



BSI Standards Publication

Safety of laser products

Part 1: Equipment classification and requirements

National foreword

This British Standard is the UK implementation of EN 60825-1:2014/A11:2021/AC:2022, incorporating corrigendum March 2022. It is derived from IEC 60825-1:2014. It supersedes BS EN 60825-1:2014, which is withdrawn.

This British Standard is the UK implementation of EN 60825-1:2014/A11:2021, incorporating corrigendum March 2022.

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Amendments/corrigenda issued since publication

Date	Text affected
31 December 2017	Implementation of CENELEC corrigendum December 2017: dow of EN 60825-1:2014 changed from 2017-06-19 to 2019-06-19 in European foreword
28 February 2021	Implementation of IEC Interpretation Sheets 1 and 2
31 March 2021	Implementation of CENELEC amendment A11:2021
30 June 2022	Implementation of CENELEC Corrigendum March 2022

English Version

**Safety of laser products - Part 1: Equipment classification and requirements
(IEC 60825-1:2014)**

Sécurité des appareils à laser - Partie 1: Classification des matériels et exigences
(CEI 60825-1:2014)

Sicherheit von Lasereinrichtungen - Teil 1: Klassifizierung von Anlagen und Anforderungen
(IEC 60825-1:2014)

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European foreword

The text of document 76/502/FDIS, future edition 3 of IEC 60825-1, prepared by IEC/TC 76 "Optical radiation safety and laser equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60825-1:2014.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2015-03-19
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2019-06-19

This document supersedes EN 60825-1:2007.

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The text of the International Standard IEC 60825-1:2014 was approved by CENELEC as a European Standard without any modification.

IEC 60027-1	NOTE	Harmonised in EN 60027-1.
IEC 60065	NOTE	Harmonised as EN 60065.
IEC 60079 (Series)	NOTE	Harmonised as EN 60079 (Series).
IEC 60204-1	NOTE	Harmonised as EN 60204-1.
IEC 60601-2-22	NOTE	Harmonised as EN 60601-2-22.
IEC 60825-2	NOTE	Harmonised as EN 60825-2.
IEC 60825-4	NOTE	Harmonised as EN 60825-4.
IEC 60825-12	NOTE	Harmonised as EN 60825-12.
IEC 60950 (Series)	NOTE	Harmonised as EN 60950 (Series).
IEC 61010-1	NOTE	Harmonised as EN 61010-1.
IEC 61508 (Series)	NOTE	Harmonised as EN 61508 (Series).
IEC 62115	NOTE	Harmonised as EN 62115.
IEC 62368-1	NOTE	Harmonised as EN 62368-1.
IEC/ISO 11553 (Series)	NOTE	Harmonised as EN ISO 11553 (Series).
ISO 11146-1	NOTE	Harmonised as EN ISO 11146-1.
ISO 12100	NOTE	Harmonised as EN ISO 12100.
ISO 13694	NOTE	Harmonised as EN ISO 13694.
ISO 13849 (Series)	NOTE	Harmonised as EN ISO 13849 (Series).
ISO 15004-2:2007	NOTE	Harmonised as EN ISO 15004-2:2007.
ISO 80000-1	NOTE	Harmonised as EN ISO 80000-1.

Foreword to amendment A11

This document (EN 60825-1:2014/A11:2021) has been prepared by CLC/TC 76 “Optical radiation safety and laser equipment”.

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

This document is expected to be read in conjunction with EN 50689¹ ‘Safety of laser products - Particular Requirements for Consumer Laser Products’, when available.

¹ Under preparation. Stage at the time of publication: prEN 50689:2019.

Annex ZA
(normative)

**Normative references to international publications
with their corresponding European publications**

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here:

www.cenelec.eu.

<u>Publication</u>	<u>Year</u> <u>series</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u> <u>series</u>
IEC 60050		International Electrotechnical Vocabulary	-	
IEC 62471 (mod)	-	Photobiological safety of lamps and lamp systems	EN 62471	-



Annex ZB (informative)

Information for the Interpretation of 4.3, 4.4 and 6.3.2

ZB.1 General remarks

This informative annex is added to EN 60825-1:2014 in order to publish the content of the IEC Interpretation Sheets IEC 60825-1:2014/ISH1:2017 and IEC 60825-1:2014/ISH2:2017 by CENELEC. The content is published as an annex to EN 60825-1, because the publication type “Interpretation Sheet” is not available at CENELEC level. Because there are no page-number limitations for an annex (contrary to an Interpretation Sheet), the text of the IEC ISH1 and ISH 2 has been somewhat extended in order to increase the readability and clarity.

ZB.2 Subclause 4.3 Classification rules (IEC 60825-1:2014/ISH1:2017)

ZB.2.1 General remarks

This subclause ZB.2 contains the text of ISH1; some examples were added for clarity.

For some complex extended sources or irregular temporal emissions, the application of the rules of 4.3 may require clarification.

In this subclause ZB.2, 4.3 (Classification rules) is clarified.

NOTE 1 For the purpose of this annex, the abbreviation “AE” is used for “accessible emission”.

NOTE 2 The clarifications also apply in an equivalent way to MPE analysis, i.e. for Annex A.

ZB.2.2 Subclause 4.3 c) (Radiation from extended sources)

When using the default (simplified) evaluation method (5.4.2) for wavelengths ≥ 400 nm and $< 1\,400$ nm, the angle of acceptance may be limited to 100 mrad for determining the accessible emission to be compared against the accessible emission limit, except in the wavelength range 400 nm – 600 nm for durations longer than 100 s where the circular-cone angle of acceptance is not limited. When evaluating the emissions for comparison to the Class 3B AELs, the angle of acceptance is not limited.

ZB.2.3 Subclause 4.3 d) (Non-uniform, non-circular or multiple apparent sources)

In 4.3 d), for comparison with the thermal retinal limits, the requirement to vary the angle of acceptance in each dimension might appear to contradict the labelling in Figure 1 and Figure 2 of 5.4.3 where the field stop is labelled as circular.

Interpretation

A circular field stop is applicable for circularly symmetric images of the apparent source and for this case is consistent with the procedure given in 4.3 d). For images of the apparent source that are not circularly symmetric, the simple example below clarifies the application of 4.3 d).

A circular field stop with an angular subtense equal to $\alpha_{\max}$ is, however, applicable for non-circularly symmetric profiles if the analysis performed according to 4.3 d), following variation of the angle of acceptance in each dimension, results in a solution which is equal to $\alpha_{\max}$ in both dimensions.

As a general principle, for whatever emission duration t that is used to determine the AEL (such as the pulse duration, the pulse group duration or the time base for averaging of the power), the same emission duration t is also used to calculate $\alpha_{\max}(t)$.

The following example demonstrates the method described in 4.3 d) to analyse irregular or complex images of a source. It is noted that the example is equivalent to the second part of the example ("Additional Remarks"; 6 mrad spacing instead of 3 mrad) B.9.1 of IEC/TR 60825-14:2004 (however, for 6 mrad element spacing, the result in terms of which grouping is critical was not correct in IEC/TR 60825-14:2004). The source is a diode array (Figure ZB.1). The task is to determine the applicable AEL that limits the AE for Class 2. Each diode contributes a partial accessible emission AE of 1 mW that passes through a 7 mm aperture stop at the distance where the analysis is performed (i.e. a total power of 20 mW passes through the aperture stop), and the emission is continuous wave. The analysis requires determination of the most restrictive (maximum) ratio of AE over AEL by variation of the angle of acceptance in position and size to achieve different field of views.

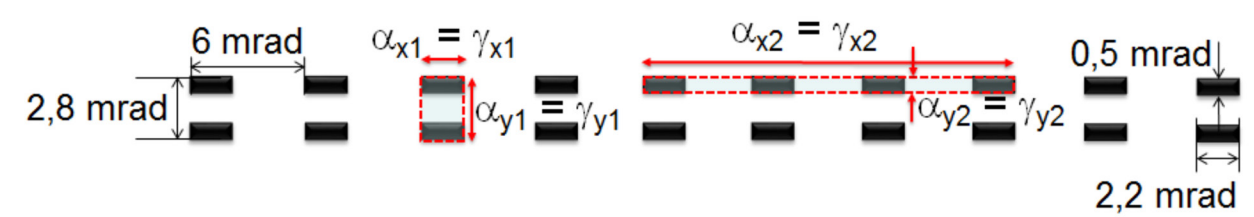


Figure ZB.1 — Retinal image of a source pattern for the example of 20 emitters. Two possible groupings are defined by the respective angle of acceptance γ_x and γ_y

