INTERNATIONAL STANDARD

IEC 60825-1

1993

AMENDMENT 2
2001-01

PUBLICATION GROUPÉE DE SÉCURITÉ
GROUP SAFETY PUBLICATION

Amendment 2

Safety of laser products –

Part 1: Equipment classification, requirements and user's guide

Amendement 2

Sécurité des appareils à laser –

Partie 1: Classification des matériels, prescriptions et guide de l'utilisateur

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Международная Электротехническая Комиссия

PRICE CODE XB

For price, see current catalogue

FOREWORD

This amendment has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

The text of this amendment is based on the following documents:

FDIS	Report on voting
76/220/FDIS	76/223/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until 2003. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition; or
- amended.

A consolidated edition incorporating IEC 60825-1 (1993), amendment 1 (1997) and the present amendment 2 (2001) is under preparation.

The contents of the corrigendum of June 2002 have been included in this copy.

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1 Scope and object

1.1 Scope

At the end of the third paragraph, add the following sentence:

See also annex G which describes information which should be provided by manufacturers of LEDs.

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3 Definitions

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*Replace, in definition 3.5, the reference in brackets by "*3.7".

Add the following new definition:

3.6
angle of acceptance
plane angle within which a detector will respond to optical radiation, usually measured in radians. This angle of acceptance may be controlled by apertures or optical elements in front of the detector (see figure 16). The angle of acceptance is also sometimes referred to as the field of view

Symbol: γ

NOTE Angle of acceptance for evaluating photochemical hazards. For evaluation of the photochemical hazard, a limiting measurement angle of acceptance, γ_p, is specified. The angle γ_p is biologically related to eye movements and is not dependent upon the angular subtense of the source. If the angular subtense of the source is smaller than the limiting angle of acceptance, the actual measurement angle of acceptance does not have to be limited. If the angular subtense of the source is larger than the specified limiting angle of acceptance, the angle of acceptance has to be limited and the source has to be scanned for hotspots. If the measurement angle of acceptance is not limited to the specified level, the hazard may be over-estimated.

Symbol: γ_p

Replace the existing definition 3.6 as follows:

3.7
angular subtense (α)
angle subtended by an apparent source as viewed at a point in space. In this standard, for classification, the angular subtense is determined at a point not less than 100 mm from the apparent source (or at the exit window or lens of the product if the apparent source is located at a distance greater than 100 mm within the window or lens). (See also 3.53 and 3.57.) For an analysis of the maximum permissible exposure levels, the angular subtense shall be determined at the viewing distance from the apparent source but not less than 100 mm. This concept is also discussed in clause A.3 of annex A

NOTE 1 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 2 The angular subtense of the source should not be confused with the divergence of the beam.

Renumber definitions 3.7 and 3.8 to read 3.8 and 3.9. Add the following new definition 3.10 and renumber the definitions 3.9 to 3.15 to read 3.11 to 3.17:

3.10
beam
laser radiation that may be characterized by direction, divergence, diameter or scan specifications. Scattered radiation from a non-specular reflection is not considered to be a beam

3.13
beam divergence

In the second sentence, change "distance *L*" *into* "distance *r*".

Change the formula to read

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

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Replace definition 3.17 as follows:

3.17
Class 1 laser product
any laser product which does not permit human access to laser radiation in excess of the accessible emission limits of Class 1 for applicable wavelengths and emission durations (see 8.2 and 8.4e))

Add the following new definition 3.18:

3.18
Class 1M laser product
any laser product in the wavelength range from 302,5 nm to 4 000 nm which does not permit human access to laser radiation in excess of the accessible emission limits of Class 1 for applicable wavelengths and emission durations (see 8.4e)), where the level of radiation is measured according to 9.2g), however, evaluated with smaller measurement apertures or at a greater distance from the apparent source than those used for Class 1 laser products. The output of a Class 1M product is therefore potentially hazardous when viewed using an optical instrument (see 8.2)

Replace definition 3.16 as follows:

3.19
Class 2 laser product
any laser product which does not permit human access to laser radiation in excess of the accessible emission limits of Class 2 for applicable wavelengths and emission durations (see 8.2 and 8.4e))

Add the following new definition 3.20 and renumber the definitions 3.17 to 3.57 to read 3.21 to 3.61:

3.20
Class 2M laser product
any laser product in the wavelength range from 400 nm to 700 nm which does not permit human access to laser radiation in excess of the accessible emission limits of Class 2 for applicable wavelengths and emission durations (see 8.4e)), where the level of radiation is measured according to 9.2h), however, evaluated with smaller measurement apertures or at a greater distance from the apparent source than those used for Class 2 laser products. The output of a Class 2M product is therefore potentially hazardous when viewed using an optical instrument

In definitions 3.21 and 3.22 change "(see 9.2)" *to* "(see 8.2)".

