SLOVENSKI STANDARD
SIST EN 60825-1:1999/A11:1999

01-julij-1999

Safety of laser products -- Part 1: Equipment classification, requirements and user's guide - Amendment A11

Safety of laser products -- Part 1: Equipment classification, requirements and user's guide

Sicherheit von Lasereinrichtungen -- Teil 1: Klassifizierung von Anlagen, Anforderungen und Benutzer-Richtlinien

Sécurité des appareils à laser -- Partie 1: Classification des matériels, prescriptions et guide de l'utilisateur

Ta slovenski standard je istoveten z: **EN 60825-1:1994/A11:1996**

ICS:

13.280	Varstvo pred sevanjem	Radiation protection
31.260	Optoelektronika, laserska oprema	Optoelectronics. Laser equipment

SIST EN 60825-1:1999/A11:1999 **en**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 60825-1/A11

October 1996

UDC 621.375.826:620.1:614.8
ICS 13.280; 31.260

Descriptors: Laser products, radiation safety, equipment classification, requirements, user's guide

English version

Safety of laser products
Part 1: Equipment classification, requirements and user's guide

Sécurité des appareils à laser
Partie 1: Classification des matériels, prescriptions et guide de l'utilisateur

Sicherheit von Laser-Einrichtungen
Teil 1: Klassifizierung von Anlagen, Anforderungen und Benutzer-Richtlinien

This amendment A11 modifies the European Standard EN 60825-1:1994; it was approved by CENELEC on 1996-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this amendment the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This amendment exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 60825-1:1994/A11:1996 E

Foreword

This amendment was prepared by the Technical Committee CENELEC TC 76, Laser equipment.

The text of the draft was submitted to the formal vote and was approved by CENELEC as amendment A11 to EN 60825-1:1994 on 1996-10-01.

The following dates were fixed:

– latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	1997-01-01
– latest date by which the national standards conflicting with the amendment have to be withdrawn	(dow)	1997-01-01

Amendment 11 to EN 60825-1:1994

Add the following text to the end of the second paragraph of 8.2 c):

, with the exception of those cases covered by 8.2 f) and 8.2 h).

Replace the text of 8.2 f) by:

8.2 f) The angle α subtended by the apparent source is determined at a free air distance of 100 mm. Any angular dimension that is greater than α_{max} shall be limited to α_{max}, any angular dimension that is less than 1,5 mrad shall be limited to 1,5 mrad.

Replace the first paragraph of 8.2 h) by:

8.2 h) For values expressed in radiant power (W) or radiant energy (J) the measurement conditions are summarized in the following table:

Table 01: Diameters of the measurement aperture and measurement distances

<table>
<tr><th rowspan="2">Angular subtense
α of the source</th><th colspan="3">Diameter of the measurement aperture d and measurement distance r in the wavelength range</th></tr>
<tr><th><302,5 nm
and
>4000 nm</th><th>≥400 nm to 1400 nm</th><th>≥302,5 nm to 400 nm
and ≥1400 nm to
4000 nm</th></tr>
<tr><td>$\alpha \leq$ 1,5 mrad</td><td rowspan="2">d as given in table 7

For r see 8.2 d)</td><td>d = 50 mm
r = 100 mm</td><td rowspan="2">d = 50 mm

r = 100 mm</td></tr>
<tr><td>α > 1,5 mrad</td><td>$d = \left(7\sqrt{\frac{\alpha_{max}}{\alpha + 0{,}46\,\text{mrad}}}\right)\,\text{mm}$
r = 100 mm
or
d = 7 mm
$r = \left(100\sqrt{\frac{\alpha + 0{,}46\,\text{mrad}}{\alpha_{max}}}\right)\,\text{mm}$</td></tr>
</table>

In cases where, by virtue of engineering design, an apparent source in the wavelength range from 400 nm to 1400 nm subtending an angle α ≤ 1,5 mrad is recessed by more than 14 mm in free air, the distance *r* of the 50 mm measurement aperture from the apparent source shall be 7,14 times the distance from the apparent source to the closest point of human access (to simulate a 7 mm aperture placed at the closest point of human access retaining the same numerical aperture for the collection of radiation).

