may also have other associated hazards, such as electricity, chemicals and high or low temperatures. Laser radiation may cause temporary visual impairment, such as dazzle and glare. Such effects depend on the task and ambient lighting level and are beyond the scope of this Part 1. The classification and other requirements of this standard are intended to address only the laser radiation hazards to the eyes and skin. Other hazards are not included within its scope.

This Part 1 describes the minimum requirements. Compliance with this Part 1 may not be sufficient to achieve the required level of product safety. Laser products may also be required to conform to the applicable performance and testing requirements of other applicable product safety standards.

NOTE 3 Other standards may contain additional requirements. For example, a Class 3B or Class 4 laser product may not be suitable for use as a consumer product.

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Where a laser system forms a part of equipment which is subject to another IEC product safety standard, e.g. for medical equipment (IEC 60601-2-22), IT equipment (IEC 60950 series), audio and video equipment (IEC 60065), audio-video and IT equipment (IEC 62368-1), equipment for use in hazardous atmospheres (IEC 60079), or electric toys (IEC 62115), this Part 1 will apply in accordance with the provisions of IEC Guide 104[2)] for hazards resulting from laser radiation. If no product safety standard is applicable, then IEC 61010-1 may be applied.

For ophthalmic instruments, to ensure patient safety, ISO 15004-2 should be consulted and the principles of the limits provided there should be applied for laser radiation (see also Annex C and D).

In previous editions, light-emitting diodes (LEDs) were included in the scope of IEC 60825-1, and they may be still included in other parts of the IEC 60825 series. However, with the development of lamp safety standards, optical radiation safety of LEDs in general can be more appropriately addressed by lamp safety standards. The removal of LEDs from the scope of this Part 1 does not preclude other standards from including LEDs whenever they refer to lasers. IEC 62471 may be applied to determine the risk group of an LED or product incorporating one or more LEDs. Some other (vertical) standards may require the application of the measurement, classification, engineering specifications and labelling requirements of this standard (IEC 60825-1) to LED products.

Laser products with accessible radiance below the criteria specified in 4.4, designed to function as conventional light sources, and which satisfy the requirements specified in 4.4 may alternatively be evaluated under the IEC 62471 series of standards, "Photobiological safety of lamps and lamp systems". Such a product remains within the scope of this part of IEC 60825, except that the above-described optical radiation emission need not be considered for classification.

The MPE (maximum permissible exposure) values provided in Annex A were developed for laser radiation and do not apply to collateral radiation. However, if a concern exists that accessible collateral radiation might be hazardous, the laser MPE values may be applied to conservatively evaluate this potential hazard, or the exposure limit values in IEC 62471 should be consulted.

The MPE values in Annex A are not applicable to intentional human exposure to laser radiation for the purpose of medical or cosmetic/aesthetic treatment.

NOTE 4 Informative Annexes A to G have been included for purposes of general guidance and to illustrate many typical cases. However, the annexes are not regarded as definitive or exhaustive.

The objectives of this part of IEC 60825 are the following:

- to introduce a system of classification of lasers and laser products emitting radiation in the wavelength range 180 nm to 1 mm according to their degree of optical radiation hazard in order to aid hazard evaluation and to aid the determination of user control measures;
- to establish requirements for the manufacturer to supply information so that proper precautions can be adopted;
- to ensure, through labels and instructions, adequate warning to individuals of hazards associated with accessible radiation from laser products;
- to reduce the possibility of injury by minimizing unnecessary accessible radiation and to give improved control of the laser radiation hazards through protective features.

2) IEC Guide 104:2010, *The preparation of safety publications and the use of basic safety publications and group safety publications*

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2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

IEC 62471 (all parts), *Photobiological safety of lamps and lamp systems*

3 Terms and definitions

For the purposes of this document, the definitions given in IEC 60050-845 as well as the following apply.

NOTE For convenience here, the definitions have been arranged in English alphabetical order. Departures from IEC 60050-845 are intentional and are indicated. In such cases, reference is made, between brackets, to the definition of Part 845 of IEC 60050, with the mention "modified".

3.1
access panel
part of the protective housing which provides access to laser radiation when removed or displaced

3.2
accessible emission
level of radiation determined at a position and with aperture stops (when the AEL is given in units of Watts or Joules) or limiting apertures (when the AEL is given in units of $W \cdot m^{-2}$ or $J \cdot m^{-2}$) as described in Clause 5

Note 1 to entry: The accessible emission is determined where human access is considered, as specified in Definition 3.40. The accessible emission (determined during operation) is compared with the accessible emission limit (Entry 3.3) in order to determine the class of the laser product. In the body of the standard, whenever the term "emission level" is used, it is to be understood as accessible emission.

Note 2 to entry: When the beam is larger than the aperture stop, the accessible emission when given in units of watts or joules is less than the total emitted power or energy of the laser product. When the beam is smaller than the limiting aperture, the accessible emission when given in units of $W \cdot m^{-2}$ or $J \cdot m^{-2}$, i.e. as irradiance or radiant exposure averaged over the limiting aperture, is smaller than the actual irradiance or radiant exposure of the beam. See also aperture stop (3.9) and limiting aperture (3.55).

3.3
accessible emission limit
AEL
maximum accessible emission permitted within a particular class

Note 1 to entry: Wherever the text refers to "emission level not exceeding the AEL" or similar wording, it is implicit that the accessible emission is determined following the measurement criteria specified in Clause 5.

3.4
administrative control
safety measures of a non-engineering type such as: key supervision; safety training of personnel; warning notices; count-down procedures; and range safety controls

Note 1 to entry: These may be specified by the manufacturer (see Clause 8).

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3.5
angle of acceptance
γ
plane angle within which a detector will respond to optical radiation, usually measured in radians

Note 1 to entry: This angle of acceptance may be controlled by apertures or optical elements in front of the detector (see Figures 1 and 2). The angle of acceptance is also sometimes referred to as the field of view.

Note 2 to entry: SI unit: radian.

Note 3 to entry: The angle of acceptance should not be confused with the angular subtense of the source or the beam divergence.

3.6
angular subtense
plane angle that is subtended by a circular arc, as the ratio of the length of the arc to the radius of the arc

Note 1 to entry: SI unit: radian.

Note 2 to entry: For small angles, the angular subtense of a line at a given distance is calculated by division of the line length by the distance. For large angles, the difference between the line as chord and the arc needs to be accounted for.

3.7
angular subtense of the apparent source
α
angle subtended by an apparent source as viewed from a point in space, as shown in Figure 1

Note 1 to entry: For the case of a Gaussian irradiance profile distribution of the image of the apparent source, such as for a diffuse reflection of a TEM_{00} beam, α is determined with the d_{63} beam diameter definition (see 3.13). For non-uniform irradiance profiles or multiple sources, α is determined according to 4.3 d).

Note 2 to entry: SI unit: radian.

Note 3 to entry: The location and angular subtense of the apparent source depend on the viewing position in the beam (see 3.10).

Note 4 to entry: The angular subtense of an apparent source is applicable in this Part 1 only in the wavelength range from 400 nm to 1 400 nm, the retinal hazard region.

Note 5 to entry: The angular subtense of the laser source should not be confused with the divergence of the beam. The angular subtense of the laser source cannot be larger than the divergence of the beam but it is usually smaller than the divergence of the beam.

3.8
aperture
any opening in the protective housing of a laser product through which laser radiation is emitted, thereby allowing human access to such radiation

Note 1 to entry: See also limiting aperture (3.55).

3.9
aperture stop
opening serving to define the area over which radiation is measured

Note 1 to entry: See also limiting aperture (3.55).