Replace the title of definition 3.21 "Class 3A and Class 3B laser products" *by* "Class 3R and Class 3B laser products".

In the text of definition 3.21, change "3A" *to* "3R".

Add the following note at the end of definition 3.29:

NOTE The laser which is incorporated in the embedded laser product is called the embedded laser.

Add to definitions 3.30 and, on page 21, 3.32 the following second sentence:

For 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

Add the following text at the end of definition 3.33:

Two extended source conditions are considered in this standard when considering retinal thermal injury hazards: intermediate source and large source, which are used to distinguish sources with angular subtenses, α, between α_{min} and α_{max} (intermediate sources), and greater than α_{max} (large sources). (See also 3.79.)

Replace, in definition 3.36a), third line, "Class 2, 3A or 3B of not more than 5 times the AEL of Class 2 in the wavelength region from 400 nm to 700 nm" *by* "Class 2, 2M or 3R".

Replace definition 3.38 as follows:

3.38
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

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Add the following new definition 3.62 after definition 3.61 and renumber definitions 3.58 to 3.73 to read 3.63 to 3.78:

3.62
photochemical hazard limit
either an MPE or AEL which was derived to protect persons against adverse photochemical effects (for example, photoretinitis – a photochemical retinal injury from exposure to radiation in the wavelength range from 400 nm to 600 nm)

Delete, in definition 3.69, at the end of the second line:

(usually expressed in $J \cdot m^{-2}$)

Add the following new definition 3.79 after definition 3.78 and renumber definitions 3.74 to read 3.80, and 3.75 to read 3.81:

3.79
small source
source with an angular subtense α less than, or equal to, the minimum angular subtense α_{min}

Add the following new definitions 3.82 and 3.83 after definition 3.81:

3.82
thermal hazard limit
either an MPE or AEL which was derived to protect persons against adverse thermal effects, as opposed to photochemical injury

3.83
time base
emission duration to be considered for classification (see 8.4 e))

Renumber definitions 3.76 to 3.80 to read 3.84 to 3.88

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4.3 Access panels and safety interlocks

Replace, in 4.3.1b) "the removal of the panel .... Class 2" *by* "the removal of the panel gives access to laser radiation levels designated by "X" in the table below."

Replace the table and the third paragraph by the following:

Product class	Accessible emission during or after removal of access panel				
	1, 1M	2, 2M	3R	3B	4
1, 1M	–	–	X	X	X
2, 2M	–	–	X	X	X
3R	–	–	–	X	X
3B	–	–	–	X	X
4	–	–	–	X	X

Removal of the panel shall not result in emission through the opening in excess of Class 1M or Class 2M as applicable according to the wavelength.

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4.4 Remote interlock connector

Replace the text of this subclause as follows:

Each Class 3B and Class 4 laser system shall have a remote interlock connector. When the terminals of the connector are open-circuited, the accessible radiation shall not exceed Class 1M or Class 2M as applicable.

4.5 Key control

Replace the first sentence as follows:

Each Class 3B and Class 4 laser system shall incorporate a key-operated master control.

4.6 Laser radiation emission warning

Subclause 4.6.1

Replace the first sentence by the following new first sentence:

Each Class 3R laser system in the wavelength range below 400 nm and above 700 nm and each Class 3B and Class 4 laser system shall give an audible or visible warning when it is switched on or if capacitor banks of a pulsed laser are being charged or have not positively discharged.

Replace, at the end of the last sentence, "in excess of the AEL for Class 1 and Class 2" *by* "in excess of the AEL for Class 1M and 2M".