The analysis of a sub-group of sources is associated with a certain value of α for that group, and a certain accessible emission associated with that sub-group. For instance, α of a single element equals $(2,2 \text{ mrad} + 1,5 \text{ mrad})/2 = 1,85 \text{ mrad}$ so that $C_6 = 1,85/1,5 = 1,23$ and therefore the AEL = 1,23 mW. The applicable AE = 1 mW and AE/AEL = 1 mW/1,23 mW = 0,81. For a vertical two-element group, as shown in Figure ZB.1 with γ_{x1} and γ_{y1} , $\alpha = (2,2 \text{ mrad} + 2,8 \text{ mrad})/2 = 2,5 \text{ mrad}$ so that $C_6 = 2,5/1,5 = 1,67$ and therefore AEL = 1,67 mW; AE = $2 \times 1 \text{ mW} = 2 \text{ mW}$ and AE/AEL = 1,2, which is more restrictive than AE/AEL for only one element. For one row of 10 diodes $\alpha = (56,2 \text{ mrad} + 1,5 \text{ mrad})/2 = 28,9 \text{ mrad}$, $C_6 = 28,9/1,5 = 19,2$ and therefore the AEL = 19,2 mW, the AE = $10 \times 1 \text{ mW} = 10 \text{ mW}$ and AE/AEL = 0,5. Analysis of all possible groupings shows that the vertical two-element group has the maximum AE/AEL and therefore is the solution of the analysis. This means that the AEL of Class 2 is exceeded by a factor 1,2. Note that only a portion of the power of 20 mW that passes through the 7 mm aperture stop is considered as the AE (2 mW; as partial power within the angle of acceptance that is associated to the part of the image with the maximum ratio of AE/AEL) that is compared against the AEL. The entire array represents the highest ratio of AE/AEL in cases where the element spacing is sufficiently close, e.g. when the contributions of added elements to the AE are not sufficiently compensated by the increased AEL due to the larger subtended angle.

For pulsed emission, for the determination of α according to the above method (4.3. d)) where the ratio of AE to AEL is maximized, requirement 3) of 4.3. f) is not applied, i.e. the AEL_{single} is not reduced by C_5 when the value of α is determined; however, C_5 is applied to AEL_{single} for the classification of the product.

Due to the dependence of α_{max} on emission duration t , the analysis of the image of the apparent source may result in different values of α and of the partial accessible emission, depending which emission duration is analysed for the requirements of 4.3 f). For example in Figure ZB.1, for emission durations shorter than $625 \mu\text{s}$ ($\alpha_{\text{max}} = 5 \text{ mrad}$), the maximum partial array to consider in the image analysis is a vertical two element group.

Ref.: Schulmeister K, Classification of extended source products according to IEC 60825-1, ILSC 2015 Proceedings Paper, Laser Institute of America, Orlando, pp. 271 – 280

It is important to note the overall methodology for this “image” analysis: a varying field of view is used and for each, the partial AE is determined, as well as the value of α associated to that field of view (setting $\alpha_v = \gamma_v$ and $\alpha_h = \gamma_h$); the respective value of α then determines the value of the AEL. For the variation of the angle of acceptance, the limits of α_{min} and α_{max} apply to the extent of the angle of acceptance in each dimension. It might also be necessary to rotate the image for the application of rectangular field of views. The solution of the analysis is *that* field of view which is associated to the maximum ratio of AE/AEL. The angular subtense of the “critical” field of view is then used to determine C_6 , and the critical field of view is also used to determine the AE. Therefore, when the image of the apparent source is larger than the critical field of view, the AE is smaller than the total radiation that passes through the 7 mm aperture stop.

The fact that the whole array in this example gives an AE/AEL factor smaller than the factor of the two-diode group does not mean that the whole array, i.e. the assembly of 20 diodes, is less “hazardous” than the two-diode group. If an injury would occur from exposure to radiation from the array, the injury would still be made up by the 20 elements. The meaning of this apparently strange result is that, in this specific case, the correct evaluation of the “hazard” is not obtained by considering the 20 diodes as one uniform source, but is given by the analysis of parts that form the array. This is due to the fact that the image of the apparent source is not uniform. If the elements would be spaced further apart also in vertical direction, the solution of the image analysis would be that one element is the critical one (associated to the maximum ratio of AE/AEL), which can also be understood in terms of thermal injury mechanism: when the retinal image elements are far enough apart, they represent thermally independent exposures.

Caution should be exercised in the assessment of irregular image profiles of the apparent source. Where uncertainty may exist, it is best to over-state the region of collected partial power, and under-state the value of α used to determine the AEL.

Alternative simplified methods to analyse the apparent source are permissible if it can be demonstrated that they are no less restrictive than the method as defined in 4.3 d). The simplest and most restrictive approach is to use the accessible emission as determined with the aperture stop (see Table 10) and an open field of view (or restricted to α_{max}) and assume a small source where $C_6 = 1$. Another method is to neglect all parts of the image where the image irradiance is less than the $1/e$ value of the peak image irradiance and, using the smallest of the remaining image feature to determine α while considering the total power that passes through the aperture stop as accessible emission.

NOTE As a simplified method for the case that the irradiance profile of the image is Gaussian, according to definition 3.7 Note 1 to entry, the d_{63} beam diameter definition can be used to determine the value of α . In this case, it is not necessary to apply the analysis method defined in subclause 4.3 d) (i.e. variation of the angle of acceptance) but then the total power or energy that passes through the aperture stop and a circular field stop with an angular subtense equal to α_{max} is considered as the accessible emission.

ZB.2.4 Subclause 4.3 f) 3); determination of α

The parameter $\alpha_{\max}$ is a function of emission duration, i.e. $\alpha_{\max}(t)$. For an analysis of pulsed emission and extended sources, $\alpha_{\max}(t)$ limits both the value of α for the determination of $C_6(\alpha)$ as well as the angle of acceptance γ for the determination of the accessible emission (see 4.3 c) and d) and subclause ZB.2.3 of this amendment). In this process, $\alpha_{\max}(t)$ is determined for the same emission duration t that is used to determine $AEL(t)$ (i.e. the pulse duration or the pulse group duration for 4.3 f) 3) and the averaging duration for 4.3 f) 2), respectively).

However, the parameter α is also used in 4.3 f) 3) in the criteria to determine which C_5 is applied to $AEL_{s.p.train}(t)$. For these criteria to determine C_5 , the parameter α is not limited to $\alpha_{\max}(t)$ in the same way as for the determination of C_6 according to 4.3 d).

To determine $T_2(\alpha)$ and in the criteria of 4.3 f) 3) "For $\alpha \leq 5$ mrad", "For $5 \text{ mrad} < \alpha \leq \alpha_{\max}$ ", and, "For $\alpha > \alpha_{\max}$ ", the quantity α is equal to the "long-term" α , i.e. equal to α as determined for a time base of 0,25 s or equal to the value of α of $T_2(\alpha)$. In the determination of this "long-term" α (applying the method specified in 4.3 d)), $\alpha_{\max} = 100$ mrad. That is, for T_2 and these inequalities, α is not limited to a value of $\alpha_{\max}(t)$ smaller than 100 mrad, and is therefore the same as the value that applies for the determination of C_6 for the time base of 0,25 s or 100 s, as applicable.

As is generally defined (see 4.3 d)) the arithmetic mean is applied to determine α , i.e. it is not necessary that both dimensions satisfy the criterion "For $\alpha \leq 5$ mrad" independently.

For the criterion "Unless $\alpha > 100$ mrad", the angular subtense of the apparent source α is not restricted by $\alpha_{\max}$. For non-uniform (oblong, rectangular, or linear) sources, the inequality needs to be satisfied by both angular dimensions of the source in order for $C_5 = 1$ to apply. The value of α determined with $\alpha_{\max} = 100$ mrad (i.e. the "long-term" α) can also be used for this criterion, alternatively: in this case the criterion is written as "Unless $\alpha = 100$ mrad", because for α to become exactly equal to 100 mrad, when applying $\alpha_{\max} = 100$ mrad, the image of the apparent source has to be larger than 100 mrad in both dimensions.

Since the "long-term" α is needed for the inequalities in 4.3 f) 3) to determine the applicable C_5 , the usual sequence is as follows.

An analysis of the image of the apparent source is performed as given in 4.3 d) while either using $AEL(t = 0,25 \text{ s})$, or $AEL(t = T_2(\alpha))$, depending on the time base. The angle of acceptance (as dimensions of the field of view) is varied between 1,5 mrad and 100 mrad in each dimension. Each field of view is associated to a certain value of T_2 and therefore $AEL(t = T_2)$. The accessible emission is also determined for the respective field of view. The result of the process to vary the field of view is the "long-term" α that is associated to the field of view that produces the maximum ratio of AE to AEL. For the case of classification as Class 1, this process to determine the "long-term" α at the same time determines the value of $T_2(\alpha)$. This "long-term" α is used for C_6 for $AEL(t = 0,25 \text{ s})$, or $AEL(t = T_2(\alpha))$, respectively, as well as the associated field of view to determine the AE for the comparison with these AEL.