To eliminate collection of errant scattered radiation, for collimated beams having a divergence less than 5 mrad, the 50 mm aperture may be placed at a distance of 2 m from the beam exit aperture.

Replace the last paragraph of 8.2 h) by:

For the determination of the AEL the value of the angular subtense of a rectangular or linear source is determined by the arithmetic mean of the two angular dimensions of the source. Any angular dimension that is greater than α_{max} or less than 1,5 mrad shall be limited to α_{max} or 1,5 mrad respectively, prior to determining the mean.

Replace the text of 9.3 e) by:

e) Time bases

The following time bases are used in this standard:

a) 0,25 s for Class 2 and Class 3A laser radiation within the wavelength range from 400 nm to 700 nm as determined by Tables 2 and 3 respectively.

b) 100 s for laser radiation of all wavelengths greater than 400 nm except for the cases listed in a) and c)

c) 30000 s for laser radiation of all wavelengths less than or equal to 400 nm, and for laser radiation of wavelengths greater than 400 nm where intentional long term viewing is inherent in the design or function of the laser product.

Subclause 13.4.1, second sentence:

Insert the words: "For ocular exposure" before "In the wavelength range" to read: "For ocular exposure in the wavelength range from 400 nm to 1400 nm a minimum measurement distance of 100 mm shall be used."

Replace the last paragraph of 13.4.2 by:

For the determination of the MPE the value of the angular subtense of a rectangular or linear source is determined by the arithmetic mean of the two angular dimensions of the source. Any angular dimension that is greater than α_{max} or less than 1,5 mrad should be limited to α_{max} or 1,5 mrad respectively, prior to determining the mean.

Table 6

Delete the word "direct" in the title to table 6 to read:

"Maximum permissible exposure (MPE) at the cornea for ocular exposure to laser radiation."

Corrections. to 5.8 and 5.9.1 d) are applicable to the French text only.

Replace the text of example A.2-4 by the following:

Example A.2-4: A Complex laser diode array source

Find the MPE applicable to intrabeam viewing for a 10 s exposure at a distance of 1 m from a complex Ga-As (905 nm) laser diode array source. The source consists of two rows of ten diodes each that are mounted behind collimating optics. The source has an output power of 6 W and apulse repetition frequency of, F, of 12 kHz. The pulse duration is 80 ns. The exit aperture (collimating lens) is 5 cm in diameter, and the emergent beam diameter is 3,5 cm at the 1/e peak irradiance points (i.e., a 3,5 cm circular measurement aperture would collect 63 % of the beam power). The axial beam irradiance (average) at a distance of 1 m is $3{,}6 \times 10^2$ W m^{-2}. The beam divergence is 25 mrad horizontally by 3 mrad vertically, and at a distance of 1 m from the exit aperture, the beam size is approximately 3,0 cm by 3,8 cm respectively.

If the structure of the source would not be known, an intrabeam photograph (using infrared film) could be taken at a distance of about one meter from the exit aperture in order to determine the angular separations and dimensions of the individual diodes. Since the source is mounted behind collimating optics, the angular dimensions are given by the dimension of the source image devided by the focal length of the camera.

Solution:

The MPE applicable to the laser diode array is the most restrictive MPE resulting of each individual source and each possible grouping of the array of diodes. However, the evaluation can be greatly simplified by using the conservative assumption that all the radiant power originates from a single "point" source. This would always overstate the hazard, and if it did not result in overly restrictive control measures, one would not have to perform the more complex analysis of the extended source.

The determination of the applicable (most restrictive) MPE requires a "trial-and-error" approach, since the MPE for a single diode, two adjacent diodes, a group of three or four, etc., and the entire array must be calculate; recognizing that in each case the power or energy is averaged over the angular subtense, α, applicable to that grouping. It is useful to draw a map of the source to study different combinations of diodes (see figure A.1). In addition to grouping, the applicable angular subtense differs depending upon the wheter the limiting case is the MPE of an individual pulse reduced by the repetitive correction factor, C_5 which case α_{min} = 1,5 mrad, or the MPE for **an at least 10 s long** the train of pulses, in which case α_{min} = 11 mrad. The number of pulses N in a 10 s exposure is 120000.