3.10
apparent source
for a given evaluation location of the retinal hazard, real or virtual object that forms the smallest possible retinal image (considering the accommodation range of the human eye)

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Note 1 to entry: The accommodation range of the eye is assumed to be variable from 100 mm to infinity. The location of the apparent source for a given viewing position in the beam is that location to which the eye accommodates to produce the most hazardous retinal irradiance condition.

Note 2 to entry: This definition is used to determine, for a given evaluation position, the location of the apparent origin of laser radiation in the wavelength range of 400 nm to 1 400 nm. In the limit of vanishing divergence, i.e. in the case of a well collimated beam, the location of the apparent source goes to infinity.

Note 3 to entry: For circular images of extended sources on the retina with Gaussian profiles, the d_{63} definition can be used to determine the angular subtense of the apparent source α.

3.11
beam
laser radiation that may be characterized by direction, divergence, diameter or scan specifications

Note 1 to entry: Scattered radiation from a non-specular reflection is not considered to be a beam.

3.12
beam attenuator
device which reduces the laser radiation to or below a specified level or by a specific fraction

3.13
beam diameter
beam width
d_u
diameter of the smallest circle which contains u % of the total laser power (or energy)

Note 1 to entry: For the purpose of this standard d_{63} is used.

Note 2 to entry: The beam waist is the position in the beam where the beam diameter is minimum.

Note 3 to entry: SI unit: metre.

Note 4 to entry: This definition of the beam diameter should not be used generally for the determination of the angular subtense of the apparent source α since the definitions are different. However, for the case of a Gaussian irradiance profile of the image of the apparent source, d_{63} can be applied for the determination of the angular subtense of the apparent source α. For non-Gaussian irradiance profiles of the image of the angular subtense of the apparent source, the method described in 4.3 d) is to be used.

Note 5 to entry: In the case of a Gaussian beam, d_{63} corresponds to the point where the irradiance (radiant exposure) falls to 1/e of its central peak value.

Note 6 to entry: The second moment diameter definition (as defined in ISO 11146-1) is not appropriate to be used for beam profiles with central high irradiance peaks and a low level background, such as produced by unstable resonators in the far field: the power that passes through an aperture can be significantly underestimated when using the 2nd moment and calculating the power with the assumption of a Gaussian beam profile.

3.14
beam divergence
far field plane angle of the cone defined by the beam diameter

Note 1 to entry: If the beam diameters (see 3.13) at two points separated by a distance r are d_{63} and d'_{63} the divergence is given by:

$$\varphi_{63} = 2 \arctan\left(\frac{d'_{63} - d_{63}}{2r}\right)$$

Note 2 to entry: SI unit: radian.

Note 3 to entry: The second moment divergence definition (ISO 11146-1) is not appropriate to be used for beam profiles with central high irradiance peaks and a low level background, such as produced by unstable resonators in the far field or beam profiles that show diffraction patterns caused by apertures.

3.15
beam expander
combination of optical elements which will increase the diameter of a laser beam

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3.16
beam path component
optical component which lies on a defined beam path

EXAMPLE A beam steering mirror, a focusing lens or a diffuser.

3.17
beam stop
device which terminates a laser beam path

3.18
Class 1 laser product
any laser product which during operation does not permit human access to laser radiation (accessible emission, see 3.2) in excess of the AEL of Class 1 for applicable wavelengths and emission durations (see 5.3 and 4.3 e))

Note 1 to entry: See also the limitations of the classification scheme in Annex C.

Note 2 to entry: As tests for the determination of the classification of the product are limited to tests during operation, it may be the case for embedded laser products, that laser radiation above the AEL of the class of the product can become accessible during maintenance (see 6.2.1) or service when interlocks of access panels are overridden or the product is opened or disassembled.

3.19
Class 1C laser product
any laser product which is designed explicitly for contact application to the skin or non-ocular tissue and that:

– during operation ocular hazard is prevented by engineering means, i.e. the accessible emission is stopped or reduced to below the AEL of Class 1 when the laser/applicator is removed from contact with the skin or non-ocular tissue,
– during operation and when in contact with skin or non-ocular tissue, irradiance or radiant exposure levels may exceed the skin MPE as necessary for the intended treatment procedure, and
– the laser product complies with applicable vertical standards

Note 1 to entry: It is not sufficient to classify a product as Class 1C only under IEC 60825-1 without consideration of requirements specified in applicable vertical product safety standards. See also the limitations of the Classification scheme in Annex C.

Note 2 to entry: Since the emitted radiation may exceed the applicable skin MPE, the output of a Class 1C laser may be potentially hazardous to the target tissue. The definition of appropriate limitations of the emission accessible under contact conditions, for example a possible contact with the eyelids, are beyond the scope of this standard and are specified in applicable vertical standards.

Note 3 to entry: As tests for the determination of the classification of the product are limited to tests during operation, it may be the case for embedded laser products that, depending on the product, radiation above the AEL of Class 1 can become accessible during maintenance (see 6.2.1) or service when interlocks of access panels are overridden or the product is opened or disassembled.

3.20
Class 1M laser product
any laser product in the wavelength range from 302,5 nm to 4 000 nm which during operation does not permit human access to laser radiation (accessible emission, see 3.2) in excess of the AEL of Class 1 for applicable wavelengths and emission durations (see 4.3 e)), where the level of radiation is measured according to 5.3 a)

Note 1 to entry: See also the limitations of the classification scheme in Annex C.

Note 2 to entry: The output of a Class 1M laser product is potentially hazardous when viewed using telescopic optics such as a telescope or a binocular (see 5.3 a)).

Note 3 to entry: As tests for the determination of the classification of the product are limited to tests during operation, it may be the case for embedded laser products that, depending on the product, radiation above the AEL of the class of the laser product can become accessible during maintenance (see 6.2.1) or service when interlocks of access panels are overridden or the product is opened or disassembled.

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3.21
Class 2 laser product
any laser product in the wavelength range from 400 nm to 700 nm which during operation does not permit human access to laser radiation (accessible emission, see 3.2) in excess of the AEL of Class 2 for applicable wavelengths and emission durations (see 5.3 c))

Note 1 to entry: See also the limitations of the classification scheme in Annex C.

Note 2 to entry: As tests for the determination of the classification of the product are limited to tests during operation, it may be the case for embedded laser products that, depending on the product, radiation above the AEL of the class of the product can become accessible during maintenance (see 6.2.1) or service when interlocks of access panels are overridden or the product is opened or disassembled.

3.22
Class 2M laser product
any laser product in the wavelength range from 400 nm to 700 nm which during operation does not permit human access to laser radiation (accessible emission, see 3.2) in excess of the AEL of Class 2 for applicable wavelengths and emission durations (see 4.3 e)), where the level of radiation is measured according to 5.3 c)

Note 1 to entry: See also the limitations of the classification scheme in Annex C.

Note 2 to entry: The output of a Class 2M laser product is potentially hazardous when viewed using telescopic optics such as a telescope or a binocular (see 5.3 c)).

Note 3 to entry: As tests for the determination of the classification of the product are limited to tests during operation, it may be the case for embedded laser products that, depending on the product, radiation above the AEL of the class of the product can become accessible during maintenance (see 6.2.1) or service when interlocks of access panels are overridden or the product is opened or disassembled.

3.23
Class 3R and Class 3B laser products
any laser product which during operation permits human access to laser radiation (accessible emission, see 3.2) in excess of the AEL of Class 1 and Class 2, as applicable, but which does not permit human access to laser radiation in excess of the AEL of Classes 3R and 3B (respectively) for any emission duration and wavelength (see 5.3 d) and 5.3 e))

Note 1 to entry: See also the limitations of the classification scheme in Annex C.