Following this step of the determination of the "long-term" α , all applicable shorter emission durations have to be analysed. For the analysis of emission durations less than 0,25 s, the "long-term" α is used to determine the appropriate C_5 in the equalities of 4.3 f) 3). $T_2(\alpha)$ is also relevant for the determination of N within $T_2(\alpha)$ or the time base, whichever is shorter.

ZB.2.5 Subclause 4.3 f) 3); groups of pulses with group duration longer than T_i

For non-uniform repetitive pulse patterns, i.e. groups of pulses (see Figure ZB.2 for an example), when $\alpha > 5$ mrad and the duration of the group of pulses is longer than T_i , it is not clearly stated how the thermal additivity expressed by requirement 3) of 4.3 f) is applied. For *uniform* (i.e. constant peak power, duration and period) repetitive pulse trains, it is not necessary to analyse the emission patterns in terms of groupings of pulses.

When individual pulses are close together, they are thermally grouped and thermally represent one “effective” pulse so that C_5 also (additionally to analysing the pulse train based on the actual pulses and the average power) applies to these “effective” pulses, where N is the number of pulse groups within T_2 or within the time base, whichever is shorter.

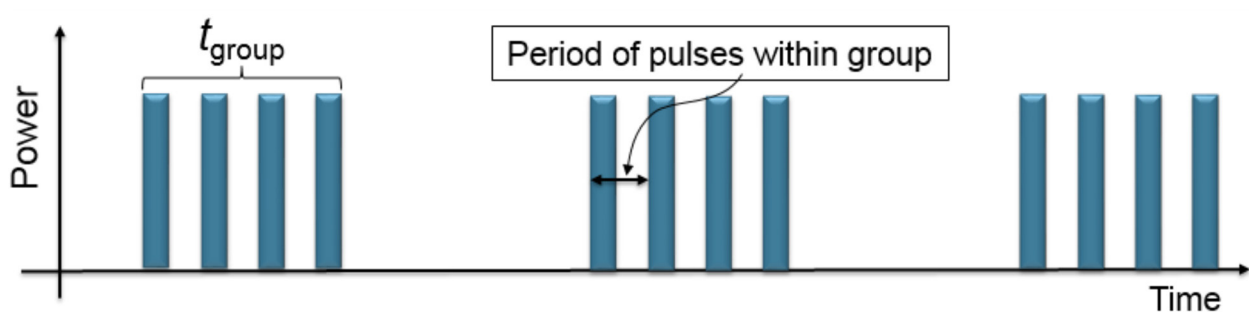


Figure ZB.2 — Example of three groups of pulses (each group duration is longer than T_i) where each group is considered as one “effective” pulse and C_5 is applied to the AEL that applies to the group duration, where C_5 is determined with the number of pulse groups within the evaluation duration (in the example of the figure $N = 3$)

For the analysis of pulse groups, the value of AEL_{single} is determined for the corresponding pulse group duration t_{group} . For the determination of C_5 , N is the number of pulse groups within T_2 or the time base, whichever is shorter. The respective value of C_5 is applied to AEL_{single} to obtain $AEL_{\text{s.p.train}}$ that limits the AE of the pulse groups, where AE is the sum of the energy of the pulses contained within the pulse group.

For the application of C_5 to groups of pulses, the $AEL(t_{\text{group}})$ applicable to the group needs to be determined, as well as the energy per group (AE_{group}). For groups of pulses where the peak power of the pulses within the group varies, the group duration is not well defined. In order to simplify the evaluation, t_{group} can be set equal to the integration duration for which the energy per group (i.e. AE_{group}) was determined; it is not necessary to determine the group duration based on the FWHM criterion, which for groups of pulses with varying peak power is not well defined. By setting t_{group} equal to the integration duration that is used to determine AE_{group} (expressed as energy), the application of C_5 to groups of pulses is a simple extension of requirement 2) of 4.3. f) where the average power per group (equal to the energy within the averaging duration t_{average} divided by the averaging duration) needs to be below the $AEL(t_{\text{average}})$ determined for the duration over which the power was averaged (AE_{group} and $AEL(t_{\text{group}})$ expressed as power). As is common for the average power requirement, for irregular pulse trains, the averaging duration window (when expressed as energy: the integration duration window) has to be varied in temporal position and duration (for instance, if there are pulses with relatively low energy per pulse at the beginning or the end of the group of pulses, integration durations that exclude those low-energy pulses need to be considered also, not only the total group).

If individual pulses have sufficient temporal spacing (period larger than T_{crit} , see below), as a simplified analysis, they need not be considered for an analysis as a pulse group under 4.3 f) 3). The temporal spacing that is necessary for pulses to only be considered separate (and not analysed additionally as a group)

depends on the angular subtense of the apparent source and the duration of the pulses t_{pulse} within the group. Note that there can be several levels of grouping, so that individual elements (with pulse duration t) within the group could themselves be “effective pulses”, i.e. subgroups.

When the

- pulse group durations (t_{group}) are between T_i and 0,25 s, and
- the angular subtense of the apparent source is larger than 5 mrad, and
- the period of the pulses (see Figure ZB.2) is shorter than a critical period T_{crit} (if $t_{\text{pulse}} < T_i$, the value of t_{pulse} is set equal to T_i ; further, for the determination of T_{crit} , α_{max} is determined for t_{pulse} , not the group duration) where:

for $\alpha \leq \alpha_{\text{max}}$: $T_{\text{crit}} = 2 \cdot t_{\text{pulse}}$ where t_{pulse} is in seconds

for $\alpha > \alpha_{\text{max}}$: $T_{\text{crit}} = 0,01 \alpha \cdot t_{\text{pulse}}^{0,5}$ where t_{pulse} is in seconds, and α is in mrad, not being limited to α_{max}

then these pulses constitute a pulse group which is treated as effective pulses and C_5 (where N is the number of groups within the time base or T_2 , whichever is shorter) is applied to the AEL applicable to the pulse group. For the determination of AE, α_{max} is determined using the duration of the evaluated pulse group, t_{group} . If one or more of the above conditions are not fulfilled, then the pulses within the group of pulses that is considered to be analysed as “effective pulse” need not be grouped, i.e. the group of pulses does not need to be analysed as one “effective” pulse.

Note that if multiple pulses occur within T_i , the rule as stated in 4.3 f) 3) applies in parallel, i.e. they are counted as a single pulse to determine N and the energies of the individual pulses that occur within T_i are added to be compared to the $\text{AEL}_{\text{s.p.train}}$ of T_i where the corresponding C_5 for emission durations $t \leq T_i$ is applied.

ZB.2.6 Subclause 4.3 f); simplifications

a) Constant peak power but shorter pulses

Depending on the angular subtense of the apparent source, it can be the case that the value of C_5 is more restrictive for pulses with pulse durations less than T_i than for pulses with durations longer than T_i which is against general biophysical principles for cases where the peak power is the same.

Interpretation

For the case of varying pulse duration within a pulse train, if the accessible emission for pulses longer than T_i is below the applicable AEL, then it can be assumed for the analysis that pulses with durations less than T_i but with the same (or lower) peak power as the longer pulses, are less critical. The rationale for this interpretation follows the principle that when pulses have the same peak power, the shorter pulse cannot be more restrictive than the longer one.

NOTE This interpretation can also be used to smooth the step function at T_i for the classification of products, i.e. the classification of a product can be based on the assumption of pulse durations longer than T_i even if they are shorter than T_i provided that the longer pulses satisfy the applicable AEL and the shorter pulses have the same or lower peak power compared to the longer pulses. For the case of more than one pulse within T_i , this provision applies to the peak power of the individual pulses, and not to the average power of the pulses within T_i .

Example

For instance, consider that the accessible emission consists of pulses with 7 μs duration and with 3 μs duration (see Figure ZB.3) with the same peak power. This accessible emission pattern could for instance arise when a collimated beam with constant power scans across the centre of the aperture stop to produce the pulse with a duration of 7 μs and another scan scans across the circular aperture towards the edges of the aperture, producing a shorter pulse. For the case of $\alpha \leq 5$ mrad, Requirement 3) of 4.3 f), for $t > T_i$, $C_5 = 1,0$ and for $t \leq T_i$, C_5 can become as low as 0,4. Assume that the AE (energy per pulse) of the pulses with $t = 7$ μs is below the AEL for that pulse duration (where for $\alpha \leq 5$ mrad, $C_5 = 1$ regardless of the number of pulses). If the $t = 3$ μs pulses do not have a higher peak power than the 7 μs pulses, it cannot be the case that a shorter pulse with the same peak power is more restrictive than a longer one, and the 3 μs -pulses also can be assumed to comply with the requirement that the accessible emission is below the AEL, even though it might not satisfy $\text{AEL}_{\text{s.p.train}} = \text{AEL}_{\text{single}} \times C_5$ where C_5 could be equal to 0,4.