The single pulse MPE for the multiple-pulse assessment is given by (using table 6 for an 80 ns pulse):

$H_{MPE, train} = C_5 \times 5 \times 10^{-3}\ C_4\ C_6$ J m^{-2}

$= 120\ 000^{-0,25} \times 5 \times 10^{-3} \times 2,57\ C_6$ J m^{-2}

$= 6,9 \times 10^{-4}\ C_6$ J m^{-2}

In order to compare the single pulse MPE with the average irradiance of the beam, it is convenient to express the above MPE (expressed in terms of radiant exposure) as an irradiance averaged over F pulses per second:

$E_{MPE, train, F} = H_{MPE, train} \times F$

$= 6,9 \times 10^{-4}\ C_6$ J m$^{-2} \times 1,2 \times 10^4$ Hz

$= 8,28\ C_6$ W m^{-2}

The single pulse MPE for the average power assessment is given by (using table 6 for a 10 s exposure):

$H_{MPE, avg} = 18 \times t^{0,75} C_4\ C_6$ J m^{-2}

$= 18 \times 10^{0,75} \times 2,57\ C_6$ J m^{-2}

$= 260 \times C_6$ J m^{-2}

The above MPE, expressed as a radiant exposure, can also be be expressed as an irradiance averaged over the 10 s exposure:

$E_{MPE, avg} = H_{MPE, avg} / t$

$= 260 \times C_6$ J m^{-2} / (10 s)

$= 26 \times C_6$ W m^{-2}

$E_{MPE, avg}$ can be compared directly with the average irradiance of the beam without any other transformation.

It is useful to make a coparison between the average irradiance values given by the two different assessments, i.e. $E_{MPE, train, F} = 8,28\ C_6$ W m^{-2} and $E_{MPE, avg} = 26\ C_6$ W m^{-2}. This comparison gives an interesting result. When the ratio between the value of C_6 for the multiple-pulse assessment and the value of C_6 for the average power assessment is less than 26/8,28 = 3,14, the multiple pulse assessment gives the most restrictive MPE, thus $E_{MPE, train, F}$ has to be used to calculate the hazard factor. In the other case, when this ratio is greater than 3,14, the value to be used is $E_{MPE, avg}$.

If the angular subtense α is less than or equal to 1,5 mrad, the ratio above described is 1, thus the value to be used $E_{MPE, train, F}$. If angular subtense alpha is greater than 1,5 mrad and less than 11 mrad, this ratio is α/(1,5 mrad). Hence, if the angular subtense of the grouping is less than 3,14 x 1,5 mrad = 4,71 mrad, the MPE value to be used is $E_{MPE, train, F}$, whereas if the angular subtense is greater than 4,71 mrad, the MPE value to be used $E_{MPE, avg, F}$. If the angular subtense α is greater than or equal to 11 mrad, this ratio is 11/1,5 = 7,33, thus the value to be used is $E_{MPE, avg}$.

These results are useful to simplify the calculations of this example. Otherwise it should be necessary to compare $E_{MPE, train, F}$ and $E_{MPE, avg}$ for each group which must be evaluate.

Single diode group

The individual diodes subtend angles of 0,5 mrad (vertical) and 2,2 mrad (horizontal). The MPE for rectangular sources is determined by the arithmetic mean of she two angular subtenses. As stated in 13.4.2, before determing the mean any angular subtense less than 1,5 mrad or greater than 100 mrad should be replaced by 1,5 mrad or 100 mrad, respectively. Therefore the mean is:

(1,5 + 2,2) / 2 mrad = 1,85 mrad

Since this value is less than 4,71 mrad, the most restrictive MPE is given by the multiple pulse assessment. This value is greater than 1,5 mrad, thus the individual diode is considered to be an extended source and the correction factor is C_6 = 1,85/1,5 = 1,23. The applicable MPE is:

$E_{MPE, diode} = E_{MPE, train, F} = 8,28 \times 1,23$ W m^{-2} = 10,2 W m^{-2}

This MPE is not applicable to the total irradiance, but rather the irradiance of each single diode. Assuming that all diodes have the same power emission, this MPE has to be comparate with the total irradiance divided by the number of diodes, i.e. 20.