4.7 Beam stop or attenuator

Replace the existing text by the following new text:

Each Class 3B and Class 4 laser system shall incorporate one or more permanently attached means of attenuation (beam stop or attenuator, other than a laser energy source switch, mains connector or key control). The beam stop or attenuator shall be capable of preventing human access to laser radiation in excess of Class 1M or Class 2M as applicable.

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4.8 Controls

Replace, at the end of the sentence, "do not require exposure to laser radiation in excess of the AEL for Class 1 and Class 2" *by* "do not require exposure to laser radiation of Class 3R, 3B or Class 4".

4.9 Viewing optics

Replace, "in excess of the AEL for Class 1" *by* "in excess of the AEL for Class 1M" (three times).

4.12 "Walk-in" access

Replace the existing texts in a) and b) by the following:

a) means shall be provided so that any person inside the housing can prevent activation of a Class 3B or Class 4 laser hazard.

b) a warning device shall be situated so as to provide adequate warning of emission of Class 3R laser radiation in the wavelength range below 400 nm and above 700 nm, or of Class 3B or Class 4 laser radiation to any person who might be within the housing.

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5.2 Class 1

Replace the existing text by the following:

Except as permitted in 1.1, each Class 1 laser product shall have affixed an explanatory label (figure 15) bearing the words:

CLASS 1 LASER PRODUCT

Each Class 1M laser product shall have affixed an explanatory label (figure 15) bearing the words:

LASER RADIATION
DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
CLASS 1M LASER PRODUCT

The type of optical instrument which could result in an increased hazard may be added in parenthesis after the word "instruments". The added wording could in particular be "(BINOCULARS OR TELESCOPES)" for a laser product with a collimated, large-diameter beam, which is classified 1M because it fails condition 1 of table 10, or "(MAGNIFIERS)" for a laser product which is classified 1M because it fails condition 2 of table 10 (highly diverging beam).

Instead of the above labels, at the discretion of the manufacturer, the same statements may be included in the information for the user.

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5.3 Class 2

Add the following text:

Each Class 2M laser product shall have affixed a warning label (figure 14) and an explanatory label (figure 15) bearing the words:

LASER RADIATION
DO NOT STARE INTO THE BEAM OR VIEW
DIRECTLY WITH OPTICAL INSTRUMENTS
CLASS 2M LASER PRODUCT

The type of optical instrument which could result in an increased hazard may be added in parenthesis after the word "instruments". The added wording could in particular be "(BINOCULARS OR TELESCOPES)" for a laser product with a collimated, large-diameter beam which is classified 2M because it fails condition 1 of table 10, or "(MAGNIFIERS)" for a laser product which is classified 2M because it fails condition 2 of table 10 (highly diverging beam).

5.4 Class 3A

Replace the title and text by the following:

5.4 Class 3R

Each Class 3R laser product in the wavelength range from 400 nm to 1 400 nm shall have affixed a warning label (figure 14) and an explanatory label (figure 15) bearing the words:

LASER RADIATION
AVOID DIRECT EYE EXPOSURE
CLASS 3R LASER PRODUCT

For other wavelengths, each Class 3R laser product shall have affixed a warning label (figure 14) and an explanatory label (figure 15) bearing the words:

LASER RADIATION
AVOID EXPOSURE TO BEAM
CLASS 3R LASER PRODUCT

5.7 Aperture label

Replace "Each Class 3B and Class 4…" *by* "Each Class 3R, Class 3B and Class 4…"

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5.8 Radiation output and standards information

Replace the existing text by the following:

Each laser product, except those of Class 1, shall be described on the explanatory label (figure 15) by a statement of the maximum output of laser radiation, the pulse duration (if appropriate) and the emitted wavelength(s). The name and publication date of the standard to which the product was classified shall be included on the explanatory label or elsewhere in close proximity on the product. For Class 1 and Class 1M, instead of the labels on the product, the information may be contained in the information for the user.