Note 2 to entry: Class 1M and Class 2M laser products may have outputs above or below the AEL of Class 3R, depending on their optical characteristics.

Note 3 to entry: As tests for the determination of the classification of the product are limited to tests during operation, it may be the case for embedded laser products that, depending on the product, radiation above the AEL of the class of the product can become accessible during service when interlocks of access panels are overridden or the product is opened or disassembled.

3.24
Class 4 laser product
any laser product which permits human access to laser radiation (accessible emission, see 3.2) in excess of the AEL of Class 3B (see 5.3 f))

Note 1 to entry: See also the limitations of the classification scheme in Annex C.

3.25
collateral radiation
any electromagnetic radiation, within the wavelength range between 180 nm and 1 mm, except laser radiation, emitted by a laser product as a result of, or physically necessary for, the operation of a laser

3.26
collimated beam
beam of radiation with very small angular divergence or convergence

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3.27
contact mode
use of a laser product where the beam delivery system is in close contact with the intended target

Note 1 to entry: The beam delivery system does not need to be in “physical” contact. It can, for example, be close to the intended target provided that adequate engineering control measures are in place.

Note 2 to entry: This definition is relevant for products classified as Class 1C.

3.28
continuous wave
CW
laser operating with a continuous output for a duration equal to or greater than 0,25 s

Note 1 to entry: This note applies to the French language only.

3.29
defined beam path
intended path of a laser beam within the laser product

3.30
demonstration laser product
any laser product designed, manufactured, intended or promoted for purposes of demonstration, entertainment, advertising, display or artistic composition

Note 1 to entry: The term "demonstration laser product" does not apply to laser products which are designed and intended for other applications, although they may be used for demonstrating those applications.

3.31
diffuse reflection
change of the spatial distribution of a beam of radiation by scattering in many directions by a surface or medium

Note 1 to entry: A perfect diffuser destroys all correlation between the directions of the incident and emergent radiation.

[SOURCE:IEC 60050-845:1987, 845-04-47, modified – The definition has been completely reworded.]

3.32
embedded laser product
in this Part 1, a laser product which, because of engineering features limiting the accessible emission, is of a class number lower than the inherent capability of the laser incorporated

Note 1 to entry: The laser product which is incorporated in the embedded laser product is called an enclosed laser product or an enclosed laser system.

3.33
emission duration
temporal duration of a pulse, of a train or series of pulses, or of continuous operation, during which human access to laser radiation could occur as a result of operation, maintenance or servicing of a laser product

Note 1 to entry: For a single pulse, this is the duration between the half-peak power point of the leading edge and the corresponding point on the trailing edge. For a train of pulses (or subsections of a train of pulses), this is the duration between the first half-peak power point of the leading pulse and the last half-peak power point of the trailing pulse.

3.34
errant laser radiation
laser radiation which deviates from a defined or intended beam path

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Note 1 to entry: Such radiation includes unwanted reflections from beam path components and deviant radiation from misaligned or damaged components.

3.35
exposure duration
duration of a pulse, or series, or train of pulses or of continuous emission of laser radiation incident upon the human body

Note 1 to entry: For a single pulse, this is the duration between the half-peak power point of the leading edge and the corresponding point on the trailing edge. For a train of pulses (or subsections of a train of pulses), this is the duration between the first half-peak power point of the leading pulse and the last half-peak power point of the trailing pulse.

3.36
extended source viewing
viewing conditions whereby the apparent source at a distance of 100 mm or more subtends an angle at the eye greater than the minimum angular subtense (α_{min})

Note 1 to entry: Two extended source conditions are considered in this standard when considering retinal thermal injury hazards: intermediate source and large source. They are used to distinguish sources with angular subtenses of the apparent source, α, between α_{min} and α_{max} (intermediate sources), and greater than α_{max} (large sources). See also 3.82.

Note 2 to entry: Examples where the factor C_6 (4.3 c) and Table 9) can be larger than 1 include viewing of some diffused laser sources, diffuse reflections, some line lasers and some laser diode arrays.

3.37
eye-safe
accessible emission below the AEL of Class 1 or an exposure below the MPE for the eye for the given exposure duration

Note 1 to entry: This term is incorrectly used in some advertising material for laser emission in the wavelength range above 1 400 nm based on higher exposure limits in that wavelength range compared to the retinal hazard region. The term “eye-safe laser” may only be used to describe Class 1 laser products. Even if Class 1 can be referred to as eye-safe, if it is visible emission, short-term visual disturbances such as dazzle “flash-blindness” and after-images may still result from direct-beam viewing.

Note 2 to entry: The term “eye-safe laser” cannot be used to describe a laser based solely on output wavelength being greater than 1 400 nm, since lasers of any wavelength with sufficient output power can cause injury.

3.38
fail safe
design consideration in which failure of a component does not increase the hazard

Note 1 to entry: In the failure mode the system is rendered inoperative or the hazard is not increased.

3.39
fail safe safety interlock
interlock which in the failure mode does not defeat the purpose of the interlock

Note 1 to entry: For example, an interlock which is positively driven into the OFF position as soon as a hinged cover begins to open, or before a detachable cover is removed, and which is positively held in the OFF position until the hinged cover is closed or the detachable cover is locked in the closed position.

Note 2 to entry: For the purpose of this Part 1 a safety interlock in the OFF position terminates the beam or reduces the output to the required level. If electrical, electronic and programmable components are used, IEC 61508 or ISO 13849 may be used to evaluate the reliability of the interlock.

3.40
human access
a) ability of the human body to meet laser radiation emitted by the laser product, i.e. radiation that can be intercepted outside of the protective housing, or

b) ability of a cylindrical probe with a diameter of 100 mm and a length of 100 mm to intercept levels of radiation of Class 3B and below, or

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c) ability of a human hand or arm to intercept levels of radiation above the AEL of Class 3B,

d) also, for levels of radiation within the protective housing that are equivalent to Class 3B or Class 4, ability of any part of the human body to meet hazardous laser radiation that can be reflected directly by any single introduced flat surface from the interior of the product through any opening in its protective housing

Note 1 to entry: For laser products that provide walk-in access, it is necessary to consider radiation both inside and outside of the protective housing for the determination of human access. Human access inside the protective housing can be prevented by engineering controls such as automatic detection systems.

3.41
integrated radiance
radiance dose
L_t
integral of the radiance over a given exposure duration expressed as radiant energy per unit area of a radiating surface per unit solid angle of emission

Note 1 to entry: In the ICNIRP guidelines, this quantity is also referred to as radiance dose and the symbol D is used.

Note 2 to entry: SI unit: joule per square metre per steradian ($J \cdot m^{-2} \cdot sr^{-1}$).

3.42
intrabeam viewing
all viewing conditions whereby the eye is exposed to the direct or specularly reflected laser beam in contrast to viewing of, for example, diffuse reflections

3.43
irradiance
E
quotient of the radiant flux $d\Phi$ incident on an element of a surface by the area dA of that element

$$E = \frac{d\Phi}{dA}$$

Note 1 to entry: SI unit: watt per square metre ($W \cdot m^{-2}$).

3.44
laser
any device which can be made to produce or amplify electromagnetic radiation in the wavelength range from 180 nm to 1 mm primarily by the process of controlled stimulated emission

[SOURCE: IEC 60050-845:1987, 845-04-39, modified – The definition has been completely reworded.]

3.45
laser controlled area
area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation hazards

3.46
laser energy source
any device intended for use in conjunction with a laser to supply energy for the excitation of electrons, ions or molecules

Note 1 to entry: General energy sources such as electrical supply mains or batteries are not considered to constitute laser energy sources.