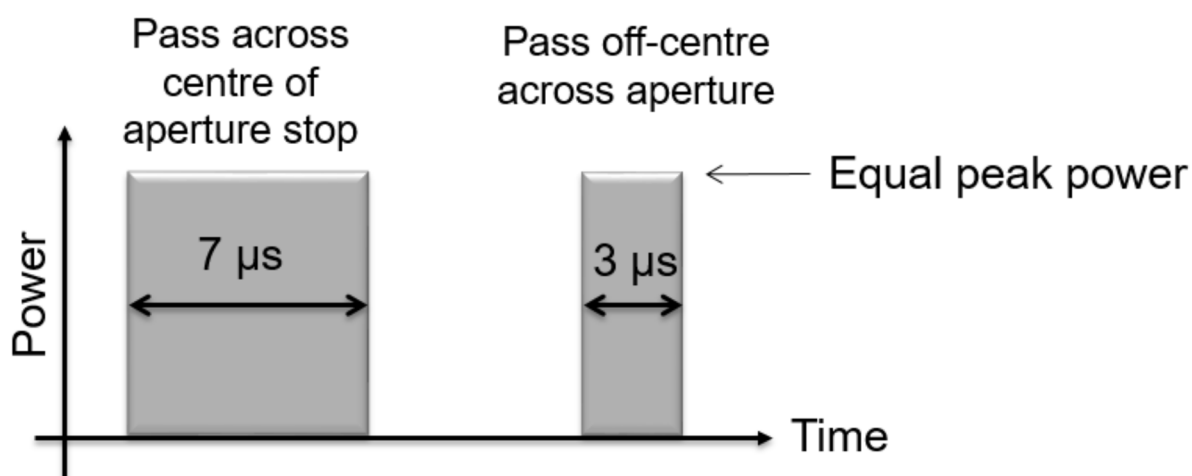


Figure ZB.3 — Example of a train of pulses consisting of pulses with a duration of 3 μs and 7 μs

b) Larger image of apparent source

For emission durations exceeding T_i , due to the step-function of C_5 at 5 mrad and at α_{max} , the AEL (as a function of C_5 and C_6) can be more restrictive for larger values of the angular subtense of the apparent source as compared to smaller ones, which is contrary to general biophysical principles.

Interpretation

When the class of a laser product is determined with the extended analysis (5.4.3) and the apparent source is larger than 5 mrad, the classification may be based on a value of the angular subtense of the apparent source less than 5 mrad (resulting in a smaller C_6 but also larger C_5). That is, when the AE is below the AEL for an assumed smaller apparent source, the resulting class is applicable even though the image of the apparent source is larger than 5 mrad. This also applies in an equivalent way to the step function of C_5 at α_{max} .

c) Using a square aperture stop

In some cases, such as 2D scanned laser beams, the use of a circular aperture stop to determine the accessible emission creates very complex pulse patterns. Due to the breakpoints in terms of pulse duration with step functions in the value of C_5 , it might not be apparent that the usage of a square aperture is acceptable as a simplified worst case analysis.

Interpretation

Analysis performed with a square aperture stop with 7 mm side length (for determination of accessible emission and pulse duration) can be assumed to be equivalent to, or more restrictive than, a circular aperture stop and is therefore a valid analysis.

d) Applicability of simplified default analysis

For pulse durations longer than T_i , the value of C_5 is smaller (more restrictive) for angular subtense values α larger than 5 mrad compared to $\alpha \leq 5$ mrad. The assumption of $\alpha = 1,5$ mrad is the basis of the simplified (default) evaluation. It is therefore not obvious if the simplified (default) analysis still applies in terms of being a restrictive simplifying analysis even for the case that the angular subtense of the apparent source is actually larger than 5 mrad, where $C_5 < 1$.

Interpretation

It is acceptable to make use of the simplified restrictive assumption of $\alpha = 1,5$ mrad ($C_6 = 1$, $C_5 = 1$ for the case that $t > T_i$) even for the case that the angular subtense of the source is larger than 5 mrad. This means it is not necessary to show that $\alpha < 5$ mrad in order to apply $C_6 = 1$ and $C_5 = 1$ for the simplified (default) analysis, because overall this is a conservative simplification. Note that the simplified default analysis implies that the determination of the accessible emission may be limited by an angle of acceptance as described in ZB.2.2.

e) Determination of the most restrictive position

For the extended analysis, it is necessary to vary the distance relative to the reference point to determine the most restrictive position. For each position in the beam, the accommodation is varied and the most restrictive image is determined. For determining the most restrictive image (where the ratio AE/AEL is maximum) at a given position, requirement 3) of 4.3 f) is not applied. Otherwise a blurred (larger) image of the apparent source, resulting from variation of the accommodation, could appear more restrictive, which is contrary to general biophysical principles. Once the most restrictive image (and associated α) is identified for each position in the beam, all three requirements of 4.3 f) are applied to determine the most restrictive position (identifying the position with the maximum ratio of AE/AEL) and the class of the product.

f) Application of the total-on-time-pulse method;

For regular pulse trains, as well as for varying pulse durations and/or varying period of pulses (but excluding strongly varying peak powers; see below), the total-on-time pulse (TOTP) method (see also IEC 60825-1 Edition 2.0 subclause 8.3 f) 3b)) may be used as an alternative to requirement 3) of 4.3 f), i.e. as an alternative to the application of C_5 to the single pulse AEL, provided that $\alpha_{\max}$ is determined for the TOTP (or using the worst case value of 100 mrad). This is more restrictive than the rules of 4.3 f) because it is equivalent to an unlimited C_5 (C_5 not limited to 0,2 or 0,4), and because the value of $\alpha_{\max}$ is typically larger for the TOTP as compared to the value applicable to the single pulse.

For the total-on-time-pulse (TOTP) method the following applies, as reproduced from Edition 2 of IEC 60825-1:

The AEL is determined by the value of the TOTP, which is the sum of all pulse durations within the emission duration or T_2 , whichever is smaller. Pulses with durations shorter than T_i are assigned pulse durations of T_i . If two or more pulses occur within a duration of T_i these pulse groups are assigned pulse durations of T_i . For comparison with the AEL for the corresponding duration, all individual pulse energies are added.

Note that the TOTP method in Edition 2 of IEC 60825-1 (incl. Corrigendum 1) was specified "For varying pulse widths or varying pulse intervals" and did not refer to varying peak powers. For the case of strongly varying peak powers, the TOTP method is not applicable, as adding pulses to the pulse train with small peak powers and low contributing energy-per-pulse values might increase the AEL (by increasing the total-

on-time) more than this increases the total energy, and thus would make the emission less critical as compared to an emission based on the pulses with the large peak power only.

g) Varying peak power but constant pulse duration

For varying peak power but constant pulse durations, requirement 3) of 4.3 f) can be applied by counting the pulses for the determination of N based on the relative peak power, i.e. N is increased by 1,0 for each pulse with the maximum peak power, and by a value of less than 1,0 for pulses with lower peak power, such as for a pulse with 70 % peak power compared to the maximum peak power in the pulse train, N is increased by 0,7. For this, based on the strong nonlinearity of thermally induced injury with temperature, it is justified not to count pulses with peak powers that are more than a factor of 10 below the pulse with the maximum peak power (i.e. less than 10 % of the maximum peak power). Note that the resulting $AEL_{s,p,train}$ is applied to the pulse with the largest AE, i.e. the largest energy per pulse, and that the interpretation in this paragraph applies only for the case of pulse trains with constant pulse durations.

ZB.3 Subclause 4.4 conventional lamp replacement (IEC 60825-1:2014/ISH2:2017)

This subclause ZB.3 contains the text of IEC 60825-1:2014/ISH2:2017 with some minor modifications for clarity.

Subclause 4.4 introduces a criterion based on radiance, which is a quantity not normally determined for laser products. This interpretation clarifies the determination of radiance and the radiance limit.

In this subclause ZB.3 of the Annex ZB, Subclause 4.4 is clarified.

Interpretation

The angular subtense α is determined based on the 50 % of the peak radiance of the apparent source, which is an equivalent criterion as given in EN 62471:2008 and EN 62471-5:2015. For this determination of α the angular resolution should be better than 1,5 mrad, i.e. for the example of a CCD camera being used to determine α , one pixel should subtend an angular subtense as seen from the imaging lens of less than 1,5 mrad. For inhomogeneous or multiple sources, the outer edge (defined by the 50 % level) of the apparent source profile is used to determine α for the calculation of the radiance limit as well as for the limit regarding the minimum size of the apparent source, even if there are hotspots within the apparent source profile. Both the radiance as well as the angular subtense of the apparent source α are determined at a distance of 200 mm from the closest point of human access.

NOTE The EN 62471 series also uses the 50 % level outer edge of the source profile for determination of α for the retinal thermal radiance limit.

The radiance limit (L_T) specified in subclause 4.4 is not an AEL but merely a criterion to fulfil this subclause. To satisfy the limit does not imply that the emission of the product is necessarily considered “safe” or of any specific Risk Group under EN 62471.