$E_{diode} = E_{total}/20 = 3600 / 20\ W\ m^{-2} = 180\ W\ m^{-2}$

This MPE is exceeded at a distance of 1 m by a factor of 180/10,2 = 17,6.

Horizontal two diode group

A plausible group of the array to consider is two horizontally adjacent diodes subtending angles of 0,5 mrad (vertical) by 5,2 mrad (horizontal). Replacing 0,5 mrad by 1,5 mrad, as stated in 13.4.2, the arithmetic mean of the two angular dimensions is (1,5 + 5,2)/2 mrad = 3,35 mrad. The most restrictive MPE is given by the multiple pulse assessment. The correction factor is C_6 = 3,35/1,5 = 2,23 and the applicable MPE is:

$E_{MPE,\ hor,\ two} = E_{MPE,\ train,\ F} = 8{,}28 \times 2{,}23\ W\ m^{-2} = 18{,}5\ W\ m^{-2}$

Since the irradiance of this grouping is twice the irradiance of the single diode, this MPE has to be compared with:

$E_{two} = E_{diode} \times 2 = 180 \times 2\ W\ m^{-2} = 360\ W\ m^{-2}$

At a distance of 1 m the hazard factor is 360/18,5 = 19,5. Hence, this grouping of two diodes produces a greater hazard factor (i.e., a more conservative MPE) than the single diode group.

Vertical two diode group

Another sub-unit of the array to consider is two vertical diodes diodes subtending angles of 2,8 mrad (vertical) by 2,2 mrad (horizontal). The arithmetic mean of the two angular dimensions is 2,5 mrad. The most restrictive MPE is given by the multiple pulse assessment. Hence the correction factor is C_6 = 2,5/1-1,5 = 1,67. The applicable MPE is:

$E_{MPE,\ vert,\ two} = E_{MPE,\ train,\ F} = 8{,}28 \times 1{,}67\ W\ m^{-2} = 13{,}8\ W\ m^{-2}$

The irradiance of this grouping is twice the irradiance of the single diode. Hence, this MPE has to be compared with:

$E_{two} = E_{diode} \times 2 = 180 \times 2\ W\ m^{-2} = 360\ W\ m^{-2}$

At a distance of 1 m the hazard factor is 360/13,8 = 26,1. Hence, this grouping produces a greater hazard factor than the previous one.

Four diode group

Next plausible sub-unit of the array to consider is four adjacent diodes (2 by 2) subtending angles of 2,8 mrad (vertical) by 5,2 mrad (horizontal). The arithmetic mean of the two angular dimensions is 4 mrad. The most restrictive MPE is given by the multiple pulse assessment and the correction factor is C_6 = 4/1,5 = 2,67. The applicable MPE is:

$E_{MPE,\ four} = E_{MPE,\ train,\ F} = 8{,}28 \times 2{,}67\ W\ m^{-2} = 22{,}1\ W\ m^{-2}$

Since the irradiance of this grouping is four times the irradiance of the single diode, this MPE has to be compared with:

$E_{four} = E_{diode} \times 4 = 180 \times 4\ W\ m^{-2} = 720\ W\ m^{-2}$

At a distance of 1 m the hazard factor is 720/22,1 = 32,5. This grouping produces a hazard factor greater than all the previous ones.

One row of ten diodes

Another interesting grouping to evaluate is one entire row of ten diodes subtending angles of 0,5 mrad (vertical) and 29,2 mrad (horizontal). Replacing 0,5 mrad by 1,5 mrad, as stated in 13.4.2, the arithmetic mean of the two angular dimensions is (1,5 + 29,2)/2 mrad = 15,3 mrad. In this case the most restrictive MPE is given by the average power assessment. Therefore the correction factor is C_6 = 15,3/11 = 1,39. Hence the applicable MPE is:

$E_{MPE,\ ten} = E_{MPE,\ avg} = 26 \times 1{,}39\ W\ m^{-2} = 36{,}1\ W\ m^{-2}$

Since this grouping contains ten diodes, this MPE has to be compared with:

$$E_{ten} = E_{diode} \times 10 = 180 \times 10 \text{ W m}^{-2} = 1800 \text{ W m}^{-2}$$

At a distance of 1 m the hazard factor is 1800/36,1 = 49,9.