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3.47
laser hazard area
area in which the exposure of the eye and/or the skin exceeds the respective maximum permissible exposure values (MPEs); see nominal ocular hazard area (3.64)

Note 1 to entry: To avoid ambiguities, information whether the hazard area is based on the eye or the skin MPEs should be added.

3.48
laser product
any product or assembly of components which constitutes, incorporates or is intended to incorporate a laser or laser system

3.49
laser radiation
all electromagnetic radiation emitted by a laser product between 180 nm and 1 mm which is produced by controlled stimulated emission

3.50
laser safety officer
one who is knowledgeable in the evaluation and control of laser hazards and has responsibility for oversight of the control of laser hazards

3.51
laser system
laser in combination with an appropriate laser energy source with or without additional incorporated components

3.52
light emitting diode
LED
any semiconductor p-n junction device which can be made to produce electromagnetic radiation by radiative recombination in the semiconductor in the wavelength range from 180 nm to 1 mm

Note 1 to entry: The optical radiation is produced primarily by the process of spontaneous emission, although some stimulated emission may be present.

3.53
limiting angle of acceptance for evaluating retinal photochemical hazards
γ_{ph}
plane angle over which radiation is detected and to be used for the determination of the accessible emission, or exposure level to be compared with retinal photochemical limits

Note 1 to entry: The angle γ_{ph} is related to eye movements and is not dependent upon the angular subtense of the source. If the angular subtense of the source is larger than the specified limiting angle of acceptance γ_{ph}, the angle of acceptance γ is limited to γ_{ph} and the source is scanned for hotspots. If the angle of acceptance γ is not limited to the specified level, the hazard may be over-estimated.

Note 2 to entry: If the angular subtense of the apparent source is smaller than the specified limiting angle of acceptance, the actual angle of acceptance of the measuring instrument does not affect the measured value and does not have to be limited, i.e. a regular “open” angle of acceptance radiometer set-up can be used.

Note 3 to entry: SI unit: radian.

3.54
limiting angle of acceptance for evaluating thermal hazards
γ_{th}
maximum angular subtense to be used for the evaluation of the retinal thermal hazard

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Note 1 to entry: The value of the angle of acceptance γ may vary between α_{min} and α_{max} (see 4.3 d) and 5.4.3 b) 2)).

Note 2 to entry: SI unit: radian.

3.55
limiting aperture
circular area over which irradiance and radiant exposure are averaged

3.56
maintenance
performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser product, which are to be performed by the user for the purpose of assuring the intended performance of the product

Note 1 to entry: It does not include operation or service.

3.57
maximum angular subtense
α_{max}
value of angular subtense of the apparent source above which the MPEs and AELs are independent of the source size

Note 1 to entry: The value of α_{max} can vary from 5 mrad to 100 mrad depending on the emission duration (see Table 9).

Note 2 to entry: SI unit: radian.

3.58
maximum output
the maximum accessible emission that is used to determine the class of the laser product

Note 1 to entry: Since the determination of the accessible emission includes, besides other conditions, considering single fault conditions (see 5.1), the maximum output may exceed the highest output during normal operation.

3.59
maximum permissible exposure
MPE
level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects

Note 1 to entry: The MPE levels represent the maximum level to which the eye or skin can be exposed without consequential injury immediately or after a long time and are related to the wavelength of the laser radiation, the pulse duration or exposure duration, the tissue at risk and, for visible and near infra-red laser radiation in the range 400 nm to 1 400 nm, the size of the retinal image. Maximum permissible exposure levels are (in the existing state of knowledge) specified in Annex A.

Note 2 to entry: The MPE values given in Annex A are informative and are provided so that the manufacturer can calculate the NOHD, perform a risk analysis and inform the user about safe usage of the product. Exposure limits for the eye and the skin of employees in the workplace and the general public are in many countries specified in national laws. These legally-binding national exposure limits might differ from the MPEs given in the informative Annex A.

3.60
medical laser product
any laser product designed, manufactured, intended or promoted for purposes of *in vivo* diagnostic, surgical, cosmetic or therapeutic laser irradiation of any part of the human body

3.61
minimum angular subtense
α_{min}
value of angular subtense of the apparent source above which a source is considered an extended source

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Note 1 to entry: MPEs and AELs are independent of the source size for angular subtenses less than α_{min}.

Note 2 to entry: SI unit: radian.

Note 3 to entry: α_{min} = 1,5 mrad.

3.62
mode-locking
regular mechanism or phenomenon, within the laser resonator, producing a train of very short (e.g. sub-nanosecond) pulses

Note 1 to entry: While this may be a deliberate feature it can also occur spontaneously as "self-mode-locking". The resulting peak powers may be significantly greater than the mean power.

3.63
most restrictive position
position in the beam where the ratio of accessible emission over AEL is maximum

Note 1 to entry: Both the accessible emission and the AEL may depend on the position of the evaluation in respect to the beam. See also 3.36.

3.64
nominal ocular hazard area
NOHA
area within which the beam irradiance or radiant exposure exceeds the appropriate corneal maximum permissible exposure (MPE), including the possibility of accidental misdirection of the laser beam

Note 1 to entry: If the NOHA includes the possibility of viewing through optical aids, this is termed the "extended NOHA".

3.65
nominal ocular hazard distance
NOHD
distance from the output aperture beyond which the beam irradiance or radiant exposure remains below the appropriate corneal maximum permissible exposure (MPE)

Note 1 to entry: If the NOHD includes the possibility of viewing through optical aids, this is termed the "extended NOHD (ENOHD)".

3.66
operation
performance of the laser product over the full range of its intended functions

Note 1 to entry: It does not include maintenance or service.

3.67
photochemical hazard limit
either an MPE or AEL which was derived to protect persons against adverse photochemical effects

Note 1 to entry: In the ultraviolet wavelength range, the photochemical hazard limit protects against adverse effects on the cornea and lens, while the retinal photochemical hazard limit, as defined in the wavelength range from 400 nm to 600 nm, protects against photoretinitis – a photochemical retinal injury from exposure to radiation.

3.68
protective housing
those portions of a laser product (including a product incorporating an embedded laser) which are designed to prevent human access to laser radiation in excess of the prescribed AEL (generally installed or assembled by a manufacturer)

Note 1 to entry: See 5.1 regarding test requirements to assess the suitability of protective housing for the prevention of human access.

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3.69
pulse duration
time increment measured between the half-peak power points at the leading and trailing edges of a pulse

3.70
pulsed laser
laser which delivers its energy in the form of a single pulse or a train of pulses

Note 1 to entry: In this Part 1, the duration of a pulse is less than 0,25 s.

3.71
radiance
L
quantity defined by the formula

$$L = \frac{\mathrm{d}\Phi}{\mathrm{d}A \cdot \cos\theta \cdot \mathrm{d}\Omega}$$

where

$\mathrm{d}\Phi$ is the radiant flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $\mathrm{d}\Omega$ containing the given direction;

$\mathrm{d}A$ is the area of a section of that beam containing the given point;

θ is the angle between the normal to that section and the direction of the beam

Note 1 to entry: This definition is a simplified version of IEV 845-01-34, sufficient for the purpose of this Part 1. In cases of doubt, the IEV definition should be followed.

Note 2 to entry: SI unit: watt per square metre per steradian ($W \cdot m^{-2} \cdot sr^{-1}$).

[SOURCE: IEC 60050-845:1987, 845-01-34, modified – The definition has been simplified.]

3.72
radiant energy
Q
time integral of the radiant flux Φ over a given duration Δt

$$Q = \int_{\Delta t} \Phi \cdot \mathrm{d}t$$

Note 1 to entry: SI unit: joule (J).