Although the accessible emission that complies with the definition of subclause 4.4 is excluded from classification under EN 60825-1, the applicable requirements of EN 60825-1 still apply (i.e. labels, engineering features, service, user information etc.) and the product is classified as a laser product under EN 60825-1, but excluding (i.e. “neglecting”) the light emission that falls under subclause 4.4 (usually, the product will be Class 1). For the case of classification as Class 1, contrary to a “normal” Class 1 laser product where placing the Class 1 label on the product is optional, for a product with light emission that is excluded under subclause 4.4, the Class 1 label is mandatory, additional to the label of the Risk Group according to the EN 62471 series.

A laser based light module that, as a component, is intended to be sold to manufacturers of luminaires is not subject to EN 60825-1 per the scope of this standard. However, the end product (i.e. the luminaire) is in the scope of EN 60825-1, including subclause 4.4. A light module can, however, be classified based on the EN 62471 series.

In order to exclude the emission from the classification under EN 60825-1, it is not a requirement that the emission is broadband; for example, the emission can be multiple monochromatic bands or in some cases even monochromatic. Also, there is no specific requirement with respect to the degree of coherence of the emission.

The conditions to determine the radiance that is compared to the radiance limit (L_T) are clarified by the following:

- a) The un-weighted maximum radiance (i.e. for pulsed or scanned emission, the temporal peak radiance during the pulse or the scan across the stationary aperture, respectively) is averaged over an acceptance angle of 5 mrad and is determined at 200 mm from the closest point of human access.
- b) If the radiance criterion is applied to beams with diameters less than 7 mm at 200 mm, the diameter of the averaging aperture stop at the imaging system for the determination of radiance is 1 mm.
- c) It is necessary to consider maximum emissions (as described in 5.2 b)) during normal operation and maintenance as well as reasonably foreseeable single fault conditions. For example, a diffusing element failure could result in exceeding the radiance criterion described in subclause 4.4. For faults that are relevant for compliance with subclause 4.4, the general criteria laid down in IEC 60825-1 with respect to faults apply, including that risk analysis can be used to determine if a given fault is relevant for compliance with subclause 4.4 or not.
- d) When laser and non-laser (incoherent) radiation are coincident within the same retinal location (i.e. emitting from within the specified angle of acceptance), both laser and non-laser (incoherent) radiation shall be included. Emissions that are excluded for laser classification are included for the determination of a Risk Group (RG) under the applicable EN 62471 standard.

Item d) also clarifies subclause 4.3 b) and with respect to intended non-laser radiation takes precedence over 5.2 f). This means that if subclause 4.4 is not applied and the emission is classified under the laser standard, both laser and non-laser emissions are included.

Clarification is needed for the case of a lighting module where a laser beam (for instance in the blue wavelength region) with a diameter of less than 1 mm is incident on a diffusing wavelength converting phosphor, resulting in a value of α less than 5 mrad and the criteria of subclause 4.4 not being fulfilled. It is clarified that if such a module is sold to other manufacturers (similarly to a lamp that is sold to be mounted in a luminaire, i.e. in a lamp system in EN 62471 series) then the module is not subject to EN 60825-1 (i.e. EN 60825-1 is not applied), since the final product will itself be subject to EN 60825-1 (see Scope of EN 60825-1). In this case it is not relevant if subclause 4.4 is fulfilled or not. Such a module can be classified as a lamp under the EN 62471 series.

ZB.4 Subclause 6.3.2 – safety interlocks

Introduction

In this subclause, additional interpretations are provided, that were not contained in the IEC Interpretation Sheets, due to limitations on the length of the Interpretation Sheets.

The requirements for safety interlocks that are provided with a deliberate override mechanism are specified in 6.3.2. The exception, described in 6.3.2 for automatically returning an overridden interlock to normal operation when an open door is closed, needs clarification. The portion of text that may cause confusion is:

“If a deliberate override mechanism is provided, the manufacturer shall also provide adequate instructions about safe methods of working. It shall not be possible to leave the override in operation when the access panel is returned to its normal position. An exception to this requirement is allowed if selection of a service “override” mode automatically isolates the laser beam and prevents automatic resumption of operation of

the machine. This exception also requires a lockable mode selector and requires a manual override to use the beam.”

Interpretation

The primary idea behind the requirement is as follows: if a panel is encountered which is normally interlocked, and it is found closed, then there is a reasonable expectation that the interlock will provide protection from the hazards beyond said panel if it is re-opened. The same logic does not apply to panels, which are not interlocked, as there is no expectation of protection if the panel is removed.

Some manufacturers address this issue by incorporating methods to prevent the panel from returning to a closed position when the interlock is in an override mode or they prevent the panel from re-opening in an override state unless manual intervention is performed to cause the interlock to remain in override mode. The diagram provided below (Figure ZB.4) provides the schematic representation of the logic.

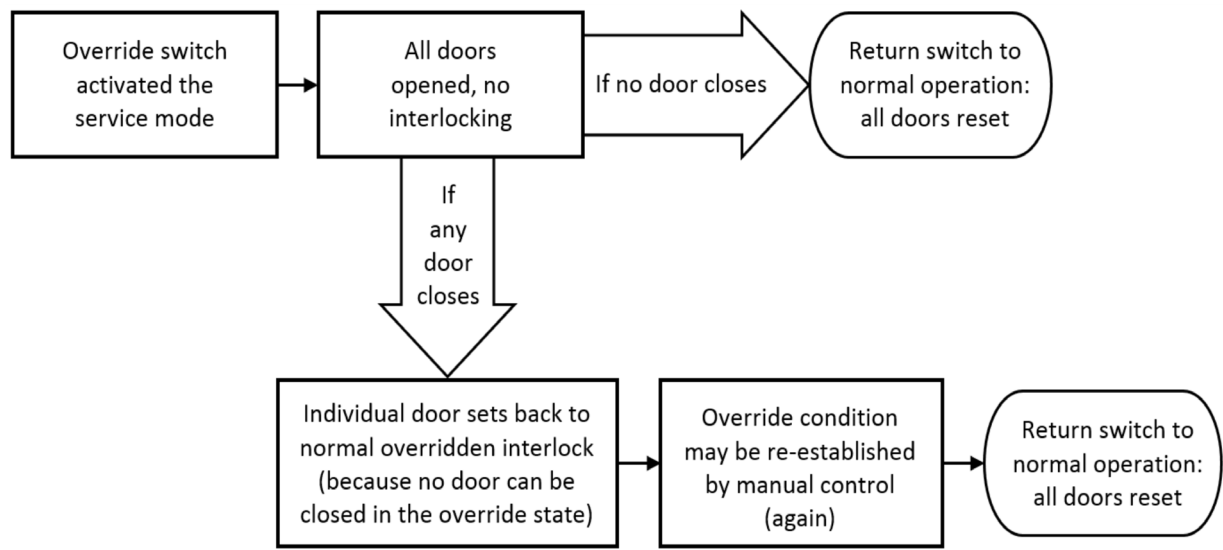


Figure ZB.4 — Flow diagram to illustrate the interpretation of subclause 6.3.2

Annex ZZ
(informative)

Relationship between this European standard and the safety objectives of Directive 2014/35/EU [2014 OJ L96] aimed to be covered

This European Standard has been prepared under a Commission's standardization request relating to harmonized standards in the field of the Low Voltage Directive, M/511, to provide one voluntary means of conforming to safety objectives of Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits [2014 OJ L96].

Once this standard is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of this standard given in Table ZZ.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding safety objectives of that Directive, and associated EFTA regulations.

Table ZZ.1 — Correspondence between this European standard and Annex I of Directive 2014/35/EU [2014 OJ L96]

Safety objectives of Directive 2014/35/EU	Clause(s) / subclause(s) of this EN	Remarks / Notes
1(a) (b)	Clause 7 (labelling) and Clause 8 (information for the user)	
1 (c)	Clause 5 (testing requirements) include intended use and maintenance	
2. (b) Protection against hazards arising from the electrical equipment with measures of a technical nature that ensure that radiation which would cause a danger is not produced.	Clauses 4–9	The scope of EN 60825-1 is limited to hazards from laser radiation to the eye or skin
3 (c)	Clause 5 (testing requirements) include single fault conditions	

WARNING 1 — Presumption of conformity stays valid only as long as a reference to this European standard is maintained in the list published in the Official Journal of the European Union. Users of this standard should consult frequently the latest list published in the Official Journal of the European Union.

WARNING 2 — Other Union legislation may be applicable to the product(s) falling within the scope of this standard.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60825-1 Edition 3.0 2014-05

SAFETY OF LASER PRODUCTS –

Part 1: Equipment classification and requirements

INTERPRETATION SHEET 1

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

The text of this interpretation sheet is based on the following documents:

FDIS	Report on voting
76/587/FDIS	76/593/RVD

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

Subclause 4.3 Classification rules

This subclause is clarified by the following:

Introduction

For some complex extended sources or irregular temporal emissions, the application of the rules of subclause 4.3 may require clarification because of changes from IEC 60825-1:2007.