5.9.1 Labels for panels

Replace, at the end of the first sentence of the first paragraph "... shall have affixed a label bearing the words:" *by* "...shall have affixed labels bearing the words (for the case of an embedded Class 1M laser, the statement instead may be included in the information for the user):"

Replace the warnings in 5.9.1 as follows:

a)

CAUTION – CLASS 1M LASER RADIATION WHEN OPEN
DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

if the accessible radiation does not exceed the AEL for Class 1M where the level of radiation is measured according to 9.2g) and 9.3;

b)

CAUTION – CLASS 2 LASER RADIATION WHEN OPEN
DO NOT STARE INTO THE BEAM

if the accessible radiation does not exceed the AEL for Class 2 where the level of radiation is measured according to 9.2h) and 9.3;

c)

CAUTION – CLASS 2M LASER RADIATION WHEN OPEN
DO NOT STARE INTO THE BEAM OR VIEW
DIRECTLY WITH OPTICAL INSTRUMENTS

if the accessible radiation does not exceed the AEL for Class 2M where the level of radiation is measured according to 9.2h) and 9.3;

d)

CAUTION – CLASS 3R LASER RADIATION WHEN OPEN
AVOID DIRECT EYE EXPOSURE

if the accessible radiation is in the wavelength range from 400 nm to 1 400 nm and does not exceed the AEL for Class 3R;

e)

CAUTION – CLASS 3R LASER RADIATION WHEN OPEN
AVOID EXPOSURE TO THE BEAM

if the accessible radiation is outside the wavelength range from 400 nm to 1 400 nm and does not exceed the AEL for Class 3R;

f)

CAUTION – CLASS 3B LASER RADIATION WHEN OPEN
AVOID EXPOSURE TO THE BEAM

if the accessible radiation does not exceed the AEL for Class 3B;

g)

CAUTION – CLASS 4 LASER RADIATION WHEN OPEN
AVOID EYE OR SKIN EXPOSURE TO
DIRECT OR SCATTERED RADIATION

if the accessible radiation exceeds the limits for Class 3B.

This information may be provided in more than one adjacent label on the product.

5.9.2 Labels for safety interlocked panels

Modify the last sentence of the first paragraph and the warning as follows, and delete the second paragraph:

Such labels shall be visible prior to and during interlock override and be in close proximity to the opening created by the removal of the protective housing. This label shall bear the words specified in items a) to g) of 5.9.1, with the introduction of an additional line, positioned after the first line, with the following words:

AND INTERLOCKS DEFEATED

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5.10 Warning for invisible laser radiation

Replace, in the first sentence, "... for explanatory labels includes the phrase" *by* "... for labels in clause 5 includes the phrase ...".

Add at the end of this subclause:

If a product is classified on the basis of the level of visible laser radiation and also emits in excess of the AEL of Class 1 at invisible wavelengths, the label shall include the words "Visible and invisible laser radiation" in lieu of "Laser radiation".

5.11 Warning for visible laser radiation

Replace, in the first sentence, "The wording "laser radiation" on the explanatory labels may be modified to read..." *by* "The wording "laser radiation" for labels in Clause 5 may be modified to read...".

6.1 Information for the user

Insert a new item at the end of 6.1a) and renumber subsequent original items to read 6.1c) to g) inclusive:

b) For Class 1M and 2M laser products an additional warning is required. For diverging beams, this warning shall state that viewing the laser output with certain optical instruments (for example, eye loupes, magnifiers and microscopes) within a distance of 100 mm may pose an eye hazard. For collimated beams, this warning shall state that viewing the laser output with certain optical instruments designed for use at a distance (for example, telescopes and binoculars) may pose an eye hazard.

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6.2 Purchasing and servicing information

Replace the text of item a) by the following:

a) In all catalogues, specification sheets and descriptive brochures, the classification of each laser product and any warnings required by 6.1b) shall be stated.

7.1 Medical laser products

Delete item b) and include item a) into the second sentence to read:

In addition, any Class 3B or Class 4 medical laser product shall comply with IEC 60601-2-22.

7.2 Laser fibre optic transmission system

Replace the title and text of this subclause as follows:

7.2 Other parts of the standard series IEC 60825

For specific applications, one or other of the following IEC 60825 series may be applicable (see also annex H).

– IEC 60825-2 is additionally applicable to optical fibre communication systems.
– IEC 60825-4 is additionally applicable to laser guards.
– Further information on laser shows may be found in IEC/TR 60825-3.
– Further information regarding a manufacturer's checklist may be found in IEC/TR 60825-5.
– Further information regarding products exclusively used for visible information transmission may be found in IEC/TS 60825-6.
– Further information regarding products exclusively used for non-visible information transmission may be found in IEC/TS 60825-7.
– Guidelines for the safe use of medical laser equipment may be found in IEC/TR 60825-8.
– Further information regarding a review of MPEs for incoherent radiation may be found in IEC/TR 60825-9.