[SOURCE: IEC 60050-845:1987, 845-01-27, modified – The definition has been simplified.]

3.73
radiant exposure
H
at a point on a surface, the radiant energy incident on an element of a surface divided by the area of that element

$$H = \frac{\mathrm{d}Q}{\mathrm{d}A} = \int E \cdot \mathrm{d}t$$

Note 1 to entry: SI unit: joule per square metre ($J \cdot m^{-2}$).

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3.74
radiant power
radiant flux
Φ, P
power emitted, transferred, or received in the form of radiation

$$\Phi = \frac{dQ}{dt}$$

Note 1 to entry: SI unit: watt (W).

[SOURCE: IEC 60050-845:1987, 845-01-24]

3.75
reflectance
ρ
ratio of the reflected radiant power to the incident radiant power in the given conditions

Note 1 to entry: SI unit: dimensionless ratio.

[SOURCE: IEC 60050-845:1987, 845-04-58, modified to refer to radiant power rather than radiant flux.]

3.76
remote interlock connector
connector which permits the connection of external controls placed apart from other components of the laser product

Note 1 to entry: See 6.4.

3.77
safety interlock
automatic device associated with each portion of the protective housing of a laser product to prevent human access to Class 3R, Class 3B or Class 4 laser radiation when that portion of the protective housing is removed, opened or displaced

Note 1 to entry: See 6.3.

3.78
scanning laser radiation
laser radiation having a time-varying direction, origin or pattern of propagation with respect to a stationary frame of reference

3.79
service
performance of those procedures or adjustments described in the manufacturer's service instructions, which may affect any aspect of the product's performance

Note 1 to entry: It does not include maintenance or operation.

3.80
service panel
access panel that is designed to be removed or displaced for service

3.81
single fault condition
any single fault that might occur in a product and the direct consequences of that fault

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3.82
small source
source with an angular subtense α less than, or equal to, the minimum angular subtense α_{min}

3.83
specular reflection
reflection from a surface that can be considered a beam (see 3.11), including reflections from mirrored surfaces

Note 1 to entry: This definition is intended to recognize that some reflecting surfaces, such as parabolic reflectors, may increase the hazard from an incident beam.

3.84
thermal hazard limit
either an MPE or AEL which was derived to protect persons against adverse thermal effects, as opposed to photochemical injury

3.85
time base
emission duration to be considered for classification of laser products

Note 1 to entry: See 4.3 e).

3.86
tool
screwdriver, hexagonal key or other object which may be used to operate a screw or similar fixing means

3.87
transmittance
τ
ratio of the transmitted radiant flux to the incident flux in the given conditions

Note 1 to entry: SI unit: dimensionless ratio.

[SOURCE: IEC 60050-845:1987, 845-04-59, modified]

3.88
transmittance density
optical density
D
logarithm to base ten of the reciprocal of the transmittance τ

$D = -\log_{10} \tau$

[SOURCE: IEC 60050-845:1987, 845-04-66]

3.89
visible radiation
light
any optical radiation capable of causing a visual sensation directly

Note 1 to entry: In this Part 1, this is taken to mean electromagnetic radiation for which the wavelengths of the monochromatic components lie between 400 nm and 700 nm.

[SOURCE: IEC 60050-845:1987, 845-01-03, modified – The note in the original definition has been replaced.]

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3.90
workpiece
object intended for processing by laser radiation

4 Classification principles

4.1 General

Classification of a laser product is based on the determination of the accessible emission level (determined according to the rules specified in Clause 5) and comparison of that level with the accessible emission limit (AEL) associated with each class. For Class 1, Class 1M, Class 2, Class 2M and Class 3R, additional measurements may be necessary to determine if additional warnings are necessary (see Clause 7). Specific rules apply for the classification of a product (e.g., for Class 1C, see 5.3 b) and 4.4 for certain radiance extended source products).

Because of the wide ranges possible for the wavelength, energy content and pulse characteristics of a laser beam, the potential hazards arising in its use vary widely. It is impossible to regard lasers as a single group to which common safety limits can apply. Annex C describes the hazards associated with the classes and possible limitations (e.g. as may arise from optically aided viewing) in more detail.

4.2 Classification responsibilities

It is the responsibility of the manufacturer to provide correct classification of a laser product. (However, see 6.1).

4.3 Classification rules

The product shall be classified on the basis of that combination of output power(s) and wavelength(s) of the accessible emission (laser radiation) over the full range of capability during operation at any time after manufacture which results in its allocation to the highest appropriate class. The evaluation shall include consideration of any reasonably foreseeable single-fault condition during operation (see 5.1 regarding the application of the principles of risk analysis for the determination of which single fault is reasonably foreseeable).

A laser product can only be assigned to a particular class when it has met all of the requirements within this Part 1 for that class; for example, engineering controls, labelling and information for the user.

For laser products emitting CW laser beams, of a single wavelength, which are well collimated or are assumed to be from a small source, the classification procedure can be simplified and the following items need not be considered:

4.3 b), 4.3 c), 4.3 d), 4.3 f).

For the purpose of classification rules, the following ranking of the classes (in increasing order of ocular hazard) shall be used: Class 1, Class 1C, Class 1M, Class 2, Class 2M, Class 3R, Class 3B, Class 4.

NOTE 1 Class 1C is considered not to be an ocular hazard (similarly to Class 1), but may represent a skin hazard if used inappropriately (see also 5.3 b).

NOTE 2 For classification of a laser product as Class 1M or 2M, the use of an aperture specified as Condition 3 limits the amount of radiation that is collected by the pupil of the eye from large diameter beams. When measured under Condition 1, Class 1M and Class 2M products may have higher energy or power level than the AEL of Class 2 or Class 3R. For such laser products, a classification of 1M or 2M is appropriate.

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The accessible emission limits (AELs) for Class 1 and 1M, Class 2 and 2M, Class 3R and Class 3B are given in Tables 3 to 8. The values of the correction factors used are given in Table 9 as functions of wavelength, emission duration, number of pulses and angular subtense.

a) Radiation of a single wavelength

A single wavelength laser product, with a spectral range of the emission line narrow enough so that the AELs do not change, is assigned to a class when the accessible laser radiation, measured under the conditions appropriate to that class, exceeds the AEL of all lower classes but does not exceed that of the class assigned.

b) Radiation of multiple wavelengths

1) A laser product emitting two or more wavelengths in spectral regions shown as additive for the eye in Table 1 is assigned to a class when the sum of the ratios of the accessible laser radiation (measured under the conditions appropriate to that class) to the AELs of those wavelengths is greater than unity for all lower classes but does not exceed unity for the class assigned. This rule applies also to non-laser radiation that is coincident on the retina for wavelengths between 400 nm and 1 400 nm or coincident on the aperture stop for other wavelength ranges. Therefore, the non-laser radiation shall be included for classification under this part of IEC 60825.

2) A laser product emitting two or more wavelengths not shown as additive for the eye in Table 1 is assigned to a class when the accessible laser radiation, measured under the conditions appropriate to that class, exceeds the AELs of all lower classes for at least one wavelength but does not exceed the AEL for the class assigned for any wavelength.

Table 1 – Additivity of effects on eye and skin of radiation of different spectral regions[c]

Spectral region[a]	UV-C and UV-B 180 nm to 315 nm	UV-A 315 nm to 400 nm	Visible and IR-A 400 nm to 1 400 nm	IR-B and IR-C 1 400 nm to 10^6 nm
UV-C and UV-B 180 nm to 315 nm	o s			
UV-A 315 nm to 400 nm		o s	s	o s
Visible and IR-A 400 nm to 1 400 nm		s	o[b] s	s
IR-B and IR-C 1 400 nm to 10^6 nm		o s	s	o s

o Eye

s Skin

[a] For definitions of spectral regions, see Table D.1.