NOTE 1 For the purpose of this interpretation sheet, the abbreviation “AE” is used for “accessible emission”.

NOTE 2 The clarifications also apply in an equivalent way to MPE analysis, i.e. for Annex A.

1 Subclause 4.3 b) Radiation of multiple wavelengths

See IEC 60825-1:2014/ISH2.

2 Subclause 4.3 c) Radiation from extended sources

When using the default (simplified) evaluation method (subclause 5.4.2) for wavelengths ≥ 400 nm and $< 1\,400$ nm, the angle of acceptance may be limited to 100 mrad for determining the accessible emission to be compared against the accessible emission limit, except in the wavelength range 400 nm to 600 nm for durations longer than 100 s where the circular-cone angle of acceptance is not limited. When evaluating the emissions for comparison to the Class 3B AELs, the angle of acceptance is not limited.

3 Subclause 4.3 d) Non-uniform, non-circular or multiple apparent sources

In subclause 4.3 d), for comparison with the thermal retinal limits, the requirement to vary the angle of acceptance in each dimension might appear to contradict the labelling in Figure 1 and Figure 2 of subclause 5.4.3 where the field stop is labelled as circular.

Interpretation

A circular field stop is applicable for circularly symmetric images of the apparent source and for this case is consistent with the procedure given in subclause 4.3 d). For images of the apparent source that are not circularly symmetric, the simple example below clarifies the application of subclause 4.3 d).

A circular field stop with an angular subtense equal to $\alpha_{\max}$ is, however, applicable for non-circularly symmetric profiles if the analysis performed according to subclause 4.3 d), following variation of the angle of acceptance in each dimension, results in a solution which is equal to $\alpha_{\max}$ in both dimensions.

As a general principle, for whatever emission duration t the AEL is determined (such as the pulse duration, the pulse group duration or the time base for averaging of the power), the same emission duration t is also used to calculate $\alpha_{\max}(t)$.

The following example demonstrates the method described in subclause 4.3 d) to analyse irregular or complex images of a source. It is noted that the example is equivalent to the second part of the example ("Additional Remarks"; 6 mrad spacing instead of 3 mrad) B.9.1 of IEC TR 60825-14:2004 (however, for 6 mrad element spacing, the result in terms of which grouping is critical was not correct). The source is a diode array (Figure 1). The task is to determine the applicable AEL that limits the AE for Class 2. Each diode contributes a partial accessible emission AE of 1 mW that passes through a 7 mm aperture stop at the distance where the analysis is performed (i.e. a total power of 20 mW passes through the aperture stop), and the emission is continuous wave. The analysis requires determination of the most restrictive (maximum) ratio of AE over AEL by variation of the angle of acceptance in position and size to achieve different fields of view.

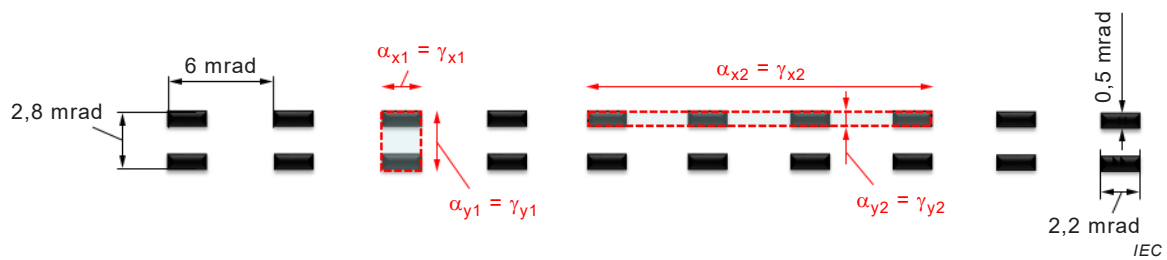


Figure 1 – Image of a source pattern for the example of 20 emitters. Two possible groupings are defined by the respective angle of acceptance γ_x and γ_y

The analysis of a sub-group of sources is associated with a certain value of α for that group, and a certain accessible emission associated with that sub-group. For instance α of a single element equals $(1,5 \text{ mrad} + 2,2 \text{ mrad})/2 = 1,85 \text{ mrad}$ so that the AEL = 1,23 mW. The applicable AE = 1 mW and $\text{AE/AEL} = 1 \text{ mW}/1,23 \text{ mW} = 0,8$. For a vertical two-element group, as shown in the figure with γ_{x1} and γ_{y1} , $\alpha = (2,8 + 2,2)/2 = 2,5 \text{ mrad}$ so that AEL = 1,66 mW; $\text{AE} = 2 \times 1 \text{ mW} = 2 \text{ mW}$ and $\text{AE/AEL} = 1,2$, which is more restrictive than AE/AEL for only one element. For one row of 10 diodes $\alpha = (1,5 + 56,2)/2 = 28,9 \text{ mrad}$, AEL = 19,2 mW, the AE = $10 \times 1 \text{ mW} = 10 \text{ mW}$ and $\text{AE/AEL} = 0,5$. Analysis of all possible groupings shows that the vertical two-element group has the maximum AE/AEL and therefore is the solution of the analysis. This means that the AEL of Class 2 is exceeded by a factor 1,2. Note that only a portion of the power of 20 mW that passes through the 7 mm aperture stop is considered as the AE (2 mW; as partial power within the angle of acceptance that is associated to the part of the image with the maximum ratio of AE/AEL) that is compared against the AEL. The entire array represents the highest ratio of AE/AEL in cases where the element spacing is sufficiently close, e.g. when the contributions of extra elements to the AE are not dominated by the increased AEL due to the larger subtended angle.

For pulsed emission, for the determination of α according to the above method (4.3 d)) where the ratio of AE to AEL is maximized, requirement 3) of 4.3 f) is not applied, i.e. the AEL_{single} is not reduced by C_5 . Due to the dependence of α_{max} on emission duration t , the analysis of the image of the apparent source may result in different values of α and of the partial accessible emission, depending which emission duration is analysed for the requirements of 4.3 f). For example, for emission durations shorter than 625 μs ($\alpha_{\text{max}} = 5 \text{ mrad}$), the maximum partial array to consider in the image analysis is a vertical two element group.

Ref.: Classification of extended source products according to IEC 60825-1, K. Schulmeister, ILSC 2015 Proceedings Paper, p 271 – 280; Download:
<https://www.filesanywhere.com/fs/v.aspx?v=8b70698a595e75bcaa69>

4 Subclause 4.3 f) 3) determination of α

For an analysis of pulsed emission, α_{max} , which is a function of time $\alpha_{\text{max}}(t)$, limits both the value of α for the determination of $C_6(\alpha)$ as well as the angle of acceptance γ for the determination of the accessible emission (see 4.3 c) and d)) and Clause 3 of this interpretation sheet; in this process, $\alpha_{\text{max}}(t)$ is determined for the same emission duration t that is used to determine AEL(t) (i.e. the pulse duration or the pulse group duration for 4.3 f) 3) and the averaging duration for 4.3 f) 2), respectively). However, the parameter α is also used in subclause 4.3 f) 3) in the criteria which C_5 is applied. For these criteria, the parameter α is not limited in the same way as for the determination of C_6 according to 4.3 d).

For the criterion “Unless $\alpha > 100 \text{ mrad}$ ”, the angular subtense of the apparent source α is not restricted by α_{max} . For non-uniform (oblong, rectangular, or linear) sources, the inequality needs to be satisfied by both angular dimensions of the source in order for $C_5 = 1$ to apply.

To calculate $T_2(\alpha)$ and in the criteria “ $\alpha \leq 5 \text{ mrad}$ ”, “ $5 \text{ mrad} < \alpha \leq \alpha_{\max}$ ”, and “ $\alpha > \alpha_{\max}$ ”, the quantity α is limited to a maximum value of 100 mrad, equivalent to $\alpha_{\max}$ that applies for 0,25 s emission duration and longer. For T_2 and these inequalities, α is not limited to a value of $\alpha_{\max}(t)$ smaller than 100 mrad, and is therefore the same as the value that applies for the determination of C_6 for an emission duration of 0,25 s and longer. As is generally defined (see subclause 4.3 d)) the arithmetic mean is applied to determine α , i.e. it is not necessary that both dimensions satisfy the criterion “For $\alpha \leq 5 \text{ mrad}$ ” independently.

For the determination of the applicable value of C_5 in 4.3. f) 3) in an analysis of moving apparent sources (originating from scanned emission when not accommodating to the pivot point or vertex) the value of α in the respective inequalities relating to the choice of C_5 in 4.3 f) 3) is determined for the *stationary* apparent source and the respective accommodation condition that is analysed (such as accommodation to infinity).