Twenty diode group

As last grouping to be considered in this example, the entire array of twenty diodes has to be evaluated. Since the diodes are arranged in two adjacent rows, the vertical angular subtense is identical to that in the four diode group, i.e. 2,8 mrad, and the horizontal angular subtense is 29,2 mrad. The average is 16 mrad and the most restrictive MPE is given by the average power assessment. Therefore the correction factor is C_6 = 16/11 = 1,45 and the applicable MPE is:

$$E_{MPE,\ twenty} = E_{MPE,\ avg} = 26 \times 1{,}45 \text{ W m}^{-2} = 37{,}7 \text{ W m}^{-2}$$

This MPE has to be compared with the total irradiance. At a distance of 1 m the hazard factor is 3600/37,7 = 95,5. This is the largest hazard factor found in this example.

It can be showed by calculations that the other groups, such as three horizontally adjacent diodes, six adjacent diodes (2 x 3), etc., give hazard factors smaller than 95,5. Therefore 95,5 is the hazard factor to be used to evaluate the hazard of this array.

Additional remarks

It is important to note that in other situations the limiting case could be obtained from a grouping of a part of the source, not by the group of entire source. For example, we can consider another array constituted by twenty diodes arranged in two rows of two diodes each, with the same angular dimensions of the diodes and the same vertical distances as in the example above described, but with horizontal center-to-center distance of 6 mrad.

In this new situation, the angular subtense that must be used for the entire array is (2,8 + 56,2)/2 mrad = 29,5 mrad, thus the most restrictive MPE is given by the average power assessment. Hence, the corrector factor is C_6 = 29,5/11 = 2,68 and the applicable MPE is:

$$E_{MPE,\ twenty} = E_{MPE,\ avg} = 26 \times 2{,}68 \text{ W m}^{-2} = 69{,}7 \text{ W m}^{-2}$$

The hazard factor of the entire array is 3600/69,7 = 51,6.

As can be showed by calculations, the greatest hazard factor is obtained by the group of eight adjacent diodes (2 x 4). The an angular subtense of this group is (2,8 + 20,2)12 = 11,5. Thus, C_6 = 11,5/11 = 1,05. Hence, the applicable MPE is:

$$E_{MPE,\ eight} = E_{MPE,\ avg} = 26 \times 1{,}05 \text{ W m}^{-2} = 27{,}3 \text{ W m}^{-2}$$

This value should be compared with:

$$E_{eight} = E_{diode} \times 8 = 180 \times 8 \text{ W m}^{-2} = 1440 \text{ W m}^{-2}$$

The hazard factor of this grouping is 1440/27,3 = 52,7. Since 52,7 is the greatest value, it must be considered the hazard factor for this array.

The fact that the whole array gives a hazard factor smaller than the hazard factor of the eight diode group does not mean that the whole array, i.e. the assembly of twenty diodes, is less hazardous than the assembly of eight diodes. 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 twenty diodes as one uniform source subtending an angular subtense of 29,5 mrad, but is given by the analysis of the parts that form the array itself. This is due to the fact that the whole source is not uniform.

Required optical density

To protect the viewer at a distance of 1 m, an attenuation factor of 95,5 or nearly 100 would be required in a protective filter. An optical density of 2 (i.e. log 100) corresponds to an attenuation factor of 100 and would provide adequate protection from this laser at a distance of 1 m.

In general, it is also necessary to be sure that the filter can withstand the level of radiation power, because the filter could have a sufficient optical density but could be damaged by the radiation, loosing its capability to protect.

Using the simplistic approach of a point source approximation instead of the group calculations, the MPE for the entire array would have been equal to 8,28 W m^{-2}. Thus, at a distance of 1 m, the point source