[b] Where AELs and ocular MPEs are being evaluated for time bases or exposure durations of 1 s or longer, then the additive photochemical effects (400 nm to 600 nm) and the additive thermal effects (400 nm to 1 400 nm) shall be assessed independently and the most restrictive value used.

[c] For determination of the AEL, only the additivity rules for the eye apply.

c) Radiation from extended sources

The ocular hazard from laser sources in the wavelength range from 400 nm to 1 400 nm is dependent upon the angular subtense of the apparent source α. This dependence is expressed in the applicable AEL values by the factor C_6 (see Table 9), as well as in the rules for the determination of the accessible emission with a specified angle of acceptance.

NOTE 3 A source is considered an extended source when the angular subtense of the source is greater than α_{min}, where α_{min} = 1,5 mrad. Most laser sources have an angular subtense α less than α_{min}, and appear as an apparent "point source" (small source) when viewed from within the beam (intra-beam viewing). Indeed a circular laser beam cannot be collimated to a divergence less than 1,5 mrad if it is an extended source [19].

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any laser where a beam divergence of 1,5 mrad or less is specified cannot be treated as an extended source. For a small source, α is set to α_{min} = 1,5 mrad and C_6 = 1.

NOTE 4 For retinal thermal hazard evaluation (400 nm to 1 400 nm), the AELs for extended sources vary directly with the angular subtense of the source. For the retinal photochemical hazard evaluation (400 nm to 600 nm), for exposures greater than 1 s, the AELs do not vary directly with the angular subtense of the source. Depending on the emission duration (see 5.4.3 b) 1), a limiting angle of acceptance γ_{ph} of 11 mrad or more is used for measurement regarding the photochemical hazard, and the relation of the limiting acceptance angle γ_{ph} to the angular subtense α of the apparent source can influence the measured value.

NOTE 5 For the default condition where C_6 = 1, a simplified Table 3 is provided for the AEL of Class 1, 1M and a simplified Table 6 is provided for the AEL of Class 3R.

For sources subtending an angle less than or equal to α_{min}, the AEL and MPE are independent of the angular subtense of the apparent source α.

For classifying laser products at the most restrictive position where Condition 1 applies (see 5.4.3), the 7 × magnification of the angular subtense α of the apparent source may be applied to determine C_6, i.e. $C_6 = 7 \times \alpha / \alpha_{min}$. The expression ($7 \times \alpha$) shall be limited to α_{max} prior to the calculation of C_6. The 7 × value of α shall be used for the determination of T_2 of Table 9.

NOTE 6 For cases where $\alpha < 1{,}5$ mrad but $7 \times \alpha > 1{,}5$ mrad, the limits for $\alpha > 1{,}5$ mrad of Table 4 and 7 apply.

d) Non-uniform, non-circular or multiple apparent sources

For comparison with the thermal retinal limits, if:

– the wavelength range is from 400 nm to 1 400 nm; and

– the AEL depends on C_6

then if:

– the image of the apparent source does not have a uniform irradiance profile[3]; or

– the image of the apparent source consists of multiple points,

then measurements or evaluations shall be made for each of the following scenarios:

– for every single point; and

– for various assemblies of points; and

– for partial areas.

This is necessary in order to ensure that the AEL is not exceeded for each possible angle α subtended in each scenario. For the evaluation of assemblies of points or for partial areas, the angle of acceptance γ is to be varied in each dimension between α_{min} and α_{max}, i.e. $\alpha_{min} < \gamma < \alpha_{max}$, to determine the partial accessible emission associated with the respective scenario. For the comparison of these partial accessible emission levels with the respective AEL, the value of α is set equal to the angular subtense that is associated with the partial image of the apparent source.

Classification is to be based on the case where the ratio between:

– the partial accessible emission within a partial area over the angular subtense α of that area; and

– the corresponding AEL

is a maximum.

The angular subtense of a rectangular or linear source is determined by the arithmetic mean value of the two angular dimensions of the source. Any angular dimension that is greater than α_{max} or less than α_{min} shall be limited to α_{max} or α_{min} respectively, prior to calculating the mean.

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3 For a Gaussian beam profile (as produced by a TEM_{00} beam), the angular subtense can be determined with the d_{63} diameter (analogous to the beam diameter definition, see 3.13) and an analysis of partial areas is not necessary.

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For the purpose of determining the angular subtense of a magnified non-circular source for Condition 1, the 7 × magnification described in c) should be applied independently for each axis prior to determining the arithmetic mean.

The photochemical limits (400 nm to 600 nm) do not depend on the angular subtense of the source, and the source is analysed with the limiting angle of acceptance specified in 5.4.3 b). For sources that are larger than the limiting angle of acceptance, the accessible emission has to be determined for the partial apparent source which produces the maximum emission value.

e) Time bases

The following time bases are used in this standard for classification:

1) 0,25 s for Class 2, Class 2M and Class 3R laser radiation in the wavelength range from 400 nm to 700 nm;

2) 100 s for laser radiation of all wavelengths greater than 400 nm except for the cases listed in 1) and 3);

3) 30 000 s for laser radiation of all wavelengths less than or equal to 400 nm and for laser radiation of wavelengths greater than 400 nm where intentional long-term viewing is inherent in the design or function of the laser product.

Every possible emission duration within the time base shall be considered when determining the classification of a product. This means that the emission level of a single pulse shall be compared to the AEL applicable to the duration of the pulse, etc. It is not sufficient to only average the emission level for the duration of the classification time base, or to merely perform the evaluation for the value of the time base without considering shorter emission durations.

NOTE 7 For a multi wavelength emission laser product with simultaneous and spatially overlapping emission in the visible and in the non-visible part of the spectrum, where the emission is assessed as additive (see Table 1), and where the visible part on its own would be classified as Class 2 or 2M or 3R and the non-visible part on its own would be classified as Class 1 or Class 1M, the time base for the assessment of the non-visible emission may be 0,25 s.

f) Repetitively pulsed or modulated lasers

The following methods shall be used to determine the class of the laser product to be applied to repetitive pulsed or modulated emissions.

As a general requirement, the accessible emission of any group of pulses (or sub-group of pulses in a train) delivered in any given time shall not exceed the AEL for that given time (see also 4.3 e) regarding considering every possible emission duration).

For all wavelengths, requirements 1) and 2) shall be assessed. In addition, for wavelengths from 400 nm to 1 400 nm, requirement 3) shall also be assessed for comparison with thermal limits. Requirement 3) does not need to be assessed for comparison with photochemical limits nor for the determination of the AEL of Class 3B.

The class (see Tables 3 to 8) is determined by applying the most restrictive of 1), 2) and, where applicable, 3).

1) The exposure from any single pulse within a pulse train shall not exceed the AEL for a single pulse ($AEL_{single.}$). For the determination of the accessible emission for an extended source, the pulse duration is used to determine α_{max} and the angle of acceptance γ_{th} (see 5.4.3 b) and Table 9).

2) The average power for a pulse train of emission duration T shall not exceed the power corresponding to the AEL for a single pulse of duration T (AEL_T). For the determination of the accessible emission for an extended source, the emission duration T is used to determine α_{max} and the angle of acceptance γ_{th} (see 5.4.3 b) and Table 9).

For irregular pulse patterns (including varying pulse energies), T has to be varied between T_i (see Table 2) and the time base. For regular pulse patterns it is sufficient to average over the time base, (T is set equal to the time base).