5 Subclause 4.3 f) 3) groups of pulses with group duration longer than T_i

For non-uniform repetitive pulse patterns, i.e. groups of pulses (see Figure 2 for an example), when $\alpha > 5 \text{ mrad}$ and the duration of the group of pulses is longer than T_i , it is not clearly stated how the thermal additivity expressed by requirement 3) of 4.3 f) is applied. For *uniform* (i.e. constant peak power, duration and period) repetitive pulse trains, it is not necessary to analyse the emission patterns in terms of groupings of pulses.

When individual pulses are close together, they are thermally grouped and thermally represent one “effective” pulse so that C_5 also (additionally to analysing the pulse train based on the actual pulses and the average power) applies to these “effective” pulses, where N is the number of pulse groups within T_2 or within the time base, whichever is shorter.

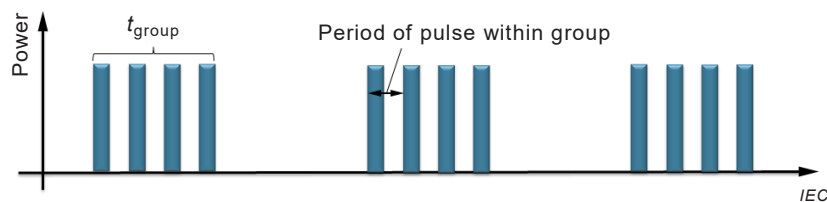


Figure 2 – Example of three groups of pulses (each group duration is longer than T_i) where each group is considered as one “effective” pulse and C_5 is applied to the AEL that applies to the group duration, where C_5 is determined with the number of pulse groups within the evaluation duration (in the example of the figure $N = 3$)

For the analysis of pulse groups, the value of AEL_{single} is determined for the corresponding pulse group duration t_{group} . For the determination of C_5 , N is the number of pulse groups within T_2 or the time base, whichever is smaller. The respective value of C_5 is applied to AEL_{single} to obtain $AEL_{\text{s.p.train}}$ that limits the AE of the pulse groups, where AE is the sum of the energy of the pulses contained within the pulse group.

For the application of C_5 to groups of pulses, the $AEL(t_{\text{group}})$ applicable to the group needs to be determined, as well as the energy per group (AE_{group}). For groups of pulses where the peak power of the pulses within the group varies, the group duration is not well defined. In order to simplify the evaluation, t_{group} can be set equal to the integration duration for which the energy per group (i.e. AE_{group}) was determined; it is not necessary to determine the group duration based on the FWHM criterion, which for groups of pulses with varying peak power is not well defined. By setting t_{group} equal to the integration duration that is used to determine AE_{group} (expressed as energy), the application of C_5 to groups of pulses is a simple extension of requirement 2) of 4.3 f) where the average power per group (equal to the energy within the averaging duration t_{average} divided by the averaging duration) needs to be below the $AEL(t_{\text{average}})$ determined for the duration over which the power was averaged (AE_{group} and $AEL(t_{\text{group}})$ expressed as power). As is common for the average power requirement, for irregular pulse trains, the averaging duration window (when expressed as energy: the

integration duration window) has to be varied in temporal position and duration (for instance, if there are pulses with relatively low energy per pulse at the beginning or the end of the group of pulses, integration durations that exclude those low-energy pulses need to be considered also, not only the total group).

If individual pulses have sufficient temporal spacing (period larger than T_{crit} , see below), as a simplified analysis, they need not be considered for an analysis as a pulse group under 4.3 f) 3). The temporal spacing that is necessary for pulses to only be considered separate (and not analysed additionally as a group) depends on the angular subtense of the apparent source and the duration of the pulses t_{pulse} within the group. Note that there can be several levels of grouping, so that individual elements (with pulse duration t) within the group could themselves be “effective pulses”, i.e. subgroups.

When the

- pulse group (t_{group}) durations are between T_i and 0,25 s, and
- the angular subtense of the apparent source is larger than 5 mrad, and
- the period of the pulses (see Figure 2) is shorter than a critical period T_{crit} (if $t_{\text{pulse}} < T_i$, the value of t_{pulse} is set equal to T_i ; further, for the determination of T_{crit} , α_{max} is determined for t_{pulse} , not the group duration) where:

for $\alpha \leq \alpha_{\text{max}}$: $T_{\text{crit}} = 2 \cdot t_{\text{pulse}}$ where t_{pulse} is in seconds

for $\alpha > \alpha_{\text{max}}$: $T_{\text{crit}} = 0,01 \alpha t_{\text{pulse}}^{0,5}$ where t_{pulse} is in seconds, and α is in mrad, not being limited to α_{max} ,

then these pulses constitute a pulse group which is treated as effective pulses and C_5 (where N is the number of groups within the time base or T_2 , whichever is shorter) is applied to the AEL applicable to the pulse group. For the determination of AE, α_{max} is determined using the duration of the evaluated pulse group, t_{group} . If above conditions are not fulfilled, then the pulses within the group of pulses that is considered to be analysed as “effective pulse” need not be grouped, i.e. the group of pulses does not need to be analysed as one “effective” pulse.

Note that if multiple pulses occur within T_i , the rule as stated in 4.3 f) 3) applies in parallel, i.e. they are counted as a single pulse to determine N and the energies of the individual pulses that occur within T_i are added to be compared to the $\text{AEL}_{\text{s.p.train}}$ of T_i where the corresponding C_5 for emission durations $t \leq T_i$ is applied.

6 Subclause 4.3 f) simplifications

a) Constant peak power but shorter pulses

Depending on the angular subtense of the apparent source, it can be the case that the value of C_5 is more restrictive for pulses with pulse durations less than T_i than for pulses with durations longer than T_i which is against general biophysical principles for cases where the peak power is the same.

Interpretation

For the case of varying pulse duration within a pulse train, if the accessible emission for pulses longer than T_i is below the applicable AEL, then it can be assumed for the analysis that pulses with durations less than T_i but with the same (or lower) peak power as the longer pulses, are less critical. The rationale for this interpretation follows the principle that when pulses have the same peak power, the shorter pulse cannot be more restrictive than the longer one.

NOTE This interpretation can also be used to smooth the step function at T_i for the classification of products, i.e. the classification of a product may be based on the assumption of pulse durations longer than T_i even if they are shorter than T_i provided that the longer pulses satisfy the applicable AEL and the shorter pulses have the same or lower peak power compared to the longer pulses.

b) Larger image of apparent source

For emission durations exceeding T_i , due to the step-function of C_5 at 5 mrad and at $\alpha_{\max}$, the AEL (as a function of C_5 and C_6) can be more restrictive for larger values of the angular subtense of the apparent source as compared to smaller ones, which is contrary to general biophysical principles.

Interpretation

When the class of a laser product is determined with the extended analysis (subclause 5.4.3) and the apparent source is larger than 5 mrad, the classification may be based on a value of the angular subtense of the apparent source less than 5 mrad (resulting in a smaller C_6 but also larger C_5). That is, when the AE is below the AEL for an assumed smaller apparent source, the resulting class is applicable even though the image of the apparent source is larger than 5 mrad. This also applies in an equivalent way to the step function of C_5 at $\alpha_{\max}$.

c) Using a square aperture stop

In some cases, such as 2D scanned laser beams, the use of a circular aperture stop to determine the accessible emission creates very complex pulse patterns.

Interpretation

Analysis performed with a square aperture stop with 7 mm side length (for determination of accessible emission and pulse duration) can be assumed to be equivalent to, or more restrictive than, a circular aperture stop and is therefore a valid analysis.

d) Applicability of simplified default analysis

For pulse durations longer than T_i , the value of C_5 is smaller (more restrictive) for angular subtense values α larger than 5 mrad compared to $\alpha \leq 5$ mrad. The assumption of $\alpha = 1,5$ mrad is the basis of the simplified (default) evaluation. It is therefore not obvious if the simplified (default) analysis still applies in terms of being a restrictive simplifying analysis even for the case that the angular subtense of the apparent source is actually larger than 5 mrad, where $C_5 < 1$.