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8 Tests

Replace the title and text of clause 8 by the following:

8 Classification

8.1 Introduction

Because of the wide ranges possible for the wavelength, energy content and pulse characteristics of a laser beam, the hazards arising in its use vary widely. It is impossible to regard lasers as a single group to which common safety limits can apply.

8.2 Description of laser classes

Class 1: Lasers that are safe under reasonably foreseeable conditions of operation, including the use of optical instruments for intrabeam viewing.

Class 1M: Lasers emitting in the wavelength range from 302,5 nm to 4 000 nm which are safe under reasonably foreseeable conditions of operation, but may be hazardous if the user employs optics within the beam. Two conditions apply:

a) for diverging beams if the user places optical components within 100 mm from the source to concentrate (collimate) the beam; or
b) for a collimated beam with a diameter larger than the diameter specified in table 10 for the measurements of irradiance and radiant exposure.

Class 2: Lasers that emit visible radiation in the wavelength range from 400 nm to 700 nm where eye protection is normally afforded by aversion responses, including the blink reflex. This reaction may be expected to provide adequate protection under reasonably foreseeable conditions of operation including the use of optical instruments for intrabeam viewing.

NOTE Outside the wavelength range from 400 nm to 700 nm, any additional emissions of Class 2 lasers are required to be below the AEL of Class 1.

Class 2M: Lasers that emit visible radiation in the wavelength range from 400 nm to 700 nm where eye protection is normally afforded by aversion responses including the blink reflex. However, viewing of the output may be more hazardous if the user employs optics within the beam. Two conditions apply:

a) for diverging beams, if the user places optical components within 100 mm from the source to concentrate (collimate) the beam, or

b) for a collimated beam with a diameter larger than the diameter specified in table 10 for the measurements of irradiance and radiant exposure.

NOTE Outside the wavelength range from 400 nm to 700 nm, any additional emissions of Class 2M lasers are required to be below the AEL of Class 1M.

Class 3R: Lasers that emit in the wavelength range from 302,5 nm to 10^6 nm where direct intrabeam viewing is potentially hazardous but the risk is lower than for Class 3B lasers, and fewer manufacturing requirements and control measures for the user apply than for Class 3B lasers. The accessible emission limit is within five times the AEL of Class 2 in the wavelength range from 400 nm to 700 nm and within five times the AEL of Class 1 for other wavelengths.

Class 3B: Lasers that are normally hazardous when direct intrabeam exposure occurs (i.e. within the NOHD). Viewing diffuse reflections is normally safe (see also note to 12.5.2c)).

Class 4: Lasers that are also capable of producing hazardous diffuse reflections. They may cause skin injuries and could also constitute a fire hazard. Their use requires extreme caution.

8.3 Classification responsibilities

It is the responsibility of the manufacturer or his agent to provide correct classification of a laser product. The product shall be classified on the basis of that combination of output power(s) and wavelength(s) of the accessible 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 accessible emission limit (AELs) for Class 1 and 1M, Class 2 and 2M, Class 3R and Class 3B (listed in order of increasing hazard) are given in tables 1, 2, 3 and 4 respectively.

The values of the correction factors used are given in the notes to tables 1 to 4 as functions of wavelength, emission duration, number of pulses and angular subtense.

8.4 Classification rules

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

NOTE For classification of a laser product as Class 1M or 2M, the use of an aperture, specified in table 10 for irradiance and radiant exposure at the distances in that table for these measurements, limits the amount of radiation that is collected from large diameter or highly diverging beams. For example, when measured under the applicable conditions, Class 1M and Class 2M products may have higher measured energy or power than the AEL of Class 3R. For such laser products, a classification of 1M or 2M is appropriate.

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 in table 5 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.

2) A laser product emitting two or more wavelengths not shown as additive in table 5 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.

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 source. 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. 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, but, depending on the exposure duration (see 9.3c) i), a limiting angle of acceptance γ_p of 11 mrad or more is used for measurement, and the relation of the limiting acceptance angle γ_p to the angular subtense α of the source can influence the measured value.