NOTE 8 For comparison of AEL_T with AEL_{single} or $AEL_{s.p.train}$, to determine which one of the criteria is most restrictive, AEL_T is expressed as energy or radiant exposure and is divided by N and is termed $AEL_{s.p.T}$.

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3) The energy per pulse shall not exceed the AEL for a single pulse multiplied by the correction factor C_5.

$$AEL_{s.p.train} = AEL_{single} \times C5$$

where

$AEL_{s.p.train}$ is the AEL for a single pulse in the pulse train;

AEL_{single} is the AEL for a single pulse (Tables 3 to 8);

N is the effective number of pulses in the pulse train within the assessed emission duration (when pulses occur within T_i (see Table 2), N is less than the actual number of pulses, see below). The maximum emission duration that needs to be considered is T_2 (see Table 9) or the applicable time base, whichever is shorter.

C_5 is only applicable to individual pulse durations equal to or shorter than 0,25 s.

If pulse duration $t \leq T_i$, then:

For a time base less than or equal to 0,25 s, $C_5 = 1,0$

For a time base larger than 0,25 s

If $N \leq 600$ $C_5 = 1,0$

If $N > 600$ $C_5 = 5\ N^{-0,25}$ with a minimum value of $C_5 = 0,4$.

If pulse duration $t > T_i$, then:

For $\alpha \leq 5$ mrad:

$C_5 = 1,0$

For 5 mrad $< \alpha \leq \alpha_{max}$:

$C_5 = N^{-0,25}$ for $N \leq 40$

$C_5 = 0,4$ for $N > 40$

For $\alpha > \alpha_{max}$:

$C_5 = N^{-0,25}$ for $N \leq 625$

$C_5 = 0,2$ for $N > 625$

Unless $\alpha > 100$ mrad, where $C_5 = 1,0$ in all cases.

If multiple pulses appear within the period of T_i (see Table 2), they are counted as a single pulse to determine N and the energies of the individual pulses are added to be compared to the AEL of T_i.

In some cases, the calculated value for $AEL_{s.p.train}$ may fall below the AEL that would apply for CW operation at the same peak power using the same time base. Under these circumstances, the AEL for CW operation may be used.

Table 2 – Times below which pulse groups are summed

Wavelength nm	T_i s
$400 \leq \lambda < 1\ 050$	5×10^{-6}
$1\ 050 \leq \lambda < 1\ 400$	13×10^{-6}
$1\ 400 \leq \lambda < 1\ 500$	10^{-3}
$1\ 500 \leq \lambda < 1\ 800$	10
$1\ 800 \leq \lambda < 2\ 600$	10^{-3}
$2\ 600 \leq \lambda \leq 10^6$	10^{-7}

NOTE 9 Examples of calculations are given in Annex B.

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4.4 Laser products designed to function as conventional lamps

For laser products, except for toys, which are designed to function as conventional lamps and emit visible and near infrared optical radiation (400 nm to 1400 nm) from extended sources with angular subtense α greater than 5 mrad at 200 mm distance, and having total (400 nm to 1400 nm) un-weighted peak radiance levels averaged with an acceptance angle of 5 mrad not exceeding L_T under operation and reasonably foreseeable single fault conditions, where

$$L_T = (1\ \mathrm{MW \cdot m^{-2} \cdot sr^{-1}})/\alpha$$

The emission may alternately be evaluated under the IEC 62471 series of standards, "Photobiological safety of lamps and lamp systems". For calculating L_T, the angular subtense α is expressed in radians and is determined at 200 mm from the closest point of human access. The value of α in the expression for L_T is limited to values between 0,005 rad and 0,1 rad so that for sources that subtend an angle of 0,005 rad the applicable radiance criterion equals 200 $\mathrm{MW \cdot m^{-2} \cdot sr^{-1}}$, and for sources that are larger than 0,1 rad the applicable radiance criterion equals 10 $\mathrm{MW \cdot m^{-2} \cdot sr^{-1}}$.

NOTE 1 The above radiance values are not exposure limits or emission limits but are criteria to establish when the emitted radiation can be evaluated under the IEC 62471 series of standards.

NOTE 2 The optical radiation excluded from laser classification can be monochromatic.

Such a product needs to comply with and be classified according to this part of IEC 60825 except that the above-described optical radiation emission during normal operation and reasonably foreseeable single fault conditions need not be considered for classification (i.e. the above-described optical radiation emission during normal operation is not considered as accessible laser radiation). The product shall comply with the requirements of IEC 60825-1 for any laser radiation accessible during maintenance or service.

NOTE 3 If there is no laser radiation accessible from such a product during operation, other than described above that is evaluated under IEC 62471, it can be considered a Class 1 laser product.

Such a product shall be assigned a risk group under the IEC 62471 series of standards and shall contain a label stating the risk group as well as the laser product classification (including Class 1 if applicable) and applicable warnings.

Accessible laser emission with wavelengths below 400 nm or above 1 400 nm is to be considered in the classification of the product under this part of IEC 60825.

5 Determination of the accessible emission level and product classification

5.1 Tests

Tests shall take into account all errors and statistical uncertainties in the measurement process and increases in emission and degradation in radiation safety with age. Specific user requirements may impose additional tests. For additional guidance on measurements, refer to IEC/TR 60825-13.

Tests during operation shall be used to determine the classification of the product. Tests during operation, maintenance and service shall also be used as appropriate to determine the requirements for safety interlocks, labels and information for the user. The above tests shall be made under each and every reasonably foreseeable single-fault condition. However, if the emission is reduced to a level below the AEL by automatic reduction in a duration within which it is not reasonably foreseeable to have human access, then such faults need not be considered. The required reliability of the automatic reduction of the emission level to stay within a given class can be assessed on the principles of risk analyses, for instance as described in IEC 61508 where safety integrity levels (SIL) are specified. Additionally, to specify SIL levels, fault reaction times also need to be defined for the design of the automatic

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reduction; the target reaction time can also be based on the risk. A complete analysis according to IEC 61508 or application of IEC 61508 is not required.

Risk analysis may be used to assist in determining reasonably foreseeable single fault conditions. To determine if a single fault condition is considered as reasonably foreseeable or not, both the probability (frequency) for the fault as well as the risk for injury (probability of exposure to a level that could induce injury and severity of injury) is to be considered. The lower the risk for injury from a given fault, the "more frequent" can the fault (that would result in a given emission level) be tolerated and not be considered for classification. An acceptable mode of analysis of the probability and risk regarding failures are FMEA (failure mode and effect analysis), and the procedures described in IEC 61508.

NOTE 1 Automatic reduction includes physical limitation of the emission such as component or system failure to a safe condition. It does not include manual reduction or termination of the emission.

NOTE 2 For example, a scanning safeguard may not react fast enough to prevent emission above the AEL during the fault condition; however, this might be acceptable based on the results of a risk analysis.

NOTE 3 Classification is determined during operation, and restrictions on maintenance are then dependent upon the classification of the product.

NOTE 4 Single fault conditions can be assessed by methods other than physically inducing the fault for the test.

When assessing the suitability of protective housings for the prevention of human access to a level of energy that is equivalent to Class 4, single fault events for all reasonably foreseeable changes of direction of the beam shall be considered. The analysis shall include whether the single fault event will result in sufficient energy to degrade or destroy the protective housing. For example, when during operation or single fault condition, the introduction of robotics or other beam manipulation mechanisms, or the use of optics or workpieces would result in energy being directed onto the surface of the protective housing, one of the following shall occur:

– the single fault shall be eliminated by engineering means; or
– the protective housing material shall withstand the energy without degradation of its protective properties sufficient to allow a hazardous exposure to laser energy; or
– the fault shall be detected and emission of laser radiation through the protective housing shall be prevented before degradation can occur.