Interpretation

It is acceptable to make use of the simplified restrictive assumption of $\alpha = 1,5$ mrad ($C_6 = 1$, $C_5 = 1$) even for the case that the angular subtense of the source is larger than 5 mrad. This means it is not necessary to show that $\alpha < 5$ mrad in order to apply $C_6 = 1$ and $C_5 = 1$ for the simplified (default) analysis, because overall this is a conservative simplification. Note that the simplified default analysis implies that the determination of the accessible emission is not limited by an angle of acceptance equal to $\alpha_{\max}$.

e) Determination of the most restrictive position

For the extended analysis, it is necessary to vary the position in the beam. For each position in the beam, the accommodation is varied and the most restrictive image is determined. For determining the most restrictive image (where the ratio AE/AEL is maximum) at a given position, requirement 3) of 4.3 f) is not applied. Otherwise a blurred (larger) image of the apparent source, resulting from variation of the accommodation, could appear more restrictive, which is contrary to general biophysical principles. Once the most restrictive image (and associated α) is identified for each position in the beam, all three requirements 4.3 f) are applied to determine the most restrictive position (identifying the position with the maximum ratio of AE/AEL).

f) Application of total-on-time-pulse method

For regular pulse trains, as well as for varying pulse durations and/or varying period of pulses (but excluding strongly varying peak powers; see below), the total-on-time pulse (TOTP) method (see also IEC 60825-1:2007, subclause 8.3 f) 3b)) may be used as alternative to requirement 3) of 4.3 f), i.e. as alternative to the application of C_5 to the single pulse AEL, provided that $\alpha_{\max}$ is determined for the TOTP (or using the worst case value of 100 mrad). This is more restrictive than the rules of 4.3 f) because it is equivalent to an unlimited C_5 (C_5 not limited to 0,2 or 0,4), and because the value of $\alpha_{\max}$ is typically larger for the TOTP as compared to the value applicable to the single pulse.

For total-on-time-pulse (TOTP) method the following applies, as reproduced from IEC 60825-1:2007.

The AEL is determined by the duration of the TOTP, which is the sum of all pulse durations within the emission duration or T_2 , whichever is smaller. Pulses with durations less than T_i are assigned pulse durations of T_i . If two or more pulses occur within a duration of T_i these pulse groups are assigned pulse durations of T_i . For comparison with the AEL for the corresponding duration, all individual pulse energies are added.

Note that the TOTP method in IEC 60825-1:2007 (incl. Corrigendum 1) was specified “For varying pulse widths or varying pulse intervals” and did not refer to varying peak powers. For the case of strongly varying peak powers, the TOTP method is not applicable, as adding pulses to the pulse train with small peak powers and low contributing energy-per-pulse values might increase the AEL (by increasing the total-on-time) more than this increases the total energy, and thus would make the emission less critical as compared to an emission based on the pulses with the large peak power only.

g) Varying peak power but constant pulse duration

For varying peak power but constant pulse durations (both less than or larger than T_i), requirement 3) of 4.3 f) can be applied by counting the pulses for the determination of N based on the relative peak power, i.e. N is increased by 1,0 for each pulse with the maximum peak power, and by a value of less than 1,0 for pulses with lower peak power, such as for a pulse with 70 % peak power compared to the maximum peak power in the pulse train, N is increased by 0,7. For this, based on the strong non-linearity of thermally induced injury with temperature, it is justified not to count pulses with peak powers that are more than a factor of 10 below the pulse with the maximum peak power (i.e. less than 10 % of the maximum peak power). Note that the resulting $AEL_{s.p.train}$ is applied to the pulse with the largest AE, i.e. the largest energy per pulse, and that the interpretation in this paragraph applies only for the case of pulse trains with constant pulse durations.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60825-1
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SAFETY OF LASER PRODUCTS –

Part 1: Equipment classification and requirements

INTERPRETATION SHEET 2

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

The text of this interpretation sheet is based on the following documents:

FDIS	Report on voting
76/588/FDIS	76/594/RVD

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

Subclause 4.4 – Conventional lamp replacement

This subclause is clarified by the following:

Subclause 4.4 introduces a criterion based on radiance, which is a quantity not normally determined for laser products. This interpretation sheet clarifies the determination of radiance and the radiance limit.

Interpretation

The angular subtense α is determined based on the 50 % of the peak radiance (not averaged over an angle of acceptance larger than 1,5 mrad) of the apparent source, which is an equivalent criterion as given in IEC 62471:2006 and IEC 62471-5:2015. For inhomogeneous or multiple sources, the outer edge (defined by the 50 % level) of the apparent source profile is used to determine α for the calculation of the radiance limit as well as for the limit regarding the minimum size of the apparent source, even if there are hotspots within the apparent source profile. Both the radiance as well as the angular subtense of the apparent source α is determined at a distance of 200 mm from the closest point of human access.

NOTE The IEC 62471 series also uses the 50 % level outer edge of the source profile for determination of α for the retinal thermal radiance limit.

The radiance limit (L_T) specified in subclause 4.4 is not an AEL but merely a criterion to fulfil this subclause. To satisfy the limit does not imply that the emission of the product is necessarily considered “safe” or of any specific Risk Group under IEC 62471.

Although the accessible emission that complies with the definition of subclause 4.4 is excluded from classification under IEC 60825-1, the applicable requirements of IEC 60825-1 still apply (i.e. labels, engineering features, service, user information, etc.) and the product is classified as a laser product under IEC 60825-1, but excluding (i.e. “neglecting”) the light emission that falls under subclause 4.4 (usually, the product will be Class 1). For the case of classification as Class 1, contrary to a “normal” Class 1 laser product where placing the Class 1 label on the product is optional, for a product with light emission that is excluded under subclause 4.4, the Class 1 label is mandatory, additional to the label of the Risk Group according to the IEC 62471 series.

A laser based light module that, as a component, is intended to be sold to manufacturers of luminaires is not subject to IEC 60825-1 per the scope of this standard. However, the end product (i.e. the luminaire) is in the scope of IEC 60825-1, including subclause 4.4. A light module can, however, be classified based on the IEC 62471 series.

In order to exclude the emission, it is not a requirement that the emission is broadband; for example the emission can be multiple monochromatic bands or in some cases even monochromatic. Also there is no specific requirement with respect to the degree of coherence of the emission.

The conditions to determine the radiance that is compared to the radiance limit (L_T) are clarified by the following:

- a) The un-weighted maximum radiance (i.e. for pulsed or scanned emission, the temporal peak radiance during the pulse or the scan across the stationary aperture, respectively) is averaged over an acceptance angle of 5 mrad and is determined at 200 mm from the closest point of human access.
- b) If the radiance criterion is applied to beams with diameters less than 7 mm at 200 mm, the diameter of the averaging aperture stop at the imaging system for the determination of radiance is 1 mm.
- c) It is necessary to consider maximum emissions (as described in 5.2 b)) during normal operation and maintenance as well as reasonably foreseeable single fault conditions. For example, a diffusing element failure could result in exceeding the radiance criterion described in subclause 4.4.
- d) When laser and non-laser (incoherent) radiation are coincident within the same retinal location (i.e. emitting from within the specified angle of acceptance), both laser and non-laser (incoherent) radiation must be included. Emissions that are excluded for laser classification are included for the determination of a Risk Group (RG) under the applicable IEC 62471 standard.

Item d) also clarifies subclause 4.3 b) and with respect to intended non-laser radiation takes precedence over 5.2 f). This means that if subclause 4.4 is not applied and the emission is classified under the laser standard, both laser and non-laser emissions are included.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF LASER PRODUCTS –**Part 1: Equipment classification and requirements**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60825-1 has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

This third edition of IEC 60825-1 cancels and replaces the second edition published in 2007. It constitutes a technical revision.

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).

This part of IEC 60825 has the status of a Group Safety Publication, in accordance with IEC Guide 104¹⁾, for aspects of laser radiation pertaining to human safety.

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

FDIS	Report on voting
76/502/FDIS	76/506/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The list of all parts of the IEC 60825 series, published under the title *Safety of laser products*, can be found on the IEC website.

This part of IEC 60825 is also referred to as "Part 1" in this publication.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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

The contents of the corrigendum of the interpretation sheets 1 (December 2017) and 2 (December 2017) have been included in this copy.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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

It gives guidance to IEC technical committees and to writers of specifications concerning the manner in which safety publications should be drafted.

This guide does not constitute a normative reference and reference to it is given for information only.

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.

A11 This Part 1 describes requirements that are considered sufficient to achieve the required level of product safety for general laser products with respect to hazards to the eye and skin posed by laser radiation, provided that consumer laser products comply with EN 50689¹ **AC1** (see 9.5 in in this amendment EN 60825-1:2014/A11:2021). **AC1** Also, as required in 5.3 b) of EN 60825-1, that laser products classified as Class 1C comply with the respective applicable part of either the EN 60601 series or the EN 60335 series that contains requirements for the safe exposure of the skin (note that the exposure of the skin is not necessarily limited to the MPE values of the skin), if applicable, as well as specific requirements for the performance and test-ing of the safeguard that prevents hazardous emission towards the eye. Depending on the type of the product, laser products such as for example medical lasers, machines or toys can be required to con-form to the applicable performance and testing requirements of their relevant product safety standards.

NOTE 3 See 3.92 for “general laser product”.

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), electrical equipment for measurement, control, and laboratory use (IEC 61010-1), 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 1042 for hazards resulting from laser radiation. A11

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 104:2019, *The preparation of safety publications and the use of basic safety publications and group safety publications*

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).

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 TEM₀₀ 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)

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

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.