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

For an extended source, the power or energy measured must be below the permitted power or energy for the AEL specified for the class as a function of the angular subtense of the source α.

For classifying laser products where condition 1 applies (see table 10), the angular subtense α of the apparent source shall be determined at the location of the 50 mm measurement aperture. The 7× magnification of the angular subtense α of the apparent source may be applied to determine C_6, i.e. $C_6 = 7 \times \alpha / \alpha_{min}$, provided that it can be demonstrated that the smallest possible retinal spot diameter will not be less than $C_6 \times 25$ µm when the radiation is viewed through an optical instrument of magnification 7. The expression $(7 \times \alpha)$ shall be limited to α_{max} prior to the calculation of C_6.

NOTE For the case that $\alpha < 1{,}5$ mrad but $7 \times \alpha > 1{,}5$ mrad, the limits for $\alpha > 1{,}5$ mrad of table 1 and 3 apply, provided that the 7× magnification of the retinal spot diameter can be demonstrated.

For classifying laser products where condition 2 applies (see table 10), the angular subtense α of the apparent source shall be determined at the nearest point of human access to the apparent source, but not less than 100 mm.

d) Non-circular and multiple sources

For laser radiation where the apparent source consists of multiple points or is a linear source with an angular subtense greater than α_{min} and within the wavelength range from 400 nm to 1 400 nm, measurements or evaluations shall be made for every single point, or assembly of points, necessary to assure that the source does not exceed the AEL for each possible angle α subtended by each partial area, where $\alpha_{min} \leq \alpha \leq \alpha_{max}$.

For the retinal photochemical hazard limits (400 nm to 600 nm), the limiting angle of acceptance γ_p to be used to evaluate extended sources is specified in 9.3 c) i).

For the determination of the AEL retinal thermal hazard limits (400 nm to 1 400 nm), the value of the angular subtense of a rectangular or linear source is determined by the arithmetic mean 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. The photochemical limits (400 nm to 600 nm) do not depend on the angular subtense of the source, and the source is measured with the angle of acceptance specified in 9.3 c).

e) Time bases

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

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

ii) 100 s for laser radiation of all wavelengths greater than 400 nm except for the cases listed in i) and iii).

iii) 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.

NOTE Every possible emission duration within the time base must be considered when determining the classification of a product. This means that the emission level of a single pulse must be compared to the AEL applicable to the emission duration of the pulse, etc. It is not sufficient to merely average the emission level for the duration of the classification time base.

f) Repetitively pulsed or modulated lasers

The following methods shall be used to determine the AEL to be applied to repetitive pulsed emissions.

The AEL for wavelengths from 400 nm to 10^6 nm is determined by using the most restrictive of requirements i), ii) and iii) as appropriate. For other wavelengths, the AEL is determined by using the most restrictive of requirements i) and ii). Requirement iii) applies only to the thermal limits, not to the photochemical limits.

i) The exposure from any single pulse within a pulse train shall not exceed the AEL for a single pulse.

ii) The average power for a pulse train of emission duration T shall not exceed the power corresponding to the AEL given in tables 1, 2, 3 and 4, respectively for a single pulse of emission duration T.

iii) The average pulse energy from pulses within a pulse train shall not exceed the AEL for a single pulse multiplied by the correction factor C_5. If pulses of variable amplitude are used, the assessment is made for pulses of each amplitude separately, and for the whole train of pulses.

$$AEL_{train} = AEL_{single} \times C_5$$

where

AEL_{train} is the AEL for any single pulse in the pulse train;

AEL_{single} is the AEL for a single pulse;

$C_5 = N^{-0,25}$;

N is the number of pulses in the pulse train during the duration according to the following:

Wavelength	Duration to determine N
400 nm to 1 400 nm	T_2 (see note 2 of the notes to tables 1 to 4) or the applicable time basis, whichever is shorter
>1 400 nm	10 s

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

In some cases, the calculated value may fall below the AEL that would apply for continuous operation at the same peak power using the same time base. Under these circumstances, the AEL for continuous operation may be used.

If multiple pulses appear within the period of T_i (see table 9), 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, provided that all individual pulse durations are greater than 10^{-9} s.

NOTE The energy from any group of pulses (or sub-group of pulses in a train) delivered in any given time should not exceed the AEL for that time.