Evaluation times of the protective housing of less than 30 000 s as specified in IEC 60825-4 are not applied for the classification of the product.

NOTE 5 This is because the class is determined without considering human intervention (see 6.2.1) and, therefore, inspection of the protective housing by the user is not considered.

NOTE 6 Protective housing evaluations that consider human inspection, or intervention, can be used to establish levels of safety, or for the detection of potential degradation of the protective housing which results from reasonably unforeseeable fault events, or multiple fault events, independent of the product classification.

Optical amplifiers shall be classified using the maximum accessible total output power or energy, which may include maximum rated input power or energy. In those cases where there is no clear output power or energy limit, the maximum power or energy added by the amplifier plus the necessary input signal power or energy to achieve that condition should be used.

Tests and procedures that are equivalent to those specified in Clause 5 are acceptable.

5.2 Measurement of laser radiation

Measurement of laser radiation levels may be necessary to classify a laser product in accordance with 5.1. Measurements are unnecessary when the physical characteristics and limitations of the laser source place the laser product or laser installation clearly in a particular class (however, the principles given in a) to f) need to be considered).

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Any measurements shall be made under the following conditions and procedures.

a) Conditions and procedures which maximize the accessible emission levels, including start-up, stabilized emission and shut-down of the laser product.

b) With all controls and settings listed in the operation, maintenance and service instructions adjusted in combination to result in the maximum accessible level of radiation. Measurements are also required with the use of accessories that may increase the radiation hazard (for example, collimating optics) which are supplied or offered by the manufacturer for use with the product and that can be added or removed without tools.

NOTE This includes any configuration of the product which it is possible to attain without using tools or defeating an interlock, including configurations and settings against which the operation and maintenance instructions contain warnings. For example, when optical elements such as filters, diffusers or lenses in the optical path of the laser beam can be removed without tools, the product must be tested in the configuration which results in the highest hazard level. The instruction by the manufacturer not to remove the optical elements cannot justify classification as a lower class. Classification is based on the engineering design of the product and cannot be based on appropriate behaviour of the user.

c) For a laser product other than a laser system, with the laser coupled to that type of laser energy source which is specified as compatible by the laser product manufacturer and which produces the maximum emission of accessible radiation from the product.

d) At points in space to which human access is possible during operation for measurement of accessible emission levels (for example, if operation may require removal of portions of the protective housing and defeat of safety interlocks, measurements shall be made at points accessible in that product configuration).

e) With the measuring instrument detector so positioned and so oriented with respect to the laser product as to result in the maximum detection of radiation by the instrument.

f) Appropriate provision shall be made to avoid or to eliminate the contribution of collateral radiation to the measurement.

5.3 Determination of the class of the laser product

The AELs of Class 1 and 1M are given in Tables 3 and 4, the AEL of Class 2 in Table 5, the AEL of Class 3R in Table 6 and 7, and the AEL of Class 3B in Table 8. The correction factors C_1 to C_7 and breakpoints T_1 and T_2 used in Tables 3 to 8 are defined in Table 9.

a) Classes 1 and 1M

Class 1 is applicable to the wavelength range of 180 nm to 1 mm. Class 1M is applicable to the wavelength range of 302,5 nm to 4 000 nm. For determination of the accessible emission under Condition 1 and Condition 3, see Table 10.

For wavelengths less than 302,5 nm and greater than 4 000 nm, if the accessible emission is less than or equal to the AEL of Class 1 for Condition 3, then the laser product is assigned to Class 1.

For wavelengths between 302,5 nm and 4 000 nm:

If the accessible emission is:

– less than or equal to the AEL of Class 1 for Condition 1 and Condition 3,

then the laser product is assigned to Class 1.

If the accessible emission is:

– greater than the AEL of Class 1 for Condition 1; and

– less than the AEL of Class 3B for Condition 1; and

– less than or equal to the AEL of Class 1 for Condition 3,

then the laser product is assigned to Class 1M.

NOTE 1 The reason for verifying the AEL of Class 3B is to limit the maximum power passing through an optical instrument for the case of exposure to a beam from a Class 1M laser product.

If the accessible emission exceeds the AEL of Class 3B as determined with a 3,5 mm diameter aperture placed at the closest point of human access, an additional warning regarding a potential skin hazard and/or cornea/iris hazard shall be given (see 7.19).

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NOTE 2 It is possible that a Class 1 laser product with a highly diverging beam can produce high enough irradiance levels near to or in contact with the source (for instance, a fibre tip) so that skin or iris injury is possible. Corneal injury may also be possible under these conditions for wavelengths longer than 1 000 nm.

b) Class 1C

Class 1C is applicable when the laser radiation is intended to be applied in contact with the intended target and has safeguards that prevent leakage of laser radiation in excess of the AEL of Class 1. The laser product can be assigned to Class 1C only if it also complies with a set of safety requirements for Class 1C laser products that can be found in an applicable IEC vertical standard.

Laser products intended to be used in contact-mode at the human skin and non-ocular tissue can be classified Class 1C only if a standard in the IEC 60601 or IEC 60335 series applies and contains a set of safety requirements expressively attributed to Class 1C laser products. Such Class 1C laser products shall incorporate engineering controls to ensure that exposure of laser radiation to the eye is not reasonably foreseeable. Classification as Class 1C is only permitted if an applicable IEC standard exists, which specifies engineering controls to prevent emission into the surrounding space or to the eye and limits the exposure of the intended target tissue to levels that are appropriate for the intended application.

For the test of stray-light or leakage radiation the AEL of Class 1 shall not be exceeded under Condition 3 with the applicator placed at the operational distance or in contact with a diffusing white surface.

NOTE 3 Typical Class 1C laser products would include those intended for hair removal, skin wrinkle reduction and acne reduction, including those for home-use.

c) Classes 2 and 2M

Classes 2 and 2M are applicable to the wavelength range of 400 nm to 700 nm. For determination of the accessible emission under Condition 1 and Condition 3, see Table 10.

If the accessible emission exceeds the limits as required for Class 1 and for Class 1M (see item a) above), and is:

– less than or equal to the AEL of Class 2 for Condition 1 and Condition 3,

then the laser product is assigned to Class 2.

If the accessible emission exceeds the limits as required for Class 1 and for Class 1M (see item a) above), and is:

– greater than the AEL of Class 2 for Condition 1; and

– less than the AEL of Class 3B for Condition 1; and

– less than or equal to the AEL of Class 2 for Condition 3,

then the laser product is assigned to Class 2M.

NOTE 4 The reason for verifying the AEL of Class 3B is to limit the maximum power passing through an optical instrument for the case of exposure to a beam from a Class 2M laser product.

If the accessible emission exceeds the AEL of Class 3B as determined with a 3,5 mm diameter aperture placed at the closest point of human access, an additional warning regarding a potential skin hazard and/or cornea/iris hazard shall be given (see 7.13).

NOTE 5 It is possible that a Class 2 laser product with a highly diverging beam can produce high enough irradiance levels near to or in contact with the source (for instance, a fibre tip) so that skin or iris injury is possible.

Outside the wavelength range from 400 nm to 700 nm, any additional emissions of Class 2 lasers shall be below the AEL of Class 1 (see 4.3 e) for time base). Additionally, if the wavelengths are additive for the eye (see Table 1), the sum of the ratios of the accessible visible light to the AEL for Class 2 and the accessible invisible light to the AEL for Class 1 shall be less than 1.

d) Class 3R

If the accessible emission, as determined according to 5.4, for Condition 1 and Condition 3 is:

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